Electric Vehicle Safety Guide

（2019 Version）

Drafting Guided by:
Ministry of Industry and Information Technology of the People’s Republic of China
National Energy Administration of the People’s Republic of China

Drafting Organized by:
China Association of Automobile Manufacturers (CAAM)
China Automotive Power Battery Industry Innovation Alliance
China Electric Vehicle Charging Infrastructure Promotion Alliance

Oct. 2019

Foreword

Vice Chairman of the CPPCC, Chairman of the CAST WAN Gang

The world's automobile industry is experiencing an unprecedented shift and industrial transformation. From the market perspective, the automobile market is extending from a few developed countries to the developing ones led by China; its size is growing rapidly. From the perspective of external conditions, global issues such as climate change, environmental pollution and energy shortage are becoming major factors restraining the development of the automobile industry. From the perspective of internal impetus, the new round of technological revolution, particularly technological innovations in electric drive, artificial intelligence and internet technologies, has been contributing to the industrial transformation of the automobile industry. In this historical transformation, the most promising directions of the industry point to the transition into a more electric powered, intelligent and sharing future.

As President XI Jinping articulated during his visit to SAIC Motor in May 2014, the race in the automobile industry has focused on the technological innovation in the field of new energy vehicles. The automobile industry is an industry with a large market, a high standard of technology and management refinement. Developing new energy vehicles is a path we must take in order to reach our aim to become a leading automobile nation. It is essential to increase our researches, with constructive studies of the market and flexible implementation of supportive policies to develop products that meet the diverse requirements of the market, hence making it a strong area. The guiding speech made by President XI Jinping articulated the new blueprint of the future of new energy vehicles.

With the combination of active government involvements, technological innovation supports, enormous market size and the innovative business models, remarkable achievements have been witnessed in our new energy vehicles industry. At a critical stage of transiting from the introduction period into a growth period, China's automobile industry plays a pivotal role in the global industrial system, leading and accelerating an electric powered, intelligent and sharing future of the global automobile industry.

At the critical stage of current market growth, safety must be the upfront indicator of success, the safety of new energy vehicles must be placed in its most important position. The safety of new energy vehicles is not only a matter of scientific research and product design, but also closely connected to the entire industry chain and the whole industrial cycle including manufacturing processes, quality control, parts production and supply, product use, charging and maintenance. Therefore, how to mobilize the enthusiasm of all stakeholders, gather the wisdom and experience of experts from all related fields, and guide the whole industry to comprehensively improve the safety of new energy vehicles has become the most urgent issue at present.

At this key conjuncture point of this industry, China Automotive Industry Association, China Automotive Power Battery Industry Innovation Alliance and China Electric Vehicle Charging Infrastructure Promotion Alliance organized industry-wide experts to have edited and published this “Electric Vehicle Safety Guideline”, which plays a timely and important role for the present situation. I believe that this guide will play an important role in improving the safety of new energy vehicles in China as well as promoting the healthy development of new energy vehicles in China. I hope that the industry will take advantage of this guide, and continue to accumulate experience from practice, enrich and improve the contents of each chapter, and work together to improve the quality and standard of new energy vehicles in China. I also hope that the China Automobile Industry Association and other organizations will continue to work on this project, keep working on summarizing the progressive experiences of our industry, update and revise this guideline year by year, gather all wisdoms and efforts, in order to better contribute to the enhancement of our quality development across the whole industry.

Preface

CAAM Executive Vice President and Secretary General FU Bingfeng

Safety is the most important indicator in the current transformation of automotive power electrification. The 2018 edition of this guide divided electric vehicle safety into 12 aspects, including new energy passenger vehicle safety, commercial car safety, battery cells and modules, battery management system, motor and electronic control, charging safety, data monitoring and management, repair and maintenance, recovery and recycling of power battery, accident handling, operational safety, safety management of operating vehicles, which gathered suggestions from hundreds of frontline experts in the industry. In view of the fact that a small amount of hydrogen fuel cell vehicles has entered market operations, the 2019 edition of this guide supplements the safety aspects of hydrogen fuel cell vehicles.

With the planning and guidance of the government, the promotion of several policies and the joint efforts of the whole industry, electric vehicle development in China is at the forefront of the world and plays a leading role. The various technologies of electric vehicles are maturing, and the market is growing at a high speed. The safety in the early stage of industrialization has become the most prominent issue in the development of electric vehicles in China. The safety of electric vehicles involves the entire industry chain and the entire life cycle of product development and manufacturing, use and charging, repair and maintenance. Therefore, China Association of Automobile Manufacturers (CAAM), China Automotive Power Battery Industry Innovation Alliance and China Electric Vehicle Charging Infrastructure Promotion Alliance organized experts in major enterprises, institutions and universities to work on this guide.

This guide strives to follow the principles of being detailed, specific and practical. The 2019 guide also adds four relevant items, which are included in appendix to make this guide more practical. Of course, this guide is a summary of the experience so far. With the deepening of industrialization and market application, the new experience, new understanding of colleagues and new development of the industry will be reflected in the subsequent versions of this guide.

Safety is a common issue faced by countries in terms of electric vehicles. The popularization and application of electric vehicles in China took a step forward, we have already encountered problems which other countries haven’t and accumulated some unique experiences. Therefore, this guide should also be a good reference for the development of electric vehicles in other countries around the world. Therefore, we have decided to publicly release this guide, waive all copyrights, and publish both Chinese and English versions as a reference for peers in various countries.

Finally, I would like to pay my highest respect to all the experts who participated in the writing of this guide! Thank you for your unselfish dedication of your experience and precious time amid your busy work!

Statement

I. Background Information:

In accordance with the overall deployment of the Central Committee of the Communist of China and the State Council on the development of new energy vehicles, the State Council's *Energy Conservation and Development Planning of New Energy Automobile Industry (2012-2020)* (DRC [2012] No. 22) and *Accelerating the Promotion and Application of New Energy Vehicles under guidance* (DRC [2014] No. 35), under the promotion of various policies and measures to encourage the promotion and application of new energy vehicles, the promotion and application of electric vehicles in China have made positive progress. The key parts and components production such as lightweight and power-driven systems and power batteries have initially formed scale, and the gap with the world's has been significantly reduced.

However, we also see that the overall development quality and level of electric vehicles in China still needs to be improved, particularly safety level. At present, the industry generally lacks understanding of safety, and the safety requirements of product design are insufficient. The mechanism of safe interaction has not been formed, resulting in many electric vehicle fire accidents, which have a negative impact on industrial development.

The causes of electric vehicle safety accidents are complex, factors such as material selection, cell and module structure, system integration, connection structure, vehicle matching design, production control, product test verification, after-sales service, charging equipment and engineering electronics, charging operation and maintenance, management, recycling and recycling process safety management, fire control methods are related. Therefore, the China Association of Automobile Manufacturers, China Automotive Power Battery Industry Innovation Alliance and China Electric Vehicle Charging Infrastructure Promotion Alliance launched the *Electric Vehicle Safety Guide* (Guide) preparation work in 2018, which systematically discussed the security risks and preventive measures of design, manufacturing, use, and reuse in order to promote the safety awareness of the entire industry chain and improve the safety level of electric vehicles throughout their life cycle.

The "Guide (2019 Edition)" released this time has been revised and improved on the basis of the 2018 version.

II. the positioning of the Guide:

This Guide starts with the whole industry chain and the whole life cycle of electric vehicles, sorts out the various safety risks of electric vehicles, and builds up the experience of first-line experts with reference to existing international and domestic standards. The purpose is to provide guidance and reference for electric vehicle development and production enterprise employees, as well as service support personnel and consumers.

I hope that through the research and development of this Guide, we will raise awareness of the safety of electric vehicles in the whole industry, improve the safety design and manufacturing level, improve the rational use and maintenance of electric vehicles, and the level of safety control, explore safe, systematic solutions and emergency response when accidents occur. At the same time, it is hoped that this Guide will also provide a basis for the formulation and revision of relevant standards for the electric vehicle industry and provide direction for conducting safety research projects.

III. The main content of the Guide:

Considering the variety of new energy cargo and special-purpose vehicles and their versatility, the 2018 edition of the Guide mainly covers the safety of pure electric commercial cars and pure electric buses produced and sold in China. It is recommended that electric commercial vehicles refer to this guide for implementation. The 2019 edition of the Guide adds safety content of hydrogen fuel cell vehicles.

The 2019 edition of the Guide is divided into two parts. The first part is electric vehicle and the second part is hydrogen fuel cell vehicle. At the same time, the standard conditions related to the preparation of the Guide are included as an appendix.

IV. Preparation and publication of the Guide:

This Guide was prepared by the Ministry of Industry and Information Technology and the National Energy Administration.

This Guide is jointly researched and developed by major domestic vehicles, power storage batteries, charging facilities, operation, recycling and other enterprises, as well as hydrogen energy supply, hydrogen fuel cell enterprises, industry organizations, research institutes and institutions. In the process of preparation, the opinions of industry experts and enterprises and institutions at home and abroad were extensively sought.

Both the Chinese and English versions of this Guide are published at the same time.

The right to interpret this Guide is in the editorial committee of the Guide (see appendix).

CONTENT

HYDROGEN FUEL CELL VEHICLES

ELECTRIC VEHICLES

1.New energy passenger vehicle safety

1.1 Anti-electric safety

1.1.1 Voltage level

Based on GB/T 18384.3, according to the maximum working voltage of the finished automobile, the electrical components or circuits include the following grades, see Table 1-1.

Table 1-1 Voltage Level

Unit (V)

Voltage level	Maximum working voltage (U)	
	DC	AC (rms)
A	0<U≤60	0<U≤30
B	60<U≤1500	30<U≤1000

According to the No.1 Modification List of GB/T 18384.3, for the A-level voltage circuit and the B-level voltage circuit which are mutually conducted and connected, when one pole of the DC live parts in the circuit is connected with the electric platform, and the maximum voltage of the pole of any other live part is not more than 30Va.c. (rms) and no more than 60Vd.c., then the conduction connection circuit is not completely a B-level voltage circuit, and only the part operating at the B-level voltage is recognized as a B-level voltage circuit.

For the 48V system, as long as the DC system can be guaranteed to not exceed 60Vd.c, the part other than the AC motor cannot be regarded as the B-level voltage circuit without meeting the relevant requirements for electric shock protection.

1.1.2 Requirements for in-use electric shock protection

The requirements for in-use electric shock protection of personnel shall include four parts: requirements for high-voltage marking, direct contact protection, indirect contact protection and waterproof.

1.1.2.1 Requirements for high-voltage marking

1.1.2.1.1 Requirements for high-voltage warning marking

Shall meet the amendments to Section 5.1 of No.1 Modification List of GB/T 18384.3.

1.1.2.1.2 Requirements for B-level voltage wire marking

Shall meet Section 5.2 of GB/T 18384.3.

1.1.2.2 Requirements for direct contact protection

Requirements for direct contact protection are proposed to avoid direct contact between personnel and live parts to cause electric shocks. Direct contact protection allows physical isolation of personnel from B-level voltage live parts by obstruction and casing of B-level voltage parts. In addition to the obstruction and casing of B-level voltage parts, high-voltage connectors, high-voltage service switches, and charging sockets shall meet the corresponding requirements in the plug/coupled and uncoupled/disconnected states.

1.1.2.2.1 Requirements for obstruction and casing

Requirements for obstruction and casing of B-level voltage parts shall meet the requirements for IPXXD protection grade. If the obstruction or casing can be opened by hand, the openable parts shall be equipped with a high-voltage interlocking device to meet the requirements for high-voltage interlocking of Section 1.1.2.2.5.

1.1.2.2.2 Requirements for connector

The high-voltage connector shall meet the requirements for IPXXD protection grade when it is assembled. If the high-voltage connector can be opened by hand, at least one of the following three conditions must be met:

(1)Meet the requirements for IPXXB protection grade in an uncoupled state;

(2)The separation of the high-voltage connector requires at least two steps, and the opening operation of the high-voltage connector can be performed only after opening a mechanical locking mechanism;

(3)After the high-voltage connector is separated, the discharge shall be performed after power-off and during power-off. Considering the time when the person can touch the live part after opening the high-voltage connector, the vehicle shall reduce the voltage of B-level voltage circuit in 1 s to 30Va.c. (rms) or less than 60Vd.c.

1.1.2.2.3 Requirements for high-voltage service disconnecting device

If the vehicle has high-voltage service switches and the high-voltage service switches can be opened or removed by hand, the high-voltage service switches shall meet at least one of the following two conditions:

In the state where the high-voltage service switches is opened or removed, the vehicle end of the high-voltage service switches shall meet the requirements for IPXXB protection grade.

After the high-voltage service switches are opened or removed, the discharge shall be performed after power-off and during power-off. Considering the time when the person can contact the live part after opening the high-voltage connector, the vehicle shall reduce the voltage of B-level voltage circuit within 1 s to 30Va.c (rms) or less than 60Vd.c.

1.1.2.2.4 Charging socket request

In the uncoupled state charging socket should meet at least one of the following requirements:

(1)The AC charging socket shall meet IPXXB in the uncoupled state, and the voltage of B-level voltage circuit shall be reduced to 30Va.c (rms) or less than 60Vd.c within 1min after the charging plug is removed.

(2)Since the DC charging stand cannot meet the IPXXB requirement in the uncoupled state, to meet the requirements for higher protection, the voltage of B-level voltage circuit shall be reduced to 30Va.c (rms) or less than 60Vd.c within 1 s after the charging plug is removed.

1.1.2.2.5 Requirements for high-voltage interlocking

The obstruction/casing and high-voltage connectors on the vehicle that are easy to remove or can be removed by hand shall have high-voltage interlocking device. The design of the high-voltage interlocking generally includes hardware design and control strategy design. It shall ensure that when the protected part is disassembled, the live part of the B-level voltage is changed to the uncharged part before the person contacts the live part of the B-level voltage, and shall meet Section 1.1.2.2.5 Requirements for power-off after faults and Requirements for discharge after power-off of Section 1.1.2.2.6.

1.1.2.3 Requirements for indirect contact protection

1.1.2.3.1 Requirements for insulation resistance (excluding fuel battery)

According to GB/T 18384.3-2015, at the maximum working voltage, the DC circuit insulation resistance shall be at least 100Ω/V, and the AC circuit shall be greater than 500Ω/V. If the DC and AC B-level voltage circuits are electrically connected together, the insulation resistance shall be greater than 500 Ω/V.

The insulation resistance of the charging socket shall meet the requirements of Section 1.1.2.3.5.

The insulation resistance of the finished vehicle is the minimum insulation resistance among the mutually isolated subsystems, and each subsystem is formed by connecting the high-voltage parts constituting the subsystem in parallel.

1.1.2.3.2 Requirements for insulation monitoring

Vehicles shall have the insulation monitoring function. The insulation monitoring function shall continuously monitor the insulation resistance of the B-level voltage circuit when the vehicle is powered on, and give an alarm when the insulation condition is below a certain threshold. The threshold of the alarm shall be greater than or equal to the insulation resistance required in Section 1.1.2.3.1. The specific value can be set by the OEMs. The alarm mode can be a prompt tone or a text or symbol display through dash board.

1.1.2.3.3 Requirements for potential equalization

The potential equalization is to ensure that the conductive housing casing of the high-voltage part in the B-level voltage circuit does not have high-voltage electricity due to the failure of the insulation resistance, thereby forming a potential difference and generating an electric shock risk.

The specific requirements for potential equalization shall meet the requirements of Section 6.9 of GB/T 18384.3-2015. When designing, the resistance of the conductive casing and electric platform of a single part can be less than 40mΩ. If the potential equalization is achieved in the form of welding, it is considered to meet the requirements.

1.1.2.3.4 Requirements for capacitive coupling

Capacitive coupling is a safety requirement for Y capacitors. If the total energy of the Y capacitor exceeds the energy limit of 0.2J for human safety, an electric shock will occur in the case of a single point failure in the high-voltage system. Therefore, it is necessary to design protection against this situation.

In summary, capacitive coupling shall meet one of the following two requirements:

(1)The total energy of the Y capacitor of the high-voltage system is not more than 0.2J;

(2)If the total energy of the Y capacitor is greater than 0.2J, each B-level voltage circuit in the high -voltage system shall be protected by double insulation layers, obstruction or casing, or its single layer of obstruction or casing is capable of withstanding at least 10kpa pressure without obvious plastic deformation.

1.1.2.3.5 Requirements for vehicle charging socket

The AC charging socket shall meet the requirements of Section 6.10.2.1 of GB/T 18384.3-2015.

The DC charging socket shall meet the requirements of Section 6.10.2.1 of GB/T 18384.3-2015.

1.1.2.3.6 Requirements for power-off after faults

According to the requirements of GBT 31498, after the collision of the vehicle, the high-voltage power-off shall be immediately carried out to avoid the electric shock accident caused by direct contact or indirect contact between the personnel and the high-voltage live parts after the collision.

In the event of insulation faults, high-voltage interlocking, etc., it is recommended to consider whether to perform power-off treatment according to the specific conditions such as the vehicle status including the driving speed.

1.1.2.3.7 Requirements for discharge after power off

After each normal power-off or after the power-off following faults, the energy of the X capacitor with an energy greater than 0.2J in the B-level voltage circuit shall be released, so that the energy will not be always stored in the B-level voltage loop or cause electric shocks in the vehicle fault or vehicle being disassembled.

The discharge forms shall have two forms: active discharge and passive discharge. The active discharge shall reduce the voltage loop of B-level voltage to 30Va.c. (rms) by the control strategy combined with the hardware design within 5s after power-off the voltage of B-level voltage circuit or below 60Vd.c or reduce the total energy stored by the X capacitor in the B-level voltage circuit to below 0.2J. Passive discharge shall always be effective and does not rely on control strategies. After the B-level voltage circuit is disconnected from the power supply, the voltage of B-level voltage circuit shall be reduced to 30Va.c within 2 min or below 60Vd.c or reduce the total energy stored by the X capacitor in the B-level voltage circuit to below 0.2J.

1.1.2.4 Requirements for waterproof

1.1.2.4.1 Requirements for vehicle waterproof

In order to ensure the electrical safety of the vehicle after wading, cleaning, exposing to heavy rain, etc., it is necessary to simulate the wading and cleaning test of the vehicle, and conduct insulation resistance testing after the test to assess whether the vehicle is at risk of electric shock.

The test requirements for simulated wading and simulated cleaning shall meet the requirements of Section 8.2.1 and 8.2.3 of GB/T 18384.3-2015. After each test, the first insulation resistance test shall be performed immediately, and the second insulation resistance testing shall be performed after 24 hours. The results of the two insulation resistance testing shall meet the Requirements for insulation resistance of Section 1.1.2.3.1.

1.1.2.4.2 Requirements for part waterproof

All high-voltage parts being assembled shall be at least IPX7 for the outer parts of the passenger compartment and at least IPX4 for the inside parts of the passenger compartment.

1.1.2.5 Maintenance disconnect device requirements

The vehicle shall have a maintenance disconnect device that can disconnect the high voltage circuit and may be in the form of a high voltage maintenance switch or a low voltage maintenance switch.

(1)High voltage maintenance switch

If the vehicle has a high-voltage maintenance switch, the high-voltage circuit shall be turned on and off by the operation of the high-voltage maintenance switch. The high voltage maintenance switch shall be equipped with a high voltage interlock to ensure that no arcing will occur during operation.

(2)Low voltage maintenance switch

If the vehicle has a low-voltage maintenance switch, the high-voltage circuit shall be disconnected indirectly by disconnecting the low-voltage maintenance switch. It is recommended to design at least two ways to ensure the indirect disconnection of the high voltage loop and improve the reliability of the operation results.

1.1.3 Electric shock safety after collision

1.1.3.1 General requirements

Electric vehicles can be in two testing states during the collision test. One is to test under high-voltage power-off state, and the other is to test under high-voltage power- on state. For the collision test conducted under high-voltage power-on state, each sub- b voltage subsystem separated from each other in the b-level voltage system of the vehicle shall meet at least one of the following four requirements to ensure that there is no electric shock accident about the vehicle caused by direct contact or indirect contact; For the collision test under high-voltage power-off, since the power load has no voltage and energy source, it shall meet the requirements for physical protection of Section

1.1.3.4 or the requirements for insulation resistance of Section 1.1.3.5. The REESS and charging subsystem shall meet one of the following four requirements.

1.1.3.2 Requirements for voltage

Shall meet the requirements of Section 4.2.2 of GB/T 31498-2015.

1.1.3.3 Requirements for electric energy

Shall meet the requirements of Section 4.2.3 of GB/T 31498-2015.

1.1.3.4 Requirements for physical protection

Shall meet the requirements of Section 4.2.4 of GB/T 31498-2015.

1.1.3.5 Requirements for insulation resistance

Shall meet the requirements of Section 4.2.5 of GB/T 31498-2015.

1.2 Functional safety

Functional safety in this Section refers to functional safety other than the battery system and charging system (see the subsequent sections for related content).

1.2.1 Vehicle functional safety development process

The functional safety development process shall comply with the relevant requirements of GB/T 34590 Road Vehicle Functional Safety.

1.2.2 Concept development stage

Concept development shall be completed based on the relevant regulations of GB/T 34590.3, and relevant item definitions, requirements for safety objectives and functional safety shall be obtained as necessary inputs for system development.

1.2.2.1 Relevant item definitions

In order to fully understand the relevant items and provide support for the safety activities in the subsequent stages, the functional and non-functional aspects of the relevant items shall be defined in detail from the aspects of the functions, elements, interfaces, environmental conditions, requirements for relevant regulatory and hazards of the relevant items.

1.2.2.2 Hazard analysis and risk assessment

The purpose of hazard analysis and risk assessment is to identify the hazards caused by faults in the relevant items and to classify the hazards and to establish corresponding safety objectives to avoid unreasonable risks.

Among them, the potential hazard events shall be analyzed based on the functional behavior of relevant items. Then systematically evaluate the relevant items from three aspects: the severity of the hazard time, the probability of exposure, and the controllability, so as to determine the safety objectives and the corresponding ASIL levels.

1.2.2.3 Functional safety concept

The functional safety concept is primarily intended to derive requirements for functional safety from safety objectives and assign them to the architectural elements or external measures of the relevant items.

When defining requirements for functional safety, consideration shall be given to the operating modes of the relevant items, the faults tolerance interval, the safety status, the emergency operating time interval, and the functional redundancy. At the same time, the safety analysis (e.g. FMEA, FTA, HAZOP) method can be used so as to make the developed requirements for functional safety more complete.

The functional safety concept shall also be verified in accordance with the requirements of GB/T 34590.9 to demonstrate consistency and compliance with safety objectives and the ability to mitigate or avoid hazard events.

1.2.3 System functional safety development

Before the formal system development, the safety activity plan for product development at the system level shall be specified based on the relevant regulations of GB/T 34590.4, including determining appropriate methods and measures, testing and verification plans, and functional safety assessment plans in the design and integration process.

1.2.3.1 Requirements for system safety design

Requirements for technical safety are the necessary technical requirements to implement the functional safety concept. The purpose is to refine the requirements for functional safety at the relevant item level to the requirements for technical safety at the system level.

Based on the relevant regulations of GB/T 34590.4, requirements for technical safety shall be formulated based on functional safety concepts, preliminary architectural assumptions of relevant items, external interfaces, and restrictive conditions.

Requirements for technical safety shall be defined in terms of fault detection/indication/control measures, safety status, fault tolerance time interval, etc., and define the necessary safety mechanisms.

1.2.3.2 System design

System design shall be based on functional concepts, preliminary architectural assumptions for relevant items and requirements for technical safety. When implementing the content related to requirements for technical safety, the system design shall be considered in terms of the ability to verify system design, the technical ability of hardware and software design, and the ability to perform system testing.

To avoid systemic failures, a safety analysis of the system design shall be performed to identify the causes of systemic failures and the impact of systemic faults.

To reduce the impact of random hardware failures during system operation, measures to detect, control, or mitigate random hardware failures shall be defined in the system design.

Software and hardware interface specifications are defined in the system design and refined in subsequent hardware development and software development processes.

1.2.3.3 System integration and testing

Based on the relevant regulations of GB/T 34590.4, the software and hardware, system, and vehicle-level integration and testing are performed separately to verify whether each functional and technical safety requirement meets the specifications, and whether the system design is correctly implemented in the entire relevant items.

In order to find out systemic faults during system integration, the following aspects shall be considered when determining the testing method:

(1)Whether requirements for functional and technical are implemented correctly at the system level;

(2)Whether the safety mechanism has correct functional performance, accuracy and timing at the system level;

(3)The consistency and correctness of the external and internal interfaces at the system level;

(4)The effectiveness of the safety mechanism's failure coverage at the system level;

(5)The level of robustness at the system level.

1.2.3.4 Safety objectives confirmation

It shall be confirmed based on the regulations of GB/T 34590.4 whether the safety objectives are correct, complete and fully realized at the vehicle level through inspection and testing.

Before confirming the safety objectives, consider the confirmation process, testing cases, environmental conditions, etc., and develop a detailed confirmation plan.

Safety objective validation at the vehicle level shall be performed as planned in

accordance with safety objectives, requirements for functional safety and intended use. Specific confirmation methods can be considered in the form of detailed definitions of repeatability testing, safety analysis, long-term testing, user sampling and review.

1.2.4 Electronic control unit hardware development

The electronic control unit hardware development process shall meet the requirements of GB/T 34590-5, perform the specified safety activities and output the specified delivery contents. The hardware design plan shall adopt internationally advanced automotive electronic technology to obtain product hardware with high reliability and acceptable functional safety risks.

1.2.4.1 Requirements for electronic control unit hardware safety

Based on the relevant regulations of GB/T 34590-5, the technical safety concept, requirements for technical safety and system design specifications shall be implemented to the hardware level, and complete and detailed requirements for hardware safety shall be designed.

In order to ensure the integrity of the requirements for hardware safety, the following shall be considered in the design:

(1)Safety mechanisms and their attributes;

(2)Standard of verification;

(3)The target value of the hardware measure;

(4)FTTI;

(5)Other safety related requirements.

In order to ensure the quality of requirements for hardware safety, the design, verification and management of requirements for hardware safety shall be conducted in accordance with the requirements of Chapter 6 of GBT 34590-8.

In order for the hardware to be properly controlled and used by the software, the hardware and software interface (HIS) shall be fully refined and each safety-related association between hardware and software shall be described.

1.2.4.2 Electronic control unit hardware design

Based on the relevant regulations of GB/T 34590-5-2017, the hardware architecture design and detailed hardware design, and conduct hardware safety analysis to meet the system design specifications and requirements for hardware safety.

In order to avoid the systemic risk of hardware, the hardware architecture design shall be conducted, and then conduct the detailed hardware design.

When designing the hardware architecture, ensure that each hardware part inherits the correct ASIL level and can be traced back to the requirements for hardware safety associated with it.

When designing the hardware, use relevant experience summary and consider the non-functional reasons for the failure of the safety-related hardware parts. If applicable, the following factors can be included: Temperature, vibration, water, dust, EMI, interference from other parts of the hardware architecture or their environment.

In order to improve the reliability of the design, the "Modular hardware design principles" and "Robustness design principles" in GB/T 34590.5-2017 including derating design and worst case analysis shall be followed.

In order to identify the cause of hardware failure and the impact of the faults, according to the requirements of GB/T 34590.5-2017 and different ASIL levels, use "deductive analysis" (such as FTA) or "inductive analysis" (such as FMEA) to conduct safety analysis.

If safety analysis indicates that production, operations, service, and scrap are safety- related, define their safety-specific characteristics and output explanatory documents. To verify the consistency and integrity of the hardware design and requirements for hardware safety, the hardware design shall be verified in accordance with the requirements of GB/T 34590.5-2017.

1.2.4.3 Identification of hardware parts of electronic control units

Based on the relevant regulations of GB/T 34590-8, hardware parts shall be identified for complex hardware parts and components to ensure the compliance of hardware parts and provide basic data for FMEDA analysis.

1.2.4.4 Evaluation of hardware architecture measure for electronic control units

Based on the relevant regulations of GB/T 34590-5, the hardware architecture measure shall be evaluated, and the evaluation results and optimization suggestions shall be fed back to the system design, hardware design and software design to optimize the product design and make the final "single point faults measure" and the "potential fault measure" meet the requirements of the corresponding ASIL.

1.2.4.5 Evaluation of violations of safety objectives caused by hardware failure of random electronic control units

Based on the relevant regulations of GB/T 34590-5, conduct PMHF evaluation or cut set analysis and evaluation and closed-loop optimization, so that the relevant safety objectives do not have unacceptable risks due to random hardware failure.

1.2.4.6 Electronic control unit hardware integration and testing

Based on the relevant regulations of GB/T 34590.5-2017, conduct hardware integration and testing to ensure that the developed hardware meets the requirements for hardware safety.

The hardware integration testing cases shall be generated in consideration of the methods listed in Table 10 of GB/T 34590.5-2017.

In order to verify the integrity and correctness of the safety mechanism, hardware integration testing shall consider the following methods: Functional testing, fault injection testing, and electrical testing.

In order to verify the robustness of the hardware under external stress, the hardware integration testing shall consider the methods listed in Table 12 of GB/T 34590.5-2017.

1.2.5 Electronic control unit software design

1.2.5.1 Requirements for software safety analysis

The purpose of requirements for software safety analysis is to specify requirements for software safety based on safety technical specifications and system design specifications, and to verify whether requirements for software safety are consistent with safety technical specifications and system design specifications. The requirements for software safety analysis phase needs to meet the requirements of integrity, testability and traceability.

When analyzing requirements for software safety, it shall be considered from the following aspects: Full identification failure will violate software features of requirements for safety technology; Design solutions based on requirements for safety technique and systems; All safety-related attributes between the software and the hardware shall be identified; Contain sufficient hardware running resources, valid safety related information, etc.; The hardware and software interface specification shall be validated; Testing verification methods shall be safe and effective.

1.2.5.2 Software safety monitoring architecture design

The software safety monitoring architecture design aims to develop a software architecture that meets and implements requirements for software safety. The software safety monitoring architecture design needs to combine functional safety related requirements for software and non-functional safety related requirements for software, and globally consider the software architecture design and conduct software safety analysis.

When designing a software safety monitoring architecture, consider the following aspects: It shall be configurable, implementable, easy to test and maintainable; Comply with the requirements for modularity, high clustering, low coupling, and low complexity; Shall be refined enough to support detailed design; Shall have static and dynamic characteristics; Shall meet the requirements for independence; Requirements for software safety shall be covered.

1.2.5.3 Software failure analysis and detailed design

The software failure analysis and software detailed design aim to design the software function module in detail based on the software architecture design and requirements for software safety, and design the model or source code according to the modeling and coding guide.

When designing the software in detail, it shall be considered from the following aspects: Sufficient information shall be included in order to allow subsequent activities to be carried out; Its functional characteristics shall be described in detail; Shall meet the requirements for testability, maintainability, low complexity, readability and robustness; The detailed design shall meet the requirements for consistency with requirements for software safety, software architecture, coding standards and detailed design specifications.

1.2.5.4 Software safety monitoring algorithm testing

The software algorithm testing is used to prove that the software unit module meets the requirements for the software detailed design specification, and the requirements include: Compliance with requirements for software functional, consistency of requirements for interface, robustness and efficiency of algorithms, etc.

In the software algorithm testing case design, according to the software detailed design specification and requirements for software failure analysis report, adopt requirements analysis, equivalence class division, boundary value analysis, error guessing and other methods.

For software algorithm testing activities, ensure detailed design, failure analysis reports, testing cases, testing data, two-way traceability of testing defects and process integrity. Software algorithm testing also needs to measure the quality of the verification software algorithm, including unit coverage (such as statement coverage, branch coverage, modified judging criteria coverage, etc.), code encoding rules, and other static measure indicators (such as circle, etc.), please refer to GB/T 34590.6-2017 for specific requirements.

1.2.5.5 Software integration and architecture compliance testing

Software integration and architecture compliance testing are primarily used to verify software part integration capabilities and verify whether the interfaces among software parts meet the requirements for software architecture design documentation.

Software integration can often be categorized into proliferating integration and one- time integration. For different integration methods, the corresponding integration testing strategy is also different. Commonly used testing methods include: Requirements-based testing, interface testing, fault injection testing, resource occupancy testing, and back-to-back testing of models and codes.

Software integration testing also includes a quality measurement process, with key measure indicators including functional coverage and function call coverage.

1.2.5.6 Requirements for software safety verification

The purpose of requirements for software safety verification is to ensure that the software can correctly implement requirements for software safety in the target hardware environment. Verification methods, including hardware-in-the-loop testing, electrical and electrical test bench testing and automobile testing are often required.

Requirements for Software safety verification not only verifies the compliance of requirements for software safety from a functional perspective, but also verifies whether requirements for performance are met from a performance perspective (such as program installation testing, load testing).

1.3 Using and handling safety

1.3.1 Basic requirements for handling safety

The vehicle enterprise shall provide the user's instruction manual to clarify the requirements for safety operation, and the vehicle must meet the basic functions of data monitoring and fault alarm.

1.3.2 Normal scene safety

1.3.2.1 Vehicle safety of power-on and power-off

Vehicle safety of power-on and power-off includes power-on and power-off flow design and safe operation step design.

Power-on and power flow design: The vehicle shall have the function of diagnosing the faults of the high-voltage parts before power-on, including the short and open circuit of the hardware circuit, too low insulation resistance and the high-voltage interlocking fault. Before closing the main relay, it must be ensured that there is no risk of high- voltage electricity. When the vehicle detects a collision, disconnect the high-voltage main contactor in time. When encountering any other high-voltage safety-related faults, it is necessary to inform the driver to disconnect the high-voltage main contactor according to the state of the vehicle.

Safe operation steps design: According to GB/T 18384.2-2015, the safe operation of vehicles must meet the following requirements:

(1)At least twice consciously different operations of the vehicle from the power-off of the drive system to the drivable state;

(2)Only one operation is required from the drivable state to the power-off of the drive system;

(3)The main switching function of the power supply to the drive circuit is a necessary part of the drive system power on/off procedure. If the power on/off procedure of the drive system is activated by the car key, it must comply with the relevant requirements for safety design;

(4)Continuously or intermittently prompting the driver that the vehicle is in the drivable mode;

(5)When the vehicle is stopped, after the drive system is automatically or manually turned off, the "drivable mode" can be re-entered only through the above procedure.

1.3.2.2 Vehicle driving operation safety

According to GB 7258-2017, when the vehicle is driven at low speed in pure electric mode, the surrounding pedestrians shall be reminded by the sound from the low speed driving sound system. When the driver actively stops the low speed driving sound system, prompt through the eye-catching prompt signal.

According to GB/T 18384.2, if the driving transition between the forward and reverse directions is changed by changing the direction of rotation of the motor, the following requirements shall be met to prevent accidental switching to reverse driving.

(1)The driving transition in both forward and reverse directions is accomplished by two different operations; or

(3)If it is done by only one operation, a safety measure shall be used to make the mode transition only when the vehicle is stationary or at low speed;

(3)If the driving transition between the forward and reverse directions is not achieved by the direction of rotation of the motor, the reverse driving requirement is not applicable.

When the driver leaves the vehicle, if the drive system is still in the drivable mode, the driver shall be prompted by an obvious signaling device. The vehicle cannot produce undesired travel caused by its own electric drive system after the power is off.

1.3.2.3 Vehicle charging operation safety

According to GB/T 18384.2-2015, when the vehicle is physically connected to an external power source for charging, it shall be equipped with a device to protect the charging gun from falling off and cannot be moved by its own drive system.

When the vehicle is being charged, be able to detect high-voltage safety related faults and shall have the ability to disconnect the high-voltage when the relevant fault is detected.

When the vehicle is being charged, it shall be possible to prohibit all operations that may cause the vehicle to move through the VCU.

1.3.2.4 Vehicle safety alarm reminder

According to GB/T 18384.2-2015, if the low power of the rechargeable energy storage device affects the driving of the vehicle, the driver shall be prompted by an obvious signaling device. When the vehicle is in a low power state as specified by the manufacturer, it shall meet at least the following requirements:

(1)The vehicle can be driven out of the traffic area by its own drive system;

(2)When there is no independent energy storage device to power the auxiliary power system, the minimum remaining power shall be able to provide the lighting system with the power required to meet the relevant regulations.

1.3.3 Special scene safety

1.3.3.1 Vehicle faults operation safety

If the electric drive system is taken measures to automatically reduce and limit the vehicle drive power and affect the travel of the vehicle, this state shall be indicated to the driver.

If the vehicle is unable to output power due to faults, the driver shall be prompted by an obvious signal (such as an audible or optical signal) and the personnel in the vehicle need to quickly determine whether they need to leave the vehicle.

1.3.3.2 Vehicle collision operation safety

Vehicles shall have the collision monitoring function. If a collision event is detected, the system shall be able to disable the power output, shut off the main contractor and actively discharge through one or more discharge devices.

It is not allowed to power on again until the vehicle has been repaired.

1.4 Safety protection measures

1.4.1 Requirements for vehicle passability

In order to ensure the safety of the bottom of the power battery during normal driving, the vehicle enterprises shall define a reasonable minimum ground clearance and minimum ramp angle according to the vehicle model. The definition and measurement of the ground clearance and ramp angle shall be in accordance with the requirements of GB/T 3730.3.

Vehicle enterprises can refer to the minimum target for vehicle passability in ADR 43 (Vehicle configuration and dimensions) (under full load):

(1)The ground clearance (in mm) of the midpoint of the front and rear axles is not less than 33.33* wheelbase (in m);

(2)The minimum ramp angle between the axes is 7.6 °.

1.4.2 Frontal collision safety

1.4.2.1 Basic requirements

According to the national standard GB/T 31498, evaluate the safety performance of the frontal collision high-voltage power of new energy. The test setting shall be in accordance with GB 11551 or GB/T 20913, and the regulations of GB/T 31498 Item 4 Technical requirements shall be met.

1.4.2.2 Additional requirements

According to C-NCAP, evaluate the safety performance of the frontal collision high-voltage power of Electric Vehicles. The test setting shall be in accordance with the C- NCAP management regulations (currently the 2018 version of the regulations, the frontal collision conditions are 50FFB and 64ODB). Evaluate the electrical safety according to the C-NCAP requirements. The technical requirements specified in the electrical safety regulations of the Testing procedure Section 1.2.1.1.3 Pure electric vehicle/hybrid electric vehicle (EV/HEV) shall be met and star-level requirements shall not be met.

1.4.3 Side collision safety

1.4.3.1 Basic requirements

According to the national standard GB/T 31498-2015, evaluate the safety performance of the frontal collision high-voltage power of new energy. The test setting shall be in accordance with GB 20071-2006, and the regulations of GB/T 31498-2015 Item 4 Technical requirements shall be met.

1.4.3.2 Additional requirements

According to C-NCAP, evaluate the safety performance of the frontal collision high-voltage power of Electric Vehicles. The test setting shall be in accordance with the C- NCAP management regulations (currently the 2018 version of the regulations, the side collision conditions are 50AEMDB). Evaluate the electrical safety according to the C- NCAP requirements. The technical requirements specified in the electrical safety regulations of the Testing procedure Section 1.2.1.1.3 Pure electric vehicle/hybrid electric vehicle (EV/HEV) shall be met and star-level requirements shall not be met.

1.4.4 Rear-end collision safety

According to the national standard GB/T 31498-2015, evaluate the safety performance of the frontal collision high-voltage power of new energy. The test setting shall be in accordance with GB 20072-2006, and the regulations of GB/T 31498-2015 Item 4 Technical requirements shall be met.

(Note: GB/T 31498-2015 has not yet cited GB20072-2006, currently in the standard discussion draft stage, which will be implemented later)

1.4.5 Side column collision protection

According to EuroNCAP, evaluate the safety performance of the side columns of Electric Vehicles collision with high-voltage electricity. The test settings shall be based on the EuroNCAP testing procedures and meet the technical requirements of EuroNCAP Technical Bulletin Testing of Electric Vehicles.

(Note: higher than the current national standard and C-NCAP and other testing systems)

1.4.6 Vehicle bottom safety protection

For electric vehicles with power batteries arranged under the chassis of the passenger compartment, it is recommended that vehicle enterprises evaluate the safety performance of vehicles with high-voltage collisions based on typical abuse of working conditions. For example, as for design protection for common bottom stone strike conditions and bottom scraping conditions, design protection, define the corresponding abuse of working conditions of the bottom of the power battery as standard conditions and propose the requirements for bottom protection performance of the power battery package. At the same time, add protection to the high voltage connector and the harness disposed under the chassis.

1.4.7 High-voltage power off and alarm reminder after collision

After the vehicle collides, it shall meet the requirements of Section 1.1.3 and shall have an alarm reminding function.

1.4.8 Controller troubleshooting

The high-voltage power device shall have a fault diagnosis function and can read the fault code through the vehicle diagnostic port.

1.5 Vehicle EMC safety

The EMC radiation intensity and anti-interference strength of the vehicle shall comply with the following provisions to ensure the safe driving of the vehicle under EMC interference and the protection of the driver and passenger.

1.5.1 Electromagnetic radiation disturbance and immunity requirements for vehicle exterior vehicles

1.5.1.1 Requirements for vehicle external electromagnetic radiation disturbance

The vehicle and its component systems shall be equipped with radio disturbance suppression devices and arrangements to ensure that the external radio communication equipment in the vehicle service environment can run normally. The electromagnetic field emission of the exterior vehicle shall be verified according to GB 14023-2011, GB 34660-2017 and GB/T 18387-2017 and meet the standard limit requirements.

(1)Vehicle static conditions: The vehicle is stationary, and the 12V system is fully powered;

(2)Vehicle dynamic conditions: The vehicle travels at a constant speed of 16km/h, 40km/h, and 70km/h.

(3)Vehicle charging conditions: The vehicle is in charging mode and the power battery state of charge (SOC) shall be between 20% and 80% of the maximum state of charge.

1.5.1.2 Requirements for vehicle anti-electromagnetic interference

The vehicle shall be designed with reasonable layout and shielding protection. When it is in the following working conditions, it shall withstand the external electromagnetic field radiation interference of the standard field strength level without functional state deviation and safety degradation. And in accordance with GB 34660-2017, verify the 20MHz-2GHz frequency band test.

(1)Vehicle dynamic conditions: The vehicle is fully powered and runs at a constant speed of 50km/h;

(2)Vehicle charging conditions: The vehicle is in charging mode and the power battery state of charge (SOC) shall be between 20% and 80% of the maximum state of charge.

1.5.2 Requirements for electromagnetic radiation disturbance and immunity for vehicle-mounted electrical equipment

1.5.2.1 Requirements for vehicle-mounted electrical equipment electromagnetic radiation disturbance

Vehicle-mounted electrical equipment (such as wiper motor, drive motor, etc.) shall be equipped with radio disturbance suppression devices to control the disturbances on emission along the conduction path and the space radiation path to protect the car radio transceivers (such as radio, GPS, T-BOX, etc.) work in a safe range. It shall be verified in accordance with the test of GB/T 18655-2018 (level 3 limit) and meet the standard limit requirements.

(1)Vehicle static conditions: Electrical equipment of the vehicle is powered separately and vehicle power system high-voltage power-on is ready (PT Ready);

(2)Vehicle dynamic conditions: The vehicle travels at a constant speed of 40km/h;

(3)Vehicle charging conditions: The vehicle is in charging mode and the power battery state of charge (SOC) shall be between 20% and 80% of the maximum state of charge.

1.5.2.2 Requirements for vehicle-mounted electrical equipment electromagnetic immunity

Vehicle-mounted electrical equipment shall be designed with reasonable layout and shielding protection. When it is in the following working conditions, it shall withstand vehicle-mounted transmitter standard transmission power field strength level electromagnetic radiation interference without functional state deviation and safety degradation. Test verification shall be carried out for different transmitter operating frequency bands in accordance with GB/T 33012.3-2016.

(1)Vehicle dynamic conditions: The vehicle is fully powered and runs at a constant speed of 50km/h;

(2)Vehicle charging conditions: The vehicle is in charging mode and the power battery state of charge (SOC) shall be between 20% and 80% of the maximum state of charge.

1.5.3 Requirements for disturbance and immunity along the power line during vehicle charging

The vehicle is in the power line conduction charging mode and shall be verified according to the ECE R10.5 test; the harmonic emission shall be along the charging power line; the characteristics of voltage variation, fluctuation and flicker emission, and RF conducted emission shall meet the standard limit requirements. It withstands surge interference from the charging power line and interference from electrical transient fast bursts, without charging function state deviation and safe degradation.

The vehicle is in a wireless charging mode and shall include a wireless charging coupling device connected to the grid, verified and passed in accordance with the ECE R10.5 test.

1.5.4 Safety requirements for vehicle occupants exposed to vehicle electromagnetic environment

This section refers to the low frequency magnetic field emission of the vehicle environment in which the human body is located.

When the vehicle is in the following working conditions, it shall be verified according to the test method of 'vehicle electromagnetic field relative to human body exposure' (for review); the magnetic field emission of 10Hz-400KHz complies with the ICNIRP 2010 limit.

Static condition: When the vehicle is in static state, electrical appliances is fully powered and vehicle power system high-voltage power-on is ready (PT Ready); Dynamic condition: The vehicle travels at a constant speed of 40km/h; The vehicle travels at an acceleration and deceleration of 2.5 m/s2;

Charging mode: The power battery state of charge (SOC) shall be between 20% and 80% of the maximum state of charge.

1.5.5 Requirements for high-voltage harness EMC

The high-voltage harness shall be equipped with EMC shielding measures, and its strike arrangement shall not form EMC radiation enhancement.

The high-voltage harness shield layer shall be operatively connected to the conductive casing of the high-voltage component.

1.6 Vehicle thermo-safety

In the design of the vehicle, consideration shall be given to preventing safety accidents caused by overheating of power batteries, motor systems and other high-voltage components.

1.6.1 Requirements for motor thermal protection

The motor shall be equipped with a temperature sensor and the temperature-detection function shall be realized through the motor controller. If it is detected that the motor temperature is too high, the motor control system shall limit the motor power or prohibit the motor from working and alert the driver via an obvious signal (e.g., an acoustic or optical signal).

1.6.2 Requirements for motor controller thermal protection

The motor controller shall be equipped with the temperature-detection function. If the temperature is detected to be too high, the system shall limit the motor power or prohibit the motor from working and alert the driver via an obvious signal (e.g., an acoustic or optical signal).

1.6.3 Requirements for charging system thermal protection

During the charging process, the charging system of the vehicle needs to monitor the temperature of the charging port. When charging according to the mode specified by the national standard, it is recommended to monitor the temperature of the charging plug. When the temperature protection threshold is exceeded, effective measures (such as power reduction or stop charging) shall be taken to avoid device damage or fire.

During the charging process, the charging system of the vehicle shall have the temperature-detection function of the vehicle charger. When the temperature protection threshold is exceeded, effective measures shall be taken to protect it (such as power reduction or stop charging) to avoid device damage or fire.

1.6.4 Requirements for power battery thermal protection

The vehicle shall be able to effectively dissipate and cool the battery system to ensure that the battery system temperature is always within the normal range of use, so as not to affect the battery system life. When designing the vehicle, it shall be considered that if the battery temperature exceeds the normal usage range, the power output shall be limited and reminded.

If there is a risk of thermal runaway, the vehicle shall have an early warning and alarm function to ensure that the driver and passenger can be evacuated in advance.

1.6.5 Requirements for vehicle air conditioning PTC thermal protection

The air conditioning PTC shall have overheat protection and fault alarm function.

1.7 Safety in vehicle manufacturing, storage, transportation,scrapping, etc.

In the manufacturing process, the high-voltage service switches of the power battery system must be in the disconnected state during the assembly process, and closed at the last part of the final assembly of the vehicle to ensure high-voltage safety during the manufacturing process. The vehicle shall go through a safety inspection process before leaving the factory.

Vehicles shall be avoided for parking long periods of time in high temperature environments, and the power battery SOC shall not be too high during parking (recommended: SOC is 40-70%).

During the transportation of the vehicle, the service switch of the power battery system must be removed to ensure that the vehicle is powered off.

Vehicle scrapping shall be carried out by professional qualification units. Before the vehicle is scrapped, it shall be confirmed that the voltage at the load terminal is lower than B-level voltage or the energy is less than 0.2J, and the power battery system shall be recycled and reused. For details, please refer to the Section on recycling and reuse of batteries.

1.8 Battery swapping design safety

Vehicle power changing refers to the method of replacing the power battery system and providing power for the Electric Vehicle. The replaced power battery system will be centrally charged and maintained at the power changing station.

In order to meet the requirements for quick changing and reliable durability of the power battery system, the battery system and the vehicle with the power changing function need to meet the safety design requirements in the battery system, the fixing/locking mechanism, the connector, the electrical and the software.

1.8.1 Structural safety requirements for power changing battery systems

The mechanical strength of the power battery system shall meet the requirements for safety testing of GB/T 31467.3-2015.

1.8.1.1 Requirements for overall structural safety

The power battery system shell shall adopt a frame structure and shall have sufficient mechanical strength to withstand the requirements for vibration and impact of Electric Vehicles.

The power changing power battery system and the vehicle shall adopt a safe and reliable fixing method. Under the random vibration caused by the vehicle travel, the power battery system will not have a harmful relative displacement or produce obvious mechanical noise. The power battery system locking mechanism shall not have deformation or structural damage.

1.8.1.2 Requirements for fixing/locking mechanism safety

The power changing power battery system and the vehicle chassis shall be fixed by a locking operation mechanism with an anti-locking failure function.

The locking mechanism shall be able to effectively fasten the battery system to the chassis, and shall meet the requirements for durability, environmental and impact performance of the vehicle; there shall be no risk of failure of the locking mechanism during vehicle travel, and the noise shall meet the requirements for vehicle NVH performance.

During the power changing process, the vehicle chassis shall be equipped with a power battery system installation guide positioning mechanism, which can automatically correct the positional deviation of the power battery system when the locking mechanism is inserted;

The power battery system locking mechanism shall be able to automatically follow the displacement change under the frequent vibration and creep caused by the vehicle running to ensure a reliable connection.

1.8.1.3 Requirements for power changing connector safety

The power changing connector shall have a guiding and three-dimensional floating function to ensure a safe and reliable connection between the power changing battery system and the vehicle; the connector shall meet the requirements for IP67 protection in the correct coupling state.

The low-voltage harness shall be inserted into the quick-changing joint to meet the requirements for plug-in wear-resisting and sealing throughout the life cycle; it shall have a guiding mechanism to meet the requirements for guiding and positioning of the low-voltage harness insertion during the power-changing process.

The high-voltage harness shall be inserted into the quick-changing joint to meet the requirements for plug-in wear-resisting and sealing throughout the life cycle; it shall have a guiding mechanism to meet the requirements for guiding and positioning of the high-voltage harness insertion during the power-changing process.

Liquid cooled connector shall be inserted into the quick-changing joint to meet the requirements for plug-in wear-resisting and sealing throughout the life cycle; it shall have a guiding mechanism to meet the requirements for guiding and positioning of the liquid cooled connector insertion during the power-changing process; the liquid cooled connector must not leak during the power changing or use.

1.8.2 Requirements for electrical safety for power changing

The high-voltage harness insertion quick-changing connector shall meet the contact protection requirements for the connector of the electric shock safety part.

The power changing connector shall have a high-voltage interlocking function.

1.8.3 Requirements for power changing control

When the vehicle is monitored and the vehicle enters the power-changing state, the high-voltage power-off process shall be actively performed.

The power battery management system BMS is recommended to have a power- changing working mode. When the BMS enters the power-changing mode, it shall be able to actively guide power-on and power-off, charging control, and battery faults handling.

The VCU or BMS shall monitor the status of the power-changing lock. When it is monitored that the power-changing lock is not in place, the high-voltage or vehicle limp shall not be allowed. It is recommended that the BMS or other controller shall record the number of times the vehicle and the corresponding battery pack are replaced, which is convenient for later maintenance.

2. Commercial car safety

2.1 Anti-electric safety

For the common high-voltage parts of new energy buses (i.e., B-level voltage, which means the maximum working voltage is greater than 60Vd.c. or 30 V.a.c., less than or equal to 1500Vd.c. or 1000 V.a.c.) (charged, electric, and transmitted B-level voltage parts), see Table 2-1:

Table 2-1 Common high-voltage parts

S/N	High-voltage part name
1	Power battery
2	Super capacitor
3	Fuel battery
4	Drive motor
5	High voltage generator
6	Electric steering oil pump
7	Electric air compressor
8	DC/DC converter (including isolated DCDC)
9	Controller (drive motor controller, generator controller, electric steering oil pump controller, electric air compressor controller)
10	High-voltage service switches
11	High-voltage power distribution
12	Electric defrost
13	Electric air conditioner
14	Charging socket
15	Vehicle-mounted charger
16	High-voltage harness and connector

2.1.1 Requirements for safety identification

2.1.1.1 Requirements for high-voltage warning marking

B-level voltage parts, such as REESS and fuel battery stacks, shall be marked with the symbols shown in Figure 2-1. Ground color of symbol is yellow, color of borders and arrowhead is black. According to the provisions of GB 2893, GB 2894 and GB/T 5465.2. When the obstruction or casing is removed to expose the B-level voltage live parts, the same symbols shall be clearly visible on the obstruction and the casing. When assessing whether this symbol is required, consideration shall be given to the case where the

obstruction/casing is accessible and removable; In the vicinity of the mark, it is suggested that there shall be a notice of obvious safety operation attention items. For example, “The motor controller can be turned on 10 minutes after measuring the bus voltage value as a safe voltage.”

Figure 2-1 High-voltage warning mark

2.1.1.2 Requirements for B-level voltage wire marking

In the B-level voltage circuit, the outer skin of the cable and harness shall be distinguished by orange, and it is recommended that skin inside the casing or behind the obstruction shall also be distinguished by orange.

B-level voltage connectors can be distinguished by the harness to which they are connected.

2.1.2 Requirements for direct contact protection

Direct contact protection refers to the physical isolation of the human body from the B- level voltage live parts by means of insulating materials, casing or obstruction. The casing or obstruction can be either a conductor or an insulator. Requirements for direct contact protection of specific components shall be in accordance with 2.1.2.1 to 2.1.2.4. For the M2 and M3 models, if the top charging device is placed on the car roof, as shown in Figure 2-2, the shortest path length from the bottommost step of the vehicle inlet to the exposed B-level voltage live parts of the top charging device shall be at least 3m, the exposed B-level voltage live part of the top charging device may not meet the requirements for direct contact protection.

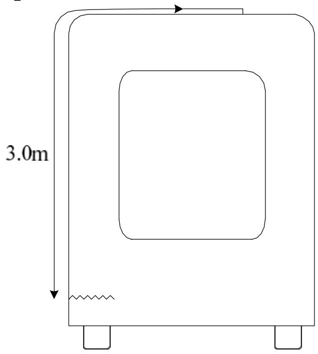


Figure 2-2 Shortest Path Measurement Schematic

2.1.2.1 Requirements for obstruction and casing

If electric shock protection is provided by an obstruction or casing, the B-level live parts shall be placed in the casing or behind the obstruction to prevent access to the live parts from any direction.

The obstruction and casing need to meet the following two requirements:

(1)The obstructions and casings in the passenger cabin and cargo cabin shall meet the requirements for IPXXD protection grade, and the obstructions and casings outside the passenger compartment and cargo cabin shall meet the requirements for IPXXB protection grade;

(2)Usually, the obstructions and the outer casings can only be opened or removed by tools; If the obstruction and the casings can be opened or removed without the use of tools, there must be some way to make B-level voltage live parts satisfy at least one of the following two requirements within 1 s after the obstruction and the casing are opened:

--The voltage of the AC circuit shall be reduced to no more than 30 Va.c. (rms), the DC circuit voltage shall be reduced to no more than 60Vd.c.; Or

-- B-level circuits store a total energy of less than 0.2 J.

2.1.2.2 Requirements for connector

High-voltage connectors shall not be opened without the use of tools, except in the following three cases:

(1)After the high-voltage connectors are separated, the requirements for protection grade shall be met; or

(2)The high-voltage connector requires at least two different actions to separate it from the mutual butt joints, and the high-voltage connector has a mechanical locking relationship with some other mechanism. Before the high-voltage connector is opened, the locking mechanism can only be opened with tools; or

(3)After the high-voltage connector is separated, the voltage of the live part of the connector can be reduced to no more than 30 Va.c. (rms) within 1s and no more than 60 Vd.c.

2.1.2.3 Requirements for high-voltage service disconnecting device

For vehicles equipped with high-voltage service disconnecting device, the high-voltage service disconnecting device shall not be opened or removed without the use of tools, except in the following two cases:

(1)After the high-voltage service disconnecting device is opened or removed, the B- level voltage live parts meet the requirements for IPXXB protection grade specified in GB/T 4208;

(2)For the high-voltage service disconnecting device, the voltage of B-level voltage live part can be reduced to no more than 30 Va.c (rms) and no more than 60 Vd.c. within 1 s after separation.

2.1.2.4 Charging socket request

When the vehicle has multiple charging interfaces, the charging interface that does not perform charging work shall be charged.

When the vehicle charging socket and the vehicle charging plug are disconnected, the vehicle charging socket shall meet at least one of the following requirements:

(1)Within 1 s after disconnection, the voltage of the B-level voltage live part of the charging socket shall be reduced to no more than 30 Va.c. (rms) and no more than 60 Vd.c. or the total energy stored in the circuit shall be less than 0.2 J; or

(2)Meet the regulations of IPXXB specified in GB/T 4208 and within 1 min, the voltage of the B-level voltage live part of the charging socket B shall be reduced to no more than 30 Va.c. (rms) and no more than 60Vd.c. or the total energy stored in the circuit shall be less than 0.2 J.

2.1.2.5 High-voltage interlocking requirement

(1)The key circuit connector in the B-level voltage live circuit is recommended to implement software or hardware interlocking function in combination with the vehicle control system;

(2)When the high-voltage safety system detects that somewhere is disconnected or somewhere is abnormal, it is recommended that the vehicle system cut off the output of the relevant power supply and issue an alarm until the faults are completely eliminated.

2.1.3 Requirements for indirect contact protection

2.1.3.1 Requirements for insulation resistance

(1)General principles

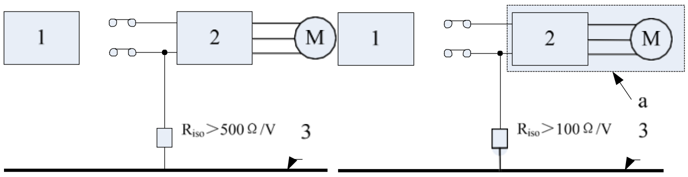
At the maximum working voltage, the minimum value of the DC circuit insulation resistance shall be at least greater than 100 Ω/V, and the AC circuit shall be at least greater than 500 Ω/V.

In order to meet the above requirements, each component of the entire circuit shall have a higher insulation resistance depending on the structure of the circuit and the number of components.

If the DC and AC B-level voltage circuits are electrically connected together (see Figure 2-3), one of the following two options shall be met:

-- Option 1: The combination circuit shall meet at least the requirements of 500 Ω/V; or

-- Option 2: If the AC circuit applies at least one additional protection method specified by b (additional protection method for AC circuits), the combination circuit shall meet at least the requirements of 100 Ω/V;



Option 1 Option 2

Figure 2-3 Requirements for Insulation Resistance of B-level Voltage Systems with DC and AC Circuits

Instructions:

1-- Power battery or high-voltage power supply; 2-- Inverter;

3-- Electrical chassis; a-- AC circuit.

(1)Additional protection method for AC circuits

One or more of the following methods shall be applied in addition to or in place of the direct contact protection described in 2.1.2 to provide protection against indirect contact failure:

-- Replace basic insulation with double or reinforced insulation;

-- Attaching one or more layers of insulation, obstruction and/or outer casing;

-- During the entire life of the vehicle, a rigid obstruction/ casing with sufficient mechanical strength and durability shall be used to cope with faults.

(2)Requirements for insulation resistance of charging sockets

-- Vehicle AC charging socket

The vehicle AC charging socket shall have terminals to connect the electric platform to the grounding part of the grid.

The insulation resistance of the vehicle AC charging socket, including the circuit that is conductively connected to the grid during charging, shall be no less than 1 MΩ when the charging interface is disconnected.

-- Vehicle DC charging socket

The vehicle DC charging socket shall have terminals to connect the vehicle electrical platform to the protective grounding of the external power supply.

The insulation resistance of the vehicle DC charging socket, including the circuit that is electrically connected to the vehicle DC charging socket during charging, shall be no less than 100 Ω/V when the charging interface is disconnected.

2.1.3.2 Requirements for insulation resistance monitoring

The vehicle shall have an insulation resistance monitoring function and shall pass the insulation monitoring function verification test of 6.2.3 of GB *Electric vehicles-Safety specification*. The device can continuously or intermittently detect the insulation resistance value of the vehicle when the vehicle B-level voltage circuit is turned on and is not conductively connected to the external power source. When the insulation resistance value is less than the manufacturer-specified threshold, an obvious signal (e.g.: sound or light signal) device shall be equipped to alert the driver and the threshold specified by the manufacturer shall not be lower than the requirements of 5.1.4.1 of GB *Electric vehicles-Safety specification*.

2.1.3.3 Requirements for potential equalization

An exposed conductive part for protection against direct contact with a B-level voltage circuit, such as a conductive outer casing and obstruction, shall be conductively connected to the electrical platform and meet the following requirements:

(1)The connection resistance between the exposed conductive portion and the electric platform shall be no more than 0.1 Ω;

(2)In the potential equalization path, any two exposed conductive parts that can be touched by people at the same time, that is, the resistance between two conductive parts having a distance of no more than 2.5 m shall be no more than 0.2 Ω.

If the welding connection method is adopted, it is considered to satisfy the above requirements.

2.1.3.4 Requirements for capacitive coupling

Capacitive coupling shall meet at least one of the following requirements:

(1)In the B-level voltage circuit, the total capacitance between any B-level voltage live parts and the electrical platform shall be no more than 0.2 J at its maximum working voltage. 0.2 J is the maximum stored electrical energy of B-level voltage circuit anode Y capacitor or cathode Y capacitor; In addition, if B-level voltage circuits are isolated from each other, 0.2 J is a separate requirement for each isolated circuit;

(2)B-level voltage circuits shall be equipped with at least insulation, obstruction or casing, which are placed inside the casing or outside the obstruction, and these casings or obstructions shall withstand pressures of no less than 10 kPa without significant plastic deformation.

2.1.3.5 Requirements for power-off after faults

For the faulty B-level voltage circuit, detecting faults or finding accidents in the circuit can be used as a judgment condition, and the controller of the vehicle shall select a power-off mode as a protection measure.

When the vehicle is in the process of running, if there is an abnormal situation of the vehicle that needs to cut off the B-level high-voltage power automatically, when the vehicle speed is greater than 5km/h, the steering system shall maintain the power- assisted state or at least maintain the steering assist state for 30s and then cut off the B- level power supply. The circuit which the power supply is cut off shall meet one of the following conditions within the time set by the vehicle manufacturer based on the predicted faults and operating conditions:

--The voltage of the AC circuit shall be reduced 30 Va.c. (rms), the DC circuit voltage shall be reduced to 60Vd.c. or less;

--Or the total energy stored in the circuit shall be less than 0.2 J.

2.1.3.6 Requirements for discharge after power off

The motor system shall have active discharge or passive discharge function. When the B-level voltage system is powered off, conduct active discharge for no more than 3s or passive discharge for no more than within 5min, and the DC bus voltage shall be reduced to a safe level (DC voltage below 60V).

And in the case that the faults have not been removed, the vehicle shall be prohibited from being powered on again.

2.1.3.7 Creep distance requirement

The insulation resistance and creep distance of the vehicle energy storage device shall comply with the requirements of Clause 5.2 of GB/T 18384.1.

2.2 Waterproof safety

2.2.1 Requirements for component waterproof

(1)The protection grade of the connector between the voltage components shall meet the IP67 specified in GB 4208 (excluding the charging port and the power receiving device);

(2)For A-level voltage connectors used in B-level voltage parts and systems formed thereby, the protection grade shall be IP67;

(3)The protection grade of the parts shall not be lower than IP68, and the protection degree of components and systems shall be in accordance with the test conditions of GB 4208.

--B-level voltage electrical equipment installed below the cabin floor and below 500 mm from the ground and connectors connected to B-level voltage parts (except charging ports);

--B-level voltage electrical equipment (except power receiving devices) installed on the roof and without protection device.

2.2.2 Requirements for vehicle wading

The vehicle shall drive at a speed of 5 to 10 km/h in a pool with the water depth of 300 mm to complete the wading test for 3 to 5 min; If the length of the pool is less than 500 m, it needs to be done several times. The total time (including the time outside the pool) shall be less than 10 min. Within 10 min after completion of the vehicle wading test, the measurement shall be completed in accordance with the insulation resistance measurement method of 7.2 of GB/T 18384.3, and the total insulation resistance value shall be greater than 1 MΩ.

2.2.3 Requirements for vehicle submerging

For the B-level voltage electrical equipment installed below the cabin floor and below 500 mm from the ground and connectors connected to B-level voltage parts (except charging ports), conduct submerging test.

In the state of electricity return, submerging the vehicle in the pool with the water depth of 50cm for 24h, then opening the fire switch, and keeping the ignition lock in “ON” state, there shall be no smoke, fire or explosion for the vehicle within 2h.

2.3 Fire safety

2.3.1 Fire early warning

(1)The rechargeable energy storage system shall be equipped with an automatic fire detection function (automatic detection of smoke, temperature, gas, etc. before the fire, for early warning), and a sound or light alarming signal shall be provided to the driver in the driving area;

(2)Pure electric passenger cars and plug-in hybrid passenger cars with a length of 6m or more shall be able to detect the working state of the power battery and alarm when an abnormal situation is found, and the outside of the battery box shall not ignite and explode within 5 min after the alarm.

2.3.2 Fire isolation

Flame-retardant insulation materials shall be used between the rechargeable energy storage system (or installation cabin) and the passenger cabin. The combustion performance of the flame-retardant insulation material shall meet the requirements for Class A specified in GB 8624 and corresponding tests shall be carried out according to GB/T10294. The thermal conductivity shall be less than or equal to 0.04 W/(m·K) at 300 ℃.

2.3.3 Flame retardant design

(1)Flame-retardant materials shall be used in the rechargeable energy storage system. The flame-retardant grade of the flame-retardant material shall comply with GB-T 2408, that is, horizontal combustion HB grade and vertical combustion V-0 grade;

(2)The flame-retardant properties of the insulation materials used for B-level voltage parts shall comply with the horizontal combustion HB grade specified in GB/T 2408 and the vertical combustion V-0 grade. The temperature grade of the B-level voltage cable protection bellows and the heat-shrinkable double-wall pipe shall not be lower than 125 ℃. The performance of the heat-shrinkable double-wall pipe shall comply with the requirements of Appendix B of QC/T 29106, and the properties of the bellows shall comply with the requirements of Appendix D of QC. /T 29106;

(3)The flame-retardant properties of the vehicle interior material shall be tested according to the method of GB 8410, and the horizontal combustion speed shall be less than or equal to 50 mm/min.

2.4 Control safety

2.4.1 Requirements for hardware design

Hardware design work is carried out from four aspects: requirements for hardware safety definition, hardware design and implementation, hardware failure mode analysis and hardware system testing.

2.4.1.1 Requirements for hardware safety

The designed hardware products shall meet the requirements for vehicle system such as electrical properties and environmental adaptability.

(1)Electric properties: The designed hardware products shall comply with the requirements for electrical property specified in QC/T 413 Automotive electrical equipment basic technical conditions; According to ISO 16750-2 and GB_T 28046.2, it shall meet requirements for the working voltage, power overvoltage property, power supply superposition AC property, power supply voltage dropping property, power startup characteristics, power supply polarity reverse connection, unloading property, power supply voltage ramp up and ramp down property and power supply voltage instantaneous drop property;

(2)Environmental adaptability: Shall meet the needs of the vehicle running environment. The product protection grade when the vehicle is placed in the chassis and other wet areas shall not be lower than IP67; According to GB_T 28046.3, it shall meet the requirements for product property including low temperature property, high temperature property, temperature impact property, temperature and humidity property, salt spray property, protection property and free fall property.

2.4.1.2 Hardware design and implementation

The evaluation of hardware architecture measure is required, and the evaluation results and optimization suggestions shall be fed back to the system design, hardware design and software design to optimize product design. In the detailed design and implementation phase, requirements for functional redundancy and functional shall be fully considered. The automotive-class mature circuit unit is preferred, and the automotive-grade chips are selected for components to meet requirements for property, function and cost.

2.4.1.3 Hardware failure mode analysis

Through the analysis of the hardware failure mode, identify the product failure caused by the potential risk in the hardware design, and establish the FMEA table to ensure the integrity of the analysis. For failure modes that impact safety, appropriate safety mechanisms shall be established to ensure safety; for safety failure modes that will not impact safety, the necessity to set safety mechanisms needs to be evaluated.

2.4.1.4 Hardware system testing

In order to verify the integrity and correctness of the safety mechanism, hardware system testing shall be considered as follows to ensure that the hardware developed meets the requirements for hardware safety.

(1)Functional testing, that is, testing the interface specifications of the hardware under test using black box testing techniques;

(2)Non-functional testing, which tests the property or reliability of the hardware.

2.4.2 Requirements for software design

Based on the relevant regulations of GB/T 34590-6, carry out definition of requirements for software safety, software architecture design, software unit design and implementation, software unit testing, software integration and testing, requirements for software safety and verification, and meet requirements for system design and software safety need.

2.4.2.1 Requirements for definition of software safety

Based on the relevant regulations of GB/T 34590-6, requirements for software safety are derived from requirements for technical safety and system design specifications. The definition of requirements for software safety considers hardware constraints and impact on software. Requirements for software safety shall be specific to each software module-based function, and failure of these functions may result in a violation of the requirements for technical safety assigned to the software. The requirements for software safety analysis phase needs to meet the requirements for integrity, testability and traceability.

2.4.2.2 Software architecture design

Based on the relevant regulations of GB/T 34590-6, the software architecture design describes all software components and their interaction in the hierarchy; Static aspects, including interfaces and data paths among all software components; Dynamic aspects, including process order and timing behavior, which will be described.

Software architecture design shall consider the verifiability of software architecture design, the applicability of configurable software, the feasibility of software unit design and implementation, the testability of software architecture in software integration testing and the maintainability of software architecture. Software architecture design needs to follow the requirements for high aggregation and low coupling with modularity, encapsulation and simplicity attributes.

2.4.2.3 Software unit design and implementation

Based on the relevant regulations of GB/T 34590-6, the detailed design of the software unit is designed and developed based on the software architecture. The detailed design of the software unit is implemented as a model or directly in source code according to the modeling or coding guidelines. Conduct static verification of detailed design and implementation before starting the software unit testing. The implementation of the software unit involves the generation and conversion of source code into object code.

2.4.2.4 Software unit testing

The purpose of the software unit testing is to prove that the software unit meets the software unit design specifications and does not contain unexpected functions. The software unit testing is based on the software unit design specification, establishes the software unit testing process and executes the testing according to the process.

In the unit testing process, in order to evaluate the integrity of the testing case and prove that there is no unexpected function, the required coverage at the software unit level shall be determined, and the coverage shall be measured. If the achieved structural coverage is considered insufficient, add additional testing cases or give reasons for acceptance.

2.4.2.5 Software integration and testing

Based on the relevant regulations of GB/T 34590-6, according to the software architecture design, the unique integration level and interface between software elements are tested. The steps of software element integration and testing directly correspond to the layered architecture of the software.

Software integration shall complete the layered integration of software units into software components until the entire embedded software is integrated, and consider the dependencies associated with software integration and the dependencies between software integration and hardware and software integration.

In the software integration testing process, in order to evaluate the integrity of the testing case and prove that there is no unexpected function, the required coverage at the software unit level shall be determined, and the coverage shall be measured. If the achieved structural coverage is considered insufficient, add additional testing cases or give reasons for acceptance.

2.4.2.6 Software security requirements verification

Based on the relevant provisions of GB/T 34590-6, the purpose of software security requirements verification is to prove that embedded software meets software security requirements in the target environment.

The test environment in the verification can be hardware-in-the-loop, test bench, or vehicle environment. Consider using tools such as the traceability matrix to ensure and evaluate the coverage of software security requirements and reuse existing test cases. If the coverage is not sufficient, increase the test case or give an acceptable reason.

2.4.3 Function and operation design

2.4.3.1 Power-on and power-off operation design

The vehicle control system shall be able to control the on/off sequence of the B-level voltage circuit. When power is on, the low voltage shall be turned on first, then the high-voltage shall be turned on. When the power is off, the high-voltage shall be disconnected first, then the low voltage shall be disconnected.

The brake pedal and gear position signals shall be detected when the vehicle is under high-voltage; simply disconnect the power switch when power is off.

2.4.3.2 Gear operation design

When the gear is switched from neutral to drive, the brake pedal needs to be stepped. When the gear is switched from the drive to neutral, only the gear is shifted to neutral.

2.4.3.3 Charging operation design

When the charging gun is connected to the vehicle, the vehicle cannot emit torque to drive the vehicle.

2.4.3.4 Steering operation design

When the vehicle is in the process of running, if there is an abnormal situation of the vehicle that needs to cut off the B-level high-voltage power automatically, the driver shall be notified through sound and light alarm. When the vehicle speed is greater than 5km/h, the steering system shall maintain the power-assisted state or at least maintain the steering assist state for 30s and then cut off the B-level power supply.

2.4.3.5 Brake priority design

While the vehicle is running, when the brake pedal and the accelerator pedal are active at the same time, the vehicle shall only respond to the brake pedal signal.

2.4.3.6 Vehicle fault level display and processing mechanism

For different fault levels, each OEM shall develop different fault handling mechanisms according to its own conditions. The following table shall be referred:

Fault level	Level III fault	Level II fault	Level I fault
Instructions	Serious fault	Relatively serious failure	Warning fault
Processing mechanism	Inform the driver while disconnecting the driving force	Limit torque output	Meter prompt

For different fault levels, each OEM shall develop different fault handling mechanisms according to its own conditions. The following table shall be referred:

Fault level	Level III fault	Level II fault	Level I fault
Instructions	Serious fault	Relatively serious failure	Warning fault
Instrument display mechanism	Sound warning, the meter shows the vehicle Level III fault	Sound warning, the meter shows the vehicle Level II fault	The meter shows the vehicle Level I fault

2.5 Collision safety

2.5.1 Side collision protection design

The side protection structure shall be tested in accordance with Appendix C of *Safety Technical Conditions for Electric* Passenger Cars. The vehicle shall meet the requirements of 4.2 to 4.4 of GB/T31498 after the collision test.

2.5.2 Rollover protection design

If the vehicle protection structure is tested according to GB17578 for the strength of the superstructure, it shall be tested in the state of power-on with charge of 30% to 50% of its rechargeable energy storage system (SOC). After the test, it shall comply with the requirements in 4.2 to 4.4 of GB/T31498.

2.5.3 Rear-end collision protection design

The arrangement position and protection structure of the B-level voltage parts of the rear high-voltage cabin shall be considered to be in line with the requirements in 4.2 to 4.4 of GB/T 31498.

2.5.4 Bottom collision protection design

The bottom collision protection design shall consider two aspects, one is the ground clearance and the other is the protection structure. If the power battery is placed under the floor, the minimum ground distance between the shafts is recommended to be 4% or 3.3% of the wheelbase (for vehicles with air suspension), but not less than 190mm, and the protective design shall be considered. The protection design shall meet the requirements in 4.2 to 4.4 of GB/T 31498 after the occurrence of the bottom collision.

2.6 Escape safety

2.6.1 Design of escape window

(1)The area of emergency window and escape hatch shall be more than or equal to (5×105) mm^2, and a rectangle which is 500 mm×700 mm (450mm×700mm for the passenger car with the length less than or equal to 7m) can be connected inside. If the emergency window is in the rear end of the passenger cars, and a rectangle which is 350mm×1550mm and with radius of curvature of four corners less than or equal to 250mm can be connected inside, it shall be deemed to meet the requirements.

(2)The emergency window shall be equipped with the device which can be opened easily inside and outside; Or use an automatic window breaking device; Or mark the center breaking point mark with a diameter of not less than 50mm in the middle or right corner above the window glass, and provide an emergency hammer in the vicinity of each emergency window to facilitate the crushing of the window glass, and when the emergency hammer is removed, it can realize alarm by sound signal; The glass breaking device of the emergency window of the rear wall of the passenger car shall be placed in the middle position above or below the emergency window, or the glass breaking device shall be placed on the left and right sides.

3()For the windows on both sides of the passenger car with the passenger standing area, if the opening can be connected with a rectangle with an area of ≥800mm×900mm, it shall be set as push-pull or push-out emergency window; If the opening can be connected with a rectangle with an area of ≥500mm×700mm, it shall be set as glass breaking type emergency window, and configure the emergency hammer nearby or have the function of automatic window breaking (the side window opening size shall be measured from the interior side window column after the vehicle is manufactured).

(4)For road passenger cars, sightseeing passenger cars and buses without passenger standing areas, when the length of the vehicle is more than 9m, at least two push- out emergency windows shall be provided on the left and right sides of the vehicle, and one emergency door shall be provided on the left side of the vehicle. When the length of the vehicle is more than 7m and equal to or less than 9m, at least one push-out emergency window shall be provided on the left and right sides of the vehicle; The upper middle or right corner of the push-out emergency window glass shall be marked with a breaking point mark, and an emergency hammer shall be placed adjacent to it; For other passenger cars with the length of more than 9m and no passenger standing area, there are at least two glass breaking type emergency windows on the left and right sides of the vehicle (when the total number of glass breaking type emergency windows on both sides of the vehicle is less than or equal to 4, if all glass breaking type emergency windows have automatic window breaking function, they shall be considered satisfactory.

(5)The emergency window hinged horizontally to the upper end shall have an appropriate mechanism to keep it fully open. The opening of the articulated emergency window shall ensure the smooth passage of the inside and outside of the vehicle.

(6)The height from the lower edge of the side window of the passenger car (the upper edge of the metal lower frame of the push-pull window) to the floor plane at the pedal below it (without any local changes, such as local deformation caused by wheels, transmissions or toilets) shall be less than or equal to 1200mm and greater than or equal to 500mm. For push-pull and push-out side windows, if the lower edge of the openable part is lower than 650mm, a protection device shall be provided at a height of 650mm to 700mm from the floor to prevent passengers from falling outside the vehicle; If the side window is used as an emergency window, the area of the opening above the protection device shall be greater than or equal to the minimum size of the emergency window; If the lower edge of the side window opening is greater than or equal to 650 mm from the floor plane below it, no protection device may be provided.

(7)An audible alarm shall be installed on the articulated emergency window if the driver cannot clearly see on the seat. The warning device shall be activated by the movement of the window lock or handle (not the window itself), alerting the driver when the emergency window is not fully closed.

2.6.2 Escape door design

(1)The net height of the emergency door shall be more than or equal to 1250mm, and the net width shall be more than or equal to 550mm; But for the passenger cars with the length less than or equal to 7m, the net height of the emergency door shall be more than or equal to 1100mm. If the wheel cover protrudes within 400mm above the lowest area of the opening, the net width of the emergency door in the protruding part of the wheel cover can be reduced to 300mm.

(2)The articulated emergency door on the side of the vehicle shall be hinged in the front end, the outward opening angle shall be more than or equal to 100 °, and the opening can be kept under such angle. If the free passage which is more than or equal to 550mm can be provided when the emergency door is opened, the opening angle which is more than or equal to 100 °may not be met.

(3)The width of approach leading to the emergency door shall be more than or equal to 300mm. If it is less than 300mm, the approach can be widened with the method of fast turnover seat. When the folding seat is installed along the approach side in the special school bus, in the case that the folding seat is opened (seat which can be folded automatically when it is not used, when the seat is in the folding position), the approach width shall be more than or equal to 300mm.

(4)The emergency door shall have the locking mechanism and the locking shall be reliable. The emergency door shall be locked when it is closed, and it will not be opened automatically due to the vehicle vibration, bump and crash in the case of normal driving.

(5)When the passenger car stops, the emergency door shall be able to be easily opened from inside and outside without the use of tools. Even if the door is locked from outside the car, it shall be able to be opened from the inside with the normal opening device. The emergency door opening device outside the vehicle shall be protected by a device that is easily removed or broken. Passenger cars shall not be fitted with other devices that secure and locking emergency doors.

(6)The exterior opening device of the emergency doors of the passenger car (including the lower layer of the double-decker passenger car) shall be 1000mm to 1800mm from the ground and less than or equal to 500mm from the door; The in-vehicle opening device of the emergency doors of Class I, Class II and Class III passenger cars shall be 1000mm to 1500mm from the upper surface of the floor (or pedal) below it, and less than or equal to 500mm from the door. This regulation does not apply to controls placed in the driving area.

(7)All emergency doors shall be provided with an audible device to alert the driver when the emergency door is not fully closed. The reminder device shall be activated by the movement of the door's locking device (such as a latch or handle) rather than the movement of the door itself.

2.6.3 Escape time requirement

Within 8 s after the operation of the passenger door emergency controller, the passenger door shall be automatically opened or easily opened by hand to the width through which the corresponding passenger door approach gauge can pass.

2.7 EMC safety

2.7.1 Requirements for radiation disturbance and immunity of vehicle exterior vehicles

The relevant requirements are strictly in accordance with GB 14023, GB/T 18387, GB 34660 and other national standards.

2.7.2 Requirements for radiation disturbance and immunity requirements of vehicle

electrical equipment

The radiation disturbance and immunity of vehicle electrical equipment shall meet the requirements of Table 2-2:

Table 2-2

Testing projects		Requirements for national standard
Emission	Radiated emission	GB/T 18655-2018
	Conducted emission	GB/T 18655-2018
	Transient conducted emission	GB/T 21437.2-2008
Immunity	Radiowave chamber method	GB/T 33014.2-2016
	Bulk current injection	GB/T 33014.4-2016
	Transient conduction immunity (power line)	GB/T 21437.2-2008
	Transient conduction immunity (signal line)	GB/T 21437.3-2012
	Electrostatic discharge	GB/T 19951-2005

2.7.3 Harassment and immunity requirements along the power line during vehicle charging

When the vehicle is in the power line conduction charging mode, the power line disturbance and immunity are recommended to be verified by ECE R10.5 test to meet the relevant requirements.

2.7.4 Vehicle occupants exposed to vehicle electromagnetic environment safety requirements

When the vehicle occupant is exposed to the electromagnetic environment of the vehicle, relevant requirements of GB/T 37130 shall be met.

2.7.5 High and low voltage wiring harness design and layout requirements

The high-voltage harness shall be equipped with EMC shielding measures, and its strike arrangement shall not form EMC radiation enhancement. The high voltage harness shield shall be operatively connected to the conductive housing of the high voltage component.

2.8 Storage and transportation safety

2.8.1 Storage safety

2.8.1.1 Requirements for site

(1)The storage sites shall be special parking lots, which shall be well ventilated and well drained. In extreme cases, the depth of water accumulation shall not exceed 300 mm;

(2)The location of the storage sites shall be away from petrol stations, gas stations, heat sources, moisture, combustible facilities/combustible material storage areas, corrosive gases and dusty places. At the same time, other vehicles or moving objects shall be avoided to cause collisions or crushes on the vehicle. In order to prevent the secondary impact of accidents, it shall also be away from residential areas or crowded areas;

(3)Metal cutting, welding or grinding is strictly prohibited within 10 m of the storage area;

(4)The special parking lots shall have a video monitoring device and regular patrol mechanism for personnel. The period shall not be less than 3 times/day, and the patrol shall have a record archive (one month for the archive period).

2.8.1.2 Requirements for storage

(1)When the vehicle is stored, the distance between the two vehicles shall be not less than 2m (distances all around vehicles need to be satisfied);

(2)When the vehicle is stored for a long time (more than 3 months), the 24V main switch shall be disconnected. The ambient temperature shall be within -40℃ to 50℃, SOC (state of charge) shall be 40% to 70% and storage environment humidity shall be 5% to 95%; If the vehicle is stored for more than 6 months, the battery needs to be fully charged and then discharged to 40% to 70% and the storage period shall be recalculated. Otherwise, it may cause excessive discharge of the power battery and reduce battery property;

(3)When the ambient temperature is below 0℃, SOC of the short-term parking (within one week) vehicle must be guaranteed at 70% to 80%;

(4)For vehicles that shall be stored for more than 3 months, the following maintenance items shall be carried out before putting into to operation again:

--Open each battery compartment and observe whether the battery pack and the chassis frame are fixed firmly. During this process, simultaneously observe the fastening of the high and low voltage harness and the connector to confirm whether there is looseness or damage; Observe the battery pack and check for deformation, damage to the cover, odor and bloating.

--Remove the battery compartment chassis seal plate, observe whether the paint mark of the battery pack fixing point is misaligned, and use the torque wrench to re-torque to confirm whether the torque is attenuated and re-tighten the battery pack.

(1)Use compressed air to remove dust and debris from all service compartments;

(2)After moving the cleaned vehicle to the garage or parking lot, pull up the parking brake handle, retract the gear to N, turn the key to OFF and disconnect the power supply main switch;

(3)Close all window glass of the vehicle, close all maintenance compartment doors of the vehicle and lock with a mechanical key. The compartment door shall be kept closed and cannot be opened at will;

(4)Close all passenger doors, disconnect the power supply main switch and keep the smart key in a safe place;

(5)For vehicles parked for a long period of time, the vehicles and key components and vehicle energy storage devices and systems shall be regularly inspected and maintained by personnel with special training qualification records. The inspection results shall be recorded in detail.

2.8.1.3 Requirements for fire extinguishing facility configuration

When the vehicle is parked in the parking lot, a CO2 fire extinguisher or dry powder fire extinguisher shall be placed on each side of the vehicle within 5 m. The position of the fire extinguisher shall be convenient for access; the parking lot needs to be equipped with sufficient fire water. When the battery is on fire, the relevant personnel battery keep at least 10 m away from the accident vehicle and use fire hydrant hose water jetting to extinguish the fire.

2.8.2 Transportation safety

2.8.2.1 Requirements for hauling

When transporting by non-driving mode, it shall be shipped with special tools or lifting platforms to prevent deformation and damage of the vehicle body and components; At the time of shipment, sufficient space shall be reserved between the passenger cars, the wheels shall be plugged with wedges, and the passenger cars shall be fastened with ropes to prevent the vehicle from slipping; After shipment, the parking brake shall be implemented, the window shall be closed and the door shall be locked and covered as needed. It is recommended that the SOC be between 40% and 70%.

When transporting vehicles, be as far away as possible from fire, heat, high-voltage lines, flammable, explosive and other dangerous goods, and set high-voltage warning signs.

2.8.2.2 Requirements for self-driving

When using self-driving, follow the regulations for driving new cars in the manual.

(1)Evaluate whether the current power meets the destination mileage requirement and avoid the vehicle being anchored due to insufficient power;

(2)A safety check must be made before self-driving.

(3)The fire extinguisher in the vehicle must be fully equipped;

(4)The vehicle must be under no-load;

(5)No rapid acceleration or sudden braking.

2.8.2.3 Rescue transportation after accident

After an accident, when the accident vehicle cannot be shipped, it is necessary to consider the convenience of the accident vehicle trailer, and trailer according to the trailer mode agreed in the vehicle instruction manual to avoid the high temperature of the motor or the high back electromotive force during the trailer process, causing a safety accident.

2.9 Safety inspection

2.9.1 Daily inspection

It is executed daily by the driver before, during and after driving. The daily inspection items of the new energy system are as follows:

Table 2-3 Daily Inspection Items of the New Energy System

S/N	Maintenance item	Operation contents	Technical requirements
1	Clean	Clean new energy components	Clean high-voltage generators, drive motors, electric steering oil pump, electric air compressor, high- voltage control cabinets, etc.
2	Check	Check the new energy high-voltage compartment	The door lock is valid and there is no dust or water leakage in the compartment. No copper is exposed in the high-voltage line terminals, no loose or worn Power battery box and each terminal are fixed reliably The high-voltage compartment ventilation fan works normally and the compartment temperature is normal.
		Check motor water cooling system	Check the water level of the water tank, add when not enough Check the pipeline for no bending, folding or water leakage
		Power battery	The box is fixed reliably, and there is no obvious dust, rust or deformation on the surface of the box Dry and clean the battery compartment The high and low voltage lines of each box are connected normally and fixed reliably without any looseness.
		Check drive motor, high-voltage generator, electric steering oil pump and electric air compressor	The motor is firmly fixed The motor has no abnormal noise and no fault Check whether the electric steering pump and electric air compressor are no oil leakage or air leakage
		Check meter and gear control panel	Normal and no fault

2.9.2 Routine inspection

The vehicle shall be routinely inspected according to the instruction manual. The new energy system inspection work items are as follows:

Table 2-4 New Energy System Inspection Operation Items

S/N	Inspection items	Operation contents	Technical requirements
1	Electric steering oil pump	(1) Inspection and cleaning (2) Check the high voltage and low voltage plug connectors (3) Check steering motor grounding	(1) Dust removal, keep dry and clean, no oil leakage to the oil pump casing and joints (2) The high voltage and low voltage plug connectors are firmly connected, and no terminals are loose. (3) The grounding wire is firm and not loose, and the grounding resistance between the steering motor and the vehicle body shall be less than 0.1Ω.
2	High-voltage controller	View and fasten the controller box	Controller is fixed firmly and no loose Dust removal. Keep dry and clean The maintenance switch can be normally disconnected, the fuse has no high temperature discoloration, and the circuit breaker works normally.

3	Drive motor controller and high-voltage generator controller	Check wiring conditions Visual inspection and cleaning Motor controller shell grounding detection Check the low-voltage plug-in interface Motor cooling water pipe	The wiring is firm and not loose Dust removal, keep dry and clean, no aging, deformation or leakage of cooling water pipes The resistance between the motor controller shell and the vehicle body shall be less than 0.1Ω Low-voltage plug-in interface is firmly connected, no terminal is loose Water pipes and joints are reliable and without damage
4	DC/DC, DC/AC and all-in-one controller	Visual inspection of each wiring pile Visual inspection and cleaning	Fixed and reliable, dry and clean surface Each wiring pile head is not loose, not allowed to be bare
5	Power battery pack	Inspect the battery box Visual inspection of fixing and each terminal pile Battery voltage and temperature Insulation testing Check the single cell dropout voltage	Check the bottom of the battery box for abnormalities such as electrolyte and water Each wiring pile head is not allowed to be exposed. The voltage dropout voltage of the single cell shall not exceed the standard, and the temperature does not exceed the requirements of the specification. The total anode and cathode insulation resistance to ground of the battery shall be greater than the standard value. The voltage dropout voltage of the single cell shall not exceed the standard
6	Drive motor High-voltage generator	Check U, V and W terminal wiring and shielding layer grounding Visual inspection of motor input line and wiring box	The U, V and W terminal wiring are firm without looseness. Check whether the motor casing grounding resistance is less than 0.1Ω The insulation of the input wire is not damaged, and the wiring box is intact.

S/N	**Inspection items**	**Operation contents**	**Technical requirements**
		Check the dust on the surface of the cleaning drive motor Check the low-voltage plug-in interface Check motor operation	Remove dust on the surface of the drive motor, keep it dry and clean, no foreign matter in the groove of the heat radiation rib, no aging, deformation and leakage of the cooling water pipe The low-voltage plug-in interface is not damaged, the resolver wire connection and the high-temperature sensor line are fixed and reliable, effective Test run, no abnormal noise when the motor works
7	Electric air compressor assembly	(1) View the air compressor power cord and ground wire (2) Check the air compressor oil level (3) Check and clean air compressor air filter motor insulation testing	Air compressor assembly power line and grounding line are firm, no loose (2) Normal oil level (3) Cleaning blast pump air filter Motor three-phase line to ground insulation resistance shall be greater than 2MΩ

8	Electric air conditioner	Check air conditioning unit Air conditioning insulation testing	(1) The surface of each component of the air conditioner is clean, watertight and reliable, and the high and low voltage wiring is not loose or worn (2) The insulation resistance between the high-voltage line of the air conditioner compressor and the inverter is higher than 2MΩ.
9	Motor water cooling system	Pipeline Water pump Cooling water tank	(1) No aging, deformation or leakage of the pipeline (2) The water pump is working properly (3) The surface of the water tank is clean, no damage, no leakage, and the fan works normally.
10	Charging interface	Inspection and cleaning	(1) The charging interface is fixed reliably, no damage, burnt, etc. (2) Dry and clean inside the socket
11	Insulation inspection	High-voltage control cabinet Drive motor, high-voltage generator, booster pump high-voltage input line	Resistance between high-voltage control cabinet high-voltage line and ground is higher than 2MΩ In the rainy season, the drive motor, high- voltage generator, and booster pump motor must be individually inspected for insulation.

2.9.3 Establishment of annual inspection mechanism

With reference to the annual inspection plan of traditional vehicles and parts, the requirements for annual inspection of new energy parts shall be formulated to reduce the faults of new energy parts and reduce the safety risks of Electric Vehicles.

Recommended Added Annual Inspection Items	
Power battery system	High-voltage parts safety marking
Motor controller	Vehicle insulation
Charging socket	Electric air compressor
Period of validity of fire extinguishing system	Drive motor
Super capacitor	Low-voltage/high-voltage electrical control system

2.10 Electric drive assembly safety

2.10.1 Electrical safety

2.10.1.1 Voltage withstand: According to the voltage level, the requirements for cold and hot conditions are different.

Apply an alternating voltage of 50 Hz to 60 Hz for 1 min, and the voltage is (2*maximum working voltage +1000) V (rms). No dielectric breakdown or arcing occurs during the experiment.

2.10.1.2 Insulation

According to the voltage level, the requirements for cold and hot conditions are different. Meet class H, the cold and the thermal insulation between the power terminal and the outer casing, between the signal terminal and the outer casing, between the power terminal and the signal terminal shall be no less than 2MΩ.

2.10.1.3 Grounding: Requirements for including shielding and grounding

The motor and motor controller casings must be reliably grounded using copper or copper woven wires that meet the requirements. The three-phase wires and DC bus shielding layer must be reliably grounded. The resistance between the accessible conductive part of the drive motor and the drive motor controller and the ground point of the casing shall not be greater than 0.1 Ω and have a significant ground mark.

2.10.1.4 Safety handling under faults: Derating, shutdown, three-phase short circuit and open circuit

As shown in Table 2-5, according to different fault levels, the drive motor system shall be able to achieve derating, notify the driver to shut down, three-phase short circuit and open circuit to ensure system safety. The specific parameters in the Table need to be determined according to the actual voltage platform and system design and the vehicle unit.

Table 2-5 Fault Situation and Treatment Measures

Parameter name (high-voltage)	Parameter values	Treatment measures	
DC voltage platform	TBD	50% SOC voltage	
Overvoltage alarm voltage	TBD	When exceeding this voltage, the motor reports warning and derating	
Overvoltage fault voltage	TBD	When exceeding this voltage, the motor reports an overvoltage fault and shuts down the pulse	
Undervoltage alarm voltage	TBD	When the bus voltage is lower than this voltage, the motor reports an undervoltage warning and operates in derated capacity	
Undervoltage fault voltage	TBD	When the bus voltage is lower than this voltage, the motor reports undervoltage fault and shuts off the pulse protection.	
Speed Level I (slight) fault	TBD	When exceeding this voltage, the motor reports faults and derating	
Speed Level II (general) fault	TBD	When exceeding this speed, the motor reports fault, zero torque output	
Speed Level III (severe) fault	TBD	When the speed is exceeded, the motor reports a fault and shuts off the pulse protection.	
Motor over temperature alarm (derating)	TBD	Controller over temperature alarm (derating)	TBD
Motor over temperature (shut down the pulse)	TBD	Controller over temperature (shut down the pulse)	TBD

2.10.2 Mechanical safety

2.10.2.1 Rotor strength

Perform strength analysis during the design phase and verify through experimentation and specific use of other similar products; Drive motor shall be able to withstand 1.2 times of its maximum working revolving speed under hot conditions; the test will last for 2 minutes, and drive motor shall not adversely deform during or after this test.

2.10.2.2 Shell strength Collision safety

According to the strength standard of the vehicle, the finite element analysis of the motor shell is carried out, and relevant vibration experiments are carried out to verify and meet the requirements of the national standard: After exerting 10kPa pressure in three directions, no distinct plastic deformation happens to controller.

2.10.2.3 Mechanical anti-touch and warning

Put a warning sign on the part that rotates or has relative motion.

2.10.3 Thermo-safety

2.10.3.1 Thermal early warning, derating and protection

The motor stator is equipped with a temperature sensor, and the motor and controller have over-temperature limit power and over-temperature protection functions.

2.10.3.2 Rotor demagnetization: Demagnetization safety and rotor temperature estimation at high temperature

Use the cooling water channel to dissipate the motor shell to ensure that the internal temperature of the motor is below normal temperature.

2.10.3.3 Temperature resistance of sealing material and insulating material.

Temperature resistance of sealing material: Under the full working condition of the motor, ensure that the sealing materials such as oil seal and O-ring are reliable and practical.

Temperature resistance of insulating material: Temperature resistance of insulating material shall be ≥Class H, and the over-temperature protection mechanism can be activated when the motor is over temperature to avoid further temperature-rise and ensure the temperature sensor works normally.

2.10.3.4 Use of flame retardant materials: Harness and injection molded parts

Both the harness and the injection molded parts reach the horizontal combustion HB grade and vertical combustion V-0 grade.

2.10.4 Protection safety

2.10.4.1 Waterproof/dustproof design: End cover and shaft seal design

The end cover and bearing adopt reasonable sealing measures and the protection grade reaches IP67.

2.10.4.2 Insulation testing: Testing with VCU and BMS

The insulation detector detects the insulation resistance of the high-voltage components to the vehicle body in real time. When the insulation resistance value is detected to be lower than the set value, the protection measures such as alarm and high-voltage power- on are taken.

3. Battery cells and modules

3.1 Requirements for battery cell safety

3.1.1 Requirements for battery cell manufacturing environment

The temperature and humidity environmental conditions of the lithium-ion battery cell production process must be determined and guaranteed. For situations where the temperature and humidity limits are exceeded, appropriate response plans shall be developed. Lithium-ion batteries are very sensitive to moisture. The relative humidity of the electrode workshop shall be controlled below 20%. The liquid injection process in the assembly workshop shall be controlled below 1%.

The dust level in the production process must be controlled. Prevent outside particles from penetrating into any production area. Production systems need to prevent metal wear. Otherwise, appropriate measures shall be taken to ensure that the particles produced by wear won't enter the production process. Cleaning in the production area can only be done by suction, glue or drawing.

Routine analysis of detected particles shall be performed to determine their amount, size, and composition, particularly electrical conductivity (such as metal particles). Corrective measures shall be taken immediately if the amount, size, and composition exceed the specifications. The dust level shall be controlled below 100,000 and below 10,000 under some key processes.

3.1.2 Battery cell design

3.1.2.1 Battery cell classification

Lithium-ion batteries currently used for power can be classified into cylindrical batteries, prismatic batteries, and pouch batteries based on their appearance. According to the anode active material used in battery cells, they can be classified into $LiFePO_4$ batteries, $LiMn_2O_4$batteries, $LiCoO_2$ batteries, NCM/NCA batteries, etc.

3.1.2.2 Battery cell capacity

The power battery cell capacity determines the combination of the battery module and system and its thermal management design. Smaller capacity battery cells facilitate heat diffusion and benefits the thermal management design of the overall battery system. The battery cell with larger capacity simplifies the combined system design and manufacturing process, as well as improvement of pack efficiency and energy density. Continuously improvement of the battery cell energy density is a long-term, systematic work, energy density of the battery cells shall be improved under the premise of ensuring safety, reliability and key electrical performance indicators.

The battery cell capacity of the $LiMnPO_4$ battery shall not exceed 200Ah; the figure for the

NCM/NCA battery shall not exceed 100Ah; a capacity below 80Ah for the NCM/NCA battery is recommended.

3.1.2.3 Key raw materials of battery cell

3.1.2.3.1 Anode materials

Currently commercialized anode materials include LiCoO2, LiMn2O4, LiFePO4, NCM and NCA. The type of anode materials is critical to the safety of the battery. The differential thermal analysis method is generally used to compare the thermal stability of the anode material.

To further improve the thermal stability of the anode body and the electrolyte interface stability of the material, doping and coating processes are generally used to significantly improve the safety and cycle performance of the battery cell.

The moisture content, particle size distribution, particle morphology, crystal shape, metal impurities and magnetic substance (Fe-Ni-Zn-Cr) content of the anodematerial directly affect the safety characteristics of the battery cell. Control standards shall be developed and optimized in terms of entire raw material evaluation, supplier audit, and production site. The content of the magnetic substance in the material shall be controlled to be 50 ppb or less.

For commercial vehicles, it is recommended to use a high-safety liFePO4 and LiMn2O4 anode material. For passenger cars, it is recommended to use LiFePO4,LiMn2O4 and NCM/NCA anode system given by balance between safety and performance.

3.1.2.3.2 Cathode material

At present, commercial cathode materials for lithium ion batteries are mainly artificial graphite, natural graphite, lithium titanate cathode and silicon carbon composite graphite material. To improve the electrolyte interface stability of the cathode material, the surface of the material shall be coated to reduce side reactions and improve the cycle performance and safety performance of the battery cell.

The reactivity of the cathode material increases exponentially with an increase in specific surface area. If the specific surface area is too large, when the battery is internally short-circuited or partially overheated, the side reaction between cathode and electrolyte increases, so does the heat generation, which is more likely to cause battery thermal runaway. The specific surface area of the cathode material shall be controlled within a suitable range.

The cathode material has a significant volume change accompanying the deintercalation of and intercalation of lithium ions. The excessive volume change can cause the electrode piece to deform and the internal pressure of the electrode group to increase, thereby resulting in an internal short circuit of the uneven portion of the electrode piece. Therefore, the choice of the cathode material shall take into account the impact of the expansion ratio on safety, and the upper limit requirement for the material expansion rate shall be proposed according to the different structural design of the battery cell.

The impurity content, specific surface area, particle size distribution and particle morphology of the cathode material directly affect the safety characteristics of the battery cell. Control standards shall be formulated and optimized in terms of the raw material evaluation, supplier audit, and production site.

3.1.2.3.3 Separator

The function of the separator is to physically isolate anode and cathode, prevent the battery cell from anode-cathode short circuit, and provide an ion transfer channel. The separartor material must have sufficient chemical, electrochemical, thermal properties and certain mechanical stability. The separator may shrink in length and width due to temperature, self-aging, etc. Under normal working conditions, it is necessary to ensure complete coverage of the positive and negative electrodes of the diaphragm.

The polyolefin separator needs to have good thermal stability, automatic shutdown protection and mechanical stability. And it requires high insulation and endures a high- voltage insulation testing of at least 250V. The heat shrinkage rate shall be controlled to prevent thermal runaway caused by a large-area short circuit after the battery cell is heated. The puncture strength has a great influence on the safety of the battery, and separator with high puncture strength are preferred. The thickness of the separator is strongly related to the safety of the battery cell. The total thickness of the power battery separator shall not be less than 12 μm.

The coating separator has excellent thermal stability and oxidation resistance, beneficial for the safety of the single cell.

3.1.2.3.4 Electrolyte

The electrolyte consists of electrolyte and solvent, and mainly functions to transport lithium ions between anode and cathode. The electrolyte shall form a stable interface on the surface of anode and cathode, with a wide electrochemical working window and strong anti-oxidation and reduction ability. The electrolyte shall have good infiltration characteristics of the electrode plate to facilitate even and rapid electrode reaction and prevent local electro-hydraulic drying and dead-zone lithium.

The ideal electrolyte additive can effectively improve the electrical and safety performance of the battery cell. The electrolyte additive for cathode can form a stable SEI film on the surface of cathode to improve the cycle and safety performance of the battery cell. The electrolyte additive for anode can prevent electro-hydraulic oxidation and dissolution of the anode material, improving cycle and safety performance of the battery cell. Under overcharge and high potential, the anode overcharged additive can generate sufficient gas to trigger a safety protection device and terminate the charging of the battery cell to provide safety protection.

The electrolyte shall have good stability, not decompose or discolor when being used, and be operated under strict management. Its moisture content shall be less than 20ppm, and its HF content less than 50ppm.

Lithium hexafluorophate is used as an electrolyte, and a lithium ion electrolyte in which a carbonate is a solvent has a combustion-supporting effect in terms of battery safety. The development of new-type lithium with high thermal stability, flame retardant solvents and solid electrolytes can greatly improve the safety performance of battery cell.

3.1.2.3.5 Cell lid design

The cell lid requires certain strength and a good seal.

Cylindrical batteries and prismatic batteries generally use nickel steel and aluminum material. It is recommended to set effective safety protection devices with such functions as power-off, fusing, and pressure relief. Parameters such as fusing current and triggering pressure are subject to rigorous experimental design and optimization verification. It is necessary to ensure that the battery is turned on in time under abuse, as well as the reliability and safety under vibration and shock. The seal ring has high thermal deformation and thermal melting temperature, ensuring sealing performance and bearing corrosion resistance and aging resistance against electrolyte throughout the life cycle of the battery cell.

The pouch battery uses aluminum-plastic multi-layer film as its packaging material, and the battery cell lid is formed by heat sealing, ensuring sealing throughout the life cycle of the battery cell. The internal pressure of the battery cell, if it increases, can be relieved from the sealing part. The material, thickness and packaging conditions of the aluminum-plastic multilayer film have a great influence on the sealing and safety of the battery cell.

3.1.2.3.6 Foil

Lithium-ion batteries generally use copper foil for cathode and aluminum foil for anode to function as an cathode and anode current collector. Foil requires high elongation and high strength to ensure the safety of the battery throughout the life cycle. The key indicators such as metal dust, oil content and dyne value on the surface of the foil shall be effectively controlled.

The surface treatment of the copper aluminum foil can effectively improve the bonding force between the active material layer and the foil material, reducing powder separating from electrode during the process and electrode peeling during the cycle.

3.1.2.4 Electrode design

The N/P ratio refers to the ratio of the cathode electrode capacity per unit area to the anode electrode capacity. The minimum N/P ratio throughout the life cycle of the battery shall not be less than 1.0 (except for LTO batteries) under the tolerance conditions such as coating amount, material gram capacity and electrode group structure.

The formulation of the electrode shall be optimized experimentally to ensure sufficient adhesive and prevent the electrode active material from falling off. With a three- dimensional porous structure, the lithium ion battery electrode shall have good electronic conductivity and ionic conductivity. The electrode coating amount, thickness and porosity shall be theoretically simulated and experimentally optimized to ensure that the cathode does not have metal lithium precipitation under the extreme conditions of use.

The portion of the electrode longitudinal burr beyond the surface of the electrode shall not be greater than half of the total thickness of the diaphragm.

3.1.2.5 Spiral battery design with small capacity

The design length of cathode in the electrode group shall be designed to completely cover the core and tail of the electrode group through anode. With respect to width, it is necessary to ensure that the diaphragm shall cover the anode and cathode cover the anode. Short- circuit analysis between the anode and cathode shall be conducted to achieve insulation protection in short-circuit weak areas.

The material, length, width and thickness of the tab shall be designed to bear current carrying capacity matching the battery application conditions to ensure a stable and reliable solder joint. The tab exposed electrode group length and the tab bending point shall be designed to ensure that they are not short-circuited with the battery case. The tab shall be protected by protective tape. The tab burr must be strictly controlled.

All protective tapes in the electrode group shall be insoluble in the electrolyte and have certain thermal stability, mechanical strength and adhesion.

The shape and dimensions of the electrode group shall be designed to match the space of the lid, and tolerance analysis shall be performed for each dimension. Protective tapes or sleeves shall be equipped outside the electrode group to prevent damage to the electrode group during assembly.

3.1.2.6 Heat dissipation design

When the battery cell is charged and discharged at a large rate, a large amount of heat will be generated inside the battery. Rising temperature may cause safety problems. To design the battery cell structure, the internal heat distribution, thermal diffusion path and transmission speed of the battery shall be analyzed through simulation to verify and optimize heat dissipation design.

3.1.3 Battery cell manufacture

3.1.3.1 Electrode manufacture

3.1.3.1.1 Requirements for electrode manufacture

The manufacture of battery cells includes pulping, coating, compressing and slitting.

During the entire electrode manufacture process, a strict isolation for anode and cathode workshops is implemented to prevent cross-contamination brought by anode and cathode dust.

3.1.3.1.2 Pulping

Pulping is a process in which active materials, conductive agents and binders are uniformly dispersed in a solvent in a certain ratio to form a stable slurry. Raw materials shall pass inspection and traceable. In the pulping process, it is necessary to ensure that the proportions of each sort of material and dispersion parameters conform to the specifications. Appropriate measurement methods shall be used to test the dispersion effect and consistency of the slurry.

The parts of the wire body that are prone to producing metal foreign matter while in contact with materials and slurry shall be identified and managed to avoid the introduction of metal foreign matters caused by abnormal wear. Take demagnetization measures and set standards for magnetic foreign matters for control.

The entire process of pulping shall be sealed to prevent material leakage or foreign matter introduction.

The filter unit specification and replacement frequency of the pulping process shall be defined, and the slurry particle size shall be effectively monitored and managed.

3.1.3.1.3 Coating

The coating process is a process in which the prepared slurry is uniformly applied to the surface of the base foil, and then the solvent in the slurry is completely evaporated by baking.

The coating equipment shall be capable of continuously monitoring the areal density in real time, as well as of raising the alarm while the density exceeds set range and handling it in subsequent processes. It also shall be able to monitor the size of the electrode piece in real time, as well as raise the alarm while the size exceeds set range, and handle it in subsequent processes.

The slurry needs to be subjected to filtration and demagnetization prior to coating. The appearance, adhesion, and solvent residual amount of the electrode piece during the coating process need to be monitored. The wind entering the inside of the oven shall be matched with measures for dust removal and dehumidification control.

When coating with a slurry containing organic solvent, the drying tunnel of the coating machine needs to be equipped with an automatic monitoring device for NMP concentration with functions of automatic monitoring, alarm raising and over-limit shutdown. It is recommended to control the NMP vapor concentration to be no more than 50% of the lower explosion limit. If the electric heating method is adopted, the electric heating part of the equipment directly contacting the NMP vapor needs to be equipped with an explosion-proof electric appliance and facilities for stopping foreign matters from igniting with a delay function for shutdown to exhaust air.

3.1.3.1.4 Compressing

The effect of compressing is to make the electrode piece after coating dense, and improve the electronic conductivity of the electrode. During the compressing process, process parameters such as compressing pressure, speed and tension of unwinding and winding shall be monitored. Monitoring measures shall be taken for electrode extension and hole morphology. The non-contact on-line thickness-measurement device can be used to monitor the engineering capability of the electrode piece during the compressing process.

The compressing machine shall be equipped with cleaning devices such as brushes and magnetic bars. The wear and effective width of the compressing shall be regularly checked to ensure the quality.

3.1.3.1.5 Electrode shaping

The shearing electrode shaping is to cut the large-volume electrode tab after the compressing into multiple strips according to a certain width that shall meet the requirements for design. The edge burr of the electrode tab shall be continuously tested. The shearing cutter shall be polished and maintained according to the specified frequency. Appropriate protective measures shall be taken during the shearing process to prevent dust from depositing on the surface of the electrode tab. The shearing machine shall be equipped with cleaning devices such as brushes and magnetic bars, as well as monitoring devices such as appearance defects and slit width of the electrode tab. Relevant measures shall be taken to ensure that defective electrode tab is avoided in the subsequent process.

Laser cutting electrode shaping adopts laser cutting and shearing process to process the desired shape on the current collector. The processed electrode width and lug size shall meet the requirements for design. Laser cutting burr shall be strictly controlled to ensure the laser cutting edge beads do not exceed the thickness of the electrode piece. Equipment laser cutting mechanism, shearing machine key spare parts specifications and replacement maintenance frequency need to be defined and effective life monitoring management. The spattering dust generated by the laser cutting electrode and the dust generated on the wire body in contact with the electrode tab shall be effectively collected and treated to prevent foreign matters from getting into the electrode piece. The equipment dust removal mechanism needs to be designed; its inspection, cleaning and replacement frequency need to be defined. Effective monitoring and management and regular analysis of foreign matters shall be carried out to ensure the effectiveness of the mechanism. It also shall able to continuously monitor the size of the electrode tab after laser cutting. While the size exceeds the set range, it shall raise the alarm, make identification on defective products and handle it in subsequent processes.

3.1.3.2 Electrode group formation

For the transfer and transportation of electrode pieces, special sealed transportation facilities shall be used to effectively protect and isolate the electrode pieces, so as to prevent cross-contamination, pollution resulting from foreign matter, collision and other damage.

The dust removal function of the winding machine shall have effective anti-cross-contamination ability, and dust prevention setting shall be provided between the anode and cathode and the diaphragm. The diaphragm needs to be installed with an electrostatic removal device. Brushes and dust exhaust apparatus shall be equipped to effectively collect dropping powder and particles. Dust exhaust apparatus shall be equipped in the ultrasonic welding position to prevent metal powder and dust shaken off during welding from falling into the electrode group. Keep the hanging shaft, third wheel, coil needle, cutter and sensor clean and free of foreign matters to prevent contamination from damaging the surface of the electrode piece and the diaphragm. Copper and zinc materials are strictly prohibited for all equipment parts.

Requirements for control must be placed on the burr at the electrode piece cutting position and lug cutting position. The cutter shall be effectively managed. The insulating tape on the lug and the soldering position shall be effectively covered.

The tension during the winding process shall be reasonably set according to the characteristics of the diaphragm to prevent the diaphragm from breaking or its hole from being deformed due to excessive tension. The end of the diaphragm shall be effectively controlled. No cracks or snagging is allowed at the cut of the diaphragm. During hole-burning process, the electrode group shall not be damaged. Controlling the hole-burning temperature to avoid burning and shrinking the diaphragm.

The electrode group shall adopt automatic baiting, avoiding the touch of the human hand and preventing the mechanical jaws from pinching and damaging the electrode group. The electrode group shall 100% pass the insulation resistance test.

3.1.3.3 Assembly

During thermoform the electrode group, the pressure, temperature and time shall be controlled; overpressure is not allowed. The external dimension of the electrode group and the case of cathode covering anode shall be 100% checked. The electrode group and the battery case shall be insulated by means of gaskets, coating and the like, and the upper end of the electrode group shall be insulated from the battery case by insulating parts.

Contusion shall be avoided while connecting the electrode group to the shell. During the welding process, the welding slag shall be prevented from splashing, and a protective cover shall be provided to prevent foreign matters from falling into the battery. The pressure, temperature zone, and penetration depth during welding shall be effectively managed.

The tab bending shape of prismatic and cylindral batteries shall be optimized. The tab at the bends cannot be folded inside the electrode group, and the poles cannot be in contact with the battery wall after bending, nor damage the electrode group.

Welding around the battery shall ensure a stable process.

In case the slot compressing of the cylindral battery case is deformed, the clad layer shall be prevented from falling as a whole, and a device for effectively removing dust and metal filing shall be installed. The residual amount of wall thickness of the slot rolling shall be controlled, and shell shall not be broken.

After assembly, the battery must be checked for 100% anode and cathode alignment via X-Ray, and shall pass 100% insulation and voltage-withstanding detection.

The pouch battery package parameters (pressure, temperature, package thickness, and effective package width) shall be optimized with effectively managed process, and pass 100% insulation and voltage-withstanding detection.

3.1.3.4 Electrolyte injection

The electrolyte injection process is to uniformly inject the electrolyte into the interior of the battery. Before the electrolyte injection, the electro-hydraulic moisture content, HF content and color scale shall be checked to see if they are qualified, and the moisture content of the positive and negative plate in the electrode group shall be controlled within the specifications.

The static temperature and time after the electrolyte injection shall be optimized and controlled to avoid insufficient electrolyte infiltration during precharge. It is necessary to develop a weighing system that 100% detects the electrolyte injection volume. The battery after electrolyte injection must be sealed in time.

The battery is subjected to a small current precharge treatment after the electrolyte injection to reduce the gas generation in the early stage, and the electrode group and the cover shall be electrochemically protected. Process conditions such as precharge rate, charging voltage and temperature need to be optimized and managed.

3.1.3.5 Formation and aging

The formation equipment shall be periodically checked according to the requirements for equipment maintenance to ensure the voltage and current control accuracy, avoiding battery overcharge, overdischarge, capacity detection error and external short circuit. Choose a suitable charging and discharging process to prevent overcharge and overdischarge, lithium deposition and excessive thickness due to process errors.

The battery cell is recommended to be delivered after undergoing the aging process. Choose a suitable aging process to prevent incomplete self-discharge screening due to too short aging time. The self-discharge screening criteria shall be verified in an effectively way.

100% of the aged battery cell shall be measured for voltage, internal resistance and thickness, all data are required to be fully traced. During battery storage and transfer, measures shall be taken to prevent damage to the battery resulting from short circuit, falling and squeezing.

3.1.4 Battery cell safety evaluation

3.1.4.1 Battery cell thermal runaway

Thermal runaway refers to a sudden change in temperature caused by an exothermic chain reaction inside the battery cell, which may cause the battery to overheat, ignite, explode, etc. At present, the reasons for the thermal runaway of the battery mainly include mechanical abuse, heat radiation, internal short circuit, and abuse in harsh environment.

Thermal runaway can be simulated and evaluated by experimental means. The evaluation method includes motivating a short circuit in the battery by heating and acupuncture to cause thermal runaway of the battery.

When the voltage drops to 25% of the initial voltage, or the temperature reaches the maximum operating temperature specified by the battery manufacturer, or the temperature rising rate reaches $dT/dt \geq 1$℃/s and lasts for more than 3s, thermal runaway is deemed to occur.

When thermal runaway occurs, the safety device on the battery cell shall be activated. The direction of pressure relief and fire-erupting shall be designed. The quantity of sprayed materials shall be controlled. The temperature, volume and composition of the sprayed gas shall be studied and analyzed to prevent the occurrence of secondary short- circuit disasters.

3.1.4.2 Requirements for battery cell safety

The battery cell shall meet the safety testing evaluation of electricity, machinery and heat. The safety evaluation of lithium ion power battery cells shall be carried out in accordance with the testing methods specified in the standard.

3.1.5 Single cell safety

There is an optimal operating temperature range for lithium-ion batteries. Safety problems are prone to occur beyond the range. Under higher temperatures, side reactions will intensified and safety problems resulting from thermal runaway are likely to occur. If the battery is charged under low temperature, the cathode is prone to lithium deposition. While above 45℃ and below 0℃, its charge and discharge shall be controlled, for example, by reducing multiplying power to ensure the battery works in a safe environment. The charging mode, generally including charging temperature, rate and voltage, shall be put under control. Single cells with different systems and design shall be charged in different ways. For a specific sort of single cell, its manufacturer shall provide a temperature-multiplying power-charging voltage relationship diagram and design system charging strategy based on the specifications.

Lithium-ion batteries shall be protected from long-term storage at high temperatures, otherwise their performance will be severely weakened. For batteries in long-term storage, it is not recommended to adopt fast charging method to use it again.

The charging speed of lithium-ion batteries is strongly correlated to their service life. When conditions permit, it is recommended to reduce the use of fast charging and choose small-rate charging as much as possible.

3.2 Requirements for battery module safety

3.2.1 Requirements for battery module environmental

The environmental temperature, humidity and dust level of the battery module production workshop shall be subject to the specifications and monitored in real time. The dust level shall be controlled below 300,000. Metal particles shall be prevented from being introduced during the manufacturing process due to equipment or process reasons.

3.2.2 Battery module design

3.2.2.1 Material safety

Sharp corners shall be avoided for the design of battery module components. Burrs and metal floating powder on the edges and surfaces shall be controlled. Antiseptic treatment shall be adopted on the surface.

Materials need to meet ROHS, and where customers have special requirements, parameters such as sulfur content shall be identified. For materials, requirements for fireproofing and antiflaming shall be put into consideration.

The electrical connection parts need to be treated with anti-corrosion process to prevent heat generation due to an increase in resistance arising from long-term use and contact. For parts in contact with single cells, materials resistant to electrolyte corrosion shall be used, and problems such as insulation failure caused by electrolyte leakage shall be considered.

All component materials shall meet the requirements for reliable durability of the complete vehicle or system, or be easily replaceable to achieve a consistent life with the complete vehicle or system.

For the selection of the material of insulating parts, the influence of the high temperature environment on the insulation shall take into account, ensuring their insulation at the highest temperature of the complete vehicle or system.

The design of the bolting structure shall meet the requirements for environment of the complete vehicle.

3.2.2.2 Mechanical safety

For the design of mechanical safety protection, the protection of the protective structure for products under the conditions of extrusion, drop, vibration, impact, inversion, collision, etc. shall be considered, so that the product can meet the functional requirements and requirements for various safety regulations.

Mechanical reliability design must meet the design life of the complete vehicle. The durability and reliability under transportation, carry and installation shall be fully considered.

The thickness of the battery cell will expand during use. During module design, expansion space shall be reasonably reserved and busbar structure shall be rationally designed according to the performance of the battery cell. Evaluate the force of the battery cell expansion on the module frame after prolonged charge-discharge cycles or storage at high temperature. The strength, fastening force and deformation of the module frame shall meet the requirements for expansion of the battery cell as well as the system.

The module shall be designed with a safety voltage protection device to protect people against electrical shock and external short circuits during manufacturing, transportation or repair operations.

Fool-proofing design shall be taken into account to prevent accidents such as fires

arising from short-circuited battery modules and electric shocks caused by personnel misoperation during production, installation and testing. Generally, such fool-proofing design involves machinery, color and logo.

3.2.2.3 Electrical safety

Insulation sheets with high dielectric strength shall be used to ensure that the insulation of the module meets the design goals. The withstand voltage shall meet at least the requirements of GBT 18384-2015, with electrical clearance and creep distance within safe range under abnormal circumstances. The insulation resistance of the battery module shall have good reliability after storage at different temperature and humidity. The risk of short circuit caused by assembly and repair shall be fully consider during design.

Choose proper materials, sizes and surface treatment technologies to ensure discharge capability and welding reliability. Connectors are recommended to meet the requirements for USCAR-2 and USCAR-37.

The voltage sampling line shall be designed with overcurrent protection at the battery end.

The modular metal structure frame shall be designed as equipotential body to avoid forming potential difference that damages people.

The assembly of the module output shall meet the requirements of GB/T4208.

The assembly of the sampling harness shall be equipped with foolproof design to avoid accidents such as short circuits caused by incorrect installation.

The sampling line adopts a heat-resistant structure design to avoid secondary short circuit accidents inside the battery pack.

The busbar shall be designed with a buffer structure to reduce the pulling of solder joints by vibration.

3.2.2.4 Thermal safety

The module structure design shall ensure that the cell has sufficient heat dissipation area to ensure the heat transfer between the module and the thermal management system to meet the corresponding requirements for heat dissipation and heating. The height difference between heat dissipation interfaces of the battery cell shall match the thickness of the heat-conducted material and maintain within a reasonable tolerance to ensure reliable contact with the thermal management system. In the life cycle, it shall meet the requirements for design of heat conduction and dissipation, and ensure that the battery works in an ideal temperature range.

The thermal conductivity, thickness and other parameters of the heat-conducted material shall meet the requirements for heat dissipation of the module; the battery cell and the thermal management system shall ensure a sound heat transfer path. The electrical insulation and fire-protection rating of the heat-conducted material shall meet the requirements for safety of the battery system.

The location and number of temperature sensors shall be able to reflect requirements for the maximum temperature and minimum temperature under different working conditions, and the accuracy, scope of application and response time of the temperature sensor shall be considered.

Thermal diffusion protection design. The module design shall consider heat insulation and fire prevention measures to delay the time of igniting the surrounding battery cells when thermal runaway occurs to one battery cell in the battery module.

The battery module shall be isolated by region in the battery system to reduce the transmission speed of thermal runaway and leave longer escape time for riders.

3.2.2.5 Functional safety

Voltage sampling accuracy. The voltage acquisition shall include at least the voltage of each string of cells, the voltage drop of the voltage acquisition harness and the accuracy of the sampling chip shall satisfy the accuracy requirement of the voltage sampling; The time for voltage sampling, conversion and transmission shall be much less than the minimum fault tolerance time of the system; It shall can detect faults such as short- circuit, disconnection, and over-limit of voltage sampling harness.

Temperature sampling accuracy. Each temperature collecting module shall contain at least two temperature collecting points, and the collecting accuracy of the temperature collecting loop shall meet the requirements for system temperature collecting accuracy; The time for temperature sampling, conversion and transmission shall much less than the system fault tolerance time; It shall can accurately identify abnormal faults such as over-range, short circuit, and open circuit of temperature sampling.

Balance control accuracy. The balance current design shall satisfy the battery system balance requirement, the balance control command shall can be executed accurately and timely, and can accurately identify the hardware and software faults of the balance control loop, such as balance control failure and other abnormal faults.

Communication transmission accuracy. The voltage and temperature of the module shall can be accurately and timely transmitted to the superior main control board. The communication loop design shall have communication redundancy mechanism such as loop short circuit, disconnection and abnormity recovery.

Electromagnetic compatibility. The module collecting harness shall be as perpendicular as possible to the high-voltage power harness to avoid high-voltage power transmission/radiation crosstalk. The module control board shall be able to ensure the anti-interference characteristics under the load electromagnetic environment, and ensure the normal operation of voltage collecting, temperature collecting, balance, communication and other functions during the anti-interference process; meanwhile, the conduction and radiation interference of the control board to other external components shall be ensured during its operation.

Modules shall usually be designed with good grounding points to avoid tip discharge of sharp charged bodies.

3.2.3 Battery module manufacturing

3.2.3.1 Battery cell insulation

Insulating materials are used for battery cells with electriferous shells to achieve effective insulation protection by coating or spraying. The battery cell shall be effectively cleaned before the insulation to avoid the risk of short circuit between the assembled battery cells due to the introduction of conductive dust particles. The insulation process must ensure that the insulation layer is effectively covered as required by the design, while ensuring that the insulation layer is not scratched or damaged.

3.2.3.2 Module assembly

The module assembly is to install the battery cell together with the frame or the fixed bracket, according to different serial-parallel modes. If the glue needs high temperature to accelerate the curing, the heating temperature shall be optimized to avoid damage to the components at high temperatures. During the installation process of LMU (Local Monitoring Unit, as a control board directly connected to a single cell), BMS (Battery Management System) or FPC (Flexible Printed Circuit), electrostatic protection shall be considered in terms of personnel protection, work environment and tools usage mode. In the assembly and extrusion process of the module, the pressure cannot exceed the extent the cell can withstand. The extrusion equipment needs to have a pressure monitoring function or the pressure shall not exceed the extent the cell can withstand, so as to avoid safety problems such as deformation and leakage due to excessive extrusion of the cell.

For the pouch battery cell, the module assembly process shall meet the flatness requirement of the cell tab, satisfy the welding conditions, and ensure the reliability of the aluminum row connection.

3.2.3.3 Frame welding

Frame welding shall ensure the strength of the frame structure of the module after welding.

Welding defects in the melt zone and heat affected zone do not exceed the acceptance specifications. The splash of welding slag shall be controlled to prevent foreign matters from entering the module, resulting in failure of the overall insulation of the module. Laser welding is required to ensure the requirements for welding strength and penetration of the frame.

3.2.3.4 Busbar connection

The busbars connects with the cell in series and parallel by bolting, electric resistance welding, laser welding and the like.

In the laser welding process, attention shall be paid to removing the oxide layer and surface contamination on the surface of the cell pole and the busbar. Suited welding parameters shall be selected during welding to prevent welding defects such as cold joint and solder skips. The design of welding tooling shall be optimized and the splash of the welding slag shall be controlled to prevent foreign matters beyond the specification from entering the unwelded module, resulting in the failure of the overall insulation of the module.

The grinding frequency and life of the welding head shall be controlled while the resistance welding process is adopted to ensure the stability and strength of the welding process.

While the bolting process is adopted, the torque shall meet the requirements for structural strength and durability to prevent loose bolting and poor contact that causes safety problems during long-term use.

Meanwhile, the CSC, BMS or FPC components in the module shall be isolated and protected from damage resulting from welding to the electronic components.

3.2.3.5 Sampling line connection

The voltage and temperature sampling lines shall be effectively connected to the busbar by a process such as bolting, ultrasonic welding and laser welding.

The torque must be controlled during the bolting process.

Ultrasonic welding and laser welding shall be welded under matching welding parameters to prevent welding defects such as cold joint and solder skips. During laser welding, particulate dust generated by welding shall be collected and disposed.

The module sampling line sequence needs to be tested to avoid installation errors, resulting in short circuit of the sampling line, damage to the collecting board or insurance, and burnout.

3.2.4 Battery module safety evaluation

3.2.4.1 Requirements for battery module safety

3.2.4.1.1 Electrical safety evaluation

The electrical safety testing of the module mainly includes overcharge, overdischarge and external short circuit testing. The electrical safety testing primarily simulates failures in battery management systems or charging piles. When the battery is overcharged, overdischarged or external short circuit and the high-voltage control device cannot effectively cut off the charge and discharge loop, the battery shall not cause fire, explosion and other safety accidents.

Overcharge testing requires that the module continues to be charged at 1C in the fully charged state until the voltage reaches 1.5 times the specified termination voltage or the charging time reaches 1 hour. Observe it for 1h. The battery module shall not explode or ignite for 1h.

The overdischarge testing requires the module to be discharged at 1C for 90 min in the fully charged state. Observe it for 1h. The battery module shall not explode, ignite or leak.

The external short-circuit testing requires the battery module to keep short-circuited the anode and cathode terminals of the battery module for 10 min with a resistance of less than 5 mΩ in the fully charged state. Observe it for 1h. The battery module shall not explode or ignite.

3.2.4.1.2 Mechanical safety evaluation

The mechanical safety testing of the battery module mainly includes extrusion, acupuncture, and dropping. The mechanical safety testing mainly simulates the external abnormal impact suffered by the battery in the case of abuse or traffic accidents, such as collisions between two cars, strike of the bottom of the vehicle hard objects. Thus it may be deformed, pierced or dropped at a high place. In such cases, the battery shall not cause any accidents such as an explosion or fire outbreaks.

Extrusion testing: Extrude the fully charged battery module by a semi-cylinder with a radius of 75 mm and a length of 1m at a speed of (5±1) mm/s, in the direction that the battery module is most prone to extrusion, to a deformation of 30% with a force of 200KN. Keep the extrusion for 10min and observe the battery module for 1h. The battery module shall not explode or ignite.

Acupuncture testing: With the battery module is fully charged, penetrate vertically at least 3 cells in sequence with a heat-resistant steel needle of φ6-φ10mm at a speed of (25±5) mm/s. Observe it for 1h with the needle staying in the battery. Record the safety level.

Drop testing: With the battery module is fully charged, drop a battery whose anode and cathode terminals facing down from the height of 1.2m to a concrete floor. Observe it for 1h.

The battery shall not explode, ignite or leak.

The bottom impact working condition testing simulates the scene where the bottom of a vehicle is hit by foreign matters such as slungshot and metal blocks, and the bottom of the module and cell is subjected to extrusion deformation. Charge the testing module to 100% SOC. Install the testing object according to the requirements of Figure 1. Use a semi-spherical cylinder with a radius of 10 mm as the tool. The hit direction shall comply with the principle that the center of the hemisphere coincides with the center of the impact surface of the testing object. See Table 1 for impact parameters. Record the voltage, temperature, extrusion force, extrusion speed, and maximum deformation of the extrusion during the testing and observed it for 1h. In this case, no explosion or ignition shall occur.

Table 3-1 Bottom impact working condition testing parameters

S/N	Impact energy /J	Impact weight /kg
1	50	5
2	100	
3	150	
4	200	
5	300	

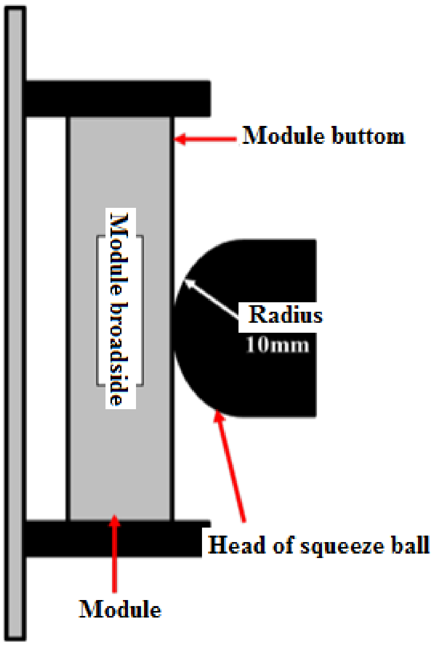


Figure 1 Module fixed installation

Remarks:

1. The impact energy is calculated according to the kinetic energy theorem $E = 1/2\ mv^2$.

2. The impact weight refers to the weight of the cylinder whose front end is a hemispheroid

with a radius of 10 mm.

3.2.4.1.3 Environmental safety assessment

Environmental safety tests for battery modules include heating, temperature cycling, low air pressure, and seawater immersion testing. The environmental safety testing mainly simulates the application of the battery in harsh environments, such as abnormal high temperature conditions, repeated high-low temperature alternation, high altitude area application, rainy season or abnormal conditions such as vehicles soaking in water. No safety problems is allowed in these environments.

Heating testing: Place the battery module in an incubator. Raise the temperature inside the box from ambient temperature to 130℃±2℃ at a rate of 5℃/min, and stop heating after maintaining this temperature for 30 min. Observe it for 1h. The battery module shall not explode or ignite.

Temperature cycle testing: Place the fully charged battery module in an incubator where the temperature cycles between -40℃ and +85℃ with 5 cycles, each lasting 8h. The battery shall not explode, ignite or leak.

Low-pressure testing: Place the fully charged battery module in an air pressure chamber with an air pressure of 11.6kpa (equivalent to an altitude of 15420m) for 6h. Observe it for 1h. The battery shall not explode, ignite or leak.

3.2.4.2 Requirements for battery module reliability

3.2.4.2.1 Thermal diffusion evaluation

Thermal diffusion testing is to evaluate the thermal diffusion protection design capability of a battery module. After the thermal runaway of a battery is simulated by heating, acupuncture and overcharging, the module design can effectively delay the heat diffusion, ensuring that the system does not cause a fire or explosion within 5 minutes and leaving riders sufficient escape time.

3.2.4.2.2 Mechanical vibration testing

The vibration testing simulates a vehicle traveling for a long time in complex road conditions (such as washboards, bumpy roads and undulating roads). After the battery is vibrated for a long time, the short circuit inside the cell cannot be short-circuited, and the module structure cannot fall off and leading to safety problems such as short circuit. In the experiment, the battery module shall be tested for vibration in three directions, X, Y and Z, each direction for 21h. After the testing, the battery is required to be in reliable connection and intact structure. No sharp change shall made to the minimum monitoring unit voltage; the absolute value of the voltage difference shall be not more than 0.15V. No leakage, cracked casing, explosion or ignition is allowed; the insulation resistance shall be not less than 100Ω/V.

The components in the battery module (including the support columns and fasteners) have no obvious displacement, torsion and bending. The deviation between the resonant frequency and the initial value of components shall be less than 10%, and the remaining tightening force of each fastening screw shall not be 60% less than the initial value. The deviation between the resistance and the initial value of electrical connection points shall be less than 5%.

3.2.4.2.3 Mechanical shock testing

Mechanical shock simulates the case of rapid acceleration and sudden braking of the vehicle, where the battery shall withstand the impact of acceleration without causing safety problems. The experiment applied an impact of 25g, 15ms, half sinusoidal waveform, in the Z direction to the battery module for 3 times. Observe it for 2 hours after the test. The battery is required to have no leakage, no cracking in its casing, no explosion and no ignition, and the insulation resistance shall be not less than 100 Ω/V.

3.2.4.2.4 High-temperature storage testing

The high-temperature storage testing primarily evaluates the battery's calendar life. The test simulates long-term stored battery in a high temperature environment (such as 45℃ or 55℃), and evaluate the ratio of its recovered capacity to its initial capacity.

3.3 Requirements for transportation safety for battery cell and module packaging

3.3.1 Requirements for packaging safety

The battery cells and modules shall be packaged to be waterproof and moisture-proof. If necessary, desiccant shall be added to the bag to dehumidify. The packaging shall consider the protection of the product under transportation conditions (road transportation, railway transportation, water transportation, etc.) to prevent extrusion and damage during its move.

The battery cell and module shall be isolated and fixed with a minimum unit, and a safe distance shall be reserved to avoid electrical safety problems.

3.3.2 Requirements for transportation safety

The battery cell and module must be securely fastened inside the transport unit.

The ambient temperature of the battery cell and module during transportation needs to be monitored. High temperatures may cause battery safety problems.

Avoid sun exposure, rain, and moisture on battery cells and modules.

Avoid battery cells and modules being pressed and place them in strict accordance with product specifications.

Lower capacity in battery cells and module are good for transportation safety. It is recommended to keep 30~70% SOC.

Lithium-ion battery cells and modules are dangerous goods. Avoid flammable, explosive, and corrosive dangerous goods during transportation. Consider equipping fire-fighting facilities.

4 Battery management system

4.1 Requirements for battery management system

4.1.1 BMS design development and troubleshooting

4.1.1.1 BMS design and development

The design and development of basic BMS functions are recommended to focus on the following:

(1)Parameters such as the cell voltage, current, temperature and insulation resistance of the battery system shall can be effectively measured. The measurement accuracy and frequency shall meet the requirements of national standards under both normal and extreme conditions. At the same time, the sampling circuit shall have a protection mechanism to avoid high-voltage short circuit faults.

(2)SOC, SOE, SOH of the battery system shall can be accurately calculated, and the safe available charge and discharge power range shall be calculated in line with the current battery voltage, temperature and other conditions to ensure that there will be no single or cumulative safety impact on the battery.

(3)The remaining battery life or the remaining mileage of the vehicle shall can be accurately estimated to prevent the power system from being interrupted abnormally due to the remaining mileage error during the use of the battery system. When the battery is low or the remaining mileage of the vehicle is not enough, the power consumption shall be reduced， and effectively measures coordinated with the vehicle shall be taken to prevent abnormal power system interruption caused by battery protection due to high-power discharge during use.

(4)During the charging process, the BMS shall monitor the battery system and the status of the charger at the same time. When the battery system or the charger fails, the charging process shall be stopped in time and an alarm shall be issued.

(5)According to the measurement information and battery use conditions, the thermal management system shall can be used to effectively control the internal temperature of the battery system. Thus the battery charging and discharging process can be performed in a suitable temperature range to avoid battery safety hazards caused by single or cumulative high-low temperature operation.

(6)The BMS function shall be verified by necessary testing, including insulation performance testing, electrical adaptability testing, environmental adaptability testing and electromagnetic compatibility testing, to ensure that it can work effectively under different working conditions and environments.

The design and verification of the basic functions of the BMS system can refer to GB/T *Technical Conditions for Battery Management Systems for Electric Vehicles*.

4.1.1.2 Basic requirements for troubleshooting

(1)Faults of the battery cell or system shall be identified in time, including but not limited to battery overvoltage, voltage shortage, overtemperature, overcurrent, reduced insulation. And inform the vehicle owner of the identified faults with reliable communication method and take corresponding measures.

Different fault thresholds shall be calibrated according to battery type

According to the usage environment and different life cycles of the battery, determine the appropriate fault threshold and the detection time to ensure system safety.

(1)The detection cycle or debounce time of BMS of the battery fault shall meet the safety requirement, that is, the battery system will not harm the vehicle or drivers before the entire fault detection, communication and processing cycle is completed.

(2)In the event of a fault, if not absolutely necessary, the battery system shall first notify the driver to take necessary measures, say, deceleration and pulling over, and then start power-off protection.

(3)After a fault occurs, the battery system can only be operated after confirming that the fault has disappeared or there is a sufficient safety margin. For permanent fault of the battery system, such as battery cell over-discharge to below 1V, it is recommended to latch the fault and prevent the battery system from being operated to avoid subsequent safety problems.

(4)The fault storage function is recommended to set in the BMS to record all fault codes that have occurred in the battery system and can be cleared by external operations during maintenance; It shall be able to record the detailed data of the first or last fault according to the needs of the manufacturer, including cell voltage, temperature and current of the battery.

4.1.1.3 Typical fault signal processing strategy

(1)The setting of the threshold is usually determined by the cell enterprise and the vehicle manufacturer according to the characteristics of the cell and the vehicle control requirements. The threshold values of different battery systems vary. Typical faults can be found in the *Technical Conditions for Battery Management Systems for Electric Vehicles* and appendix. The following is a reference processing strategy:

• The battery temperature is greater than the set threshold: It is recommended to use protective measures such as reducing the charge and discharge power; if the protection measures are invalid, it is recommended to perform the power-off protection process or stop charging.

• The battery temperature is less than the set threshold: It is recommended to activate the heating function to limit the input and output power. If the charging process is required, it is recommended to charge the battery after it has been heated to the minimum allowable charging temperature.

• The cell voltage or total voltage is greater than the set threshold: it is recommended to stop charging or disable feedback. If the voltage continues to rise or exceed the absolute safety threshold, it is recommended to perform the power-off protection process.

• The cell voltage or total voltage is lower than the set threshold: different measures can be taken depending on the degree of discharge depth, such as prompting the user to charge, prohibiting discharge or performing the power-off protection process.

• The cell consistency deviation is greater than the set condition: different measures can be taken according to the judgment conditions formulated by the OEM and the battery factory, such as starting the balance, prompting the user to enter the store for maintenance or performing the power-off protection process.

• The charging current (power) is greater than the maximum allowable threshold: if during driving, it is recommended to reduce or stop the feedback; it is recommended to reduce the current during charging. If the above measures are invalid, it is recommended to perform the power-off protection process.

• The discharge current (power) is greater than the maximum allowable threshold: it is recommended to reduce the operating power; if it is invalid, it is recommended to perform the power-off protection process.

• The insulation resistance is less than the set threshold: it is recommended to notify the whole vehicle or perform the power-off process according to the degree of insulation failure.

• The internal temperature difference of the battery system is greater than the set threshold: It is recommended to use protective measures such as reducing the charge and discharge power; if the protection measures are invalid, it is recommended to perform the power-off protection process or stop charging.

• High voltage loop abnormality: It is recommended to perform the power-off protection process.

• BMS sampling, processor and actuator related faults (e.g. voltage sampling faults, temperature sampling faults, current sampling faults, MCU faults, power faults, storage faults, actuator faults, collision events, etc.) detection, determination and handling It is recommended to combine the functional safety requirements for comprehensive design to meet the relevant security needs.

(2)The fault handling strategy shall be distinguished according to fault characteristics, and faults shall be hierarchically managed. Different strategies, such as alarm, power limit, high-voltage, reminding the user to stay away from the vehicle, shall be adopted for different levels of faults, for example, direct high-voltage power-off during driving shall be avoided, if possible.

(3)The fault threshold setting, judgment time and recovery time shall fully consider the capacity of the battery system and the requirements for running of the vehicle to avoid false negatives and misinformation.

4.1.2 Allowable current/power control under charging and operating conditions

4.1.2.1 Allowable current/power limit

(1)Under charging and operating conditions, the allowable current/power control limit meter shall be set in line with the battery system's capacity (according to the allowable current/power limit table provided by the cell manufacturer) and the requirements for vehicle usage, as well as given the need for the current duration of charging and operating conditions (brake feedback, discharge). Generally, peak current / power meter (for example: 2s, 5s, 10s, 30s), continuous current / power meter (for example: 60s, 3min, continuous, etc.) shall be set.

(2)The BMS shall ensure a smooth transition of the allowable current/power when switching between peak power and continuous power due to changes in temperature and SOC.

(3)BMS shall fully consider the allowable capacity of the battery system. The allowable current / power limit value throughout the life cycle shall be determined combined with the available power and allowable power attenuation at the end of the battery system life.

(4)The power limit value shall take into account the maximum bearing capacity of the system components, and be determined according to the minimum value of the maximum current carrying capacity of each component of the system.

(5)The BMS shall monitor the current and voltage in real time and calculates the real- time charge and discharge power. If the real-time charge and discharge power exceeds the allowable current/power, the BMS shall record the DTC and notifies the vehicle.

(6)When the charge/discharge current/power exceeds the allowable current/power, the BMS shall perform a multi-level control strategy to actively reduce the power in stages to avoid fire outbreaks and explosion of the battery system.

4.1.2.2 Charging power control strategy

(1)DC charging

DC charging shall follow the GB/T 27930 Communication Protocol between Electric Vehicle Non-vehicle-mounted Conductive Charger and Battery Management System, GB/T 18487.1-2011 Electric Vehicle Conduction Charging System Part 1: General Requirements, GB/T 20234.1-2015 General Requirements for Connecting Devices for Conductive Charging of Electric Vehicles and other relevant standard requirements.

During the charging process, the BMS shall monitor various parameters, including abnormal parameters (such as overvoltage, overtemperature and overcurrent). When the charging ends or fault occurs, it shall send a charging-stop command to the charger to make it stop the charging process.

(2)AC charging

Typically, the BMS sends current and voltage demand to the OBC, and controls charging process by the OBC. During the charging process, the BMS shall monitor various parameters, including abnormal parameters (such as overvoltage, overtemperature and overcurrent). When the charging ends or fault occurs, it shall send a charging-stop command to the OBC to make it stop the charging process.

4.1.2.3 High-power charging strategy

(1)The battery supplier shall fully perform the high-power charging testing to provide the maximum current value allowed within the specified time (for example, 10 min, 15 min, 20 min, 30 min), which is taken into account the effects of temperature, SOC and SOH.

(2)Temperature measurements shall cover possible high temperature points as much as possible in the charging loop, including the highest/lowest temperature point of the battery module, the connector of the vehicle and the charging pile, the charging cable, and the current sensor in the form of a shunt. Meanwhile, attention shall be paid to the temperature of the connection copper bar between modules and the battery pack charging connector.

(3)The BMS shall monitor the charging power and temperature at temperature control points. When they exceed the limit threshold, it shall notify the fault to the charger in time.

(4)When a fault occurs and high-power charging needs to be stopped, the BMS first applies to a charging pile for reducing the output power, and stopping the charging process. If the charging pile fails and cannot stop charging, the BMS shall urgently disconnect the charging relay and stop the high-power charging.

(5)For the large amount of heat that may be continuously generated by high-power charging, the thermal management strategy shall be optimized to appropriately lower the temperature threshold for starting the cooling function. After charging, if the battery pack temperature is still high, it is necessary to continue to maintain the cooling function, so that the battery system temperature can return to a reasonable range.

(6)The usage frequency of high-power charging shall be monitored to avoid battery performance degradation or safety hazards that may result from frequent high-power charging.

4.1.3 BMS functional safety

The main purpose of BMS functional safety is to avoid the risk of serious personal injury events (fire, explosion, exhaust and electric shock) caused by abnormal electronic/electrical functions of the BMS system.

BMS functional safety activities focus on the following areas: Identify functional safety objectives and requirements for safety, functional safety product development, functional safety objectives verification and validation.

4.1.3.1 Identify functional safety objectives and requirements for safety

The hazard analysis and risk assessment of the battery system shall be performed at the vehicle level; clarify functional safety objectives, ASIL levels, safety status and FTTI (fault tolerant time interval), and define requirements for functional safety and control strategies.

It is recommended that the BMS include the following functional safety objectives to avoid the risk of thermal runaway of the battery system:

• Prevent battery overcharge from causing thermal runaway

• Prevent battery from being out of control after recharging after over-discharging

• Prevent battery from overheating and cause thermal runaway

• Prevent thermal runaway caused by overcurrent of the power battery system

It is recommended that the BMS include the following functional safety objectives to avoid the risk of electric shock to the battery system:

• Ensure that the high-voltage loop is cut off when a vehicle collision occurs

• If insulation becomes invalid, it is forbidden to pull in the high-voltage contactor

• If high-voltage interlocking becomes invalid, it is forbidden to pull in the high-voltage contactor

It is recommended that the BMS include the following functional safety objectives to avoid abrupt interruptions in system power:

• Avoid unintended cut-off of high voltage contactors

For battery system hazard analysis and risk assessment and requirements for functional safety, please refer to the *GB/T Battery Management System Functional Safety Requirements and Test Methods for Electric Vehicle* (estimated to be released in 2019)

4.1.3.2 Functional safety product development

BMS functional safety design and development shall follow strict process specifications and focus on the following activities:

(1)Use DIA to define the division of responsibilities between OEMs and suppliers.

(2)Perform design activities at all levels in the automotive safety lifecycle. For different design stages, implement corresponding verification activities (review/ testing), verify the effectiveness of the safety mechanism with appropriate testing methods (such as defect injection method), and ensure the completeness of test cases and test coverage.

(3)Conduct functional safety analysis (FMEA, FTA, DFA and FMEDA) during the design of system, software and hardware to meet requirements for ASIL level.

• Conduct system safety analysis to identify failure modes that violate functional safety objectives. Ensure the vehicle can get into a safe state within FTTI time while failures occur through system design.

• Conduct software safety analysis to determine software safety mechanisms for software failure modes

• Conduct hardware safety analysis, evaluate hardware architecture based on the failure rate, failure mode and failure distribution of the hardware (SPFM, LFM and PMHF), improve hardware safety mechanism, and ensure it to satisfy requirements for safety level.

• Safety analysis shall be conducted continuously and iteratively. For problems found in safety analysis, it is necessary to continuously optimize and update safety mechanism.

(4)For software design, it is recommended to adopt standardized software architecture (such as AUTOSAR). Software development shall follow modeling and code specifications that meet requirements for functional safety. And multiple model/code test methods (such as MIL, SIL, PIL and HIL) shall be adopted for software integration and testing to satisfy requirements for software coverage.

(5)Pay close attention to two-way traceability and consistency between requirements,design, and verification to ensure the traceability of requirements changes and defect corrections.

(6)Perform appraisal and reuse certification for software/hardware components to ensure the suitability of their use. Implement a tool chain confidence assessment to ensure that the tool confidence level (TCL) meets relevant requirements.

(7)Implement accreditation measures appropriate to the current safety level, including accreditation review, safety review and safety assessment.

Refer to *GB/T 34590-2017 Road Vehicle Functional Safety* for functional safety product development activities.

4.1.3.3 Functional safety objectives verification and validation

The BMS requirements for functional safety and functional safety objectives shall be verified and confirmed at the system level and the vehicle level to achieve the vehicle safety function objectives.

In addition to the BMS functional safety protection mechanism, the vehicle is also designed with other safety mechanisms (such as machinery and chemistry), and the verification and validation of functional safety objectives shall also cover these safety mechanisms.

Refer to the *GB/T Battery Management System Functional Safety Requirements and Test Methods for Electric Vehicles* (estimated to be released in 2019) for functional safety objectives verification and validation activities of battery systems.

4.1.4 Identification strategy for thermal runaway, early warning

4.1.4.1 Basic protection for battery pack thermal runaway

Thermal runaway protection measures shall be taken for the battery pack to ensure that the no incident causing personal injury (fire, explosion, etc.) occurs within a certain period after the thermal runaway takes place.

4.1.4.2 Thermal runaway early detection and prevention

BMS may monitor incidents that cause thermal runaway (such as voltage, current, temperature exceeding safe use range, and internal short circuit), take emergency measures (such as alarm, power limit, and cut off high-voltage loop) before a thermal runaway occurs, and remind riders to take precautionary measures.

4.1.4.3 Thermal runaway detection and alarm

(1)During thermal runaway and thermal diffusion, the internal temperature, gas composition, pressure and other parameters of the battery system will change. Experimental research shall be conducted on thermal runaway and thermal diffusion. Through theoretical analysis and experimental verification, determine suitable thermal runaway and thermal diffusion detection methods (such as temperature, gas and pressure), and ensure the detection accuracy of the detector to meet the requirements.

(2)When the BMS confirms that thermal runaway occurs to the battery, the thermal runaway signal shall be transmitted to the vehicle. The vehicle shall provide an obvious thermal runaway alarm signal and warning sound through an indicating device (like dashboard) to remind the driver and the passenger to evacuate; Meanwhile, the BMS shall request to stop high-voltage, and the vehicle shall enter the emergency power-off process according to the current working conditions.

(3)The BMS shall accurately monitor the abnormal temperature rise of the battery system and its components, and issue an early warning signal to the thermal runaway of the battery system as early as possible.

(4)The thermal runaway detection and alarm function shall be executed in the operation mode, and its effectiveness shall pass the vehicle-level testing to avoid false negatives and misinformation.

(5)The thermal runaway detection and early warning function shall meet the requirements for functional safety of the vehicle.

4.2 Battery system safety

Based on the fire outbreaks causing by the soaking, collision and chassis scratch of the electric vehicle, the safety of the battery system shall be carried out in three phases: system design (mechanical safety, thermal safety, and electrical safety), safety testing and production to ensure the safety of the battery system.

4.2.1 Machinery safety

The battery system shall have sufficient mechanical strength to ensure that safety risks will not be caused by vibration, mechanical shock and other working conditions during the normal use within the lifecycle of the vehicle.

4.2.1.1 Battery and vehicle safety design based on front collision, side collision, side column collision, bottom collision, and stone collision

In view of the collision and extrusion conditions of the battery system derived from the collision of the vehicle, it is necessary to combine the design of the whole vehicle and the installation position of the battery system to make targeted structural design to ensure the mechanical safety of the battery system.

The structural strength of the battery system shall meet at least the standard requirements for battery system simulated collisions or the standards of vehicle manufacturers specified in the *GB/T 31467.3-2015 Lithium Ion Power Battery Packs and Systems for Electric Vehicles Part 3: Safety Requirements and Testing Methods*.

4.2.1.1.1 Battery system collision safety design

(1)Analyze the maximum deformation caused by the battery case and its internal structure (battery module, high and low voltage harness) during the collision process, and judge the safety risk during the collision process in line with the maximum deformation allowed by the battery module shall be used;

(2)Incorporate structural design with energy absorption effect, and take into account the requirements for plasticity of corresponding in the design;

(3)Incorporate reasonable internal reinforcement design to improve the overall structural strength;

(4)Consider the reliability of the electrical connector to avoid the risk of short circuit during the collision;

(5)Improve the structural strength of the thermal management system, increase protection design, and avoid the risk of coolant leakage during the collision.

4.2.1.1.2 Battery system extrusion safety design

(1)The battery system shall be designed to meet corresponding requirements for stiffness and strength, for example, by adopting an anti-collision beam structure in the periphery;

(2)Design reasonable internal safety distances in the battery system;

(3)Design reasonable thermal management system layout. It is recommended that the liquid cooling system water pipe layout shall avoid the side prone to collision;

(4)Design reasonable electrical system layout. The wiring path of the high and low voltage harnesses in the battery system shall be connected to the non-deformed area structure of the battery system as much as possible, and the insulation protection and harness fixing shall be strengthened.

4.2.1.1.3 Battery system anti-stone collision safety design

(1)Design reasonable bottom armor or preventer plate;

(2)The protection of the connector end of the case is weak and vulnerable to impact by sand and stone. It is recommended to add preventer plates for blocking.

4.2.1.2 Vibration reliability safety design

Vibration is a test of the durability of structural parts. Unlike traditional vehicles, the excitation source of the battery system is mainly caused by the unevenness of the road during driving. The excitation frequency of the road is mostly concentrated at the low frequency end. The main purpose of the system in the design process is to improve the overall inherent frequency of the battery system.

The structural strength of the battery system shall meet at least the standard requirements for battery system vibration reliability or the standards of vehicle manufacturers specified in the GB/T 31467.3-2015 Lithium Ion Power Battery Packs and Systems for Electric Vehicles Part 3: Safety Requirements and Testing Methods.

(1) Improve the overall inherent frequency of the battery system:

• Improve the stiffness of the battery system, for example, by adding installation points on the vehicle body and optimizing the fixed beam structure design;

• Reduce the weight of the battery system: Lightweight structural design and material selection;

(2) Material selection with high fatigue strength;

(3) Improve the strength of the battery system: avoid excessive concentration of quality and enhance the structural design in quality-concentrated spots; fixed beam welding, structural fastener selection and fixed torque design shall comply with design specifications.

4.2.1.3 Full lifecycle high protection grade safety design

The battery system installed outside the vehicle body shall have a protection grade of IP67 or higher and shall be regularly detected to prevent the degree from degrading during the entire life cycle.

4.2.1.3.1 Battery system contact protection

(1)Integrated BDU with casing protection design;

(2)Module-level anode and cathode position protection design;

(3)High-voltage connector protection:

• Both the connector socket and the contact in the plug need to be insulated from the protective casing to ensure that the insulation of the casing and the safety of the operator.

• In the protection design of the high-voltage connector of the battery system, the protection grade of IPXXB/IPXXD is used most commonly.

4.2.1.3.2 Battery system waterproof and dustproof

(1)Requirements for battery system case protection:

・The battery case protection reaches IP67 level at the full lifecycle level;

・When designing the battery case gasket, consider its water absorption, compression ratio, and flame retardant characteristics;

(2)Waterproof breathable valve: The protection degree at the joint connected with the case shall reach IP67 at the full lifecycle level;

(3)Requirements for electrical interface protection:

The connector socket and the plug connection end are outside the case, and the end must ensure good contact between the socket and the plug, overcurrent, sustaining overvoltage, stability, and easy disassembly, and socket port protection covers. The following requirements shall be satisfied:

・The protection grade at the joint between the connector socket and the case shall reach IP67;

・The protection grade of the connector socket after connecting with the plug shall reach IP67;

・When the connector socket port is unplugged and stored in the warehouse, the protection cover must be dust-proof and moisture-proof and will not fall off after long- distance transportation vibration.

4.2.1.3.3 Battery system explosion-proof protection

The battery system shall have an effective pressure relief device that can quickly balance internal and external air pressure changes to prevent degradation or failure of the protection grade caused by deformation of the shell due to excessive internal air pressure.

The installation position and direction of the pressure relief device shall avoid personal injury to the passenger compartment or personnel around the vehicle, and avoid igniting the entire vehicle.

4.2.1.3.4 Battery system anti-corrosion protection

The requirements for anti-corrosion throughout the life cycle shall be based on the requirements for battery system life and the environmental requirements of the area for use to determine the corrosion resistance level of the battery system.

4.2.2 Thermal safety

The thermal management system shall be used to heat, dissipate, balance the battery system and for thermal insulation. There shall be a structural design to prevent heat diffusion inside the battery system, as well as a flame retardant design of key components to ensure the thermal safety of the battery system.

4.2.2.1 Reliable thermal management system design

According to the structure and working principle of lithium-ion batteries, there is a risk of thermal runaway, whether at high or low temperatures. The design goal of the battery thermal management system is to, combined with the BMS control strategy and adjustment function, make the cell work at a comfortable temperature and achieve performance balance by reducing the temperature difference between the cells to ensure system thermal safety and extend system life. To achieve the above goals, it is necessary to design from cooling, heating and thermal insulation. At the same time, it is necessary to ensure the airtight safety of the whole system, and no leakage of coolant is allowed. Pay attention to the condensation water that may be caused by the low-temperature cooling pipeline, avoid the hidden dangers of insulation and short-circuit caused by this.

(1)Cooling

a.Determine the heat dissipation form and control boundary of the battery pack according to the heat generated by the system under the specified severe working conditions, ensure the maximum temperature of the battery does not exceed the allowable temperature range, and make it work in the comfortable temperature range most of the time.

b.It is recommended that the maximum temperature difference between the temperature points collected inside the battery system under normal working conditions does not exceed 5℃, the maximum temperature difference under the limiting working conditions does not exceed 10℃, and the continuous operation can be satisfied under such conditions (for example, accelerated charging under continuous high-speed working conditions).

c. In order to adapt to different working conditions, the cooling system can be divided into multiple loop, according to the presence or absence of chiller and fan gear:

• In the air-cooled heat dissipation system, the state of the fan shall can be detected and determine whether it is working normally; When the fan or other components of the cooling system fail, it shall can raise alarm and take protective measures (such as limiting the charge and discharge power);

• In the liquid cooling system, it shall can detect components such as compressors and pumps to determine whether they are working normally; When the cooling system fails, it shall can raise alarm and take protective measures (such as limiting the charge and discharge power);

(2)Heating

a.The battery system shall be heated to a specified temperature within a specified period at a specified ambient temperature, enabling the system to quickly reach an operating temperature that allows charge and discharge.

b.When the minimum temperature of the battery system is lower than the minimum allowable charging temperature, it is recommended to charge the battery after heating it.

c.Minimize the maximum temperature difference between the temperature points collected inside the battery system while heating it.

d.For heating the battery pack with built-in heating components (such as PTC), the corresponding safety design shall be made (such as the introduction of secondary hot melt protection mechanism). When the temperature of the heating component is too high, the power supply of the heating component shall can be cut off to prevent dry burning and then ignite the battery.

(3)Thermal insulation

a.While battery system is transferred from a normal temperature environment to a high and low temperature environment separately, the maximum/minimum temperature of the battery in the system does not exceed the target value within a specified time.

b.When it is kept in a high temperature environment, it is recommended to reduce the temperature difference between the temperature points collected inside the battery system.

(4)Airtight safety

a.For liquid cooling systems, corresponding measures shall be taken to prevent leakage of pipelines and joints, and corresponding testing processes shall be taken during the production process to ensure product safety.

b.When the liquid cooling system leaks to a threshold that may cause a safety hazard, it is recommended to provide a detection means to detect and alarm in time.

4.2.2.2 Battery system thermal diffusion protection design

There are many factors that can cause the risk of thermal runaway, such as extreme environment temperature, overcharge and overdischarge, inside and outside short circuit and battery manufacturing defects. Since the risk of thermal runaway cannot be completely avoided, relevant protection designs shall be taken to reduce the hazard of thermal runaway. Heat transfer is an important reason for the spread of thermal runaway diffusion, so heat transfer characteristics directly affect the rate of thermal runaway diffusion. In addition, the electrical connection between batteries also affects the spread of thermal runaway. The current thermal diffusion test standards and regulations can be found in the *Safety Requirements for Lithium Ion Power Batteries for Electric Vehicles*. The test object is a module and a battery pack. A thermal event warning signal shall be provided 5 minutes before a thermal runaway of a single battery is caused, causing heat to spread, which in turn causes danger to the passenger compartment. It is also recommended that the system be capable of preventing thermal runaway events from propagating to adjacent batteries. Therefore, thermal diffusion protection shall be considered from three aspects: cell, module and system.

(1)Cell level

a.It is recommended to adopt the thermal insulation design between adjacent cells (such as adding thermal insulation felt, aerogel, and other thermal insulation and flame retardant materials) to delay heat spread.

b.The explosion-proof design of the cell (such as explosion-proof valves) is recommended to avoid directly directing to adjacent cells, so as to prevent chain reaction. The valve opening protection time of the cell shall keep consistent in the single cell and the module, and the conditions for opening the valve shall be within a certain range of deviation.

(2)Module level

a.It is recommended to set suitable spacing between modules to prevent heat spread to a certain extent; It is also recommended to adopt the thermal insulation design (such as heat shield) to suppress the heat spread between adjacent modules.

b.Design reasonable electric connection holes, vents and flame pilot holes to prevent the heat spread.

c.For batteries that do not have the cell fusing function, the module is recommended to adopt the fusible connection design to prevent current flow-backwards of other parallel batteries in case of the short circuit inside the cell, causing thermal runaway.

(3)System level

a.The battery shell (including the upper cover, the bottom plate and the sealing strip and other accessories) shall be made of flame-retardant materials to avoid the open fire from igniting the vehicle;

b.It is recommended that the internal high-voltage harness of the battery pack (including the main loop high-voltage harness and battery voltage collection harness) shall have a fuse protection to prevent secondary damage caused by the short circuit of the damaged harness during thermal runaway.

4.2.2.3 Flame-retardant design of key components of batteries

In order to delay the thermal runaway diffusion and extend the passenger's escape time, the components of the battery system shall be made of materials with high flame- retardant grade or non-combustible materials, so that these components will not further aggravate the reaction in the extreme environment of thermal runaway.

(1)The organic materials inside the battery system (such as structural adhesive and heat-conducting adhesive) shall be made of materials with higher flame-retardant grade.

(2)The flame-retardant grade of the non-metallic sheets in the battery pack shall be evaluated emphatically.

(3)Other materials that are in direct contact with the cell, as well as electrical components and thermal management components shall be made of materials with higher flame-retardant grade or non-combustible materials.

(4)After thermal runaway occurs to the cell, it is recommended to evaluate the secondary heating caused by the eruptive materials due to the short circuit arising from the insulation deterioration of the module.

4.2.3Electrical safety

4.2.3.1 Requirements for insulation

4.2.3.1.1 Electrical insulation

(1)The insulation design of the battery system shall meet GB/T18384 or the enterprise requirements;

(2)If the electrical shock protection is provided by insulating materials, the live parts of the electrical system shall all be covered with insulators;

(3)The insulating material shall withstand the temperature grade and maximum working voltage of the electric vehicle and its system;

(4)The insulator shall have sufficient voltage withstand capability, and insulation breakdown or arcing shall not occur during the voltage withstanding test.

4.2.3.1.2 Electrical clearance and creep distance

(1)For the electrical clearance and creep distance of the high-voltage system in the battery system, please refer to GB/T18384;

(2)Determine the electrical clearance according to the voltage withstand level and environmental pollution level.

(3)Determine the creep distance according to the environmental pollution level, CTI value of materials, working voltage, working altitude, etc.

(4)When the rated insulation voltages of the main circuit and the control circuit or the auxiliary circuit are inconsistent, the electrical clearance and creep distance can be determined according to their rated values. When there are different rated values between the conductive parts of the main circuit or the control circuit, the electrical clearance and creep distance shall be determined according to the highest rated insulation voltage.

4.2.3.1.3 Potential equalization

(1)All components (conductors, connecting parts) of the potential equalization current path shall be able to withstand the maximum current at a single point of failure;

(2)The resistance between any two exposed conductive parts of the potential equalization path that can be touched by people simultaneously shall not exceed 0.1Ω and meet the requirements of GB/T 18384.3-2015.

4.2.3.2 Electric connection reliability safety design

The electric connection design in the battery system includes the design of the electric connection inside the module and the design of the electric connection outside the module. The design of the electric connection inside the module includes: Electric connection, temperature and voltage sampling between cells;

(1)Electric connection between cells

The electric connection between cells shall meet the overcurrent requirements. Generally, the material shall be copper, aluminum or nickel. Electrochemical corrosion between copper and aluminum shall be avoided.

(2)Temperature sampling

a.As an important means of detecting the battery status, the design shall focus on two aspects: Arrangement position and connection reliability.

b.The arrangement position is recommended to be able to measure the highest and lowest temperatures in the module.

c.For the sampling line, short-circuit prevention measures may be considered.

(3)Voltage sampling

As the voltage sampling is directly connected to the anode and cathode of the cell, if the impedance of the connection position is too large, it will affect the sampling accuracy of the voltage. Therefore, the voltage sampling shall select a relatively safe and reliable connection method with a smaller impedance, and short-circuit prevention measures may be considered for the sampling line.

(4)Electric connection design outside the module

Including the electric connection design between the modules, electric connection design between the module and the electrical components, and electric connection design between the electrical components.

The electric connection outside the module generally uses a lock bolt or nut as the external electric connection port. In the design, it shall avoid load on the electric connection part, and ensure the reliability of the bolt connection.

(5)For the convenience and safety of battery system maintenance, it is recommended to design a special repair interface for the system, such as replacement of fuse.

4.2.3.2.1 System overcurrent capability

(1)Each connection part of the main loop inside the battery system shall have the capability to withstand the maximum continuous current of the system throughout the life cycle.

(2)The electric connection area shall consider the requirements for temperature rise and aging.

4.2.3.2.2 Electrical connection reliability

(1)The electric connection part of the main loop inside the battery system shall have an effective design. It is recommended to use the thread-locking adhesive to lock, so as to ensure the reliability of the connection impedance throughout the life cycle.

(2)The connection impedance of each electric connection part of the main loop inside the battery system shall have specific indicators and detection methods, convenient for detection during production and maintenance;

(3)The connection between the high and low voltage harness connection terminals and the electric wires in the battery system shall be firm and meet the regulations for technical conditions of automotive wiring harness in QC/T 29106;

(4)The connector shall have a locking device to avoid separation or poor contact. The high-voltage connector shall have a high-voltage interlocking function.

4.2.3.2.3 Grounding requirement

Grounding of high-voltage components is to improve EMC and meet requirements for safety. Grounding of high-voltage components shall meet the following requirements:

(1)All metal conductors close to the high-voltage components must be grounded, such as cooling plate, connector fixing plate, water nozzle connected to a cooling pipe close to the high-voltage wire, BMU (HVM) casing, EDM metal bottom plate and metal tray;

(2)The surface of all grounding points shall be electrically conductive, no paints and oxides with poor electrical conductivity, to prevent poor grounding;

(3)All grounding points shall ensure a certain installation torque;

(4)It is recommended to use a special grounding bolt nut or a braided wire for the internal grounding of the battery system. It is recommended to use a braided wire as the grounding wire of the battery system and the chassis, and the grounding terminal shall be tinned;

(5)The grounding wire shall be as short as possible;

(6)The grounding point in the battery system shall be connected to the electric chassis of the vehicle.

4.2.4 Battery system safety testing method

Battery system-level verification is mainly to verify the complete performance and function of the battery system. The following aspects may be considered:

(1)Conduct testing via vibration, mechanical shock, simulated collision, extrusion, wet heat cycle, water immersion, thermal stability, temperature shock, salt spray, high altitude, over temperature protection, overcurrent protection , external short circuit protection, overcharge protection, over discharge protection, according to the requirements specified in the national standard requirements of *Safety Requirements for Power Battery for Electric Vehicles*.

(2)It is recommended to carry out the load vibration test to fully explore the connection abnormality and temperature rise abnormality, and evaluate the safety reliability (charge and discharge during vibration).

(3)It is recommended to carry out the dynamic IP simulation testing (vibration, impact, vehicle wading, etc.).

(4)It is recommended to use the same testing sample to simultaneously perform multi-factor stress comprehensive evaluation under ambient temperature, ambient humidity and vibration state. After completing the evaluation, further evaluate the IP protection grade of the test sample, which shall meet the requirements for IP protection grade.

4.2.5 Requirements for battery system production safety

4.2.5.1 Requirements for safety protection in the production process

(1)Assemble strictly in accordance with the process flow, and avoid pressing lines and other phenomenon during the assembly process, to prevent short circuit during operation.

(2)During the production and operation process, necessary protection measures shall be taken for the cell, module, system and key component (fuse, contactor, etc.) to avoid potential safety hazards caused by impacting and dropping.

(3)Exposed BMS or collecting boards shall have effective electrostatic protection in the production and operation process.

(4)The battery system shall be equipped with a manual repair switch. During the production and operation process, the repair switch on the battery system shall be unplugged and covered with a protective cover to ensure that the high-voltage output of the battery system is cut off. The high-voltage connector on the battery system shall be equipped with a protective cover to ensure the safety of the operator.

(5)Provide necessary protection for the connection hard points of the module and the shell to avoid failure of fastening point due to deformation of the components.

(6)Provide tooling protection for flexible or deformable components (e.g. gasket, foamed silicone) to avoid failure due to deformation of the components.

(7)In the battery system, it shall provide effective protection for the live parts and connection points to meet the requirements for IPXXB protection grade specified in GB 4208, and prevent potential safety hazards caused by mistakenly touching during production or maintenance.

(8)The parts of the tooling and tools contacting with the products in the assembly process shall be made of insulation materials or have the insulation protection to avoid the short circuit in the assembly process.

(9)The components shall be fixed firmly in the production and operation process to avoid short circuit caused by friction damage in the process of movement.

(10)Before connecting the high-voltage power, it shall check the grounding of the high-voltage component shell, and confirm that the assembly and connection of the high-voltage components are reliable.

(11)Before disassembling the high-voltage components, it must conduct a power-off operation, and confirm that the emergency switch and 12V power supply have been disconnected.

(12)During the disassembly, installation or other operation of high-voltage components, the operator shall obtain the low-voltage electrician certificate, wear high-voltage insulating gloves and insulating boots, make well their own insulation protection, and does not carry any metal items.

4.2.5.2 Reasonable offline detection

S/M	Testing category	Testing projects	Testing purpose
1	Harness testing	Harness testing	Check whether all pins on the low voltage interface of the battery system are correct
2	Static testing	CAN communication	Check whether the product communication is normal
3		Insulation resistance	Check the insulation resistance performance of the product
4		Insulation and voltage resistance	Check the insulation voltage-withstanding performance of the product
5		Insulation detection function	Check the insulation detection function of BMS
6		High-voltage interlocking function	Check the high-voltage interlocking function of BMS
7		Software version	Check whether software version is correct
8		Hardware version	Check whether hardware version is correct
9		Dropout voltage	Check whether dropout voltage meets the requirements before charging and discharging.
10	Charge- discharge testing	Total voltage	Check whether the total voltage of the battery system meets the requirements.
11		Charging function	Check whether charging is normal
12		Discharging function	Check whether discharging is normal
13		Total voltage accuracy	Check whether BMS voltage accuracy meets the requirements.
14		Current accuracy	Check whether BMS current accuracy meets the requirements.
15	DC internal resistance testing	DCR testing	Check whether the DC internal resistance of the battery system meets the requirements.

4.3 Requirements for power battery transportation

Define the safety requirements for packing, storage and other conditions of the battery system in the transportation process to prevent potential safety hazards in the transportation process or avoid damage to the environment or surrounding personnel and property caused by their own safety problems.

4.3.1 Transportation test standard

The battery system transportation test can be carried out with reference to Paragraph 38.3, Part 3 of UN *Recommendations on Transport of Dangerous Goods-- Manual of Tests and Criteria* (UN38.3).

4.3.2 Requirements for packaging and transportation

4.3.2.1 Requirements for package

(1)The packing of the battery system shall comply with the requirements for moisture- proof and shock-proof, and measures shall be taken to prevent the battery system from contacting with the conductive materials in the same package.

(2)All components in the battery system shall be fixed in accordance with requirements for normal production.

(3)All interfaces of the battery system shall have independent protection to prevent collisions and short circuits. All electrical interfaces shall be equipped with insulated flame-retardant protective covers to ensure that no metal parts are exposed at the interface.

(4)If the battery system is equipped with a repair switch (MSD). Before packed, it shall ensure that the repair switch has been taken down, and the repair switch interface is covered and protected with insulation materials.

(5)With respect to the selection of the packing case, the transportation environment conditions (road transportation, railway transportation, waterway transportation, etc.) shall be considered, and the packing case shall pass the stacking test, drop test and other tests.

(6)The packing case shall be easy to manufacture and assembly, convenient for storage, transportation and mechanical handling.

(7)Documents and materials provided with the battery system shall be put at the specified location of the packing case.

(8)The packing case shall paste a product label, including the following contents: Name, material code, customer name, manufacturer name or trademark, production date, SN, quantity per case, net weight and gross weight, and stacking weight limit.

4.3.2.2 Requirements for transportation

(1)The battery system is recommended to be transported below 40% SOC, advisable to 30% SOC;

(2)According to the requirements of UN *Recommendations on the Transport of Dangerous*

Goods - Model Regulations (TDG), the battery system shall be away from flammable, explosive and corrosive dangerous goods during transportation;

(3)The battery system and the packing case must be completely positioned and locked, and the packing cases and tools must also be completely locked by the transportation frame. During the transportation, violent vibration, shock, sunshine and raining damage shall be prevented.

(4)During the packing and transportation process, operators shall avoid stepping on the power battery system and improperly contacting with the power battery system;

(5)The transport device shall meet the requirements for transportation test;

(6)Transport device shall be insulated to prevent accidental short circuits;

(7)Fire-fighting equipment can meet the needs of transportation vehicles in case of emergency.

4.4 Requirements for power battery after-sales maintenance

Define the maintenance measures, items, frequency and other basic requirements as well as recommendations of the battery system in the use process and track the safety status of the battery system to eliminate potential safety hazards.

4.4.1 Power battery maintenance and detection specifications

4.4.1.1 Routine maintenance

(1)Charging and discharging

It is recommended to charge and discharge the battery system at appropriate ambient temperature and SOC state.

(2)Storage

For long-term storage, the electric quantity of the battery system shall be in an appropriate state, and deep charge and discharge shall be carried out regularly; Storage area shall be away from heat source, chemical corrosion, etc.

(3)Traveling

The user is recommended to form good driving habits and avoid stepping on the accelerator pedal violently to cause instantaneous large current discharge.

4.4.1.2 Regular maintenance

In order to ensure the safe operation of the battery system, it is recommended to drive Electric Vehicles regularly to the after-sales service center for maintenance (every 5,000 km / half a year recommended).

Regular maintenance and detection of the battery system must be completed by professional personnel. The maintenance and detection center shall be equipped with an insulation protective cover suitable to the battery system interface. Before operation, it shall install an insulation protective cover on the electrical interface to ensure the safety of the operator.

The following items can be selected for regular maintenance and detection:

(1)Equilibrium charging - it can use a diagnostic tool to read the internal cell voltage consistency status of the battery system through the maintenance interface, and use a special maintenance instrument or a on-board charger for equilibrium charging and maintenance according to the dropout voltage of the cell.

(2)Air tightness detection - Detect the protection state of the battery system shell, seal the external interface of the battery system with a dedicated detection tool, inject gas into the shell, and test it by the pressure maintaining method.

(3)Insulation performance detection - Detect the insulation performance of the battery system in two ways.

・In the "start" state of the vehicle, use the diagnostic tool to read the insulation value reported by BMS software; (recommended)

・In the "off" state of the vehicle, use the insulation tester to detect the insulation value of the high-voltage output terminal of the battery system to the grounding point.

(1)Appearance inspection - Check whether there is deformation, damage, cracks,looseness, etc. on the battery system casing and surface parts (connector, pressure valve, fastening bolt). If any abnormality is found, open the shell for inspection as needed.

(2)Fault code inspection - Use a diagnostic tool to read the internal fault code of the battery system, evaluate the current fault and historical faults, and further diagnose the function and safety related fault codes.

(3)Conduct the cooling system inspection and maintenance, such as cleaning of filtration system near the air outlet of the air-cooling system, to ensure the smooth heat dissipation channel. Regularly detect and replace the refrigerant in the water-cooling system to avoid the decrease of cooling performance and function due to the denaturation of the refrigerant.

4.4.2 Power battery annual inspection items and methods

In order to ensure the safe operation of the Electric Vehicle battery system, it is recommended to conduct regular annual inspection of the battery system.

The battery system annual inspection items may include the items related to "battery system maintenance and detection specifications". Meanwhile, it can add power consumption testing (vehicle) and capacity testing as needed. For vehicles with a significant attenuation of driving range, it can use professional testing equipment to detect the capacity, internal resistance, temperature rise and other parameters of the battery system.

If a specific fault is found during the annual inspection, it can open the shell to inspect the internal state of the battery system, mainly checking the internal environment (whether there is water or leakage), the surface condition (rust, mildew) of components, connector status, module appearance (whether there is bulge and deformation), high- voltage connection point fastening state, etc. It shall focus on vehicles with a history of collision accidents and vehicles with long service life and driving mileage.

5 Motor system and electric drive assembly safety

5.1 General requirements

With the introduction of national energy strategy, four-stage fuel consumption and carbon emission points regulations, electric vehicles will occupy a larger market in the future. Electric vehicles are dominated by hybrid and pure electric vehicles. In hybrid vehicles, in addition to conventional engines, there are drive motor systems for combined drive and brake energy recovery. In pure electric vehicles, the motor is the only power drive.

From the development trend and configuration characteristics of the electric drive assembly, the development of passenger car drive motor features high speed, high pressure and integration. The current maximum speed of the mainstream products does not exceed 16000 rpm, and the future speed will reach 18000 rpm or higher. DC bus voltage is about 150 ~ 350 ~ 800VDC, motor output power is between 30kW ~ 250kW, output torque is between 100Nm ~ 500Nm, with appropriate speed ratio reducer or transmission rear electric drive assembly output torque (wheel end) 2000Nm ~5000Nm; the motor output is arranged coaxially or in parallel with the wheel drive shaft.

For commercial vehicles, the most popular form of drive is the direct drive of the motor, the powertrain with the motor matching fixed speed ratio reducer (wide range of light commercial vehicles), and the heavy-duty commercial vehicle usually uses two or more gears for the motor. The commercial vehicle drive motor usually has an output power of 50 kW to 300 kW, and the dedicated engineering vehicle drive power demand can reach 400 kW or more. The driving motor torque required for commercial vehicles with different loads is different from 400Nm to 5000Nm, and the DC bus voltage of commercial vehicle motor systems is usually between 350VDC and 800VDC or higher. The most important drive system layout for commercial vehicles is still the form of a powertrain similar to a conventional commercial vehicle connected to the final drive through a drive shaft. Wheel-side drive and integrated electric drive axles are also widely used in commercial vehicles.

In the powertrain, the motor is not only a power source, a transmission component, but also a safety component and a regulatory component. The motor is used as the power source. Compared with the engine, the motor can operate in four quadrants, mainly in the torque control mode. In the case of software function or hardware failure, the electric drive assembly may have unexpected torque output, such as excessive torque output or reverse, causing unexpected personal injury. As the transmission part, the motor is a ring on the transmission chain. The motor torque fluctuation or improper adjustment of the PI parameters may cause problems in the comfort of the vehicle caused by the torsional vibration of the drive train. In terms of high-voltage safety, in addition to the 48V motor, the working voltage of the vehicle motor exceeds the safety voltage of 60V, and some can reach 500V or even higher, posing a high-voltage safety risk. The announcement on the whole vehicle requires the motor to be tested in accordance with GB/T 18488. In the aspects of enterprise access and subsidy application, information such as the code of the motor and the rubbing of the casing are required. Therefore, the motor is a regulatory component. The electric drive assembly is usually located at the bottom of the whole vehicle, and the operating environment is bad; most of the working conditions of the motor are in a high-speed rotation state, especially the working speed of the passenger car driving motor is much higher than the engine working speed of the conventional fuel car, thereby bringing special attention for the mechanical safety issue . The steady-state operating temperature of the motor is usually around 120 ℃. Under some operating conditions, it even reaches or exceeds 160 ℃. The maximum operating temperature of the motor controller will reach 100 ℃ or above. The temperature of the electric drive assembly is monitored to prevent high-temperature demagnetization of the permanent magnet synchronous motor. The requirements for preventing high temperature contact burns are urgently required. Electric drive assemblies work in complex environments and require adaptation to a variety of climates throughout their life, especially in severe areas in the summer and extremely cold areas in winter. The safety requirements for electric drive assemblies are more demanding. Compared to conventional fuel vehicles, the complex electromagnetic environment is another challenge that the electric drive assembly needs to face, which puts higher demands on the electromagnetic compatibility of the electric drive assembly. The high-voltage, high-current, high-temperature and other working characteristics of the electric drive assembly cause the maintenance of the electric drive assembly to be quite different from that of the conventional fuel-powered vehicle assembly. The personal safety during the maintenance process requires special attention.

In summary, the safety of the electric drive assembly shall be fully considered from seven aspects: high pressure safety, mechanical safety, thermal safety, protection safety (including electromagnetic radiation and anti-interference), safety protection strategy, functional safety, and maintenance safety.

5.2 High voltage safety

Compared with traditional internal combustion engine vehicles, electric vehicles generally have electrical systems up to hundreds of volts, exceeding the DC safe voltage range (DC 60V). Without proper design and protection, high voltage safety issues such as electric shocks may be brought about. In the aspect of high voltage safety, the following technical requirements and measures shall be considered, such as insulation resistance, withstand voltage, high voltage safety mark, high voltage contact protection, equipotential bonding, high voltage discharge, high voltage interface safety, leakage protection and post-collision safety.

5.2.1 Insulation resistance requirements

5.2.1.1 Motor stator windings on the insulation resistance requirements of the casing

Shall comply with the provisions of 5.2.7.1 of GB/T 18488.1-2015.

5.2.1.2 Motor stator windings for temperature sensor insulation resistance requirements

Shall comply with the provisions of 5.2.7.2 of GB/T 18488.1-2015.

5.2.1.3 Motor controller insulation resistance requirements

The motor controller of Class B voltage shall comply with the provisions of 5.2.7.3 of GB/T 18488.1-2015 and meet the following requirements:

(1)The cold state and the thermal insulation resistance between the power terminal and the outer casing are not less than 5MΩ;

(2)The power terminal is connected to the low voltage terminal (not ground), and the cold state and the hot insulation resistance are not less than 5MΩ;

The above measurement shall be based on the highest working voltage to select the megohmmeter. The test method is in accordance with GB/T 18488.2.

5.2.1.4 Insulation test requirements

Usually, the integrated insulation detection function inside the battery pack can monitor and alarm the DC side insulation of the high-voltage system of the vehicle. It is recommended that the motor controller have an AC side insulation detection function.

5.2.2 Withstand voltage requirements

According to the highest working voltage of the electric drive assembly, set the test voltage and consider the cold state and the hot state, and make different requirements, as follows:

5.2.2.1 Inter-turn impulse withstand voltage requirements for drive motor windings

It shall comply with the provisions of 5.2.8.1 of GB/T 18488.1-2015, and the maximum working voltage shall refer the effective value of the three-phase AC line voltage.

5.2.2.2 Drive motor windings for the power frequency withstand voltage requirements of the chassis

It shall comply with the provisions of 5.2.8.2.1 of GB/T 18488.1-2015. The highest working voltage is the rms value of the three-phase AC line voltage. The leakage current control value is performed in accordance with the technical documentation requirements.

5.2.2.3 Drive motor windings for temperature sensor power frequency withstand voltage requirements

It shall comply with the provisions of 5.2.8.2.2 of GB/T 18488.1-2015. The temperature sensor test requirements and limits for the drive motor housing are the same as those specified in 5.2.8.2.2.

5.2.2.4 Drive motor power frequency withstand voltage test voltage and test times

requirements

According to the requirements of GB 755, the power frequency withstand voltage of the drive motor shall only be tested on the finished motor, and the full value withstand voltage test of the winding shall not be repeated during the acceptance. If the second or more withstand voltage test is carried out according to the customer's requirements, the test voltage value shall be 80% of the previous test voltage value until the test voltage drops to the minimum test voltage of 1500VAC, and the test time is 1 minute.

For fully rewinding windings, equivalent to the new motor, a full value withstand voltage test is used.

For voltage withstand tests on partially rewinded windings or overhauled motors, the following rules are recommended:

(1)The test voltage value for the partially rewinding winding is 75% of the new motor test voltage value. The old windings shall be carefully cleaned and dried before testing.

(2)For the overhauled motor, after cleaning and drying, it shall withstand the test voltage of 1.5 times the rated voltage. If the rated voltage is 100VAC or above, the test voltage shall be at least 1000VAC. If the rated voltage is below 100VAC, the test voltage shall be at least 500VAC.

5.2.2.5 Motor controller power frequency withstand voltage requirements

In product certification, the motor controller shall be tested for power frequency withstand voltage in accordance with the provisions of 5.2.8.2.3 of GB/T 18488.1-2015. For the motor controller with Y capacitor, the factory test is allowed to perform DC withstand voltage test, and the test value is 1.414 times of the specified power frequency withstand voltage value.

After the complete assembly of the controller, the insulation and withstand voltage must be tested. After the test is passed, the upper high voltage operation is allowed.

The withstand voltage test requirements are as follows:

(1)The voltage level requirements refer to the provisions of Table 2 of GB/T 18488.1-2015.

(2)The test procedure and experimental method refer to the provisions of 5.8.4 of GB/T 18488.2-2015.

(3)The leakage current limit is implemented in accordance with the technical documentation.

Because the withstand voltage test causes certain damage to some devices, it will affect the service life of the device, so the number of withstand voltage tests shall be minimized. If the second or more withstand voltage test is carried out according to the customer's requirements, the test voltage value shall be 80% of the previous test voltage value until the test voltage drops to the minimum test voltage of 1500VAC, and the test time is 1 minute.

5.2.3 Shielding and grounding

5.2.3.1 High voltage harness shielding and grounding requirements between motor and motor controller

The high-voltage multi-phase connection system shall be provided with a shielding layer. Both ends of the shielding layer and the high-voltage component housing are effectively grounded to realize 360-degree omnidirectional shielding at both ends of the cable, and the grounding resistance of each end is not more than 40mΩ. The shielding layer of high-voltage shielding cable shall meet the requirements of 6.3 of GB/T 25087-2010 and meet the electromagnetic compatibility requirements of the whole vehicle.

5.2.3.2 Controller DC bus shielding and grounding requirements

The high-voltage connection system shall be provided with a shielding layer. The controller end of the shield motor and the controller casing are effectively grounded to achieve 360-degree shielding of the cable. The grounding resistance is not more than 40mΩ.

5.2.3.3 Position sensor wiring harness shielding and grounding requirements

The position sensor harness shall be twisted pair and have a shield. It is recommended that the shield be well grounded at both ends.

5.2.3.4 CAN bus shielding requirements

It is recommended that the motor controller CAN communication harness be shielded twisted pair, the shield shall be well grounded at the motor controller end; or as required by the technical documentation.

5.2.3.5 Grounding requirements for motors, motor controllers and other power controllers

The grounding resistance of the metal casing of the drive motor, motor controller and other power controller products shall be no more than 100mΩ.

There shall be permanent, reliable and good electrical connections between the motor frame, the controller housing, etc. and the chassis or body.

The connection of the grounding wire terminal shall be securely locked and protected against loosening.

5.2.3.6 Equipotential bonding

The figure below shows a typical high voltage topology for a motor system. In the case of insulation problems between the positive and negative poles of the high-voltage components (such as short-circuit or partial leakage of the positive and negative poles at the same time), in order to meet the requirements of personnel protection against electric shock, the motor system shall be electrically conductive (obstructed) and the vehicle electric platform shall be reliable. Equipotential bonding.

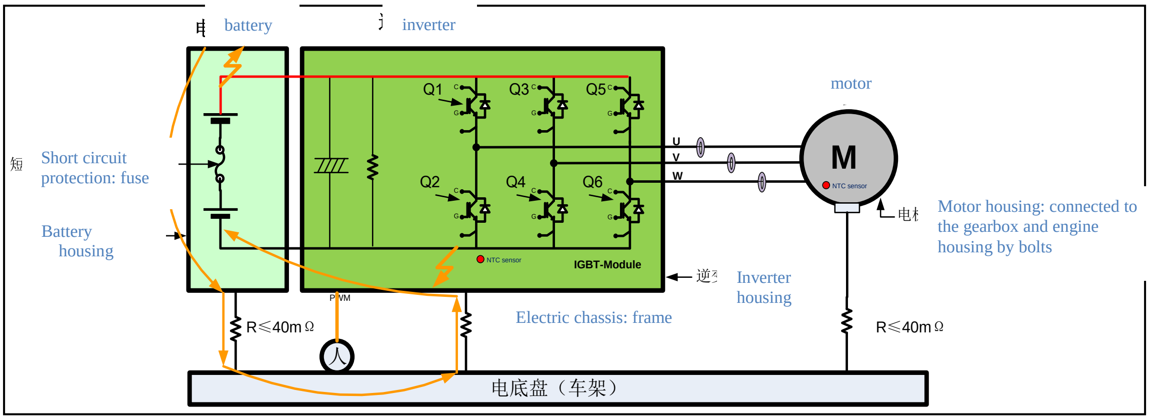


Figure1 Typical high voltage topology for motor systems

The equipotential bonding form can be connected in the following three ways, as shown in the figure:

(1)Through the conductor: such as an electrically conductive bracket

(2)Wiring harness: such as equipotential bonding wire, the color is brown

(3)Direct connection: the motor controller is directly connected to the electric platform by bolts or welded to the vehicle body.

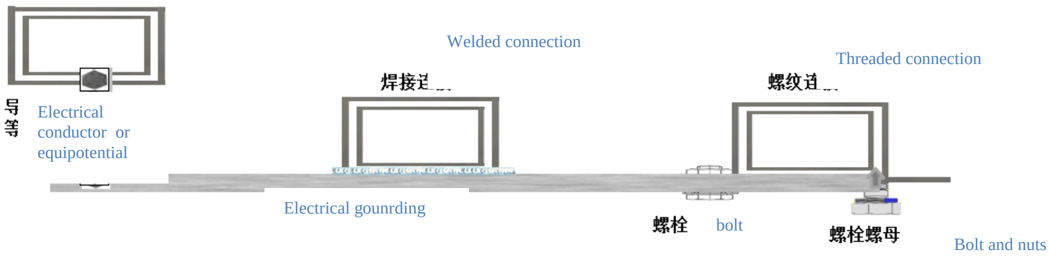


Figure1 Equipotential bonding form

Equipotential bonding requirements:

(1)Resistance requirements; the resistance between the electrically conductive outer casing (obstruction) of the motor system and the vehicle's electrical platform shall be less than 100mΩ.

(2)Short-circuit current: The equipotential bonding shall carry the short-circuit current until the overcurrent protection acts.

(3)Lifetime: The equipotential resistance must be maintained until the end of the specified life of the high voltage component.

(4)Connection requirements: For equipotential bonding forms that are fastened to the body, the equipotential bonding wires and bolts shall be corrosion resistant beyond their specified lifetime and shall not be automatically released.

(5)The grounding terminal shall not be used for other purposes.

(6)The bolts of the grounding terminal and the whole vehicle ground shall have sufficient cross section. The minimum diameter of the grounding bolt is as specified in Table 3 of GB14711-2006 (same as Table 1 below). The cross-sectional area of the grounding conductor is in accordance with Table 19 of GB 755-2008 (same as Table 2 below) provisions.

Chart 1 Protective earthing bolt minimum diameter

Motor rated current A	Protective earthing bolt minimum diameter mm
≤20	4
＞20~200	6
＞200~630	8
＞630~1000	10
＞1000	12

Chart 2 Grounding conductor cross-sectional area

Phase line cross-sectional area /mm ^{2}	Ground wire or shield wire cross-sectional area /mm ^{2}	Phase line cross-sectional area /mm ^{2}	Ground wire or shield wire cross-sectional area /mm ^{2}
4	4	95	50
6	6	120	70
10	10	150	70
16	16	185	95
25	25	240	120
35	25	300	150
50	25	400	185
70	35		

5.2.3.7 Grounding mark requirements

The grounding point shall have an obvious grounding mark. If there is no specific grounding point, the grounding mark shall be set at a representative location.

The grounding mark shall be marked with the protective grounding symbol "⏚" according to GB/T 4026-2010, and the letter symbol "PE" shall be applied if necessary. These markings shall not be placed on bolts, detachable gaskets or as parts of possible removal of connecting wires.

5.2.4 High voltage connectors and connectors

(1)The obstruction and casing of the B-level voltage components shall comply with the requirements of IPXXB protection according to GB/T 18384.3-2015.

(2)The connection guiding part on the physical structure of the selected paired coupling high voltage connector shall be different to meet the error prevention insertion function.

5.2.5 High voltage discharge

After the motor system is disconnected from the high voltage circuit, due to the existence of energy storage devices inside the motor controller, such as DC bus support capacitors, the internal high voltage of the motor system does not disappear immediately, but slowly decreases during routine maintenance or after-sales maintenance. It may cause a high voltage electric shock and result in casualties. Therefore, in order to avoid the above accidents, the motor system needs to have both active discharge and passive discharge functions. Even if the active discharge fails, the passive discharge is still effective and must fall below the safe voltage within the specified time. The specific requirements are as follows:

5.2.5.1 Active discharge requirements

The input voltage of the motor controller used in electric vehicles and hybrid vehicles is usually higher than the safety voltage. To protect personal safety, the DC side capacitor of the motor controller must be equipped with a discharge circuit to quickly reduce the voltage of the DC side capacitor. The electric drive assembly must have an active discharge function. Active discharge can be implemented by motor windings or by external dedicated discharge resistors.

According to the requirements of 5.5.3 of GB/T 18488.1-2015, when the B-level voltage system is powered off, the DC bus voltage shall be reduced to a safe level (DC voltage below 60 V) within 3 s.

5.2.5.2 Passive discharge requirements

The electric drive assembly shall also have the function of passive discharge, and the passive discharge component is connected to the DC side. Even if the active discharge function cannot be completed, the passive discharge device can discharge the DC side capacitor. This feature must always be active, not valid until it is triggered.

When the Class B voltage system is de-energized, the DC bus voltage shall be reduced to a safe level (DC voltage below 60 V) within 2 min.

5.2.6 High voltage protection against electric shock and warning

The electric drive assembly shall have a high-voltage warning sign, and the high-voltage warning sign shall meet the contents of Article 5.1 of GB/T 18384.3-2015.

Figure 3 High-voltage warning sign

The obstruction, casing and connectors of the B-level voltage components of the electric drive assembly shall meet the requirements of direct contact protection in the following two ways or one of them.

(1)Basic insulation of the live part;

(2)Block or cover to prevent access to live parts.

(3)The obstruction, casing and connectors of the B voltage components must meet at least the IPXXB protection level specified in GB/T 4208.

If the enclosure or enclosure can be opened by hand, the openable section shall have a high voltage interlock that meets the high voltage interlock requirements of Section 5.2.7 of this document.

5.2.7 High voltage interlock

High Voltage Inter-lock (HVIL) is a safe design method for monitoring the integrity of high voltage circuits with low voltage signals. The interlocking circuit is connected end to end on the automatic disconnecting device. When any high voltage protective cover or connector on the high voltage electrical circuit is disconnected from the circuit, a low voltage electrical signal is triggered, the high voltage is immediately disconnected, and the high voltage system shall not power up again. High-voltage interlocking measures are adopted for high-voltage connectors that meet the protection class IPXXB; high-pressure interlocking measures are adopted for the detachable casing; if there is no interlocking measures, it shall be ensured that the high-voltage system is first cut off and sufficient time is available before the casing is removed. The high voltage system voltage is below 60Vdc. The high-voltage interlocking forms are various, and the male-female terminal connector can be used for matching, micro-switching or mechanical interlocking. It is recommended that passenger car products have high-voltage interlock function, and it is recommended that commercial vehicle products use high-voltage interlock function. If the high voltage wiring system has a high voltage interlock function, the power terminals and signal terminals of the system shall meet the following requirements:

(1)When the high voltage connection system is connected, the power terminal is turned on first, and the signal terminal is turned on;

(2)When the high voltage connection system is disconnected, the signal terminals are disconnected first and the power terminals are disconnected.

5.2.8 High voltage contact protection

The detachable motor controller housing must conform to complex disassembly and must be tooled (not specifically designed) and removed in one of two ways:

Remove the shell by removing more than three bolts or two different types of bolts.

Only the special tool can be used to remove the outer casing. The motor controller is installed in the front engine room. The fully assembled motor controller shall have the protection level of IPXXB or IPXXD as specified in ISO20653.

Other optional measures include high voltage interlock or delayed contact:

Delayed contact: It shall be ensured that two separate operations can be performed before the live parts can be accessed. The first step must trigger the cutoff of the high voltage system and ensure that the voltage of the high voltage part is lower than 60Vdc or lower than 30Vac during the second step of operation. At the same time, it shall meet the requirements of GB/T 18384.3.

5.2.9 Safety after collision

If a collision occurs during the use of the vehicle, the electric drive assembly shall perform one or more of the following protection measures in accordance with the vehicle controller command:

(1)The motor controller cuts off the load current and has no power output;

(2)The electric drive assembly activates the no-load condition;

(3)Activate the electric drive assembly safety state;

(4)Active discharge of the high voltage circuit.

The specific indicators are as follows:

(1)When the high voltage system is cut off, the active discharge of the high voltage circuit must be started immediately according to the requirements of the vehicle controller;

(2)The voltage of the high voltage circuit must drop below 60Vdc within 3s of the collision signal.

5.2.10 Electric drive assembly creepage distance and clearance requirements

The clearance is the shortest distance between the two conductive parts in the air, which is related to the product impact withstand voltage, pollution level and altitude.

5.2.10.1 Motor creepage distance and clearance requirements

According to the pressure rating and altitude of the motor, refer to the provisions of Section 11 of GB14711-2013 to determine the creepage distance and clearance of the motor. For specific requirements, see Table 4 of GB14711-2013 (operating voltage 31V~750V) and Table 14 (above 1000V). This voltage platform is less used in the current electric vehicle field). When the working voltage is between 750V and 1000V, it is recommended to design the creepage distance and clearance according to the working voltage of 1000V in Table 14 of GB14711-2013.

5.2.10.2 Controller creepage distance and clearance requirements

(1)Refer to GB/T 16935.1-2008 for the clearance and creepage distance of the high voltage system of the motor controller;

(2)Determine the clearance according to the pressure rating, environmental pollution level, working altitude, etc. Refer to Appendix F.2 of GB/T 16935.1-2008, reference to the altitude correction coefficient GB/T 16935.1-2008, Table A.2

(3)Determine the creepage distance according to the environmental pollution level, material CTI value, working voltage, etc. Refer to Appendix F.4 of GB/T 16935.1-2008

(4)When the rated insulation voltage of the main circuit and the control circuit or auxiliary circuit is inconsistent, the clearance and creepage distance can be selected according to their rated values. When there is a different rating between the main circuit or the conductive part of the control circuit, the clearance and creepage distance shall be selected according to the highest rated insulation voltage.

5.2.11 High-voltage interface safety requirements

5.2.11.1 Anti-loose design requirements

5.2.11.1.1 Pluggable high voltage connector requirements

The pluggable high-voltage connector has at least two levels of locking devices, and at least two different actions are required to separate them from the mutual butting ends; the plug-ins have an error-proof insertion function. Pluggable high voltage connectors shall meet the requirements of Appendix A of GB/T 37133-2018.

5.2.11.1.2 Requirements for other ways of connection

Connections such as cable crimping, screwing, and welding of high-voltage connection systems shall be free of connection defects such as looseness and breakage.

5.2.11.2 High-voltage connection system protection requirements

The protection level of the high-voltage connection system during normal connection shall not be lower than IP67. If the high-voltage connection system can be manually disconnected without the tool, the protection level of each part of the non-connected high-voltage connection system shall meet IPXXB.

5.2.11.3 High-voltage connection system vibration resistance requirements

The vibration resistance requirements of the high-voltage connection system shall meet the requirements of 7.4 of GB/T 37133-2018.

5.2.12 Low-voltage harness connection safety requirements

5.2.12.1 Low-voltage harness connection reliability

The vibration resistance requirements of the low-voltage connection system shall meet the requirements of 4.10 of QC/T 29106-2014.

5.2.12.2 Low-voltage plug-in collision protection requirements

The low-voltage connector shall be placed in a place that is not easily bumped or shall have certain anti-collision protection during design to avoid damage during transportation, installation and operation.

5.2.12.3 Low-voltage harness sealing inspection requirements

The protection rating of the low-voltage connection system during normal connection shall not be lower than IP67.

5.3 Mechanical safety

Compared with traditional internal combustion engine vehicles, the speed of the driving motor on the electric vehicle is usually much higher than that of the engine. At the same time, the powertrain has lightweight design requirements. This requires that the electric drive assembly must pay special attention to the mechanical strength of the product during development and verification. The contradiction between stiffness and lightweight engineering is handled. The bearing is the key part of the electric drive assembly that is more prone to failure, affecting the safety of the whole vehicle; compared with the traditional transmission system, the shaft current caused by the high frequency, high voltage and high power of the electric drive assembly is easy to make the bearing Early electrical corrosion failure occurred. The gears and shafting of the transmission system have special requirements for high speed and reliability. All of these aspects make the mechanical safety of the electric drive assembly particularly important.

5.3.1 Rotor strength

The motor rotor is one of the important components of the motor energy conversion. It is the main rotating component of the motor and is used to output the power of the motor. The main direction of rotor mechanical safety design is high-speed rotor core shape variable control, rotor punch structure strength and allowable imbalance.

The rotor of the drive motor shall be able to operate normally under all specified operating conditions without any abnormalities such as deformation, looseness, increased vibration and noise, and breakage, breakage and shedding of components.

Through CAE-assisted design, considering the maximum working speed of 1.2 times motor, the deformation of the rotor core shall be less than 10% of the air gap of the motor, and the maximum stress of the rotor core shall meet the safety factor.

5.3.1.1 Overspeed test requirements

The drive motor shall be able to withstand 1.2 times the maximum working speed test in the hot state, the duration is 2 min, and the mechanical structure shall not be harmfully deformed.

5.3.1.2 Rotor system dynamic balance requirements

The rotor dynamic balance shall meet the G2.5 and above standards specified in GB/T 9239.1, except for special requirements.

5.3.2 Bearing reliability

5.3.2.1 Bearing grease, lubrication, seal maintenance requirements

Bearings need to have a good working environment, and no water or other impurities can enter the bearing during assembly, transportation and operation. Allow the bearing to change grease or even replace the bearing according to maintenance requirements to ensure the lubrication and normal operation of the bearing. It is necessary to replace the new bearing every time when the motor is disassembled and repaired. Maintenance of bearings needs to be carried out by professional manufacturers.

5.3.2.2 Bearing sound subjective testing requirements

The noise is factory-tested for the electric drive assembly, and the acoustic characteristics of the electric drive assembly are judged by the acoustic device. When necessary or when conditions are temporarily not available, certain subjective judgments can be combined.

5.3.2.3 Protection of shaft voltage and shaft current

Larger shaft currents can cause early electrical corrosion of the motor bearings, reducing bearing life and generating abnormal vibration noise. It is recommended that the high frequency motor adopts shaft current suppression measures. The following main measures are recommended to suppress the shaft current:

(1)Design a reasonable filter to reduce the common mode voltage of the variable frequency power supply, which can better eliminate the high frequency harmonic generated by the PWM motor controller.

(2)Insulate the bearing at one end of the motor to suppress the shaft current. The specific method may be implemented by using an insulating bearing or by providing an insulating structure on the bearing housing or the end bearing housing.

(3)When the double-ended bearing is insulated, the shaft and the outer casing are directly short-circuited to suppress the common mode shaft voltage caused by static electricity, and the oil film voltage can be further reduced to protect the bearing from electrical corrosion and damage.

5.3.3 Shell strength

The strength of the shell shall meet the requirements of the vehicle under different working conditions. Generally, refer to GB/T 28046.3-2011 or customer standard to ensure that in the case of collision, under the premise of ensuring the safety of the personnel in the vehicle, the damage to the motor can be reduced.

5.3.3.1 Shell ground clearance requirements

During the layout of the whole vehicle, it shall be ensured that the drive motor housing is higher than the frame (or sub-frame) and a certain safety distance is set to ensure that under extreme conditions such as full load and over-pit road, the motor bottoming problem can be avoided to ensure safe driving.

5.3.3.2 Maintenance, inspection, and anti-shedding requirements

The position of the electric drive assembly in the overall vehicle layout shall be considered for convenience during inspection and maintenance. After the vehicle has been running for a certain period of time, it is necessary to inspect and maintain the relevant components of the electric drive assembly. Usually, the torque check method or the scribing mark method (special case) is used to determine whether the connection is loose. If looseness is found, the connection position shall be immediately performed to be locked in order to avoid causing the drive motor to loosen or fall off during use, resulting in traffic accidents.

5.3.4 Mechanical anti-touch and warning

The vehicle transmission is a rotating component, and the damage caused by the rotating component shall be considered in the design process, and the rotating component is isolated from the human body through the physical structure. For rotating parts that cannot be protected, attach or install a warning sign on the perimeter to avoid injury.

The design of the water joint shall first ensure the tightness, pressure resistance and ease of installation of the cooling line. Ensure that the pressure detection value of the cooling channel is not less than 250 kPa or according to customer requirements, the wetness test or dry test method is usually used to judge the sealing and pressure bearing of the water channel.

The high and low voltage connectors shall meet the IP67 protection level of the product, and the wire harness shall be installed and fixed within a certain length to prevent damage to the connector sealing and protection under long-term vibration environment. The perimeter of the connector and the harness shall be provided with effective physical protection (such as metal or non-metallic protective covers, nets) to prevent damage to the connectors during transportation, assembly, and vehicle operation.

5.3.5 Output flange anti-loose inspection requirements

The output flange of the drive motor system must be connected to the drive shaft reliably to avoid loosening. After the vehicle has been running for a certain period of time, it is necessary to inspect and maintain the motor output flange, the drive shaft and the fasteners between them. Usually, the torque check method or the scribing mark method is used to judge whether the motor connection is loose. If looseness is found, the connection position shall be locked immediately to avoid causing the drive motor to loosen or fall off during use, resulting in traffic accidents.

5.3.6 Spline lubrication inspection requirements

The powertrain usually consists of a reducer and a drive motor. The drive shaft is usually an inner/outer spline connection. It is exposed to the air for a long time, which is prone to rust and wear, resulting in failure of the spline connection. At the beginning of the design, consideration shall be given to the lubrication and sealing of splines. Usually, a sealing ring is arranged at both ends of the spline, and a certain amount of grease is filled in the sealed spline cavity (the oil is added in an appropriate amount, and the excess grease may cause pressure to damage the bearing) to ensure the spline lubrication is effective. At the same time, the inspection interval between the spline grease and the grease filling amount shall be given in combination with the actual endurance test. Usually, every 5 years or 100,000 km or according to the requirements of the OEM, an inspection is carried out. At the same time, the criterion for the spline wear is given, and the spline needs to be replaced if necessary.

5.3.7 Mechanical strength of the shaft

The motor shaft shall be able to meet the maximum torque output requirements of the vehicle under various working conditions. The mechanical strength of the motor shaft depends on optimized structural design, accurate force analysis and calibration, material selection, heat treatment and machining assembly. If necessary, static torsion test and torsional fatigue test are required.

Standard QC/T 534-1999 shall be referred, the static torsional strength reserve factor shall be greater than 1.8 times of the peak torque

5.3.8 Variable torque reducer

The static torque reduction ratio of the variable/reducer is not less than 2.5, and the test method is in accordance with 6.2.4.9 of QC/T 1022-2015.

5.3.9 Transmission shift safety

The transmission shift shall be reliable, there is no disorder, off gear, upshifted or unopened gear.

5.3.10 Parking safety

When the vehicle speed is higher than 5km/h, it shall not be parked when the parking function button is accidentally touched; when it is in the non-parking state, the parking mechanism cannot automatically park the car regardless of any abnormal situation; after parking, the parking mechanism cannot automatically off-load; when the car needs to drive, the parking mechanism can make the car smoothly off the parking stall; and shall have a manual unlock function.

5.4 Thermal safety

The thermal failure is a common failure mode of the electric drive assembly. Due to the fault or long-time overload operation, the motor winding is burnt out or the motor controller power module is damaged, which will directly cause the electric vehicle to lose power and greatly affect the driving safety. Therefore, in the design of the electric drive system, thermal safety factors must be considered, and corresponding countermeasures shall be taken to ensure the safe operation of the system. The performance of an electric drive system is often limited by temperature rise and operating temperature limits. A reasonable temperature design maximizes the performance of the electric drive system. Temperature field simulation, test verification and real-time monitoring and protection of the trinity shall ensure the safe operation of electric vehicles. The life of the motor stator insulation system is strongly related to its operating temperature. Experience has shown that insulating materials are used at temperatures above their operating temperature, with a lifetime reduction of about half for every 10 ℃ increase. Working under high temperature for a long time is likely to cause premature aging and failure of insulating paper and insulating paint, causing serious consequences such as short-circuiting of windings. The focus of motor thermal performance design is to control the operating temperature of the motor and ensure the life. The rotor heat dissipation condition of the motor is generally poor, and the heat generated by the rotor iron loss and the magnetic eddy current loss is easily accumulated, resulting in an increase in the rotor temperature. As the motor develops at a higher speed, the rotor will face greater heat dissipation pressure. In terms of design, the temperature field simulation can be used to make a preliminary evaluation of the permanent magnet temperature, but it cannot be completely covered in the face of complex and varied actual use conditions. In terms of temperature monitoring, the rotor as a rotating component is generally difficult to directly arrange the temperature sensor to monitor the working temperature of the rotor core and the magnetic steel in real time. The rotor temperature can be estimated in real time by establishing a rotor temperature model, and a corresponding temperature protection control algorithm is established. Ensure that the magnetic steel is always working within its allowable operating temperature range.

5.4.1 Thermal warning, derating, protection

5.4.1.1 Redundant design recommendations for temperature sensors

It is recommended that both the motor and the motor controller use two temperature sensors for temperature monitoring and display the temperature of one of the higher temperature sensors in real time in the meter.

5.4.1.2 Temperature sensor measurement point and software design relationship

In the development of the motor system, it is recommended to test the multi-temperature sensor prototype. According to the multi-temperature sensor prototype test results, determine the highest temperature point of the batch supply product and the temperature difference with other possible buried temperature sensors. It is recommended that the temperature sensor be arranged at the three-phase neutral point to monitor the three-phase temperature, and the other end may be placed at the highest temperature point. When the protection software is written, it is necessary to perform a data collection and reporting list according to the aforementioned test and the temperature sensor buried position. Once a temperature sensor fails, the software switches the sampling to another effective temperature sensor and also adjusts the software alarm temperature setting based on the cut-in sensor sampling. In addition, the software shall also leave sufficient safety margin according to the aforementioned test certification.

5.4.1.3 Overheated three-level fault protection mechanism requirements

The system needs to use a three-level fault handling mechanism; the processing strategy shall be in accordance with the product technical documentation. The recommended protection strategy is described in section 5.6 of this chapter.

5.4.2 Rotor demagnetization: demagnetization safety at high temperatures, rotor temperature estimation

Permanent magnets can cause demagnetization problems caused by temperature effects, over currents, or improper current control angles. In the motor design stage, it is necessary to fully check the peak operating conditions and the demagnetization critical point under the three-phase short-circuit condition to avoid the motor operating conditions above the critical point. At the same time, the rotor temperature during continuous operation of the motor is estimated to ensure that the temperature of the permanent magnet does not exceed the demagnetization temperature limit of the selected grade of magnetic steel under high current load and control angle. In the development phase of the motor system, it is recommended to carry out the necessary demagnetization test certification. It is recommended to establish a more accurate rotor temperature estimation model and incorporate the estimation model into the control software protection program. The following is a temperature estimation scheme: the relationship between the stator winding temperature and the rotor magnet temperature is established through a large number of tests, and the rotor magnet temperature is indirectly monitored by monitoring the stator temperature in software.

5.4.3 Bearing temperature resistance, sealing material temperature resistance, insulation material temperature resistance requirements

The temperature resistance of the bearing shall be limited to the temperature range of the extreme working conditions. The temperature range is specified by the technical documents of the OEM and the motor supplier. Recommended bearing operating temperature range -40 °C ~ 150 °C.

Sealing materials for electric drive assemblies, such as seals, gaskets and oil seals, shall have a temperature resistance greater than 150 ℃.

The temperature resistance grade of the insulation material of the motor shall use H (allowable working temperature 180 °C) grade and above temperature resistant materials (refer to GB/T 20113-2006). The temperature rating of the insulation system depends on the minimum temperature rating of the various insulation materials (insulation paper, magnet wire, insulating varnish and end lashing wire) of the motor. The supplier shall clearly mark the insulation system rating on the product nameplate.

5.4.4 Use of flame-retardant materials

The flame-retardant performance of the wire harness and injection molded parts used for high pressure connection shall comply with the horizontal burning HB grade specified in GB/T2408-2008 and the vertical combustion V-0 grade. The temperature class of the B-class voltage cable protection bellows and the heat-shrinkable double-wall pipe shall not be lower than 125 ℃. The performance of the heat-shrinkable double-wall pipe shall comply with the requirements of Appendix B of QC/T 29106-2014, and the performance of the bellows shall be Meets the requirements of Appendix D of QC/T 29106-2014.

5.4.5 Human body protection and warning

5.4.5.1 shutdown high temperature warning

Any high temperature components that may be touched by operational and maintenance personnel, such as the housing, shall have a high temperature warning sign. The specific high temperature warning requirements for shutdown are determined by the OEM. For example: for motors with Class H insulation, when the winding temperature exceeds 160oC, the motor panel shall indicate that the motor temperature is too high. After the motor winding temperature reaches 170 oC, it shall be stopped and protected. After the shutdown, the temperature of the metal casing of the water-cooled motor may be as high as 120oC. Do not touch it directly within 30min to avoid burns!

It is recommended to attach the beware of high temperature surface warning signs on the electric drive assembly. Beware of the high temperature surface warning signs shall meet the contents of Section 4.2.3 of GB2894.

Figure 4 high temperature surface warning signs

5.4.5.2 Fault alarm requirements

When the electric drive assembly fails, it must be prompted on the instrument panel and perform comprehensive alarms of sound, light and electricity.

5.4.6 Electric drive cooling system (pump, pipeline, connecting parts, etc.) regular inspection requirements

It is recommended that the cooling system of the electric drive assembly travels 40,000 kilometers per half year or the entire vehicle, and a periodic inspection or a maintenance manual provided by the OEM is required. Check whether there is any coolant leakage on the outside of the cooling pipe, near the inlet and outlet, on the motor and motor controller; if there is any abnormality, judge the leaked parts and replace or repair them accordingly.

5.4.7 Variable/reducer oil temperature requirements

The temperature of the variable/reducer oil pool shall not exceed 130 degrees.

5.5 Protection and safety

IP protection is a factor that must be considered in mechanical safety design. The sealing design or selection of the electric drive system shall meet the requirements of IP6K7 and IPX9K. The electric drive assembly works in a complex electromagnetic environment, which puts higher requirements on the electromagnetic compatibility of the electric drive assembly. The electric drive assembly must have strict electromagnetic radiation and conduction indexes, and also have excellent resistance. Interference ability.

5.5.1 Waterproof/dustproof design: end cap and shaft seal design

5.5.1.1 Liquid cooling (water, oil, etc.) medium dustproof requirements

The drive motor and controller shall be dust-proof and waterproof. The degree of protection shall meet the requirements of the standard or customer. The minimum requirement is not less than IP67.

After the vehicle is installed, the motor shall be in the state of power failure. After soaking for 24 hours in the water depth of 50 cm, the whole vehicle is turned on, and the electric drive switch is placed in the "ON" position. The motor and motor controller shall not cause safety incidents by their own reasons. (e.g. fire, etc.).

5.5.1.2 Dust-proof requirements for oil-cooled motor production process

Oil-cooled motors shall pay special attention to the dust-proof of the motor during assembly and use. Prevent dust, foreign matter, etc. from entering the inside of the motor and affecting insulation, bearings, etc.

Cleanliness control indicators need to be developed for different parts and components. The control of cleanliness requires simultaneous control of the total weight of impurities and the maximum impurity particle size. Cleanliness indicators are implemented in accordance with internal corporate standards.

5.5.1.3 Rotary seal design requirements

The rotary seal design of the water-cooled motor and the oil-cooled motor is significantly different. The former generally has no lubricating medium, while the latter has a lubricating medium.

For water-cooled motors, such as the traditional rotary sealing technology with rubber oil seals, the rubber seals fail prematurely due to lack of lubrication.

(1)Standardize the installation of the oil seal and check the tightness after the oil seal is installed.

(2)The motor adds a breather valve to balance the air pressure inside and outside the motor to avoid airflow in and out of the seal portion of the oil seal due to the breathing effect.

Rotary seals need to be inspected and maintained regularly in accordance with the maintenance manual and replaced if necessary.

5.5.1.4 Dust control requirements of the controller (for on-site maintenance)

Drive motor controller repairs need to be carried out in a dry, dust-free, static-protected area. Before the maintenance, the drive motor controller needs to be thoroughly cleaned. After the repair, it shall be thoroughly tested.

5.5.1.5 High-voltage harness sealing design requirements

The protection level of the high-voltage connection system during normal connection shall not be lower than IP67. If the high-voltage connection system can be manually disconnected without tools, the protection level of each part of the high-voltage connection system in the unconnected state shall meet the IPXXB.

5.5.1.6 Low-voltage harness sealing design requirements

The protection rating of the low-voltage connection system during normal connection shall not be lower than IP67.

5.5.2 Airtight

5.5.2.1 Drive assembly cooling line sealing inspection requirements

The air pressure of the cooling channel needs to consider the inflation pressure, inflation time and dwell time. The detection time and pressure drop must be determined according to the specific product specifications; negative pressure test can also be used.

5.5.2.2 Motor rotary seal inspection requirements

There are two methods for motor rotary seal inspection:

(1)Carry out the test of relevant requirements in accordance with the GB/T 4942.1-2006 standard;

(2)Inflation pressure, inflation time and dwell time shall be considered when using the airtight test. The detection time and pressure drop must be determined according to the specific product specifications; negative pressure test can also be used.

5.5.2.3 Controller seal inspection requirements

Controller cooling water channel seal inspection requirements: inflation pressure, inflation time and dwell time shall be considered. The detection time and pressure drop must be determined according to the specific product specifications; negative pressure test can also be used.

Controller housing seal inspection requirements: In the state of high-voltage connector, low-voltage connector coupling, the inflation pressure, inflation time and dwell time shall be considered. The detection time and pressure drop must be determined according to the specific product specifications; negative pressure test can also be used.

5.5.2.4 Electric drive assembly high- and low-pressure connection sealing requirements

When the high-pressure connection system and the low-voltage connection system are normally connected, the inflation pressure, inflation time, and dwell time shall be considered. The detection time and pressure drop must be determined according to the specific product specifications; negative pressure test can also be used.

5.5.2.5 Anti-condensation requirements

The motor system and electric drive assembly products shall be IP67 in their life cycle. On this basis, it is necessary to further consider the internal pressure change and respiratory effect caused by temperature changes, which will cause condensation and make the product cavity. Water accumulates in the body, causing electrical failure and corrosion of parts. Motor system and electric drive assembly products shall be equipped with a waterproof and breathable valve with reasonable air permeability. Selection of breathable valve: The protection with the cabinet is IP67 rated at the full life cycle level. Vent valves are usually mounted on the top or side of the product.

5.5.2.6 Inspection requirements for electric drive assembly after wading and wading

According to the requirements of 8.3.1 and 8.3.2 of GB/T 18384.3-2015:

(1)The motor and motor controller shall be tested for withstand voltage according to the requirements of 5.2.82 of GB/T 18488.1-2015. The cold insulation resistance shall comply with the factory test standards.

(2)Check the airtightness of the controller and drive motor according to the factory test standards.

5.5.3 EMC and protection: electromagnetic noise to vehicle equipment

New energy vehicles are becoming more and more demanding on EMC. Many auto parts and components company's hard indicators require motor controllers to meet Class 3 standards. Electromagnetic compatibility shall be considered in the design of motor controllers. Electromagnetic disturbances mainly affect electronic devices through radiation and conduction.

5.5.3.1 Electromagnetic radiation disturbance

The electric drive assembly shall meet the requirements of GB/T 18655-2018 (recommended level 3 limit) and the GB/T 36282-2018 standard limit requirements. After the electric drive assembly is installed in the whole vehicle, the whole vehicle shall meet the requirements of GB/T 18387.

According to the requirements of GB/T 36282-2018, during the launch test, the electric drive assembly shall be in working condition, the rotational speed is 50% of the rated speed, the torque is 50% of the rated torque, and the mechanical output load reaches 25 % of the continuous power.

When the speed or torque does not reach its test state, the torque or speed can be adjusted to achieve 25% of the continuous power and is specified in the test report.

5.5.3.2 Electromagnetic radiation immunity

The electric drive assembly shall meet the requirements in Table 3 by reasonable arrangement and shielding protection design.

Table 3 electromagnetic radiation immunity test standard

Test project	GB requirements
Radio wave chamber method	GB/T 33014.2-2016
High current injection method	GB/T 33014.4-2016
Transient conducted immunity (power line)	GB/T 21437.2-2008
Transient conducted immunity (signal line)	GB/T 21437.3-2008
Low-voltage transient conduction emission	GB/T 21437.2-2008
Electrostatic discharge	GB/T 19951-2005

5.5.3.3 Electromagnetic radiation Safety assessment of human health

When the vehicle is in the following working conditions, it shall be tested and verified according to GB/T 37130-2018; the magnetic field emission of 10Hz-400KHz shall comply with Table A.1, Table A.2 and Table A in Appendix A of GB/T 37130-2018. 3 limit requirements.

(1)Static working condition: the vehicle is fully open with electric appliances, and the vehicle power system is powered on at high voltage (PTReady);

(2)Dynamic working conditions: The vehicle travels at a constant speed of 40km/h;

5.6 Electric drive assembly fault protection mechanism

The protection mechanism of the passenger car electric drive assembly needs to include at least the following contents: The specific processing strategy implementation can be agreed upon by the OEM and the electric drive assembly supplier; The protection mechanism of the commercial vehicle electric drive assembly can refer to the passenger car requirements and can be implemented in accordance with the results of the consultation with the OEM.

Passenger car-related fault protection related to functional safety is to consider the safety state, which is described in the 5.7 Functional Safety section. The fault triggering mechanism and recovery mechanism need to be designed and verified according to the needs of the OEM. In addition, the problem of fault tolerance time and priority is introduced in the functional safety development of 5.7.

5.6.1 Fault trigger mechanism

According to the judgment of one or more conditions, a mechanism for determining whether the current fault state has been triggered within a certain time is called a fault triggering mechanism.

The basic fault triggering mechanisms include the following types:

After the fault state is triggered, according to the current actual operating state, the mechanism for entering the safe state under the premise of minimizing interference to the driver is called a fault protection mechanism.

The basic fault protection mechanisms include the following types:

(1)A single physical quantity on the board exceeds a predetermined limit in a single time, triggering a fault condition. It can be an analog signal triggering hardware fault protection, or a hardware driver fault triggering fault protection.

(2)The internal single quantity of the software exceeds the limit [calibratable], triggering the fault status.

(3)The internal single quantity of the software exceeds the limit multiple times [calibratable], triggering the fault status.

(4)The internal quantity of the software is within a period of time T [calibratable] N [can be calibrated] times exceeded the limit [calibratable], triggering the fault state.

(5)The internal quantity and real-time monitoring calculation value of the software [uncalibratable, variable] deviation exceeds the limit [calibratable], triggering the fault status.

(6)The internal quantity of the software exceeds the limit [calibratable], and after a certain logic judgment, the fault status is triggered.

(7)The main control chip uses its own detection mechanism to ensure the correctness of the program execution, otherwise it triggers the fault state (for example, the main control chip detects the clock and other information, the trigger of the fault is to detect the loss of the phase-locked loop PLL (not calibratable),) It is also necessary to ensure the correct calculation results. The fault can be detected by a mechanism such as lockstep. The program flow can also guarantee the execution cycle according to the built-in watchdog of the chip and detect the fault at the same time.

(8)Peripheral other function security chip ensures that the main control chip works normally, otherwise the fault state is triggered. Specific timing reference chip manual. The peripheral function safety related chip detects the running status of the program. The question-and-answer test online mechanism or timeout (calibratable) enters the Safety Sate state.

(9)The preset function is not completed within a period of time T [calibratable], triggering the fault status. The preset function here does not refer to the failure of the chip itself, but the basic functions of the motor controller design, such as: self-learning, active discharge, etc.

5.6.2. Fault protection mechanism (enter security or switch security)

After the fault state is triggered, according to the current actual operating state, the mechanism for entering the safe state under the premise of minimizing interference to the driver is called a fault protection mechanism. When the fault condition changes, the safety status can also be switched.

The basic fault protection mechanisms include the following types:

(1)The software detects the analog value including whether the voltage, speed, temperature, etc. exceed the set value [calibratable], the system enters the ASC active short circuit state or the three-phase open state, reports the fault information, stores the fault information, and freezes the relevant data frame.

(2)According to the current state of the IGBT (normal, upper bridge fault, lower bridge fault), the system enters the ASC upper bridge short circuit state or the ASC lower bridge short circuit state. The hardware detects whether the analog value exceeds the limit value or there is a hardware driver failure, and the system enters the ASC active short circuit state.

(3)According to the system status, the system enters the ASC active short circuit state or the three-phase open state, reports the fault information, stores the fault information, and freezes the relevant data frame. According to the current state of the IGBT (normal, upper bridge fault, lower bridge fault), the system enters the ASC upper bridge short circuit state or the ASC lower bridge short circuit state.

(4)Enter zero torque mode. Report fault information, store fault information, and freeze related data frames.

(5)Enter the limp-home mode and take derating measures. The amount and proportion of the specific derating are related to the physical quantity of the fault source, and the correlation can be calibrated. Report fault information, store fault information, and freeze related data frames.

(6)Enter the redundancy mode, do not report the fault, and store the fault information.

(7)When the fault condition disappears, clear the fault, according to the current speed, voltage and other analog signals, after a certain period of time (can be calibrated), the safety state of the active short circuit ASC can be switched to the safe state of the three-phase open circuit, and enter the low voltage power-on initial state mode.

5.6.3 Failure Recovery Mechanism

After the fault state is triggered and enters the safe state, the mechanism that causes the system to exit the fault state and has the ability to re-implement the original function according to the current actual running state is called a fault recovery mechanism.

The basic failure recovery mechanisms include the following types:

(1)Pull out the key and wait a few seconds, then re-execute KL15 to restart the low-voltage power to clear the fault.

(2)KL15 wakes up again with low voltage and clears the fault.

(3)When the fault condition is not met, the KL50 restarts the high voltage and clears the fault.

(4)When the fault condition is not met, the CAN communication clears the fault after issuing a specific command.

(5)When the fault condition is not met, after a period of time T [calibratable], or a certain counting condition [calibratable] is met, the fault is cleared.

(6)When the fault condition is not met, the fault is automatically cleared. Some derating faults or zero torque modes can be automatically recovered, but it is recommended that the design of the recovery threshold be considered hysteresis.

5.6.4 Example of electric drive system fault protection

The following is a protection strategy implementation case:

5.6.4.1 Torque feedback abnormality

Fault Description: When the actual torque and command torque deviation exceed a certain range, the fault count is performed. At the same time, the deviation is within the normal range, and the fault count value needs to be reduced. According to the fault count value reaching different thresholds for classification processing, the fault grading threshold can be calibrated. The cause of the torque abnormality may be that the initial rotational position is wrong, or the motor parameters are abnormal.

Troubleshooting strategy:

(1)The level 1 fault is derated, and the derating factor can be calibrated. If the count value is less than the fault threshold, the fault can be recovered. Cancel derating protection.

(2)The 3rd level fault is based on the current speed information to close the tube seal pulse or the active short circuit. When the speed is reduced to a certain speed, the active short circuit state is recommended to enter the initial state after the low voltage power is completed.

5.6.4.2 CAN communication failure

Fault description:

(1)Timeout monitoring. By monitoring the Livecounter count value of the same ID message for monitoring, when the discontinuous condition of the Livercounter occurs once, the fault count is recorded once, and when the fault count occurs for a certain number of times within a certain period of time, the communication failure fault is reported, otherwise clear 0 fault count value.

(2)The probe bus communication is invalid, and the information is sent back. The MCU reads back the transmitted information from the bus and compares it with the original information. The MCU sends a frame of special information frame to the vehicle controller. The vehicle controller replies this information after one cycle, and the MCU compares it after receiving it. If the information is inconsistent, the communication failure is reported.

(3)Used to detect frame loss, frame counter. When the MCU receives the vehicle message, the whole vehicle sends a message to the MCU, and counts the same frame ID. Each individual security-related frame contains a counter as part of the information. The counter value is incremented (flip) as each successive frame is generated. The MCU can then detect any frame loss or frame not being updated by verifying that the value of the counter has increased by one. If the frame is not updated, the frame loss fault is reported.

Fault protection strategy: After the communication fault is reported, the derating can be performed. This fault can set a certain torque recovery slope after the CAN communication monitoring is restored. However, it is recommended to cancel the recovery mechanism after the can fault occurs multiple times within a certain period of time.

5.6.4.3 Microcontroller failure (three examples, depending on the security mechanism of the chip itself)

Fault description:

(1)Clock frequency monitoring, MCU provides internal clock monitoring function, which can monitor the clock signal of each module of the chip. A 100MHz clock signal can be generated in the chip, working independently of the PLL system. The system uses this clock as a reference to generate a reference counter to verify the clocks of other modules. If the counter overflows, an error has occurred. It can be detected that the counter is either below the lower limit (the clock is too slow) or above the upper limit (the clock is too fast).

(2)Static random-access memory error detection error correction code, static random-access memory can perform error correction of 4 code spacing errors, correct single byte errors and detect double byte errors.

(3)Program memory error detection error correction code, in order to prevent data corruption, the data in the program memory contains error detection error correction code. Data can be corrected for two bits in the program memory and three-bit errors are detected.

(4)Fault protection strategy: According to the chip manual, the relevant security mechanism is related to the design of the hardware peripheral circuit.

5.6.4.4 High-voltage capacitor rapid discharge failure

Fault Description: When the active discharge time exceeds 3 seconds and the bus voltage does not decrease to the discharge request voltage, the discharge timeout is reported.

Fault protection strategy: Exit the discharge mode, or cut into other discharge modes, it is recommended to use one of the motor discharge and resistance discharge.

5.6.4.5 Controller DC side short circuit

Fault description: When a short circuit occurs on the DC side, a fault is reported.

Fault protection strategy: The controller generally reports Desat fault, the driver chip will turn off the IGBT. If it enters the three-phase short-circuit state, it needs to know which Desat fault is reported. When the speed is low, the pulse can be processed.

5.6.4.6 Controller AC side short circuit

Fault description: It is divided into phase-to-phase short circuit, short circuit to the housing, negative to the busbar positive or to the busbar. When the AC sensor detects overcurrent or other driver chip reports Desat fault.

Fault protection strategy: The overcurrent fault enters the processing strategy of closing the seal pulse or active short circuit according to the current speed information. When the speed decreases to a certain value, the active short circuit can exit and enter the closed state. Desat failed the same. In which the short circuit of the casing is generally detected, the sum of the three-phase currents is relatively unreasonable.

5.6.4.7 Self-test abnormality

Fault description: The MCU detects an abnormality.

Fault protection strategy: report self-test failure and prohibit pre-charge operation. The OEM will generally specify the requirements of self-test time.

In addition, according to the individual requirements of the OEM, the self-learning function will be added, so it is necessary to consider the self-learning time and the self-learning failure alarm.

5.6.4.8 Overvoltage (high pressure)

Fault Description: The bus detection voltage is higher than the overvoltage threshold.

Fault protection strategy:

(1)One-stage overvoltage: As the voltage increases, the motor response torque decreases linearly.

(2)Secondary overpressure: The motor response torque remains at zero.

(3)Three-stage overvoltage: three-phase short circuit. When the speed is reduced to a certain value, the active short circuit can exit and enter the closed state. Avoiding the vehicle's quiescent state is still in a three-phase short circuit, causing the IGBT to burn out.

5.6.4.9 Undervoltage (high pressure)

Fault Description: The bus detection voltage is lower than the overvoltage threshold.

Fault protection strategy:

(1)One-stage undervoltage: As the voltage decreases, the motor response torque decreases linearly.

(2)Secondary undervoltage: The motor response torque remains at zero.

5.6.4.10 Open/open circuit (high voltage)

Fault description: When an open/open circuit is detected, the fault is reported, and the AC side open circuit can detect the three-phase unbalance.

Fault protection strategy: According to the current speed information, enter the closed loop or active short circuit processing strategy. When the speed decreases to a certain value, the active short circuit can exit and enter the closed state.

5.6.4.11 Overcurrent (high voltage)

Fault Description: When an overcurrent is detected, a fault is reported.

Fault protection strategy: According to the current speed information, enter the closed loop or active short circuit processing strategy. When the speed decreases to a certain value, the active short circuit can exit and enter the closed state.

5.6.4.12 Drive motor over temperature protection

Fault description: The motor temperature detection is higher than the over-temperature threshold. It shall be noted here that in thermal safety, the rotor temperature of the motor needs necessary monitoring means.

Fault protection strategy:

(1)One-stage over-temperature: As the motor temperature rises, the motor response torque decreases linearly.

(2)Two-stage over-temperature: The motor response torque is zero.

(3)Three-stage over-temperature: According to the current speed information, enter the processing strategy of closing the tube seal pulse or active short circuit. When the speed is reduced to a certain value, the active short circuit can exit and enter the closed state.

5.6.4.13 Drive motor controller over temperature protection

Fault Description: The controller temperature detection is higher than the overtemperature threshold.

Fault protection strategy:

(1)One-stage over-temperature: As the motor controller temperature rises, the motor response torque decreases linearly.

(2)Two-stage over-temperature: The motor response torque is 0.

(3)Three-stage over-temperature: According to the current speed information, enter the processing strategy of closing the tube seal pulse or active short circuit. When the speed is reduced to a certain value, the active short circuit can exit and enter the closed state.

5.6.4.14 Drive motor controller low voltage undervoltage

Fault description: When the motor controller low voltage undervoltage is detected, the fault is reported.

Fault protection strategy: According to the current speed information, enter the closed loop or active short circuit processing strategy. When the speed decreases to a certain value, the active short circuit can exit and enter the closed state.

5.6.4.15 Rotational fault

Fault description:

(1)SIN/COS is out of range (magnitude overrun) (DOS);

(2)EX short circuit, open circuit, phase of EX and SIN/COS phase out of range (LOT);

(3)SIN/COS short circuit, open circuit (LOS);

(4)SIN/COS sinusity is not good (DOS);

(5)SIN/COS size wave (envelope amplitude changes periodically) (DOS).

Fault handling strategy: The fault count is performed. At the same time, the deviation is within the normal range, and the fault count value needs to be reduced. According to the fault count value reaching different thresholds for classification processing, the fault grading threshold can be calibrated.

(1)Level 1 fault is derated, and the derating factor can be calibrated. If the count value is less than the fault threshold, it indicates that the fault can be recovered, and the derating protection is cancelled.

(2)The 3rd level fault is based on the current speed information to close the tube seal pulse or the active short circuit. When the speed is reduced to a certain speed, the active short circuit shall exit the switch off state.

5.6.4.16 Location Information Detection Abnormal

Fault description: In the torque control process, whether it is based on the position information obtained by the external decoding chip or the position information obtained by the software decoding function of the MCU itself, it is recommended to perform the secondary verification with the estimated rotor position. Ensure the correctness of the rotor position information.

Fault handling strategy: When the rotor position deviation is detected to be large, according to the current speed selection strategy, it is necessary to switch the position sensorless control algorithm and reduce the torque output or enter the three-phase short circuit protection state.

5.6.4.17 Drive motor overspeed

Fault description: A fault is reported when it is detected that the motor speed exceeds the overspeed threshold.

Fault protection strategy:

(1)One-stage overspeed: As the motor speed increases, the motor response torque decreases linearly.

(2)Two-stage overspeed: The motor response torque is zero.

(3)Three-stage overspeed: three-phase short circuit When the speed is reduced to a certain speed, the active short circuit shall be exited into the closed state.

5.6.4.18 12V/24V power supply is lost or abnormal

Fault description:

(1)No power, glitch, shock, offset;

(2)Overpressure;

(3)Undervoltage.

Fault handling strategy: The chip detects that the power supply is abnormally cut into the standby 12V/24V power supply. If there is no backup power supply, consider delaying the power-off to perform the derating shutdown processing.

5.6.4.19 PWM output is abnormal

Fault description:

(1)normally open;

(2)lack of phase (no output);

(3)frequency drift;

(4)duty cycle drift;

(5)The rising and falling edge drifts.

Fault handling strategy: According to the current speed information, the switch-off pulse or active short-circuit processing is performed. When the speed is reduced to a certain speed, the active short-circuit shall exit the switch-off state.

5.6.4.20 Abnormal IGBT power output module

Fault description:

(1)Short circuit;

(2)Overvoltage (busbar voltage main contactor disconnected; integrated inductance is too large);

(3)Overcurrent (overload causes excessive flow);

(4)Open the road.

Fault handling strategy: According to the current speed information, the switch-off pulse or active short-circuit processing is performed. When the speed is reduced to a certain speed, the active short-circuit shall exit the switch-off state.

5.6.4.21 IGBT temperature is too high

Fault description: The IGBT uses the information such as controller loss to estimate the temperature of the junction. When a certain threshold is exceeded, the fault is processed.

Troubleshooting strategy:

(1)One-stage over-temperature: As the motor controller temperature rises, the motor response torque decreases linearly.

(2)Two-stage over-temperature: The motor response torque is zero.

(3)Three-stage over-temperature: According to the current speed information, enter the processing strategy of closing the tube seal pulse or active short circuit. When the speed is reduced to a certain value, the active short circuit can exit and enter the closed state.

5.7 Electric drive assembly function safety

The main function of functional safety: When the impact of the hazard occurs, let the electrical and electronic system enter a safe state and maintain a safe state. There are two aspects: system failure (such as: wrong system design) and random hardware failure (such as aging of electrical and electronic components). The goal is to minimize the harm that technology cannot avoid but that must be dealt with.

This guide is modified to comply with ISO 26262 and applies to all activities of safety-related systems consisting of electronic, electrical and software components on road vehicles throughout the safety lifecycle.

(1)Provide a vehicle safety lifecycle (management, development, production, operation, service, scrap) and support tailoring of necessary activities during these lifecycle phases;

(2)Provide a vehicle-specific risk-based analysis method to determine the Automotive Safety Integrity Level (ASIL);

(3)Application of Automotive Safety Integrity Level (ASIL) Definition - The requirements applicable to this guide to avoid unreasonable residual risks;

(4)Provide requirements for validation and accreditation measures to ensure an adequate and acceptable level of safety is achieved;

(5)Provides requirements related to the supplier.

Functional safety is influenced by the development process (e.g., requirements specification, design, implementation, integration, validation, approval, and configuration), production processes, service processes, and management processes. Security issues are interrelated with regular, function-oriented and quality-oriented development activities and work products. This guide covers safety-related development activities and work products.

This guide is intended for safety-related systems that contain one or more electrical and electronic systems installed on a production passenger car.

Functional safety is usually set by the OEM to provide safety objectives, and the electric drive assembly company designs and implements a functional safety program. Different OEMs and electric drive assembly companies have differences in functional safety requirements and implementation plans. The following description is only an illustrative example and does not need to be strictly followed.

5.7.1 Functional Safety Management

5.7.1.1 Definition of safety culture

Summary: The organization creates a safety culture that supports the implementation of functional safety. In this way, establish and maintain the organization's rules and management processes.

Claim:

(1)Cultivation of corporate culture that supports functional safety activities.

(2)Follow the principles of functional safety standards.

(3)Analysis, evaluation, and traceability of functional safety related issues.

(4)Perform functional safety related activities and document management regulations.

(5)Follow the guidelines for the establishment, implementation and maintenance of the process.

(6)Ensure that the functional security-related management personnel are given appropriate authority.

5.7.1.2 Talent management related to security activities

Summary: Ensuring the ability to implement security activities and supporting the allocation and development of talents for the project.

Requirements: Provisions for personnel skills and authority.

(1)Safety-related design and verification capabilities.

(2)The ability to review and evaluate.

(3)Knowledge of ISO 26262 and other safety standards.

(4)Internal regulations of the company.

(5)Domain knowledge.

(6)Management capabilities.

5.7.1.3 Quality Management in the Safety Lifecycle

Summary: Establish and manage ISO/TS 16949 and ISO 9001 quality management standards or equivalent quality management systems.

Requirements: Internal quality management regulations.

Clearly describe the association between quality management and functional safety.

5.7.1.4 Division of work and responsibility for functional safety management

Summary: Appoint a security manager with authority and responsibility.

5.7.1.5 Planning and adjustment of functional safety activities

Summary: Develop a safety plan, conduct approval and accreditation review, and maintain and manage it.

5.7.1.6 Process of functional safety life cycle

Reference: ISO 26262-1 Figure 1 - Overview of ISO 26262.

5.7.1.7 Management of security files

Develop an accreditation plan, implement independence according to independence and authority, and implement the independence required by the safety of the accreditation measures. The personnel who implement the accreditation measures can access the organization, necessary product project information and tools.

5.7.1.8 Functional safety management after mass production

Safety Integrity: Whether the safety function can work normally for 15 years, whether the system error can be detected in time (for example: before the hazard has an impact).

Integrity: Whether all aspects have been considered and all details have been collected and stored in an understandable manner.

Documentation: Whether all the details have been proven, even later (product life cycle 15 years).

5.7.1.9 Mass production management after SOP

The organization shall specify the responsibilities of the relevant personnel and provide a basis for maintaining the functional safety related laws of the project after the release of the project.

The specifications released after production shall ensure the safety of the project.

5.7.2 Functional Safety Concept Design Phase

5.7.2.1 Definition of related items

Purpose: The first objective is to define the dependencies and interactions of the relevant items, i.e. the motor control system, with its environment and other related items. The second objective is to provide support for the full understanding of the relevant item, the motor control system, in order to carry out the activities of the subsequent phases.

Requirements: Confirmation of functional requirements, non-functional requirements and environmental dependencies of related items.

Define the boundaries, interfaces, and interactions with other related items and features.

Definition of related items: function list, usage environment requirements, legal and regulatory requirements, known security requirements, functional block diagrams, and functional block diagram boundaries.

5.7.2.2 Structure

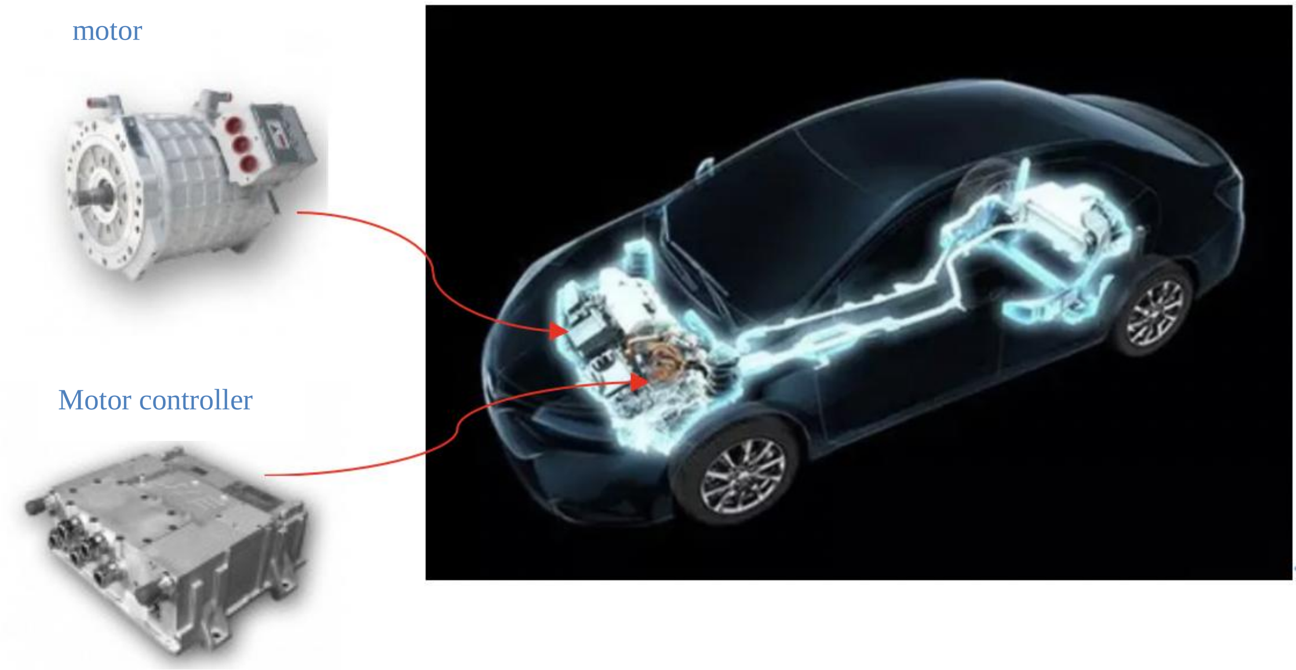


Figure5 Motor control system block diagram

The motor control system includes the following components:

Motor control unit;

Motor control actuator.

5.7.2.3 Features

The motor control system shall provide the following functions based on current vehicle status and road conditions:

(When the functional safety boundary is defined, the motor is not considered here)

Table 4, motor controller function

control unit	function
Motor Controller	Torque control Speed control Other controls (such as bus voltage control, shift control, etc.) Communication with the whole vehicle Other functions

Table 5, motor controller detailed function

Function description	subfunction
Basic function	Torque control
	Speed control
	Torque safety fault protection
	High voltage safety fault protection (active discharge / passive discharge / high voltage interlock, etc.)
	Current fault protection (overcurrent, hardware/software grading)

	Voltage-type fault protection (overvoltage/undervoltage/voltage unreasonable (divided into high voltage and low voltage and chip power, divided into electric and power generation), hardware, software grading)
	Speed type fault protection (overspeed)
	Temperature type fault protection (over temperature, hardware/software rating)
	Sensor-type fault protection (all sensor faults, including but not limited to short-circuit to power/short-circuit to ground/signal over-limit/unreasonable signal, etc.)
	Communication fault protection (CAN communication, SPI communication, LIN communication, etc.)
	Chip type fault protection (chip watchdog, clock, timing, memory, etc.)
	Motor body type fault protection (phase loss, turn-to-turn short circuit, etc.)
	Connection reliability type fault protection (three-phase connection, etc.)
	Other functional fault protection (self-learning function, anti-slope, active damping, etc.)
	Other fault protection
Other function	Software encryption
	OTA（*Over*－*the*－*Air* Technology）

5.7.2.4 Non-functional requirements

(1)DC bus voltage range;

(2)Working environment temperature range (℃);

(3)The pressure difference between the inlet and outlet;

(4)Cooling method;

(5)Cooling water inlet temperature;

(6)Water cooling flow;

(7)Auxiliary power or other means to ensure that the system is in a safe state;

(8)Effective waterproof and dustproof measures are required;

(9)The insulation resistance of the motor controller shall meet the safety standards;

(10)The MCU shall meet the protection requirements of IP67 or higher;

(11)The electromagnetic radiation interference generated by the drive motor system during operation shall comply with the relevant national standards and product technical documents;

(12)The electromagnetic radiation immunity of the drive motor system shall comply with the relevant national standards and product technical documents.

5.7.2.5 Start of the security life cycle

After the definition of the relevant items, it is necessary to determine the safety life cycle of the project and initialize the safety life cycle of the project, that is, to begin to refine the safety life cycle of the project. To refine, it is necessary to distinguish whether the project is a new product development or an existing product transformation. If it is a new device development, the related work must start from the beginning of the safety life cycle. If it is a retrofit of an existing product, then the processes starting with the project definition can be customized with the existing files using some existing files. To upgrade existing products, we must pay attention to the following issues:

(1)Analyze the product and usage environment to make the expected changes and evaluate the impact of those changes.

a)Changes to the project include design changes and implementation changes. Design changes shall be caused by an increase in requirements specifications, functionality and performance, or cost optimization. Execution changes cannot affect the specification and performance of the project but can affect execution characteristics. Execution changes can be caused by soft failure changes, using new developments or production tools.

b)If changes to the configuration data and calibration data affect the behavior of the product, the changes must take into account these data.

c)Changes to the product environment shall be triggered by new target environments to be used by the product or due to upgrades of other related products or elements.

(2)To express the difference between the conditions before and after the use of the product, including:

a)operating conditions and operating modes;

b)environmental interface;

c)installation features such as: location within the vehicle, configuration and changes of the vehicle, etc.;

d)The range of environmental conditions, such as temperature, altitude, humidity, vibration, EMC and gasoline marking.

(3)Be clear about the description of the product change and the scope of the impact. If it is not clear what changes to the product and changes in the impact on the environmental data, the analytical data on the impact will be recorded.

(4)The affected service products that need to be upgraded shall be listed one by one.

(5)Customized related safety activities shall meet the requirements of each application life cycle stage, including:

a)Customization shall be based on the results of the impact analysis.

b)Customized results shall be included in the safety plan in accordance with ISO26262-2.

c)The affected products must be reworked, including confirmation plans and verification plans.

(6)After determining the above basic information, there is a clear and clear definition of the product development or equipment change work to be carried out, and a clear definition of the intended use function, environment, and interface with related equipment. Risk analysis and risk assessment can be carried out.

5.7.2.6 Hazard Analysis and Risk Assessment

The purpose of hazard analysis and risk assessment is the same as the previous ISO13849, IEC62061, etc., in order to identify the hazards of the equipment and classify them according to the degree of danger according to the degree of danger, so as to set different risks. Specific safety objectives, and ultimately reduce or eliminate risks, to avoid the occurrence of unknown risks.

Condition Analysis: The fault behavior describes the operating conditions and operating modes of the hazard event.

Hazard identification: The hazard is defined by the state or behavior that can be observed at the vehicle level.

The purpose of hazard analysis and risk assessment by HTA (Fault Tree Analysis) is to identify the hazards caused by the faults in the relevant items and classify the hazards, and to set corresponding safety objectives to avoid unreasonable risks. Among them, the potential hazard events shall be analyzed based on the functional behavior of related items. Then systematically evaluate the relevant items from the three aspects of the severity of the hazard, the probability of exposure and the controllability, so as to determine the safety target and the corresponding ASIL level. Summary: At the vehicle level, a combination of operational scenarios and operational modes is used to describe hazard events, and event outcomes are identified by combining hazard events.

5.7.2.7 ASIL level definition

Summary: For each hazard event, the ASIL rating is defined by an assessment matrix of severity/exposure probability/controllability

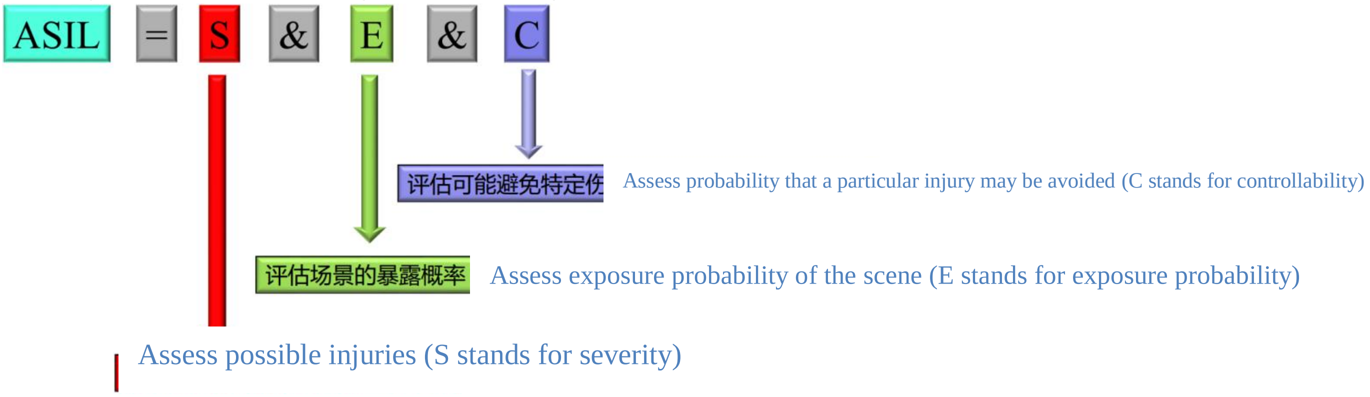


Figure6 ASIL level definition

Table 6 Evaluation matrix for severity/exposure probability/controllability

		C1	C2	C3
S1	E1	QM	QM	QM
	E2	QM	QM	QM
	E3	QM	QM	A
	E4	QM	A	B
S2	E1	QM	QM	QM
	E2	QM	QM	A
	E3	QM	A	B
	E4	A	B	C
S3	E1	QM	QM	A
	E2	QM	A	B
	E3	A	B	C
	E4	B	C	D

5.7.2.8 Security objectives

Summary: For a hazardous event with an ASIL rating, define its corresponding safety objectives.

Requirements: Implement a hazard analysis and risk assessment for each hazard, define its ASIL level, and establish a safety goal.

Functional safety objectives can also include high-voltage shocks and battery fires, depending on the requirements of the OEM, but not here.

Table 7 Function security objectives

Number	ID	Security objectives	FTTI	ASIL	Security status
1	SG-01	Avoid unexpected torque increases	-ms (The setting of FTTI fault tolerance interval shall take into account the specific conditions of the system and software)	C (score based on specific analysis)	Alarm prompt, and turn off the PWM or enter the three-phase short-circuit state by the state machine for logical judgment
2	SG-02	Avoid unexpected torque reversal	-ms		Alarm prompt, and turn off the PWM or enter the three-phase short-circuit state by the state machine for logical judgment
3	SG-03	Avoid unexpected shocks and rapid shocks	-ms		Alarm prompt, and turn off the PWM or enter the three-phase short-circuit state by the state machine for logical judgment
4	SG-04	Avoid unexpected torque loss	-ms		Alarm prompt, and turn off the PWM or enter the three-phase short-circuit state. The state machine makes a logic judgment alarm prompt, and turns off the PWM.

5.7.2.9 Functional safety concept

The main purpose of the functional safety concept phase is to identify specific functional safety requirements through the safety objectives derived from the previous hazard analysis and risk assessment and assign them to the preliminary design architecture or external risk reduction measures to Ensure that relevant functional safety requirements are met.

The security concept is primarily intended to derive functional safety requirements from safety objectives and assign them to the architectural elements or external measures of the relevant items. When formulating functional safety requirements, consideration shall be given to the operational modes of the relevant items, fault tolerance time intervals, safety status, emergency operation time intervals, and functional redundancy. At the same time, safety analysis (e.g. FMEA, FTA, HAZOP) methods can be used. Make the developed functional safety requirements mor[illegible]afety concept shall also be verified in accordance with the requirements of GB/T34590.9, indicating consistency and compliance with safety objectives, i.e. the ability to mitigate or avoid hazard events.

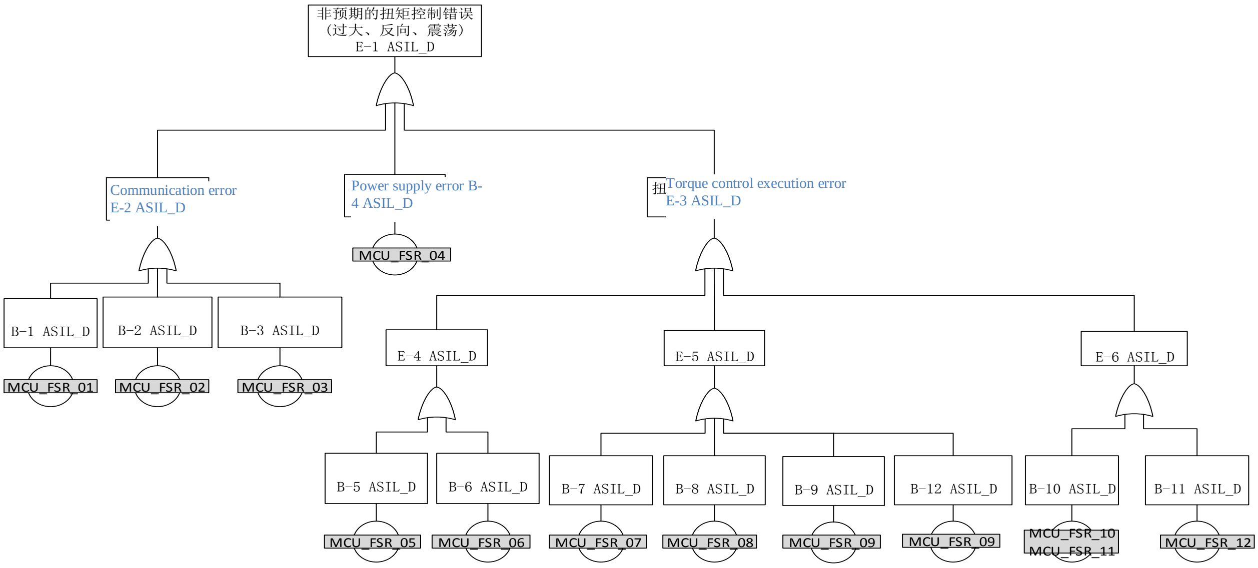


Figure 7. FTA analysis corresponding to FSR

5.7.2.10 Functional safety requirements allocation

The functional safety requirements assigned to the elements need to consider the following:

(1)Elements based on the initial structure of the relevant item

(2)Inheritance: ASIL and functional safety requirements information

The highest ASIL rating is accepted in the following cases

If the next functional security requirement is assigned to the same architectural element.

Export functional security requirements for standalone systems and their interfaces if the correlation contains multiple systems

If independent redundancy: ASIL allocation is possible

In addition, if the ASIL rating needs to be dismantled, it must comply with the requirements of Section 5 of ISO 26262-9.

5.7.3 Functional safety system phase

5.7.3.1 Start system level product development

Before the formal system development, the safety activity plan for product development at the system level shall be specified based on the relevant provisions of GB/T34590.4, including the determination of appropriate methods and measures, test and verification plans, and functional safety assessment plans in the design and integration process.

The goal of system-level product development startup is to identify and plan functional safety activities at various sub-phases of system development. This part is also described in ISO26262-8. System level security activities are included in the security plan.

5.7.3.2 Technical security requirements design

Technical security requirements are necessary technical requirements for implementing the functional safety concept. The purpose is to refine the functional safety requirements at the relevant level to the technical security requirements at the system level. Based on the relevant provisions of GB/T34590.4, technical safety requirements shall be formulated based on functional safety concepts, preliminary architectural assumptions of related items, external interfaces, and constraints. Technical safety requirements shall be defined in terms of fault detection/indication/control measures, safety status, fault tolerance time interval, etc., and define the necessary safety mechanisms.

The input, processing, and output TSR are determined based on the Input-Process Processing-Output (I-P-O) model used to develop the FSR and the initial architecture.

Here are a few examples to illustrate:

Table 8 technical security requirements in the input

Req.ID	TSR	ASIL	Export source	Corresponding security mechanism	FTTI
	The MCU detects the 12V input voltage through AD. Whether it is within a reasonable range, if it is out of range, it will not respond to the open pipe command.	C	Corresponding FSR functional security requirements	Corresponding hardware and software decompose	1ms

Table 9. Technical security requirements for the process

Req.ID	TSR	ASIL	Export source	Corresponding security mechanism	FTTI
	The MCU monitors the actual three-phase current value of the motor: When the sum of the three-phase currents is greater than 20A (tbd), it is considered that there is a problem with the current sensor sampling and enters the fault state; when the three-phase current is at 0~20A, it is considered normal. Sampling error, no processing.	C	Corresponding FSR functional security requirements	Corresponding hardware and software decompose	20ms

Table 10, technical security requirements for output

Req.ID	TSR	ASIL	Export source	Corresponding security mechanism	FTTI
	PWM output module circuit hardware redundancy (such as dual-core lock step, asymmetric redundancy, encoding processing), using the chip's dual-core lock-step mechanism to ensure PWM output. The processing unit runs twice in lockstep (or with a fixed delay) and compares the results. Any mismatch can result in an error condition and usually results in a reset. This is just an example of not limiting any chip type.	C	Corresponding FSR functional security requirements	Corresponding hardware and software decompose	20ms

5.7.3.3 Develop security mechanisms

Develop a security mechanism based on technical security requirements: propose technical security requirements that need to be developed. Example: Further develop technical security requirements and assign fault tolerance interval requirements.

Discussion of security mechanisms: Based on technical security requirements and system design architecture, discuss the mechanisms for achieving their functional operation. Example: Angle detection function, based on factors and limit values, where to test.

The safety mechanism for the project to achieve or maintain a safe state shall specify:

(1)Switching of the security status;

(2)The time interval of fault tolerance;

(3)If the safety status cannot be reached immediately, the time interval for emergency operations shall be determined;

(4)Measures to maintain a safe state.

ASIL is broken down according to ISO 26262-9:2011, clause 5.

5.7.3.4 System Design

System design shall be based on functional concepts, preliminary architectural assumptions for related items, and technical safety requirements. When implementing the content related to technical security requirements, the system design shall be considered in terms of the ability to verify system design, the technical capabilities of hardware and software design, and the ability to perform system testing. To avoid systemic failures, a safety analysis of the system design shall be performed to identify the causes of systemic failures and the effects of systemic failures. To reduce the impact of random hardware failures during system operation, measures to detect, control, or mitigate random hardware failures shall be defined in the system design. Software and hardware interface specifications are defined in the system design and refined in subsequent hardware development and software development processes.

Reference: ISO 26262-4 table2 properties of modular system design

In order to avoid the high complexity caused by failure, the architecture design needs to be carried out through the following principles:

(1)Modularity;

(2)An appropriate level of granularity;

(3)Simplicity.

5.7.3.5 Exporting technical security concepts

Purpose: Based on the results of system design, assign hardware and software to technical security requirements.

Summary: The technical security requirements are derived from functional security requirements, system design is carried out, and the technical security concept is derived.

(1)Verifiability of the system design;

(2)Technical implementation of software hardware;

(3)Execution test capability in system integration.

5.7.3.6 Implement security analysis

Based on the results of the system design architecture and technical safety concept, the FTA and FMEA methods are used for safety analysis.

5.7.3.7 System Design Verification

Reference: ISO 26262-4 Table 3 — System design verification.

5.7.3.8 System Integration and Testing

Based on the relevant provisions of GB/T 34590.4, the integration of software and hardware, system and vehicle level are tested to verify whether each functional and technical safety requirement meets the specifications, and whether the system design is correctly implemented in the entire relevant item.

The integration and testing phase consist of three phases and two main objectives as follows: The first phase is the integration of the hardware and software of the components contained in each project. The second phase is the integration of components of a project to form a complete system. The third stage is the integration of the project with the surrounding system of the vehicle.

The first goal of the integration process is to meet the various safety requirements in accordance with ASIL ratings and safety requirements specifications. The second objective is to verify that the security requirements covered by the "system design" are correctly implemented by the entire project. The integration of project components is from software and hardware integration, system integration to vehicle integration systems. Integration testing will demonstrate the correct interaction of system components at each stage of execution. Complete hardware and software development in accordance with ISO26262-5 and ISO26262-6, then begin system integration in accordance with Section 8 (Project Integration and Testing).

5.7.3.9 Planning and definition of integration and testing

Test method export method

Reference: ISO 26262-4 Table 4 — Methods for deriving test cases for integration testing

5.7.4 Functional Safety Hardware Design Phase

Based on the relevant provisions of GB/T 34590-5, the technical safety concept, technical safety requirements and system design specifications are implemented to the hardware level, and complete and detailed hardware safety requirements are designed.

In order to ensure the integrity of the hardware security requirements, the following shall be considered in the design:

(1)Security mechanisms and their attributes;

(2)the standard of verification;

(3)the target value of the hardware metric;

(4)FTTI;

(5)Other safety related requirements.

In order to ensure the quality of hardware security requirements, the design, verification and management of hardware security requirements shall be carried out in accordance with the requirements of Chapter 6 of GB/T34590-8.

In order for the hardware to be properly controlled and used by the software, the hardware and software interface (HSI) shall be fully refined and each security-related association between hardware and software shall be described.

5.7.4.1 Start hardware level product development

Summary: Define and update system-level security activity plans based on security plans and project plans.

Plan activities for hardware components in product development (including support processes).

Appropriate methods and measures shall be used during the design process.

The hardware and software life cycle shall be considered in the hardware development process.

5.7.4.2 Hardware Security Requirements Specification

Hardware Security Requirements Specification: Hardware security requirements shall be derived from technical security concepts and system design specifications:

(1)Detailed hardware-software interface (HSI) requirements.

(2)All safety-related hardware requirements must be in the form of hardware security requirements.

(3)Fault tolerance to external interference (e.g. open input).

(4)The safety mechanism is used to detect and repair internal (e.g. component failure) and external (control failure) failures.

(5)Security mechanisms are used to repair temporary and permanent failures.

(6)The target value of the hardware indicator.

5.7.4.3 Hardware Architecture Design

Design Principles:

(1)Layered design

(2)Avoid unnecessary interface complications

(3)Avoid unnecessary hardware component complications (simple design)

(4)Maintainability

(5)Testability

Based on the relevant provisions of GB/T 34590-5, the hardware architecture design and hardware detailed design, and hardware security analysis to meet the system design specifications and hardware security requirements.

In order to avoid the systemic risk of hardware, the hardware architecture design shall be carried out, and then the hardware detailed design. When designing the hardware architecture, ensure that each hardware component inherits the correct ASIL rating and can be traced back to the hardware security requirements associated with it.

5.7.4.4 Detailed hardware design

In the hardware design, the relevant experience shall be summed up, and the non-functional reasons for the failure of safety-related hardware components shall be considered. If applicable, the following factors can be included: temperature, vibration, water, dust, EMI, other components from the hardware architecture or Crosstalk in its environment.

In order to improve the reliability of the design, the “modular hardware design principles” and “robust design principles” in GB/T 34590-5, such as derating design and worst-case analysis, shall be followed.

In order to identify the cause of hardware failure and the impact of the failure, according to the requirements of GB/T 34590-5, according to different ASIL levels, use "deductive analysis" (such as FTA) or "inductive analysis" (such as FMEA) Safety analysis.

If safety analysis indicates that production, operations, service, and scrap are safety-related, define their safety-specific characteristics and output explanatory documents. To verify the consistency and integrity of the hardware design and hardware security requirements, the hardware design shall be verified as specified in GB/T 34590-5.

5.7.4.5 Hardware Design - Security Analysis

Identify the cause of the failure and the impact of the failure;

Perform safety analysis and identification for the safety objectives considered;

Evidence to avoid the effectiveness of a single point of failure;

Evidence to avoid the effectiveness of latent faults;

Determine the independence of the hardware design;

If a new hazard is introduced, the hazard analysis and risk assessment are repeated.

5.7.4.6 Hardware Design - Identification of Components

Based on the relevant provisions of GB/T 34590-8, hardware components shall be identified for complex hardware components and components, ensuring the compliance of hardware components and providing basic data for FMEDA analysis.

5.7.4.7 Evaluation of hardware architecture metrics

Based on the relevant provisions of GB/T 34590-5, the hardware architecture measurement is evaluated, and the evaluation results and optimization suggestions are fed back to the system design, hardware design, and software design to optimize the product design and make the final “single point failure measurement”. And the "latent fault metric" meets the requirements of the corresponding ASIL.

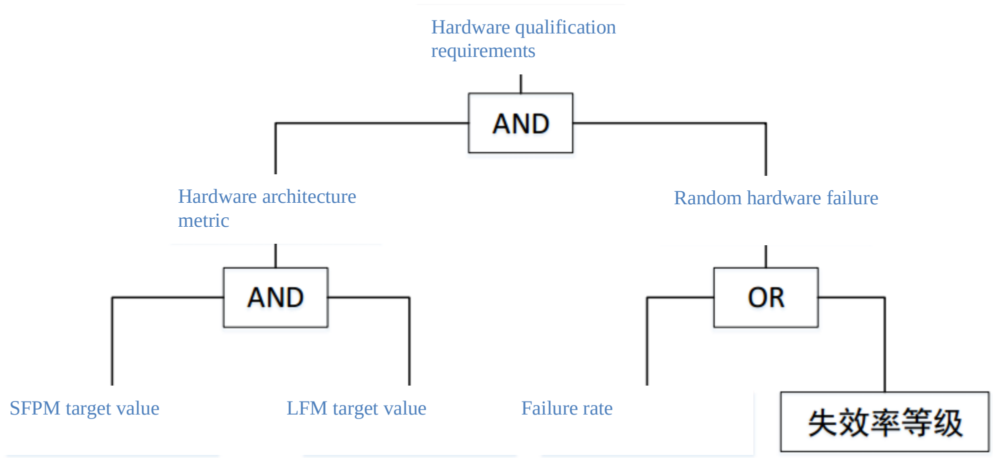


Figure 8, hardware quantification requirements

Table 11, evaluation of fault indicators

	ASIL B	ASIL C	ASIL D
Single point failure indicator	≥90%	≥97%	≥99%
Potential failure indicator	≥60%	≥80%	≥90%

5.7.4.7.1 Hardware Diagnostic Coverage

Refer to ISO26262-5.

5.7.4.7.2 Failure mode classification

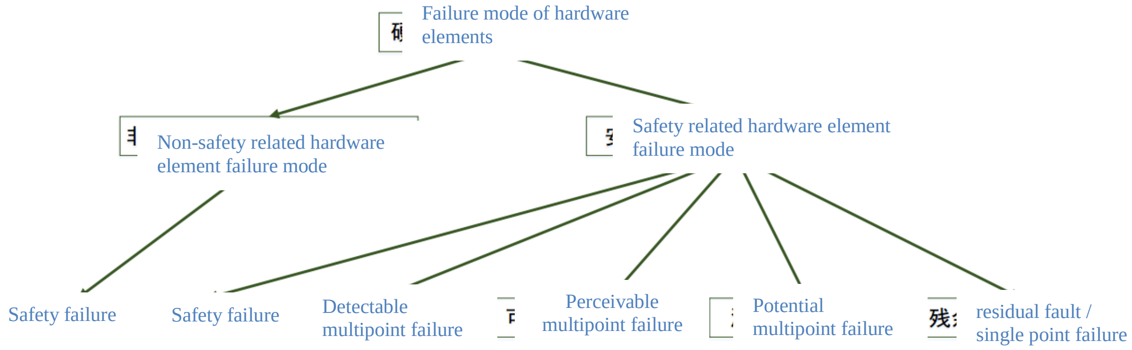


Figure 9 Hardware failure mode analysis

5.7.4.7.3 Random Hardware Failure Leads to Evaluation Against Security Objectives

The target value of the safety target due to random hardware failure is based on the relevant provisions of GB/T 34590-5, and the PMHF evaluation or the cut analysis is performed. The optimization makes the relevant safety target have no unacceptable risk due to random hardware failure.

5.7.4.8 Hardware Integration and Testing

Based on the relevant provisions of GB/T 34590-5, hardware integration and testing are carried out to ensure that the developed hardware meets the hardware security requirements. Hardware integration test cases shall be generated taking into account the methods listed in Table 10 of GB/T 34590-5.

To verify the integrity and correctness of the security mechanism, hardware integration testing shall consider the following methods: functional testing, fault injection testing, and electrical testing. In order to verify the robustness of the hardware under external stress, the hardware integration test shall consider the methods listed in Table 12 of GB/T 34590-.

5.7.5 Functional Safety Software Design Phase

5.7.5.1 Start product development at the software level

Write startup plan content

(1)appropriate methods for initiating software development activities;

(2)tailoring of software development;

(3)Configuration software development;

(4)Consistency of the software life cycle;

(5)the choice of methods and corresponding tools;

(6)Choose the appropriate modeling and programming language;

(7)Design and coding guidelines.

5.7.5.2 Software Security Requirements Specification

The purpose of software security requirements analysis is to develop software security requirements based on security technical specifications and system design specifications, and to verify that software security requirements are consistent with security technical specifications and system design specifications.

The software security requirements analysis phase needs to meet the requirements of integrity, testability, and traceability.

Software security requirements analysis shall be considered from the following aspects: adequately identify software functions that fail to violate security technical requirements; need to be derived from security technical requirements and system design; identify all security-related attributes between software and hardware; Hardware operation resources, effective security related information, etc.; software and hardware interface specifications shall be validated; test verification methods shall be safe and effective.

5.7.5.3 Software Architecture Design

The software security monitoring architecture is designed to develop a software architecture that meets and implements software security requirements. The software security monitoring architecture design needs to combine functional security related software requirements and non-functional security related software requirements and consider the software architecture design and software security analysis.

The software security monitoring architecture shall be designed from the following aspects: it shall be configurable, implementable, easy to test and maintainable; it must follow the requirements of modularity, high aggregation, low coupling, and low complexity; it shall be refined enough Support detailed design; shall have static and dynamic characteristics; shall meet the requirements of independence; shall cover software security requirements.

5.7.5.3.1 Software Architecture Design Principles

Reference ISO26262 Table 3 — Principles for software architectural design

(1)Software architecture design shall be developed to the software unit level, that is, no further level.

(2)The software architecture shall describe the static design of the software unit.

(3)Static design:

a)the software structure contains its level;

b)the logical sequence of data processing;

c)data types and their characteristics;

d)an interface between software components;

e)the interface between the external and the software;

f)Constraints on the architecture and external parts.

(4)If based on model development, the model structure is inherent.

(5)Dynamic design of software components:

a)function and behavior;

b)the flow of data between software components;

c)the data flow of the external interface;

d)time constraints;

e)Control the concurrency of flows and processes.

5.7.5.3.2 Software Architecture Design Security Analysis

purpose:

(1)Clear order and fault response

(2)Recommended test cases

(3)Identify software failure avoidance strategies

(4)The effect of the security mechanism. For example: diagnosis, control of hardware failure recovery, in order to solve the system failure mechanism.

(5)Assess resource use and distribution

Authentication method:

Reference ISO26262-5 Table 6 — Methods for the verification of the software architectural design

5.7.5.4 Software unit design and implementation

When designing the software in detail, it shall be considered from the following aspects: it shall contain enough necessary information to facilitate the follow-up activities; its functional characteristics shall be described in detail; it shall meet the requirements of testability, maintainability, low complexity, readability and robustness. The detailed design shall meet the requirements for consistency with software security requirements, software architecture, coding guidelines, and detailed design specifications.

Software unit design principles reference ISO26262-Table 8 — Design principles for software unit design and implementation

5.7.5.5 Software Security Algorithm Testing

The software algorithm test is used to prove that the software unit module meets the requirements of the software detailed design specification. The requirements include compliance of software function requirements, consistency of interface requirements, robustness and efficiency of the algorithm, and the like. Software algorithm test case design, in accordance with the software detailed design specification, software failure analysis report requirements, using requirements analysis, equivalence class division, boundary value analysis, error guessing, fault injection and other methods.

Software algorithm testing activities, detailed design, failure analysis reports, test cases, test data, two-way traceability of test defects and process integrity. Software algorithm testing also needs to measure the quality of the verification software algorithm, including unit coverage (such as: statement coverage, branch coverage, modified decision condition coverage, etc.), code encoding rules, and other static metrics (such as: circle complexity) Etc.), please refer to GB/T34590-6 for specific requirements.

5.7.5.6 Software Integration and Architecture Compliance Testing

Software integration and architecture compliance testing is primarily used to verify that software component integration capabilities and interfaces between software components conform to software architecture design documentation requirements.

Software integration can often be divided into proliferating integration and one-time integration. Different integration methods, the corresponding integration test strategy is also different. Commonly used test methods include requirements-based testing, interface testing, fault injection testing, resource occupancy testing, and back-to-back testing of models and code.

Software integration testing also includes a quality measurement process, with key metrics including functional coverage and function call coverage.

Refer to ISO26262-5Table 10 — Methods for software unit testing

5.7.5.7 Software Security Requirements Verification

The purpose of software security requirements verification is to ensure that software can properly implement software security requirements in the target hardware environment. Verification methods, including hardware-in-the-loop testing, electrical and electronic test bench testing, and real-world testing, are often required. Software security requirements verification not only verifies the compliance of software security requirements from a functional perspective, but also verifies whether performance requirements are met from a performance perspective (e.g., program installation testing, load testing, software security requirements coverage, etc.).

5.8 After-sales maintenance and safety

Electric drive system maintenance personnel requirements:

Before the maintenance of the electric drive system, the maintenance personnel shall be professionally trained, and the personnel who need to obtain the electrician's employment certificate and the maintenance electrician qualification certificate shall perform maintenance work. The high-voltage power supply of the motor controller must be disconnected during operation to ensure safety and safety, to ensure that maintenance personnel are aware of safety precautions, to be familiar with the measuring equipment and tools used, and to be familiar with operational requirements.

5.8.1 Motor Controller Maintenance Requirements

5.8.1.1 Maintenance site and environmental requirements

When maintenance of the motor controller, avoid open-air operation under meteorological conditions such as dust, rain and snow. If conditions have to be maintained under the above meteorological conditions, proper protection shall be taken to avoid dust, water or other impurities. Enter the interior of the motor controller system. Disassembly and maintenance are not allowed when the environment does not meet the requirements.

5.8.1.2 Tool Requirements

Use professional inspection and maintenance equipment and insulation tools. For example; insulation tools, insulation hooks, insulation meters, insulated gloves, goggles, anti-static clothing, etc.

5.8.1.3 Security requirements

Due to the danger of high-voltage electric shock (different models, different voltage values), it is necessary to wear insulated gloves and insulated shoes as required during operation. All operations require power-off, discharge, and high-voltage DC+, DC-ground voltage checks to ensure no live operation.

5.8.1.4 Motor Controller Maintenance Requirements

Before the overhaul, the motor controller is powered off, discharged, and checked for safety:

(1)Before overhaul, unplug the high-voltage repair switch, turn off the low-voltage power supply main switch, and discharge the DC+ and DC- terminals with the discharge lead clamp.

(2)Use the multimeter DC voltage file to measure the high voltage DC+, DC-ground voltage ≤36V, and then carry out maintenance operations.

5.8.1.5 Environmental Safety Management Requirements

(1)Hazard source description: High voltage electric shock.

(2)Personal labor protection products: Wear overalls, insulated smash-proof shoes, and insulated gloves. Before use, the insulation gloves must be inspected for damage, holes, cracks, etc., and shall be intact. Do not carry water to ensure that the inner and outer surfaces are clean and dry to ensure safety. When working in a humid environment, blow the insulated gloves with a hair dryer for 5 minutes.

(3)Safety operation requirements: Before the maintenance, the high-voltage maintenance switch shall be unplugged to perform power-off, discharge and high-voltage DC+, DC-ground voltage inspection; all operations must not be carried out, and the vehicle must not be tested. An eye-catching maintenance warning sign shall be set during maintenance to prevent other personnel from mishandling (such as starting the vehicle, powering on, etc.) causing personal injury.

(4)Environmental protection requirements: Wastes generated during the operation are collected and sorted according to customer requirements and placed in designated locations. Be very careful when overhauling the water-driven motor drive assembly! For the electric drive assembly suspected of entering the water, the insulation resistance test must be performed before the maintenance and the vehicle is strictly powered off.

5.8.2 Drive motor maintenance requirements

5.8.2.1 Maintenance site and environmental requirements

When the motor is being maintained, it shall be avoided in the open-air operation under the meteorological conditions with dust, rain and snow. If the condition has to be maintained under the above meteorological conditions, it shall be properly protected to prevent dust, water or other impurities from entering the motor. internal. Disassembly and maintenance are not allowed when the environment does not meet the requirements.

5.8.2.2 Tool requirements

Use professional testing equipment and insulation tools.

5.8.2.3 Security requirements

Due to the danger of high-voltage electric shock (different models, different voltage values), it is necessary to wear insulated gloves and insulated shoes as required during operation. All the following operations shall ensure that power-off, discharge and high-voltage DC+, DC-ground voltage check are performed according to the operation requirements to ensure no live operation.

5.8.2.4 Pre-inspection safety inspection

(1)Unplug the high-voltage service switch, turn off the low-voltage power supply main switch of the controller, and discharge the three-phase line (U, V, W) with the discharge wire clamp.

(2)Use a multimeter to check that the three-phase line-to-ground voltage shall be ≤36V for maintenance operation.

(3)Check the appearance of the motor without damage.

(4)Rotate the motor output shaft to check if it can rotate normally without abnormal noise.

(5)Check if the motor water cooling system cycle is normal and there is no leakage.

5.8.2.5 Detection of resolver coil and temperature sensor (for permanent magnet synchronous motor, position sensor is rotary transformer as an example)

Use the multimeter ohm file to check the resistance of the motor's resolver coil and the resistance of the temperature sensor:

(1)Cosine coil resistance;

(2)sinusoidal resistance;

(3)the resistance of the excitation coil;

(4)Temperature sensor resistance value.

It shall be noted that the above resistance value will be affected by factors such as changes in ambient temperature, measuring tools, and testing personnel.

5.8.2.6 Three-phase winding detection

(1)Open the motor junction box, remove the three-phase line, and test the phase-to-phase resistance between the three-phase lines (U, V, W) of the motor with a multimeter ohmmeter (shall be balanced and equal).

(2)Measure the insulation resistance value of the three-phase line (U, V, W) on the outer casing with the 500V voltage test of the insulation tester, which shall meet the technical requirements of each product (the insulation resistance of different products is quite different, and the measured data is qualified according to the corresponding Technical requirements of the product).

5.8.2.7 Environmental Safety Management Requirements

(1)Hazard source description: High voltage electric shock.

(2)Personal labor protection products: Wear overalls, insulated smash-proof shoes, and insulated gloves. Before use, the insulation gloves must be inspected for damage, holes, cracks, etc., and shall be intact. Do not carry water to ensure that the inner and outer surfaces are clean and dry to ensure safety. When working in a humid environment, blow the insulated gloves with a hair dryer for 5 minutes.

(3)Safety operation requirements: Before the maintenance, the high-voltage maintenance switch shall be unplugged to perform power-off, discharge and high-voltage DC+, DC-ground voltage inspection; all operations must not be carried out, and the vehicle must not be tested. An eye-catching maintenance warning sign shall be set during maintenance to prevent other personnel from mishandling (such as starting the vehicle, powering on, etc.) causing personal injury. Precautions when loading the trailer: The overall trailer or motor linkage wheel is lifted.

(4)Environmental protection requirements: Wastes generated during the operation are collected and sorted according to customer requirements and placed in designated locations. Be very careful when repairing the motor drive assembly of the water inlet! For the electric drive assembly suspected of entering the water, the insulation resistance test must be performed before the maintenance and the vehicle is strictly powered off.

5.8.3 Variable/reducer maintenance requirements

(1)Unplug the high-voltage service switch, turn off the low-voltage power supply main switch of the controller, and discharge the three-phase line (U, V, W) with the discharge wire clamp.

(2)Use a multimeter to check that the three-phase line-to-ground voltage shall be ≤36V for maintenance operation.

(3)Check the appearance of the transformer/reducer without damage.

(4)Rotate the output shaft of the variable/decelerator to check if it can rotate normally without abnormal noise.

(5)Check the variable speed reducer for oil leakage.

5.8.4 Emergency treatment after the occurrence of danger

5.8.4.1 Electric shock rescue method

In the process of disassembly and assembly of the electric drive assembly, if the operator accidentally has an electric shock accident, the following methods shall be followed instantly for help.

(1)In the process of rescue, first ensure that the rescuer is safe.

(2)Do not touch electric shock directly.

(3)Use non-conductive tools (insulation hooks, dry wood sticks, brooms, etc.) to quickly remove the electric shock from the power source.

(4)Call 120 emergency number immediately.

(5)Check the life function of the electric shocker. If there is no breathing or pulse, perform artificial respiration and cardiopulmonary compression before the doctor arrives.

5.8.4.2 Electrical fire rescue

(1)Self-protection! Do not breathe fumes.

(2)Call the fire department.

(3)When the firefighters arrive, they must inform the fire that the new energy electric drive assembly is involved.

(4)If necessary, extinguish the nearby fire source or use the cover method to ensure safety.

People shall be quickly evacuated and kept away from faulty parts to ensure personal safety.

6. Charging safety

The electric vehicle charging infrastructure consists of power supply system, charging equipment, monitoring system, and metering system. The power supply system consists of power equipment and distribution lines; The charging facility consists of charging equipment (including conductive AC/DC charging equipment and wireless charging equipment), charging cable and correlative devices; The monitoring system consists of computer equipment and information network equipment, monitoring and managing the charging equipment, power supply equipment, facility operating status, environment, safety status and data resources. Charging facility is an indispensable power supply facility of electric vehicles. It shall pay attention to the charging safety of the charging facility throughout its life cycle, including design, manufacturing, construction, information transmission and data storage, and operation service guarantee, and establishing a good and reliable charging safety mechanism to resist safety risks and accidents.

6.1 Charging safety mechanism

6.1.1 Safety protection target

For component entities, software, design, construction, operation and maintenance of the charging application system, the safety objectives setting shall focus on prevention, ensure personnel safety, realize the safety of electric vehicle charging application, and:

(1)Personnel safety: Under various environmental conditions, charging equipment, electric vehicles and auxiliary facilities shall ensure the personnel safety;

(2)Charging equipment and system: The charging equipment shall adopt the design with electrical safety protection capacity as stipulated by the corresponding standards. Meanwhile, it shall ensure that the appropriate protective measures are available in various failure modes in the charging process of electric vehicles;

(3)Power supply safety: The load constraint, overload protection, harmonic parameters and short circuit protection of the charging pile shall not affect the normal running of the power supply;

(4)Control & protection: In the charging process of electric vehicles, it shall monitor the fault risk and take corresponding protection and control measures for the vehicle. In the fault mode, it shall have the ability to control the diffusion of safety accidents.

(5)Operation safety: Charging environment, station operation, and operation management shall meet the basic requirements of charging service operation safety.

(6)Safety control: It shall establish the safety control mechanism of the whole process. In the design stage, it shall pay full attention to the implementation of safety related standards and technical requirements for charging equipment, and fully utilize the functional protection design to effectively reduce the safety risk of the system function failure. In the manufacturing stage, it shall pay attention to the improvement of the production and manufacturing quality of the product, production inspection, and certification testing and network access management. In the construction stage, it shall strictly implement the quality requirements for completion of charging facilities. In the operation stage, it shall improve the operation and maintenance capability and the safety management level.

6.1.2 Charging protection mechanism

The charging process is a process in which the vehicle and the charging system cooperate with each other and realize the power transmission. Once the charging process is out of control, easy to cause power battery safety accidents, so it shall pay attention to the safety performance risk management of the charging process.

(1)Active safety measures

The charging control system of the charging equipment shall fully consider the function design of the active safety protection. During the charging process, it shall verify the BMS data, monitor the key parameters of the battery including the total voltage, cell voltage and temperature extreme value, as well as SOC, SOH in real time, verify the feasibility of charging mode and charging state, and have the ability of real-time monitoring, diagnosis, error identification, fault prediction and early warning control for abnormal conditions. When finding that it may exceed the severity level of safety risk, it shall stop charging actively and take maintenance measures.

(2)Charging characteristics and protection

At present, the vehicle BMS is the controlling side for the charging management, and the charging equipment, as the controlled side, implements the charging instructions of BMS. Combined with the charging characteristics of the electric vehicle and the power battery management system, it shall further optimize the charging mode and the charging characteristics control requirement and form a protection mechanism matching with the safety margin of charging characteristics through data interaction and feasibility determination. It is recommended that the battery system and the charging system shall have the functions of health monitoring, diagnosis and setting fault early warning. There shall be corresponding protection measures when the battery system is in a risky situation. Meanwhile, the electric vehicle monitoring platform shall have the function of assessing the battery system safety risk, establish and implement the communication capability with the charging system, form a charging safety redundancy protection mechanism, provide the optimal charging voltage and current under current conditions through the charging process data and historical charging information analysis, and identify the online charging risk to prevent overcharge and large current shock from damage to power battery performance, realize the multiple safety protection of the charging equipment, and ensure the battery charging safety.

(3)Function failure risk

The performance degradation of the hardware and software system and functional components of the charging system and the communication error caused by electromagnetic interference are easy to cause the charging management function failure during the charging process. Therefore, the power transmission deviates from the expected requirement, it may cause the risk of overvoltage, overcurrent and overcharge accidents.

No matter it is the control unit of the vehicle or the control unit of the charging equipment, the function design shall have the anti-crash, dull and CPU processing recovery capabilities to ensure reliable communication between the BMS and the charging control unit. The communication connection shall have heartbeat detection, data error correction, and necessary fault tolerance capabilities, to avoid the formation of false message transmission, key parameter distortion and the like due to communication processor or control processor failure during the charging process, and effectively control the risk of failure or loss of control of the charging function.

6.1.3 Data resource utilization

Reasonably use the charging data resource information, various public data service platforms, industry alliances, and safety operation monitoring platforms, fully utilize new technologies to play the supporting role of charging safety function, use big data analysis and privacy information data cleaning, improve the demand of charging safety under the premise of no disclosure of user privacy and information safety, it is aimed at improving the demand for charging safety, explore the application and information retrieval mechanism of establishing battery property traceability and health status data support, implement preventive battery health assessment identification, especially the rationality assessment of charging methods, and improve the safety assurance ability of the charging service industry.

6.1.4 Focus on safety protection measures

The charging station shall provide a safe charging place for the electric vehicle to ensure the safety of charging operation and power transmission. The established corresponding functional system shall have electrical energy and fire safety measures. In the event of an accident, the corresponding protective measures shall be able to inhibit the expansion of accident hazards and reduce major hazard to surrounding people and the environment.

6.1.5 New technology application and standard guidance

Fully utilize technologies related to improving charging safety and reliability, give full play to the role of demonstration and standard guidance of scientific and technological innovations, and promote the safety performance improvement of power batteries and the transformation of generic technology research results such as monitoring and effective early warning of charging facilities. Conduct in-depth collaborative research on Electric Vehicles and standard technologies for charging facilities, continuously improve the accuracy level of charging safety standards, and play a guidance role of standards.

6.2 Charging system design

The safety performance of the charging system shall be considered from the design stage. The application of safety measure design can effectively prevent the safety risks caused by function failure.

6.2.1 Requirements for general design

(1)The charging equipment shall have an obvious safety identification and a reminder for the handling method in case of emergency faults;

(2)The electrical components of the charging system, the withstanding voltage level and electromagnetic compatibility of the complete set of cables shall meet the high- voltage DC characteristics and other relevant requirements specified by corresponding standards;

(3)The heat dissipation capability of the charging gun line shall meet the requirements for high-current long-term working. In addition, it shall consider the solar radiation of the gun line, vehicle rolling, drop, and the adaptability to high and low temperature environment;

(4)The use of charging equipment shall consider the environmental temperature, humidity, altitude, air pressure, weather resistance and other influencing factors. The equipment layout environment shall have lightning protection measures, and the working environment shall consider the humidity, dust, smoke and other requirements for safety;

(5)The live conductor sheath of the charging and power supply equipment shall be made of flame retardant material.

6.2.2 Structural design

Charging equipment products shall be designed from the aspects of requirements for equipment grounding, output overload protection, emergency power off / emergency stop (loading, breaking capacity) safety, requirements for cable anti-rolling, charging interface arrangement, locking structure, interlocking device function, connector plugging requirements, anti-loose and anti-theft, requirements for structural error prevention, contact sequence, mechanism strength and other safety, power supply equipment repair switches, etc. according to the relevant standards and technical requirements.

The structure design safety of the charger shall also consider the following three aspects:

(1)Prevent the human body from approaching dangerous parts in the shell;

(2)Prevent solid foreign matter from entering the equipment in the shell;

(3)Prevent damage to equipment due to water entering the shell.

6.2.2.1 Dustproof and waterproof design standard

According to GB 4208, the protection grade of the charger shall be at IP54 at least to ensure the safety of equipment and personnel.

The dust screen is installed at the air inlet of the charging pile. The main function of dust screen is to prevent dust in the air (there are charged particles in the dust) from entering the equipment and affecting the reliability of the equipment. Moreover, the dust screen can also prevent harmful insects from entering the equipment through the air inlet and causing damage to the equipment.

6.2.2.2 Anti-theft design

The equipment installation shall be firm and reliable. Under the condition of no damage to the equipment or installation parts, it cannot move the equipment or touch and get the parts of the equipment (excluding the mobile charger);

It must use a key or special tool to start the equipment;

The charger is designed with an access control system to prevent equipment theft through background monitoring;

Components of the charger must not be removed directly from the equipment by using common tools (cross/slotted screwdriver, sharp-nose pliers, flat-nose pliers, hammer, etc.). Fasteners assembled outside the equipment must be anti-theft fasteners or conduct anti-theft treatment after assembly;

The anti-theft level of outdoor cabinet locks shall meet the A-level standard at least according to the regulations stipulated in GA/T73-94 *Mechanical Anti-theft Lock* promulgated by the Ministry of Public Safety.

6.2.2.3 Fireproof design

Fire hazard may occur due to over-temperature, equipment overload, component failure, insulation breakdown and connection loosening. The materials and components in the charger shall have sufficient capacity to prevent the flames from extending beyond the fire source. In order to reduce such risk, the charger equipment shall adopt the following measures:

Provide overcurrent protection;

Use materials with appropriate flammability; Avoid concentration of heat sources;

Use heat sinks and temperature control systems to prevent high temperatures that may cause a fire;

Use fire screens and covers to isolate possible fire sources from the outside.

6.2.2.4 Rat-proof design

(1)The charging cabinet casing shall consider adopting a rat-proof design, and the openings and gaps shall be able to prevent the entry of small rodents;

(2)An end cap shall be provided at the inlet and outlet of the cabinet cables or the inlet and outlet holes must be blocked with fireproof mud. It must be made of metal or anti- rat materials.

(3)Interconnecting cables between outdoor equipment shall not fail due to the bite of small rodents.

6.2.2.5 Installation design

The fixed charging equipment shall be installed firmly, with anti-theft, anti-collision and anti-malicious damage measures. When the charging equipment is set in the underground or semi-underground garage, it shall determine the waterproof elevation reasonably to meet the requirements for waterproof. It shall take sealing measures at the cable pipe trenched and the cable inlet inside the foundation base to prevent small animals from entering the bottom cabinet. When the charging equipment bureau uses wall-mounted supports, it shall consider the load and structural durability of the charging equipment.

6.2.3 Electrical safety

The charging equipment shall be designed according to the requirements of GBT18487.1-2015, GBT27930-2015, NBT33001-2018, NBT33002 and other standards, and shall meet the following requirements:

(1)Requirements for touch current safety:

Personnel touch current shall meet the safety requirements of 11.2 of GB/T 18487.1;

The voltage requirements shall meet the safety requirements of 4.4 of GB/T 18487.1;

The residual current shall meet the safety requirements of 10.3 of GB/T 18487.1.

(2)Ground safety

The requirements of 7.5.4 of NB/T 33001 shall be met.

(3)Requirements for electrical clearance and creep distance:

The requirements of 10.4 of GB/T 18487.1 shall be met.

(4)Electromagnetic radiation (electromagnetic exposure) safety

For human and equipment damage, conducted interference shall meet the requirements of Chapter 7 of GB/T 18487.2-2017.

(5)Current surge, voltage fluctuation

Current surge shall meet the requirements of 9.7 of GB/T 18487.1.

Voltage fluctuations shall meet the requirements of 7.7.6 of NB/T 33001.

(6)Charging start and stop,

There shall be relevant safety guarantee measures such as output soft start self-test, reverse current testing, contactor turn-off testing and contactor adhesion testing.

(7)Residual charge bleed

The charging equipment shall have a discharge function for the residual charge. The design shall meet GB 18487.1-2015 Electric Vehicle Conductive Charging System Part 1: General Requirements. For applications of charging mode 3 and charging mode 4, the voltage value measured between the power lines of its output terminals or between the power line and the protective grounding conductor shall be less than or equal to 60VDC within 1s after the power supply equipment of the electric vehicle is cut off, or the equivalent stored energy storage energy is less than or equal to 0.2J; There are two types of design. One is to install a discharge resistor at the back end of the output DC relay. The value of the discharge resistor is calculated according to the module voltage and capacitance. The other is to use a charging module with a built-in discharge resistor. After the charging equipment completes IMD detection, discharge the charging output voltage. The charging output voltage can also be discharged after charging. Meanwhile, during the charging process, the charging equipment shall have input and output overvoltage and undervoltage protection, output short circuit protection, output reverse connection protection, output overload protection, output grounding monitoring, etc.

(8)Over temperature protection

For the temperature change during charging, voltage and current limit protection of power module inside the equipment, charging interface function and communication network, and sensor status, it shall adopt the abnormal temperature condition monitoring and protection function design.

6.2.4 Electrical protection function

Off-board chargers shall have input overvoltage and undervoltage protection, output overvoltage protection, output short-circuit protection, output overload protection, grounding continuity protection, input surge current, output surge current, battery reverse connection protection, anti-reverse current protection, contactor adhesion testing, lightning protection and other high-voltage electrical protection testing. It shall conduct relevant protective function tests in accordance with 5.4 in NBT33008.1, and the results shall comply with the regulations of 6.10 in NBT33001. Where:

(1)Failure protection: Including requirements for fault, overload, short circuit, over-temperature protection safety;

(2)Software protection: Including system and equipment software module function protection;

(3)Hardware protection: Includes high-voltage component insulation monitoring and electrical isolation protection.

6.2.5 Charging connection testing

Charging connection implements requirements for interoperability, and shall comply with

GB/T34657.1 *Electrical Vehicle Conductive Charging Interoperability Test Specification Part 1: Power Supply Equipment* 6.3.4.4 testing of output voltage exceeding the vehicle allowable value, 6.3.4.5 insulation fault testing, 6.3.4.6 protective grounding conductor continuity loss testing,6.3.4.7 other charging fault testing, 6.4.4.4 protective grounding conductor continuity loss testing, and 6.4.4.5 output overcurrent testing in GBT34657.1.

6.2.6 Data communication and safety

At present, the communication protocol of the BMS and the charging equipment is transparent, the information interaction adopts the plain code mode, and the bus network allows multi-node access. From the perspective of information safety, the third party is easy to monitor and steal the interaction information, causing information disclosure. It is easy for the counterfeit communication node to send interference information and false information, causing data error in the charging process and triggering charging safety events. Send storm data, causing network congestion. Through the bus, conduct destructive intervention on the internal program of the ECU or the charging pile, and implant an illegal code, causing the vehicle use safely or the charging pile working error, etc. It shall be fully aware of its harmfulness, and take measures to prevent eavesdropping, attacking, falsification and implantation, and improve the charging information safety.

6.2.7 Communication control failure

Due to the degradation of software and hardware functional components, communication errors or data quality are degraded, the system control or service function is lost, and the system deviates from expected requirements in the process of power exchange, resulting in accidents and safety risks.

The system design shall adopt software heartbeat detection, data error correction and necessary activation measures to prevent the communication processor and control unit crash, false message transmission, key parameter distortion, etc. during the charging process, effectively improve the communication quality between BMS and the charging control unit, and reduce the risk of failure or loss of control of the charging control function.

6.2.8 Charging data collection, cleaning, storage, and query

The charging system shall have the function of recording the extreme cell voltage, cell number and extreme temperature, and determine the charging abnormality according to the charging current and voltage response curve, for example, by determining whether the battery is abnormal based on the voltage change rate; With data cleaning and storage functions, provide corresponding protection mechanisms according to battery abnormal conditions.

The charging safety related data generated by the BMS and the charging equipment during the charging process shall conduct a safety-related design in the whole link of data processing and utilization process.

In the data collection phase, due to the diversity of transmission modes, it shall carry out the safety design for each transmission mode to prevent data loss, manipulation, etc. In the data cleaning phase, due to the high frequency of data generation and large concurrency of data access, it shall carry out the design for the high concurrency to avoid higher delay in real-time application of subsequent data (such as charging safety monitoring and early warning) caused by untimely data cleaning.

In the data storage and query use phase, it shall carry out the hierarchical design for the data safety protection to prevent unauthorized use of data and ensure safety data use. Due to the large amount of data, it shall carry out the targeted design for efficient storage and query of massive data, to ensure that data is not lost and is retrieved and used efficiently.

6.3 Requirements for charging facility safety

Charging facilities shall be built through the implementation, operation and maintenance, monitoring and management of body safety design, system safety measures, engineering construction and other safety standards, to ensure the safety of charging infrastructure.

6.3.1 Ensuring the implementation of standard safety technical requirements for charging equipment.

6.3.1.1 Equipment and interface standards

Charging equipment shall comply with the requirements of GB/T 18487.1 Electric Vehicle Conductive Charging System Part 1: General Requirements, NB/T 33001 Specification for Electric Vehicle Off-Board Conductive Charger, and NB/T 33002 Specification for Electric Vehicle AC Charging Pile. In terms of structure, it shall have discharge circuit, contactor, breaker, lightning protection device, emergency stop protection, locking device for preventing accidental electrification cut off, etc. to ensure safety and protect components. In terms of insulation protection, it shall pass the relevant insulation safety testing, including insulation resistance testing, dielectric strength, and impulse withstand voltage testing. Meanwhile, the charging equipment shall have solid grounding protection, protection grounding, grounding continuity monitoring and other anti-electric shock safety protection measures.

6.3.2 Electrical safety and protection

6.3.2.1 Equipment electrical safety

The high-voltage electrical part of the off-board charger shall be tested in accordance with the requirements for safety set out in 4.2 of *NB/T33008.1 Inspection and Test Specifications for Electric Vehicle Charging Equipment Part 1 Off-board Charger*:

(1)Insulation testing

The electrical part insulation detection function of off-board charger shall be conducted in accordance with 5.3.3 in NBT33008.1, and the results shall comply with B.4.1 and B.4.2 of GB/T 18487.1 -2015.

Before the insulation detection, select the following test resistance Rt, respectively, conduct the asymmetric insulation testing between the DC output DC+ and PE or between DC- and PE of the equipment under testing, as well as the symmetric insulation testing between the DC output DC+ and PE and between DC- and PE. The testing voltage is the rated charging voltage of the equipment under test. The accuracy of the testing resistance Rt shall meet the requirements in Table 3 of DL/T 1392-2014. 100Ω/V< Rt≤500Ω/V, check whether there is an insulation alarm prompt, and whether charging is allowed. Rt ≤ 100 Ω / V, check whether there is an insulation alarm prompt, and whether charging is allowed.

In the self-test phase, the insulation detection output voltage shall be the smaller value of the maximum allowable total charging voltage and the rated voltage of the power supply equipment in the vehicle communication handshake message.

After completing the insulation detection, the discharge loop shall comply with B.4.2 in GB/T 18487.1-2015. Check whether there is an alarm prompt or charging is not allowed when the off-board charger detects that the insulation level drops below the required value before charging.

The insulation detection function of the charger shall be compatible with the vehicle insulation inspection project.

The closing time and detection method are taken according to the requirements of GB/T18487.1-2015 B.4.1, DC+, insulation resistance between PE, insulation resistance between DC- and PE, and the difference between the two. Do not detect DC+, DC- between. At the same time, before the insulation detection, the outside voltage of the DC output contactor K1, K2 shall be detected. When the voltage exceeds +10V or less than -10V, the insulation detection process shall be stopped, and an alarm shall be issued.

Note the process timing of the insulation test: When starting to the insulation detection voltage -10V, close K1, K2, and then perform insulation detection.

(2)Electrical isolation requirements

Electrical isolation protection measures shall be taken between the power supply input and the DC output of the charging equipment; for a multi-charged charging machine, electrical isolation protection measures shall also be taken between the DC output interfaces.

(3)Grounding safety

It shall meet GB 18487.1-2015 Electric Vehicle Conductive Charging System -- Part 1: General Requirements, GB/T 20234.1-2015 Connecting Devices for Conductive Charging of Electric Vehicles Part 1: General Requirements, NBT 33001-2018 Specification for Electric

Vehicle Off-board Conductive Charging Equipment. For all modes, it shall provide a protective grounding conductor between the AC grid (power) grounding terminal, the DC grid (power) grounding terminal and the grounding terminal of the vehicle plug. The AC and DC charging equipment must have a protective grounding conductor; the size of the protective grounding conductor shall comply with the requirements of GB 16895.3, and the vehicle plug shall also be equipped with a protective grounding conductor. The size of the AC charging-to- protection grounding conductor is the same as that of the phase line, and the size of the DC protective grounding conductor shall comply with the requirements of GB/T 33594- 2017. The AC/DC charging equipment has the grounding continuity detection function, and the PE is connected to the AC grid and the vehicle at the same time. The grounding protection of the electric vehicle charging connection set shall accept the short-time high-current withstand testing, and the components in the grounding circuit shall not be melted, broken or damaged. The cross-section area of the grounding line and the neutral line (if any) shall be equal to the cross-sectional area of the phase line at least, or meet the requirements in Table 2 of GB 20234.1-2015. The metal shell of the charging equipment shall be set with grounding terminal (bolt), with the diameter of not less than 6mm and shall be marked with grounding mark. For the metal door sheet, cover plate, surface plate and similar parts of the charging equipment, the copper protective conductor shall be used to connect these parts and the major framework of the charging equipment, and the sectional area of the protective conductor shall not be less than 2.5mm2. All metal casing, clapboard, metal casing of the electric installation and metal handle which are used for insulating the live conductors shall be treated with effective equipotential connection, and the grounding continuity resistance shall not be greater than 0.1Ω; The working grounding and the protective grounding in the charging equipment shall be connected to the grounding conductor (copper bar) independently, multiple electric installation required to be grounded shall not be connected on one ground lead in series. All connections between the grounding busbar and the cabinet shall avoid the paint layer (or penetrate the insulating layer) to ensure an effective electrical connection.

The working ground and protective ground in the charging equipment are separately connected to the grounding conductor (copper bar), and the grounding line and the pile sheet metal directly break the paint layer through the serrated washer to ensure the continuity of the grounding.

(4)Residual current protection

It shall meet GB/T 18487.1-2015 Electric Vehicle Conductive Charging System -- Part 1: General requirements and NB/T 33002 Specification for Electric Vehicle AC Charging Equipment. For AC charging equipment, it shall install a residual current action protector on the power supply line side to detect the type A residual current, and the action current value is 30 mA.

(5)DC output loop short circuit protection

The DC output loop short circuit protection function of the electrical part of the off- board charger shall be carried out in accordance with 5.3.4 of NBT33008.1. The charging equipment shall stop the charging process and send an alarm prompt.

(6)Protection against electric shock

It shall meet GB 18487.1-2015 Electric Vehicle Conductive Charging System -- Part 1: General Requirements, GBT 18487.3-2001 Charging System: Electric Vehicle AC/DC Charging Equipment (Station) and NBT 33001-2018 Specification for Electric Vehicle Off-board Conductive Charger. It shall detect the contactor and relay working status in real time, and conduct the voltage sampling at the input end of the relay, read the sampling voltage after starting the charging equipment and before closing the DC relay, to determine whether the main contact of the DC relay is adhered. If it is adhered, stop working immediately and send the alarm prompt. It is recommended to use a residual current action breaker. If the excessive residual current causes action, the breaker shall be reset manually, and the reset operation can be implemented outside the cabinet. The charging equipment must be equipped with a travel switch on the cabinet door. If the door is open, the travel switch signal is transmitted to the main control panel, and the main control panel controls the cutting off of AC contactor. Charging equipment shall use basic insulation as a basic protection measure, use additional insulation as a fault protection measure, or use reinforced insulation that can provide basic protection and fault protection function. The charging equipment casing shall be made of insulating flame-retardant material.

(7)Vehicle plug locking function

The plug of the charger shall have a locking device, and its function shall meet the requirements of 9.6 of GB/T 18487.1-2015, 6.3 of GB/T 20234.1-2015, and Appendix A of GB/T 20234.3-2015.

In the event of a fault that cannot continue to be charged or when charging is complete, the locking device shall be unlocked, and the vehicle plug port voltage shall not exceed 60 V before unlocking.

The locking function test of the off-board charger vehicle plug shall be conducted in accordance with 5.3.5 in NBT33008.1, and the vehicle plug of the charging equipment shall be effectively locked or unlocked.

The vehicle plug locking device can be divided into electromagnetic type (pulse voltage holding type) and motor type.

The feedback of the vehicle plug lock device can be divided into mechanical switch and optical isolation.

When emergency unlocking is required, the charging gun generally uses a built-in electronic lock unlocking box, and the unlocking is completed by reverse discharge of the capacitor.

(8)Precharge function

Off-board charger shall have the precharge function to prevent excessive surge current generated during the process of starting charging. And improve the electrical life of the output DC contactor. After the charging phase is started, after the electric vehicle closes the vehicle-side DC contactor, the charger shall detect the battery voltage and determine whether the voltage is normal. When the charger detects that the battery voltage is normal, adjust the output voltage to the current battery terminal voltage minus 1 V to 10 V, and then close the DC output contactor on the charger side.

The precharge function testing of charging equipment shall be conducted in accordance with 5.3.6 in NBT33008.1, and the results shall comply with regulations in 6.6 of NB/T 33001-2018.

(9)Emergency stop function

It shall meet GB 18487.1-2015 Electric Vehicle Conductive Charging System -- Part 1: General Requirements, NBT 33001-2018 Specification for Electric Vehicle Off-board Conductive Charging Equipment. The off-board charger shall have an emergency stop device. When the emergency stop device is activated, the integrated charger shall cut off the power supply input and DC output at the same time; the split charger shall cut off the DC output of the corresponding charging terminal, or cut off the power input of the charger at the same time.

Among them, cutting off the power supply input has three ways to cut off the power input of the charger (remote), cut off the charger inlet switch (shunt release), and cut off the power supply of the charging module.

When the emergency stop device is activated, the charger shall disconnect K1 and K2 within 100 ms, and the vehicle interface voltage shall not exceed 60 VDC when the electronic lock is unlocked. Therefore, the emergency stop shall be connected in series in the K1, K2 power supply loop, and the charge controller needs to collect this state, perform shutdown, bleed, and unlock operation.

The emergency stop function testing shall be conducted in accordance with

5.3.10 in NBT33008.1, and the results shall comply with regulations in 6.9 of NB/T 33001.

(10)Requirements for insulation status monitoring and protection

The charging equipment shall have the DC side insulation detection and ground fault protection device to prevent equipment damage, fire, electric shock, and other life and property loss in case of poor insulation at the DC side. Charging insulation detection shall be conducted in accordance with the requirements of Appendix B in GB/T18487.1, setting an insulation detection circuit at both the charger end and the vehicle end. Before the power supply interface is connected to the charging equipment for charging, the charger is responsible for the insulation inspection inside the charger (including the charging cable). In the charging process, the electric vehicle is responsible for the insulation inspection of the entire system. Insulation detection is to measure the insulation resistance between DC+ and PE of the charging DC loop, and the insulation resistance between DC- and PE (take a smaller value R). Where R > 500 Ω/V, it is considered as safe; Where 100Ω/V < R ≤ 500 Ω/V, it shall conduct an insulation abnormality alarm, but it can still be charged normally; Where R ≤ 100 Ω/V , it is considered as an insulation fault and shall stop charging.

(11)Temperature monitoring and protection: Temperature sensing, monitoring and protection of key components

The charging equipment shall monitor the temperature inside the charging connector and the charging equipment. When the temperature exceeds the limit, the charging equipment shall implement the over-temperature protection. The loop through which the internal power supply input current flows inside the charging equipment, such as connection terminal, input circuit-breaker and input contactor; power conversion unit and its internal components, input and output terminals; The loop through which the DC output current flows, such as connection terminal, DC fuse, DC contactor, power resistor, current sampling shunt and vehicle plug. The maximum temperature of these heat-generating parts and components is less than or equal to 90% of the maximum tolerable temperature of parts and components, and shall not affect the normal operation of the surrounding parts, and cause damage to components. Under normal conditions, the charger operates for a long time at the maximum output current. The temperature rise of the internal heating components and the connection terminals of each part shall not exceed the regulations of Table 2 of NB/T 33001. The temperature of charging equipment components, parts, insulators and plastic materials shall be lower than the temperature that may reduce the electrical and mechanical properties when the equipment is normally used in the service life.

6.3.2.2 Over-temperature protection

It is recommended to install temperature sensors in the casing of charging equipment and the charging cable skin, to conduct the real-time detection of temperature. After the temperature reaches the set threshold, immediately send the temperature early warning prompt to the platform. After the temperature reaches the set temperature threshold, immediately reduce the output current or stop the charging process, and transmit the related information back to the platform.

Increase the internal temperature detection of the charging gun, and the charging gun manufacturer provides the alarm threshold under various working conditions. The charging device utilizes thresholds for more precise over-temperature protection.

6.3.2.3 Requirements for resistance to environment

The charging equipment shall pass the waterproof testing and dustproof testing, and meet the requirements for IP protection grade. It shall conduct the test of preventing solid foreign matter from entering the battery, preventing water from entering the battery and preventing salt spray in accordance with 5.5 in NB/T33008.1, and the results shall comply with the regulations in 7.3 of NB/ T33001-2018.

(1)Anti-condensation gel

GB 18487.1-2015 Conductive Charging System for Electric Vehicles-Part 1: General Requirements. For indoor equipment, the relative humidity of the atmosphere is recommended to be no more than 50% at a maximum temperature of +40℃, and the higher relative humidity is allowed at a lower temperature, for example, 90% at +20℃. Due to the temperature change, it shall consider the occasional humidity condensation; For outdoor equipment, the relative humidity is 5%-95%. For the charging equipment with liquid cooling system, the pipeline shall be wrapped with the insulation layer, and the cooling pipeline with special structure design is required to ensure that water can smoothly flow out the shell through the pipeline without touching the electrical components when forming condensation. The charging equipment shall be equipped with the humidity sensor to monitor the environmental humidity inside the pile in real time. When exceeding the dangerous value, it shall take corresponding measures.

(2)Anti-collision

The charging equipment shall be equipped with the collision travel switch. In case of collision, it shall trigger the switch, send an alarm signal and stop charging. The charging parking space shall set the limit device, which is compiled into the product instruction manual. The shape design of the charging equipment shall avoid irregular and low protrusions difficult to find, to prevent that the vehicle cannot detect it, causing collisions. When designing the charging equipment, it shall consider the structural strength of the part below 1m, and such part must have a certain anti-collision function.

(3)Prevention of water overflow

The charging equipment shall be equipped with the float switch, and two float switches are installed at the lowest point of the power supply, with the redundant design, to ensure to trigger the switch in case of water overflow in the equipment, send a signal to the controller, and stop the equipment urgently.

(4)Wind protection

Outdoor chargers shall be able to withstand the maximum wind speeds in different regions as specified in GB/T 4797.5.

(5)Anti-rust (anti-oxidation) protection

The iron casing and exposed iron brackets and parts of the charging equipment shall be protected by double-layer rust prevention. The non-ferrous metal casing shall also have an anti-oxidation protective film or anti-oxidation treatment.

(6)Three-proof (anti-moist, mildew-proof, salt-proof) protection

The printed circuit board, connectors and other components in the charging equipment shall be protected against moisture, mildew and salt spray. Among them, the anti-mildew corrosion test refers to the test method 1 in GB/T 2423.16-2008, the degree of mildew is not lower than the 2a required in the standard; the anti-salt corrosion test refers to the test specified in 6 of GB/T 2423.17-2008 Method, test time 48 h, after the test, wash with soft brush in flowing water at 15 ℃ ~ 40 ℃ for 7 minutes, dry for 1 h, the product shall be free of red/green rust, no coating drop, no buffing .

(7)Emergency fault protection

Define key sensors. When a fault occurs, the charging equipment can be turned off immediately, and all key sensors are connected to an additional safety circuit, to ensure that any one sensor can detect the fault signal, and the pile end power supply immediately conducts the automatic physical cutoff.

(8)High temperature coastal areas

Based on the NB/T 33001-2018 compliant electric vehicle non-vehicle chargers used in high-temperature coastal areas south of the Yangtze River in China, consider the most significant environmental factors (wet heat, salt spray, solar radiation) on the high temperature coastal areas. Make special requests. Among them, the high-temperature coastal area refers to the area within 50km of the coastline south of the Yangtze River in China, or the entire island with an area of no more than 40,000 square kilometers.

The salt spray protection performance is determined according to Table 101 of T/CEC 214-2019 "Special requirements for high-temperature coastal areas of electric vehicle non-vehicle chargers". No ventilation holes and no condensation inside the cabinet, the protection level reaches IP54, and the IP65 is not charged. The test period of the parts belonging to the type II surface can be lower than the level specified in Table 102 of T/CEC 214-2019 "Special requirements for high-temperature coastal areas of electric vehicle non-vehicle chargers". The anti-corrosion level shall be Class A charger II. Parts of the surface shall not be degraded.

6.3.2.4 Electromagnetic compatibility

Electromagnetic compatibility (EMC) of charging equipment includes radiation disturbance limit testing, conduction disturbance limit testing, electrostatic discharge immunity testing, surge immunity testing, voltage sag, short-term interruption immunity testing, in line with requirements in 7.1, 8.2 and 8.3 of GBT18487.2-2017 Electric Vehicle Conductive Charging System Part 2: EMC Requirements for Off-board Electric Vehicle Supply Equipment.

6.3.2.5 Reliability requirements

The design life of the charging equipment shall be at least 8 years. The structural strength shall ensure normal operation, the outer surface shall not be rusted, the wire sheath shall not be cracked, the waterproof part shall not leak, and the product function shall keep working normally during the life of the equipment. Do not exceed the tolerance value; the average fault interval of the charging equipment shall not be less than 26280h.

6.4 Charging control strategy

Charging control strategy includes requirements for safety and protection for charging maximum voltage, maximum allowable current, temperature limit, and cell extreme value.

Exchange the message with BMS in the charging process message, monitor the change of the charging voltage, current, and temperature. When exceeding the allowable charging limit, it shall conduct the shutdown protection in time.

For the monomer extreme value monitoring of different types of batteries, when the cell voltage exceeds the allowable charging limit, the charging equipment shall be able to send the alarm and stop charging in time.

The charger shall be able to sense the working status of the power battery and the vehicle electrical equipment according to the charging process parameters, determine the validity and consistency of the BMS data, and prevent the power battery from overcharging.

The charging control strategy shall use the big data analysis capability of the charging system to provide an early warning of the safety risk of the power battery to prevent a safety accident that triggers the power battery.

6.4.1 Charge control

6.4.1.1 Charging timing requirement

The charging sequence shall comply with the charging timing requirements of GB/T 18487.1 Electrical Vehicle Conductive Charging System Part 1: General Requirements, GB/T 27930 Communication Protocol between Electric Vehicle Off-Board Conductive Charger and Battery Management System.

6.4.1.2 Charging process data requirements

The status data during the charging process shall be accurately reported, especially the total charging voltage, total current, limit value, and cell value shall be reported as required. As long as the vehicle BMS transmits, the dual protocol module and the charger need to correctly process and then forward the data. The charging monitoring needs to be displayed correctly. Meanwhile, for the total charging voltage, total current, limit value, and cell value, the charging monitoring needs to be sent periodically for inquiry. The data of time, charging volume, and charging duration during the charging process shall be reported correctly. Among them, charging related BMV (single cell temperature), BMT (single cell voltage) message GB/T 27930 "electric car non-vehicle conductive charger and battery management system communication protocol" is defined as optional message However, in order to be able to discover the charging security risk in time, the charging device needs to be defined as a mandatory message and increase the frequency of transmission.

The vehicle identification code VIN in BMS and Vehicle Identification Message (BRM) in GB/T 27930 is defined as an optional message, but the charging safety risk is found based on the properties of the vehicle itself and the charging history data of the vehicle itself. Must be defined as a mandatory message.

6.4.1.3 Control strategy based on charging process data

The charging device can build a charging safety protection model by using the accumulated charging process big data, and build a second line of defense in addition to the BMS abnormal alarm based on the security protection model and the BMS data in the charging process in real time, when an abnormal situation is detected, timely shutdown protection.

(1)Dual protection function for the battery

The charging equipment shall have the dual protection function for the battery. 1) In the charging process of constant current and constant voltage mode, when the detected output voltage is greater than the maximum allowable total charging voltage of the vehicle or the detected output current after the current response is greater than 110% of the current demand of the vehicle (the currently demand current value is greater than or equal to 30A) or greater +3A than the currently demand current of the vehicle (when the currently demand current value is less than 30A), or, when the cell voltage of the BMS interaction data reaches the highest cell voltage of the battery and continues for a certain period of time (15s), the charging equipment shall disconnect K1K2 within 1s and send an alarm prompt.

2) During the charging process, when the maximum temperature of the BMS data reaches the maximum allowable temperature of the battery and continues for a certain period of time, the charging device shall stop charging and issue an alarm.

3) The charging device shall be equipped with battery overcharge protection. When it is detected that the charge and charge time of the battery is greater than the rated capacity and energy of the battery, stop charging and report the alarm.

4) The charging device shall have the function of judging the interference of the BMS interaction data, the data is not updated, and the data is abnormal. When the abnormal data causes the battery to overcharge, overheat, overvoltage, overcurrent, the control strategy shall be adopted, or the charging shall be stopped. Prevent battery safety risks and issue alarms.

(2)Charging system utilizes big data analysis function control strategy

The charging system shall make full use of the role of charging big data analysis, establish the data support role of battery characteristic traceability and health status information retrieval, and identify the risks in the vehicle charging process. Based on longitudinal charging history data, the battery safety traceability model and the horizontal data statistical analysis of the same model, the charging security model helps to regulate the charging process, reduce the risk of battery accidents, delay the deterioration of battery health indicators, and the future health of the vehicle. The situation is predicted.

The security protection model needs to consider the goals of the implementation and the dimensions it includes:

1) Estimating the attenuation degree of the vehicle battery capacity based on the battery attenuation characteristics of the vehicle and the historical charging data of the vehicle and predicting the future capacity attenuation trend of the battery in combination with the charging behavior characteristics of the vehicle and the type of operation of the vehicle.

2) Due to different operating environment, operation type, charging habits and operating habits, the vehicle may trigger the cycle of each safety core indicator, the rate of change or its actual threshold data. In order to realize and detect the abnormal indicators of the vehicle as early as possible, it is necessary to establish a corresponding model for the threshold of the security core indicators. The security indicators to be included and the analysis dimensions of the model calculation are as follows:

The threshold of the highest temperature during battery charging, the threshold of temperature rise rate, the threshold of maximum temperature difference, the threshold of maximum differential pressure, the threshold of soc rate, the threshold of single overvoltage, and the threshold of battery overcharge need to be combined with vehicle type, city, time. And the big data features of the vehicle's own historical charging data are dynamically determined.

6.4.2 Fault and abnormal condition monitoring and protection

(1)When various faults occur in the charging system, it shall be able to ensure charging safety through the reasonable handling strategy;

(2)After the safety monitoring parameter exceeds the limit, the charging monitoring system sends an emergency stop instruction to the charger, the charger needs to implement the emergency stop instruction;

(3)The charging pile control system detects each relay, contactor and fuse in the charging loop, to check whether the device is normal, and sends a fault alarm;

(4)Each charging loop is equipped with an anti-reverse diode to prevent the fault from expanding in case of the charging equipment internal fault;

(5)It shall detect the charging point temperature during charging, and the charging can be interrupted when the temperature is too high;

(6)Store relevant information in a network database, and ensure that the network database is valid. If the storage fails, it shall send an error message.

6.4.3 Fault classification and processing

Major fault refers to the fault directly affecting personal safety. Such as insulation fault and electric leakage fault. When a major fault occurs, the equipment or charging module shall be shut down immediately, waiting for professional maintenance personnel to repair.

Battery thermal runaway: Failure of battery total voltage overcharge, battery cell overcharge, battery capacity overcharge, battery over temperature, etc., which may cause battery thermal runaway risk, stop charging immediately, and actively alarm and record in the background charging system.

General fault refers to the fault that does not affect personal safety but requires timely maintenance. Mainly including faults at the equipment safety level, such as connector faults (fault detected by the pilot circuit), mismatch of charging current detected by the charger, etc. When a general fault occurs, the charging equipment stops charging and makes a fault record (it needs to plug-in and pull-out the charging cable before starting the next charging).

Send an alarm prompt on related problems that need the attention of the operator. Such as the timeout at the charging handshake phase, the timeout at the configuration phase, and the charging process timeout. When the charging equipment is in the alarm prompt state, the charging equipment stops charging, and automatically restores charging after the fault is eliminated (after detecting that the fault is eliminated, restore the communication handshake and start charging).

Table 1 Fault classification

Fault classification	Fault description	Fault name
Serious fault	Faults that directly affect personal safety	Insulation fault
		Electric leakage fault
		Discharge loop fault
		Lightning protection fault
Battery system	Failure that may cause battery thermal runaway risk	Reach the maximum voltage of the unit without stopping charging
		Reach the battery total voltage without stopping charging

		Reach the maximum allowable temperature of the battery without stopping charging
General fault	Fault that does not affect personal safety but requires timely maintenance	Connector fault (fault detected by the pilot circuit)
		Electronic lock fault
		Sudden stop fault
		Input overvoltage/undervoltage
		Input phase loss
		AC contactor fault
		DC contactor fault
		Charging module fault
		Mismatch of charging current
		Output short circuit
		Output overvoltage/overcurrent
		Battery reverse connection
		Charging system over-temperature
		Charging gun over-temperature
Alarm prompt	Equipment in the alarm prompt state	Communication timeout

According to the requirements for charging end, it can be divided into normal stop charging, fault stop charging, and emergency stop charging.

Normal stop charging: The user, vehicle or power supply equipment stops the charging process, and the shutdown is not caused by fault. Including active stop charging by the users, vehicles or power supply equipment.

Fault stop charging: When the charging equipment or the vehicle detects a fault, the charging process is stopped. When an output overvoltage protection or an abnormal communication line fault occurs, the power supply equipment shall turn on the contactors K1, K2, K3 and K4 within 1s and 10s respectively.

Emergency stop charging: The charging process is stopped urgently when the power supply equipment or the vehicle detects a fault, such as safety hazards. When the control pilot signal is abnormal, the protection grounding continuity is lost, and the charging cannot be continued, the power supply equipment shall turn on the contactors K1 and K2 at 100ms.

It shall comply with the above principles when enterprise standards are designed.

6.5 Charging system and equipment function design

6.5.1 Functional safety design of controller software

(1)Output over-voltage protection

The charging system software shall have the function of output overvoltage detection and protection. When the output voltage is greater than the demand voltage or the maximum allowable voltage of the battery, the output power loop shall be cut off within 1s to stop charging, and the charging system shall report an output overvoltage fault.

(2)Output over-current protection function

The charging system software shall have the function of an output overcurrent detection and protection. When the output current is greater than the demand current or greater than the maximum allowable charging current of the battery, the output power loop shall be cut off within 1s to stop charging, and the charging system shall report an output overcurrent fault;

(3)Output contactor anomaly detection

The charging system shall have the function of power loop abnormal detection,including output contactor adhesion detection, output contactor drive failure detection, and fuse fault detection, and can stop charging and report the fault in time after detecting the above faults.

DC contactor adhesion detection method can be used in the following three ways:

1) Refer to the vehicle contactor adhesion detection method, and compare the inner and outer voltages of K1 and K2 with the insulation voltage;

In this way, the control logic is complicated, but the insulation test is performed by using the existing voltage sampling circuit and the insulation voltage of the charging system, and the cost is low.

2) The peripheral circuit detects the contactor resistance;

It is necessary to inject the signal to detect the state of the contactor, which has the risk of affecting the insulation detection of the vehicle; when the contactor works for a long time, the main contact will be oxidized, and the internal resistance will greatly affect the detection accuracy when there is no current.

3) The contactor itself has its own node;

The contactor itself has a position node and feedbacks the position of the main contact in real time; there are currently three feedback mode travel switches, reed switches, and built-in control boards.

(4)Discharge loop fault detection

The charging system shall have the function of discharge loop adhesion and failure detection. In case of discharge loop adhesion and failure, the charging system shall stop charging to prevent safety accidents.

(5)Auxiliary power circuit protection

DC charging equipment shall be able to provide low voltage auxiliary power for electric vehicles. The low-voltage auxiliary power supply shall have output over-voltage, over-current, and short-circuit protection. Avoid current backflow damage to the charging device.

(6)Insulation testing

The charging system shall have the function of insulation detection. For DC+ to PE and DC- to PE , when the impedance of either side is less than 100 ohm/V, the charging system shall accurately report the insulation fault and stop charging; When the impedance of either side is less than 500 ohms/V, the charging system shall send an insulation detection alarm prompt, but can continue charging;

(7)Lightning protection

The installation and selection of surge protection devices for lightning-proof protection shall meet the requirements specified in 11.7 of GB/T 18487.1 *Electric Vehicle Conductive Charging System Part 1: General Requirements*.

(8)System fault detection

The charging system software shall have the functions of door magnetic fault detection, lightning protection fault detection, humidity fault detection and fan fault detection, etc. When the system fault is detected, it shall accurately report the fault and stop charging within 1s.

(9)Input low-voltage protection

The charging system shall have the function of input undervoltage detection and protection. In case of undervoltage in the system, the charging system shall timely report the undervoltage fault, and stop charging. Before the charging system input, if there is the ac contactor, it shall cut off the ac contactor in time to prevent the repeat actuation of contactor coils due to undervoltage, burning out the input ac contactor, causing a serious accident.

(10)Input low-voltage protection

The charging system shall have the function of input overvoltage detection and protection. In case of overvoltage in the system, the charging system shall timely report the overvoltage fault, stop charging, and cut off the input level distribution loop to prevent major accidents due to the overvoltage damage of the devices in the later stage.

(11)Input default phase protection

The charging system shall have the function of input phase loss detection and protection. In case of phase loss in the system, the charging system shall timely report the phase loss fault and stop charging.

(12)System over-temperature protection

The charging system shall have the function of over-temperature detection and protection. When the system environment temperature is too high, it has the temperature limit power strategy to prevent the system temperature from becoming higher; When the system temperature exceeds the environment temperature protection value, it shall stop charging, and the charging system reports the over-temperature fault;

(13)Charging gun over-temperature protection

The charging system shall have the function of charging gun over-temperature detection and protection. The temperature of the charging gun can be detected in real time during charging. When the temperature is too high, it can restrict the charging gun output function to prevent the temperature from rising again. When the temperature exceeds the protection value, it shall stop charging timely, and report the charging gun over- temperature fault.

(14)Battery cell overvoltage protection

The charging system shall have the function of cell overvoltage protection. When it is detected that the current cell voltage of the battery is greater than the maximum allowable cell voltage, it shall stop charging and report the alarm timely.

(15)Battery over-temperature protection

The charging system shall have the function of battery over-temperature protection function. When it is detected that the current maximum temperature of the battery is greater than the maximum temperature allowed by the battery, it shall stop charging and report the alarm in time.

(16)Battery thermal runaway protection

The charging system shall have the function of battery thermal runaway detection and protection. According to the battery type, when the battery temperature rise exceeds the threshold within a certain period of time, it shall stop charging and report the alarm timely.

(17)Battery data non-refresh protection

The charging system shall have the function of battery data non-refresh detection and protection. When the battery data does not refresh for a period of time, it shall stop charging and report the alarm timely.

(18)Battery reverse connection protection

The charging system software shall have the function of battery reverse connection detection and protection. From the beginning of charging, the battery voltage shall be detected in real time. If the reverse connection occurs, it shall timely report the fault, cut off the power loop, turn off the charging module, and stop charging.

(19)Battery overcharge protection

The charging system shall have the function of battery overcharge detection and protection. When it is detected that the charging volume and the ampere-hours into the battery is greater than the rated capacity and energy of the battery, it shall stop charging and report the alarm timely.

(20)Charging gun aging early warning protection

The charging system shall have the function of charging gun aging early warning protection. When it is detected that the charging gun is used for a long time, the contactor resistance becomes larger and the aging has occurred, it shall prohibit charging at the terminal, and send an alarm to remind the replacement of the charging gun so as to prevent a larger accident.

6.5.2 Requirements for interoperability

The charging equipment shall be tested according to the requirements of GB/T 34657.1 *Electrical Vehicle Conductive Charging Interoperability Test Specification Part 1: Power Supply Equipment* for charging interface interoperability testing, DC charging interoperability testing, and AC charging interoperability testing. Electric vehicles shall be tested for DC charging interoperability and AC charging interoperability according to GB/T 34657.2 *Electrical Vehicle Conductive Charging Interoperability Test Specification Part 2: Vehicles*. For DC charging, electric vehicles and off-board chargers need to perform affirmative and negative tests in accordance with GB/T 35658 *Communication Protocol Conformance Test between Electric Vehicle Off-Board Conductive Charger and Battery Management System*.

Charging interoperability is the ability of the same or different models and versions of power supply equipment and electric vehicles to achieve charging and interconnection through information exchange and process control. Protocol conformance testing is a functional test. It uses a set of test sequences to test the implementation of the tested protocol in a certain network environment. By comparing the similarities and differences between the actual output and the expected output, it is determined how big the measured implementation is. The extent is consistent with the description criteria. Protocol conformance testing is the basis of interoperability testing. Only products that pass the protocol conformance test indicate that they meet the requirements of the relevant protocol standards, so that interoperability testing is meaningful.

6.5.2.1 Charging interface interoperability

The charging interface is the basis for ensuring the safety and interchangeability of electric vehicle charging. The structural dimensions of the vehicle plug, vehicle socket, power plug and power socket shall comply with GB/T 20234.2 *Connecting device for conductive charging of electric vehicles Part 2: AC charging interface Appendix A, GB/T 20234.3* Electrical car conduction charging connection The third part of the device: DC charging interface, within the allowable tolerances specified in Appendix A. At the same time, the maximum outer contour of DC charging vehicle plug, AC charging vehicle plug and AC charging power plug shall comply with GB/T 20234.3-2015 *Connecting device for conductive charging of electric vehicles Part 3: DC charging interface* Appendix C, GB/T 20234.2 The provisions of Appendix C of *Connecting devices for conductive charging of electric vehicles - Part 2: AC charging interface*. Such plugs and sockets manufactured by different manufacturers shall meet the requirements of interchangeability.

6.5.2.2 Communication protocol conformance requirements

The electric vehicle DC charging communication protocol is the basic element to realize the conductive charging of electric vehicles. The standardization and standardization of the protocol is the basis for ensuring the interconnection and intercommunication between electric vehicles and charging infrastructure and is an effective guarantee for the safety and compatibility of electric vehicle charging. Therefore, it is necessary and necessary to conduct protocol conformance testing to reduce the barriers to interconnection between electric vehicles and charging facilities due to incompatible protocols. Protocol conformance testing is listed as a mandatory item for type inspection of charging equipment.

The electric vehicle DC charging communication protocol conformance test cases are divided into physical layer test, data link layer test, application layer test, charging process test, and data correctness test. However, the physical layer and link layer characteristics are mainly determined by the CAN controller. Therefore, the main contents of the conformance test are application layer test, charging process test, and data correctness test, and are specifically classified into positive test and negative test. The specific test requirements and test cases are specified in GB/T 34658 *Communication Protocol Conformance Test between Electric Vehicle Off-Board Conductive Charger and Battery Management System*.

6.5.2.3 DC charging process and communication interoperability

6.5.2.3.1 Requirements for interoperability in the connection confirmation phase

Connection confirmation is the basic link to achieve normal charging. During the insertion process of the vehicle plug and the vehicle socket, the charging equipment and the electric vehicle confirm whether the charging interface is fully connected by monitoring the voltages of the connection confirmation signals (CC1 signal and CC2 signal).

The vehicle interface shall have the locking function. This function shall comply with the relevant requirements of GB/T 20234.1. The mechanical locking device shall be installed at the plug end of the vehicle. The power supply equipment shall be able to determine whether the mechanical lock is firmly locked. The electronic locking device shall be installed on the vehicle plug. When the electronic lock is in the locking position, the mechanical lock shall not operate. The power supply equipment shall be able to determine whether the electronic lock is firmly locked. When the mechanical locking or electronic lock is not firmly locked, the power supply equipment shall stop charging or not start charging.

Power supply equipment connection confirmation test. The charger determines whether the vehicle plug and the vehicle socket are completely connected by measuring the voltage value of the detection point 1. When the voltage value of the detection point 1 is 4V, it is determined that the vehicle interface is completely connected.

Vehicle connection confirmation test. The vehicle control device determines whether the vehicle interface is completely connected by measuring the voltage value of the detection point 2. When the voltage value of the detection point 2 is 6V, the vehicle control device starts sending the communication handshake message periodically.

6.5.2.3.2 Requirements for interoperability in the self-test phase

After the vehicle interface is completely connected, first confirm whether the vehicle contactors K5 and K6 are adhered. Then, close K1 and K2 for insulation detection. The output voltage during insulation detection shall be the smaller value of the maximum allowable total charging voltage in the vehicle communication handshake message and the rated voltage of the power supply equipment. After completing the insulation detection, separate IMD (insulation detection) physically from the high-voltage loop, put it into the discharge loop to discharge the charging output voltage, and disconnect K1 and K2 when the bleeder voltage drops below 60V DC. Meanwhile, start sending the communication handshake message periodically. The vehicle determines whether the vehicle interface is connected according to the voltage value of the detection point 2. If the voltage value of the detection point 2 is 6V, the vehicle control device starts sending the communication handshake message periodically.

Vehicle contactor adhesion detection. Before the insulation detection, the charger closes the contactors K1 and K2 and does not output the insulation voltage. When detecting whether the outside voltage is greater than 10V, confirm that the vehicle contactors K5 and K6 are adhered, therefore, the charger shall not allow charging.

Charging parameter matching detection. When the maximum allowable total charging voltage in the vehicle communication handshake message is lower than the lower limit of the charger output voltage range, the charger shall not allow charging.

Insulation resistance conformance detection. It shall set IMD circuits on both the charger end and the vehicle end. Before the power supply interface is connected to K5 and K6 for charging, the charger is responsible for the insulation inspection inside the charger (including the charging cable). The IMD loop at the charger end is disconnected from the charging DC loop through the switch. During the charging process after K5 and K6 are closed, the electric vehicle is responsible for the insulation inspection of the entire system. The insulation resistance between DC+ and PE of the charging DC loop, and the insulation resistance between DC- and PE (take a smaller value R). Where $R > 500\ \Omega/V$, it is considered as safe; Where $100\Omega/V < R \leq 500\ \Omega/V$, it shall conduct an insulation abnormality alarm, but it can still be charged normally; Where $R \leq 100\ \Omega/V$, it is considered as an insulation fault and shall stop charging.

Requirements for discharge switching. After the charger completes IMD detection, the charger shall discharge the charging output voltage in time to avoid voltage surge to the battery load in the charging phase. At the end of the insulation detection, the charger shall discharge the insulation output voltage in time. When the interface voltage drops below 60V DC, disconnect the contactors K1 and K2.

6.5.2.3.3 Requirements for interoperability in the charging readiness phase

The vehicle and the charger enter the charging parameter configuration phase, the charger sends a message with the maximum output capability to the BMS, and the BMS determines whether to charge according to the maximum output capability of the charger. When the charging parameters are successfully matched, the vehicle first closes the contactors K5 and K6 to connect the charging loop; the charger performs precharge detection. When it is detected that the battery voltage of the vehicle is normal and within the normal output range of the charger, close K1 and K2 to connect the DC power supply loop.

Battery voltage matching detection. In the configuration phase, when the charger detects that the error range of the contactor external terminal voltage and the communication message battery voltage is >±5% and/or is not within the normal output voltage range of the charger, the charger shall not allow charging.

Requirements for precharge voltage output. When the output voltage of the charger is lower than the contactor external terminal voltage (1V-10V), close the contactors K1 and K2 to avoid the surge current caused by closing the contactor due to the excessive dropout voltage between the internal and external of the contactor.

6.5.2.3.4 Requirements in the charging phase

In the charging phase, the vehicle BMS sends the battery charging demand parameter to the charger control device in real time, and the charger adjusts the charging voltage and the charging current according to the battery charging demand to ensure the normal charging process. Meanwhile, the charger and the BMS send the charging state to each other. In addition, the BMS also sends the specific status information, voltage, temperature and other information of the power battery to the charger according to requirements. BMV, BMT, and BSP are optional reports, and the charger does not determine whether the message times out. The BMS determines whether to stop charging according to that whether the charging process is normal, whether the battery state reaches the charging completion condition set by the BMS itself, and whether receiving the message sent by the charger to stop charging (including the specific stopping reason, all message parameter values are 0 and the untrusted state). The charger determines whether to stop charging according to that whether it receives the stop charging instruction, whether the charging process is normal, whether the manually set charging parameter value is reached, or whether receiving the message sent by the BMS to stop charging (including the specific stopping reason, all message parameter values are 0 and the untrusted state).

Communication timeout detection. During the charging process, if the communication timeout occurs, the charger shall stop charging and disconnect K1 and K2 within 10s, and the vehicle shall disconnect K5 and K6; After restoring the communication, the vehicle shall re-establish the handshake connection when the charger re-enters the handshake identification phase. When the communication timeout occurs 3 times, it shall confirm communication interruption, the charger shall stop charging and disconnect K1, K2, K3 and K4 within 10s, and the vehicle shall disconnect K5 and K6. After restoring the communication, the vehicle shall not allow charging.

Detection of charging demand exceeding the BMS parameter limit. During the charging process, when the charging demand voltage value is greater than the maximum allowable charging voltage of the BMS, the charger shall send a stop charging message and stop charging, or output according to the maximum allowable charging voltage of the BMS. During the charging process, when the charging demand current value is greater than the BMS maximum allowable charging current, the charger shall send a stop charging message and stop charging, or output according to the maximum allowable charging current of the BMS.

Detection of charging demand exceeding the supply equipment parameter limit. During the charging process, when the BMS charging demand voltage value is greater than the rated voltage of the power supply equipment, the charger shall send a stop charging message and stop charging. During the charging process, when the BMS charging demand current is greater than the maximum output current of the power supply equipment, the charger shall output according to the maximum output capability of the power supply equipment.

Demand detection when the charging demand is 0. During the charging process, when the BMS charging demand current is 0, the charger shall output according to the minimum output capability.

Output response detection of real-time collected data exceeding the limits. During the charging process, when the voltage collected by the BMS exceeds the maximum allowable total charging voltage of the BMS, the charger shall send a stop charging message and stop charging.

Output response testing of estimated total power exceeding the total battery capacity. During the charging process, when the power battery is fully charged but allows to continue charging, the charger shall stop charging.

Output overvoltage detection. During the charging process, when the output voltage of the charger is greater than the maximum allowable total charging voltage of the vehicle, the charger shall stop charging within 1 s, and disconnect K1, K2, K3, and K4.

6.5.2.3.5 Requirements for the end of normal charging

At the end of normal charging process, the vehicle control device judges whether it will finish the charging on the basis whether the battery system is fully charged or whether it receives the "message that charger stops charging". When the above charging end conditions are met, the vehicle control device starts to send "the message that vehicle control device (or battery management system) stops charging" periodically, and then disconnects K5 and K6 after confirming that the charging current is less than 5A. Once the charging end conditions set by the operator are met or "the message that vehicle control device (or battery management system) stops charging" is received, the non- vehicle charger control device sends the "message that charger stops charging" periodically, and controls the charger to stop charging to reduce the charging current at a rate not less than 100A/s. When the charging current is less than or equal to 5A, it will disconnect K1 and K2. When the operator implements the stop charging instruction, the non-vehicle charger control device starts to send the "message that charger stops charging" periodically, and controls the charger to stop charging. After confirming that the charging current is less than 5A, it will disconnect Kl and K2 and put the discharge loop into operation again. The parameters of the discharge circuit shall be chosen to ensure that the voltage of the power supply interface is reduced to below 60V DC within one second after the disconnection of the charging connector. Then it disconnects K3 and K4. When the unlocking conditions are met, the electronic lock of the vehicle plug shall be able to unlock correctly.

When the charger and BMS stop charging, both sides enter the charging end stage. At this stage, BMS sends charging statistics to the charger throughout the charging process, including: Initial SOC, final SOC, minimum and maximum battery voltage; After receiving the charging statistics of BMS, the charger sends the information of output power and accumulated charging time to BMS during the whole charging process, and finally stops the output of low-voltage auxiliary power supply.

6.5.2.3.6 Requirements for charging sequence

Charging connection control sequence and charging state flow include voltage value of detection point 1, K 1 and K2 states, K3 and K4 states, K5 and K6 states, charging state, communication state, vehicle interface locking state and charging state transition interval time, which shall conform to B.5 of GB/T 18487.1-2015. The communication status shall conform to B.6 of GB/T 18487.1-2015 and the corresponding regulations in GB/T 27930 -- 2015.

6.5.2.3.7 Requirements for the end of abnormal charging

Detection of abnormal state of communication line. For the power supply equipment with charging mode 4, the charger shall stop charging and alarm when short circuit, break circuit or grounding fault occurs in the communication line before and during charging.

Detection of protection grounding continuity. During the charging process, the charger shall be able to detect the protective grounding of PE wire from the inside of the charger to the plug of the vehicle. When the protective grounding loss occurs, the charger shall be able to cut off the power supply within 100ms. During the charging process, when PE pin breaks, the message that BMS stops charging shall be sent to vehicles with pull- up voltage U2 greater than 15.2 V and less than 31 V and accuracy less than 1%, or U2 greater than 22 V and less than 30 V and accuracy less than 5%.

Detection of control guidance signal. During the charging process, the charger detects the voltage of detection point 1. When the switch S changes from in to off or the vehicle interface changes from fully connected to disconnected, the charger shall reduce the output current to 5A or less within 50ms, disconnect K1 and K2 within 100ms, and disconnect K3 and K4 after the statistical message interaction is completed.

Detection of other faults to charge. During the charging process, when there are any faults of the charger to continue charging, it sends the "message that charger stops charging" to the vehicle periodically, and controls the charger to stop charging, disconnects K1 and K2 within 100ms, and disconnects K3 and K4 after the statistical message interaction is completed. During the charging process, when there are any faults of the charger to continue charging, it sends the "message that vehicle stops charging" to the charger, and disconnects K5 and K6 within 300ms (depending on the severity of the fault).

6.5.2.4 AC charging process and communication interoperability

6.5.2.4.1 Requirements in the connection confirmation phase

Connection confirmation is the basic link to achieve normal charging. During connection between power supply plug and power supply socket (connection mode B), vehicle plug and vehicle socket (connection mode A, C), charging equipment and electric vehicle confirm whether the power supply interface and vehicle interface are fully connected by monitoring and controlling the voltage of guidance signal (CP signal) and connection confirmation signal (CC signal).

When the vehicle plug is plugged into the vehicle socket (power supply plug and power supply socket in mode A), the overall design scheme of the vehicle can automatically start some trigger conditions (such as opening the charging door, connecting the vehicle plug to the vehicle socket or setting the function trigger for the charging button and switch of the vehicle), and make the vehicle in an inaccessible state by interlocking or other control measures.

Vehicle control device judges whether vehicles plug and vehicle socket are connected fully (for the connect way B and C) by measuring the resistance value between the testing point 3 and PE. After they are fully connected, the vehicle socket with AC charging current greater than 16A is equipped with an electronic lock. The electronic lock shall lock the vehicle plug before starting power supply (with K1 and K2 closed) and keep it in the whole charging process (state

3). If it cannot be locked, the next operation is decided by the electric vehicle, such as: The charging process will continue, and it will notify the operator to wait for further instructions or terminate the charging process. Vehicle control device judges whether power supply plug and power supply socket are connected fully (for the connect way A and B) by measuring the voltage values between the testing point 1 and testing point 4. After they are fully connected, the power supply socket with AC charging current greater than 16A is equipped with an electronic lock. The electronic lock in the power socket shall lock the power plug before starting power supply (with K1 and K2 closed) and keep it in the whole charging process (state 3). If it cannot be locked, it will terminate the charging process and prompt the operator. The locking function shall meet the relevant requirements of GB/T 20234.1. Electric locking devices shall be installed in power supply sockets and vehicle sockets to prevent accidental disconnection during charging.

Power supply equipment connection confirmation test. If the power supply equipment is fault-free and the power supply interface is fully connected (for the connection mode A and B of charging mode 3), the switch S1 is switched from the connection state of 12V + to the connection state of PWM, and the power supply control device sends out the PWM signal. The power supply control device determines whether the charging connection device is fully connected by measuring the voltage value of the detection point 1 or the detection point 4.

Vehicle connection confirmation test. Vehicle control device judges whether vehicles plug and vehicle socket are connected fully by measuring the resistance value between the testing point 3 and PE. When it is not connected, S3 is in closed state, CC is not connected, and the resistance value between detection point 3 and PE is infinite; When it is semi-connected, S3 is disconnected, CC is connected, and the resistance value between detection point 3 and PE is Rc + R4. When fully connected, S3 is in closed state, CC is connected, and the resistance value between monitoring point 3 and PE is Rc. The vehicle control device determines whether the charging connection device has been fully connected by measuring the PWM signal of the detection point 2.

6.5.2.4.2 Requirements in the charging readiness phase

The vehicle control device closes the switch S2 when the vehicle charger is qualified through self-check without any fault and the battery pack is in the charging state. Vehicle control device judges whether vehicle is ready by measuring the voltage value of testing point 1. When the peak voltage value of testing point 1 is the corresponding voltage value of state 3 in Table A.2, the power supply control device will break over the AC power supply loop through closed contact Kl and K2.

Requirements for PWM signal parameter. The detection point 1 voltage and PWM signal parameters (positive amplitude, negative amplitude, duty cycle, frequency, rising time and falling time) of the power supply equipment output in each stage shall conform to Table A.5 of GB/T 18487.1.

6.5.2.4.3 Requirements for interoperability for start-up and charging stages

After the electric connection between electric vehicle and power supply equipment is established, the vehicle control device confirms the maximum power supply capacity of power supply equipment by judging the duty cycle of PWM signal of detection point 2, and confirms the rated capacity of cable by judging the resistance value between detection point 3 and PE. Vehicle control device compares the current maximum supply current value of power supply equipment, rated input current value of vehicle charger and rated capacity of cable, and sets its minimum value as the current maximum allowable input current of vehicle charger. On-board charger starts to charge for the electric vehicle before the vehicle control device judges the charge device has been connected completely and the max allowable input current of on-board charger has been set.

During the charging process, the vehicle control device shall periodically monitor the resistance between the detection point 3 and PE (for connection mode B and C) and the duty cycle of the PWM signal of the detection point 2. The power supply control device shall periodically monitor the voltage values of the detection point 4 and the detection point 1 (for connection mode A and B of charging mode 3). It confirms the connection status of power supply interface and vehicle interface, and the monitoring period is not more than 50ms. The vehicle control device checks continuously PWM signal of monitoring point 2, in the case of the duty ratio changed, it can adjust the output power of on-board charger in real time, and the check period shall be less than 5s.

Requirements for power supply equipment output capacity. For power supply equipment with adjustable duty cycle function, the output duty cycle is set at 5%, 10% and the corresponding duty cycle of maximum power supply current respectively. Its charging state shall conform to requirements of Table A.1 of GB/T 19487.1. For the power supply equipment with non-adjustable duty cycle function, the output duty cycle corresponding to its maximum supply current shall be set, and the power supply equipment shall be able to output its corresponding maximum supply current.

PWM duty cycle change requirement. When the duty cycle of PWM is 10%, switch S2 (if the vehicle is equipped with S2) remains closed, and the vehicle shall be able to charge normally, and the charging current is not more than 6A. When the duty cycle of PWM is 90%, switch S2 (if the vehicle is equipped with S2) remains closed, and the vehicle shall be able to charge normally. The charging current is not greater than A.3.7.1 in GB/T 18487.1-2015. When the duty cycle of PWM changes within the normal range, switch S2 (if the vehicle is equipped with S2) remains closed, and the vehicle shall be able to charge normally. The vehicle shall adjust the charging current within 5 seconds after detecting the change of the duty cycle of PWM, and the charging current is lower than the maximum current corresponding to the duty cycle of PWM.

PWM duty cycle over-limit requirement. When the duty cycle of PWM is 6.5% and 98.5%, the vehicle shall be able to reduce the charging current to the lowest level within 8 seconds (<1A).

Requirements for PWM frequency boundary value. When the PWM frequency is 1030Hz and 970Hz, switch S2 (if the vehicle is equipped with S2) remains closed, and the vehicle shall be able to charge normally.

Output over-current protection. The power supply equipment detects the actual working current of the vehicle charger. When (1) the maximum power supply current corresponding to the PWM signal of the power supply equipment ≤20A, and the actual working current of the vehicle charger exceeds the maximum power supply current+2A and remains for 5 seconds, or (2) the maximum power supply current corresponding to the PWM signal of the power supply equipment > 20A. the actual working current of the vehicle charger exceeds 1.1 times of the maximum power supply current and remains for 5 seconds, the power supply equipment shall disconnect the output power supply within 5 seconds and control switch S1 to switch to the + 12V connection state.

6.5.2.4.4 Requirements for the end of normal charging

During the charging process, when the end conditions of the vehicle are met or the driver gives the vehicle instruction to stop charging, the vehicle control device disconnects switch S2 and the vehicle charger stops charging.

During the charging process, the power supply control device shall be able to switch control switch S1 to the + 12V connection state when the end conditions set by the operator are met and the operator gives the power supply device instruction to stop charging. When the S2 switch is detected to be disconnected, the AC power supply loop is cut off by disconnecting contactor K1 and K2 within 100ms. If S2 switch is not detected for more than 3 seconds, the AC power supply loop can be forced to be disconnected by on-load disconnecting contactor K1 and K2. In case of connection mode A or B, the power supply interface electronic lock is unlocked 100ms after the AC power supply loop is cut off.

6.5.2.4.5 Requirements for charging sequence

Charging connection control sequence and charging state flow include voltage value of detection point 1, voltage value of detection point 3, PWM signal, charging state, power supply interface locking state and vehicle interface locking state (for charging current greater than 16A and connection mode A or connection mode B); and interval time of charging state transition, which shall conform to regulations of A. 4 and A.5 in GB/T 18487.1-2015.

6.5.2.4.6 Requirements for the end of abnormal charging

Detection of abnormal state of CC loop of vehicle. Vehicle control device judges the connection state of vehicle plug and socket by detecting the resistance value between PE and detection point 3 (for connection mode B and C). During the charging process, when it is judged that switch S3 changes from in to off (state B), vehicle control device controls vehicle charger to stop charging within 100 ms, and then disconnects S2 (if the vehicle is equipped with S2); When it is judged that the vehicle interface changes from full connection to disconnection (state A), the vehicle control device controls the vehicle charger to stop charging, and then disconnects S2 (if the vehicle is equipped with S2).

Detection of abnormal state of CP loop of vehicle. Vehicle control device detects the PWM signal of detection point 2. During the charging process, when the signal is interrupted, the vehicle control device controls the vehicle charger to stop charging within 3 seconds, and then disconnects S2 (if the vehicle is equipped with S2).

Detection of abnormal state of CC loop of vehicle. The power supply control device detects the detection point 4 (connection mode A and B for charging mode 3). Before charging, when it is detected that the power supply interface changes from full connection to disconnection (state A), the power supply control device controls switch S1 to switch to + 12V connection state without closing the AC power supply loop. During the charging process, when it is detected that the power supply interface changes from full connection to disconnection (state A), the power supply control device controls the switch S1 to switch to + 12V connection state and disconnects the AC power supply loop within 100ms.

Detection of abnormal state of CP loop of vehicle. Before charging, when it is detected that the voltage value of detection point 1 is 12V (state 1), 9V (state 2) or other non-6V (state 3), the power supply control device shall control switch S1 to switch to + 12V connection state within 100ms without closing the AC power supply loop. During the charging process, when it is detected that the voltage value of detection point 1 is 12V (state 1), 9V (state 2) or other non-6V (state 3), the power supply control device shall disconnect the AC power supply loop within 100ms.

6.5.2.5 Abnormal charging end requirement

Regardless of the vehicle end and the charging device end, once the charging connection is activated, it is strictly forbidden to send the other party's message required for interoperability to avoid disorder of the charging control.

6.6 Charging interface safety

6.6.1 Requirements for charging interface safety

6.6.1.1 Requirements for charging interface safety design

The safety design of charging interface shall include current carrying safety, temperature monitoring, preventing live plug-in and pull-out, IP protection grade, contact resistance and pressing resistance, interface strength, cable connection strength, electrical safety, cable assembly length and cable structure. Specifically, the following requirements shall be met:

(1)Design of current carrying safety and temperature monitoring for charging interface For applications with rated charging current greater than 16A, temperature monitoring devices shall be installed in power supply sockets and vehicle sockets. Power supply equipment and electric vehicles shall have temperature monitoring and over- temperature protection functions. For example, use temperature switch or temperature sensor. For charging piles with temperature switches, charging shall be stopped when terminal temperature reaches the protection threshold.

(2)Preventing live plug-in and pull-out

Charging interface shall meet the requirements of 6.3 in GB20234.1-2015, 9.3 in GB18487.1-2015 and 9.6 in GB18487.1-2015. Charging interface shall be equipped with locking device. When the current is greater than 16A, the power supply socket and vehicle socket terminals need to be designed with electronic lock, and DC charging products need to be designed with electronic lock structure and interlocking structure. When it is disconnected under DC load due to fault, there shall be no danger. When charging, the vehicle interface is locked electronically to prevent live plug-in and pull- out. Mechanical locking device shall be installed at the plug end of the vehicle. Power supply equipment can judge whether the mechanical locking is reliable or not. The electronic locking device shall be installed on the vehicle plug. When the electronic lock is in the locking position, the mechanical lock shall not operate. The power supply equipment shall be able to determine whether the electronic lock is firmly locked. When the mechanical locking or electronic lock is not firmly locked, the power supply equipment shall stop charging or not start charging.

(3)IP protection grade

The charging interface shall meet the requirements for protection grade of 6.9 in GB20234.1-2015. After connecting to the corresponding protection device, the protection level of the charging interface shall meet IP54. The protection grade of charging interface is IP55 after use.

(4)Design of contact resistance and pressing resistance

The temperature rise shall meet the requirements of 6.13 in GB20234.1-2015, and the terminal temperature rise shall not exceed 50K.

(5)Interface strength design

The strength of charging products shall meet the rolling requirements for vehicles in 6.21 of GB 20234.1-2015 and the mechanical strength requirements in Chapter 24 of GB 11918.1.

(6)Cable connection strength

The charging interface shall be designed with cable fixed structure to meet the requirements of GB 20234.1-2015 7.14 cable and its connection.

(7)Electrical safety of charging interface

The creep distance and electrical clearance of charging interface shall meet the requirements of Chapter 26 of GB 11918.1.

(8)Length design of charging cable assembly

Cable length shall not be designed too long; otherwise, the charging cable is easily distorted and bulged in the process of use.

(9)Structural design of charging cable

Charging cable structure shall meet the requirements of 9.2 cable lengthening components in GB18487.1-2015. Except cable components, cable lengthening components shall not be used to connect power supply equipment of electric vehicles and electric vehicles.

6.6.1.2 Detection requirements for AC/DC connectors

AC and DC connectors shall be subject to mandatory test by the testing institutions with CMA and CNAS qualification approved by the state. The testing criteria are based on:

(1)Off-board chargers shall meet the requirements of GBT 20234.1 and GBT 20234.3;

(2)AC charging piles shall meet the requirements of GBT 20234.1 and GBT20234.2 standards.

6.6.1.3 Manufacturing safety of charging interface

(1)In the production process of electrical products, the process of spring in socket shall be strictly controlled to ensure the consistency of contact resistance of charging products.

(2)In the process of charging cable assembly, the pressing process of cable assembly shall be strictly controlled to ensure the consistency of the pressing resistance after pressing.

(3)In the process of temperature sensor assembly, it is also necessary to strictly control the assembly process of temperature sensor to ensure the stability of temperature sensor detection after assembly.

6.6.1.4 Safety in use of charging interface

(1)Charging equipment shall be installed in the place with rain protection facilities;

(2)There shall be no water accumulated in the place where charging equipment is installed;

(3)Charging facilities shall not be installed in places where dust is serious;

(4)The charging gun with temperature sensor shall be selected for charging, and the charging gun shall have the functions of high temperature alarm control and power off;

(5)Maintain the charging connector regularly, always check whether the charging cable and its contact location are damaged and polluted before use is necessary, and not use damaged charging cable or vehicle socket, etc.;

(6)The charging gun shall be used alternately in the charging process. The charging gun with lower temperature shall be selected for charging, and the cleaner charging gun shall be selected for charging;

(7)The charging gun shall not be obliquely inserted into the charging socket when charging;

(8)The charging gun shall be vertically plugged into the charging socket, and shall not be shaken.

(9)When charging, the charging gun cables must be smoothed, not distorted, otherwise, and the charging gun socket will be forced in use;

(10)During the charging process, it is necessary for the charging operator to monitor the charging process. In case of typhoon, rainstorm, hail and other extreme weather (including but not limited to the above three), and the charging process shall be terminated immediately;

(11)During the charging process, if the charging interface continuously emits strong irritating odor, the charging process shall be terminated immediately and reported to the equipment safety officer at the first time;

(12)After use, the charging connector shall be positioned in place and the charging gun wire shall be smoothed and the charging gun wire shall not be coiled and dragged forcibly in the charging process, otherwise, it will result in distortion and bulging of the charging wire harness.

6.6.1.5 Maintenance safety of charging interface

(1)Power supply plugs and vehicle plugs shall be subject to regular maintenance and abnormal detection, including anomaly detection of plug appearance, voltage testing between phases of vehicle plugs and between wires and ground wires, insulation resistance and withstand voltage testing of plug phase wire to ground wire, detection of abnormal oxidation on the surface of plug terminal, testing of conductor of plug phase wire and cable resistance. When the mechanical lock hook breaks, the terminal anti- contact cap melts, the terminal hole is filled with foreign matter, the tail outlet loosens, the terminal displacement shrinks in, and the terminal anti-contact cap falls off, the plug shall be replaced;

(2)Power supply sockets and vehicle sockets shall be subject to regular maintenance and abnormal detection, including anomaly detection of socket appearance, insulation resistance and withstand voltage testing of socket phase wires to ground wires (it must be confirmed that there is no voltage between phases before testing), the socket shall be maintained regularly (e.g. foreign matter cleaning, special treatment of spring surface, replacement of spring, etc.), socket plug-in and pull-out force testing, socket electronic lock testing, torque testing of socket fixed bolt and grounding wire harness bolt, and testing of resistance of phase line conductors and cables in sockets. When there are normal silver plated terminals, terminal sheath hot melt, terminal over- temperature yellowing, terminal serious over-temperature dark yellow, spring surface covered with foreign matter, it is recommended to replace sockets;

(3)Under normal use, it shall be cleaned with high-voltage air gun and brush every week, if there are no such conditions, dust-free cloth or cotton swabs can be used to clean the charging socket plug gun. Under unexpected circumstances (such as, the charging gun is discarded or drops on the ground), it shall be timely cleaned in the above ways;

(4)It is strictly forbidden to use screwdriver, tweezers and other sharp objects to touch charging gun pins and charging socket, so as to avoid damaging pins and sockets.

6.6.2 Safety design for loosening prevention of electrical connection

The power supply equipment includes casing, partition, door locking device and hinge. Connection and splicing shall have enough mechanical strength to withstand the stress encountered in normal use and fault conditions. All connections and splices shall be mechanically firm and electrically continuous to avoid mechanical damage. All wires, contacting conductors or bare live components for external connection, components and internal connection shall have insulation protection or insulation distance that meets the maximum working voltage. Screws, nuts, washers, springs or similar parts shall be fully fixed and able to withstand the mechanical stress caused by normal use, so as to prevent potential safety hazards of spanning additional insulation caused by looseness or enhanced insulation electrical clearance or creep distance. All cables used as electrical connections within the charging equipment shall meet the current requirements for carrying capacity matching the diameter of the cables. All electrically connected cable terminals or joints shall meet the requirements for connection strength. When the charging cable connected with the output is disconnected under the external force beyond the pulling force requirement, it shall be ensured that the protective grounding wire in the cable is the last disconnected wire harness. In the charging process, when the charging cable is broken by external force, the power supply equipment shall stop charging output immediately, and there is no electric shock or energy risk.

6.7 Charging equipment test and safety evaluation

Detection refers to the specified technical performance indicators for testing an object (gas, liquid, solid) by a specified method. Electric vehicle charging equipment testing is a large engineering system with many factors, wide coverage and strong dynamics. Through testing and testing, we can explore and determine the impact of single or multiple environmental factors on charging, assess the environmental adaptability of charging equipment, verify whether the charging equipment meets the specified environmental requirements, and whether the charging product is qualified, and charge the operators and users. The decision-making basis for receiving or rejecting the device; in addition, it can detect unqualified or potentially defective charging products, and promote manufacturers to improve the design process and improve the technology, thereby promoting the reliability and safety of the charging device.

At present, the domestic standards for testing and testing mainly include national standard GB/T 34657.1 Electrical Vehicle Conductive Charging Interoperability Test Specification Part 1: Power Supply Equipment, GB/T 34658 Electric Vehicle Off-Board Conductive Charger and Battery Management" "Communication Protocol Consistency Test between Systems, in the preparation of Electric Vehicle Power Supply Equipment Safety Requirements and Test Specifications (reporting phase), NB/T 33008.1 Electric Vehicle Charging Equipment Inspection Test Specification Part 1: Non-vehicle Charger, NB/T 33008.2 Electrical Vehicle Charging Equipment Inspection Test Specification Part 2: AC Charging Pile, in addition, the State Grid Corporation also issued the relevant enterprise standards for charging and replacing facilities testing series. These standards are mainly in the current national standard GB/T 18487.1 Electrical Vehicle Conductive Charging System Part 1: General Requirements, GB/T 20234.1 Electrical Vehicle Conductive Charging Connections Part 1: General Requirements, GB/T 20234.2 Connecting device for conductive charging of electric vehicles Part 2: AC charging interface, GB/T 20234.3 Connecting device for conductive charging of electric vehicles Part 3: DC charging interface, industry standard NB/T 33001 Electric vehicle non-vehicle conduction. Charger safety test method and evaluation method based on the requirements of Technical Conditions for Charger and NB/T 33002 Technical Conditions for AC Charging Piles for Electric Vehicles.

6.7.1 DC charging equipment testing requirements

At present, the domestic non-vehicle charger testing standards are basically compliance testing standards, that is, the standard specifies low temperature, high temperature, damp heat, temperature rise, electric shock protection, insulation resistance, power frequency withstand voltage, steady current accuracy, electromagnetic compatibility, mechanical strength. Test items for electrical, mechanical, and safety performance, such as noise, to ensure the safety of off-board chargers during use. According to the status quo of China's electric vehicle industry development and safety standards, according to the environmental differences in various regions of China, the non-vehicle charger operating conditions and some testing indicators are adjusted and supplemented in time.

(1)General inspection

General inspections mainly include checking the appearance, signs, basic components, mechanical switchgear, anti-theft measures, charging mode and connection method, cable management and storage, and electrical isolation of off-board chargers and their components. It is mainly through visual inspection or simple test to confirm whether the off-board charger and its components meet the structural requirements.

(2)Functional test

The functional test mainly includes charging control function test, communication function test, insulation detection function test, DC output circuit short circuit detection function test, vehicle plug lock function test, precharge function test, display function test, input function test, metering power test, Emergency stop function test.

(3)Safety requirements test

Safety requirements test mainly includes input overvoltage protection test, input undervoltage protection test, output overvoltage protection test, output short circuit protection test, over temperature protection test, open door protection test, start emergency stop device test, input current overshoot test, battery Reverse test, anti-backflow function test, contactor adhesion test.

(4)Electric shock protection test

The electric shock protection test mainly includes direct contact protection test and power supply input loss test. Electric shock is the pathophysiological effect caused by current passing through the human body. When the current passes through the human body, it mainly affects the muscles, blood circulation and respiratory functions of the human body, and sometimes causes severe burns. The degree of damage to the human body is related to the magnitude of the current, the current passing through the body, and the duration of the current.

(5)Clearance and creepage distance test

The creepage distance is between two conductive parts measured along the insulating surface. Under different conditions of use, the insulating material around the conductor is charged, resulting in charging phenomenon in the charged area of the insulating material. The clearance is the shortest distance between two conductive parts or between the conductive parts and the equipment protection interface. That is to say, under the premise of ensuring the stability and safety of electrical performance, the air can reach the shortest insulation distance. In view of the rated insulation voltage level of the off-board charger, it corresponds to different clearances and creepage distances. The clearance between the small busbars, busbars or different exposed live conductors, and the clearance between the exposed live conductor and the uninsulated uncharged conductor shall be no less than 12 mm and the creepage distance shall be no less than 20 mm.

(6)Electrical insulation performance test

Electrical insulation performance test, mainly including insulation resistance test, power frequency withstands voltage test, impact withstand voltage test.

To measure the ability of an insulating material to "limit" current, the concept of insulating resistance is introduced, which is used to characterize the ability of an insulator to block current flow. The insulation resistance is too low, and the leakage current will be large, which not only causes waste of electric energy, but also causes heat generation and damages the insulator. Therefore, the insulation resistance is one of the basic parameters characterizing the characteristics of the insulator.

The power frequency AC withstand voltage test is the most effective and direct method for identifying the insulation strength of power equipment and is an important part of preventive tests. In addition, since the AC withstand voltage test voltage is generally higher than the operating voltage, the equipment has a large safety margin after the test, so the AC withstand voltage test is an important means to ensure the safe operation of the power equipment.

The impact withstand voltage test can be used to study the insulation performance of the charger when it is subjected to atmospheric overvoltage (lightning strike) and can also be used to study the insulation performance of power equipment subjected to operating overvoltage.

(7)Grounding test

Check that the grounding bolt diameter of the metal shell of the charger shall not be less than 6 mm and have a grounding mark; the door, cover, cover and other parts of the charger shall be connected with the fuser body frame by protective conductors. The cross-sectional area of the protective conductor measured by the gauge or vernier caliper shall not be less than 2.5 mm2; the resistance between any point in the charger that shall be grounded to the total ground shall not be greater than that measured by a bridge, grounding resistance tester or digital low-resistance tester. 0.1 Ω, the measuring point shall not be less than 3. If the measuring point is coated with anti-corrosive paint, the anti-corrosive paint shall be scraped off to expose the non-insulating material before testing. The grounding terminal shall have obvious mark; the internal working place of the charger and the protective grounds shall be independent of each other and shall be directly connected to the grounding conductors (copper bars). Multiple electrical devices that need to be grounded shall not be connected in series in one grounding wire.

(8)Charging output test

According to the different output characteristics of the current charger, the test points of the charger with constant power and no constant function are given. The output test of the charger mainly includes the maximum constant power output test, the power control test, the low voltage auxiliary power test, and the steady current precision. Test, voltage regulation accuracy test, voltage ripple factor test, current ripple test, output current setting error test, output voltage setting error test, current limiting characteristic test, voltage limiting characteristic test, output current response time test, output current stop rate test, start output overshoot test, output current measurement error test, output voltage measurement error test, measured value update time test, efficiency test, power factor test.

(9)Standby power consumption test

When the charger is not connected to the test system and there is no personnel operation, only the state of the basic functions such as background communication and status indicator is retained, and the standby power consumption of the measurement charger shall not be greater than N×50 W.

(10)Protocol conformance test

According to the method specified in GB/T 34658 *Communication Protocol Conformance Test between Electric Vehicle Off-Board Conductive Charger and Battery Management System*, the communication protocol for checking each vehicle interface of the off-board charger shall meet the standard requirements.

(11)Control guidance test

According to the method specified in GB/T 34657.1 *Electrical Vehicle Conductive Charging Interoperability Test Part 1: Power Supply Equipment*, the control guidance function of each vehicle interface of the off-board charger shall be checked to meet the standard requirements and be independent of each other. Mainly includes charging control state test, charging connection control timing test, control pilot voltage limit test, communication interruption test, protection ground conductor continuity test, connection detection signal disconnection test, output surge current test, battery voltage and communication message Inconsistent test, battery voltage exceeds charger range test, battery double protection function test, vehicle maximum allowable charging total voltage mismatch test, charging demand is greater than battery parameter test.

(12)Noise test

Noise is a combination of cluttered sounds of various frequencies and different intensities. Evaluate the performance of the off-board charger in a strong noise field and the ability to withstand strong noise and measure the response of the device to strong noise.

(13)Internal temperature rise test

The loss generated by the motor in the electromechanical energy conversion process is finally converted into the temperature rise of the motor components. When the single motor capacity of the electric motor drive motor is large, the motor volume is small, the motor heat dissipation environment is bad, and the operation will produce a high loss per unit volume, causing serious temperature rise problems, which affect the life and operational reliability of the motor. The circuit including the power supply input current flowing through the charger, such as the wiring terminal, the input circuit breaker, the input contactor, etc.; the power conversion unit and its internal components, the input and output terminals; the circuit through which the DC output current flows, Install temperature measuring components such as terminal blocks, DC fuses, DC contactors, power resistors, current sampling shunts, and vehicle plugs. The temperature can be measured using melted particles, change indicators or thermocouples.

(14)Allow temperature test

During the charging process, check that the charging interface is under rated load. The temperature of the metal material and non-metal material that can be touched by the charger and that is accessible but not hand-held shall meet the standard requirements.

(15)Mechanical strength test

Mechanical stress can be generated by impact testing of electrical equipment with different hammers. The impact of the charger can be assessed by impacting the charger under severe conditions.

(16)Protection test

The protection test mainly includes dustproof test, waterproof test, salt spray test, and rust preventive (antioxidation) test. The dustproof test is used to prevent solid foreign matter from entering the equipment inside the casing. The waterproof test is used to prevent harmful effects on the equipment due to water entering the casing. The salt spray test is used to improve the protection of key components such as printed circuit boards and connectors in the charger. Salt spray capacity, anti-rust (anti-oxidation) test is used to require a representative sample of the charger iron casing, exposed iron brackets, parts and non-ferrous metal casing for anti-rust treatment.

(17)Environmental test

Environmental tests mainly include low temperature test, high temperature test, and alternating heat and humidity test. The purpose of the environmental test is limited to the ability to determine the use of off-board chargers in low temperature, high temperature and hot and humid environments. Test whether the off-board charger can be placed under low temperature and high temperature conditions for a long time to achieve temperature stability, and the adaptability of use, transportation and storage under the combination of high humidity and temperature cycle change and surface condensation. Prevents harmful effects on off-board chargers due to temperature changes.

(18)Electromagnetic compatibility test

Electromagnetic compatibility tests mainly include electrostatic discharge immunity test, radio frequency electromagnetic field radiation immunity test, electric fast transient pulse group immunity test, surge (impact) immunity test, radiation disturbance test, and conducted disturbance test. Harmonic current test.

The electrostatic discharge immunity test is used to evaluate the performance of an electric vehicle's off-board charger when it is subjected to electrostatic discharge, and the electrostatic discharge that may occur when the human body is close to the charger.

Radio frequency electromagnetic field radiated immunity test to assess the effect of electromagnetic radiation on most electronic devices in some way.

The electrical fast transient burst immunity test is designed to evaluate the performance of the off-board charger's power supply port, signal, control, and ground ports when subjected to electrical fast transients (bursts).

Surge (impact) immunity test to find out the response of a surge (shock) voltage generated by a switch or lightning action to a certain level of damage when the charger is in a specified operating condition.

Radiation disturbance tests and conducted disturbance tests prevent the off-board charger from affecting radio broadcast and telecommunications services, while allowing other equipment to operate at a reasonable distance to meet predetermined requirements.

Harmonic current test, the rectifying device of the electric vehicle charger is the main reason for the electric vehicle charging station to connect to the power system to generate harmonics. The so-called harmonics are Fourier series decomposition of periodic non-sinusoidal electric power, except that the same component with frequency and power frequency is obtained (this component is called fundamental wave), and a series of components larger than the power frequency are obtained. It is called harmonics. As with many other forms of pollution, the generation of harmonics affects the overall (electrical) environment, and the extent of the impact may extend farther from its source.

6.7.2 AC charging equipment testing requirements

At present, the domestic AC charging pile testing standards are basically compliance testing standards, including electrical, mechanical and safety performance test items to ensure the safety of AC charging piles in use. At present, the technology of AC charging piles is still being continuously improved and updated. Especially in the interaction between AC charging piles and power grids, the demand for orderly charging is put forward. The new functions and technical requirements are in their infancy, and it is necessary to keep track of new electric vehicles. The development of technology ensures that the technical content of the standard is advanced and operability.

(1)General inspection

The general inspection mainly includes checking the appearance, signs, basic components, mechanical switch equipment, anti-theft measures, charging mode and connection mode, cable management and storage of AC charging piles and their parts. Mainly through visual inspection or simple test to see whether the electric vehicle AC charging pile and its components meet the structural requirements.

(2)Functional test

The functional test mainly includes the communication function test, the charging connection device check, the lock device check, the display function test, the input function test, and the measurement function test.

(3)Safety requirements test

The safety requirements test mainly includes output short circuit protection test, over temperature protection test, emergency stop protection test, contactor adhesion monitoring test, contact current test and leakage protection test.

(4)Internal temperature rise test

The circuit of the AC charging pile includes the input circuit of the power supply input current, such as temperature measuring devices including the fuse housing, the busbar connection, copper-copper, copper-bismuth-copper-bismuth-tin, copper-plated silver-copper-plated silver, etc. The temperature can be measured using melted particles, change indicators or thermocouples.

(5)Allow temperature test

During the charging process, check that the charging interface is under rated load. The temperature of the metal material and non-metal material that can be touched by the charger and that is accessible but not hand-held shall meet the standard requirements.

(6)Electric shock protection test

The electric shock protection test mainly includes direct contact protection test, open door protection test, and power supply input loss test.

(7)Clearance and creepage distance test

The creepage distance is between two conductive parts measured along the insulating surface. Under different conditions of use, the insulating material around the conductor is charged, resulting in charging phenomenon in the charged area of the insulating material. The clearance is the shortest distance between two conductive parts or between the conductive parts and the equipment protection interface. That is to say, under the premise of ensuring the stability and safety of electrical performance, the air can reach the shortest insulation distance. In view of the rated insulation voltage level of the off-board charger, it corresponds to different clearances and creepage distances. The clearance between the small busbars, busbars or different exposed live conductors, and the clearance between the exposed live conductor and the uninsulated uncharged conductor shall be no less than 12 mm and the creepage distance shall be no less than 20 mm.

(8)Insulation performance test

Electrical insulation performance test, mainly including insulation resistance test, power frequency withstands voltage test, impact withstand voltage test.

Generally speaking, the insulation is not completely electrically isolated. To measure the ability of the insulation material to "limit" the current, the concept of insulation resistance is introduced. The insulation resistance is used to characterize the ability of the insulator to block current flow. The insulation resistance is too low, and the leakage current will be large, which not only causes waste of electric energy, but also causes heat generation and damages the insulator. Therefore, the insulation resistance is one of the basic parameters characterizing the characteristics of the insulator.

The power frequency AC withstand voltage test is the most effective and direct method for identifying the insulation strength of power equipment and is an important part of preventive tests. In addition, since the AC withstand voltage test voltage is generally higher than the operating voltage, the equipment has a large safety margin after the test, so the AC withstand voltage test is an important means to ensure the safe operation of the power equipment.

The impact withstand voltage test can be used to study the insulation performance of the charger when it is subjected to atmospheric overvoltage (lightning strike) and can also be used to study the insulation performance of power equipment subjected to operating overvoltage.

(9)Grounding test

Check the grounding bolt diameter of the AC charging pile metal casing shall not be less than 6 mm and have a grounding mark; the door, cover plate, superstrate and similar parts of the charging pile shall be connected with the charging pile main frame by protective conductors. The cross-sectional area of the protective conductor measured by the gauge or vernier caliper shall not be less than 2.5 mm2; the resistance between any point in the charging pile that shall be grounded to the total ground shall not be measured by the bridge, grounding resistance tester or digital low-resistance tester. More than 0.1 Ω, the measuring point shall not be less than 3. If the measuring point is coated with anti-corrosive paint, the anti-corrosive paint shall be scraped off to expose the non-insulating material before testing. The grounding terminal shall have obvious mark; the internal working place of the charging pile and the protection ground shall be independent of each other and shall be directly connected to the grounding conductor (copper row). Multiple electrical devices that need to be grounded shall not be connected in series in one grounding wire.

(10)Standby power consumption test

For the AC charging pile below one unit, only the status of basic functions such as background communication and status indicator are retained, and the standby power consumption of the charging pile shall not be greater than 15 W.

(11)Control guidance test

In accordance with the method specified in GB/T 34657.1 "Electrical Vehicle Conductive Charging Interoperability Test Part 1: Power Supply Equipment", check the control guide of each power supply interface (connection mode B) or vehicle interface (connection mode C) of the AC charging pile. The lead function shall meet the standard requirements and be independent of each other. It mainly includes charging control state test, charging connection control timing test, control pilot voltage limit test, protective ground conductor continuity test, control pilot signal abnormal test, open switch S2 reclosing test, overcurrent test.

(12)Noise test

Noise is a combination of cluttered sounds of various frequencies and different intensities. Evaluate the performance of the AC charging pile in a strong noise field and the ability to withstand strong noise and measure the response of the equipment to strong noise.

(13)Mechanical strength test

Mechanical stress can be generated by impact testing of electrical equipment with a spring hammer. The impact of the AC charging pile can be assessed by impacting the AC charging pile under severe conditions.

(14)Protection test

The protection test mainly includes dustproof test, waterproof test, salt spray test, and rust preventive (antioxidation) test. The dust test is used to detect the ability of an AC charging post to prevent solid foreign objects from entering the casing. The waterproof test is used to test equipment to prevent the harmful effects of water entering the casing from harmful effects on the equipment. The salt spray test is used to improve the salt spray resistance of key components such as printed circuit boards and connectors in charging piles. The rust prevention (anti-oxidation) test is used to require the charging pile iron casing, exposed iron brackets, parts and non- A representative sample such as an iron metal casing is subjected to rustproof treatment.

(16)Environmental test

Environmental tests mainly include low temperature test, high temperature test, and alternating heat and humidity test. The purpose of the environmental test is limited to the ability to determine the use of off-board chargers in low temperature, high temperature and hot and humid environments. Test whether the AC charging pile can be placed under low temperature and high temperature conditions for a long time to achieve temperature stability, and the adaptability of use, transportation and storage under the conditions of high humidity and temperature cycle change combination and surface condensation. Prevents harmful effects on AC charging posts due to temperature changes.

(17)Electromagnetic compatibility test

Electromagnetic compatibility tests mainly include surge (impact) immunity test, electric fast transient pulse group immunity test, radio frequency electromagnetic field radiation immunity test, electrostatic discharge immunity test, and radiation test.

Surge (impact) immunity test to find out the response of a surge (shock) voltage generated by a switch or lightning action to a certain level of damage when the charger is in a specified operating condition.

The electrical fast transient burst immunity test is designed to evaluate the performance of the AC charging stub's power supply port, signal, control, and ground ports when subjected to electrical fast transients (bursts).

Radio frequency electromagnetic field radiated immunity test to assess the effect of electromagnetic radiation on most electronic devices in some way.

The electrostatic discharge immunity test is used to evaluate the performance of an electric vehicle AC charging pile subjected to electrostatic discharge and the electrostatic discharge that may occur when the human body is close to the charger.

Radiation tests prevent AC charging piles from affecting radio broadcasting and telecommunications services and allow other equipment to work at predetermined distances at predetermined distances.

6.7.3 Performance evaluation of charging equipment performance

6.7.3.1 Full life cycle detection

The whole life cycle test emphasizes the continuous and coordinated detection of the life-cycle development process of the charging equipment, ensuring the convergence of activities at various stages, and the consistency of decision-making at each stage. Under the premise of meeting the requirements of functional performance indicators, make optimal input of human and material resources during the life cycle of the charging equipment. Subjects that apply to the life cycle approach must meet two conditions, namely the characteristics of life and the finiteness of existence. The electric vehicle charging facility meets these two conditions, and thus the electric vehicle charging facility is researched, and the full life cycle method is innovatively applied to the detection of the electric vehicle charging facility.

The whole life cycle detection of charging equipment refers to the comprehensive implementation of charging equipment from the planning, demonstration, research and development, mass production, delivery, delivery, commissioning, use until the depreciation of the charging equipment or before the end of the period. Reasonable detection, establish a unified inspection schedule, use workflow technology, string together the data flow generated in each link of the charging equipment life cycle, form a closed-loop detection of the charging equipment from research and development to operation and maintenance, and dynamically adjust each The testing items and requirements of the charging equipment finally reach the goal of ensuring the quality and technical indicators of the charging equipment. The life cycle detection of the charging device is roughly divided into three stages: pre-detection of the charging device, mid-term detection of the charging device, and post-detection of the charging device.

(1)Early detection of equipment. The pre-testing contents of the charging equipment mainly include the testing of the equipment development stage and the type test stage detection before the mass production of the equipment. The pre-test ensures the equipment is technically advanced, economically reasonable, applicable in production, and meets the testing standards. The pre-testing of the charging equipment is important because it: 1 improves the investment efficiency of equipment, because it has the largest proportion of investment in the entire life cycle testing; 2 determines the quality and level of equipment to ensure the efficiency of equipment use. In research and development, for charging equipment, the detection order of electrical performance, mechanical performance, safety performance, etc. is followed in the development of the test to ensure that the standard requirements are met before the type test; in the type test, all the test standards are to be completed. The project is specified, and the indicator meets the standard requirements.

(2)Mid-term testing of charging equipment. The mid-term inspection of the charging equipment includes the detection of the factory stage and the inspection of the arrival stage. The mid-term inspection ensures the quality technical standards of the charging equipment during mass production and transportation, laying a good foundation for the future operation of the equipment. In the mass production process of charging equipment, there will be some advantages and disadvantages of the equipment produced, and there will also be charging equipment that is not up to standard. The goal of testing at the factory stage is to eliminate equipment that does not meet the technical specifications and ensure the qualified equipment. Rate; equipment faces various challenges in the process of transportation and disassembly, resulting in equipment failure at the time of arrival, so it is necessary to carry out the arrival test of the equipment.

(3)Late detection of the charging device. The post-testing of the charging equipment is the detection of the installation phase of the equipment, including the detection and operation and maintenance phases of the commissioning phase. During this period, the detection is complicated, and the time span is large, accounting for most of the life cycle of the charging equipment, which is an important part of the life cycle detection of the charging equipment. The post-testing ensures the normal operation of the charging device, and at the same time eliminates the safety hazard of the device during operation. Therefore, it is of great significance to carry out the detection during the commissioning and operation and maintenance phases of the charging device. Proper use and maintenance, maintenance equipment can keep the equipment in good condition, meet the technical indicators of detection, reduce or prevent sudden failures and abnormal shutdown, so that the charging equipment can maximize its efficiency and improve the efficiency of the equipment.

Once the charging device is scrapped, it does not make sense to detect the charging device, so the detection of the charging device is not performed from the stage of the life cycle.

The life cycle detection of charging equipment adheres to the consistency and consistency of the inspection ideas. It not only pays attention to the functional testing of charging equipment, but also pays attention to the planning and distribution of testing items. Through reasonable planning of charging equipment resources, it is aimed at different life periods of equipment. The effective and reasonable configuration of the test items not only enables the charging device to meet the performance requirements of each stage, but also avoids the repeatability of the charging device detection items, reduces the cost of the charging device detection, and satisfies its economy.

6.7.3.2 Performance evaluation system

Establishing the performance evaluation system of the charging equipment is an effective method for judging the performance status of the charging equipment. Each evaluation index in the performance evaluation system of the charging equipment can measure the performance of a certain aspect of the evaluated charging equipment, and thus the performance evaluation established. The pros and cons of the system will directly affect the correctness of the discrimination results of the performance status of the charging device. In order to establish a scientific performance evaluation system for charging equipment, the performance status of the evaluated charging equipment is fully reflected. The establishment of the performance evaluation system must comply with the principles of integrity, scientific principles, objectivity, operability, independence, the principle of combining qualitative analysis with quantitative analysis.

(1)Principle of completeness. The evaluation system must be able to comprehensively evaluate the evaluated objects. The evaluation targets are different, and the selected evaluation indicators are different. The evaluation indicators must be selected according to the characteristics of the evaluation objects. However, the selected evaluation indicators shall not be too singular, and must cover all aspects. It is necessary to reflect the main situation of the evaluated objects from different aspects, so as to establish a hierarchical indicator system to make the evaluation system an organic whole.

(2)Scientific principles. In order to establish a scientific evaluation index system, the evaluation indicators must reflect the status of all aspects of the evaluation object scientifically and objectively. Any evaluation is carried out around the evaluation objectives. The scientific nature of the evaluation requires the evaluator to scientifically and reasonably measure the evaluated object and achieve the evaluation target under certain constraints. The scientific performance of the evaluation indicators is that the evaluation indicators are in line with objective reality and conform to the scientific theory that has been proved by practice.

(3)The principle of objectivity. The selection of evaluation indicators shall be based on objective facts and cannot be subjectively determined. On the basis of extensive scientific analysis and relevant literature review, a well-defined evaluation system is established. The evaluation indicators of the charging equipment are determined on the basis of reviewing existing domestic and foreign relevant standards and a large number of scientific analysis and consulting the relevant technical personnel.

(4)Operational principle. The evaluation indicators shall be measurable and comparable, that is, the evaluation indicators can be qualitatively or quantitatively measured, and the similar indicators can be compared with each other. The selected evaluation indicators must be clearly defined, the relevant data is easy to obtain, and the calculation is simple and feasible.

(5)The principle of independence. The evaluation indicators shall be as independent as possible from each other. Try to avoid repeated consideration of a certain aspect of the evaluation object, make the evaluation system concise, reduce the redundancy of the evaluation indicators, and make the evaluation results more accurate and not distortion.

(6)The principle of combining qualitative analysis with quantitative analysis. In order to fully reflect the situation of the evaluated objects, there shall be qualitative indicators and quantitative indicators in the evaluation indicators and quantify the qualitative indicators to lay the foundation for the method of quantitative evaluation.

6.8 Manufacture of charging equipment

The product quality of the charging equipment is the basic condition for ensuring the safety of charging. The charging equipment manufacturing manufacturer shall establish a quality management system according to the relevant requirements of ISO9001 and IATF16949, form a manufacturing quality management document and process system, and implement and maintain it. And continue to improve to meet the legal requirements of product quality, environmental and occupational health and safety management.

The quality management system for charging equipment manufacturing shall be managed from the aspects of design and development quality, supplier and material quality, manufacturing process quality, inspection and testing quality, and process system quality, including the following quality process systems:

1) Design and development project management

Effectively carry out product development work, ensure that products meet customer and national standards, improve product quality; provide standardized operation procedures for new product development, as a basis for product development.

2) Product manufacturing management procedures

Ensure that the product manufacturing process is controlled, and that the quality system and products continue to be effective, suitable for the company's mass production products.

3) Production planning and delivery management procedures

Ensure the 100% on-time delivery of orders by summarizing and reviewing sales orders/sales forecast orders, planning sales plans, production plans, material requirements planning, purchase delivery schedules, and facilitating the effective execution of all plans. Applicable to the compilation, review, planning, sales planning, production planning, material demand planning, procurement delivery planning and management implementation of sales orders/sales forecast orders.

4) Project management program

Comprehensively implement national, local, and industry-related laws and regulations, promote the normal and orderly management of the company's engineering and technical management, provide technical support for the company's construction and production activities, promote the standardization and standardization of enterprise engineering management, and strengthen the quality management of construction projects. To ensure the normal operation of the project construction and the realization of project management technology and quality objectives.

5) Operation and maintenance service management program

With the goal of establishing a quality engineering service system, improve the engineering service system and improve the quality of the company's operation and maintenance services.

6) Document and record control procedures

Standardize the application, preparation, distribution, use, revision, abolition, management and maintenance of various controlled documents/records within the company. In order to maintain the identification and collection of documents/records, archive storage and maintenance, search, recovery and destruction processing, etc., to prove the effective operation of the system.

7) Human Resource Management Procedures

In order to maintain stable development of the company's human resources, establish a fair, open, fair and efficient human resources system, enhance the professional knowledge and work skills of employees, and promote the selection and cultivation of outstanding talents.

8) Equipment tooling management program

In order to standardize the equipment from the application to the end of the process, life-long management, to ensure the normal operation of the equipment and reasonable use.

9) Procurement management procedures

Use the reasonable cost to obtain the most appropriate quantity, load specification and quality materials with the highest efficiency at the most needed time and place, and hand it over to the required department; at the same time establish a written procedure to ensure the purchase product load specification requirements.

10) Supplier Management Program

In order to ensure that new suppliers meet development requirements and ensure product quality, the company establishes and develops a stable supplier development system and daily management of suppliers.

11) Logistics management procedures

The logistics management process is controlled from the suppliers' materials, logistics, in-plant logistics and delivery logistics to ensure that the logistics management process meets the requirements of the quality management system.

12) Warehousing management procedures

To standardize warehouse site management, strengthen company warehouse safety management, ensure warehouse material accuracy and ensure warehouse personnel and items safety

13) Laboratory management procedures

To regulate the management and testing methods of the laboratory inside and outside the company.

14) Measuring equipment management program

Selection and calibration of inspection, measurement and test equipment. Maintenance and management are effectively controlled to ensure that the measurement accuracy and accuracy of the equipment used meet the requirements of use.

15) IT management program

In order to ensure the normal operation and maintenance of the company's information system, the problems in the process of using the information system can be solved in a timely manner, and the workflow between the information center and various departments can be standardized.

16) Non-conforming product management procedures

The identification, recording, review, isolation and disposal of suspicious and unqualified products or materials are effectively controlled by non-conforming products produced during the stages of incoming materials and processes, preventing misuse of non-conforming products and ensuring that non-conforming products do not flow. The next process.

17) Process and finished product inspection

Ensure that the quality of the feed, process, finished product and shipment is effectively controlled to meet customer requirements.

18) Feed inspection management program

Define the company's material incoming inspection procedures and warehouse material re-examination inspection procedures to ensure that the feed quality characteristics meet the company's requirements, and control the quantity and duration of the feed so that it does not affect the factory production schedule and ensure that the incoming quality meets the specifications. Requirements, and ultimately make the product quality meet customer requirements.

19) Management procedures

The SPC statistical process is controlled to ensure that the organization conducts process studies for all new manufacturing, validates process capabilities, and provides additional inputs for process control.

20) System Audit Management Procedure

Ensure that system audits are effectively implemented and verify the effectiveness and compliance of the company's management system implementation.

21) Process Audit Management Procedure

Identify defects and take action to improve processes and optimize systems by assessing the quality capabilities of products and processes.

22) Product Audit Management Procedure

Review whether the products that have passed the final inspection and are ready for delivery are consistent with the customer's characteristic data to determine the quality of the product and trace the cause of the quality defect.

23) Management Review Management Procedure

Review the continuous suitability, adequacy and effectiveness of the company's quality management system to ensure that the system and its operational effects continue to improve.

24) Continuous improvement management procedures

In order to ensure the effectiveness of the company's quality, occupational health, safety and environmental management system, we will continue to improve.

6.9 Construction of charging facilities

In terms of safety production management of charging facilities, adhere to the principle of safety first and prevention first, and establish and improve the responsibility system of safety production and the system of mass prevention and mass control. Engineering design and construction shall conform to the building safety regulations and technical specifications formulated in accordance with the national provisions and ensure the safety performance of the project.

6.9.1 Charging station construction planning and location layout of charging station

(1)The location of charging station shall be closely combined with the planning and construction of urban medium and low voltage distribution network to meet the requirements for power supply reliability, power quality and automation.

(2)In terms of the planning of charging station, make full use of the public facilities such as power supply, transportation, firefighting, water supply and drainage, flood control and drainage nearby. It shall keep a reasonable safe distance from the important or densely personneled public buildings such as Party and government office buildings, primary and secondary schools, kindergartens, hospital outpatient buildings and inpatient buildings, large libraries, cultural relics and monuments, museums, large gymnasiums and cinemas.

6.9.1.2 Environmental requirements for charging station

(1)Charging station shall not be close to potential fire or explosion hazards. When adjacent to buildings with explosive hazards, it shall comply with the relevant regulations of *Current National Standard for the Design of Electric Power Devices in Explosive Hazardous Environment* (GB 50058);

(2)Charging station shall not be located in dusty or corrosive gas places, and shall not be located in the downwind side of the prevailing wind of pollution sources when it cannot be far away;

(3)The charging station shall meet the requirements for environmental protection and fire safety, and the fire protection spacing between the charging station and other buildings and structures shall meet the requirements of *Code for Fire Protection in Design of Thermal Power Plant and Power change station* GB50229 and *Code for Fire Protection in Architectural Design* GB50016;

(4)The location of charging station shall avoid low-lying outdoor areas, places prone to water accumulation, and places prone to secondary disasters and severe vibration;

(5)The charging area shall have certain ventilation conditions;

(6)The ambient temperature of charging station shall meet the requirement of normal charging for electric vehicle battery;

(7)In areas where severe wet weather may occur, equipment and means for monitoring and treating air humidity shall be provided;

(8)When charging equipment is installed indoors, ventilation facilities shall be installed to prevent excessive temperature;

(9)Charging equipment shall be installed at a certain height from the ground to prevent rain and water seepage.

6.9.2 Safety design requirements for charging station

(1)Station layout

The station includes buildings inside the station, lanes inside and outside the station, charging area, temporary parking area and the power supply and distribution facilities. The general layout of the station area shall meet the requirements for the overall planning, and conform to the principles of rational process layout, clear functional zoning, convenient transportation and land saving. The layout of the buildings in the station shall be convenient to observe the charging area. The accesses of the station shall be smoothly connected with the municipal road outside the station.

(2)Equipment layout

The arrangement of charging equipment shall not hinder the charging and passage of other vehicles. Meanwhile, measures shall be taken to protect the safety of charging equipment and operators. The layout of electrical equipment shall follow the principles of safety, reliability and applicability, and be convenient for installation, operation, treatment, and maintenance and commissioning. In case of serious charging safety accident, other users shall have sufficient time to escape. After the accident occurs, multi-level rescue operations, such as firefighting and medical treatment, can be realized quickly to ensure the safety of life and property.

(3)Charging station shall meet the requirements for environmental protection and fire safety

The fire hazard classification of charging station construction (structure) shall conform to the relevant regulations of current national standards *Code for Fire Protection Design of Thermal Power Plants and Power Transformers* (GB 50229) and *Code for Fire Protection in Architectural Design* (GB 50016). The fire protection spacing between the charging area and the building (structure) of the distribution room in the charging station and the buildings inside and outside the station shall conform to the relevant regulations of the current national standards *Code for Fire Protection in Architectural Design* (GB 50016) and *Fire Protection of High-rise Civil Architectural Design* (GB 50045). The classification of the corresponding workshop of the charging station building (structure) shall conform to the regulations of Table 4.9-1.

(4)The site shall not be close to the places with potential fires or explosive danger. When adjacent to buildings with explosive hazards, it shall comply with the relevant regulations of the current national standard *Code for Design of Electric Power Devices in Explosive Hazardous*

Environment (GB 5058).

(5)Charging station constructed in automobile gas station

The construction shall conform to the current national standard *Design and Construction Code for Automobile Gas Station* (GB 50156). The distribution of charging piles shall be in the auxiliary service area. Box power change stations, distribution boxes and charging piles are classified into types C, D and E. The safe distance between box power change stations and refueling, gas storage tanks and equipment shall meet the regulations of Table 4.9 2-4.

(6)For charging station with low voltage 0.38kV power supply, when power cable is used for power supply, the power supply distance shall not exceed 200m.

(7)Charging equipment shall be arranged close to the charging parking space for charging.

The net distance between the outer contour of the equipment and the edge of the charging parking space shall not be less than 0.4m. The arrangement of charging equipment shall not hinder the charging and passage of other vehicles. Meanwhile, measures shall be taken to protect the safety of charging equipment and operators.

(8)The setting of roads in charging stations shall meet the requirements for access of firefighting and service vehicles.

There shall be not less than 2 accesses of charging station. There shall be one access for not more than 50 parking spaces of charging station, an entrance and exit shall be set separately, and clearly indicated and marked.

(9)When charging space is arranged in the double-row way in charging station, the middle lane shall be set up in double-lane way according to the type of vehicle. When charging parking space is arranged in the unit-row way, the lane shall be set up in double-lane way according to the type of vehicle.

(10)The construction of charging site shall ensure that there is the safe distance of more than 3m between the charging vehicle and other vehicles.

6.9.3 Building safety

(1)Design requirements for seismic, rainfall, wind and lightning protection Architectural design shall meet the *Code for Load of Building Structures* (GB 50009- 2012), *Code for Design of Concrete Structures* (2015 edition) (GB 50010-2010), *Code for Design of Building Foundation* (GB 50007-2011), *Code for Seismic Design of Buildings* (2016 edition) (GB 50011-2010) and *Design Code for Protection of Structures Against Lightning* (GB 50057-2010) to ensure safety, applicability, economy and rationality.

(2)Design requirements for anti-collision parking

In order to ensure the safety of charging infrastructure, effective measures shall be set up to prevent electric vehicles from colliding charging facilities.

6.9.4 Requirements for transformer and distribution

1.The overall design of power change station meets requirements for safety

Charging station shall not be close to potential fire or explosion hazards. When adjacent to buildings with explosive hazards, it shall comply with the relevant regulations of *Current National Standard for the Design of Electric Power Devices in Explosive Hazardous Environment* (GB 50058). The safe distance of box power change station shall meet the national standard *Code for Fire Protection in Architectural Design* (GB 50016-2006).

2.With the reasonable capacity configuration, the design of high and low voltage transformer meets the requirements for safety.

(1)Transformer capacity shall not be greater than 1250kVA. When electrical equipment with large capacity and concentrated load is reasonably operated, the transformer with larger capacity can be selected.

(2)The non-combustible transformer shall be selected, and the protection grade of the casing shall not be lower than IP2X.

(3)Transformer cabinet, bracket, foundation section steel and casing shall be separately and reliably connected with protective conductor with complete fasteners and anti- loosening parts.

(4)The middle and low voltage distribution system shall be connected by unit bus by sections. TN-S system is suitable for low voltage grounding system.

(5)Circuit breaker is suitable for low-voltage inlet and outlet switch and sectional switch. Mechanical and electrical interlocking devices shall be installed between low- voltage incoming circuit breakers and low-voltage sectional circuit breakers from different power sources to prevent parallel operation of different power sources.

(6)Low-voltage incoming circuit breaker shall have short-circuit instantaneous, short-circuit short-time delay, long-time delay and grounding protection functions. It is advisable to install the excitation release device, not the loss (low) pressure release device.

(7)Radioactive power supply is suitable for non-vehicle chargers, monitoring devices and important electrical equipment.

(8)Switchgear shall be miniaturized, oil-free, repair-free or less maintenance products.

(9)Five-core cable is suitable for low-voltage three-phase loop and three-core cable for unit-phase loop, and the section of neutral line shall be the same as that of phase line.

(10)Power and lighting shall share transformers.

3.Reasonable cable selection, optimized route, reasonable and safe laying

If the power change station is close to the charging facilities, the low-voltage cable shall be as shortest as possible. Copper core XLPE insulation type and flame retardant cable shall be selected for power cables. Protective measures shall be taken when cabling is likely to be damaged by mechanical external force, vibration, immersion and corrosive or contaminant substances. Defects such as wringing, armored squash, sheath faults and serious hurt on the surface must be forbbiden for the cable laying.

4.The selection of distribution boxes meets the national compulsory acceptance criteria

(1)Reliable protection against electric shock shall be provided in the distribution box. The grounding conductor bars in the device shall have bare terminals connected with the external grounding conductor, and shall be reliably connected. When the design is not required, the minimum cross-sectional area of the connecting conductor shall conform to regulations of the current national standard *Code for Design of Low Voltage Distribution* (GB 50054).

(2)Distribution box foundation shall be grounded reliably.

6.9.5 Subsidiary building

6.9.5.1 Necessary awning, cable trench and other ancillary buildings

In order to ensure the safety of charging facilities and charging process, the charging infrastructure shall be equipped with necessary ancillary facilities such as awning, whose requirements for design and construction meet the requirements of relevant national and industrial standards.

6.9.5.2 Equipped with effective lightning protection grounding system

Effective lightning protection and grounding measures shall be taken for buildings and charging facilities, and meet the requirements of national and industrial codes like *Design Code for Protection of Structures Against Lightning* (GB 50057-2010).

6.9.6 Clear safety identification

Charging facilities shall be equipped with obvious safety signs to ensure smooth and safe operation process.

6.9.7 Weak current and monitoring system

6.9.7.1 Weak current equipment design meets requirements for safety

Weak current equipment shall meet the requirements for lightning protection, grounding, fire prevention, power outage prevention and static electricity protection, so as to ensure the normal operation of weak current system.

6.9.7.2 Charging monitoring

(1)Charging monitoring system shall collect information such as working status, temperature, and fault signal, power, and voltage, current and electric energy of charging equipment.

(2)Charging monitoring system shall realize the control and adjustment functions of issuing control commands to charging equipment, remote starting and stopping, timing, emergency stopping, remote setting of charging parameters, etc.

6.9.7.3 Power supply monitoring

(1)The power supply monitoring system shall include switch status, protection signal, and voltage, current, active power, reactive power, power factor, and energy metering information of the charging station power supply system.

(2)The power supply monitoring system shall be able to control the separation of load switches or circuit breakers in the power supply system.

(3)The power supply monitoring system of large and medium-sized charging stations shall have data processing functions such as over-limit alarm, event recording and fault statistics.

6.9.7.4 Safety and protection monitoring

6.9.7.4.1 Safety and protection monitoring system

(1)The design of safety monitoring system for large charging station shall be set up with video safety monitoring system, intrusion alarm and entrance and exit control design in accordance with the relevant regulations of the current national standard *Technical Specification for Safety Protection Engineering* (GB 50348). Small and medium-sized charging stations can be simplified appropriately.

(2)The design of video safety monitoring system shall conform to the relevant regulations of the current national standard *Code for Design of Video Safety Monitoring System Engineering* (GB 50395). According to the requirements of safety management, monitoring cameras shall be set in charging area and business window of charging station. It shall have a linkage interface with fire alarm system.

(3)The design of intrusion alarm system shall conform to the relevant regulations of *Code for Design of Intrusion Alarm System Engineering* (GB 50394). According to the requirements for safety management of charging station, intrusion detectors are installed in the power supply area and monitoring room of charging station.

(4)The design of entrance and exit control system of charging station shall conform to the relevant regulations of *Code for Engineering Design of Entry and Exit Control System* (GB 50396). According to the requirements for safety management of charging station, entrance and exit control equipment shall be set up at the entrance and exit of charging station.

6.9.7.4.2 Requirements for monitoring system

(1)The camera shall be installed near the surveillance target and not vulnerable to external damage. The installation position shall not affect the operation of the equipment on site and the normal activities of the personnel. In case of indoor installation, the height shall be 2.5 to 5m away from the ground; In case of outdoor installation, please keep 3.5 to 10m distance from the ground, in other words, not smaller than 3m.

(2)The camera lens shall avoid direct light, and ensure that the image in the camera surface will not be damaged by strong light. In the field of view of the lens, there shall be no objects that can occlude the surveillance target.

(3)All detection points need to support 24-hour uninterrupted video recording, planning video and other modes, administrators can choose according to different needs;

(4)The retention time of audio and video information collected by video surveillance system shall not be less than 30 days, and the storage and playback of audio and video information shall have original integrity.

(5)All detection points can also see the scene images in the absence of light at night.

(6)The system shall have networking function to satisfy remote users to watch video through the network.

6.9.8 Fire safety

6.9.8.1 Requirements for fire protection of buildings (structures)

(1)Combustion performance, fire resistance limit, fire protection spacing between buildings (structures) in charging station and civil buildings (structures) outside the station, and all kinds of factory buildings, warehouses, yards and storage tanks shall comply with the regulations of Chapter 3 of GB 50016-2006.

(2)The doors of transformer room, distribution room and battery room shall be opened in the direction of evacuation. When public walkways or other rooms are outside the door, Class B fire prevention doors shall be adopted. Two-way spring doors made of non-combustible materials shall be used as doors in the middle partition wall.

(3)The doors of monitoring room, office and lounge shall be made of non-combustible materials and opened outwards. The door shall lead to a place without explosion or fire hazard. The windows of non-explosive structure shall be set in the direction without explosion and fire hazard;

(4)Fire retardant or separating measures shall be taken to prevent the spread of cable fire at the entrance of cable from outdoor to indoor, at the entrance of cable shaft, at the junction of cable, between monitoring room and cable interlayer, and in cable trench or cable tunnel with the length of more than 100m. One or more of the following measures shall be taken according to the scale and importance of charging station;

(5)Fire-proof partition wall or partition board is used, and fire-proof material is used to plug the holes through the cable;

(6)The cable is partially coated with fire-proof paint or partially coated with fire-proof belts and fire-proof tank boxes.

6.9.8.2 Fire prevention of power equipment

(1)The fire resistance grade of transformer room, distribution room and outdoor electric power equipment, and the fire prevention distance between transformer room, distribution room and other buildings (structures) and equipment shall conform to the regulations of Chapter 11 of GB 50229-2006.

(2)The requirements for fire safety of electric power equipment shall comply with the relevant regulations of *General Fire Fighting Regulations for Power Equipment* DL 5027.

(3)Power cables shall not be laid in the same trench as thermal pipelines, flammable, explosive and combustible gas pipelines or liquid pipelines.

(4)For live equipment, dry powder extinguishers, halogenated alkanes extinguishers or carbon dioxide extinguishers shall be provided, but carbon dioxide extinguishers equipped with metal horn nozzles shall not be provided.

(5)According to different energy storage devices, special fire extinguishers shall be equipped. If there is no special fire extinguisher, measures for isolation (such as covered by dry sand) shall be provided according to the characteristics of the ignition material.

6.9.8.3 Firefighting facilities and alarm devices

Fire design shall meet the requirements of national and industrial codes such as *Code for Fire Protection in Architectural Design* (2018 edition) (GB 50016-2014) and *Code for Design of Fire Extinguisher Configuration in Buildings* (GB 50140-2005). There shall be reasonable firefighting equipment, smooth fire evacuation passage, and clear fire fighting signs and the environmental conditions of the place where the firefighting facilities are placed or installed shall conform to the regulations and requirements of the production plant.

1.Fire types of electric vehicle charging station

The main types of fire in electric vehicle charging station are type A and type E, which are defined as follows:

Class A fire: Solid material fires;

Type E fire (live fire): Fires caused by materials burning with electricity;

2.Selection of the fire extinguisher

(1)The selection of fire extinguishinger shall be based on the principle of improving the effectiveness of fire extinguishing and reducing the impact on equipment and human body;

(2)Water type extinguishers, ammonium phosphate dry powder extinguishers, foam extinguishers or halogenated alkane 1211 fire extinguishers shall be selected for Type A fire sites;

(3)Ammonium phosphate dry powder fire extinguisher, sodium bicarbonate dry powder fire extinguisher, halogenated alkane 1211 fire extinguisher or carbon dioxide fire extinguisher shall be selected for Type E fire sites. However, carbon dioxide fire extinguishers equipped with metal horn nozzles shall not be used;

(4)Ammonium phosphate dry powder fire extinguishers can cover type A, B, C and E fire types, so all fire extinguishers in charging stations are ammonium phosphate dry powder fire extinguishers.

3.Configuration level and number

(1)In the charging parking area, 3A fire extinguishing grade and 5kg portable ammonium phosphate dry powder extinguisher are adopted;

(2)The configuration of portable fire extinguisher is related to the number of parking spaces and charging equipment. One fire extinguisher shall cover two DC charging piles, one fire extinguisher shall cover four 7kW charging piles and there shall be at least two fire extinguishers in a unit location;

(3)For charging stations without shed, protective measures to prevent direct sunshine and rain shall be built for fire extinguishers.

4.Alarming apparatus

(1)The charging station shall be set up with the automatic fire alarm system. When fire occurs or it is threatened by fire, the power supply shall be cut off immediately;

(2)When flammable gas or toxic gas may appear in the room, the corresponding detection alarm shall be set up.

6.9.8.4 Fire-fighting water supply

(1)The design of fire water supply pipeline and hydrant shall conform to the relevant regulations of GB 50016-2006.

(2)A water spraying fire extinguishing system shall be designed in accordance with the regulations of GB 50219.

6.9.8.5 Fire power supply and lighting

(1)Fire pumps, fire detection and alarm and fire extinguishing systems, and fire emergency lighting shall be supplied according to level-II load;

(2)Fire-fighting electrical equipment shall adopt the separate power supply loop. When production and domestic electricity is cut off due to fire, fire-fighting electrical power shall still be guaranteed, and its distribution equipment shall be marked clearly;

(3)The distribution circuit of the electrical equipment for fire-fighting shall meet with the requirements for continuous power supply during fire;

(4)Fire emergency lighting shall be set up in control room, distribution room, fire pump room and evacuation passage;

(5)The illuminance of the emergency lighting for personnel evacuation shall not be lower than 0.5 lx and the emergency lighting working continuously shall not be lower than 10% of the illuminance for normal lighting;

(6)Continuous power supply time of standby power supply for fire emergency lighting shall not be less than 30 minutes.

6.9.8.6 Lightning protection

(1)The requirements for lightning protection of charging stations shall comply with the relevant regulations of GB 50057 and DL/T 620.

(2)When the charging station is equipped with special power transformer, the power line shall be buried with metal sheath or insulated sheath cable to be introduced into charging station through steel tube. The metal sheath of power cable or both ends of steel tube shall be grounded near and reliably;

(3)Signal cables shall access the charging station from underground, and corresponding signal arresters shall be installed at the inner core of the cables. Both arresters and empty cables in the cables shall be protected and grounded. It is strictly forbidden to lay overhead cables in the station area;

(4)The normal non-charged metal parts of the charging station power supply equipment and the grounding end of the arrester shall be protected and grounded, and zero-connection protection shall be strictly prohibited;

(5)The lightning protection ground wire inside the electrical equipment shall be connected to the shell nearby.

6.9.8.7 Others

(1)Charging station shall have access for safe evacuation of personnel in monitoring room, office, lounge and charging area;

(2)The safety of charging station facilities and charging vehicles, power batteries and operators during charging operation shall be improved;

(3)Effective isolation measures and striking warning signs shall be taken to prevent unrelated personnel from entering the charging station.

6.9.9 Construction of charging station

Construction units, survey units, design units, engineering supervision units and other units concerned with safety in production of construction projects must abide by the provisions of safety in production laws and regulations such as the *Construction Law of the People's Republic of China*, *Safety Production Law of the People's Republic of China* and *Regulations on Safety in Production Management of Construction Projects*, guarantee the safe production of construction projects and assume the responsibility for the safe production of construction projects according to law.

The construction enterprises shall take measures aimed at maintaining safety, preventing dangers and fires at the construction site. When condition allows, the construction site shall be sealed up.

6.9.9.1 Safety construction preparation

(1)It shall provide the water supply, drainage, power supply, gas supply, heat supply, communication, radio and television and other underground pipelines information, meteorological and hydrological observation data, relevant data of adjacent building and structure and underground project to the relevant party in construction and adjacent area for Party B. All these data shall be true, accurate and complete;

(2)Be responsible for reviewing whether the technical safety measures and special construction schemes in the organization and design of construction meet the mandatory construction standards;

(3)Where the general contractor subcontracts the construction project to other units according to law, the rights and obligations in respect of safety in production shall be clearly defined in the subcontract. The general contractor and the subcontractor shall bear joint and several responsibilities for the safe production of the subcontracted projects.

6.9.9.2 Safety management in construction process

(1)The main person in charge of the construction unit is fully responsible for the safety production of the unit in accordance with the law. The construction unit shall establish and improve the responsibility system for safety production and the training system for safety production education, formulate rules and regulations for safety production, ensure the effective use of safety production costs, organize and formulate safety construction measures according to the characteristics of the project, eliminate hidden dangers of safety accidents, and report production safety accidents promptly and truthfully;

(2)Operators shall receive safety education and training before entering new positions or new construction sites. Personnel who fail to pass the educational training or examination shall not be allowed to work on their posts.

6.9.9.3 Requirements for engineering acceptance

The acceptance shall be carried out in accordance with the relevant acceptance criteria of the state and industry. The completed construction project may be put into use only after it has passed the acceptance inspection; Construction projects having not been examined and accepted or having failed in examination shall not be delivered for use. All acceptance data must be stored in the construction archives, which shall meet the requirements of *Code for Archiving Construction Engineering Documents* GB/T 50328-2014.

6.10 Safety requirements for operation and maintenance of charging facilities

6.10.1 Safety risk identification and preventive measures

6.10.1.1 Safety risk identification of charging system

Daily inspections shall be carried out to eliminate potential safety hazards such as electrical grounding of equipment, anti-electric shock of high-voltage insulation, aging of charging gun, leakage of electricity, overheating, overload, waterproof, failure of fire control logic, etc.

6.10.1.2 Safety protective measures

6.10.1.2.1 Safety precautions for charging equipment

(1) Anti-electric shock risk: Charging equipment is equipped with special keys, which are maintained by professionals. It is necessary to do a good job of the cabinet grounding protection function, and the main input switch shall be configured with leakage protection function; Charging gun: The high-voltage DC side avoids leakage risk through pile end insulation detection before charging and vehicle end insulation detection during charging;

(2) The charger is equipped with AC input circuit breaker with short circuit and overload protection functions to ensure the safety of the front stage. A fast fuse with short circuit and overload protection is added between the charger and the electric vehicle to ensure the safety of the rear end after risk. The redundant protection function of software function and the charging strategy of multiple protection functions can ensure the charging safety;

(3) The charging control logic fully meets the new national standard, which requires charging piles and electric vehicles to fully comply with it;

(4) Through structural design and software simulation, the system heat dissipation and protection functions can meet the requirements. At the same time, in the system design, secondary protection functions shall be provided after the protection or heat dissipation failures, so as to ensure the adaptability of the charging process of the system to the environment.

6.10.1.2.2 Information safety risk prevention and control

6.10.1.2.2.1 Requirements for vulnerability scanning

(1) It is necessary to periodically scan all hosts in the platform for vulnerabilities. When there are major safety risks or risk early warning, it is necessary to scan the vulnerabilities of hosts involved in safety risks immediately;

(2) Vulnerability scanning tools shall adopt special scanning tools which are tested by national authoritative assessment agencies. Vulnerability scanning devices and vulnerability scanning software shall scan operating system for vulnerabilities, and other mainstream scanning tools shall be used for cross-validation. The vulnerability database of vulnerability scanning tools shall be upgraded before use;

(3) After the vulnerability scanning, the vulnerability repair work is completed according to the vulnerability problems found by scanning. "High-risk" vulnerabilities shall be repaired within three working days, "medium-risk" vulnerabilities shall be repaired within five working days, and "low-risk vulnerabilities" shall be repaired within the same month. After the

vulnerability repair work is completed, the safety responsible department shall retest it.

6.10.1.2.2.2 Requirements for risk assessment

(1) Risk assessment of the platform should be conducted once a year. It is necessary to entrust third-party institutions with relevant risk assessment qualifications to carry out assessment work;

(2) According to the risk assessment report, it is necessary to rectify and deal with the safety risks mentioned in the report. After disposing of the risk, it is necessary to organize the third-party organization for secondary assessment to verify the effectiveness of the risk disposal work;

(3) File risk assessment reports and process documents

6.10.1.2.2.3 Requirements for permeation testing

(1) The penetration testing of the vehicle networking platform shall be conducted quarterly. The penetration test shall adopt artificial penetration test method, which includes but is not limited to the testing of loopholes such as ultra vires, injection, and cross-station and sensitive information leakage;

(2) The penetration testing report shall be issued after the completion of the penetration testing. The testing time, testing scope, testing cases and testing results shall be recorded in the report.

(3) After the penetration testing is finished, the vulnerability is repaired according to the vulnerability problems found in the testing. "High-risk" vulnerabilities shall be repaired within three working days. "Medium-risk" vulnerabilities shall be repaired within five working days. "Low-risk vulnerabilities" shall be repaired within the same month. After the vulnerability repair work is completed, the safety responsible department shall retest it.

6.10.2 Operations

1. Standardization of operation and management; Daily safety operation management and responsible personnel implementation. It is necessary to formulate safety operation criteria for charging equipment to ensure the safety of charging operation.

2. Safety guards are well equipped.

3. It is necessary to establish and improve the safety inspection mechanism, eliminate the hidden dangers of operation safety and ensure the safety of charging operation.

4. Construction of professional team of operation and maintenance personnel

(1) Operations and maintenance personnel must obtain special operating permits for electricians and be on duty with certificates;

(2) In principle, there shall be two people for electrical work, one person operates and the other monitors;

(3) Operating and maintenance personnel shall be familiar with electrical safety knowledge, and be familiar with first aid of electric shock and emergency treatment measures.

6.10.3 Warning level and emergency disposal

(1) During the charging process, the safety alarm level of the charging equipment shall be set, and the corresponding safety disposal plan of the charging equipment shall be carried out according to the alarm level, including: The special emergency disposal plans, such as insulation fault disposal plan, leakage fault disposal plan, discharge loop fault disposal plan, lightning protection fault disposal plan, personnel shock disposal plan, fire accident disposal plan, etc., which need to be evaluated by relevant experts. It is necessary to conduct regular emergency drills of special plans;

(2) Alarm and disposal of equipment overvoltage, over-current, over-temperature and overcharge energy.

6.10.4 Repair and maintenance of charging equipment

(1) Charging equipment operators shall regularly organize professional personnel to repair and maintain charging equipment;

(2) They shall check whether the whole casing of the charger is flat or not, check whether there are concave and convex marks, scratches, deformation and other defects. They shall check whether the incoming lines inside the charger are loose with some defects and damages, such as rust, burr and crack after a long period of use. They shall check whether the charger is clean and tidy, whether the suction outlet dust-proof net and exhaust outlet of the power module are full of dust, if they are full of dust, they shall be cleaned up in time, and if necessary, the dust-proof net shall be replaced and maintained to prevent the fault of the power module. They shall check whether the electrical components inside the charger are discolored and deformed. They need to be replaced and maintained in time if necessary. They shall check whether the electrical components in the charger are loosely connected. If the electrical components in the charger are loose, they shall be solved in time to prevent the occurrence of faults.

(3) They shall check whether the connection terminals of charger main board and power board are loose. If the power supply board 220V input terminal is loose, the charging screen will not be bright, the insulation detector will not be bright, and the remote signal lamp on the main board will not be bright. The terminal of power supply board shall be connected in time. They shall check whether the devices inside the charger can be used normally. Whether the touch of the display screen reacts or not; Whether the communication between the main board and the display screen is normal, and whether the manual charging can be started normally;

(4) They shall check whether all kinds of switches, relays and contactors are working normally, whether the contacts are intact, and measure the on-off of all kinds of switches, relays

and contactors by multi-meter. They shall test insulation resistance of charger. Insulation resistance of charger input loop to ground, output loop to ground and between input and output shall be no less than 10 MΩ.

6.10.5 Maintenance method and requirements for charging connector interface

Charging equipment operators shall regularly organize professional personnel to maintain charging equipment; In maintenance, first of all, it is necessary to check whether the charging gun head and charging socket are clean. There shall be no dust on the surface of the gun pin and no sediment residue in the gun head. The insulating cap of the charging gun shall not fall off, the insertion pin is correct, without abnormalities such as burning, oxidation and discoloration, the plug plastic parts shall not melt, the cable shall not fall or be broken, and there is no overheating of charging.

Secondly, it is necessary to clean and maintain the charging connector, clean the dust on the surface of charging gun with a small brush, and clean the dust inside the charging gun head (the inner control of charging gun head and the surface of inserting pin terminal) with an air gun, and then clean the dust on the surface and surrounding of charging pile hanger socket with a small brush, and clean the dust inside the charging pile hanger socket with an air gun.

When the charging gun is idle or after charging, it is necessary to arrange and suspend the cable of the charging gun on the charging pile, and insert the charging gun back into the charging pile hanger socket to prevent dust from entering the gun head.

6.10.6 Safety measures for charging operation

(1) Fire extinguishers shall be installed in all kinds of stations. The configuration of charger fire extinguishers for electric vehicles shall conform to the relevant regulations of the current national standard *Code for Configuration Design of Building Fire Extinguishers* (GB 50140).

(2) Lightning protection grounding, static-proof grounding and working grounding of electrical equipment in the charging station shall share grounding devices, and grounding resistance shall not be greater than 4Ω.

(3) The charging station shall be equipped with lighting facilities and monitoring devices. Lighting is mainly about outdoor lighting. The monitoring system shall be able to intuitively overview the scene and observe the details of the local area. The monitoring information can be recorded and replayed.

6.10.7 Safety management of charging facility operation

6.10.7.1 Requirements for operation and maintenance

1. It is necessary to do a good job of daily inspection and maintenance of charging equipment, charging connector and distribution equipment

2. Repair and management of charging equipment

3. Remote monitoring and equipment maintenance

4. Establishment of safety production system Charging operators shall establish the sound charging facilities management system, standard documents, operating procedures and so on.

(1) Charging facilities operation agencies shall establish and improve management systems and safety standards;

(2) For the operation of charging facilities, it is necessary to set up posts according to service links, clarify the responsible person, work flow and responsibilities, and formulate post operation rules;

(3) Charging facilities operation agencies shall set up safety management organizations, equipped with full-time or part-time safety personnel, clarify the responsible person for the safety of each link, and implement the safety management throughout the all-round operation services;

(4) Charging facilities operation agencies shall conduct self-assessment by means of routine inspection, regular inspection, random inspection, census and special inspection. Conduct self-assessment on the overall operation of charging facilities at least once every month;

(5) Self-assessment shall include: —Inspection and assessment of the formulation and implementation of rules and regulations and operational rules; —Check the on-site records of the operators;

(6) Before assessment, make the assessment plan and set up the assessment group. prepare the valuation reports after assessment.

6.10.7.2 Safety operation training

(1) Managers and operators shall receive training in safety production education and job skills, master safety knowledge of electric vehicles, safety specifications for electricity use, and emergency treatment methods for electric vehicles and first aid methods for electric shock, and take up posts after passing the examination;

(2) Managers shall understand the structure of electric vehicles and the working principle of charging and switching equipment, and master the charging and switching service process;

(3) Safety personnel shall understand the structure of electric vehicles, the working principle of charging facilities and equipment, and master the charging and switching operation rules, safety knowledge and emergency treatment methods;

(4) Operators shall understand the principle and structure of electric vehicles, and master the operation rules of the post and emergency treatment methods;

(5) Charging and switching operators shall understand the basic knowledge of the application of power storage batteries, master the charging safety knowledge of electric vehicles, the operating rules of the post and emergency treatment methods.

(6) Battery maintenance personnel shall understand the charging and switching equipment and the structure of electric vehicles, master the basic knowledge of power batteries and the operating rules of the post, battery detection, fault diagnosis and treatment;

(7) Charging supervisors shall understand the basic knowledge of the electrochemical performance of power batteries and the application of power batteries, and master the use of monitoring systems and charging control methods.

(8) DC charging service personnel shall be provided by charging operators for users. The whole vehicle AC charging service can be provided by the customer self-service mode.

(9) Equipment or system shall be set up with all levels of operation authority to prevent misoperation.

6.10.7.3 Hidden danger and investigation

Establish the routine inspection system for equipment, carry out safety risk analysis, timely maintain faults, investigate problems, maintain and repair, and make relevant records:

(1) Infrastructure of charging facilities shall be complete and meet the requirements of relevant standards. The use and management of equipment shall be in the charge of special personnel, and the equipment shall be inspected, maintained and repaired regularly;

(2) Operators shall regularly inspect, maintain and repair the equipment, and shall not provide charging services with malfunctioning equipment.

(3) The overhaul, testing and repair of electrical equipment shall be carried out by professional technicians. Non-professional personnel shall not engage in the maintenance of electrical equipment and electrical devices. Power supply shall be cut off before the maintenance of equipment;

(4) Managers and operators shall regularly inspect various safety signs and repair or replace those that are deformed, damaged or discolored;

(5) Inspection safety officers shall inspect charging facilities, correct illegal operations, and timely dispose of potential safety hazards;

(6) Conduct self-assessment by means of routine inspection, regular inspection, random inspection, census and special inspection. Make one self-inspection report on the overall operation of charging facilities at least once every month;

(7) The charging facilities managed within the jurisdiction shall be recorded for faults and accidents.

6.10.7.4 Treatment pre-plan for emergency of power failure at pump station

(1) Operation agencies of charging facilities shall set up emergency organizations and establish emergency pre-plans for emergencies, including fire, vehicle fault, battery damage, combustion and explosion, power supply system fault, personnel electric shock, battery fault,

and equipment fault.

(2) The emergency pre-plans shall be subject to the unified command and responsibility at different levels; complete organization and institute; adequate personnel and material allocation; smooth communication; and the basic requirements for quick and accurate action. Main contents of the emergency pre-plans include: Organizational structure, personnel, materials, event level, reporting procedures, accident disposal methods, rapid evacuation methods, emergency rescue measures, on-site protection, cleaning and rehabilitation work;

(3) Emergency equipment involved in the emergency pre-plans shall be stored in designated places, supervised by special personnel, and the validity of materials required for the emergency plan shall be checked regularly;

(4) The whole personnel shall be trained and rehearsed based on the emergency pre- plans at least once every six months, and the emergency plan shall be revised and perfected according to the problems in the rehearsal;

(5) Disposal of emergencies shall be carried out in accordance with the requirements for emergency pre-plans.

6.11 Information safety

6.11.1 Technical requirements for the operation platform

6.11.1.1 System safety protection

6.11.1.1.1 There shall be redundancy configuration consist of at least two nodes in the system, and there shall be access mode consist of at least two links in the network, to avoid business system collapse caused by the failure of a node or a link of the hardware.

6.11.1.1.2 The server host shall adopt dual configuration to provide redundant protection in the form of cold standby or hot standby. If the mode of renting cloud service is adopted, the redundant quantity of computing resource nodes shall be increased

6.11.1.1.3 The network and security equipment shall be matched with the access network link during the configuration. When the dual link access is adopted, the network and security equipment shall be configured in the dual node mode.

6.11.1.1.4 Safety equipment or equivalent components shall be provided.

6.11.1.1.5 When allocating storage resources, the capacity shall be calculated according to the business data scale of the operating platform. When the data center is built, with the guaranteed sufficient storage space of the server, the independent storage equipment shall be configured. It shall have dual computers, or have a remote data center backup. When the renting cloud services is adopted, storage resources with redundant configuration or remote backup shall be provided.

6.11.1.2 Network security protection

6.11.1.2.1 The operating platform system should be divided into different sub network segments according to different services.

6.11.1.2.2 The important server host and core business area shall be deployed in the internal network area to establish a safe access path through routing equipment to avoid its direct connection with the external network;

6.11.1.2.3 Network access points should be controlled and isolated by security protection equipment to establish complete filtering policies and intrusion protection policies.

6.11.1.2.4 Access to networks should be controlled and the platform should adopt the protection standards of security audit. The data and operations generated during service should be logged with backups.

6.11.1.2.5 Each business operation section should have independent and complete hardware and network plans to prevent any influence on the formal operation system caused by disordered hardware or infrastructure resources in all phases of business operations.

6.11.1.2.6 Important operation platform systems should be equipped with active-active hot standby in the configurations with the capability of autonomous operation handover.

6.11.1.2.7 Access to the network of charging equipment should be provided to block exceptions.

6.11.1.3 Basic Software Protection

6.11.1.3.1 The operating system and relevant modules should be regularly upgraded with patches to guarantee the stability and reliability of the software systems.

6.11.1.3.2 Loophole scanning should be regularly conducted in the systems to detect and prevent intrusions and malwares.

6.11.1.3.3 The system should be monitored in real time for security to ensure that all the operations are legal with audit records of operations.

6.11.1.3.4 The infrastructure software in all mainframes should have strict identity authentication configurations and password should be complex to a certain degree with periodic changes.

6.11.1.3.5 The memory resources in the hard drives of all servers should be monitored in real time and there should be a real-time alerting function.

6.11.1.4 Operation System Protection

6.11.1.4.1 The business operation software should be equipped at least with a dual redundancy structure to prevent any application single node failure caused by any operation software crash, which results in operational malfunction and impacts business operation systems.

6.**11.1.4.2** In the process of data exchange with external sources, there should be a data exchange protocol or encryption schemes of the operation company to prevent disordered and unidentifiable data or leakage of data and information caused by illegal resolution in the process of exchange.

6.11.1.4.3 There should be its own data verification mechanism of the business software to guarantee the integrity and security.

6.11.1.4.4 Where there is sensitive data and information that needs intensive protection in the business information, there should be desensitization mechanism for data.

6.11.1.4.5 A security protection of the business system operation should be equipped with an audit system and all the business operations should be logged in detail.

6.11.1.4.6 A business system should be updated and upgraded, according to the problems and loopholes identified in the process of operations. All the versions in all phases and upgrading notes should be put into record.

6.11.1.4.7 Business data should be equipped with a data backup mechanism, which, according to operational demand, determines cache time and number of backups of historical data.

6.11.1.4.8 Any real-time access should be monitored and alarms should be given immediately.

6.11.2 Technical Requirements for Charging Equipment

6.11.2.1 Security of Equipment

6.11.2.1.1 Cable entrances and outlets of equipment should be sealed with suitable devices or measures to prevent any external instrument from entering it.

6.11.2.1.2 There should be evident and hard-to-remove label on the communication components inside equipment to prevent being replaced.

6.11.2.1.3 When detecting exceptions, charging equipment should actively give an alarm and stop charging.

6.11.2.1.4 The operating system should guarantee that codes are controllable or necessary measures should be taken to guarantee security.

6.11.2.1.5 An immunity mechanism of security that can identify charging equipment codes and actively block unknown code executions should be established, where the integrity of the charging equipment is verified to prevent being tampered and can automatically recover in case of exceptions.

6.11.2.1.6 Software configurations should be minimized to prohibit and restrict unnecessary functions.

6.11.2.1.7 There should be an authentication mechanism for upgrading application software and loading software of charging equipment, and only authenticated software can run in the system proper.

6.11.2.2 Security Data

6.11.2.2.1 Charging equipment has the function of reading charging records and should not display complete sensitive information of users.

6.11.2.2.2 Without consent from the user, charging equipment should not actively acquire or send to any third party the information except for charging authentication.

6.11.2.2.3 Charging equipment should have the function of data validity authentication to guarantee the data serve the requirements set by the system.

6.11.2.2.4 Any unauthorized entity must not recover the authentic content of user private data from the data in encrypted memory.

6.11.2.2.5 User information should not be changed and shown without authorization.

6.11.2.2.6 Data integrity should be guaranteed in the process of storage and transmission of charging equipment.

6.11.2.2.7 The confidentiality of sensitive data should be guaranteed in the process of storage and transmission of charging equipment.

6.11.2.3 Security Control

6.11.2.3.1 Technologies of identity management and authentication should be applied in the process of maintenance, upgrading and commissioning of charging equipment.

6.11.2.3.2 Where a charging equipment has the function of account management, the information of user identity authentication should have a certain degree of complexity.

6.11.2.3.3 Where a charging equipment has the function of account management, the function of handling logging-on failure should be provisioned and enabled. Necessary protection measures should be taken on condition of multiple logging-on failures. When the number of failures surpasses a threshold, certain measures should be taken.

6.11.2.3.4 Where a charging equipment has the function of account management, the mechanism of authenticating and recovering information can be available when user identity authentication information is missing or invalid.

6.11.2.3.5 A charging equipment with the function of account management should allocate accounts and right of access for logging-on users.

6.11.2.3.6 A charging equipment with the function of account management should delete or disable any redundant account or any account that has expired to prevent any shared account from existing.

6.11.2.3.7 Security protection measures should be taken at the external access interface of charging equipment.

6.11.2.3.8 Charging equipment should be equipped with a switch that controls access. When data connection is established, charging equipment can detect the connection and send notification of status to the user. Only when the user confirms the connection can the connection be established.

6.11.2.3.9 Charging equipment should provide different access permissions according to different access requests. The principle of minimum privilege should be abided by for classification of access permissions.

6.11.2.3.10 Close the network communication ports that are not necessary for system operation and maintenance.

6.11.2.3.11 Unauthorized users are prohibited from reading the audit information.

6.11.2.3.12 All the audit records should be backed up to local storage according to corresponding frequencies, or event data should be securely sent outside.

6.11.2.3.13 Charging equipment should protect the stored audit records to prevent unauthorized deletions, changes or replacements and detect the changes to audit records.

6.11.2.3.14 Charging equipment should guarantee a certain number and hold time of audit records and the capacity of keeping audit logs should be no less than 10,000.

6.11.2.3.15 Audit logs should replace the operations that have comparatively large impact on equipment.

6.11.3 Technical Requirements for Smart Mobile Terminal Software

6.11.3.1 Requirements for Operating Mechanism

6.11.3.1.1 In the process of installing and uninstalling the software, it is prohibited that any other bundled application software be downloaded. It is prohibited that any additional function without instructions in the readme text and that any third-party application be installed without the knowledge and consent from users.

6.11.3.1.2 Uninstallation should be complete and thorough. Temporary files, active programs or modules should not remain after uninstallation.

6.11.3.1.3 Signature information and software property information should be included that can characterize the supplier or developer.

6.11.3.1.4 The integrity and validity of installation packages and upgrade packages should be verified.

6.11.3.2 Requirements for Application Security

6.11.3.2.1 There should be the function of identity authentication that can identify and verify the identity of logging-on users.

6.11.3.2.2 There should be no internal anonymous account and anonymous users are prohibited from logging on.

6.11.3.2.3 There is the mechanism for inspecting password strength and time-effectiveness.

6.11.3.2.4 Authorized users are prohibited from the access to scope beyond authorization.

6.11.3.2.5 Access to terminal data and resources should be prohibited without prior consent.

6.11.3.2.6 Terminal data should not be changed or deleted without prior consent.

6.11.3.2.7 Unauthorized users are prohibited from reading audit information.

6.11.3.2.8 All the audit records should be backed up in local storage according to corresponding frequencies, or the event data should be sent securely outside.

6.11.3.2.9 The audit logs should be kept for at least six months.

6.11.3.2.10 Any unauthorized entity is prohibited from recovering the authentic content of user private data from the data in the encrypted storage.

6.11.3.2.11 There shall be no illegal calling and stealing loopholes in the process of data storage and processing.

6.11.3.2.12 User-sensitive data shall not be stored in plaintext or transmitted through the network to prevent unauthorized access to data.

6.11.3.2.13 The backup mechanism shall be complete and effective, and the backup data shall be protected.

6.11.3.3 Requirements for prevention of malicious acts

6.11.3.3.1 The application program shall not order illegal business without the user's knowledge or authorization.

6.11.3.3.2 The application program shall not obtain information illegally without the user's knowledge or authorization.

6.11.3.3.3 The application program shall not accept remote control instructions and carry out relevant operations without the user's knowledge or authorization.

6.11.3.3.4 The application program shall not cause the intelligent charging terminal of electric vehicle to be out of normal use.

6.11.3.4 Other safety requirements

6.11.3.4.1 The application software code shall be prevented from being decompiled and debugged.

6.11.3.4.2 No published high-risk loopholes shall exist in the source code.

6.11.3.4.3 The application software shall take precautions against log leakage.

6.11.4 Technical requirements for interface safety

6.11.4.1 Interface between charging equipment and operation platform

6.11.4.1.1 Communication between the charging equipment and the operation platform shall be authenticated and encrypted by the hardware encryption authentication equipment, and safety identification and data integrity verification measures shall be taken for the control command and parameter setting command from the operation platform.

6.11.4.1.2 Encryption measures shall be adopted for amateur data between charging equipment and operation platform to ensure data confidentiality, and shall comply with relevant national management regulations. It is forbidden to use encryption algorithms and security measures known as unsafe.

6.11.4.1.3 The charging equipment shall have the function of preventing network interference. In case of network paralysis and other emergencies, normal use of the charging equipment can be ensured through alternative schemes. startup of alternative schemes shall be clearly marked. The charging equipment shall actively upload the network abnormality and the charging record of alternative schemes upon network recovery.

6.11.4.1.4 If remote maintenance is required, secure access path and communicable channel shall be established by using technologies such as security encryption protocol or virtual private network etc. to ensure security of remote access.

6.11.4.2 Interface between charging equipment and electric vehicle

6.11.4.2.1 Communication network between the charging equipment and the electric vehicle shall be isolated from external network through security gateway, and the gateway shall distribute and process credible messages.

6.11.4.2.2 Application data of the protocol shall not be transmitted in plaintext, and application protocol shall be responsible for the implementation of security encryption mechanism.

6.11.4.2.3 After a safe transmission channel has been established between the charging equipment and the electric vehicle, communication parties shall be able to verify the integrity of the message.

6.11.4.3 Interface between operation platforms

6.11.4.3.1 Multifactorial authentication shall be adopted for platform authentication to ensure safe, stable and reliable operation of information exchange interface.

6.11.4.3.2 IP access control, time access control and other means or combination shall be used to limit the high-frequency access of the same terminal to the platform data interface within a certain period of time.

6.11.4.3.3 The message sender shall adopt safe, reliable and commonly used encryption algorithm for data involving transaction and privacy in the message field, and the message receiver shall carry out subsequent business processing after verifying the validity of parameters.

6.11.4.3.4 Integrity of the transmitted and received data shall be guaranteed by means of digital signature and retransmission mechanism, etc.

6.11.4.4 Mobile intelligent terminal as authentication interface

6.11.4.4.1 The QR code attached to the equipment shall be equipped with appropriate encryption mechanism, which shall be encrypted before the QR code is encoded, so as to ensure that only the code-scanning equipment identified through decryption can correctly identify the equipment information.

6.11.4.4.2 Key and sensitive data involved in the QR code shall have safety protection.

6.11.4.4.3 To obtain service certificate by scanning QR code of mobile intelligent terminal, it is necessary to exchange information with the background system to obtain real service authentication result.

6.11.4.4.4 Authentication process of mobile intelligent terminal and operation platform shall adopt safe transmission mode. The QR code involves information transmission between systems. A secure communication channel shall be established between systems. The transaction data shall be transmitted in a secure manner to ensure that the data is not monitored and tampered with.

6.11.4.4.5 Transmitted data shall be protected for confidentiality, and information leakage shall be avoided.

6.11.4.4.6 There shall be an authentication mechanism for the transmitted data to ensure the integrity of the sent and received data.

6.11.4.5 Smart card as authentication interface

6.11.4.5.1 The application management data shall be created during card initialization, and initial security domain shall be defined.

6.11.4.5.2 The card issuing institution shall establish a reliable and sophisticated management system for the secret key.

Data representation	Length/byte	Data type	Description and requirements
Vehicle data			
Vehicle condition	1	BYTE	0x01: vehicle start status; 0x02: flameout; 0x03: other status; 0xFE: abnormal; 0xff: invalid
Charging state	1	BYTE	0x01: parking charging; 0x02: driving charging; 0x03: non-charging state; 0x04: charging completed; 0xFE: abnormal; 0xff: invalid
Operation mode	1	BYTE	0x01: pure electric; 0x02: hybrid; 0x03: fuel; 0xFE: abnormal; 0xff: invalid
Speed	2	WORD	Valid range: 0 ~ 2200 (0km / H ~220km/h),minimum measurement unit:0.1km/h; 0xFE:abnormal; 0xff: invalid
Accumulated mileage	4	DWORD	Valid range: 0-999999 (0km-999999.9km), minimum measurement unit: 0.1km/h; 0xFE:abnormal; 0xff: invalid
Total voltage	2	WORD	Valid range: 0 ~ 10000 (0V ~ 1000V), minimum measurement unit: 0.1V; 0xFE: abnormal; 0xff: invalid
Total current	2	WORD	Valid range: 0 ~ 20000 (offset: 1000A, -1000A~ 1000A), minimum measurement unit: 0.1A; 0xFE: abnormal; 0xff: invalid
SOC	1	BYTE	Valid range: 0 ~ 100 (0% ~ 100%), minimum measurement unit: 1%, 0xFE: abnormal; 0xff: invalid
DCDC state	1	BYTE	0x01: working; 0x02: disconnected; 0xFE: abnormal; 0xff: invalid

Gear	1	BYTE	Bit7: reserved. The reserved bit is represented by 0. Bit6: reserved. The reserved bit is represented by 0. Bit5: 1 for driving force; 0 for no driving force Bit4: 1 for braking force; 0 for no braking force Bit3 ~ bit0: 0000 for neutral gear; 0001 for first gear; 0010 for 2nd gear; 0011 for 3rd gear; 0100 for 4th gear; 0101 for 5th gear; 0110 for 6th gear; 1101 for reverse gear; 1110 for automatic D gear; 1111 for parking P gear
Insulation resistance	2	WORD	Valid range: 0 ~ 60000 (0k Ω ~ 60000 K Ω, minimum measurement unit: 1K Ω
Accelerator pedal travel value	1	BYTE	Valid range: 0 ~ 100 (0% ~ 100%), minimum measurement unit: 1%, 0xFE: abnormal; 0xff: invalid
Brake pedal state	1	BYTE	Valid range: 0 ~ 100 (0% ~ 100%), minimum measurement unit: 1%, "0" indicates the status of brake switch; "0x65" or "101" indicates valid brake status in case of no specific travel, 0xFE: abnormal; 0xff: invalid
Driving motor data			
Driving motor serial number	1	BYTE	Driving motor sequence number, valid range 1-253
Drive motor state	1	BYTE	0x01: power consumption; 0x02: power generation; 0x03: off state; 0x04: preparation state; 0xFE: abnormal; 0xff: invalid
Driving motor controller temperature	1	BYTE	Valid range: 0 ~ 250 (value offset: 40 ℃, -40 ℃ ~210 ℃), minimum measurement unit: 1 ℃; 0xFE: abnormal; 0xff: invalid
Driving motor speed	2	WORD	Valid range: 0 ~ 65531 (value offset: 20000, -20000r / min ~ 45531r / min), minimum measurement unit: 1r / min; 0xFE: abnormal; 0xff:invalid
Driving motor torque	2	WORD	Valid range: 0 ~ 65531 (value offset: 20000, -2000N. m~ 4553.1rn. m), minimum measurement unit: 0.1N. M; 0xFE: abnormal; 0xff: invalid
Driving motor temperature	1	BYTE	Valid range: 0 ~ 250 (value offset: 40 ℃, - 40 ℃ ~210 ℃), minimum measurement unit: 1 ℃; 0xFE: abnormal; 0xff: invalid
Motor controller input voltage	2	WORD	Valid range: 0 ~ 60000 (0V ~ 6000V), minimum measurement unit: 0.1V, 0xFE: abnormal; 0xff:invalid
DC bus current of motor controller	2	WORD	Valid range: 0 ~ 20000 (value offset: 1000A, -1000A ~ +1000A), minimum measurement unit: 0.1A, 0xFE: abnormal; 0xff:invalid
Extreme value data			
Maximum voltage battery subsystem number	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid

Maximum voltage battery cell code	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Maximum cell voltage	2	WORD	Valid range: 0 ~ 15000 (0V ~ 15V), minimum measurement unit: 0.001V, 0xFE: abnormal; 0xff: invalid
Minimum voltage battery subsystem number	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Minimum voltage battery cell code	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Minimum cell voltage	2	WORD	Valid range: 0 ~ 15000 (0V ~ 15V), minimum measurement unit: 0.001V, 0xFE: abnormal; 0xff: invalid
Maximum temperature subsystem number	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Maximum temperature probe No.	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Maximum temperature	1	BYTE	Valid range: 0 ~ 15000 (0V ~ 15V), minimum measurement unit: 0.001V, 0xFE: abnormal; 0xff: invalid
Vehicle location data			
Positioning state	1	BYTE	Bit0:0 for valid positioning; 1 for invalid positioning Bit1: 0 for north latitude; 1 for south latitude Bit2:0 for east longitude; 1 for west longitude Bit3 ~ 7: reserved
longitude	4	DWORD	Dimension value in degrees multiplied by 10^6 to the nearest millionth of a degree.
dimension	4	DWORD	Dimension value in degrees multiplied by 10^6 to the nearest millionth of a degree
Alarm data			
Maximum alarm level	1	BYTE	It is the highest level of current faults, with a valid range of 0 ~ 3, and "0" for no fault; "1" for level 1 fault, which does not affect the normal driving of the vehicle; "2" for level 2 fault, which affects the performance of the vehicle and requires the driver to limit driving; "3" for level 3 fault, which is the highest level fault, which means the driver should stop the vehicle immediately or ask for assistance. the fault content corresponding to the specific level is defined by the manufacturer; "0xFE": abnormal; "0xff": invalid

General alarm marks	4	DWORD	Bit0:1 for temperature difference alarm; 0 for normal Bit1: 1 for high battery temperature alarm; 0 for normal Bit2: 1 for overvoltage alarm of the on-board energy storage device; 0 for normal Bit3:1 for under-voltage alarm of the on-board energy storage device; 0 for normal Bit4: 1 for low SOC alarm; 0 for normal Bit5:1 for overvoltage alarm of single battery; 0 for normal Bit6:1 for under voltage alarm of single battery; 0 for normal Bit7: 1for high SOC alarm; 0 for normal Bit8: 1 for jumping SOC alarm; 0 for normal Bit9:1 for mismatch alarm of the rechargeable energy storage system; 0 for normal Bit10:1 for inconsistency alarm of single battery; 0 for normal. Bit11:1 for insulation alarm; 0 for normal Bit12:1 for DCDC temperature alarm; 0 for normal Bit13:1 for brake system alarm; 0 for normal Bit14:1 for DCDC status alarm; 0 for normal Bit15:1 for temperature alarm of driving motor controller; 0 for normal Bit16:1 for high voltage interlock status alarm; 0 for normal Bit17:1 for temperature alarm of driving motor; 0 for normal Bit18:1 for overcharge alarm of on-board energy storage device; 0 for normal Bit19-31: reserved
Total failures of rechargeable energy storage device N1	1	BYTE	N1 rechargeable energy storage device failures, valid range: 0 ~ 252, "0xFE": abnormal; "0xff": invalid
Fault code list of rechargeable energy storage device	4xN	DWORD	Expansibility data, defined by the manufacturer; the number of failures of rechargeable energy storage device is equal to the total number of failures of rechargeable energy storage device N1
Total failures of driving motor N2	1	BYTE	N2 driving motor failures; valid range: 0 ~ 252, "0xFE": abnormal; "0xff": invalid
Fault code list of driving motor	4xN2	DWORD	As defined by the manufacturer, the number of driving motor failures is equal to the total number of driving motor failures N2.
Other failures N4	1	BYTE	N4 other failures; valid range: 0 ~ 252; "0xFE": abnormal; "0xff": invalid
Fault code list of other failures	4xN4	DWORD	Defined by the manufacturer, the number of faults is equal to the total number of faults N4

6.12 Safety of power change station

Battery power change station shall provide safe, fast and reliable place for battery box replacement for pure electric vehicle users. The process of battery box replacement and charging shall always be monitored. The related requirements and construction requirements for safety specification, fire safety, monitoring and charging of power change station are designed to standardize the construction, fire protection, monitoring and other requirements for battery replacement station, and achieve the requirements for rapid battery replacement for electric vehicles.

6.12.1 Location safety of power change station

The location of battery replacement station shall meet the requirements of Chapter 3 of GB/T 51077-2015. The fire protection spacing between the building (structure) inside the battery replacement station and the building outside the station shall conform to the relevant regulations of the current national standard Code for Fire Protection in Architectural Design (GB 50016) and the current national standard Code for Fire Protection of High- rise Civil Building Design (GB 50045).

6.12.2 Fire safety

The requirements for safety and fire protection of battery replacement stations shall meet the requirements of Chapter 12 of GB/T 29772-2013. Accident battery isolation measures shall be set up in battery replacement station.

Battery storage area shall be equipped with emergency transportation channels for accident batteries. Emergency transporters and mobile sandboxes shall be equipped in battery replacement stations to effectively deal with the accident batteries so as to ensure that the accident batteries can be transported out of the charging rack quickly and safely.

6.12.3 Requirements for monitoring

The monitoring system shall meet the requirements of Chapter 9 of GB/T 29772-2013. The monitoring system shall have real-time storage of battery charging data, battery replacement information (battery code, battery information, etc.) and vehicle information.

The monitoring system shall have the function of data interface and transmit to the operation platform: Battery replacement station status, battery pack usage information (including vehicle batteries), charger working status, metering and billing information, license plate recognition information, and help upload all data to the cloud server through TCP/IP protocol.

The monitoring system shall have the functions of license plate recognition (VIN coding), metering and billing, and cost settlement.

The monitoring system has the functions of data acquisition, data processing and storage, event recording, man-machine operation and graphics editing, alarm processing, communication, report management and printing, system maintenance and system self-inspection, scalability, charging information management, etc.

The data that the monitoring system shall be able to collect include: Charger working status, temperature fault signal, charger power, charging voltage, charging current, charging power, vehicle mileage, battery replacement times, etc. Battery box manufacturer number, version, cell voltage, temperature, SOC, fault signal, etc.

The monitoring system shall meet the requirements of Chapter 6 of NB/T 33005-2013. Monitoring: The monitoring system shall be able to monitor the operation parameters and equipment status, communication status and communication messages of the main equipment in the station, and display them in real time.

Alarm: The monitoring system shall be able to alarm and deal with the abnormal condition and faults of the equipment in the station, the exceeding limit of the measured value, the abrupt change and the faults of the software, hardware, communication interface and network of the monitoring system.

6.12.4 Equipment safety

Fast change battery box shall meet the requirements of NB/T 33025-2016:

Quick change battery box shall meet the requirements for vehicle operating conditions. Mechanical locking mechanism shall be used for fixing battery box, and it has the function of preventing lock failure. Battery box locking mechanism shall enable the battery box to be fixed on three mutual perpendicular axes on the bracket, to ensure that no obvious relative displacement or mechanical noise will occur under frequent vibration when the vehicle is running.

The unlocking and locking of the battery box locking mechanism shall be operated by controlled mode, and the working state of the locking mechanism shall be able to be reliably detected.

Battery box locking mechanism shall be able to withstand the impact caused by vibration and shock.

Manual unlock to pull out the battery box shall be achievable in exceptional situation.

Battery box connectors shall meet the requirements of GB/T 32879-2016:

The anti-electric shock protection of connectors shall meet the requirements of Chapter 9 of GB/T 11918-2001. The grounding protection of connectors shall meet the requirements of Chapter 10 of GB/T 11918-2001.

After the connector plug and socket are connected, the protection grade shall not be lower than the IP55 requirement in GB 4208-2008. After the connector plug and socket are disconnected, the protection grade shall comply with the requirements of IP2X in GB 4208-2008.

Battery box replacement equipment shall meet the requirements of Section 5 of Chapter 5 of N/BT 33006-2013. 5.12.5 Vehicle safety The fixed safety of quick change battery box and vehicle shall meet the requirement of QC/T 743.

6.12.6 Battery replacement safety

Power change station equipment shall be able to identify the power-changing vehicle, and be informed of the identity code of the battery box (which shall meet the requirements of 20132391-T-524 (national standard, not issued) *Coding Technical Specification for Battery Box for Electric Vehicle Battery Replacement*), as well as the factory number, version, mileage, number of replacements, current status and other information of the battery box, and guarantee the safety of the battery box in the process of changing power in the station and charging after changing power.

6.13 Quality assurance system

According to the GB / T 19001, GB / T 24001 and GB / T 28001 standards and relevant laws and regulations, combined with the design, construction, operation and maintenance of charging facilities, and according to the activity process mode and PDCA cycle principle, the quality, environment and occupational health and safety management system is established and documented. Through the implementation, maintenance and continuous improvement of the quality assurance system, to ensure the reliability and stability of its quality.

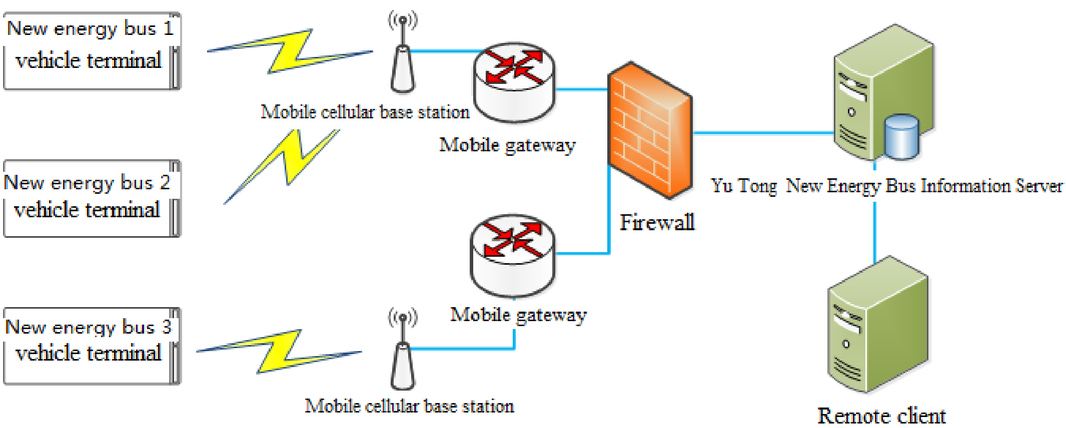
7. Data monitoring and management

Vehicle condition monitoring is mainly used to monitor the operation status of the new energy EIC system, collect vehicle driving data, and serve the design and improvement of the EIC system. Because the interactive design data are sensitive data, especially the data related to vehicle control, there are anti-intrusion, anti-monitoring and anti- tampering requirements in both hardware and software environment.

7.1 Vehicle condition monitoring

It shall have the functions of collecting, storing, transmitting vehicle running status, and alarming, charging and positioning data. Supported by GB/T 32960 *Technical Specification for Electric Vehicle Remote Service and Management System*, the data of electric vehicles can be reported to the government platform step by step, forming the three-level safety supervision system.

It is necessary to establish a remote monitoring platform with advanced satellite positioning technology (GPS), wireless communication technology (GPRS/3G/4G), geographic information technology (GIS) and cloud computing and data mining technology for new energy buses enterprises to monitor the parameters of vehicle geographic location and operation status, including vehicle speed, battery status, motor status, safety alarm and other information, for instance, the battery safety monitoring can be realized through real-time collection and analysis of power battery data during vehicle driving and charging process, high and low temperature alarm, insulation alarm and other information. It is necessary to adopt big data technology, and analyze the data of battery cell dropout voltage, cell temperature, charging and discharging current and battery equilibrium state to provide the reliable basis for the life analysis of power batteries. It is necessary to realize the condition monitoring of motor control system through real-time acquisition and analysis of motor status during vehicle driving. It is necessary to realize vehicle driving data monitoring through real-time data acquisition and analysis of speed, gear, hand brake, brake and vehicle status.



7.1.1 Data collection Data collection parameters range includes but is not limited to GB/T 32960.3 (see Table 7-1). The collection frequency of real-time data shall not be less than 1/s.

Data representation	Length/byte	Data type	Description and requirements
Vehicle data			
Vehicle condition	1	BYTE	0x01: vehicle start status; 0x02: flameout; 0x03: other status; 0xFE: abnormal; 0xff: invalid
Charging state	1	BYTE	0x01: parking charging; 0x02: driving charging; 0x03: non-charging state; 0x04: charging completed; 0xFE: abnormal; 0xff: invalid
Operation mode	1	BYTE	0x01: pure electric; 0x02: hybrid; 0x03: fuel; 0xFE: abnormal; 0xff: invalid
Speed	2	WORD	Valid range: 0 ~ 2200 (0km / H ~220km/h),minimum measurement unit:0.1km/h; 0xFE:abnormal; 0xff: invalid
Accumulated mileage	4	DWORD	Valid range: 0-999999 (0km-999999.9km), minimum measurement unit: 0.1km/h; 0xFE:abnormal; 0xff: invalid
Total voltage	2	WORD	Valid range: 0 ~ 10000 (0V ~ 1000V), minimum measurement unit: 0.1V; 0xFE: abnormal; 0xff: invalid
Total current	2	WORD	Valid range: 0 ~ 20000 (offset: 1000A, -1000A~ 1000A), minimum measurement unit: 0.1A; 0xFE: abnormal; 0xff: invalid
SOC	1	BYTE	Valid range: 0 ~ 100 (0% ~ 100%), minimum measurement unit: 1%, 0xFE: abnormal; 0xff: invalid
DCDC state	1	BYTE	0x01: working; 0x02: disconnected; 0xFE: abnormal; 0xff: invalid
Gear	1	BYTE	Bit7: reserved. The reserved bit is represented by 0. Bit6: reserved. The reserved bit is represented by 0. Bit5: 1 for driving force; 0 for no driving force Bit4: 1 for braking force; 0 for no braking force Bit3 ~ bit0: 0000 for neutral gear; 0001 for first gear; 0010 for 2nd gear; 0011 for 3rd gear; 0100 for 4th gear; 0101 for 5th gear; 0110 for 6th gear; 1101 for reverse gear; 1110 for automatic D gear; 1111 for parking P gear
Insulation resistance	2	WORD	Valid range: 0 ~ 60000 (0k Ω ~ 60000 K Ω, minimum measurement unit: 1K Ω
Accelerator pedal travel value	1	BYTE	Valid range: 0 ~ 100 (0% ~ 100%), minimum measurement unit: 1%, 0xFE: abnormal; 0xff: invalid
Brake pedal state	1	BYTE	Valid range: 0 ~ 100 (0% ~ 100%), minimum measurement unit: 1%, "0" indicates the status of brake switch; "0x65" or "101" indicates valid brake status in case of no specific travel, 0xFE: abnormal; 0xff: invalid
Driving motor data			

Driving motor serial number	1	BYTE	Driving motor sequence number, valid range 1-253
Drive motor state	1	BYTE	0x01: power consumption; 0x02: power generation; 0x03: off state; 0x04: preparation state; 0xFE: abnormal; 0xff: invalid
Driving motor controller temperature	1	BYTE	Valid range: 0 ~ 250 (value offset: 40 ℃, -40 ℃ ~210 ℃), minimum measurement unit: 1 ℃; 0xFE: abnormal; 0xff: invalid
Driving motor speed	2	WORD	Valid range: 0 ~ 65531 (value offset: 20000, -20000r / min ~ 45531r / min), minimum measurement unit: 1r / min; 0xFE: abnormal; 0xff:invalid
Driving motor torque	2	WORD	Valid range: 0 ~ 65531 (value offset: 20000, -2000N. m~ 4553.1rn. m), minimum measurement unit: 0.1N. M; 0xFE: abnormal; 0xff: invalid
Driving motor temperature	1	BYTE	Valid range: 0 ~ 250 (value offset: 40 ℃, - 40 ℃ ~210 ℃), minimum measurement unit: 1 ℃; 0xFE: abnormal; 0xff: invalid
Motor controller input voltage	2	WORD	Valid range: 0 ~ 60000 (0V ~ 6000V), minimum measurement unit: 0.1V, 0xFE: abnormal; 0xff:invalid
DC bus current of motor controller	2	WORD	Valid range: 0 ~ 20000 (value offset: 1000A, -1000A ~ +1000A), minimum measurement unit: 0.1A, 0xFE: abnormal; 0xff:invalid
Extreme value data			
Maximum voltage battery subsystem number	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Maximum voltage battery cell code	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Maximum cell voltage	2	WORD	Valid range: 0 ~ 15000 (0V ~ 15V), minimum measurement unit: 0.001V, 0xFE: abnormal; 0xff: invalid
Minimum voltage battery subsystem number	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Minimum voltage battery cell code	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Minimum cell voltage	2	WORD	Valid range: 0 ~ 15000 (0V ~ 15V), minimum measurement unit: 0.001V, 0xFE: abnormal; 0xff: invalid
Maximum temperature subsystem number	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid
Maximum temperature probe No.	1	BYTE	Valid range: 1 ~ 250, 0xFE: abnormal; 0xff: invalid

Maximum temperature	1	BYTE	Valid range: 0 ~ 15000 (0V ~ 15V), minimum measurement unit: 0.001V, 0xFE: abnormal; 0xff: invalid
Vehicle location data			
Positioning state	1	BYTE	Bit0:0 for valid positioning; 1 for invalid positioning Bit1: 0 for north latitude; 1 for south latitude Bit2:0 for east longitude; 1 for west longitude Bit3 ~ 7: reserved
longitude	4	DWORD	Dimension value in degrees multiplied by 10^6 to the nearest millionth of a degree.
dimension	4	DWORD	Dimension value in degrees multiplied by 10^6 to the nearest millionth of a degree
Alarm data			
Maximum alarm level	1	BYTE	It is the highest level of current faults, with a valid range of 0 ~ 3, and "0" for no fault; "1" for level 1 fault, which does not affect the normal driving of the vehicle; "2" for level 2 fault, which affects the performance of the vehicle and requires the driver to limit driving; "3" for level 3 fault, which is the highest level fault, which means the driver should stop the vehicle immediately or ask for assistance. the fault content corresponding to the specific level is defined by the manufacturer; "0xFE": abnormal; "0xff": invalid
General alarm marks	4	DWORD	Bit0:1 for temperature difference alarm; 0 for normal Bit1: 1 for high battery temperature alarm; 0 for normal Bit2: 1 for overvoltage alarm of the on-board energy storage device; 0 for normal Bit3:1 for under-voltage alarm of the on-board energy storage device; 0 for normal Bit4: 1 for low SOC alarm; 0 for normal Bit5:1 for overvoltage alarm of single battery; 0 for normal Bit6:1 for under voltage alarm of single battery; 0 for normal Bit7: 1for high SOC alarm; 0 for normal Bit8: 1 for jumping SOC alarm; 0 for normal Bit9:1 for mismatch alarm of the rechargeable energy storage system; 0 for normal Bit10:1 for inconsistency alarm of single battery; 0 for normal. Bit11:1 for insulation alarm; 0 for normal Bit12:1 for DCDC temperature alarm; 0 for normal Bit13:1 for brake system alarm; 0 for normal Bit14:1 for DCDC status alarm; 0 for normal

			Bit15:1 for temperature alarm of driving motor controller; 0 for normal Bit16:1 for high voltage interlock status alarm; 0 for normal Bit17:1 for temperature alarm of driving motor; 0 for normal Bit18:1 for overcharge alarm of on-board energy storage device; 0 for normal Bit19-31: reserved
Total failures of rechargeable energy storage device N1	1	BYTE	N1 rechargeable energy storage device failures, valid range: 0 ~ 252, "0xFE": abnormal; "0xff": invalid
Fault code list of rechargeable energy storage device	4xN	DWORD	Expansibility data, defined by the manufacturer; the number of failures of rechargeable energy storage device is equal to the total number of failures of rechargeable energy storage device N1
Total failures of driving motor N2	1	BYTE	N2 driving motor failures; valid range: 0 ~ 252, "0xFE": abnormal; "0xff": invalid
Fault code list of driving motor	4xN2	DWORD	As defined by the manufacturer, the number of driving motor failures is equal to the total number of driving motor failures N2.
Other failures N4	1	BYTE	N4 other failures; valid range: 0 ~ 252; "0xFE": abnormal; "0xff": invalid
Fault code list of other failures	4xN4	DWORD	Defined by the manufacturer, the number of faults is equal to the total number of faults N4

7.1.2 Data transmission

It shall have the function of sending the collected real-time data to the enterprise remote monitoring platform. Types of transmission data: (See table above) Transmission time interval: The time period for transmitting information shall be adjustable. When the vehicle is running normally, the maximum time period for reporting information shall not exceed 30 seconds. At the same time, the enterprise remote monitoring platform shall have the ability to transfer the data and related information collected by the vehicle terminal to the public platform according to the platform change communication protocol stipulated in GB/T 32960.3.

7.1.3 Vehicle battery condition monitoring

Based on battery capacity, temperature, current, voltage, SOC, charging mode and other battery-related data, it is necessary to set up indicators including, but not limited to, vehicle charging times, charging types, charging SOC distribution, maximum/minimum temperature distribution of batteries, and cell voltage distribution, analyze and monitor the battery status of electric vehicles from the use of batteries, battery health, battery fault alarm and other dimensions combined with the influencing factors of battery health and battery health prediction.

In addition to monitoring the battery status of vehicles through big data analysis, push the data of battery health and battery early warning for repair stations or users from time to time to further monitor the battery status, so as to prevent battery problems in time and greatly improve the safety performance of batteries.

7.1.4 Vehicle motor condition monitoring

Based on the motor speed, torque, temperature, temperature difference, motor fault alarm and other data related to the motor, analyze and monitor the motor status of the Electric Vehicle from the speed-motor speed distribution, motor torque distribution, motor temperature distribution, motor temperature alarm and other dimensions.

In addition to monitoring the battery status of vehicles through big data analysis, push the data of battery health and battery early warning for repair stations or users from time to time to further monitor the battery status, so as to prevent battery problems in time and greatly improve the safety performance of batteries.

7.1.5 Vehicle driving behavior monitoring

Based on the data related to user driving behavior such as travel days, travel times, mileage and speed, combined with the algorithm models such as mileage anxiety model and driving safety model, monitor the driving behavior of vehicles from the aspects of monthly average travel days, daily average travel times, travel time distribution, unit cycle speed distribution and mileage anxiety score.

Through big data analysis, analyze and monitor vehicle driving behavior, regularly push driving behavior reports, driving behavior scores and driving suggestions for users, so as to guide users to drive healthily and improve travel safety.

7.2 Remote control in dangerous conditions

Enterprises shall establish and improve the operation and peacekeeping service system of enterprise remote monitoring platform. For vehicles with grade 3 faults reported to the enterprise remote monitoring platform, the enterprise shall take the initiative to notify the corresponding after-sales service personnel through the platform for timely troubleshooting.

7.3 Vehicle information security

7.3.1 Vehicle hardware information security

The information security objective of automobile hardware is to ensure the safety of vehicle hardware in data operation and data storage. It can resist the safety threats that destroy data confidentiality and integrity, such as cryptanalysis attacks, side channel attacks and fault injection attacks against encryption and decryption operations, and prevent vehicle network system from being intruded to ensure the normal use of vehicle hardware functions.

In the design of vehicle hardware, it is necessary to consider removing readable screen prints that mark chips, ports and pins on the circuit board in mass-produced products, and closing debugging interfaces that can illegally access the memory of the chip or change the function of the chip.

Sensitive data communication lines in vehicle controllers shall be as concealed as possible to prevent eavesdropping and forgery attacks on board-level data transmission. Key chips shall minimize exposure, such as chips packaged in BGA/LGA. Controller shall be equipped with hardware module to achieve physical isolation of key sensitive data storage and operation, so as to ensure that the data in the module cannot be accessed in the unauthorized way.

Vehicle hardware shall be designed with the necessary safety mechanism or protection mechanism to defend and resist the corresponding attacks, such as:

(1) A single fault injection attack against the voltage or clock of the chip;

(2) A single fault injection attack against the electromagnetism or laser of the chip;

(3) Simple power analysis (SPA) attack on the side channel of the encryption chip;

(4) Simple first order differential power analysis (SPA) attack on the side channel of the encryption chip;

(5) Simple correlation power analysis (CPA) attack on the side channel of the encryption chip.

7.3.2 Vehicle network environment information security

Vehicle network environment includes the internal network environment and the external network environment. The internal network mainly refers to the communication between the subsystems of the vehicle. The external network includes the communication between the cellular network and the server, the collaborative communication between vehicles and between vehicle and road, and the short-distance communication in the vehicle (Bluetooth, WIFI, etc.).

Vehicle network environment is complex. It is necessary to consider data interaction under different business scenarios in vehicle network design to ensure that command data transmitted among internal subsystems will not be attacked by forgery, eavesdropping, replay and other means. Secure isolation of in-vehicle network from external threats.

When the vehicle communicates with cellular network and mobile terminal, it can resist safety threats such as sniffing, man-in-the-middle attack and replay, and ensure the safety of vehicle network environment. Use the necessary protective technology to divide the subsystems inside the vehicle into information security domains, define the safety levels of different domains, and establish safety access strategies between domains.

When vehicles are connected through cellular network, adopt corresponding safety strategies to guarantee to access real and reliable network and identify illegal connection requests from the cellular network.

When communicating with the core business platform, it is necessary to be logically isolated from the public network, and use strong verification means to ensure that only authorized subjects can implement corresponding operations.

In case of vehicle-vehicle communication and vehicle-road cooperative communication, the vehicle end needs to authenticate the identity of the connected nodes, and the data shall be encrypted for transmission. In case of communication between vehicle and mobile devices, users can manually open or close short-distance wireless connections, and the vehicle can display the established connections clearly by necessary means. Vehicles only accept external communication connection requests under certain conditions, and authenticate and authorize the connected devices.

7.3.3 OTA data safety encryption and tamper proof

OTA of vehicles can be divided into two main categories. One is FOTA (Firmware- over-the-air), referring to firmware upgrade for vehicle systems or internal controllers. The other is SOTA (Software-over-the-air), referring to software upgrades other than firmware (such as maps). No matter what kind of upgrade, there are risks of upgrade packet transmission and tampering between vehicle and server.

In the process of OTA upgrade, defend from three stages: upgrade package publishing, upgrade package transmission and terminal upgrade. OTA server can be deployed with additional safety servers and safety infrastructure, such as key generation and management, digital encryption and digital signature, to resist reverse analysis attacks and tampering attacks against upgrade packages. Based on the safety server, the upgrade package is reinforced. Finally, the strengthened upgrade package is issued by OTA server. The basic functions of the safety server can be realized by software solutions or by deploying hardware encryption machines.

In order to ensure the safety of the upgrade package transmission process, a secure transmission channel is constructed between the OTA server and the vehicle to realize the functions of bidirectional identity authentication and transmission encryption. The terminal system is added with upgrade package verification mechanism before the upgrade process to decrypt and verify the validity of the upgrade package, and it shall be qualified before accessing the system upgrade process.

7.4 Information data preservation and analysis

Data monitoring platform shall ensure the safety of data storage, ensure that data will not be leaked during analysis and use, and data shall not be illegally used.

7.4.1 Local storage of information data

(1) The real-time data collected by the vehicle terminal shall be stored in the internal storage medium at the time interval of no more than 30 s. When there is a three-level alarm, the real-time data collected by the vehicle terminal shall be stored in the internal storage medium at the time interval not exceeding 1s. Three-level alarm refers to the fault that the driver shall stop

immediately to deal with or request rescue. For example: Battery high temperature alarm, vehicle insulation alarm, etc.

(2) The internal storage medium capacity of the vehicle terminal shall meet the requirement of real-time data storage for at least 7 days. When the internal storage medium of the vehicle terminal is full, it shall have the function of automatic cyclic coverage of the internal storage data.

(3) The data stored in the vehicle terminal shall be readable.

(4) When the vehicle terminal stops working after power failure, the data stored in the internal medium before power failure shall be preserved completely without loss.

7.4.2 Information data is storage on platform server

The data of the vehicle terminal is uploaded to the enterprise remote monitoring platform in real time. The vehicle running status can be monitored in real time through the enterprise remote monitoring platform. At the same time, the relevant running data can be saved to the server. In order to ensure the traceability of the vehicle historical data, the data storage time shall be no less than 5 years (refer to Tianjin landmark).

7.4.3 Information data analysis

Based on the real-time monitoring of new energy buses, build the remote monitoring platform for enterprises, and establish standard data archive for each operating vehicle. With the technology of big data and data mining, from the angle of safety, energy consumption and energy saving, realize the monitoring and analysis of new energy buses throughout the life cycle in many aspects. For example: Vehicle fault analysis, energy consumption analysis of 100 kilometers, power battery status analysis, driver driving behavior analysis, etc.

7.5 Charging data management

Charger shall send charging data to the whole vehicle in accordance with GB/T 27930 Communication Agreement between Electric Vehicle Non-Vehicle Conductive Charger and Battery Management System.

Vehicles shall monitor the online status of charging equipment, voltage, current, electric quantity, battery and other information during charging process through BMS, and have the following functions:

(1) On-line condition monitoring of charging equipment;

(2) Continuous monitoring of voltage, current and electric quantity during charging process of charging equipment;

(3) Battery information monitoring of charging vehicles;

(4) Early warning of potential safety problems in charging process;

(5) Record vehicle charging, including but not limited to start time, end time, charging current, start SOC, end SOC.

8. Repair and maintenance

8.1 General repair and maintenance of electric vehicles

Although the driving mode of electric vehicles is different from that of traditional vehicles, they still need to be maintained daily. Electric vehicles need to be maintained daily for high-voltage components such as battery systems and motors. With the increase of service life, due to the performance wear, aging, corrosion and other reasons of functional components, driving safety performance may be gradually reduced. Electric vehicles shall be regularly maintained in accordance with regulations for driving safety.

Due to the characteristics of high-voltage electricity used in Electric Vehicle, there is a risk of electric shock during maintenance of high-voltage harness and high-voltage components. It shall be maintained by professionals with professional equipment in 4S stores or professional places, and informal disassembly by non-professional personnel is strictly prohibited.

Electric vehicles must undergo professional repair and maintenance under the following special circumstances:

(1) Electric vehicles soak or wade for a long time;

(2) The bottom power battery of the Electric Vehicle is collided;

(3) After the collision accident of the Electric Vehicle;

(4) Fault light shows that it needs to be repaired and maintained in stores. Periodic maintenance shall be carried out according to the period specified in the user's manual.

8.1.1 Requirements for operator

Maintenance personnel of B-level voltage components shall be trained professionally, obtain the certificate of electrician's induction, the certificate of electrician's qualification for maintenance and shall be qualified through training, and strictly abide by the electrical safety operating regulations.

Maintenance personnel must use professional operating tools (upper monitor, insulating meter, torsion wrench, insulating shoes, insulating gloves, etc.).

8.1.2 Requirements for pre-operation

Before overhaul and maintenance, it is necessary to cut off the high-voltage power supply. Refer to 11.4 for operation method

8.1.3 Requirements for operational process

Refer to 11.5 for operation method

8.1.4 Other operational requirements

(1) When cleaning the vehicle, it is forbidden to wash B-level voltage system with water to avoid short circuit or fire after the failure of the water intake insulation.

(2) Check the waterproof and cooling equipment in the equipment cabin regularly, and

check whether the exhaust fan can work properly in rainy weather and whether the ventilation outlet of the exhaust fan has rainwater in it.

(3) Use chargers that meet the national standards. Charging operators need to be trained and certified. When charging, it is necessary to use "automatic charging" function. Manual charging function is strictly prohibited. It is strictly forbidden to charge the battery system blindly, pull the charging gun with electricity, and drive without pulling the charging gun. It is forbidden to charge electric vehicles in open air in thunder and lightning weather or rainy day. In thunderstorm weather, it must be charged in the area that is protected from rain and lightning. When charging, it is necessary to check whether there is any water mark on the charging plug. During charging, it is necessary to check whether there is insulation alarm at any time.

8.2 Requirements for repair and maintenance of power batteries

8.2.1 Maintenance requirements for power batteries

8.2.1.1 Charging and discharging correctly

Master the charging time during use according to the actual situation and control the charging frequency according to the ordinary operating frequency and driving mileage. Please charge the vehicle in time to avoid charging when the battery is dead and the vehicle stops.

8.2.1.2 Vehicles must be charged regularly when they are stationary for a long time When the vehicle is idle, the battery will discharge very slowly because of the self- discharge characteristics of the battery itself and the dormancy power consumption of the vehicle electronic equipment. In order to prevent battery over discharge, the vehicle shall be charged regularly when it is stationary for a long time. The longest time that a vehicle can be stationary in different SOC is as follows. The vehicle shall be charged within this period of time until SOC≥50% as shown in the table below.

S/N	SOC range	Typical maximum standing time of vehicles
1	SOC>40%	Three months
2	SOC≤40%	Two months
3	SOC≤20%	One month
4	SOC≤10%	20 days
5	SOC≤5%	7 days

8.2.2 Repair of power battery

Power batteries need to be repaired by professionals because of high-voltage characteristics.

8.2.2.1 Requirements of repair personnel

Repair of power batteries must be carried out by professionals with new energy experience or relevant qualification certificates. Repair personnel shall wear insulating gloves and insulating shoes.

8.2.2.2 Requirements on repair site

Power battery repair sites must be clean (without grease, stain or metal wastes), dry (without liquid leakage), and free of sparks. Therefore, it shall not be maintained in the vicinity of vehicle cleaning area or body repair area, and movable partition shall be used when necessary. Repair sites shall be well ventilated (indoor) or as open as possible (outdoor), with clear signs that fireworks, waterproof and high-voltage hazards are strictly prohibited, and non-repair personnel are prohibited from entering repair sites.

8.2.2.3 Requirements for repair process

Repair personnel shall disconnect one or more high-voltage bus bars to reduce the voltage of repair unit to less than 60V.d.c during power battery maintenance.

When the quality problem of battery cell is detected, in principle, the whole shall be replaced. When the single cell has to be replaced, it must be replaced strictly according to the relevant operating rules by the professionals who have been trained accordingly.

Tools with sharp edges/corners shall not be used at or near high-voltage components or lines. Wire shears are allowed to be used on low voltage wire harnesses to open wire bands. Failed or damaged high-voltage lines must be discarded in order to avoid reuse. Tools shall not be left inside the power battery. Before closing the shell cover, check the integrity of the tools in the toolbox and whether the small parts such as bolts are left in the box. It is recommended to use general magnetization tools so that bolts will not be left in the power battery when repairing.

If the repair process is interrupted, cover the shell cover and screw several bolts to prevent it from being opened by accident. The air tightness of power battery system and battery liquid cooling system shall be checked at the end of repair.

Repair sites shall be equipped with fire safety measures to deal with emergencies such as smoke, open fire, etc. At the same time, it is necessary to make emergency call and set up warning signs.

8. 3 Requirements for repair and maintenance of motor controller

8.3.1 Requirements for motor controller maintenance

The motor controller is a high-voltage electric device. Professional personnel shall be equipped with professional equipment to operate during repair. Illegal disassembly by non-professional personnel is strictly prohibited. After the motor controller is disassembled from the whole vehicle, it is strictly forbidden to disassemble.

Before disassembling the motor controller, it is necessary to ensure that:

(1) When working, disconnect the low voltage power supply of the whole vehicle and the high-voltage power supply of the motor controller, do a good job of safety protection, be aware of safety, and be familiar with the operation equipment and tools as well as the requirements for

operation.

(2) It is necessary to not operate in the open air under the weather conditions of dust, rain and snow, otherwise, dust, water and other impurities will enter the motor controller.

(3) During operation, personnel shall use professional inspection and maintenance equipment and insulation tools shall use and wear insulating gloves and shoes. For all operations, it is necessary to cut off power, discharge and detect high-voltage DC+/DC- to-ground voltage to ensure there is no electricity;

(4) The specific operation contents and requirements are implemented according to the maintenance manual of the main engine plants.

8.3.2 Repair requirements for motor controller

8.3.2.1 Repair premise for motor controller

The motor controller is a high-voltage electric device. Professional personnel shall be equipped with professional equipment to operate during repair. Illegal disassembly by non-professional personnel is strictly prohibited. After the motor controller is disassembled from the whole vehicle, it is strictly forbidden to disassemble.

Before disassembling the motor controller, it is necessary to ensure that:

(1) It is necessary to remove the power battery repair switch when the vehicle is powered down at high-voltage.

(2) The whole car is powered down by low voltage.

8.3.2.2 Inspection and replacement of motor controller

(1) Disassembly of the complete unit: It is necessary to remove the bolts, water inlet and outlet pipes and high and low-pressure connectors of the motor controller, and then remove the motor controller to prevent the coolant from entering the connectors during the disassembly;

(2) Repair is carried out by professionals according to motor controller fault diagnosis and treatment methods.

(3) Re-install motor controller to the vehicle.

(4) Check the high-voltage terminals: The high-voltage terminals shall be shielded for insulation.

(5) It is necessary to check the shielding terminal: The shielding terminals shall be taped for insulation.

(6) It is necessary to measure the insulation between high-voltage wire and shielding wire.

(7) It is necessary to install high- voltage terminals: It is necessary to install the high-voltage terminal back to motor controller and lock it with bolts. The high-voltage terminal shall be installed strictly according to the shell mark to avoid mis-installation. The flat surface of the power terminal is close to the plane of the bus, and the bending surface is not allowed to be

installed.

(8) It is necessary to fix shielded wiring harness: Fix shielding terminals, which requires that shielding terminals and power bus terminals are strictly separated, without contact.

(9) The high-voltage terminals shall be subject to insulation test after installation.

(10) Install all covers, and tighten bolts according to torque requirement, preferably with torque wrench.

(11) Re-install low-voltage connector and low-voltage power supply.

(12) Install the cooling pipeline and check for leakage. No air is allowed to stay in the motor controller.

(13) The waterproof grade of the controller is IP67, please do not use high-pressure water gun or other tools to wash the controller, if it needs to be cleaned, please use soft and dry cotton cloth, please do not use alcohol or organic solvent;

(14) After the completion of repair and maintenance, the whole vehicle will be electrified. It is necessary to carry out insulation testing through the vehicle insulation testing equipment. If there are insulation faults, it is necessary to timely treat them.

8.4 Requirements for repair and maintenance of power batteries

When cleaning vehicles, it is necessary to try to avoid washing the high and low-voltage connector parts of the motor with high-voltage water flow, so as to avoid electrical fault and insulation fault.

8.4.1 Requirements for drive motor maintenance

(1) When working, disconnect the low voltage power supply of the whole vehicle and the high-voltage power supply of the motor controller, do a good job of safety protection, be aware of safety, and be familiar with the operation equipment and tools as well as the requirements for operation.

(2) In maintenance operations, avoid open-air operation under dust, rain and snow weather conditions. Avoid dust, moisture and other impurities from entering the motor.

(3) In maintenance operations, professional inspection and maintenance equipment and insulation tools are required, and personnel shall wear insulated gloves and insulated shoes. For all operations, cut off power, discharge and detect high-voltage DC+/DC-to- ground voltage to ensure there is no electricity;

(4) The specific operation contents and requirements are implemented according to the maintenance manual of the main engine plants.

8.4.2 Requirements for repair of drive motor

The drive motor is a high-voltage electrical device. Professional personnel shall be equipped with professional equipment to operate during repair. Illegal disassembly by non-professional personnel is strictly prohibited.

After the drive motor is disassembled from the whole vehicle, it is strictly prohibited to disassemble cell.

(1) Turn off the low-voltage power supply, pull out the high-voltage circuit repair switch, and discharge the three-phase wire end with the discharge wire clamp.

(2) Detect with multi-meter and make sure that the voltage of three-phase wire to ground shall be ≤30V.a.c before repair operation can be carried out.

(3) Check the motor water-cooled circulating system without leakage of anti-freeze fluid.

(4) Check whether the motor shell is damaged or not, and replace the drive motor if it is damaged.

(5) It is necessary to check whether the steel wire screw sleeve is damaged or not, whether it is assembled in place or falls off, if so, it is necessary to replace the drive motor.

(6) It is necessary to check whether the copper bars of three-phase high-voltage connection are damaged or not, if so, it is necessary to replace the drive motor.

(7) It is necessary to check whether there are crooked pins, withdrawal pins and broken pins in low-voltage sockets. If there are crooked pins, it is necessary to correct them with special tools. If there are withdrawal pins and broken pins, it is necessary to replace the drive motor.

(8) It is necessary to check the seal ring, if it is lost or damaged, it is necessary to supplement or replace the seal ring.

(9) It is necessary to check the spline shaft grease, if not uniform, it is necessary to timely replenish grease.

(10) It is necessary to check the spline shaft, if there is wear and tear, it is necessary to replace the drive motor.

(11) It is necessary to check whether the motor is running smoothly under no-load condition, if there is stuck, frustration, it is necessary to replace the drive motor.

8.5 Requirements for repair and maintenance of high-voltage electric connections

8.5.1 Requirements for repair and maintenance of high-voltage cables

(1) High-voltage harness has no fracture, aging crack, discoloration, ablation, skin damage, conductor exposure, and has good insulation performance.

(2) High-voltage harness is fixed firmly without loosening or falling off. The high- voltage harness of drive motor, steering motor and electric air compressor has reserved (30 to 50) mm vibration margin, which is protected from edges and has no wear and tear around it.

(3) There are no defects in the terminal of the electrical connection between the high-voltage harness and the B-level voltage components, and the fixed bolt has no loosening,

terminal oxidation and ablation. After the repair and disassembly of the high-voltage harness, the conductive surface of the terminal is clean, without dust and oil-stains, so as to avoid the increase of contact resistance and abnormal heating.

(4) Insulation resistance between high-voltage wire and ground is higher than 2MΩ. The grounding resistance of shielding layer is less than 0.5Ω.

(5) After the completion of repair and maintenance, the whole vehicle will be electrified. Carry out insulation testing through the vehicle insulation testing equipment. If there are insulation faults, timely treat them.

8.5.2 Requirements for repair and maintenance of high-voltage connector

(1) High-voltage connectors shall not be damaged and deformed. There shall be no dismantling difficulties caused by rust at the socket. High-voltage connectors shall be installed firmly without loosening. Seal rings shall not be removed from the sheath.

(2) Requirements for connector insulation resistance: The insulation resistance between the terminal and shielding layer of high-voltage connector is ≥20MΩ.

(3) The casing of high-voltage connector is not corroded and damaged, there is no foreign matter and water in the interior of connector, and there is no oxidation, abnormal heating and ablation in the conductive part of high-voltage connector.

(4) After the high-voltage connector is repaired and plugged, it shall be plugged in position, the lock structure is installed in place, without virtual connection.

(5) After the completion of repair and maintenance, the whole vehicle will be electrified. It is necessary to carry out insulation testing through the vehicle insulation testing equipment. If there are insulation faults, it is necessary to timely treat them.

(6) The high-voltage harness assembly shall be replaced directly when there are connector faults. The replacement method can be found in the Maintenance Manual of the vehicle.

8.5.3 Requirements for repair and maintenance of AC/DC charging sockets

8.5.3.1 Requirements for maintenance of AC/DC charging sockets

It is suggested that AC and DC charging sockets shall be cleaned regularly.

8.5.3.1.1 AC/DC charging socket inspection

(1) The protective end cover of the charging socket is intact and undamaged, the inside of the socket is clean, without foreign matter and water, with good insulation performance, and the inner waterproof ring (if visible) of the charging socket is not damaged or falls off.

(2) The cover and locking buckle of charging socket is not damaged or broken. There is no oxidation, abnormal heating and ablation in the conductive part of charging socket.

(3) The charging socket is fixed firmly, without loosening, and the terminals are not blackened, broken, and the spring does not fall off.

(4) After 30 minutes of vehicle charging (fast charging battery charging not less than 10 minutes), the temperature of charging socket is not higher than the ambient temperature by 10 ℃.

(5) After the completion of repair and maintenance, the whole vehicle will be electrified. It is necessary to carry out insulation testing through the vehicle insulation testing equipment. If there are insulation faults, it is necessary to timely treat them.

8.5.3.1.2 Procedures and measures for handling abnormal problems

(1) In case of problem of AC and DC charging socket, high-voltage harness assembly shall be replaced.

(2) If there is any foreign matter, it shall be removed by means of tweezers with insulated handle or blown out by air gun.

(3) If there is water stain, it shall be cleaned with clean dust-free cloth (no paper towel is allowed at charging port terminal), or dried by air gun;

(4) In case of dust, it shall be cleaned with nylon soft bristle round brush (diameter of soft bristle round brush: 10 mm for DC outlet, 5 ~ 6 mm for AC outlet) and dust-free cloth.

8.5.3.2 Requirements for repair of AC/DC charging sockets

8.5.3.2.1 Common fault diagnosis and processing method of AC/DC charging socket

Fault description	Treatment method
Insulation fault	Replacement of high-voltage harness assembly
Over-temperature fault	It is necessary to clean up the charging socket and replace the charging gun, and replace the high-voltage harness assembly when the fault recurs.
Cover of charging socket is damaged	Replacement of high-voltage harness assembly
Terminal ablation	Replacement of high-voltage harness assembly
Seal ring rupture	Replacement of high-voltage harness assembly

8.5.3.2.2 Requirements for repair of AC/DC charging sockets

Before repairing AC/DC charging sockets, it is necessary to make sure:

(1) It is necessary to remove the power battery repair switch when the vehicle is powered down at high-voltage.

(2) The whole car is powered down by low voltage.

8.5.3.2.3 Repair, inspection and replacement of AC/DC charging socket

The high-voltage harness assembly shall be replaced directly when there are charging socket faults. The replacement method can be found in the *Maintenance Manual* of the vehicle.

8.5.4 Requirements for repair and maintenance of charging guns

8.5.4.1 Requirements for maintenance of charging guns It is recommended that the charging gun be cleaned regularly.

8.5.4.1.1 Charging gun inspection

The protective cover of charging gun is not damaged or cracked.

There is no foreign matter such as water stain and dust around the terminal. The terminals are not blackened, broken and shed.

Charging wires and cables are not damaged or cracked.

8.5.4.2 Requirements for repair of charging guns

8.5.4.2.1 Common fault diagnosis and processing method of charging gun

Fault description	Treatment method
Damage to gun head or wiring harness	Replacement of charging harness
Failure of charging function	Replacement of charging harness

8.5.4.2.2 Charging gun maintenance requirements

Non-work state.

8.5.4.2.3 Repair, inspection and replacement of charging gun

The charging line assembly needs to be replaced.

8.6 Requirements for repair and maintenance of high-voltage components of power electronics

Power electronic components include vehicle chargers, DCDC converters, DC/AC inverters, etc.

8.6.1 Requirements for maintenance of high-voltage components of power electronics

When cleaning vehicles, it is necessary to try to avoid washing the connector parts of high-voltage components of power electronics with high-voltage water flow, so as not to cause electrical fault.

8.6.2 Requirements for repair of high-voltage components of power electronics

8.6.2.1 Requirements for repair of high-voltage components of power electronics

High-voltage components of power electronics are high-voltage electrical appliances. Professionals shall be equipped with professional equipment for operation during repair. Illegal disassembly by non-professionals is strictly prohibited.

Before repairing power electronic high-voltage components, it is necessary to ensure that:

(1) It is necessary to remove the power battery repair switch when the vehicle is powered down at high-voltage.

(2) The whole car is powered down by low voltage.

8.6.2.2 Replacement of high-voltage components of power electronics

If it is a liquid cooling system, the liquid-cooled pipeline shall be separated first.

(1) Disconnect the coolant pipe;

(2) Remove the coolant pipe clasp;

(3) Pull out the coolant pipe.

(4) The water nozzle is used to cover the coolant pipe opening and the water nozzle of high-voltage components such as power electronics. Then separate the high-voltage connection:

(1) Separate low-voltage connectors and disconnect low-voltage harness.

(2) Separate high-voltage connectors and disconnect high-voltage harness.

(3) Remove high-voltage components of power electronics.

9. Recycling of power battery

In accordance with the requirements of *Energy Conservation and Development Planning of New Energy Automobile Industry*, it is necessary to strengthen graded recycling utilization of power batteries, and clarify responsibilities, rights and obligations of all parties in the establishment of management methods and systems. The government shall not only guide battery manufacturers to recycling batteries, but also encourage the development of specialized battery recycling enterprises.

In order to achieve the win-win goal of environmental and economic benefits of power battery recycling industry, it is necessary to take safety measures to prevent possible safety accidents and realize that "safety" is the basis of development. Therefore, in order to realize the healthy development of power battery recycling industry, it is necessary to carry out prior assessment in all relevant links, adopt feasible safety assessment and prevention strategies, and carry out safety control in the process.

9.1 Summary of graded utilization and recycling of power battery

9.1.1 Definition of terms

The terms and definitions defined in the *Electric Vehicle Safety Guide* are applicable to this document

Power battery: Batteries that provide energy for new energy automotive power systems are composed of battery packs (batteries) and battery management systems, including lithium ion power batteries, metal hydride/nickel power batteries, etc., without lead- acid batteries.

Waste power batteries:

(1) Power batteries whose residual capacity or charge-discharge performance after use cannot guarantee the normal running of electric vehicles, or that are no longer used after disassembly for other reasons.

(2) Power batteries on abandoned electric vehicles.

(3) Power batteries discarded after graded utilization.

(4) Power battery waste in battery manufacturing process

(5) Other power batteries to be recycled and recycled.

Above waste power batteries include waste battery packs, battery modules and cell batteries.

Recycling: The process of collection, classification, storage and transportation of waste power batteries.

Disassembly: The process of removing power batteries from electric vehicles.

Dismantling: The process of separating waste power batteries step by step.

Storage: Storage behavior of waste power batteries in the process of collection, transportation, graded utilization and recycling, including temporary storage and regional centralized storage.

Utilization: Recycling of waste power batteries after recovery includes graded utilization and recycling.

Graded utilization: The process of applying waste power batteries (or battery packs/battery modules/cell batteries) in other fields, including one level or multiple levels.

Recycling and utilization: Waste power batteries are dismantled, crushed, separated, purified and smelted for resource utilization.

Automobile manufacturer: Domestic new energy automobile manufacturers and importers of new energy automobiles that have obtained *Announcement of Road Motor Vehicle Manufacturing Enterprises and Products*.

Battery manufacturer Domestic power battery manufacturers and power battery importers:

Waste automobile recovery and disassembly enterprises: Enterprises that have obtained qualification certification and engaged in the business of recovery and disassembly waste automobiles.

Comprehensive utilization enterprises: Waste power battery graded utilization enterprise or recycling enterprise in accordance with the requirements of *Standard Conditions for Comprehensive Utilization of Waste Power Batteries in Electric vehicles*.

Graded utilization enterprises: That is to say, the production and application enterprises of batteries with graded utilization refer to the enterprises that need to test, classify, disassemble and reorganize the waste power batteries (or battery packs/battery modules/ cell batteries) so that they can be applied in other fields.

Recycling enterprises: Enterprises that dismantle, crush, separate, purify and smelt waste power batteries to realize the recovery and recycling of resources and raw materials.

9.1.2 Power battery graded utilization and recycling process

According to the relevant specifications and requirements of electric vehicles, the process of echelon utilization and recycling of power batteries and the operation procedures of recycling service outlets are shown in Figure 9-1-1, Figure 9-1-2, and Figure 9-2.

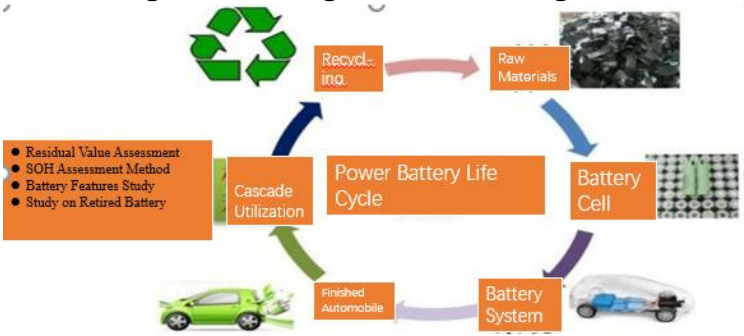


Figure 9-1-1

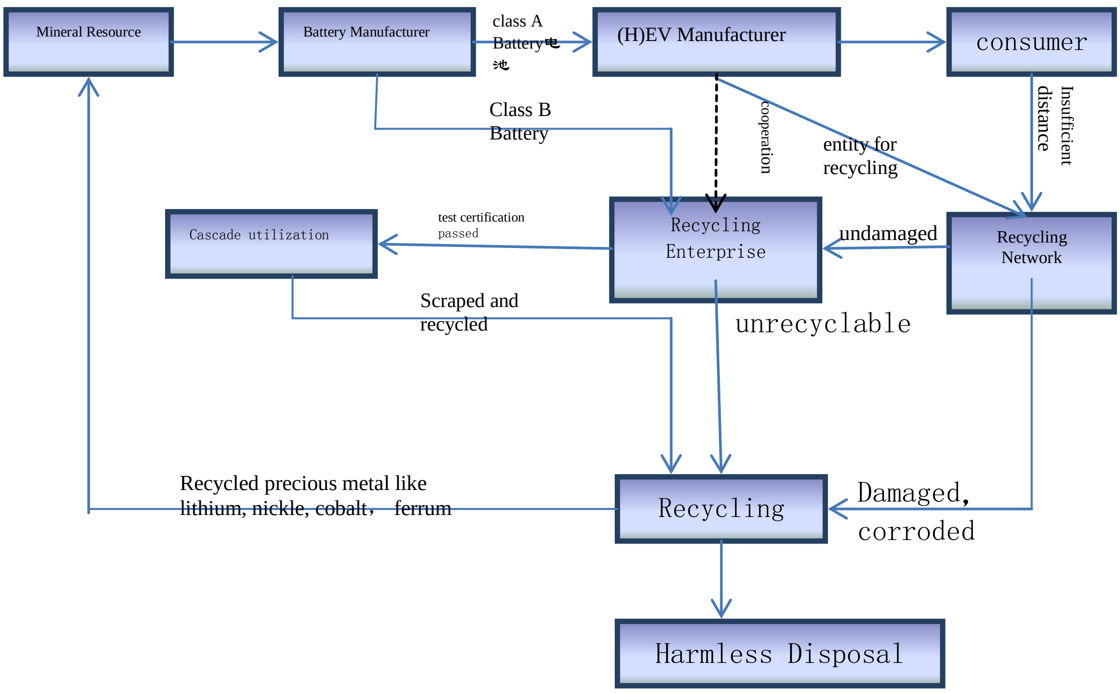
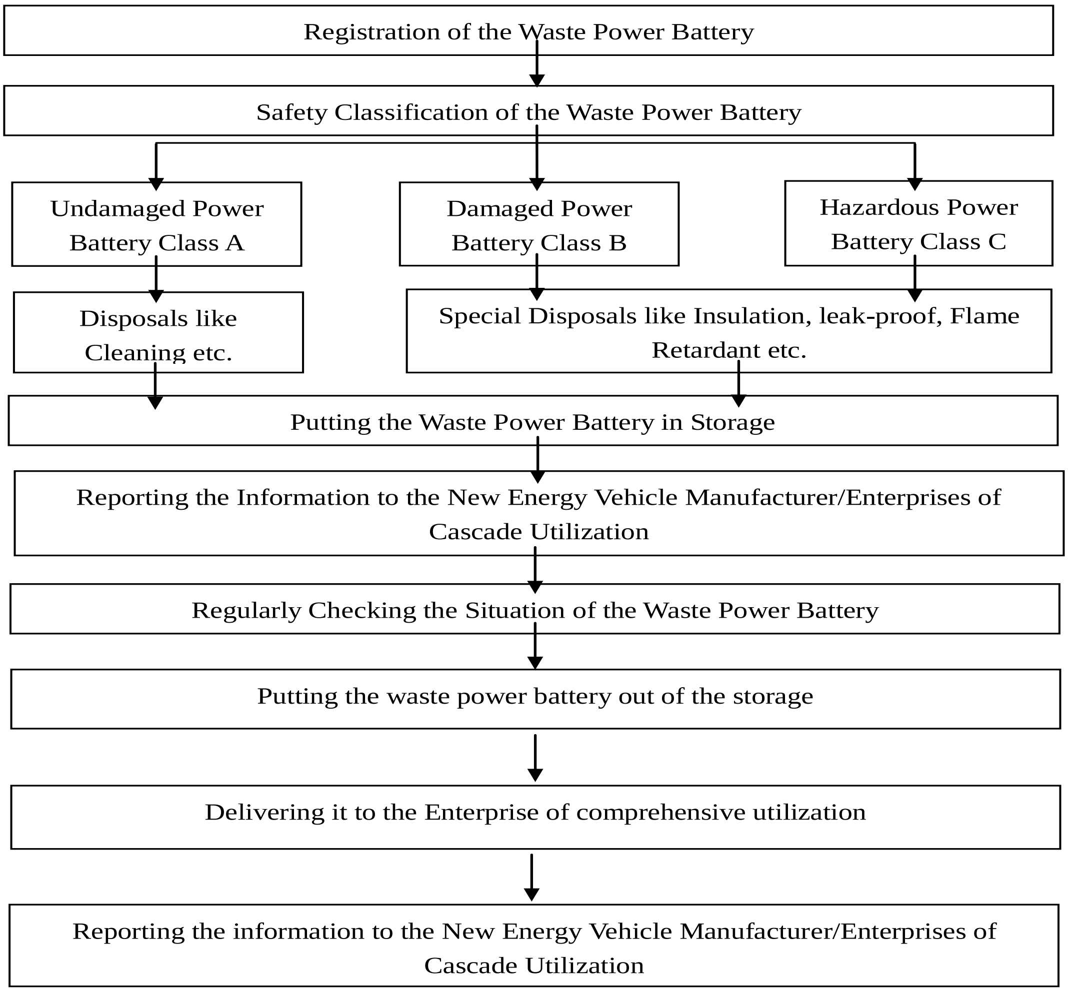


Figure 9-1-2

Harmless Disposal

The Operating Procedures of the Recycling Station



9.1.3 Environmental safety

9.1.3.1 General requirements

Enterprises engaged in comprehensive utilization and graded utilization of power batteries shall follow the following general requirements:

1. Relevant enterprises shall establish and improve the responsibility system for safety and environmental protection of various departments

(1) Enterprises engaged in comprehensive utilization and graded utilization shall organize and formulate departmental safety and environmental protection regulations and operating rules.

(2) Enterprises engaged in comprehensive utilization and graded utilization shall regularly carry out safety and environmental protection inspection to eliminate potential accidents.

（3）Enterprises of comprehensive utilization and cascade utilization shall regularly organize safety and environmental protection training for the staff in every department, as well as regular assessments for the relevant administrators in the enterprise.

2. Requirements for environmental safety of all relevant enterprises in the whole industrial chain;

(1) Enterprises engaged in comprehensive utilization and graded utilization shall properly manage and dispose of toxic, harmful, inflammable and explosive residues (including waste, waste gas, waste water and waste residue) produced in the process of comprehensive utilization. If they have no corresponding disposal capacity, they shall be subject to treatment by enterprises with relevant qualifications for centralized treatment according to relevant requirements.

(2) The enterprises engaged in comprehensive utilization and graded utilization shall meet the requirements of relevant laws and regulations of the state in terms of transportation process to ensure the integrity of the battery structure, adopt safety safeguards such as fire prevention, water prevention, explosion prevention, insulation and heat insulation, and formulate emergency plans.

(3) The enterprises engaged in comprehensive utilization and graded utilization shall meet the requirements of GB 12348 in terms of noise emission, and the specific standards shall be implemented according to the regional categories defined by the local people's government.

(4) The enterprises engaged in comprehensive utilization and graded utilization shall meet the requirements of GB Z1 and GB Z2 in terms of working environment.

(5) Enterprises of cascade utilization shall formulate safety and environmental protection emergency plans in accordance with the Guidelines for the Preparation of Emergency Plans for Production Safety Accidents of Production and Business Units (GB/T 29639), and equip with the ability to handle safety and environmental protection emergencies. The waste power

batteries shall be regularly checked. If any hidden dangers of safety and environmental protection are found, measures shall be taken in time. In addition, it shall also be handed over to the enterprise of comprehensive utilization.

9. 2 Recovery network and storage and transportation safety of power batteries

9.2.1 Responsibilities and obligations of battery graded utilization enterprises Enterprises engaged in comprehensive utilization and graded utilization of power batteries shall follow the following requirements in responsibilities and obligations:

9.2.1.1 Automobile manufacturers provide operation data information of graded utilization batteries with graded batteries enterprises

(1) The automobile manufacturers provide enterprises engaged in graded utilization of batteries with information about the voltage, capacity, lithium ion category and series- parallel connection of the batteries;

(2) Automobile manufacturers provide enterprises engaged in graded utilization of batteries with information such as the number of cycles of batteries and the production time of batteries;

(3) Automobile manufacturers provide enterprises engaged in graded utilization of batteries with information about battery system structure design.

9.2.2 Disposal requirements for battery system before transportation of recycled power batteries

Enterprises engaged in the recycle of power batteries shall comply with the following requirements in terms of responsibilities and obligations:

(1) The minimum and maximum capacity of batteries before transportation shall meet the requirements for safe transportation.

9.2.3 Packaging requirements for recycled power batteries before transportation

9.2.3.1 Specification for packaging and stacking of recycled power batteries before transportation

Enterprises engaged in the comprehensive utilization and graded utilization of power batteries shall follow the following requirements in terms of specifications for packaging and stacking when recycling power batteries:

(1) The enterprises engaged in comprehensive utilization shall formulate packaging requirements for battery cells and battery systems before transportation of recycled power batteries. For pre-treatment against vibration, water, sunscreen and anti-collision, they shall adopt boxes, including ordinary wooden boxes, plywood boxes, metal boxes, plastic boxes and carton boxes, which meet the requirements of category II packaging corresponding to category IX dangerous goods, and select for loading, unloading, transportation and storage according to

the quality and characteristics of packaging containers, quality, type, specification, method and weight of power battery;

(2) Class A and Class B waste power batteries with a net weight of not more than 400 kg shall be packaged in accordance with the requirements of the General Technical Conditions for the Transport and Packaging of Dangerous Goods (GB 12463), and the net weight of more than 400 kg shall be packaged in accordance with the requirements of the Safety Regulations for the Inspection of Dangerous Goods Packaging (GB 19432);

(3) The packaging of Class B waste power batteries shall have sufficient strength to withstand various operational risks under normal transportation conditions;

(4) The packaging of Class C waste power batteries shall be selected according to their characteristics, and shall not be mixed with other goods. The packaging shall be able to effectively block the leakage of the waste liquid from batteries.

(5) The enterprises engaged in comprehensive utilization formulate regulations on stacking layers of battery cells and battery systems before transportation of recycled power batteries. The stacking layers shall be limited for wooden boxes or carton packages corresponding to their respective load-bearing capacity in order to prevent safety accidents due to collision and friction during transportation;

(6) It shall be marked in accordance with the requirements of the Packaging Marks for Hazardous Goods (GB 190);

(7) The packages of treated batteries shall be labeled with "damaged/defective lithium batteries or lithium battery packs";

(8) Emergency contact information shall be attached to the packages of batteries.

9.2.3.2 Requirements for recycled power batteries transportation tools

Enterprises engaged in the comprehensive utilization and graded utilization of power batteries shall follow the following requirements in terms of transportation tools when recycling power batteries:

(1) Before transporting batteries, enterprises engaged in comprehensive utilization and automobile manufacturers shall work out transportation routes and transportation emergency plans jointly;

(2) Whoever transports hazardous waste shall adopt measures for the prevention and control of environmental pollution and observe State regulations on the control of transportation of hazardous goods;

(3) Vehicles used for transporting batteries shall be kept clean and dry, and residues shall not be discarded at will. Vehicles polluted by power batteries shall be cleaned at places where appropriate conditions are met after transportation;

(4) The unrelated personnel shall not take vehicles for transporting battery goods;

(5) Vehicles for transporting battery goods shall not park in residential settlements, dense pedestrian areas, government organs, and scenic spots. Safety measures shall be taken if loading and unloading operations or temporary parking are required in the above-mentioned areas.

9.2.4 Requirements for information traceability for recycling power batteries

Enterprises engaged in comprehensive utilization and graded utilization of power batteries shall follow the Interim Provisions on the Traceability Management of the Recycling and Utilization of Power Battery for New Energy Vehicles:

1. Identification requirements for special systems for recycling battery

(1) Before recovery, the corresponding retrospective coded serial number tags are affixed to the unified positions of the batteries and battery systems.

(2) The retrospective coded serial number label is compiled according to GBT 34014- 2017 *Coding Rules for Automotive Power Batteries.*

2. Retrospective and physical requirements for data and information of recycled power battery and battery system

Enterprises engaged in graded utilization manage, control and trace batteries according to their serial number codes and classifications.

9. 3 Detection, classification and disassembly safety of power battery recycling

9.3.1 General requirements

9.3.1.1 Requirements for safe disassembly tools and facilities

The enterprises engaged in the disassembly of power batteries shall meet the following requirements in respect of safety facilities and disassembly tools:

(1) Enterprises engaged in graded utilization shall have special classified collection and storage facilities to meet the requirements of corrosion resistance, ruggedness, and fire protection and insulation;

(2) Enterprises engaged in graded utilization shall have high-voltage insulated gloves, high-voltage arc mask, insulated arc protective clothing and other safety protection tools, insulated rescue hooks, automatic external defibrillator, medical first aid box and other rescue medical equipment;

(3) Enterprises engaged in graded utilization shall have environmental protection facilities to treat poisonous and harmful gases, waste water and slag, and safety firefighting equipment to deal with the corresponding fire hazards;

(4) They shall be equipped with hazardous waste temporary storage warehouse to collect toxic and harmful liquids such as coolant, electrolyte and batteries containing heavy metals that

leak out when damaged. The ground shall be treated against corrosion and seepage, and an emergency collection pool shall be built against corrosion and seepage;

(5) Enterprises engaged in graded utilization shall have traceability and management equipment for power battery coding information;

(6) Enterprises engaged in graded utilization shall have insulation testing equipment, such as insulation resistance tester;

(7) Enterprises engaged in graded utilization shall have firefighting facilities as stipulated by the state, such as fire hydrants, sand boxes and fire extinguishers;

(8) Enterprises engaged in graded utilization shall be equipped with special lifting tools, special disassembly workbenches, insulating set tools, etc. Special disassembly workbenches need to be reliably grounded.

9.3.1.2 Site requirements

Enterprises engaged in graded utilization of power battery shall comply with the following requirements in terms of site:

(1) The plant buildings shall be in line with the requirements of GBZ 1, and the fire resistance rating and lighting design of the building shall be in line with the requirements of GB 50016 and GB 50034.

(2) The plant shall be equipped with the fire extinguisher as per the requirements of GB 50140, and for those designed with water supply and sewerage works, the regulations in GB 50069 shall be met.

(3) The workshop shall be equipped with ventilation installation, liquid waste treatment facility and waste residue collection facility.

(4) For enterprises engaged in graded utilization, the site shall be built with fences and divided into functional areas, storage area, treatment area, analysis and detection area and management area according to treatment technology. Each functional area shall have clear boundaries and signs.

9.3.1.3 Personnel requirements

Enterprises engaged in graded utilization of power battery shall comply with the following requirements in terms of personnel:

(1) Before the operation, the personnel shall wear and use the labor protection appliances as per the requirements of GB/T 11651; personnel that fails to abide by the requirements cannot approach the operation area and operate the equipment;

(2) The accident emergency processing and first aid methods shall be mastered;

(3) The personnel shall be made with periodic physical examination as per the regulations of GBZ 188, and its physical condition shall be in line with the requirements for job category.

(4) The operator shall accept the pre-job training and regular training, and pass the assessment.

(5) Enterprises engaged in graded utilization shall be staffed with professionals with professional skills that can meet the requirements of environmental protection, safety operation (including collection, storage and transportation of hazardous wastes) and first aid knowledge, as well as hold corresponding qualification certificates.

9.3.1.4 Standard for safety disassembly of enterprises engaged in graded utilization

Enterprises engaged in graded utilization of power battery shall comply with the following requirements in terms of standards for safety disassembly:

(1) It is strictly prohibited to operate battery system disassembly process alone;

(2) They shall check tools and facilities before disassembly to ensure safe and normal use;

(3) Before disassembly, they shall work out safety disassembly procedures or operation instructions, and disassemble according to the designated disassembly operation procedures or operation instructions;

(4) The unrelated personnel are not allowed to be present during disassembly, and it is necessary to do a good job in safety precautions.

9.3.1.5 Requirements for material management and control in enterprises engaged in graded utilization

Enterprises engaged in graded utilization of power battery shall comply with the following requirements in terms of material management and control:

(1) After disassembly, the battery module and battery cell shall be insulated and protected, with insulation mark;

(2) The disassembled power battery shall be marked live and transferred to the storage area with warning signs in time for isolation;

(3) After the removing, components, materials and wastes shall not be discard carelessly, but shall be classified and stored in the special vessels and marked, so as to avoid the mixed storage and placement;

(4) The hazardous wastes such as waste oil and waste circuit board shall be managed by the specially-assigned person, and shall be stored as per the requirements of HJ 2025, and made with normative transference regularly;

(5) The storage of coolant shall be carried out as per the requirements of GB 29743.

9.3.2 Safety requirements for battery system disassembly in enterprises engaged in graded utilization

Enterprises engaged in graded utilization of power battery shall comply with the following requirements in terms of battery system disassembly safety:

(1) They shall adopt special lifting tools and lifting equipment to lift the recycled power battery system to a special disassembly table;

(2) They shall adopt insulation tools to disassemble high-voltage harness, circuit board, battery management system, high-voltage safety box and other functional components;

(3) In the process of disassembly, they shall avoid contact between metal objects and high and low voltage joints in order to avoid short-circuit fire.

9.3.3 Safety requirements for battery module disassembly in enterprises engaged in graded utilization

Enterprises engaged in graded utilization of power battery shall comply with the following requirements in the safety of battery module disassembly:

(1) They shall adopt special module disassembly equipment to disassemble the module safely and environmentally;

(2) They shall adopt special lifting tools and lifting equipment to lift the module to the disassembly table;

(3) They shall adopt insulation tools to disassemble the wires and connectors on the module;

(4) In the process of disassembly, they shall take insulation protection measures, plug high and low voltage connection joints with insulation materials in time, and shall not disassemble modules by hand.

9.3.4 Inspection safety in the process of disassembly and separation of enterprises engaged in graded utilization

9.3.4.1 Protective requirements of sorting and testing for enterprises engaged in graded utilization

The enterprises engaged in graded utilization shall follow the following protective requirements in sorting and testing power batteries:

(1) The grounding device of testing equipment shall comply with regulations of GB 50057-2010;

(2) Before the operation, the personnel shall wear and use the labor protection appliances as per the requirements of GB/T 11651, for the personnel that fails to abide by the requirements, it cannot approach the operation area and operate the equipment.

9.3.4.2 Operational safety in sorting and testing for enterprises engaged in graded utilization

The enterprises engaged in graded utilization shall follow the following operation safety requirements in sorting and testing power batteries:

(1) The operator shall accept the pre-job training and regular training, and pass the assessment;

(2) Personnel who operate the testing equipment must be familiar with the instructions before using them and operate strictly in accordance with the operating rules;

(3) They shall check and maintain the testing equipment regularly;

(4) The testing site shall be equipped with fire-fighting facilities in line with relevant national regulations, such as fire hydrants, sand boxes and fire extinguishers.

9.3.5 Battery classification and separation requirements for enterprises engaged in graded utilization

In classification and separation of batteries, the enterprises engaged in graded utilization shall test the open circuit voltage and internal resistance of batteries and grade by chemical component capacitance in order to improve the consistency of cells.

9.4 Safety requirements for design of battery pack by recycled power batteries

9.4.1 Design safety of graded battery system

The graded battery system consists of four parts: graded batteries, battery management system, and structural parts and harness. The safety design of the system shall be considered comprehensively from the aspects of the separation of graded batteries, the design of electronics and electricity, flame retardant structure, thermal management design, multiple anti-combustion design and design of battery management system to ensure the safety of the system.

9.4.1.1 Sorting of graded batteries

According to the capacity, voltage, internal resistance and self-discharge of graded batteries or modules, the battery cells or modules are sorted strictly and then used in groups. There are different requirements for different application scenarios.

9.4.1.2 Design requirements for electronics and electricity of graded battery pack

The electronic and electrical design of graded batteries shall be considered from the aspects of warning signs, contact protection, insulation protection, external short circuit protection and over-current protection.

(1) The warning sign has yellow background and black border. When personnel approach the battery system, they shall be able to clearly see the warning signs and reminded to pay attention to high-voltage safety. It is recommended to refer to GB 2894-2008 *Safety Signs and Guidelines for Use*;

(2) In the design of direct contact protection, measures such as insulation, protective cover and obstruction are adopted. In the design of indirect contact protection, equipotential protection (grounding protection), protection cut-off and leakage protection are adopted.

(3) The electrical insulation design of graded batteries is mainly three aspects: cell, module and system.

(4) In order to prevent short circuit and overload of batteries, fuses shall be selected in the loop of batteries system for protection. The fuse is designed to be the weakest link in the loop. Under normal operation, the fuse will not fuse. When short circuit or serious overload occurs in the loop, fuses in the fuse will immediately fuse to protect the circuit and electrical equipment. It is recommended to refer to GB/T 34131-2017 *Standard for Technical Conditions of Lithium Ion Battery Management System for Electrochemical Energy Storage Power Station*.

(5) Over-current protection design means that when the battery system monitors the current exceeding the prescribed range and duration during operation, the battery system sends the abnormal information to BMS and requests power reduction. If the loop current has not dropped to the prescribed range within the prescribed time, the battery system will cut off the current of the whole loop to prevent fire and explosion of the whole power supply loop because of long-time over-current.

9.4.1.3 Requirements on the Design of Thermal Management

Two important aspects of power battery thermal management design:

(1) Maintaining a balance between the temperature inside and outside the battery;

(2) The absolute temperature of the battery shall be controlled within a reasonable range. The design of the thermal management of the cascade battery pack must be available under different temperature conditions in different industries.

(3) A flame retardant structure is required.

9.4.1.4 Requirements on the Design of the Flame Retardant Structure

Fireproofing and flame retardant can be considered from two aspects: 1) passive fireproofing and flame retardant; 2) active fireproofing and flame retardant.

Passive fireproofing and flame retardant means that when designing a battery system, its components shall be the materials with high flame retardant grade or incombustible. If the plastic parts inside the battery systems which reach a certain level of flame retardant, its high-low voltage harnesses shall use the products with high flame retardant grade. It is recommended that the high-low voltage harnesses shall stand the temperature above 125 ℃. Reference GB/T 2408-2008 Determination of burning properties of plastics - Horizontal method and vertical method

Active fireproofing and flame retardant design can be considered from two aspects: First, adding a fireproof structure into the battery system to prevent the external flame directly entering the interior of the cabinet; second, adding a fireproofing system inside the cabinet in the power battery system.

9.4.1.5 Design of multiple combustion prevention mechanisms

The application of graded batteries requires multiple safety handling mechanisms, including active anti-combustion, early warning of combustion and passive anti- combustion processing.

(1) Active anti-combustion In charging, multi-level protection measures shall be taken into account to avoid battery charging accidents due to over-voltage of batteries under various abnormal conditions. Redundant design of communication shall be considered to ensure the accuracy of communication.

(2) Early warning of combustion Before the failure of the battery cell, early warning shall be made according to the operation parameters and alarm signals of the battery to avoid the occurrence of accidents.

(3) Passive anti-combustion

The anti-combustion mechanism shall be adopted to block the contact between fire source and air oxygen, such as hexafluoroheptapropane.

9.4.1.6 Safety requirements for production process of graded batteries

Foolproof design of battery sampling terminals shall be installed in accordance with the management system specifications. The damage to the management system due to unnecessary operational errors can be avoided.

Foolproof design is adopted for the anode and cathode of batteries to avoid hidden troubles caused by subsequent installation and reverse connection.

9.4.2 Safety requirements of lithium battery management system

9.4.2.1 Reliability design of management system

(1) Insulation detection, short circuit protection and restoration, over-current protection and restoration conform to the industry or national specifications of application scenarios;

(2) The design of EMI meets the requirements of EMI design in related application fields;

(3) Battery management system shall have lower temperature rise, which can increase its reliability and reduce local thermal radiation to batteries;

(4) It is necessary to prevent starting large current or the sudden change of running current; otherwise, it will cause the instantaneous impact of large current on graded batteries;

(5) For application scenarios, reliability design index (MTBF) shall meet the standard requirements.

9.4.2.2 Management system requirements for charge and discharge safety management

(1) The charging current design of graded battery products shall meet the requirements for charging design;

(2) The discharging current design of graded battery products shall meet the requirements

for discharge design and requirements for temperature rise;

(3) Overcharge, under-voltage and over-temperature protection shall conform to industry standards or international standards;

9.4.2.3 Requirements for battery fault management and on-line monitoring and analysis

Battery management system warns all kinds of battery faults. Battery management system shall be able to give differentiable warning instructions according to the fault level.

Through the analysis of the operation parameters of the battery, it can obtain the attenuation status of the battery and adjust the operation parameters of the battery to avoid the risk.

9.5 Safety requirements for production of batteries by recycled power batteries

9.5.1 Detection

9.5.1.1 Appearance detection

(1) The inspectors shall be trained in relevant positions, have certain knowledge of safety and protection, and equipped with corresponding insulation measures, such as insulating gloves and insulating shoes (boots);

(2) The testing equipment and tools shall be insulated to avoid short circuit of battery pack during use;

(3) The detection area shall be clearly divided and marked, and a safe escape passage shall be set up reasonably.

9.5.1.2 Performance detection

1. Capacity separation and matching

(1) Capacity separation equipment shall be adopted, that is, the battery part shall be separated from the electronic control part of the equipment. The equipment shall have the alarm function of abnormal battery voltage, current and capacity, the ability of safety diagnosis, the test of global protection and distributed protection (global protection means that the diagnosis function of high-voltage, low voltage and abnormal voltage change rate in each step; distributed protection is to check whether the parameters of each step are abnormal, such as the charge and discharge capacity value of this step). For power battery charging and discharging equipment, safety redundancy can be achieved based on two voltage reference benchmarks;

(2) No open fire or high fire risk processes shall be arranged in the surrounding safety range for the matching process;

(3) The capacity separation process shall have accident ventilation capability to ensure the air circulation in the workplace.

2. Aged

(1) Placement area shall be clearly planned, and test batteries shall be distinguished from production batteries;

(2) If batteries need to be isolated, the isolator shall be non-combustible material;

(3) Remote or on-site monitoring measures shall be adopted, and smoke and temperature alarms shall be installed;

(4) Workplaces shall be equipped with adequate fire extinguishing equipment, personal protective equipment and emergency supplies;

(5) Firewalls shall be set up in aging rooms, and there shall be no doors, windows or openings between aging rooms and adjacent rooms.

9.5.2 Graded battery assembly

(1) Relevant operators need to participate in the corresponding job training, operate according to the corresponding operation instructions, and shall have the corresponding safety operation skills;

(2) Workplace facilities and equipment shall be equipped with protective measures to prevent external short circuit and high-voltage arc of battery pack;

(3) The equipment in high-voltage area shall have the functions of safety self-locking and fault self-diagnosis, so as to avoid short-circuit combustion of battery modules and electric boxes connected to wrong lines. High-voltage areas shall be isolated, and relevant staff shall have certain professional knowledge and safety knowledge;

(4) Insulation measures shall be taken in the assembly and testing process of battery packs. The exposed parts of tools contacting battery packs shall be wound with insulating materials to reduce the risk of short circuit. The relevant workbench and ground shall be insulated to avoid short circuit or arc damage caused by contact between live wire of battery module and metal conductor;

(5) It is suggested that the turnover box or tray with anti-collision and anti-drop protective measures shall be added in the production turnover process;

(6) The workplace site shall be clearly divided into areas, the working procedures of each position shall meet the operational requirements, and the positions for which personnel need to contact relevant electronic components shall be subject to anti-static treatment, such as wearing electrostatic bracelets and electrostatic treatment on the ground.

(7) The workplace site shall be equipped with emergency isolation measures when fire and explosion accidents occur, which can effectively isolate battery packs;

(8) Workplace site shall be equipped with fire hydrants, fire extinguishers, fire buckets or fire sandbags and other emergency items, and escape passages shall be reasonably established, so that emergency items can be correctly used in case of abnormal circumstances.

9.5.3 Function and performance testing of graded batteries

(1) The testing process shall be monitored by professionals with knowledge of battery pack testing;

(2) The necessary insulation measures such as insulating gloves, insulating shoes (boots) and insulating tools shall be taken in the testing process;

(3) Testing instruments shall meet requirements for installation and instruments with special operating specifications shall be marked with obvious safety identification, such as high-voltage and keep away.

(4) The detection process shall be carried out in the environment with the temperature of 25 ℃±5 ℃, relative humidity of 15% - 90% and atmospheric voltage of 86 kPa - 106 kPa;

(5) The detection area shall be clearly marked and equipped with separate isolation area, where the abnormal situation can be isolated and dealt with on the spot, and safe escape passages are reasonably set up, equipped with corresponding fire hydrants, fire extinguishers, fire sandbags and other emergency items.

9.5.4 Warehousing

(1) The ground of the storage site shall be hardened, leak-proof and insulated. The warning signs of solid waste shall be set in accordance with the requirements of "Environmental Protection Graphic Mark-Solid Waste Storage (Disposal) Field" (GB 15562.2), while at a prominent position. Set warning signs such as danger, flammable, explosive, and hazardous substances, and set a yellow marking line on the ground. Refer to the Waste Battery Recovery Management Code (WB/T 1061), the Battery Waste Storage and Transportation Specification (GB/T 26493) and the General Industrial Solid Waste Storage and Disposal Site Pollution Control Standard (GB 18599) for waste. Power battery storage work;

(2) The storage of waste power batteries shall be stored according to their types (lithium iron phosphate, ternary, etc.) and classification results, as follows:

The same type of Class A (see Figure 8-2 for class A, B, and C) shall use cut-off storage.

Different types of Class A waste power batteries and the same type of Class B waste power batteries shall use segregated storage.

Different types of Class B waste batteries and Class C waste power batteries shall use isolated storage.

The storage methods shall meet the following requirements:

Storage method requirements	Cut-off storage	Segregated storage	Isolated storage
Storage area spacing/m	0.5-1.0	0.3-0.5	0.5-1.0
passage width/m	1-2	1-2	5
Wall width/m	0.3-0.5	0.3-0.5	0.3-0.5

(3) Regular safety inspections shall be conducted when the finished battery pack is stored for a long time; on-site monitoring, smoke and temperature alarms shall be installed;

(4) Warehouse carriers shall use appropriate handling tools (such as forklifts, carts, etc.). Batteries shall be handled lightly to avoid mechanical damage to batteries;

(5) Warehouse shall be divided into corresponding areas, and isolation areas shall be set up to effectively prevent abnormal spread of battery packs;

(6) The warehouse shall be reasonably equipped with fire hydrants, fire extinguishers, fire buckets or fire sandbags, where escape passages shall be reasonably set up.

9.6 Safety requirements for use of graded batteries

9.6.1 Scenarios and requirements for the use of graded batteries

(1) Lithium-ion batteries have the best operating temperature range and are prone to safety problems beyond the scope of use. The upper limit temperature of battery shall be lower than 45 ℃. It is easy to cause thermal runaway safety problems when used at higher temperatures. Lithium precipitation is likely to occur to cathode in case of low temperature charging. It is necessary to control charging mode, charging current shall be reduced or prohibited properly below 0 ℃;

(2) In order to work beyond the temperature range for a long time, built-in heating or cooling elements or air-conditioning constant temperature shall be adopted to maintain the appropriate temperature of batteries;

(3) Batteries stored for more than half a year shall be activated by low current charging and discharging before they are normally reused. Charging speed has strong correlation with service life and safety risk. If conditions permit, charge at low current;

(4) Full batteries stored at high temperature shall be avoided for a long period of time, so as to prevent the degradation of battery performance and the increase of safety risk;

(5) For graded batteries used for standby, it is advisable to consider the appropriate amount of charged batteries for long-term standby, so as to ensure the sufficient amount of standby power and the safe state of live storage of batteries;

(6) For graded batteries used for power storage, appropriate partial charge and partial discharge strategy shall be set. It can prolong the service life of batteries and reduce safety risks.

9.6.2 Requirements for charging and discharging current, voltage and protection function

(1) The charging and discharging current and voltage shall be adjusted properly according to the environment when the graded batteries are used. When the service temperature tends to the limit of battery service temperature, the charging and discharging current and voltage shall be reduced appropriately;

(2) Charging equipment shall meet the requirements for battery charging maximum voltage, maximum allowable current, temperature limit, cell extreme value, etc, equipped with safety and protection mechanism. In the charging process, the charging equipment shall monitor the change of the charging voltage, current, and temperature. When exceeding the allowable charging limit, it shall conduct the shutdown protection in time;

(3) Electrical equipment shall be adapted to the allowable range of working voltage and current for battery operation. During the discharging process, when the battery voltage or current exceeds the standard, power shall be restricted to prevent the damage of the battery due to overpower operation.

9.6.3 Requirements for battery installation and construction

(1) Graded batteries with small capacity can be fixed with reliable anchors or other structures. They shall not be stacked too high or too much. The heat dissipation capacity of batteries, the load-bearing capacity of the box and the stability shall be taken into account to prevent the safety risks caused by temperature accumulation, battery sliding or accidental movement;

(2) Graded batteries with large capacity shall be installed with battery cabinet. Battery cabinet shall be well ventilated and heat dissipated. Battery cabinet shall be reliable and firm and it will not be deformed with load for a long time;

(3) Graded batteries that are deployed at large scale shall be installed in the battery room, battery room shall be equipped with good ventilation and lighting, appropriate temperature and automatic fire protection device. When the battery room is installed on the floor, the load-bearing capacity of the floor shall meet the needs. Batteries shall be fixed in an appropriate way to prevent safety risks caused by sliding or accidental movement;

(4) The graded batteries shall be connected by the national standard wires. The specifications of the connecting wires shall match the capacity of batteries and the feeding distance to meet the requirements for current carrying capacity and voltage drop. Connected wires, contacting conductors or bare live components shall have insulation distance for protection. Screws and nuts shall be fully fixed and able to withstand the mechanical stress caused by normal use. All electrically connected cable terminals or connectors shall meet the requirements for connection strength. Insulation caused by loosening or potential safety hazards caused by impedance rise shall be prevented.

9.6.4 Requirements for use protection

(1) In the process of use, the circuit system shall have the function of automatic protection of over-current and short-circuit. After over-current or short-circuit faults are eliminated, the circuit system shall automatically or manually resume its normal working state;

(2) When accessing the equipment system, the graded batteries shall be equipped with suitable circuit breakers. The circuit breakers shall have the functions of automatic disconnection and manual disconnection and recycle when the current exceeds the standard. Protective disconnection can be performed when the loop current is abnormal;

(3) When accessing the equipment system, the graded batteries shall be equipped with suitable fuse devices, which can perform protective disconnection when the loop current is abnormal;

(4) When the circuit breaker cooperates with the fuse, the differential shall be adjusted appropriately considering different operation characteristics;

(5) After installation, the graded batteries shall be placed neatly, with adequate space and spacing, waterproof, dust-proof, lightning protection and constant temperature. The graded battery cabinets or battery compartments shall be equipped with automatic firefighting devices.

9.6.5 Requirements for operation monitoring

(1) When the graded batteries are used, the parameters of total voltage, cell voltage, current and temperature shall be monitored. When the parameters exceed the safety risk level, it is necessary to stop the charging and discharging and start the alarm. When the cell voltage and temperature change abruptly or exceed normal level, the battery shall be alarmed and not used.

(2) For graded batteries that are deployed at large scale, BMS data shall be checked during operation. The key parameters of batteries, such as total battery total voltage, cell voltage, temperature extreme value, SOC and SOH, shall be monitored in real time. If there is any possibility of safety risks, it is necessary to stop charging and discharging, start the alarm, and notify manual processing.

9.6.6 Requirements for regular inspection and maintenance

(1) Users deploying graded batteries shall regularly organize professional personnel to inspect and maintain the batteries. Regularly check whether the battery box and panel components are clean. The surface of the battery output terminal shall be free of dust.

The communication terminal and the indicator lamp shall work normally. Copper ear insulating cap shall not fall off, bolt shall be tightened, without abnormalities such as burning, oxidation and discoloration, plug plastic parts are not melted, cable do not fall off or is damaged;

(2) For standby use scenarios, it shall be regularly maintained and diagnosed as follows Regular discharging: The long-term standby operation of graded batteries is not conducive to the maintenance of battery performance, so the battery shall be regularly discharged and maintained. It is advisable to discharge a certain proportion of the capacity with small current at constant current, and recharge the charged capacity with constant current and voltage limit in time once a month.

Checking discharge: It is advisable to conduct the checking discharge at least once every three years, and the graded batteries that have run for four years shall be subject to checking discharge at least once a year. It shall be recharged in time after checking discharge. After checking discharge and recharging, if the capacity of graded batteries cannot reach the intended use effect, they shall be replaced.

(3) For power storage use scenarios, it shall be regularly maintained and diagnosed as follows

Checking discharge: It is advisable to conduct the checking discharge at least once every two years, and the graded batteries that have run for two years shall be subject to checking discharge at least half a year. It shall be recharged in time after checking discharge. After checking discharge and recharging, if the capacity of all graded batteries cannot reach the intended use effect, they shall be replaced.

9.7 Safety requirements for recycling and utilization of power battery materials

9.7.1 General requirements

9.7.1.1 Personnel requirements

(1) Establish and improve safety production management institutions, equipped with full-time safety production management personnel according to regulations. The head of production and operation and the safety management personnel shall have the qualification certificate for safety production management;

(2) Personnel shall be subject to regular safety education and training in safety laws and regulations, safety production norms and labor protection and they can take up their posts after passing the examination;

(3) Special operation personnel and special equipment personnel must be trained by special safety training institutions in accordance with the relevant provisions of the State and they can take up their posts after obtaining certificates of special operation qualification and special equipment;

(4) Before taking up the post, personnel shall wear complete labor protective articles according to the regulations to ensure standardization and effectiveness;

(5) Visitors must receive corresponding safety education before entering the factory and enter the site under the guidance of special personnel;

(6) It is recommended to establish the guardian system: Personnel with experience in hazardous disposal shall be appointed as guardians during operation. Safety management personnel shall supervise on site during hoisting operation, fire operation, restricted space operation and high-altitude operation. It is necessary to stop illegal operations in time, take

emergency rescue measures in case of danger, and clean up the site with relevant personnel after operation.

9.7.1.2 Requirements for recycling tools and equipment

(1) Lifting equipment: It must be in good condition, qualified with the usage license issued by the competent crane authority. All kinds of safety protection devices and monitoring, indication, automatic alarm signal devices on lifting machinery shall be complete and intact. Lifting machinery with incomplete or ineffective safety protection devices shall not be used. The lifting work area shall be marked clearly and guarded by special personnel. Personnel unrelated to lifting shall be strictly prohibited;

(2) Large equipment: There shall be error-proof facilities at the entrance of the crusher to ensure that personnel will not enter by mistake or the equipment will not start when the personnel enter for overhaul. Switches shall be marked clearly, with anti- misoperation mechanism.

(3) It is necessary to control and manage waste water, waste gas and noise discharge on the daily basis, and record operation of facilities for water gas, waste water and slag treatment, and stipulate the storage period;

(4) Enterprises shall adopt effective and reliable fire prevention, explosion prevention and leakage prevention measures in accordance with relevant regulations for facilities involved in the production, transportation, use and storage of inflammable and explosive dangerous chemicals such as gas, oxygen and hydrogen, as well as key fire prevention parts such as fuel depots and cable tunnels (ditches). Enterprises shall set up automatic detection, alarm and fire extinguishing devices for places with explosive dangerous environment in accordance with *Electrical Equipment for Explosive Gas Environment* (GB3836) and *Code for Design of Electrical Devices in Explosive Dangerous Environment* (GB50058);

(5) Enterprise shall take anti-corrosion measures for reactors, tanks, pools, kettles, liquid storage tanks and pickling tanks, set up accident pools, carry out regular safety inspection, maintenance and regular testing to ensure normal operation. For leaching and extraction operations, enterprise shall take safety measures such as fire prevention, explosion prevention, spray prevention and poisoning prevention.

9.7.1.3 Requirements for raw materials

(1) Live raw materials: In transportation and production process, live raw materials will not cause fire and explosion due to short circuit, knock and other reasons;

(2) Non-charged raw materials: Powder will not be dispersed into the air to ensure health and safety of workplace personnel;

(3) If there is residual electrolyte on raw materials, it needs to be collected in a container

rather than directly leaked to the ground, nor can the electrolyte be dried and directly discharged into the atmosphere.

9.7.1.4 Method requirements

(1) Identify hazardous and harmful factors and formulate corresponding safety measures, including but not limited to process safety and energy isolation;

(2) There shall be various emergency plans, including but not limited to fire and explosion, production safety, special equipment, occupational health, toxic and harmful operations, and regular evacuation exercises;

(3) The lifting position shall strictly comply with the national standard or industry standard, such as (HG30014);

(4) In accordance with the requirements of laws and regulations, industry standards or enterprise norms, all documents or records in appropriate forms shall be retained for a certain period of time as evidence;

(5) Enterprise shall establish the repair and approval system for hazardous operations such as limited space, fire, high-altitude operations and energy medium transportation, implement the management of work tickets and operation tickets, strictly carry out internal examination and approval procedures, and arrange special personnel to conduct on-site safety management to ensure operation safety.

9.7.1.5 Requirements for environment and site

(1) The design of new construction, reconstruction and expansion projects shall be designed and accepted in accordance with relevant national standards;

(2) The environment and hygiene of workplaces and factories shall meet the requirements of GBZ1 Hygienic Standard for Industrial Enterprise Design, GBZ2.1 Occupational Contact Limits for Hazardous Factors in Industrial Places Part 1: Chemical Hazardous Factors, GBZ2.2 Occupational Contact Limits for Hazardous Factors in Industrial Places Part 2: Physical Hazardous Factors, GB3095 Environmental Air Quality Standard and GB12348 Industrial Enterprise Noise Standard;

(3) In the factory area, necessary fire facilities and fire passages shall be set up in accordance with GB15630 *Requirements for the Setting of Fire Safety Signs*. The location of fire facilities shall be marked clearly;

(4) Smoking and fire are strictly prohibited in the no-fire area.

9.7.2 Safety requirements for recycling process

9.7.2.1 Disassembly of single cell

(1) It shall be disassembled harmlessly without manpower;

(2) Before disassembly, the cell voltage shall be ensured within the safe range;

(3) In the process of disassembly, wastewater, waste gas and residue of product shall be treated according to corresponding environmental protection standards.

9.7.2.2 Wet smelting

(1) It shall be implemented in accordance with the relevant requirements in No. 91 *Regulations on Safety Production of Metallurgical Enterprises and Non-ferrous Metals Enterprises* of the State Administration of Safety Supervision and Administration and No. 26 *Regulations on Safety Production Supervision and Administration of Metallurgical Enterprises* of the State Administration of Safety Supervision and Administration;

(2) Before operation in the tank, the workload and time shall be analyzed and the working route shall be worked out. Poisoning or asphyxiation shall be prevented during operation;

(3) Detection and alarm of combustible gases in the air;

(4) Toxic and harmful operations: detect and record the toxic and harmful factors in the working area. Enterprise shall take measures to prevent burns of personnel and set up safe spraying or washing facilities in working places where acid and alkali are used;

(5) In the implementation of multi-shift work, conscientiously implement the handover system and do a good job of recording and checking.

9.7.3 Requirements for warehousing

(1) Reference9.2.3.1 and 9.5.4;

(2) It is strictly forbidden to dump the waste directly, and it shall be centrally stored and handed to the manufacturer with recycling qualification.

9.8 Requirements for safety data control for recycling of power batteries

9.8.1 Traceability management of power battery recycling

In terms of data information traceability, three-dimensional traceability of data, objects and application scenarios shall be realized in seven links: battery recycling, storage and transportation, detection, classification and disassembly of recycle and reuse, reused battery pack design, reused battery production, graded battery use, power battery material recycling, and safety accident handling.

9.8.1.1 Data management in each process phase

1. Object code

(1) In the process of battery recycle, the recycled battery pack shall be labeled and matched with its exclusive serial number corresponding to its original factory code according to GB/T 34014-2017 *Coding Rules for Automotive Power Batteries*, so as to realize the connection between the factory data of batteries and the subsequent reuse data.

(2) In the process of battery reuse (including the disassembly of recycled battery packs into minimal cells (modules or cores), the restructuring of battery packs and material regeneration),

the minimal cells and the restructured battery packs shall be labeled, matched with their exclusive serial numbers and associated with the process data, respectively.

(3) Each label number corresponds to a series of data that can be collected by the label object in different processes, and they can be connected in series to achieve the purpose of data traceability and management.

2. Data collection and management

(1) In the process of battery recycle and reuse, collect the inducement data and phenomenal data of safety accidents in each link, and sort out the data according to the order of hidden trouble traceability, cause analysis and accountability.

(2) Combined with the actual scene of battery recycling process, achieve low cost, high efficiency, conciseness and non-repetition of data collection.

(3) For other safety risks existing in the process that are difficult to correspond to data types, it is necessary to consider adding data collection modules and data sources to achieve comprehensive supervision of safety risks.

9.8.1.2 Processing and storage of process data

(1) According to the difference of data attributes, completeness and collecting difficulty, preprocess different types of data for data storage;

(2) According to the reasonable association between data, design the storage plan matching the data. On the premise of ensuring data safety, it is necessary to optimize the speed of reading, writing and updating data as much as possible;

(3) It is necessary to determine the logical relationship between data and safety risks in the traceability process;

(4) Combined with the practical application scenarios, it is necessary to excavate the quantitative assessment criteria of potential safety hazards, and put forward the rational suggestions of investigation and treatment methods.

9.8.2 Big data analysis and operational management

9.8.2.1 Prediction and warning of potential safety hazards

(1) Process regulation: According to the collected data and information, combined with production, storage, transportation and use, it is necessary to conduct the whole process safety supervision in the principle of mutual verification between products and scenarios;

(2) Intermediate product quality supervision in each link: It is necessary to test intermediate products of each link correspondingly, and analyze whether the output data meet the requirements for product safety. If necessary, it is necessary to introduce a third-party inspection organization to supervise the quality coordinated with the process;

(3) Product use monitoring: It is necessary to collect in all directions and analyze in stages

the battery data in the use scenario, and judge whether there are potential safety hazards by the changes of various performance indicators, so as to achieve the purpose of early warning.

9.8.2.2 Feedback and handling of potential safety hazards

(1) It is necessary to investigate the potential safety hazards of early warning in time;

(2) It is necessary to implement data traceability of hidden danger objects and assist analysts to find the source of hidden danger;

(3) It is necessary to follow up the results of hidden danger treatment to see if this type of hidden danger can be accurately predicted and handled in time, and continuously optimize the risk management and control capability of the whole process;

(4) It is necessary to associate the feedback, processing and follow-up tracking records related to safety risks with the relevant process data to realize the interconnection and interoperability of the whole process data.

9.8.3 Data application in safety accidents

9.8.3.1 Data traceability before safety accidents After the occurrence of safety accident, adjustable accident-related information mainly includes:

(1) The whole process data of accident object in the recycle and reuse, historical alarm of hidden dangers, feedback processing and follow-up tracking records;

(2) Combined with the site situation after the accident, it is necessary to sort out the whole process of the accident object to obtain data, and analyze comprehensively the causes of the accident.

9.8.3.2 Safety optimization suggestions

(1) In order to ensure the accuracy of traceability process, the inspectors must regularly calibrate or verify the data collection methods and record the corresponding data. Relevant testing organizations shall do a good job in product quality verification, data accuracy assessment and other supervision work according to the actual conditions of use;

(2) They shall analyze the causes of accidents through data traceability, and define the responsible parties according to the data records;

(3) For safety accidents that cannot be judged, they shall summarize the potential factors of accidents by tracing the historical data information of the accident objects, and avoid reasonably the accidents of this type;

(4) Relevant responsible parties shall make detailed analysis of the accidents, supplement the data items which were neglected before but were vital to the actual safety, optimize the logical relationship between the data items and the safety items, achieve more accurate early warning, more efficient investigation, constantly upgrade and optimize the traceability process.

10. Accident handling

10.1 Accident handling method and procedure

It is necessary to list the types of accidents that may occur, and deal with the corresponding types of accidents in order to rapidly handle accidents and strive for rescue time.

10.1.1 Collision rescue

10.1.1.1 General Vehicle damage is handled in the following steps:

(1) It is necessary to switch the vehicle key or start switch off and disconnect the low-voltage battery;

(2) If conditions permit, it is necessary to disconnect the repair switch (if any);

(3) If the vehicle is seriously collided, it is necessary to help all personnel on the vehicle flee the vehicle at the first time, call 4S store rescue telephone and contact traffic police and insurance company for rescue, liability and damage determination;

(4) Please refer to the fire rescue plan for the spontaneous combustion accident caused by the accident.

10.1.1.2 Personnel search and rescue

1. Detection and definition of rescue areas

After the rescue vehicle arrives, the scene commander immediately investigates the accident scene, understands the trapped person's position, number and wound situation.

If two or more vehicles collide, it is necessary to define the rescue area with the accident vehicle as the center, and non-rescue personnel are strictly forbidden to enter the area. In case of the leakage of electrolyte from power battery of accident vehicle, it is necessary to define the warning area through detection.

2. Safety protection, alert range setting

It is necessary to set up the scope of the accident site and do a good job in the safety protection of the whole accident site. Vehicle collision accidents often lead to traffic congestion.

In order to avoid secondary accidents caused by other vehicles that enter the site, the on-site commander shall cooperate with traffic police departments to implement traffic control on the accident section in time. Personnel entering the rescue area shall wear safety protective gear strictly in accordance with requirements for personal safety protection, and set up safety personnel for on-site safety monitoring in the process of disassembly and cutting at any time.

3. Operation to rescue trapped personnel

According to the presence force, the rescuer is grouped into 5-6 persons, with 1 on- site commander, who is responsible for organizing and coordinating their personnel in conducting the rescue work, determining the rescue methods, and acting as a safety officer at the same time. The disassembly and rescue team consists of 2-3 persons, who are responsible for rescuing the trapped persons. They are required to be familiar with the performance of equipment and equipment and be skilled in operating various disassembly tools.

There is one equipment coordinator, responsible for providing and delivering equipment, and he can assist the disassembly team to carry out work at any time in case of personnel shortage. There is one medical nurse, responsible for understanding the injuries of the trapped persons, carrying out emergency medical assistance, monitoring the vital signs of the wounded persons, and stabilizing the emotions of the trapped persons when necessary. If professional medical personnel are present in time, doctors can take the job.

Disassembly and rescue:

(1) Vehicle fixation:

According to the rollover and overturn of the accident vehicle, three or four-point support system is used to fix the vehicle;

(2) Door removal

If the passengers are trapped by steering wheel and brake device in chest, abdomen or lower limbs, the first choice is to open a lifesaving passage by breaking the adjacent door;

(3) Vehicle roof removal

In order to open up more space for rescuing people and get close to the wounded as far as possible, when the internal situation of the accident vehicle is more complex and there are more people trapped, remove the roof of the vehicle for rescue.

(4) Raising dashboard

If the passenger's chest and abdomen are stuck by the steering wheel, first try to see whether he can move the seat backwards. If it can't be moved, it is suitable to raise the dashboard by means of top bracing. Notes for rescue

(1) Before rescue work, it is necessary to first ensure that the fuel and power supply (high-voltage and low voltage) of the vehicle has been cut off, and try to avoid touching the fuel circuit and electric circuit, so as to avoid secondary accidents, otherwise, it will endanger rescue and trapped personnel;

(2) In the process of disassembly, it is necessary to not damage power battery. If the power battery has been deformed or damaged in the accident, the temperature of the battery shall be monitored in real time. In case of abnormal temperature rise, it shall be continuously cooled with water to prevent explosion and fire;

(3) Before rescue, it is necessary to immediately clear sharp objects such as glass, and protective devices such as seat belts and airbags. If the airbags are not deployed, it is necessary to take measures to prevent the airbags from bouncing. During the rescue process, it is necessary to observe the situation of the wounded at any time. If necessary, it is necessary to help the

medical and nursing staff to carry out first aid, actively communicate with the trapped personnel, inform them of the progress of rescue, and encourage them to cooperate with the rescue work;

(4) It is necessary to reduce obstacles on the rescue site, and timely clean up the parts that have been broken down and disassembled beyond the first area to avoid tripping, so that rescue personnel will not be tripped and collided in the rescue process;

(5) When shearing vehicle body posts and roof rails, it is necessary to disassemble decorative plastics, sealant tape and other items, avoid airbag inflatable device, seat belt reinforcement device, seat belt extender and other items, so as to prevent personnel injury and equipment damage;

(6) In the process of removing the injured person, it is necessary to be aware of the injured parts beforehand. If necessary, it is necessary to fix the limbs, bandage and lift them out with wooden boards and stretchers so as to avoid secondary injury.

10.1.1.3 Vehicle disposal

Slight impact

In case of mild collision, without damage to the new energy high-voltage system or power battery accident, it is necessary to contact service store for repair and treatment after the traffic police and insurance company determine the responsibility and damage.

Serious collision

In case of damage to the new energy high-voltage system or power battery accident, it is necessary to contact trailers to tow it to 4S store for repair and treatment after the traffic police and insurance company determine the responsibility and damage. When it is towed to 4S store, it is necessary to monitor the temperature of power battery in the whole process. In case of abnormal temperature rise, it is necessary to carry out physical cooling to prevent fire and explosion.

Leakage and deformation of power battery shall be treated as follows:

(1) Leakage of power battery

a. Return the power supply of the vehicle to gear off;

b. Take the next step until the low-voltage battery accessories are off for 3 minutes;

c. The power repair switch shall be disconnected (if any);

d. Disconnect the connection between anode and cathode of the power battery;

e. The anode and cathode bus connectors and harness terminal connectors of power batteries shall be insulated and sealed with insulating tape to prevent short circuit and foreign matters;

f. When a small amount of electrolyte leaks, stay away from the fire source, use suction pad to absorb and place it in an airtight container, or burn it. When a large amount of electrolyte leaks, collect them and treat them according to hazardous chemicals, and add calcium gluconate solution to treat the toxic gas HF.

g. Tow the vehicle to the store to disassemble the power battery and store the power battery safely after disassembly;

Notes: For steps c, d and e, operators need to wear insulated rubber shoes + insulated gloves. For steps f and g, operators need to wear: Insulated rubber shoes + anti-acid and alkali gloves + protective eyeglasses;

The temperature of power battery shall be monitored throughout the whole process before the battery is stored safely. In case of abnormal temperature rise, it shall be subject to physical cooling to prevent fire and explosion.

(2) Power battery deformation

a. Return the power supply of the vehicle to gear off;

b. Take the next step until the low-voltage battery accessories are off for 3 minutes;

c. The power repair switch shall be disconnected (if any);

d. Disconnect the connection between anode and cathode bus of the power battery;

e. The anode and cathode bus connectors and harness terminal connectors of power batteries shall be insulated and sealed with insulating tape to prevent short circuit and foreign matters;

f. Tow the vehicle to the store to disassemble the power battery and store the power battery safely after disassembly;

g. Disconnect and store the power battery modules when it is seriously deformed.

Notes: For steps c, d, e, f and g, operators need to wear insulated rubber shoes + insulated gloves.

The temperature of power battery shall be monitored throughout the whole process before the battery is stored safely. In case of abnormal temperature rise, it shall be subject to physical cooling to prevent fire and explosion.

(3) Impairment of vehicle sealing

a. Before repair, the vehicle shall be stored in a safe place without water intake and corrosion risk;

b. If the vehicle cannot be moved to a place without water intake and corrosion risk for safe storage, it shall be covered with waterproof garment to avoid the risk of water intake and corrosion.

10.1.1.4 Clearance of site

(1) Thoroughly and carefully inspect and clean up the site and hand it over to the owner and relevant departments. Before evacuating from the scene, count the personnel and sort out

the equipment. Rescue the vehicle to nearby 4S store for inspection, and assist in identifying the cause of the accident;

(2) Clean up the garbage on the spot and check whether there are any accident remnants for identifying the cause of the accident. It is necessary to remind the owner and relevant departments to properly handle damaged batteries and adopt reasonable transshipment methods to prevent fire during transshipment and post-stationary process of accident vehicles. When vehicles are transferred, they cannot be directly towed but transferred according to relevant technical requirements. Vehicles shall be placed 15m away from buildings or other vehicles before all the power of high-voltage batteries is released;

(3) If the power battery leaks (there is obvious liquid outflow), please follow the following methods to operate:

When a small amount of leakage occurs, stay away from the fire source, use suction pad to absorb and place it in an airtight container, or burn it. Please wear anti-corrosion gloves before operation. When a large amount of electrolyte leaks, collect them and treat them according to hazardous chemicals, and calcium gluconate solution can be added to treat the toxic gas HF. When the human body accidentally contacts the leaked liquid, immediately rinse it with a large amount of water for 10-15 minutes. If there is pain, 2.5% calcium gluconate ointment can be applied, or soak it in 2-2.5% calcium gluconate solution to relieve pain. If there is no improvement or there is discomfort, see a doctor immediately.

10.1.2 Water accident rescue

10.1.2.1 Investigation

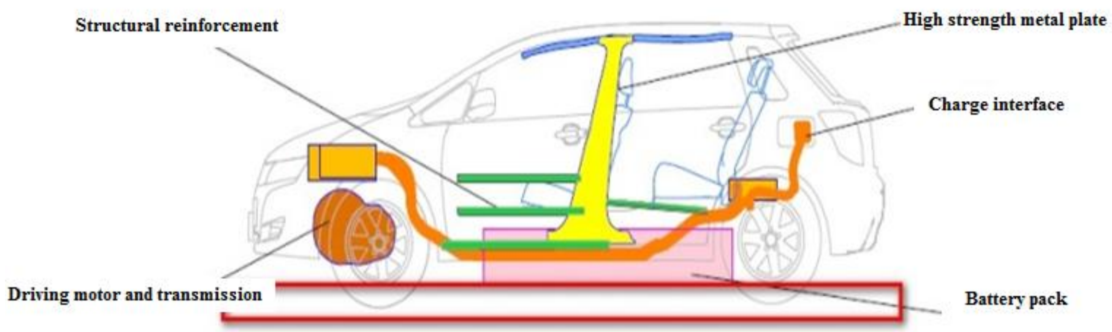
Investigate the depth of water of vehicle and take rescue measures according to different depth of water. It shall be noted that the power battery system will also ignite and explode in the water. Pay attention to safety in the rescue process.

(1) The water below the threshold (as shown below)

a. Slowly drive the vehicle away from the waterlogged road surface and park it in the safe area to check whether water enters the vehicle, and dispose of the water accumulated inside the vehicle. If the vehicle can continue to drive, drive the vehicle to the repair point for comprehensive investigation;

b. In case of anything abnormal, call 4S store for rescue;

c. If the vehicle cannot drive anymore, cut off the power supply immediately and call 4S store and insurance company for rescue in case of safety.

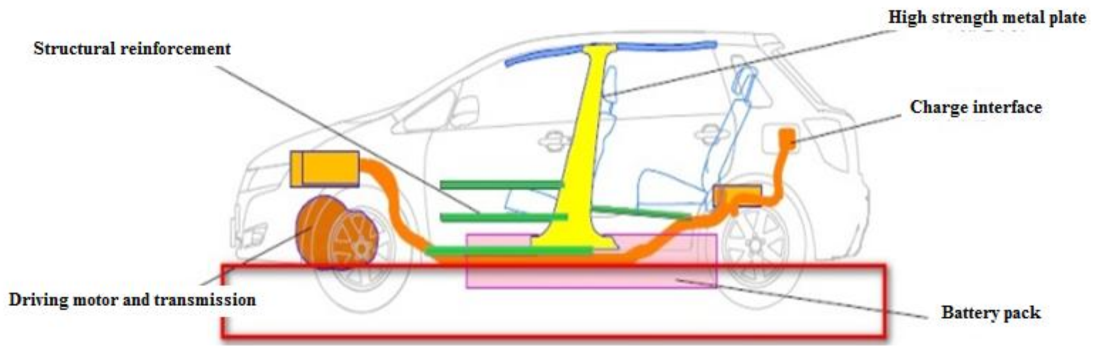


(2) Water at or near the threshold (as shown below)

a. Slowly drive the vehicle away from the waterlogged road surface and park it in the safe area to check whether water enters the vehicle, and dispose of the water accumulated inside the vehicle. If the vehicle can continue to drive, drive the vehicle to 4S stores for comprehensive investigation;

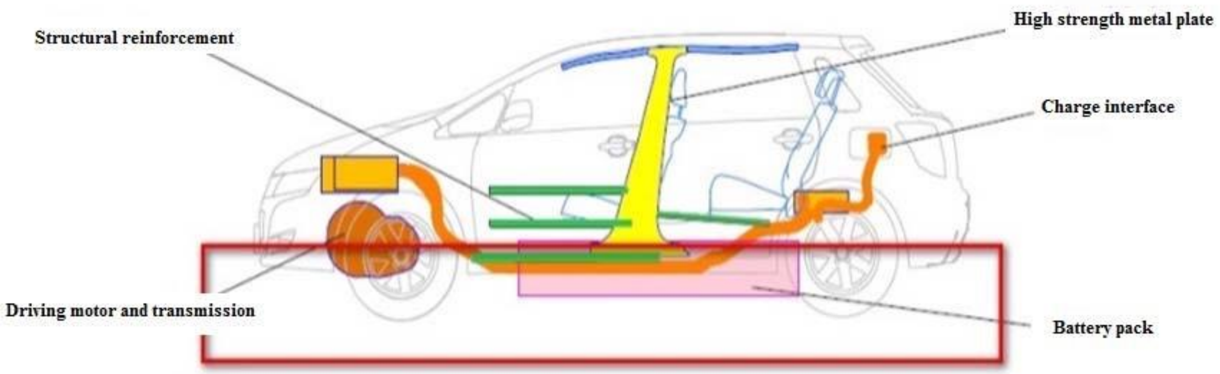
b. In case of anything abnormal, call for rescue;

c. If the vehicle cannot drive anymore, cut off the power supply immediately and call 4S store for rescue in case of safety.



(3) The water above the threshold (as shown below)

All personnel shall leave the vehicle to ensure safety. Call 4S store for rescue and cut off the power supply in case of safety.



10.1.2.2 Personnel search and rescue

It shall include the following:

(1) Water temperature, depth, water surface width, water flow direction, shore topography and other conditions, the accident site and the surrounding roads, traffic, water sources, etc.;

(2) Location, number and casualties of persons in distress;

(3) Through external observation, judge the damage of power battery and high-voltage system of accident vehicle;

(4) Assess the manpower, equipment and other resources required for on-site rescue and disposal;

(5) Conduct safety protection of rescuer for personnel search and rescue;

(6) Analyze the situation on the spot, fully consider the possible risk factors in the rescue process, and determine the rescue plan;

(7) If a person is in the car, he shall break the window or open the door in time, and dial 120 for rescue in time. After the rescue vehicle arrives, the scene commander immediately investigates the accident scene, understands the location, number and injuries of the trapped people, and the rescued people shall be handed over to the medical emergency personnel for rescue;

(8) Find out the traction position and route of the vehicle, and define the safe parking area of the vehicle;

(9) Assign the large crane to the scene, determine the lifting plan, and lift the vehicle falling water up onto the road.

10.1.2.3 Vehicle treatment

(1) High-voltage components of vehicles not soaked with water

a. Determine whether the leakage fault has been reported;

b. Routine overhaul without report of leakage fault;

c. The reported leakage faults are treated according to the plan of "3) immersion above bus bar of vehicle power battery pack".

(2) High-voltage components of vehicles soaked with water

a. Return the power supply of the vehicle to gear off;

b. Take the next step until the low-voltage battery accessories are off for 3 minutes;

c. The power repair switch shall be disconnected (if any);

d. Disconnect the connection between anode and cathode bus of the power battery;

e. Transport vehicles to service stores;

Notes: For steps c, d and e, operators need to wear insulating rubber shoes + insulating gloves;

The temperature of power battery shall be monitored throughout the whole process before the battery is stored safely. In case of abnormal temperature rise, it shall be subject to physical cooling to prevent fire and explosion.

(3) The part above bus of vehicle power battery pack is soaked with water.

a. Return the power supply of the vehicle to gear off;

b. Take the next step until the low-voltage battery accessories are off for 3 minutes;

c. The power repair switch shall be disconnected (if any);

d. Disconnect the connection between anode and cathode bus of the power battery;

e. The anode and cathode bus connectors and harness terminal connectors of power batteries shall be insulated and sealed with insulating tape to prevent short circuit and foreign matters;

f. Tow the vehicle to the store for power battery disassembly.

Notes: For steps c, d and e, operators need to wear insulating rubber shoes + insulating gloves;

The temperature of power battery shall be monitored throughout the whole process before the battery is stored safely. In case of abnormal temperature rise, it shall be subject to physical cooling to prevent fire and explosion.

10.1.2.4 Clearance of site

(1) Return the power supply of the vehicle to gear off;

(2) Take the next step until the low-voltage battery accessories are off for 3 minutes;

(3) The power repair switch shall be disconnected (if any);

(4) Disconnect the connection between anode and cathode bus of the power battery;

(5) The anode and cathode bus connectors and harness terminal connectors of power batteries shall be insulated and sealed with insulating tape to prevent short circuit and foreign matters;

(6) Clean up the vehicle water and tow the vehicle back to 4S store for further inspection.

Notes: For steps (3), (4) and (5), operators shall wear insulating rubber shoes and gloves.

The temperature of power battery shall be monitored throughout the whole process before the battery is stored safely. In case of abnormal temperature rise, it shall be subject to physical cooling to prevent fire and explosion.

10.1.3 Fire rescue

10.1.3.1 Fire-fighting tactics

(I) Users find electric vehicles on fire

Drivers are advised to follow the following steps:

(1) Stop the vehicle;

(2) If possible, pull it aside, disconnect the cathode of the battery and emergency repair

switch, and leave the vehicle;

(3) Stay away from the vehicle for about 30m, and pay attention to traffic safety;

(4) Call 119 for help.

Don't extinguish the fire by yourself.

(II) Treatment method by service store if it finds Electric Vehicle on fire

(1) Return power to OFF;

(2) If conditions permit, disconnect the cathode of low voltage batteries and emergency repair switches (if any);

(3) Extinguish fire with fire-fighting sand, dry powder and water (dry powder and water need to be used continuously, and power batteries must be disassembled and treated safely after the fire is extinguish with water or water-based fire extinguishers);

(4) If the fire rapidly develops or is out of control, fire fighters need to be notified to extinguish fire continuously with large quantities of fire water;

(III) Requirements for rescue specification

(1) Wear safety protection equipment: Insulating gloves (high-voltage electrician and acid-alkaline anti-battery electrolyte), insulating rubber shoes, insulating rubber pads, insulating jackets and protective glasses, etc., with the voltage withstand level greater than 1000V; (2) In case of fire, appropriate fire extinguishing agent shall be used wh

en the fire is small and controllable. Dry sand, chemical powder, carbon dioxide, not water-based fire extinguishers;

(3) When the vehicle is on fire or the battery is seriously damaged due to extrusion and bending, the fire develops rapidly or the fire is out of control, fire fighters need to be notified to extinguish fire continuously with large quantities of fire water for 30 minutes;

(4) When the fire is extinguished, pay attention to it at any time to prevent the resumption of fire;

(5) In order to prevent the fire from expanding, any combustibles around shall be kept away from the vehicle on fire.

10.1.3.2 Clearance of site

(1) Check whether there is residual fire source on site to avoid re-ignition;

(2) Rescue the vehicle to nearby 4S store for inspection, and assist in identifying the cause of the accident;

(3) Clean up the garbage on the spot and check whether there are any inflammables for identifying the cause of the fire.

10.1.4 Treatment of electric shock accident

10.1.4.1 General

(1) Identify the cause of electric shock and determine the rescue plan after assessment;

(2) Do a good job of safety protection for rescuer;

(3) Cut off the shock power before rescue;

(4) Treat personnel after they are isolated from power supply;

(5) Dispose of vehicle equipment after it is isolated from power supply;

(6) Conduct site clearance.

10.1.4.2 Treatment method

The following methods shall be followed to deal with the electric shock and short circuit of electrical equipment on the vehicle that is running, under maintenance, debugging and charging on the site.

People under electric shock: Firstly, confirm whether the body of the person under electric shock has contact with the electrical equipment on the vehicle. If there is contact, the disposal personnel shall first wear insulating gloves to isolate the personnel from equipment with insulating rods, and then carry out rescue by artificial breathing according to the situation.

Electrical equipment short circuit: In case of short circuit of electrical equipment, there will be explosion and arc discharge. Personnel shall stay away from electrical equipment to prevent burns and close the car keys at the first time, pull out manual fast breaker and cut off the power supply of charger (at the time of charging). If arc discharge is still in progress, the operation cannot disconnect short circuit power supply. In this case, people shall be evacuated from vehicles immediately.

10.1.4.3 Precautions

(1) Emergency disposal of vehicle power supply and high-voltage system shall be carried out by certified high-voltage electrical repair personnel under the protection of standard protective measures;

(2) The ambulance personnel are not allowed to touch the wounded directly with their hands before the person before electric shock is out of the power;

(3) Without any insulation measure, rescue workers shall not directly touch the skin and damp clothes of the person under electric shock;

(4) It is strictly forbidden for the rescuer to directly push, pull and touch the person under electric shock; the rescuer shall not adopt metal or other objects with low insulativity (such as damp stick, and straps, etc.) as rescuing tools;

(5) In the process of pulling the person under electric shock out of the power supply, rescuer shall operate with one hand, and the body parts and shoes of the rescuer shall not be wet, which is safe for the rescuer.

10.1.5 Treatment of electric charging accident

10.1.5.1 General

(1) Identify the cause of charging accident, determine the rescue plan after assessment, and pay attention to fire and explosion in charging accident;

(2) Do a good job of safety protection for rescuer;

(3) Cut off the power supply of charging station;

(4) Dispose of vehicle equipment after it is isolated from power supply;

(5) For on-site cleaning, pay attention to the toxic liquid produced by leaking electrolyte when it meets water, which will affect the on-site environment.

10.1.5.2 Treatment method

(1) Firstly, determine and cut off the power supply of charging station;

(2) Under the premise of personal safety, first disconnect the charging equipment from the vehicle by pulling out the charging gun or cutting the charging line of the electric vehicle.

Carry out emergency rescue according to the above requirements for firefighting and electric shock.

10.2 Methods and procedures for investigating causes of safety accidents

In order to clarify the causes and consequences of accidents and ensure the accuracy of the investigation process, it is necessary to explain the investigation methods for the causes of various types of accidents. In order to accurately locate the cause of the accident, the following relevant procedures shall be followed.

10.2.1 Establishment of an investigation team

After a safety accident occurs, the relevant traffic accident handling department shall take the lead in organizing an investigation team to conduct accident investigation and treatment.

The accident investigation team shall be composed of personnel organized by people's governments at or above the county level or authorized relevant departments and the corresponding vehicle manufacturers to investigate and analyze the causes of the accident. According to the needs of accident investigation, relevant experts may also be invited to participate in accident investigation.

The accident investigation team shall be reasonably divided and complete the investigation as soon as possible under the premise of objective science.

In the process of accident investigation, members of the accident investigation team shall be conscientious, objective and impartial, and realistic. They shall observe the discipline of the accident investigation team, keep the secret of the accident investigation, and may not express opinions to the outside world without authorization before the end of the accident investigation and treatment.

10.2.2 Investigation and gather evidence

It is necessary to investigate and gather evidence for the possible causes of accidents, the following requirements and steps shall be followed in accordance with the prescribed investigation and evidence collection process.

10.2.2.1 General

In order to investigate and gather evidence in the efficient and orderly way and guide relevant units to perform their duties reasonably, it is necessary to formulate the guidance methods to investigate and obtain evidence. It is necessary to investigate and gather evidence of safety accidents in the principle of objectivity and fairness, and shall not conceal or fabricate. Neither units nor individuals may illegally interfere with the investigation and evidence collection of safety accidents. The process and results of investigation and evidence collection shall be recorded and filed in real time to ensure the effectiveness and traceability of investigation and evidence collection.

10.2.2.2 Site survey

After the accident, the members of the accident investigation team shall rush to the accident scene in time for investigation. Accident scene shall be protected in time, and shall not be destroyed or shall be recycled in time under special circumstances. It is necessary to ask the parties or witnesses about the accident, and extract relevant traces and physical evidence (video surveillance data, residues, harmful substances, etc.) from the accident scene, and seal and record accident-related objects.

Before investigation, inspect the circumstance around the scene and determine the scope and sequence of the scene investigation. After investigation, combined with the relevant information gathered by on-site investigation and the results obtained through visits around the accident site, preliminarily analyze and judge the accident.

10.2.2.3 Vehicle censorship

It is necessary to extract the annual inspection, maintenance and repair records of the accident vehicle from the accident investigation, and record potential vehicle problems that may cause accidents.

It is suggested to obtain relevant vehicle information from accident vehicle manufacturer, and verify the compliance declaration of relevant vehicle regulations, technical specifications documents and testing reports, etc.

10.2.2.4 Analysis of specific reasons

Accidents can be divided into collision accidents, water accidents and fire accidents according to the scene. The possible causes of accidents shall be analyzed and judged according to different accident scenarios.

10.2.2.4.1 Collision accident

10.2.2.4.1.1 Analysis of human factors

The causes of accidents are analyzed from the driver's point of view. The collision between vehicles or between vehicles and other obstacles is caused by human factors. It is necessary to analyze and judge whether the driver has the following bad behaviors in the event of collision accident:

(1) Acts of speeding, drunk driving, fatigue driving, unlicensed driving, violation of traffic laws and regulations, emotional driving and aggressive driving;

(2) Driving after taking cold medicine, and answering the phone, smoking, chatting and watching the scenery during driving.

(3) Vehicle fails to be decelerated in harsh weather conditions such as wind, snow and fog. Vehicle is not subject to annual inspection, routine maintenance and overhaul as required. From the perspective of others, the causes of the accident are analyzed. Interfered by others, the driver cannot focus on driving, which leads to collision.

10.2.2.4.1.2 Cause analysis of road conditions

In the course of driving, collision accidents occur because of abnormal road traffic or other environmental problems.

It is necessary to analyze whether there are any vehicles or obstacles in front of the road which cannot be easily perceived by the driver, and whether there are unpredictable road condition changes in the course of driving which lead to collision accidents.

10.2.2.4.1.3 Analysis of product reasons

Because the collision accident or the severity of the collision caused by the sudden fault of the vehicle exceeds the protection design of the vehicle, the following problems may exist in the collision of the vehicle:

(1) Operating mechanism: Because of the abnormal braking, steering and other operating devices, vehicle control functions are partially lost or completely out of control such as the vehicle cannot be effectively braked due to braking failure, the direction cannot be effectively controlled due to steering wheel failure, gears cannot be shifted due to control rod failure, the driver cannot effectively control the vehicle and lead to collision accidents;

(2) Battery system: Under the abnormal circumstances of short circuit, over- temperature, under-voltage, leakage, etc., the battery system may lead to protective power failure, power loss, which leads to collision accidents. Different collision severity may also lead to deformation and short circuit of battery system, which may lead to other hazards such as fire;

(3) Power distribution system: Under the circumstances of short circuit and leakage, the battery system may lead to protective power failure and power loss, which may lead to collision accidents;

(4) High-voltage harness: In the case of short circuit, over-temperature and leakage of high-voltage harness, the vehicle may have protective power failure, or the abnormal connection of high-voltage harness may directly lead to power failure, power loss and other conditions leading to collision accidents. After the collision, if high-voltage harness is unreasonably arranged, there may be dangerous situations such as electric shock and arcing, and even fire;

(5) Driving system: In the case of short circuit, over temperature and leakage of the driving system, it may cause protective power failure or break down of the vehicle due to its own fault, which leads to collision accident;

(6) Low-voltage system: In terms of low-voltage system, vehicle breakdown due to abnormal power supply or incorrect alarm information or incorrect vehicle status prompt because of the abnormal system error may affect the safety of driving, leading to collision accidents.

10.2.2.4.2 Water accident

10.2.2.4.2.1 Analysis of human factors

From the driver's point of view, the causes of the accident are analyzed. The vehicle breaks down when it is partially or completely immersed by water caused by human factors. It is necessary to analyze and judge whether the driver has the following bad behaviors in case of water accident:

(1) Acts of speeding, drunk driving, fatigue driving, unlicensed driving, violation of traffic laws and regulations, emotional driving and aggressive driving;

(2) Driving after taking cold medicine, and answering the phone, smoking, chatting and watching the scenery during driving.

(3) Vehicle fails to be decelerated in harsh weather conditions such as wind, snow and fog. Vehicle is not subject to annual inspection, routine maintenance and overhaul as required. From the perspective of others, the causes of the accident are analyzed. Interfered by others, the driver cannot focus on driving, which leads to water accident.

10.2.2.4.2.2 Cause analysis of road conditions

In the course of driving, water accidents occur because of abnormal road traffic or other environmental problems. It is necessary to analyze whether there are dangerous waters ahead or potential dangerous road conditions on the lane that drivers are not easily aware of, and whether there are unpredictable road conditions or environmental changes in the course of During the parking process, water accidents occur because of the change of external environmental factors.

10.2.2.4.2.3 Analysis of product reasons

For the water accident because of the design defect of the vehicle itself or the fault of the vehicle, the following problems may exist in case of water accident:

(1) Operating mechanism: Because of the abnormal braking, steering and other operating devices, vehicle control functions are partially lost or completely out of control such as the vehicle cannot be effectively braked due to braking failure, the direction cannot be effectively controlled due to steering wheel failure, gears cannot be shifted due to control rod failure. Drivers are unable to control vehicles effectively. Vehicles enter dangerous waters when they are out of control, which leads to water accident. When water accident occurs, the vehicle will stall. Because the dangerous parts may enter the water, it may lead to worse results, such as leakage, short circuit and fire;

(2) Battery system, distribution system, high-voltage harness, drive system, low- voltage system and other components break down in the wading section due to device failure. Due to possible waterproofing problems, vehicles may have more serious water accident such as leakage or fire. In addition, water-proof problems may lead to more serious water accidents such as electric leakage or fire when the vehicle goes through wading sections or is parked in dangerous waters.

10.2.2.4.3 Fire accident

10.2.2.4.3.1 Analysis of human factors

From the perspective of vehicle driver, the causes of accidents are analyzed, and fire accidents occur because of the abnormal situation of vehicles caused by human factors. It is necessary to analyze and judge whether the driver has the following bad behaviors in the event of collision accident:

(1) Acts of speeding, drunk driving, fatigue driving, unlicensed driving, violation of traffic laws and regulations, emotional driving and aggressive driving;

(2) Driving after taking cold medicine, and answering the phone, smoking, chatting and watching the scenery during driving.

(3) Vehicle fails to be decelerated in harsh weather conditions such as wind, snow and fog. Vehicle is not subject to annual inspection, routine maintenance and overhaul as required.

From the perspective of others, the causes of the accident are analyzed. There are fire accidents because the driver cannot focus on driving interfered by others or because by intentional arson by other people.

10.2.2.4.3.2 Cause analysis of road conditions

In the course of driving, fire accidents occur because of abnormal road traffic or other environmental problems. It is analyzed that there are some things on the roadway, such as potential fire sources or combustibles, which may induce vehicle fire accidents.

Components damage or even vehicle overturning under extreme road conditions may lead to auto-ignition accidents. Vehicles may be ignited by other sources of fire in other scenarios, such as normal parking or charging.

10.2.2.4.3.3 Analysis of product reasons

For the fire accident because of the design defect of the vehicle itself or the fault of the vehicle, the following problems may exist in case of fire accident:

(1) Operating mechanism: Because of the abnormal braking, steering and other operating devices, vehicle control functions are partially lost or completely out of control such as the vehicle cannot be effectively braked due to braking failure, the direction cannot be effectively controlled due to steering wheel failure, gears cannot be shifted due to control rod failure; the driver cannot effectively control the vehicle and the vehicle is out of control and collides, causing a fire or the vehicle entering a dangerous fire field, causing a fire accident;

(2) Battery system: When the battery system is over-charged, over-discharged, internal short-circuit, over-heated and damaged by external impact, it may cause fire accidents;

(3) Power distribution system: The internal fault short circuit in the distribution system and short circuit caused by foreign matter and the external shock deformation may cause fire accidents;

(4) High-voltage harness: When high-voltage harness is short-circuited or overheated, it may cause fire accidents;

(5) Driving system: When driving system is short-circuited or overheated, it may cause fire accidents;

(6) Low-voltage system: When low-voltage system is short-circuited or overheated, it may cause fire accidents; The failure and fire of a single system or component may also lead to the fault of other high-voltage components, or directly ignite other components, which leads to more serious fire accidents.

10.2.2.4.4 Other accidents

In addition to collision accidents, water accidents and fire accidents, electric shock accidents and charging accidents may occur during daily driving, repair, maintenance or charging.

10.2.2.4.4.1 People under electric shock

10.2.2.4.4.1.1 Analysis of human factors

From the point of view of drivers, repair personnel or other personnel who are in contact with vehicles, the causes of the accidents are analyzed. The electric shock accidents are caused by human factors. It is necessary to analyze and judge whether the relevant personnel have corresponding bad behaviors in case of electric shock accident.

Driver: During collision accident and water accident due to incorrect operation, illegal driving and other causes, there is leakage of electricity, which leads to electric shock of relevant personnel, or unauthorized vehicle disassembly and repair without relevant professional training leads to electric shock accidents;

Repair personnel: In the process of vehicle repair and maintenance, electric shock accidents occur because of illegal operations in violation of relevant guidance manuals.

Other personnel: In the process of vehicle driving or parking, electric shock accidents are caused by intentional damage or contact with the high-voltage part of the vehicle by means of tools, or by accidental contact with potentially dangerous accident vehicles.

10.2.2.4.4.1.2 Cause analysis of road conditions

In the course of driving, electric shock accidents occur because of road traffic abnormalities or other environmental problems, such as normal parking or charging conditions may be overlapped by other dangerous circuits or short-circuit, which leads to electric shock accidents.

10.2.2.4.4.1.3 Analysis of product reasons

For the electric shock accident because of the design defect of the vehicle itself or the fault of the vehicle, the following problems may exist in case of electric shock accident:

(1) Operating mechanism: Electric shock accidents occur due to vehicle collision caused by abnormal operation device, water accident;

(2) Battery system: When the insulation resistance between the high-voltage loop and the body of the battery system decreases or overlaps, the metal body will be charged and the electric shock will occur;

(3) Power distribution system: The metal body is charged and the electric shock accident occurs due to leakage between the high-voltage loop and the body of the distribution system, and the abnormal potential equalization caused by the abnormal grounding of the distribution system may also lead to the electric shock accident;

(4) High-voltage harness: The insulation layer of high-voltage harness is worn and the connector is broken off, and the high-voltage harness is cut off, which leads to the exposure of high-voltage circuit or short circuit with other metal parts, and the electric shock accident occurs;

(5) Driving system: The metal body is charged and the electric shock accident occurs due to leakage between the high-voltage loop and the body of the driving system, and the abnormal potential equalization caused by the abnormal grounding of the driving system may also lead to the electric shock accident;

(6) Low-voltage system: The isolation between the low-voltage system and the high-voltage power supply system may fail, resulting in low-voltage system with high- voltage and

electric shock accident.

10.2.2.4.4.2 Charging accident

The charging process involves the conversion of large energy, which requires cable connection and related energy transmission and storage system, and accidents are relatively easy to occur.

10.2.2.4.4.2.1 Analysis of human factors

From the point of view of installation personnel of charging circuit, charging operator or other personnel who are in contact with vehicles, the causes of the accidents are analyzed. The charging accidents are caused by human factors. It is necessary to analyze and judge whether the relevant personnel have corresponding bad behaviors in case of charging accident.

Charging line installer: Charging line is not installed strictly according to the installation instructions provided by vehicle manufacturers, specifications fail not meet the requirements in the wiring process, charging boxes are installed in potential risk areas, which may lead to fire in the actual charging process, and charging accident will occur.

Charging operator: In the charging process, operators use charging equipment illegally and refit charging equipment privately. When the vehicle is in unstable state, they connect charging lines. During the charging process, they move vehicles or fail to act in accordance with the operation instructions, which may bring potential fault to charging equipment and lead to charging accidents.

Other personnel: In the process of vehicle charging, they deliberately destroy charging equipment or use other tools to interfere with the normal charging of equipment, which may lead to charging accidents.

10.2.2.4.4.2.2 Analysis of product reasons

For the electric shock accident because of the design defect of the vehicle itself or the fault of the vehicle, the following problems may exist in case of electric shock accident:

(1) Charging device: Short circuit, virtual connection of connectors and failure of charging protection, overvoltage, over-current and over-temperature of vehicle chargers, over-current and over-temperature of charging cables in the charging process of vehicles due to the abnormal charging device may lead to charging accidents;

(2) Battery system: During the charging process, the abnormal conditions of battery system such as overcharge, over-temperature, over-current and overvoltage may lead to charging accidents;

(3) High-voltage harness: Internal high-voltage harness may be overheated during high current transmission, and over-current may lead to charging accidents;

(4) Protection policy: In the charging process, failure of possible protection strategy,

undesirable actions, or failure to implement the protection strategy correctly under the conditions of abnormal charging voltage and current, battery pack overcharge leads to charging accidents.

10.2.2.4.4.2.3 Analysis of other reasons

In the charging process, changes in the external environment, abnormal grid voltage, aging charging lines, external accidents and other reasons may indirectly lead to vehicle charging abnormalities or even fire and leakage accidents.

(1) External environment: In the charging process, the change of external environment leads to the failure of charging, and the dangerous sources affecting the charging safety may lead to charging accidents;

(2) Gird voltage: In the charging process, abnormal charging voltage exceeds the charging specifications due to abnormal grid voltage, leading to charging accidents;

(3) Charging line: Aging cables are used for a long period of time. The large internal resistance of cables may lead to heating, which may lead to charging accidents;

(4) External accidents: In the charging process, the abnormal charging accidents occur because of the impact of external accidents such as fire and collision.

10.2.3 Summary of accident analysis

It is necessary to analyze the accident by referring to the above accident causes and investigation methods, and summarize according to the actual accident severity and analysis. The head of the accident investigation team presides over the accident analysis meeting. The meeting will inform the investigation of the accident, analyze the causes of the accident, and put forward preventive measures.

(1) It is necessary to investigate accidents, scientifically analyze the causes of accidents, summarize the lessons and rules of accidents, put forward targeted preventive and rectification measures, promote product improvement and prevent similar accidents from happening again;

(2) It is necessary to analyze the nature of the accident according to the cause of the accident, and identify the severity of the accident and whether it belongs to a responsible accident or a non-responsible accident;

(3) According to the facts confirmed by the accident investigation and the nature of the accident, it is necessary to analyze and judge the accident liability, and judge the person (party) responsible for the accident.

10.3 Assessment method of safety accident rectification

By correcting and evaluating safety accidents, discover and eliminate vehicle problems and eliminate hidden dangers in time, which can effectively control and prevent all kinds of accidents.

10.3.1 General

In order to establish the follow-up supervision process for the implementation of safety accident correction and responsibility investigation for electric vehicles, promote the implementation of responsibility investigation and correction measures for electric vehicles, check and evaluate the effect of safety accident correction measures, put forward the assessment method.

Set up the evaluation group: Assessment group shall generally be composed of personnel from relevant manufacturers and traffic accident management departments who participate in accident investigation and treatment. If necessary, assessment group can employ third-party organizations (institutions with professional skills associated with the units responsible for accidents) or experts familiar with relevant business.

In the process of assessment, the assessment group shall adhere to the "Four" principles and scientific rigor and seeking truth from facts, and do a good job in clarity, accuracy, legitimacy and completeness. Any inconsistency or inadequacy with the rectification measures shall be corrected in time or required to be rectified within the time limit. After the completion of the rectification, it needs to be reconfirmed by the assessment group before the next assessment step can be carried out.

Assessment plan: The assessment group shall evaluate the accident liability units (departments) in accordance with the following methods:

(1) It shall make the assessment list, including, but not limited to, the assessment of accident elimination methods and processes, the assessment of corrective measures and technical documents, and the assessment of the implementation of corrective measures;

(2) It shall listen to the report of the management and rectification work of the accident liability units (departments) after the accident occurs;

(3) It shall ask the relevant personnel about the implementation of corrective measures after the accident;

(4) It shall collect relevant documents and information, including but not limited to detailed accident analysis summary report, technical process documents before and after modification, and test report. Documents can be typed, scanned, electronic and other formats that have been confirmed by signature and can be traced back effectively in the later period;

(5) The site status of the accident liability unit (department) after rectification shall be comprehensively inspected by random spot check, audio and video recording to truly reflect the implementation of the rectification measures of the accident liability unit (department) after the accident occurs.

The evaluator shall make a good record of the whole process, including time, place, inspection content, and problems still existing after rectification, and be confirmed by the signature of the relevant responsible person.

The corrective effect of safety accidents is evaluated from the following two aspects:

10.3.1.1 Analysis of technical reasons

(1) Correct location S

pecify the time, place, opportunity, phenomenon and environmental conditions, batch and fault-related data and list all possible causes of failure by means of fault tree and causality diagram.

(2) Clear mechanism

Analyze the mechanism of the problem in the theoretical analysis or experimental way, and consider clearly various factors such as design, process, manufacturing, components and raw materials.

(3) Problem repetition

Carry out fault repetition by means of experiment, simulation experiment and principle repetition. Under safety, the experimental conditions shall be consistent with the site where the problem occurs. (

4) Verification of measures

The measures to be taken shall correspond to the causes one by one. Clarify whether the measures taken will cause the fault and explain how to solve it.

(5) Draws inferences

Measures shall be promoted among products in production and similar products to ensure that similar problems do not occur.

10.3.1.2 Requirements for implementation of management

(1) Clear process

Specify the time, place, opportunity, phenomenon and environmental conditions, batch and fault-related data and whether similar problems have occurred in the process of R&D, production and use, and preliminarily restore the whole process of the occurrence and development of the problem.

(2) Practical measures

Make plans for the implementation of measures, whether the rectification measures are comprehensive, feasible and effective, and whether the relevant evidence is complete.

(3) Perfected rules

In view of the existing problems, whether the management system or technical documents need to be improved or not, and the perfect content must be effectively reviewed and examined.

10.3.2 Assessment group

Assessment group is composed of various personnel, such as the owner of the vehicle, the vehicle manufacturer, the competent department of the industry, and the specialized agencies. The members of the assessment group can be adjusted according to the circumstances and consequences of the accident.

10.3.3 Assessment work program:

(1) After the disposal of accident, keep the state of the vehicle unchanged. The vehicle owner and the vehicle manufacturer jointly inspect the vehicle and preliminarily analyze the cause of the accident. If a major accident occurs, the competent authorities of the industry shall be notified to participate;

(2) If the cause of accident is the vehicle product through preliminary analysis, the vehicle owner and the vehicle manufacturer shall jointly disassemble and inspect the parts and components related to the cause of the accident. If a major accident occurs, the competent authorities of the industry and professional institutions shall participate;

(3) After ascertaining the cause of the accident, the assessment group shall issue an analysis report on the cause of the accident. If it is a safety accident caused by vehicle products, the vehicle manufacturer shall provide corrective measures, which shall be implemented after the approval of the vehicle owner. If it is not the safety accident caused by the vehicle product, the vehicle manufacturer shall provide improvement suggestions and deliver them to the vehicle owner for reference. If a major accident occurs, the competent authorities of the industry and professional institutions shall participate;

(4) After the improvement, the vehicle owner and the manufacturer shall regularly inspect the vehicle for safety to verify the effect of the improvement, with a period of six months to one year.

10.3.4 Evaluation criteria

Assessment criteria for safety accident rectification plan:

(1) Validity: It is required that the rectification plan can effectively solve the hidden dangers of accidents and avoid the same problems from happening again;

(2) Operability: It is required that the rectification plan be operationally implemented;

(3) Timeliness: It is required that the rectification plan can be implemented in time (temporary plan shall be formulated if solidification measures take a long time);

10.4 Requirements for accident reporting

Accident reports are compiled according to Table 10-1:

Table 10-1

Occurrence time of accident	Accident location		Casualties	Type of accident
				Fire/water/collision/other
Accident vehicle manufacturer	Accident vehicle brand	Accident vehicle type	Power type of accident vehicle	Battery supplier of accident vehicle
Accident description	1 Description of occurrence 2 Description of rescue process 3 Result description			
Accidents cause	Subjective reason		Objective reason	
Rectification measures				
Accident investigation team List of members				
Other instructions				

11. Operational safety

11.1 Operational guidance training and qualification certification system

11.1.1 Classification of operational qualifications, authority and requirements

(1) Installation, commissioning (including charging and commissioning) and repair of new energy high-voltage electrical systems must be carried out by qualified electricians with electrician certificates in accordance with the safety operation rules of electricians. Maintenance of other non-high-voltage systems can be carried out by maintenance personnel such as machine repairer, electrician, sheet metal worker, etc;

(2) Repair personnel of new energy high-voltage system shall be engaged in motor vehicle electrical repair for more than 3 years, or for more than 2 years after graduating from technical secondary school, or for more than 1 year after graduating from vocational college (or above). They have the ability of fault diagnosis and repair of high and low voltage circuit systems and control systems of electric vehicles. They are skillful in using testing equipment for Electric Vehicle repair, accurately judge vehicle faults and clear new energy system faults. They have the ability to apply technical data to solve technical problems of new energy systems;

(3) Maintenance personnel of Electric Vehicle maintenance station shall be trained by manufacturer (or training institutions accredited by industry). After passing the theoretical and practical examination, they can repair the new energy high-voltage system.

New energy buses repair station shall have the qualifications of automobile repair enterprises above Class II. The maintenance stations with the qualifications of automobile maintenance enterprises Class III can repair vehicles according to the scope of operation. In case of the maintenance of electric vehicles circuit and control system, they need to be equipped with professional maintenance personnel for new energy electrical appliances.

11.1.2 Qualification assessment of repair personnel of new energy high-voltage system

(1) Personnel shall be trained and evaluated according to their post requirements. After passing the assessment, they will be issued with post certificate for three years. Internal examinations are conducted regularly every year. If they are not qualified, they will be re-trained or transferred;

(2) Personnel responsible for training shall confirm the qualifications of personnel in specific positions and conduct spot checks of theoretical or practical operations when necessary;

(3) The methods of qualification appraisal for personnel in specific positions are as follows: Examine the validity of qualification certificate, actual operation assessment, daily work performance assessment, etc.

11.2 General requirements for operational guidance of electric vehicles

11.2.1 Notes for repair personnel carrying medical electronic devices

The components of the car adopt strong magnetism, while the vehicle will generate radiated electromagnetic waves when it is charged and operated in remote communication system. Personnel who use implantable cardiac pacemaker or implantable cardioverter defibrillator shall not operate such vehicles so that the functions of medical equipment will not be affected by electromagnetic waves.

11.2.2 Cautions for airbag repair and inspection

In order to avoid the failure of the airbag, the repair of the airbag must be carried out by the operator authorized by the manufacturer or the manufacturer.

When operating near the safety airbag sensor or other safety airbag system sensors, they shall turn power off and shall not tap the sensor. Large vibration will start the sensor and open the safety airbag, which may cause serious injury.

11.3 Preparation before operation

11.3.1 Requirements for protection

Repair personnel must wear necessary safety protective equipment, such as: Insulating gloves, insulating rubber shoes, insulating rubber pads and protective glasses, with voltage rating greater than 1000V. Safety protective articles shall be replaced in time according to their service life.

Before use, check whether insulating gloves, insulating rubber shoes and other protective devices are damaged or cracked. It is forbidden to operate with water to ensure that the inner and outer surfaces are clean, dry and safe.

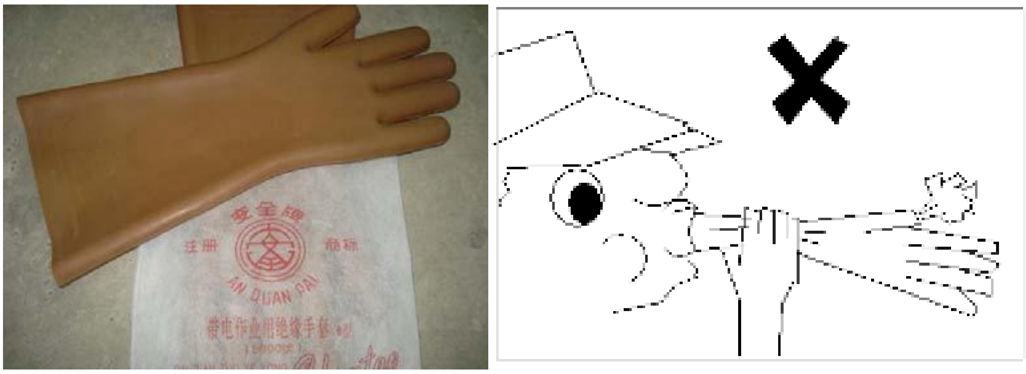


Figure 11-1 Inspection of insulating gloves

11.3.2 Requirements of special tools:

Tools needed to maintain and maintenance new energy: Megawatt-hour meter, multi- meter, clamp current meter (including DC and AC), operating tools with insulating handle (including torque wrench, fast wrench, screwdriver, etc.), insulating gloves, insulating shoes, etc. For testing instruments, their functions and accessories shall worm normally before they can be used.

Operating tools shall be wrapped with insulating tape in advance to disassemble exposed metal parts other than contact points with standard parts, so as to avoid high-voltage accidents caused by instrument fault or inappropriate contact between exposed metal parts of operating tools and live parts.

11.3.3 Monitoring by specially-assigned personnel

They shall supervise whether the qualifications of repair personnel, the use of tools, the wearing of protective articles, the safety protection of spare parts and the maintenance safety warning signs meet the requirements.

They shall check the operation rules of safety repair in the process of repair, and direct the operation according to the operation rules of safety repair. After finishing operation, the repair personnel shall inform the supervisor, and the supervisor shall mark the work flow sheet.

Supervisor and repair personnel must have the state-approved Special Operating Certificate (Electrician) and Primary (Including) Electrician Certificate Above;

Supervisor and repair personnel must undergo professional training in new hybrid and pure electric vehicles and pass the examination.

11.3.4 Prohibited items

It is strictly forbidden for the untrained personnel to carry out high-voltage overhaul, and all dangerous operations with lucky mentality shall be prohibited to avoid safety accidents. It is strictly forbidden to operate in violation of regulations.

11.4 Disconnection of high-voltage loop

The power supply must be cut off before the system is repaired and maintained.

Disconnection method:

(1) Switch the key switch to "OFF" and pull out the key (during maintenance, the key shall be put away and properly kept);

(2) Turn off the low-voltage main fire warping switch, and dial the handle of the low-voltage power supply main switch to the "OFF" position, and then pull out the total positive and negative fast breakers in turn;

(3) The high-voltage system can be maintained and repaired only after 15 minutes of disconnection. Method to recover operation: Ensure that the low-voltage 24V main power switch is "OFF", the main fire warping switch is in the closed state, and the key switch is "OFF", and then insert the total positive and negative fast breakers in turn.

11.5 Operation cautions

(1) Maintenance of electrical circuits must be carried out by qualified electricians with electrician's certificates in accordance with the safety operating rules of electricians.

(2) Integrated controller: It includes high-voltage DC input line and high-voltage AC

output line. When maintenance personnel unplug the fast breaker and check and maintain the high-voltage power supply, they shall not contact the anode and cathode of the battery at the same time under any circumstances. They must wear insulating gloves and insulating shoes, and use insulating tools for the above operation. They shall wait for 15 minutes after power failure before measuring whether the voltage value is within the safe voltage range.

(3) When inspecting the insulation of the motor, they shall quickly pull out the fast breaker and separate the motor connecting wire from the integrated controller. (

4) When welding the whole vehicle, they must disconnect 24V power supply, and pull out ABS, CAN module, whole vehicle controller and all harness plug-ins on integrated controller; otherwise, the above control modules may be damaged. In order to ensure the normal operation of the vehicle after welding, please restore the connectors after welding.

(5) It is strictly forbidden to disassemble and assemble any component of battery system assembly without authorization. It is strictly forbidden to use the battery box as a bearing platform and cover it with other articles. It is forbidden to contact the battery box with the fire source and expose it to the sun.

(6) If low-voltage electrical appliances are maintained without driving, you can set the gear switch set to neutral, and then maintain it according to the traditional vehicle method. If only mechanical equipment is repaired, the key switch and power switch shall be turned off.

(7) All orange wires of vehicles are high-voltage harnesses. Non-professionals cannot cut or open high-voltage lines and components. (8) The insulation layer of high-voltage harness shall be strictly prevented from being broken and leakage during maintenance operation.

(9) When it is necessary to disassemble the high-voltage components for maintenance, please contact the manufacturer or disconnect the plug of the energy storage device by professional high-voltage electrician, and then cut off the high-voltage power supply.

(10) When cleaning vehicles, please avoid high and low voltage components. It is strictly forbidden to wash high and low voltage components directly with water.

(11) The moment of each bolt connection shall be strictly in accordance with the requirement of bolt torque.

12. Safety management of operating vehicles

In order to ensure the safe operation of electric operating vehicles, it is necessary to ensure the safety of people's lives and property, and promote the healthy and sustainable development of electric operating vehicles, compile the safety management guide for electric operating vehicles in accordance with the relevant requirements of various ministries and commissions. The safety of electric operating vehicles includes the vehicle itself, drivers and operating environment. Local operating vehicle management departments have different requirements for operating vehicles. This chapter regulates the safety requirements for electric vehicles from the vehicle perspective.

12.1 General requirements for electric operating vehicles

12.1.1 Operation certificate handling

Operating certificates shall be handled according to the requirements for the local operating vehicles and the operation certificate handling procedures.

12.1.2 Monitoring platform for electric automobile manufacturing enterprises

According to the *National Regulations on New Energy Automobile Manufacturing Enterprises and Product Access Management*, new energy automobile manufacturing enterprises shall establish a platform for real-time monitoring of the operation status of new energy automobile products, and the whole life cycle operation and safety status of all new energy automobile products sold. Enterprise monitoring platform shall be connected with local and national monitoring platform. New energy automobile manufacturers shall establish files for each new energy automobile product in the whole life cycle of the product, and track and record the use, maintenance and repair of the automobile (including the recycle and disposal of power batteries). According to the national standard, the enterprise Electric Vehicle monitoring platform can realize the functions of battery information real-time monitoring, vehicle operation status monitoring, vehicle fault real-time early warning, vehicle historical condition data query, docking with the national monitoring platform, configured with CAN vehicle terminal (hardware) and server (hardware). According to the actual situation, it also has the functions of battery performance comparison, vehicle energy consumption comparison, driving behavior quantitative analysis, health analysis of important components, automatic report generation and export, repair and maintenance tracking and reminder.

12.1.3 Requirements for operating vehicle refitting

Operating enterprises shall not privately refit vehicles. If it is necessary to refit for operation, the written permission of the vehicle manufacturer must be obtained in advance.

12.2 Safety requirements for electric operating vehicle configuration

12.2.1 Test one-button alarm function

Electric vehicles are equipped with alarm functions such as one-button alarm mode.

(1) When the vehicle breaks down or fails to drive normally, you shall contact the nearest service station through one-button alarm for rescue, repair or related guidance;

(2) In case of danger, one-button alarm can be sent to the call center, which will give an alarm.

12.2.2 Vehicle-end GPS positioning system

Electric vehicles must be equipped with GPS positioning system. The collected information refers to the real-time information of the vehicle, such as location, on-line situation, electricity, etc. The vehicle scheduling, assistance in repair and rescue can be realized according to the location of the vehicle and online time.

12.2.3 Pre-collision early warning function

Electric vehicles can be equipped with pre-collision early warning system. Its main function is to identify pedestrians or motor vehicles. In case of possible collision with the obstacles ahead, it can be warned by voice or instrument display to avoid collision.

12.2.4 Driver fatigue detection function

Electric vehicles can be equipped with driver fatigue detection function. The main function is to monitor the driver's condition in real time. In case of monitoring lens occlusion, fatigue, eyes closing, yawns, calls, smoking and other abnormal behavior, it can warn to avoid the occurrence of safety accidents.

12.2.5 Protective function against pressing accelerator mistakenly

Electric vehicles can be equipped with protective function against pressing accelerator mistakenly. The main function is to cut off the power output of the vehicle and reduce the probability of collision accidents such as rear-end collision when the distance between obstacles in front of the vehicle and the vehicle is less than the safe time distance, and the driver has to step on the throttle in a hurry.

12.2.6 Collision mitigation control function

Electric vehicles can be equipped with collision mitigation control function. The main function is when the distance between obstacles in front of the vehicle and the vehicle is less than the safe time distance, and the driver does not take corresponding actions, the control system will in turn: Alarm - cut fuel - brake, reduce accident probability.

12.3 Safety requirements for repair and maintenance of electric operating vehicles

New energy manufacturers shall establish and improve the after-sale safe operation files of electric operating vehicles, do a good job in safety inspection and maintenance services, and especially strengthen the inspection and maintenance of high-voltage systems including power batteries, harnesses and connectors. They shall focus on the maintenance of vehicles with IP protection failure, vehicle soaking, vehicle collision, loose harness connection, frequent charging and discharging, long-term stock and poor working environment.

Operating vehicles are frequently used with long driving mileage. On the basis of general vehicle maintenance, the maintenance frequency of operating vehicles shall be improved and the maintenance items shall be increased. Maintenance frequency is mainly based on mileage intervals by 100,000 km, 100,000 to 200,000 km and 200,000 to 300,000 km. Maintenance items are set up according to different mileage. The main items are power batteries, drive motors and motor controllers. Power battery inspection includes at least battery appearance inspection, software diagnosis, air tightness testing, open-box inspection, replacement and capacity testing. For the problems found in the inspection process, personnel shall be organized to deal with them immediately to eliminate potential safety hazards.

Specific inspection items shall be set for vehicles with IP protection failure, vehicle soaking, vehicle collision, loose harness connection, frequent charging and discharging, long-term stock and poor working environment.

12.4 Safety requirements for remote monitoring of electric operating vehicles

12.4.1 On-board monitoring

Electric vehicles are monitored in accordance with the *Technical Specification for Electric Vehicle Remote Service and Management System* stipulated by the state, which can collect basic information of vehicles, such as license plate number, location, speed, power battery, motor and charging.

12.4.2 Requirements for communication interface

It mainly serves remote monitoring platform, first of all, it shall meet the national and local (Beijing, Shanghai, etc.) data collection technical specifications. If enterprises have more needs, communication interface is different according to the actual situation. For example, according to the standard of GB/T 3296-2016, the national platform designs communication data structure and data item fields to realize the standardization of data interface.

12.4.3 Enterprise monitoring platform

Enterprise monitoring platform shall check the real vehicle and information exchange of fault/alarm, make relevant records, and further improve the emergency response mechanism and emergency response plan. The function of safety monitoring system shall meet the requirements of national standards, and can timely feedback vehicle safety information. It can timely warn and take effective measures to solve the problems of vehicles with abnormal operation status and potential safety hazards found in key systems such as whole vehicles and power batteries.

It can carry out safety hazard investigation on long-term off-line vehicles to determine the actual use status of vehicles.

12.5 Requirements for safety accident handling for electric operating vehicles

Electric vehicles must first meet the requirements of Chapter 10 for handling safety accidents.

New energy automobile operators shall work with manufacturers to formulate emergency plans, rescue plans and accident investigation plans for electric operating vehicles.

Emergency rescue plan and rescue work shall be started immediately after fire and other safety accidents occur in electric vehicles.

If fire, burning and other safety accidents occur in new energy passenger vehicles without casualties, the relevant enterprise shall take the initiative to report it to the local government within the prescribed time. If it causes death or major social impact, it shall be reported voluntarily within 6 hours.

12.6 Perfect safety management mechanism

Driver management: Compared with the traditional passenger car, the new energy buses has better starting and accelerating performance directly driven by motor. In addition, the participation of the drive motor in auxiliary braking can save energy and reduce the wear and tear of the traditional braking system. For drivers, they can operate new energy buses after they have adapted to the characteristics. Drivers can avoid or reduce accident risk if they orderly operate according to the driving operation rules provided by automobile enterprises. Therefore, it is necessary to establish and improve the requirements for driving operation theory and training of new energy buses and incorporate them into the driver's assessment index.

Vehicle management: Electric vehicles shall provide emergency plans for possible safety risks, collision accidents and fire accidents during operation and storage. If the information can be obtained at the first time and implement it according to the emergency plans, it is necessary to avoid accidents and reduce social impact. Therefore, it is necessary to establish and improve the safety management mechanism, such as establishing vehicle monitoring center, monitoring vehicle status in real time, especially the health status of batteries, and formulate emergency response plan for vehicle fire safety accidents.

12.7 Perfect safety training mechanism

Management layer: Formulate the safety assessment mechanism for all personnel and take responsibility for it, take regular training of safety training and maintenance methods of new energy components as performance assessment indicators, and take safety accidents of all vehicles as the most important assessment content at the same time.

Operator: Regularly organize and train the requirements for maintenance of key components of new energy buses and emergency treatment methods of new energy accidents, take the new energy safety accidents caused by vehicle failure to maintain in time or improper maintenance as the monthly assessment index, and improve the responsibility of operators to maintain on time.

12.8 Strengthen the safety management of decommissioning and scrapping

Operating units shall set up special regulations for the safety management of electric vehicles in decommissioning and scrapping. For vehicles in decommissioning, they shall regularly maintain parts with potential safety hazards. Vehicles that shall be scrapped shall not be operated. For high-risk components such as scrapped power batteries, the operating units shall recycle batteries according to the *Interim Measures for the Recycling and Management of New Energy Batteries* and shall not treat them privately.

Hydrogen Fuel Cell Vehicles

1. General safety of vehicle

1.1 General Principles for Design

As compared with pure electric vehicles, the safety of hydrogen fuel cell electric vehicles has an additional element of hydrogen safety. In view of the flammable and explosive nature of hydrogen and the electric coupling environment in which the vehicle works, hydrogen safety will directly affect the safety of the whole vehicle, and it is more complex than the safety of pure electric vehicles. The general principles for hydrogen safety design of fuel cell electric vehicles are as follows:

(1)Fail-safe principle. In the design of the hydrogen system, it must be ensured that even when a part fails, it will not lead to more serious consequences. In other words, when a single part of the system fails, the system is safe

(2)Utmost simplicity principle. The design of the system should be simplified as much as possible to avoid redundancy on the premise of meeting the requirements for safety and use.

(3)Regional layout principle. During the installation of the hydrogen system, the components should be arranged according to their different pressure levels in a centralized manner.

(4)Principle of hydrogen electric isolation. During the installation of the hydrogen system, the hydrogen system should be effectively isolated from the electrical system. The isolation measures can either be the physical isolation of the system, or the isolation of the parts that may generate sparks, by means of, e.g. using explosion-proof electrical components.

1.2 Failure assessment and fail-safe design

1.2.1 General principles for fail-safe design

The core of vehicle general safety is to protect personnel from the impact of risk factors. For the potential failure of a fuel cell electric vehicle, corresponding safety designs should be carried out. The potential failure consequences of a fuel cell electric vehicle mainly include:

(1)Failure of system parts during the vehicle's operation and/or damage to vehicle system caused by external events (e.g. collision);

(2)Dangers caused by operational error during the vehicle's operation and maintenance (such as high voltage, extreme temperature, high air pressure, and flammable or toxic fluids);

(3)Damage to the vehicle system caused by subsystem or component failure, resulting in malfunction.

1.2.2 Isolation and separation of hazards

Effective isolation of hydrogen should be considered with focus in fuel cell electric vehicles. A common design is to isolate the points that may generate arc or spark with the hydrogen system, or to ground the positions that may generate static electricity, arc and spark.

At design level, the hydrogen system should be preferably arranged in positions that are conducive to ventilation and release. If it is impossible to do so, necessary ventilation design should be added to avoid dangers caused by hydrogen accumulation. At the same time, a certain safety distance should be kept between the hydrogen system and the electrical system, especially the high-voltage electrical system (for commercial vehicles, special attentions should be paid to the safety distance between the harness connector and the hydrogen pipe joint, which should generally be more than 100mm; if the joint is protected, the distance can be reduced as appropriate) to prevent the energy of electric spark from igniting hydrogen; in case of a vehicle failure or collision accident, the hydrogen system can rapidly cut off hydrogen supply based on physical indicators such as temperature, pressure and flow.

With respect to use, it is forbidden to apply high pressure in the vehicle’s fueling process, and only necessary controllers should be awakened (to realize the fueling function and the monitoring function of the fueling process), so as to reduce the risk of coupling between the electrical system and the hydrogen system.

1.2.3 Fail-safe design

The purpose of hazard analysis and risk assessment is to identify the hazards caused by failures in relevant items, to classify the hazards, and to develope safety objectives to prevent the occurrence of hazardous events or reduce the degree of hazards, so as to avoid unreasonable risks. Based on the design FMEA and process FMEA, fail-safe design is carried out from four aspects: functional safety, system safety, hardware safety and software security.

1.2.3.1 Functional safety design

Based on the relevant provisions of GB/T 34590.2-2017, the functional safety review and assessment should be conducted according to the safety objectives at ASIL level. Reference should be made to GB/T 24549-2009 for the functional safety design requirements of fuel cell electric vehicles. According to different levels of vehicle failures, different failure handling mechanisms should be developed. Table 1-1 shows examples of failure classification and handling mechanism in the design of a certain model.

Table 1-1 Failure classification and treatment mechanisms for fuel cell electric vehicle

Failure classification	3rd class failure	2nd class failure	1st class failure
Description	serious failure	moderately serious failure	failure requiring warning
Treatment mechanism	shutdown of high-voltage system	limited torque output	alert on instruments

1.2.3.2 System safety design

Based on relevant provisions of GB/T 34590.4-2017, technical safety requirements are defined according to the concept of functional safety and system architecture, and the external interface, restriction conditions and system configuration requirements of software and hardware

are defined; meanwhile, the response of the system to incentives affecting the realization of safety objectives, including failure and related incentive combinations, is defined, and is combined with each relevant operation mode and specified system status. In the process of system architecture design, in order to ensure the safety of the system, special attention should be paid to the following elements:

(1)The identified internal/external causes of systematic failure should be eliminated or their effects be reduced;

(2)In order to reduce systematic failure, it is advisable to apply reliable design principles for the automobile system, including the reuse of technical safety concept, element design, detection and control failure mechanism and standardized interface.

1.2.3.3 Hardware safety design

The hardware safety design is carried out in four aspects, including definition of hardware security requirements, design and implementation of hardware, hardware architecture evaluation and failure analysis, hardware system integration and testing. Reference may be made to GB/T 34590.5-2017.

Definition of hardware safety requirements: Based on the concept of technology security and system design specification, the hardware security requirements are defined, while the hardware-software interface (HSI) specification for security design is refined. The design of hardware safety requirements should include the following:

(1)An internal security mechanism that covers transient failure (e.g. transient failures as a result of the technology used);

(2)Tolerance for external failures;

(3)Having the functions of detecting hardware component failure, failure diagnosis and sending failure information.

Hardware design and implementation: Based on the evaluation of hardware architecture measurement and taking into full consideration functional redundancy and requirements, automotive-grade mature circuit units and automotive-grade components are used and selected as a priority. Meanwhile, non-functional causes of safety-related components failure, including elements such as temperature, vibration, humidity, dust, electromagnetic interference, noise, environmental crosstalk, should be considered. The specific design requirements are as follows:

(1)Compliance with the electrical performance requirements specified in the basic technical conditions of automotive electrical equipment in QC/T413-2002; compliance with performance requirements with respect to working voltage, over-voltage performance, superposed AC performance, voltage drop performance, power start features, polarity reverse connection, load dump performance, supply voltage ramp-up and ramp-down performance, supply voltage instantaneous drop performance, etc., as contained in GB/T 28046.2-2011; compliance with the design requirements in Chapter I and II of the *Guidelines for Electric Vehicle Safety* with respect to high voltage protection.

(2)Compliance with the requirements of vehicle operation environment and the protection level of the products arranged in the wet areas such as chassis should not be lower than IP67; compliance with product performance requirements with respect to performance under low and high temperature, temperature shock, temperature and humidity, salt haze, protection, free fall, etc., according to the requirements of GB/T 28046.3-2011; taking into account fire-proof isolation and fire-retardant design, and applying fire-retardant and insulation materials to separate the fuel cell system and the cabin, and the combustion performance of the fire-retardant materials should meet Level A requirements specified in GB 8624-2012. The fire-retardancy requirements of parts and materials in the fuel cell system should be considered to meet the following requirements: metal parts and components should meet the requirements of Class HB and Class V-0 for vertical combustion, and other non-metallic components should meet the requirements of Class HB75 for horizontal combustion and Class V-2 for vertical combustion.

Hardware failure mode analysis: By means of analyzing the hardware failure modes, product failure caused by potential risks in hardware design are identified, and FMEA tables are established to ensure the integrity of the analysis. For failure modes endangering safety, corresponding mechanisms should be established to ensure safety; for failure modes of not endangering safety, the necessity of setting up safety mechanisms should be evaluated. Hardware failure analysis should identify the following items and provide corresponding measures:

(1)Safety measures should be developed for safety failures mainly with regard to detection, indication and control measures in relation to hardware malfunction; detection, indication and control measures in relation to malfunction of the system's external equipment affecting the hardware in the system; measures for realizing or maintaining safety of the system; and measures for detailing the concept for implementing alarm and degradation.

(2)For single-point or residual failures, the necessity of setting up safety mechanisms should be evaluated with the focus on the effectiveness of measures to realize or maintain safety status of the system and the diagnostic coverage of residual failures.

(3)For multi-point failures (whether perceptible, detectable or latent), the necessity of setting up safety mechanisms should be evaluated with the focus on the effectiveness of failure detection and warning measures for latent failures within the interval of acceptable multi-point failure detection events, and the diagnostic coverage of latent failures.

Hardware system test: in order to verify the correctness, consistency and integrity of hardware design and hardware security requirements, the following methods should be considered for hardware system test. The subject of such tests should be based on the specific requirements of hardware design:

(1)Functional test. The test should cover electrical performance and high-voltage protection of the tested hardware.

(2)Non-functional test. The test should cover environmental adaptability, waterproof and fire-retardant performance, durability and reliability of hardware.

1.2.3.4 Software security design

Based on relevant provisions of GB/T 34590.6-2017, the definition of software security requirements, software architecture design, software unit design and implementation, software unit test, software integration and test and software security requirements verification should be carried out, and the requirements of system design and software security should be complied with.

Definition of software security requirements: the definition of software security requirements comes from technical security requirements and system design specifications, and the impacts of hardware constraints (hardware interface specifications, design specifications and operation modes, etc.) on software are considered as well. Software security requirements should be specific to each software-based function the failure of which may result in a violation of the technical safety requirements assigned to the software. Software security definition should meet the requirements of integrity, testability and traceability.

Software architecture design: software architecture design describes all software components and their interactions in the hierarchy. At the static level, examples are interfaces and data paths between all software components; at the dynamic level, examples are process order and temporal behavior. Software architecture design provides a way to implement software security requirements and manage the complexity of software development. The verifiability of software architecture design, the applicability of configurable software, the feasibility of software unit design and implementation, the testability of software architecture in software integration test and the maintainability of software architecture should be considered in designing the software architecture. In order to avoid failures caused by high complexity, software architecture design should have the attributes of modularity, encapsulation and simplicity. The specific methods include optimizing the level of software components, limiting the scale of software components, limiting the scale of interfaces, maintaining high cohesion within and low coupling between components, proper scheduling characteristics and limiting the use of interrupts.

Software unit design and implementation: the detailed design of software unit is based on the software architecture design. The detailed design is implemented in the form of model or direct source code according to the modeling or coding guidelines respectively. Before entering the stage of software unit test, the detailed design and implementation are statically verified. The implementation of software unit includes the generation and transformation of source code into target code. The specific methods include: (1) the adoption of one entry and one exit for subroutines and functions; (2) no dynamic object or dynamic variable, otherwise they need to be aligned for online testing during their generation; (3) variable initialization; (4) variable names not reusable; (5) global variables should be avoided, otherwise it needs to be proved that the use of global variables is reasonable; (5) limited use of pointer; (6) no implicit type conversion; (7) no hidden data flow or control flow; (8) no unconditional jump; (9) no recursion.

Software unit test: the purpose of software unit test is to prove that the software units meet their design specification and do not contain unexpected functions. According to the software unit design specification, the software unit test process is established, and the test is carried out according to that process. In the process of software unit test, it needs to be proved that the software units have: (1) complied with the design specification of software unit; (2) complied with the definition of software and hardware interface; (3) defined functions; (4) made sure there are no unexpected functions; (5) had robustness; (6) had enough resources to support their functions. In order to evaluate the integrity of test cases and prove that there is no unexpected function, the required coverage at the software unit level should be determined, and the structural coverage should be measured at the same time. If the achieved structural coverage is considered insufficient, additional test cases should be defined or reasons for acceptance given.

Software integration and test: according to the software architecture design, the unique integration level and interface between software elements are tested. The steps of software element integration and test directly correspond to the hierarchical architecture of software. Software integration should complete the hierarchical integration of each software unit into software components until the whole embedded software is integrated, while taking into account the functional dependency related to software integration and the dependency between software integration and software hardware integration. Software integration test methods are similar to those of software unit test, which aim to prove that both software components and embedded software achieve corresponding functional requirements.

Software security requirements verification: the purpose of software security requirements verification is to prove that embedded software meets the software security requirements in the target environment. The test environment for software security requirements verification can be hardware in the loop, ECU network environment and vehicle environment. The use of tools (such as trace capability matrix) may be considered to ensure and evaluate the coverage of software security requirements, and existing test cases might be reused. If coverage is inadequate, new test cases should be added or reasons for acceptance given.

1.3 EMC and electrical reliability of vehicle

All electrical components on the fuel cell electric vehicle that having the possibility of affecting the safe operation of a vehicle should, with regard to functions, be able to withstand the electromagnetic environment exposed by the vehicle. When the on-board energy storage system, driving system and control system operate under the conditions of high voltage, high current and large dU/dt or dI/DT, the vehicle should be able to operate normally and should not cause false stop. The vehicle should not only meet the EMC requirements for traditional internal combustion engine vehicles, but also the special EMC requirements for vehicles under different operating conditions.

1.3.1 Radiation disturbance and immunity requirements for vehicle

The electromagnetic disturbance of the vehicle to the outside environment should meet the relevant requirements of GB 14023-2011 and GB/T 18387-2017 to protect the normal functioning of the radio communication equipment outside the vehicle;

The vehicle should be able to withstand external electromagnetic radiation interference in compliance with the relevant requirements of GB/T 34660-2017 to ensure the functional status and safety level of the vehicle.

1.3.2 Requirements for radiation disturbance and immunity of on-board electrical equipment

The radiation disturbance and immunity of on-board electrical equipment should meet the requirements in Table 1-2.

Table 1-2 Radiation disturbance and immunity test requirements

Test items		National standard
Emission	Radiation emission	GB/T 18655-2018
	Conduction emoission	GB/T 18655-2018
	Transient conduction emission	GB/T 21437.2-2008
Immunity	Anechoic chamber method	GB/T 33014.2-2016
	High current injection	GB/T 33014.4-2016
	Transient conduction immunity (power supply wires)	GB/T 21437.2-2008
	Transient conducted immunity (signal cables)	GB/T 21437.3-2012
	electrostatic discharge	GB/T 19951-2005

1.3.3 Requirements for disturbance and immunity along power line during vehicle charging

When the vehicle is in the power line conduction charging mode, the power line disturbance and immunity are recommended to be verified according to the test method set out in UN R10-*Regulations on Approving Vehicle Electromagnetic Compatibility* (5th Edition). The relevant requirements must be met.

1.3.4 Safety requirements in relation to exposure of vehicle occupants to the vehicle's electromagnetic environment

Relevant requirements in GB/T 37130-201 should be complied with for the exposure of vehicle occupants to the vehicle's electromagnetic environment

1.3.5 Layout design requirements for high and low voltage harnesses

High-voltage harnesses should have EMC shielding measures, and their routing should not enhance EMC radiation. The shielding layer of high-voltage harnesses should be effectively connected with conductive shell of high-voltage components.

1.3.6 Electrical reliability requirements of vehicle

The fuel cell electric vehicle needs to complete the electrical reliability test and meet the requirements. The specific test items and reference standards are shown in Table 1-3.

Table 1-3 EMC test items and reference standards

Test items	Standard
Overvoltage	GB/T 28046.2-2011
Superimposed A/C	
Supply voltage ramp-up and ramp-down	
Instantaneous drop of supply voltage	
Voltage sag reset	
Power start features	
Load dump	
Reverse voltage	

1.4 Vehicle collision safety

When the collision sensor detects a collision of the vehicle, it should be able to automatically cut off the power and hydrogen supply to ensure the integrity of the on-board hydrogen supply and electrical systems after the collision. Specific requirements are as follows:

(1)Integrity of on-board hydrogen supply system

The fixing device of the high-pressure hydrogen cylinder should not be broken or detached, or displaced or deformed, which would cause failure of the safety function of the high-pressure hydrogen storage system; the high-pressure pipeline system should not be damaged or broken, and the cylinder valve should not be damaged; Within 60 minutes, the average hydrogen leak rate of the on-board hydrogen supply system should not exceed 118 NLPM; the hydrogen concentration in the enclosed space should not exceed 4%.

(2)Integrity of on-board electrical system

According to the applicable scope of GB 11551-2014 and GB 20071-2006, after the collision test of fuel cell electric vehicle with class B voltage circuit, the high voltage safety should comply with the relevant requirements of GB/T 31498-2015.

1.4.1 Side impact protection design

Collision test may be performed with reference to to GB 20071-2006 for the side protection structure. After the collision test, the vehicle should meet the requirements of Items 4.2-4.4 in GB/T 31498-2015.

1.4.2 Rollover protection design

If the strength verification test of the upper structure is carried out according to GB 17578-2013 with respect to the body protective structure, the test should be carried out under the condition that the state of charge (SOC) of the rechargeable energy storage system is 30%-50% and the system is powered on. After the test, the requirements of Items 4.2-4.4 in GB/T 31498-2015 should be met.

1.4.3 Rear impact protection design

The layout position and protective structure of class B voltage components of the rear high voltage cabin should compy with the requirements of Items 4.2-4.4 in GB/T 31498-2015 after a rear impact. With respect to fuel cell passenger cars, reference may be made to GB/T 20072-2006 for the rear impact test method.

1.4.4 Bottom collision protection design

Two aspects should be considered in the design of bottom collision protection, one is the ground clearance, the other is the protective structure. The protection design should meet the requirements of Items 4.2-4.4 in GB/T 31498-2015 after a bottom collision.

1.5 Safety marking requirements

1.5.1 High pressure warning marks

Class B voltage components, such as REESS (rechargeable energy storage systems) and fuel cell stack, should be marked with the symbols shown in Figure 1-1 subject to the stipulations in GB 2893-2008, GB 2894-2008 and GB/T 5465.2-2008. The ground color of the symbol is yellow, and the border and arrow are in black.

When the live part with Class B voltage are exposed by removing the barrier or shell, the same symbol should be clearly visible on the barrier and shell. When evaluating whether this symbol is needed, the possibility that the barrier/shell might be accessed and removed should be taken into account; it is suggested that there should be clearly visable warning instructions for safe operation near the mark, such as “further operation on the motor controller is allowed only when the bus voltage is measured within safety range xx minutes after the shell is removed”.

Figure 1-1 High-voltage warning

1.5.2 Marking requirements for Class B voltage wires

The outer skin of cables and harnesses in Class B voltage circuits should be distinguished in orange, and the instructions inside the shell or behind the barrier should also be distinguished in orange.

Class B voltage connector can be distinguished by the wiring harness connected to it.

1.5.3 Identification of hazardous substances

Graphic identification indicating the type of hydrogen fuel should be posted at easily visible positions in the vehicle. The identification code of compressed hydrogen is CHG, and the identification code of liquid hydrogen is LH2. The graphic identification is shown in the figure below. The size and font of the identification marks should comply with the stipulations of GB/T 17676-1999. The marks should be clear, eye-catching, waterproof and anticorrosive, and should be pasted at eye-catching positions in vehicles.

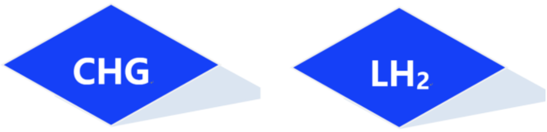


Figure 1-2 Identification marks for hydrogen fuels

2. On-board hydrogen system safety

2.1 Installation and layout

2.1.1 General principles for installation and layout of on-board hydrogen system

(1)The installation of on-board hydrogen system should comply with the provisions of GB/T 24549-2009 *Fuel Cell Electric Vehicles - Safety Requirements*, GB/T 26990-2011 *Fuel Cell Electric Vehicles – On-board Hydrogen System – Specifications* and GB/T 29126-2012 *Fuel Cell Electric Vehicles-On-board Hydrogen System-Test Methods*, so as to ensure that the vehicle hydrogen system can operate safely and reliably under normal conditions of use after installation. In addition, there should be a protective pad between the hydrogen storage cylinder and the fixing device in the vehicle hydrogen system to prevent the fixing device from wearing the body of the cylinder, and it is strictly prohibited to damage the wrapping layer of the hydrogen cylinder.

(2)The on-board hydrogen system (from hydrogen fueling port to fuel cell inlet, mainly including hydrogen storage cylinder, pipeline, connector, valve and bracket) should be subject to type test by applying in three directions of vehicle coordinate system X, y and Z respectively a force 8 times the gravity of the hydrogen cylinder filled with hydrogen under the nominal working pressure, and measuring and checking the relative displacement between hydrogen storage cylinder and the fixing base; the displacement should be less than 13mm. In addition, the nozzle of hydrogen storage cylinder and the attached valve or fusible alloy plug should not be subjected to long-term stress. In the process of transportation, installation and disassembly of hydrogen storage cylinder, try not to directly lift the mouth of the cylinder, valve or fusible alloy plug.

(3)The installation position of the hydrogen storage cylinder and accessories should be at least 100mm away from the edge of the vehicle; otherwise, protection measures should be added.

(4)The installation position and direction of the pipeline and joint of the hydrogen system should avoid positions prone to generating arc or spark, such as heat source, electrical apparatus, battery; the pipeline joints, in particular, should not be installed in enclosed spaces, and should be installed in the position where it can be seen or easy to operate by the operator. The positions where static electricity may be generated by high-voltage pipelines and components should be reliably grounded, and other measures should be taken to control hydrogen leakage and concentration, so as to ensure that no safety problems will occur even if static electricity is generated.

(5)Generally, the hydrogen storage cylinder and pipeline should not be installed in the passenger compartment, luggage compartment or other places with poor ventilation, but if it is inevitable to be installed in the luggage compartment or other places with poor ventilation,

ventilation pipeline or other measures should be designed to discharge leaked-out hydrogen in a timely manner. The pipeline joints should not pass through or be installed in the passenger compartment, and should not be installed in positions with high heat source, easy wearable or prone to impact.

(6)The metal parts supporting and fixing the pipeline should not be in direct contact with the pipeline, and non-metallic gasket should be added, with the exception that the pipeline is directly welded with the support and fixing parts or connected with solder.

(7)The refueling receptacle should not be installed in the passenger compartment, luggage compartment or other places with poor ventilation; the refueling receptacle should have a dust cover which can prevent dust, liquid and pollutants from entering, and the maximum fueling pressure of the refueling receptacle should be indicated beside the dust cover; the refueling receptacle should be installed at the side of the passenger vehicle; the refueling receptacle should be able to bear 670N load from any direction, and should not affect the air tightness of the hydrogen system.

(8)Hydrogen leakage detectors should be reasonably installed at the positions where leakage may occur and in the passenger compartment. The detectors should be installed at the position where hydrogen is most likely to accumulate, generally the peak position of a local area and the place with poor ventilation.

(9)When the hydrogen storage cylinder is arranged under the frame, effective protection measures should be taken under the hydrogen storage cylinder to prevent any splash caused by the driving wheel from hitting the hydrogen storage container, and the hydrogen storage cylinder and its accessories are not allowed to be arranged before the front axle of the passenger vehicle.

(10)When the hydrogen storage cylinder is installed in an exposed position on the vehicle, effective protective measures should be taken.

(11)The presence of sharp and angular parts should be avoided around the hydrogen storage cylinder.

(12)In the design of the bottom of the hydrogen storage cylinder, there should be grills on the doors on both sides of the hydrogen storage cylinder to ensure normal ventilation.

(13)In the design of the bottom of the hydrogen storage cylinder, the body of the cylinder and the passenger compartment should be effectively isolated to prevent leaked hydrogen from entering the passenger compartment.

(14)When the hydrogen storage cylinder is designed to be installed in the bottom of the vehicle, the electrical wires and gas pipeline joints unrelated to the hydrogen system should avoid the hydrogen storage cylinder compartment as much as possible

(15)The hydrogen storage device on the fuel cell vehicle should be firmly installed during use or storage, with buffer protection measures to prevent it from moving or damaging during use. The amount of lateral movement should not cause danger. Any complete high-pressure hydrogen storage container should include a connecting and fixing device, and necessary measures should be taken to avoid the impact on the hydrogen supply system of heat source, electric apparatus, storage battery and other components that may generate arc.

2.1.2 Example of installation and layout of on-board hydrogen storage cylinder on passenger vehicle

The configuration of on-board hydrogen storage cylinder in a passenger vehicle should comprehensively consider sufficient passenger space, luggage storage space and fuel storage, and take into account vehicle safety and average distribution of weight. It is recommended that the on-board hydrogen storage cylinder in a passenger vehicle be placed in the middle of the car chassis, under the rear seat, as well as the open space between the back trunk and the rear wheels. Two or three 35MPa/70MPa high-pressure hydrogen storage cylinders can be used due to space restrictions and to avoid the risk of discharge when the vehicle is stopped. See Figure 2-1 for an example of the installation and layout strategy of hydrogen storage cylinders in passenger vehicles.

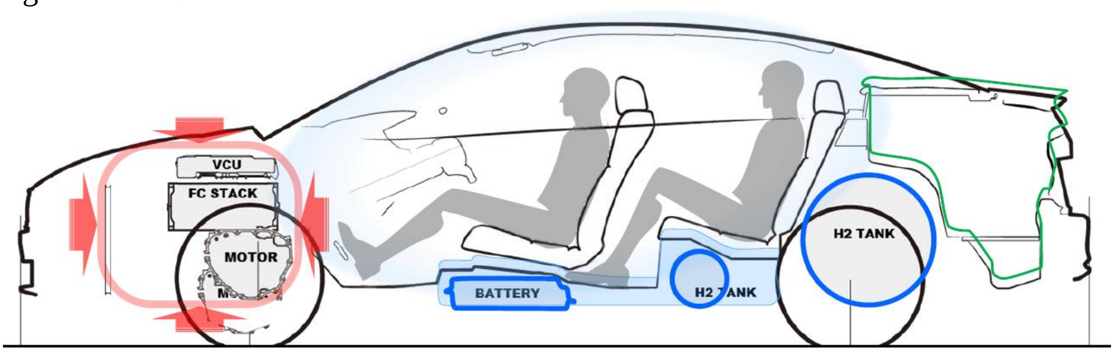
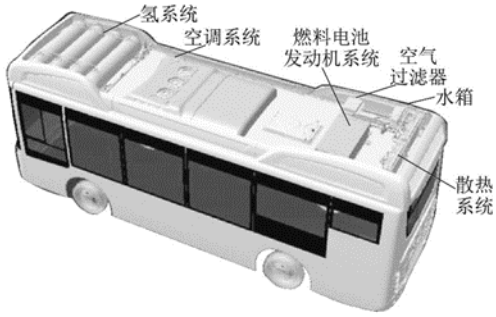


Figure 2-1 Installation and layout strategy of hydrogen storage cylinders in a fuel cell passenger vehicle

2.1.3 Example of installation and layout of on-board hydrogen storage cylinder for commercial passenger vehicles

As power battery, DC/DC converter and drive motor are installed on the chassis, and the current commercial buses are mostly low-chassis for easier access, it is recommended to arrange the multi-cylinder on-board hydrogen system of fuel cell commercial buses on top of the vehicles. In addition to the consideration of load balance and no impact on the internal passenger space of the bus, the cover of the hydrogen system on the roof can be made of fiberglass, and the top skirt can be made of formed aluminum alloy plate to effectively ensure the flatness and continuity of the vehicle’s appearance. The space at the top is more conducive to arranging multiple hydrogen cylinders to increase the hydrogen storage capacity and driving range. In addition, the top cover of the hydrogen system can be opened to facilitate the maintenance and safe operation of the hydrogen storage cylinders. Figure 2-2 shows an example of fuel cell commercial bus with hydrogen supply system arranged on top of the front section of the vehicle.



氢系统：hydrogen system

空调系统：Air-conditioning system

燃料电池发动机系统：fuel cell and engine system

空气过滤器：Air filter

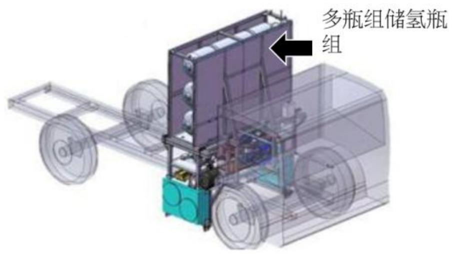
水箱：Water tank

散热系统：Cooling system

Figure 2-2: Example of layout of on-board hydrogen storage cylinders for commercial passenger vehicles

2.1.4 Example of installation and layout of on-board hydrogen storage cylinders for commercial trucks

In order to ensure a driving range of more than 350 kilometers, commercial trucks usually have a multi-cylinder set of 35 MPa on-board hydrogen system. Small and medium-sized trucks can be equipped with two or three cylinders. Large trucks might have more than four hydrogen storage cylinders. Where necessary, a 70MPa hydrogen storage system may be installed to increase hydrogen storage capacity and driving range. It is recommended that the hydrogen storage cylinders be placed in a horizontally stacked manner on the chassis of the vehicle near the traction head to increase space utilization of the truck. Figure 2-2 shows an example of the layout of hydrogen system on commercial trucks.



多瓶组储氢瓶组：Multi-cylinder hydrogen storage set

Figure 2-3 Layout strategy of hydrogen cylinders on fuel cell commercial truck

2.2 Safety design and management

2.2.1 General principles of safety design for hydrogen system

(1)Hydrogen supply, connecting devices and piping should be able to prevent hydrogen corrosion and hydrogen embrittlement.

(2)The hydrogen supply system should be equipped with overflow protection device or other measures, which can automatically shut off the hydrogen supply in the hydrogen storage cylinder when the pressure in the hydrogen storage container or pipeline is abnormally reduced or the flow is abnormally increased; if an over-current protection valve is adopted, the valve should be installed on the main shut-off valve or close to the main shut-off valve; pressure release device should also be set up, which should be installed at the outlet of the release pipeline. Necessary protective measures should be taken to prevent blockage by foreign objects in the process of operation and thus affecting gas emission.

(3)The hydrogen supply valve set should meet the following requirements: supplying hydrogen to the fuel cell system, functioning as a pressure reducing valve and a safety shut-off valve. The valve should be able to shut off within 1 second. The electrically operated hydrogen supply valve should comply with the requirements in GB14536.19-2017.

(4)Where the hydrogen system might generate static electricity, it should be reliably grounded. Copper nut should be applied at the grounding point. The resistance between the hydrogen supply system casing and the grounding terminal should be less than 0.1Ω. Alternatively, measures to control the hydrogen leakage and concentration may be taken so that there will be no safety issues at the position where static electricity is generated.

(5)The hydrogen system should be equipped with a hydrogen concentration detection device, which can automatically shut off the hydrogen supply in the hydrogen storage cylinder when the hydrogen concentration is detected to be more than 50% LFL.

(6)Other technical requirements with respect to the safety of hydrogen system should be consistent with those of GBT34872-2017.

2.2.2 High-pressure hydrogen storage cylinder

On-board high-pressure hydrogen storage cylinders should be designed, manufactured and inspected in accordance with the regulations and standards such as GB/T 35544-2017 *Fully-Wrapped Carbon Fiber Reinforced Cylinders with an Aluminum Liner for the On-Board Storage of Compressed Hydrogen as a Fuel for Land Vehicles*, TSG R0006-2014 *Supervision Regulation on Safety Technology for Gas Cylinder*; The fueling, transportation, storage, use and inspection of hydrogen storage cylinders should comply with TSG R0006-2014 *Supervision*

Regulation on Safety Technology for Gas Cylinder and TSG R0009-2009 *Gas Cylinders Safety and Technical Supervision Regulation*. The commonly used nominal working pressure of hydrogen storage cylinders on vehicles is 35 MPa and 70 MPa. The working environment temperature is -40℃~ 85℃, and the designed service life is 15 years (35 MPa) and 10 years (70 MPa). According to the different working pressure and use scenarios, a cylinder is designed to withstand 7500-11000 fueling and discharging cycles. When the actual service life of the cylinder does not reach the designed limit, but the fueling cycles have reached the designed limit. In addition, when a vehicle has reached the service life or has necessitated retirement, the gas cylinder should retire along with the vehicle.

2.2.2.1 Qualification for manufacturing high pressure hydrogen storage cylinders

A manufacturer of high-pressure hydrogen storage cylinders should have the special equipment-manufacturing license for pressure vessels that is consistent with the hydrogen storage cylinder produced. The manufacturing of Fully-Wrapped Carbon Fiber Reinforced Cylinders with an Aluminum Liner for the On-Board Storage of Compressed requires a B3 (3) license.

2.2.2.2 Type test and delivery test

In accordance with the provisions of GB/T 35544-2017 Fully-Wrapped Carbon Fiber Reinforced Cylinders with an Aluminum Liner for the On-Board Storage of Compressed Hydrogen as a Fuel for Land Vehicles, on-board high-pressure hydrogen storage cylinders should be subject to type test according to the specifications, and destructive test in batches, and delivery test one by one to ensure that all products meet the quality standard. In order to ensure the safety of high-pressure hydrogen storage cylinders, the test items include mechanical properties of winding layer, tensile test, hydraulic test, air tightness test, hydraulic blasting test, normal temperature pressure cycle test, fire test, limit pressure temperature cycle test, accelerated stress rupture test, crack tolerance test, environmental test, drop test, hydrogen cycle test, gunshot test, resistance test, durability test, service performance test, etc.

2.2.2.3 Regular inspection

(1)Subject to the requirements of the *Supervision Regulation on Safety Technology for Gas Cylinder*, hydrogen storage cylinders should be one by one or along with the vehicle every three years. The inspection should be carried out by qualified institutions.

(2)The disassembly and inspection of hydrogen storage cylinder will change the sealing state of the pipelines and valves in the system, and the process of reassembly may lead to the failure of the pipeline connection and necessitate replacement. At the same time, the reliability of the system sealing needs to be re-tested. Where the quality of the body of a cylinder is reliable, the disassembly inspection of the hydrogen storage cylinder should be avoided or reduced as much as possible.

(3)Where serious corrosions or damages are detected or doubts raised about the reliability during the process of using a hydrogen storage cylinder, an inspection should be put ahead of schedule.

(4)Any retired hydrogen storage cylinders should be destroyed to ensure that it could not be refilled.

2.2.2.4 Safe use of hydrogen storage cylinders

(1)Purchase and use products of licensed manufacturers, the inspection clearance of which is valid.

(2)Users must fill hydrogen at entities registered for fueling service or sales.

(3)Before using the hydrogen storage cylinder, the safety condition of the cylinder should be inspected and the gas to be filled verified. The use of hydrogen storage cylinders that fail to meet the Technical Safety requirements is strictly prohibited. The hydrogen storage cylinders should be used in strict accordance with the requirements of the operation manual.

(4)Hydrogen storage cylinders should be stored away from heat source, flames and positions prone to lightning strikes. The body of the cylinder should be kept dry.

(5)Hydrogen storage cylinders and its system should not be stored in an environment subject to excessive sun exposure, high humidity and corrosive medium. If long-term storage is required, reliable moisture-proof protection measures should be taken.

(6)The composite layer of hydrogen storage cylinder should not be scratched, bumped or corroded by acid and alkali.

(7)It is strictly prohibited to knock, collide, polish, or to conduct electric welding or arc striking on the hydrogen storage cylinder. It is strictly prohibited to damage the winding layer and change the label of the cylinder without permission, or to heat the hydrogen storage cylinder with a heat source above 85℃.

(8)Before opening the cylinder valve, the operator should stand at the side of the direction of gas spray of the cylinder valve to avoid airflow towards the human body.

(9)It is prohibited to tighten the cylinder valve or washer nut on a pressure cylinder to eliminate any leakage.

2.2.2.5 Contingency measures in the event of a fire in a hydrogen storage cylinder

(1)Cut off the gas supply on the condition that personal security is ensured.

(2)Evacuate personnel away from the fire zone towards the upwind direction; isolate the fire zone to prevent personnel from entering. If possible, transfer to a safe area the hydrogen storage cylinders located near the fire zone that are not directly affected by the fire.

(3)If the hydrogen supply cannot be cut off, the gas can be allowed to burn until the hydrogen in the cylinder is burnt out. Note: this treatment method is adopted on the premise that the fire can be controlled. In addition, during the combustion process, the hydrogen storage cylinder should be continuously cooled with water until the hydrogen is completely burned out, so as to avoid explosion accident due to overheating of the hydrogen storage cylinder.

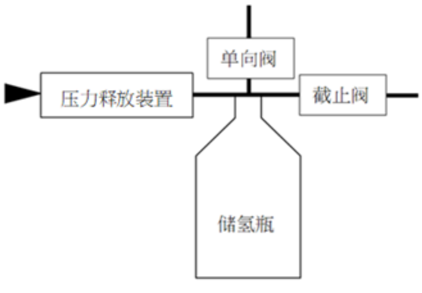
(4)Where the fire zone is in a place with good outdoor ventilation conditions, and if possible, one should stand in a safe position to put out the fire and use water to cool down the hydrogen storage cylinder on fire and all pressure vessels near the fire zone. Do not try to move or get close to the hydrogen storage cylinder heated by fire.

(5)In the event of fire emergency, one should immediately call the fire squad and inform them about the specific location and causes of the fire. After the fire is put out, any hydrogen storage cylinder affected by the fire should not be used.

2.2.3 High pressure system valves

In addition to the hydrogen storage cylinder, on-board hydrogen system can also include: refueling receptacle (fueling port); pressure reducing valve, safety valve and manual emptying valve installed between the electric reactor and the on-board hydrogen system; integrated cylinder port valve, including solenoid valve, one-way valve, manual stop valve, temperature sensor, thermally-activated pressure relief device (TPRD), pressure sensor, etc.; or pressure-driven (such as bursting disc, etc.) pressure release device (PRD), which constitutes the core safety valves of a high pressure system. Basic and typical fueling and protection measures are shown in Figure 2-4. In addition, the hydrogen sensor or hydrogen leakage detection device should be installed near the hydrogen storage cylinder and the driver's seat, which can sense the hydrogen leakage within the specified response time (generally 1s), shut off the solenoid valve of the hydrogen cylinder and send an alarm, forming multiple protection measures.

The refueling receptacle should comply with the provisions of GB/T 26779-2011 *Fuel Cell Electric vehicle – Refueling Receptacle*, and should be subject to separate mandatory inspection. In addition to the separate type test, the integrated valve and thermally activated pressure relief device should also be subject to fire test together with the high-pressure hydrogen cylinder to verify their safety, and a type test report should be issued.



单向阀：one-way valve

压力释放装置：pressure relief device

截止阀：stop valve

储氢瓶：hydrogen storage cylinder

Figure 2-4 Basic refueling process and protective measures

2.2.3.1 Excessive internal pressure and temperature in hydrogen storage cylinder

(1)A hydrogen storage cylinder installed with PRD would automatically release the excess pressure when the internal pressure of the cylinder exceeded the rated value.

(2)When the temperature inside and outside the hydrogen storage cylinder is too high, TPRD will fuse and release the excess pressure caused by the temperature rise inside the cylinder to protect it.

2.2.3.2 Hydrogen leakage

(1)A hydrogen sensor can sense a hydrogen leakage within its response time (generally 1s). In the fuel cell system, the positions that are prone to hydrogen leakage or hydrogen accumulation (within the dilution range of hazardous zones 0 and 1) and positions that are easily visible for the driver should be installed with hydrogen leakage warning devices. The levels of leakage and warning signals should be determined by the manufacturer according to the use environment and requirements of the vehicle. It is recommended to install a safety interlock device corresponding to the sensor. When the content of hydrogen in the air is not less than 2.0% ±1.0%, a warning should be given; when the volume content of hydrogen in the air is not less than 3.0% ±1.0%, the hydrogen supply will be shut down immediately; however, if the vehicle is equipped with multiple hydrogen systems, it is allowed to shut down only the hydrogen supply affected by leakage.

(2)In the event of a hydrogen leakage, while ensuring personal safety, power supply to the vehicle could be cut off according to the practical situation, and the solenoid valve in the cylinder mouth valve could be automatically closed to cut off the source of hydrogen leakage from the cylinder.

(3)Extinguish any fire in the surrounding area and stop all operations that may generate fire or spark.

(4)Evacuate personnel, avoid gas flow and evacuate swiftly towards the upper wind direction; isolate the gas-leakage area and prevent irrelevant personnel from entering.

(5)When the hydrogen storage cylinder on the vehicle leaks, the hydrogen should not be discharged to an airtight position or a place with sparks, poor ventilation conditions, or where oxidants (such as oxygen) are stored. Note: when emptying the hydrogen storage cylinder, the hydrogen flow rate should be controlled to avoid any hydrogen ignition accident caused by the excessive hydrogen flow rate. In the process of emptying the hydrogen, appropriate fire extinguishing devices should be prepared at the site and there should be persons there to monitor and ensure safety. The cylinder valve should be shut of once it is emptied.

(6)Before entering the leaking area, the area should be properly ventilated in advance to accelerate diffusion and ensure safety.

(7)The leaking hydrogen storage cylinder should be properly treated, repaired and reused after passing the inspection.

2.2.4 Control instruments (pressure gauge, various sensors and controllers, liquid level gauge, etc.)

All on-board instruments should comply with the provisions of QC/T 727 *Instruments for Automobile and Motorcycle* and QC/T 824-2009 *Tachometer Sensor for Automobile*, to be specific:

(1)The pressure gauge should be able to withstand 30,000 times of alternating cycle test. During the test, there should be no abnormal change in each part.

(2)The tachometer sensor should be able to withstand a 1000h alternating cycle test. During the test, there should be no abnormal change in each part.

(3)The on-board electronic speedometer should be able to withstand a100000km alternating cycle test. During the test, there should be no abnormal change in each part.

(4)The ammeter should be able to withstand 30,000 times of alternating cycle test. During the test, there should be no abnormal change in each part.

(5)The thermometer should be able to withstand 3,000 times of indication alternating cycle test. During the test, there should be no abnormal change in each part.

(6)The voltmeter should be able to withstand 20,000 times of voltage alternating cycle test. During the test, there should be no abnormal change in each part.

(7)The hydrogen leakage sensor should have a service life of 8 years.

(8)Regular inspection on whether the instruments are functioning normally.

(9)Self-checking function is recommended for fuel cell vehicle, which can automatically diagnose the fatigue times of all electronic sensors on the vehicle, and provide information for the driver to judge the safety status of the vehicle.

2.2.5 Fixing structure of hydrogen storage cylinder

The failure of the fixing structure of a hydrogen storage cylinder will render it and its pipeline valves unprotected, shorten its service life and even cause safety accidents such as hydrogen leakage.

(1)After a hydrogen storage cylinder is installed in the frame, it is recommended to carry out vibration reliability test for each series of on-board hydrogen supply system to check the strength of structural parts and supports and the reliability of pipelines and supports of the on-board hydrogen system.

(2)It is recommended that the tightness of the fixed structure of the on-board hydrogen system be regularly checked, and observation be made as to whether the hydrogen cylinder has been displaced or rotated.

2.3 Hydrogen fueling

2.3.1 High pressure hydrogen fueling techniques

High-pressure hydrogen fueling mainly involves such steps as transferring the hydrogen in the long tube trailer of high-pressure hydrogen to the fueling station, pressurizing and delivering it to the high-pressure hydrogen storage cylinder (cylinder set or accumulator) through the hydrogen compressor, cooling it through the heat exchange system, and finally fueling the vehicle through a fueling machine.

The fueling process and facilities, hydrogen compression process and equipment, hydrogen storage system and equipment, fueling machine and hydrogen pipelines and accessories should meet the requirements of GB 50516-2010 *Technical Code for Hydrogen Fueling Stations* and GB/T 34584-2017 *Technical Safety Regulations for Hydrogen Fueling Stations*; the design and manufacture of fueling machine should comply with the relevant provisions of GB/T 31138-2014 and GB 50516-2010.

The quality of hydrogen used for fueling fuel cell vehicles should comply with the provisions of GB/T 37244-2018 *Fuel Specification for Proton Exchange Membrane Fuel Cell Vehicles* - Hydrogen or SAE J2719-2015 *Hydrogen Fuel Quality for Fuel Cell Vehicles*. In particular, special attention should be paid to the control and detection of gas impurities, because a slight amount of impurities such as CO, CO2, sulfide, alkane and halide will lead to PT catalysis poisoning, bipolar plate corrosion and mea degradation, causing degradation and irreparability in fuel cell performance. Halide will also cause stress corrosion of stainless steel equipment in fueling station. Quality standard for industrial hydrogen and high-purity should not be used be directly.

Before fueling hydrogen into a hydrogen storage cylinder for the first time, in order to ensure that there is no possibility of combustion of hydrogen in the cylinder, it is recommended to use nitrogen or inert gas to purge the cylinder, and then replace it with hydrogen conforming to GB/T 37244-2018.

If the quality of hydrogen provided at the station fails to meet the standard, corresponding hydrogen purification devices should be selected according to the purity level or impurity content in the hydrogen provided at the station, and the hydrogen purification devices should be installed before the hydrogen compressor; stress detection points should be set during the purification, compression, metering, mixing, transportation, storage and other relevant processes in the fueling processing system, and overpressure or low pressure alarms should be installed according to the requirements of safe operation.

2.3.2 Fueling safety and smart monitoring

(1)Hydrogen fueling should be operated in an open and ventilated environment, and the fueling machine should not be placed indoors. If fueling operation is to be carried out indoors, open ventilation area must be selected, and safety measures should be taken to prevent accumulation of leaked hydrogen and fire accidents.

(2)The fueling machine should be placed on a base with a height of more than 120 mm, and the edge of the base should be at least 200 mm away from the fueling machine. Anti-collision column (fence) should be installed around the fueling machine to prevent damage to the machine caused by vehicle impact.

(3)The fueling machine or fueling island should be equipped with emergency cut-off button and automatic control device matched with the fueling system. When the emergency cut-off button is triggered, the following interlock control should be realized:

• Power cut-off at the fueling station (excluding power for monitoring and lighting);

• Automatic shut-off of stop valve at the inlet pipe of the fueling machine;

• Automatic shutdown of upstream compressing system.

(4)Hydrogen leakage detection and alarm devices should be installed in the fueling machine. When the content of hydrogen leakage in the air reaches 0.4%, alarm signals should be sent to the control system in the fueling station. When the content of hydrogen leakage in the air reaches 1.6%, shutdown signal should be sent to the control system in the station, and the valve should be shut off automatically to stop fueling.

(5)In order to prevent the consumer from driving the vehicle away from the fueling station when the fueling gun is still attached to the vehicle and thus resulting in a large amount of hydrogen leakage caused by the rupture of the relevant pipeline, a pull-off valve should be installed on the refueling hose connecting the fueling gun. The pull-off valve, fueling hose and hose connector should meet the following requirements:

• After the pull-off valve is separated under external force, both ends should be able to seal themselves to prevent hydrogen leakage;

• The fueling hose and joint should be made of materials with corrosion resistance.

2.3.2.1 Temperature monitoring during high pressure fueling

During the rapid fueling process of high-pressure hydrogen storage bottle, heat will be generated, which will cause the temperature in the hydrogen storage bottle to rise rapidly along in the fueling process, bringing safety hazards to the use of the bottle. Therefore, reasonable fueling procedures and means to control the temperature rise in the fueling process must be developed for the fueling machine, so as to ensure the safe and rapid fueling of high-pressure hydrogen.

(1)70MPa fueling machine must have hydrogen-precooling function. With respect to precooling temperature and fueling rate, reference can be made to SAE J2601 *Fueling Protocols for Light Duty Gaseous Hydrogen Surface Vehicles*. If the fueling machine has infrared communication function, it should meet the requirements of SAE J2799-2014 *Hydrogen Surface Vehicle To Station Communications Hardware And Software.*

(2)With respect to 35 MPa fueling machine, such measures as precooling, fueling rate control, fueling time prolongation and other measures can be taken to ensure that the temperature in the hydrogen storage bottle does not exceed 85℃ during the fueling process.

2.3.2.2 Anti-overpressure fueling and anti-overfueling

The hydrogen fueling machine should have fueling, metering and control functions, and should meet the following requirements:

(3)The rated working pressure of the fueling machine is 35MPa or 70MPa, each dedicated to a different on-board hydrogen system.

(4)Automatic fueling procedure for protection should be installed, which would stop fueling automatically when the hydrogen storage bottle reaches the set pressure.

(5)Configure the safety valve to prevent system overpressure.

(6)The fueling gas flow of fueling machine should not be more than 3.6kg/min.

(7)The fueling machine should be measured by mass flowmeter, and the minimum division value should be 10g.

2.3.2.3 Communication protocol between fueling gun and fueling port

In the application scenario for 70MPa high-pressure hydrogen, there should be a communication protocol between the fueling gun and the fueling port installed on the vehicle, so that the management system center in the station can monitor the pressure, temperature and other safety data of the hydrogen storage bottle on the vehicle in real time. This communication protocol should comply with the relevant provisions of SAE J2799-2014 *Hydrogen Surface Vehicle to Station Communications Hardware and Software*. The communication interface is shown in Figure 2-5.

The communication protocol should meet the following requirements:

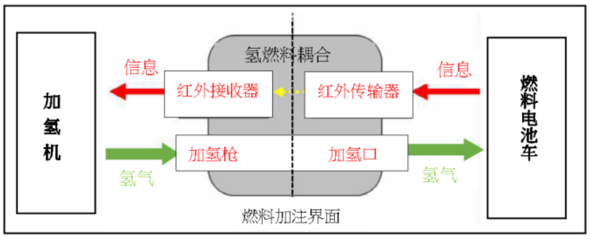
(1)Information such as the internal temperature, fueling pressure and parameters of hydrogen storage bottle on the vehicle can be fed back to the fueling machine through this type of communication and then sent back to the station's management system;

(2)The station's management system can adjust the fueling procedures according to the received pressure, temperature and other information;

(3)when the internal temperature, fueling pressure and other information of the hydrogen storage bottle on the vehicle exceed the designed limit of the vehicle itself, the information can be fed back through this protocol to stop the fueling of the fueling machine;

(4)when the fueling times (fatigue fueling and discharging times) of the hydrogen storage bottle on the vehicle are accumulated close to the preset cap, the protocol can be used to feed back information and display warning signs on vehicle’s instruments and the management system; when the accumulation reaches the preset cap, the protocol can be used to feed back information and the management center can decide to discontinue the hydrogen fueling.

(5)If the communication protocol cannot be identified by the fueling machine or the management system, or signal of the protocol is interrupted, fueling will be stopped.



加氢机：hydrogen fueling machine

信息：information

红外接收器：infrared receptor

红外传输器：infrared transmitter

氢燃料耦合：coupling of hydrogen fuel

燃料电池车：fuel cell vehicle

燃料加注界面：fueling interface

加氢枪：fueling gun

加氢口：fueling port

Figure 2-5 Interface between the fueling gun and the fueling port

2.3.2.4 Fueling safety mechanism and control strategy

The measurement and control of hydrogen in the process of fueling should comply with the provisions of GB/T 34584-2017 *Technical Safety Regulations for Hydrogen Fueling Stations* and GB 50516-2010 *Technical Code for Hydrogen Fueling Stations*.

(1)Before fueling, fuel cell system and on-board high voltage system must be shut down; the vehicle must be grounded at the fueling station (unless the vehicle manufacturer states that grounding measures are not required).

(2)Hydrogen emission should be collected from the discharge points and discharged uniformly.

(3)When there is an alarm, the system will cut off the hydrogen gas inlet automatically.

(4)The fueling machine should be equipped with safety pressure relief devices, pipeline system purging and high-pressure gas relief functions.

(5)The ends of pipelines are equipped with pressure gauge and pressure sensor to indicate the internal pressure of each pipeline. The outlet of the high-pressure pipeline is equipped with a safety relief valve, which plays the role of pressure relief protection and protects the pipeline pressure from exceeding the preset pressure limit.

2.4 Safe hydrogen release

2.4.1 Release of high-pressure hydrogen

The release of high-pressure hydrogen at fueling stations and fuel cell vehicles should comply with the provisions of GB 4962-2008 *Technical Safety Regulation for Gaseous Hydrogen Use* GB/T 24549-2009 *Fuel Cell Electrical Vehicles – Safety Requirements*.

2.4.1.1 Fueling Stations

(1)The hydrogen discharge pipes should be made of metal material, and plastic pipe or rubber pipe should not be used.

(2)The hydrogen discharge pipe should be equipped with flame arrester, which should be set at the pipe orifice.

(3)The hydrogen discharge port should be installed vertically. When discharging hydrogen containing saturated water vapor (generating two-phase flow), a certain amount of inert gas should be introduced into the discharge pipe or electrostatic elimination device be installed to ensure the safety of discharge.

(4)The outlet of indoor discharge pipe should be more than 2m higher than the roof, and the discharge pipe of outdoor equipment should be more than 2m higher than the highest equipment nearly with personnel working on it.

(5)The discharge pipe should be provided with electrostatic grounding and within the lightning protection range.

(6)The discharge pipe should be provided with measures to prevent air backflow.

(7)If the storage facility is equipped with a hydrogen vent pipe, the horizontal distance between the outdoor hydrogen vent pipe and the lightning rod should be no less than 10m, and the height of the vent pipe should be 5m lower than the lightning arrester.

(8)The hydrogen discharge rate should not exceed 150m/s.

(9)The discharge pipe should be provided with measures to prevent rain and snow intrusion, vapor condensation, freezing and blockage caused by foreign objects.

2.4.1.2 Fuel cell vehicles

(1)The hydrogen discharge system is connected to the air discharge system and effect discharge to the outside environment after mixing. Therefore, the discharge system should be made of materials resistant to condensate corrosion. If non-metallic materials are used, its temperature limit, strength and corrosion resistance to condensate should be considered.

(2)Exhaust parts of the fuel cell system should be durable. The exhaust pipe should be properly supported and equipped with rain cover or other devices enabling unrestricted or obstructed gas discharge from the exhaust pipe. Measures such as drainage should be provided to prevent water, ice and other debris from accumulating in or blocking the exhaust pipe. The exhaust system should be well sealed without leakage.

(3)Release outside the vehicle: during the normal operation such as start, driving, parking, etc., it should be ensured that no hydrogen-related hazard should happen in the event of release, purging and other forms of overflow. During exhaust discharge, the hydrogen concentration around the vehicle should not exceed 75% LFL, which should be measured on the airflow centerline 100mm from the exhaust port.

(4)Release inside the vehicle: hydrogen concentration in the passenger compartment and other compartments should be less than 25% LFL.

(5)In the event of a failure or accident, ventilation is required for the fuel system. The position and direction of gas flow should be far away from people, electricity and electrostatic accumulation sources. Hydrogen release devices should be installed at a high position in the vehicle, and the discharged hydrogen should be prevented from causing harm to the personnel and from flowing to the passenger compartment, luggage compartment and where wheels are located, and from flowing to the electrical terminals, electrical switch devices and other parts of the vehicle.

2.4.1.3 General principles of all PRD exhaust

(1)It should not be directly discharged to the passenger compartment and luggage compartment;

(2)It should not be discharged to the space where the wheels are located.

(3)It should not be discharged to other hydrogen containers.

(4)Pipes, channels and outlets connected to PRD should be made of metal materials with melting point higher than 538℃ (1000℉).

3. Fuel cell stack and system safety

3.1 Fuel cell stack safety

3.1.1 Fuel cell stack design

3.1.1.1 Fuel cell stack classification

At present, proton exchange membrane fuel cell (PEMFC) is the main type of vehicle fuel cell stack, which can be divided into metal plate fuel cell stack and graphite plate fuel cell stack.

3.1.1.2 Fuel cell stack power

The volume specific power of fuel cell stack determines the combination mode of stacks and systems and the thermal management design of stacks. Cell stacks with lower volume specific power are conducive to thermal diffusion and to thermal management design of the whole stack and system. Cell stacks with higher volume specific power is beneficial for the simplification of system design and manufacturing process and the reduction of battery stack volume.

It is a long-term and systematic work to continuously improve the volume specific power of fuel cell stack. It is recommended that the specific power and power of fuel cell stack be improved on the premise of ensuring safety, reliability and key electrical performance indicators.

3.1.1.3 Key materials in fuel cell stack

The materials used in a fuel cell stack should be resistant to the working environment, including vibration, impact, variable temperature and humidity, electric potential and corrosion environment; in positions prone to corrosion and friction, necessary protective measures should be taken.

(1)Proton exchange membrane

Proton exchange membrane is the core component of PEMFC. Its main function is to separate anode and cathode, prevent the direct mixing of fuel and air to produce chemical reaction, and conduct protons and prevent the conduction of electrons in the membrane. The higher the proton conductivity of PEMFC, the smaller the internal resistance of the membrane, and the higher the efficiency of the fuel cell. Proton exchange membrane materials should have sufficient chemical, electrochemical, thermal stability and certain mechanical stability, so as to ensure that the fuel cell can withstand the airflow impact, current impact and free radical attack without degradation in the working process, and ensure that no risk of gas leakage, short circuit, etc., exists inside the fuel cell.

For proton exchange membrane falling into the category of perfluorinated sulfonic acid membrane, it is necessary to have good thermal, chemical and mechanical stability, to avoid chemical degradation at high temperature, and to prevent hydrogen-oxygen mixing as a result of gas leakage due to chemical degradation when the fuel cell is exposed to high temperature and high electric. Gas leakage has a great impact on the safety of fuel cell, thus proton exchange membrane with high mechanical strength should be preferred. The thickness of proton exchange membrane is closely related to the safety of fuel cell. The selection of the thickness of proton exchange membrane of fuel cell should fully consider the safety risks caused by reducing the thickness of membrane.

(2)Gas diffusion layer

The gas diffusion layer consists of two parts: the supporting layer and the microporous layer. It mainly functions as a buffer and gas diffusion layer before the fuel gas enters the catalytic layer; as a transmission channel for electrons and water generated in chemical reaction; and as the supporting framework of the membrane electrode, providing physical support for the proton exchange membrane and the catalyst.

The main materials in the gas diffusion layer are carbon fiber paper, carbon fiber woven fabric, non-woven fabric and carbon black paper. Carbon fiber paper is the preferred choice of diffusion layer materials owing to its mature manufacturing process, stable performance, relatively low cost and adaptability for reprocessing. In the process of making the gas diffusion layer, long burrs, which might penetrate the proton exchange membrane when the diffusion layer is hot pressed with the latter and further cause gas leakage, should be avoided.

(3)Membrane electrodes

The membrane electrodes are mainly composed of a proton exchange membrane, a gas diffusion layer and a catalytic layer. There are three generations of membrane electrodes preparation technologies: the first generation is the GDE, the second the CCM and the third the ordered membrane electrode. Membrane electrodes are the main places for electrochemical reaction, and improving the performance of membrane electrodes can effectively improve the performance of fuel cell.

During the preparation of the membrane electrodes, excessive compression of the carbon paper may pierce the proton exchange membrane, causing gas leakage on both sides of the cathode and anode, posing a hazard. Therefore, the degree of hot pressing of the carbon paper should be controlled within a suitable range depending on the thickness of the proton exchange membrane used.

With the progress of electrochemical reaction, the proton exchange membrane in the membrane electrodes gradually fails. On the one hand, it will lead to the loss of sulfonic acid group and reduce the conductivity of the proton exchange membrane; on the other hand, it will lead to the degradation of the proton exchange membrane, which will also lead to gas leakage between the anode side and the cathode side, resulting in danger.

(4) Bipolar plates

Bipolar plates are core components of fuel cells. Their main functions comprise connecting individual cells, transporting oxygen and hydrogen on the surface of the membrane electrode assembly, collecting and conducting the current generated by the membrane electrode assembly, and transferring heat and water generated during the chemical reaction out of the system. Currently, commercial fuel cell bipolar plates are mainly graphite, composite and metal plates.

Bipolar plates need to have high electrical and thermal conductivity and high strength to ensure the safety of fuel cells in their lifetime. Key surface indicators like metal and oil content as well as the dyne value of bipolar plates should be controlled effectively. Surface treatment can improve the corrosion resistance of bipolar plates and thus prolong their service life and reduce the corrosion of fuel cells in acid and humid operating environment.

(5) End plates

End plates of fuel cells require a certain level of strength and good insulation.

Raw materials of end plates generally are metal, epoxy, fiberglass and polyester fiber. There are current collector plates on end plates to transmit current out of fuel cells. End plates are also equipped with springs and spring lids through which the fastening force of a fuel cell stack can be controlled within a certain range. End plates are subject to rigorous experiment design, optimization and verification. Strength testing is also required to ensure reliability and safety under vibration and shock. Meanwhile, the fuel cell stack is at a high temperature during operation, so it should be ensured that end plates are stable and do not deform at a high temperature.

3.1.1.4 Heat dissipation

When the fuel cell stack discharges at a high power, a large amount of heat will be generated inside and result in an increase in temperature, which may cause safety problems. So during the structural design of the fuel cell stack, it is necessary to simulate and analyze heat distribution, diffusion path and transmission speed inside the cell, and verify and optimize cooling water flow and temperature to ensure timely and efficient discharging of heat from the stack and control the stack temperature within a reasonable range.

3.1.1.5 Sealing

The sealing of the fuel cell stack is mainly that of the active area between the membrane electrode assembly and bipolar plates which usually uses highly-elastic materials like silicone rubber, fluorosilicone rubber, EPDM, PIB, neoprene and NBR. In addition, there are seals between layers of the membrane electrode assembly, in the joints and in the housing to prevent water and dust. The main function of seals in the active area is to prevent gas and cooling water from leaking out from the edges of bipolar plates and the membrane electrode assembly, causing the leakage of flammable gas. Therefore, bipolar plates and the membrane electrode assembly should have sealing structures and sealant lines. Since the sealant lines deform greatly and its compression set worsens under the assembly stress of the stack and at a higher temperature, and they degrade slowly in the operation environment of the stack, the resistance to temperature, pressure and free radicals and the F-attack of the sealant lines and sealing rings should be considered to ensure their reliability during the lifetime of the stack.

3.1.1.6 Encapsulation

The fuel cell stack needs to be encapsulated after assembly, otherwise the sides of bipolar plates and the membrane electrode assembly are exposed and if a conductive object contacts the bipolar plate when the stack is outputting electricity, it will be charged and a short circuit in the stack may be caused, endangering relevant personnel, equipment and the stack. The encapsulation material must have good insulation and high reliability to ensure that it does not fall off or fail during the lifetime of the stack.

The fuel cell stack should have a shell to prevent its components from contacting with external high temperature parts or environment. The shell should avoid structures that are easy to cause harm to the human body.

Dimensions of the encapsulation material should match those of the stack and bipolar plates. Tolerance analysis should be carried out on dimensions in all directions. Ensure that the encapsulation material is not damaged during assembly, otherwise the membrane electrode assembly or bipolar plates will be exposed.

3.1.2 Fuel cell stack manufacturing environment requirements

The temperature and humidity values of the fuel cell stack production environment must be specified and guaranteed. Exceeding the temperature and humidity limits is generally not allowed, so appropriate countermeasures should be developed. The membrane electrode assembly is very sensitive to water. Typically, the relative humidity of the membrane electrode assembly workshop should be controlled at 40% ±5% at 25 ℃.

The dust concentration in the fuel cell stack production process must be controlled, and extraneous particles should be prevented from penetrating into any production area. Make sure the production system does not abrade metal. If this is not possible, appropriate measures should be taken to prevent particles resulting from such abrasion from entering the production process. Routine analysis of regularly detected particles should be performed to determine their quantity, size, composition, and especially their electrical conductivity (e.g. metallic particles). If any of them exceeds the specifications, corrective measures should be taken immediately. Dust concentration should be controlled below 100,000; that of key processes like membrane electrode assembly production and metal plate coating should be below 10,000.

3.1.3 Fuel cell stack tests

3.1.3.1 Fuel cell stack test requirements

The fuel cell stack needs to be tested before it leaves the factory to ensure both performance and safety. At the same time, its appearance should be inspected to ensure that there is no obvious defect.

3.1.3.2 Fuel cell stack leak test

A leak test is required in order to ensure the airtightness of the fuel cell stack. First, respectively connect hydrogen, air and cooling water ports of the stack to the three ports of a leak tester. Then start the leak tester to test the external leakage of the stack (total external leakage, external leakage of the air chamber, hydrogen chamber and cooling chamber) and its internal leakage (leakage from the air chamber to hydrogen chamber, hydrogen chamber to air chamber, air chamber to cooling chamber, and hydrogen chamber to cooling chamber). The external and internal leakage of each single cell in the stack shall not exceed corresponding specified values determined by the type of the test gas, pressure and the area of the membrane electrode assembly.

3.1.3.3 Fuel cell stack insulation and high-voltage tests

A high voltage insulation tester is used to test the insulation of the fuel cell stack: put the stack on the test board; short the terminals of the current collector plates on the anode and cathode sides; use multi-meter to measure the resistance between the port terminals and the anode and cathode terminals. The reading should be very high ("OL" is displayed).

High-voltage test should be carried out on the stack: make sure all the straps are pressed by the metal bar; short the two ends of the stack; clamp the red anode wire of the high-voltage insulation tester to the terminal of the short circuit; connect the black cathode wire to the metal bar; cover the stack with a safety shield; turn on the power to start the test. The insulation resistance should be recorded when the timer ends.

3.1.3.4 Fuel cell stack performance test

Fuel cell stack performance test can only be performed after the leak, insulation and high-voltage tests are completed and there is no problem.

Procedures of the performance test are as follows: put the fuel cell stack onto the test board; connect air and cooling water supply pipelines as well as load and check circuits; heat up the stack after all connections are finished; supply air and power to the stack after its temperature reaches the specified value. The loading current is different according to the design of the stack. Generally, it is loaded to the rated working current and the stack voltage should be measured at the same time. The voltage of individual cell should not be lower than 0.3V, otherwise polarity reversal may be caused which can burn through the proton exchange membrane to result in mixing of air and hydrogen that poses a safety hazard. When the voltage of single cell is lower than 0.3V, the current output should be reduced promptly to increase the cell voltage. If the cell voltage remains lower than 0.3V, the test should be stopped immediately to find causes.

3.1.4 Fuel cell stack safety evaluation

3.1.4.1 Mechanical shock evaluation

After the fuel cell stack is installed and fixed, a shock test should be conducted with an impact acceleration of 5.0g in three axial directions: X direction, Y direction and Z direction. Half sine shock impulse should be adopted and the test should last 15 minutes, once in each direction.

After the shock test, the mechanical structure of the stack should not be damaged, and its airtightness and insulation should meet the requirements in Section 3.1.3.2 and 3.1.3.3.

3.1.4.2 Vibration evaluation

The vibration test stimulates a vehicle travelling on complex roads (e.g. washboard road, bumpy road and undulating road). Displacement of internal components of the stack must not occurred after long-time vibration, otherwise safety problems like short circuit and gas leakage may be caused. The vibration test should be conducted in three directions of X, Y and Z, each direction 21 hours. It is required that after the test, the stack should be intact in connection and structure; there is no sharp change in the voltage of the smallest monitoring unit; the absolute value of the voltage difference is not greater than 0.15V; there is no leakage, shell cracking, explosion or fire. There is no significant decrease in the insulation and airtight performance of the stack.

After the vibration test, the components in the fuel cell stack should have no obvious displacement, torsion or bending; the deviation between their original and after-vibration resonant frequency should be less than 10%; the remaining tightening force of each fastening screw is not lower than 60% of the initial value; the resistance of each electrical connection point should be less than 5% different from the initial value.

3.1.4.3 Airtightness evaluation

Close the hydrogen, air and coolant outlets of a cold fuel cell stack. Then supply nitrogen into the hydrogen, air and coolant channels and the pressure is set to normal working pressure. After the pressure is stable, close the inlet valve and measure the gas leakage, which should meet the requirements in Section 3.1.3.2.

3.1.4.4. Electrical safety

(1) Insulation

When the fuel cell stack is filled with coolant and the coolant is in a state of cold recycling, the insulation between the anode and the ground and that between the cathode and the ground positive and negative should not be lower than 100 Ω/V.

(2) Personnel electric shock protection

Personnel electric shock protection requirements of the fuel cell stack should comply with relevant provisions of GB/T 18384.3-2015.

Direct contact with the live parts of the class B voltage circuit should be prevented, so the charged outer layer of the fuel cell stack should be covered by a screen or casing.

(3) Ground protection

When the output voltage of the fuel cell stack is higher than 60V, the fuel cell stack needs to be grounded, and the resistance between the grounding point and all bare metal should be less than 0.1Ω.

The specific measurement method is: firstly disconnect the fuel cell stack from other power supply and loads; then respectively connect the terminals of the measuring instrument to the grounding point and the fuel cell stack housing.

3.1.4.5 Warning labels

The warning labels of the fuel cell stack should meet the following requirements:

(1)When the maximum voltage of the fuel cell stack is greater than 60V, there should be a "high voltage" label on the fuel cell stack, and the marking symbol should be that specified in GB/T 18384.1-2015;

(2)The polarity of the fuel cell stack should be indicated, red for the anode and black for the cathode;

(3)The symbols and description of other contents should comply with the provisions of Chapter 8 of GB/T 20042.2-2008.

3.1.5 Fuel cell stack transportation and storage safety

3.1.5.1 Packaging safety requirements (including nameplates, warning labels and packaging)

The package of the fuel cell stack should be waterproof and moisture-proof, and desiccant should be added to the package when necessary. The package should prevent the fuel cell stack from squeezing and damaging during transportation (road transport, rail transport, water transport, etc.) which may cause safety problems.

The fuel cell stack should be isolated and fixed at a minimum unit, and a safe distance should be reserved to avoid electrical safety problems.

3.1.5.2 Transportation and storage safety requirements

The fuel cell stack must be firmly fixed to the interior of the transport device and be protected from sunlight, rain, and moisture. The fuel cell stack should not be squeezed and should be placed in strict accordance with its specifications.

3.2 Fuel cell system safety requirements

3.2.1 General safety

3.2.1.1 Housing protection

The housing of the fuel cell system should protect the operator from charged, overheated (maximum surface temperature exceeds 60℃) and other dangerous components. Warning labels should be provided on the charged or overheated parts, and they should comply with the provisions of GB 2894-2008.

The design of the housing should ensure the fuel cell system can be well protected and function normally under circumstances like external press, drop, vibration and shock. The housing material should meet ROHS requirements and the special requirements of a customer such as identifying hazardous chemical components like sulfur.

(1)The housing should not have sharp edges and rough surfaces that may cause personal injury. The metal housing should generally be well grounded to avoid point discharge of sharp charged objects;

(2)The housing should have sufficient strength, stiffness, durability, corrosion resistance and other physical properties to avoid partial collapse, narrowed gap, loose structure, component displacement or other serious defects which may prevent increase the possibility of fire and accidents;

(3)If the installation position of the fuel cell system is easily exposed to water, the housing should be designed and tested to meet the IP67 protection grade;

(4)Parts in the fuel cell system may be loose or thrown out due to failure or other reasons, so the housing should be large enough to accommodate these parts and prevent them from being thrown out;

(5)The housing vents should be designed to ensure that they will not be blocked by dust, snow or plants during the lifetime of the system and under normal operating conditions;

(6)The corrosion resistance level of the housing should be determined according to the service life and working environment of the system;

(7)If there is insulation material in the housing, the insulation material should have the characteristics of low thermal conductivity, low water absorption, good flame retardancy and good electrical insulation.

3.2.1.2 Control system and protection components

The control system for the fuel cell system should be designed and manufactured to meet safety and reliability analysis requirements to ensure the single point of failure of the system components does not result in hazardous conditions. Designed manual devices should be clearly identified to prevent accidental regulation, startup and shutdown.

The control system should generally have the following alarms: overload, hydrogen leakage, fuel cell failure, failure of auxiliary energy storage module, DC/DC module failure, hydrogen supply under-pressure, hydrogen supply overpressure, system output overvoltage, system output under-voltage, short circuit, over temperature, high ambient temperature, low ambient temperature, air supply under-pressure, air supply overpressure, cooling water under-pressure, cooling water overpressure, communication failure, poor system insulation, air compressor fault, etc. The system should be able to send alarm signals automatically and transmit them to the near-end and remote monitoring equipment through the communication interface.

The fuel cell system should provide emergency shutdown and abnormal shutdown functions in the control system under the following conditions:

(1)Overload protection: When the system output is between 100%-110% of the rated power for 10min or exceeds 110% of the rated power for 3s, the voltage conversion unit should automatically enter the output-current-limiting state, and it should be able to resume operation automatically after the fault is eliminated. The fuel cell system should be able to send alarm signals under the above conditions.

(2)Hydrogen supply under-pressure and overpressure protection: When the system detects that the hydrogen supply pressure is lower than the specified minimum pressure, an alarm should be sent, the fuel cell system should be shut down, and the valve should be automatically shut off to stop the hydrogen supply. When the system detects that the hydrogen supply pressure is higher than the specified maximum pressure, an alarm should be sent, the fuel cell system should be shut down, the solenoid valve of the hydrogen storage system should be shut off to stop the hydrogen supply, and the pressure should be released promptly through the pressure relief device.

(3)Output overvoltage and under-voltage protection: When the system output voltage exceeds the overvoltage set value or is lower than the under-voltage set value, an alarm signal should be sent. When the output voltage exceeds the overvoltage set value, the fuel cell system should be able to automatically shut down to protect itself.

(4)Short circuit or electrical leakage protection: When there is a short circuit or electrical leakage in the system, the control system should be able to send out an alarm signal through the display screen or sound and light, and at the same time automatically cut off the fuel cell power output line or shut down the system.

(5)Hydrogen leakage protection: The system should have a hydrogen leakage detection function and can send out an alarm signal when a leakage occurs. When the hydrogen leakage exceeds 20000 ppm, the fuel cell system should automatically cut off the power output line or shut down.

(6)Over-temperature protection: When the cooling water outlet temperature exceeds the limit, an alarm signal should be sent out, and the fuel cell system should shut down.

(7)Fuel cell failure protection: When the cell voltage or the pressure difference of fuel cells exceeds the limit value, the fuel cell system should automatically enter the output-current-limiting state, and it should be able to resume operation automatically after the fault is eliminated. If the fault cannot be eliminated, an alarm signal should be sent out and the fuel cell system should be requested to stop.

In order to ensure the normal and safe operation of the fuel cell system, appropriate protective components should be installed and the following requirements should be met:

(1)The installation position of protective devices should meet maintenance and testing requirements.

(2)Protective devices should be independent of the functions that other devices may have.

(3)Pressure limiting devices such as safety relief valves should be provided.

(4)The hydrogen sensor should be selected, installed, proofread, used and maintained in accordance with IEC61779-6.

3.2.1.3 Hoses and hose assemblies

Hoses and hose assemblies should at least comply with the provisions for the I-type hoses in GB/T15329.1-2003.

(1)Hoses used for conveying water, hydrogen and air should be corrosion-resistant, reduce ion precipitation, have no unacceptable physical deterioration, and cause no chemical pollution to the medium during usage.

(2)The design, installation and testing of hose assemblies whose internal pressure exceeds 100 kPa should comply with the provisions of GB/T 20801.2-2006.

(3)Hydrogen hoses and connecting devices should be able to prevent stress corrosion cracking. The hose assemblies should be capable of operating at the maximum allowable working pressure and temperature when the fuel cell system is under normal, emergency, fault and shutdown conditions.

3.2.1.4 Requirements for metal piping and its fittings

The metal pipeline and its fittings should comply with the provisions of GB/ T20972.1-2007. The hydrogen-related metal parts should have the hydrogen embrittlement resistance specified in HB5067-2005 to avoid hydrogen embrittlement when the reducing valve at the front end of the hydrogen supply pipeline fails.

The hydrogen piping and connecting devices should be able to prevent stress corrosion cracking. Rigid and flexible piping and fittings carrying or transporting fluid under high pressure should be designed, installed and tested in accordance with the requirements of ISO

16528-2007.

Metal piping systems should be able to withstand the combination of the highest operating temperature and the maximum operating pressure and be compatible with other materials and chemicals that may be in contact with during service, repair and maintenance. They should be kept intact and should have sufficient mechanical strength to meet the vibration resistance requirements. Metal forming elbows should not have defects that affect their usage when they are bent. Before the installation of the metal pipes, the particles on their inner surface should be thoroughly cleaned, and the obstacles and burrs at their edges should be carefully removed.

3.2.1.5 Requirements for vulcanized rubber and thermoplastic rubber components

Vulcanized rubber and thermoplastic rubber components should meet the following requirements:

(1)All materials should meet the requirements for the highest working temperature and pressure during the lifetime specified by manufacturers and should be compatible with other materials and chemicals that will be in contact with during normal use, maintenance and overhaul;

(2)The polymer parts and rubber parts of the outer shell should be protected from mechanical damage. Polymer and rubber pipelines may be equipped with protective sleeves or covers if necessary. Hydrogen and air discharge pipelines should be made of materials resistant to condensate corrosion, and their strength and resistance to high temperature and condensate reaction should be evaluated.

(3)Polymer or rubber tubing conveying hydrogen should be prevented from possible overheating. The control system should be able to cut off the hydrogen supply before the temperature reaches 10℃ lower than the minimum heat distortion temperature of the tubing. For the sake of safety and reliability, appropriate pressure relief devices or methods should be designed to protect components from being damaged by overpressure.

(4)Non-metallic tubes transporting fluids (such as hydrogen) will accumulate static charges on their inner and outer surfaces, and some of the charges can move to the metal fittings connected to their ends. Discharge of the outer surface of the tube or the fittings may be sufficient to ignite flammable gases in the environment. Therefore, effective measures should be adopted to prevent polymer or rubber materials used in hazardous areas from accumulating static charges, like choosing materials having electrical conductivity; or materials whose end resistance is less than 1 MΩ/m when the test voltage is 1000 V; or materials whose static charges accumulated when transmitting fluids under normal and abnormal working conditions can’t cause ignition during an electrostatic accumulation test. If the above requirements can’t be met, the fluid velocity should be limited to a specific range during design to avoid static charge accumulation on the non-metallic materials.

(5)Vulcanized rubber and thermoplastic rubber components should be subjected to hot air accelerated aging test (aging time should not be less than 96h) and heat resistance test in accordance with GB/T3512-2014, and their performance should still meet the requirements of the power generation system after the tests.

3.2.1.6 Requirements for materials, components and structural design

Materials, components and the structural design should comply with the explosion-proof safety regulations for Class II equipment in GB3836.1-2010. The materials and components inside the power generation system should meet the following requirements:

(1)When the power generation system is working, its internal wires and components should withstand the maximum current and any temperature that may reach under normal operation of the power generation system.

(2)Under the specified allowable temperature, the mechanical strength of the wires and components in the power generation system should not decrease; their allowable stress should not be exceeded due to thermal expansion; and they should not damage the adjacent insulation parts.

(3)The selection of the internal wires should comply with the provisions of 5.6 of GB3836.4-2010.

(4)The connecting devices of the internal wires and components should comply with the provisions of 7.2 of GB3836.4-2010. The internal wires in contact with metal parts should be mechanically protected or properly fixed to prevent damage.

3.2.17 Grounding requirements

The conductor housing of the internal components of the power generation system should be connected to the electrical platform to ensure that hydrogen will not be ignited by static electricity when it leaks.

The CAN bus branch distance control should conform to the specification, and the shielding should be grounded at a single point. Please ensure the area with the worst anti-interference ability is grounded at a single point. The twisting method should be avoided when connecting shielded wires.

The high-voltage components inside the fuel cell system should be grounded in accordance with general principles to improve the EMC and to meet safety requirements. Their grounding should meet the following requirements:

(1)All conductive parts in contact with the high-voltage components must be grounded.

(2)The system grounding points should be clearly marked and should use copper nuts. The conductivity of all grounding points should be ensured, and there should be no poorly conductive paint or oxide which may cause ineffective grounding. The resistance between the system housing and the grounding terminal and that between all accessible metal parts and the grounding terminal should be no more than 0.1Ω.

(3)The lock nuts of all grounding points should have a certain installation torque, and the grounding wire should be as short as possible.

(4)A safety gap should be maintained between the high and low-voltage wiring harnesses. The shielded wires should be connected as required, and be as short as possible.

3.2.1.8 Fuel cell system thermal safety

The heat dissipating components of the fuel cell system mainly include water-cooled radiators and air-cooled radiators. They should have sufficient heat dissipation area to ensure the heat transfer between the internal heat source and the thermal management system meets design requirements. How to prevent high-voltage components such as the fuel cell stack and air compressors from overheating which may cause safety accidents should be considered during design.

(1)The motor used inside the fuel cell system should be equipped with a temperature sensor and its temperature should be detected by the motor controller. If its temperature detected by the controller is too high, a motor overheating alarm or signal should be sent to the fuel cell system controller through CAN communication, and the controller should limit the motor power or stop the motor. The installation position and quantity of the temperature sensors should meet the requirements of the highest and lowest temperature under different working conditions, and their accuracy, applicable range and response time should be considered.

(2)The fuel cell system should be able to effectively dissipate and cool the fuel cell stack to ensure its operating temperature is always within the normal range, so as to avoid lifetime shortening caused by overheating.

(3)Heating components are designed to ensure the low-temperature start-up of the fuel cell system used in specific areas. The heating components should have corresponding safety design (such as the adoption of the secondary hot melt protection mechanism), so that their power supply can be cut off when they are overheating.

(4)The thermal management system should have corresponding detection means so as to send an alarm signal when the coolant pipeline may leak or even has safety risks.

(5)In view of the possible fire risk of the fuel cell system, its components should be made of highly fire-retardant or non-combustible materials, so that even in extreme thermal runaway conditions, they will at least not aggravate the combustion reaction.

3.2.2 Component installation and protection

(1)During the designing and manufacturing of a fuel cell system, due consideration should be given to the mounting stability of its components and fittings so that there is no risk of tipping, falling or accidental movement during use under predetermined operating conditions.

(2)All fuel cell system components and connections should be firmly installed with rigid supports. If necessary, use shock-proof brackets to avoid damage, leakage and other faults caused by car vibration.

(3)All parts of the fuel cell system should be properly protected and not be placed at the outermost edge of the vehicle, except for pressure relief devices and exhaust ducts. Outlets that may emit or leak hydrogen should be kept away from devices that may generate sparks or high temperatures.

3.2.3 Fuel cell system safety test

3.2.3.1 Gas leak test

When the fuel cell system is tested for gas leak, its leakage must not exceed the specified limit. Before the test, respective maximum internal pressure values required to ensure the normal operation of the fuel cell system for the hydrogen system, air system and cooling system should be determined. The hydrogen system, air system, and cooling system should be pressurized as separate test sections.

A suitable pressurization or stabilizing system capable of providing a test pressure to the gas medium and a flow measuring device capable of accurately measuring the leakage should be connected to the inlet of the test section. The flow measuring device should be located between the pressurization system and the test section. The test section outlet should be sealed using a suitable method. Keep all functional units open and maintain the required test pressure on all units in the test section.

The gas medium should be gradually supplied to the test section so that the test section gradually reaches a pressure value not lower than that specified in the table below within about 1min. The pressure should be maintained for at least 1min, or longer, and any leakage shown by the flow measuring device during this period should be recorded.

Table 3-1 Leakage test requirements

Hazards	Test type	System design conditions	Test parameters	Pass/fail criteria
Inflammable/air/coolant	Pneumatic	All pressures	1.1 times as high as the design pressure	No bubbles in an industrially recognized leak detecting solution and the leak rate doesn’t exceed L.

3.2.3.2 Pneumatic strength test

When this test is carried out with inert gases or air, the fuel cell system components under test should be free of cracks, ruptures, denaturation or other visible physical damages.

Before the test, respective maximum internal pressure values required to ensure the normal operation of the fuel cell system for the hydrogen system, air system and cooling system should be determined. The hydrogen system, air system, and cooling system should be pressurized as separate test sections. The test section can be separated from the rest of the fuel cell system by a convenient method if necessary.

A suitable pressurization or stabilizing system capable of providing a test pressure to the gas medium should be connected to the inlet of the test section. Keep all functional units open and maintain the required test pressure on all units in the test section. The gas medium should be gradually supplied to the test section so that the test section gradually reaches a pressure value not lower than that specified in Table 3-2 within about 1min. The pressure should be maintained for at least 1min, or longer, then it should be reduced to the design pressure. Whether the test section passes the test should be determined according to the following table.

Table 3-2 Pneumatic strength test requirements

Hazards	Test type	System design conditions	Test parameters	Pass/fail criteria
Inflammable	Pneumatic	≥13kPa	1.3 times as high as the design pressure	No cracks, ruptures, denaturation or other visible physical damages
		13kPa＞P＞3.5kPa (fuel cell stack is more than 5.5kPa, less than 13kPa）	17kPa	No cracks, ruptures, denaturation or other visible physical damages
		≤3.5kPa(fuel cell stack is less than 5.5kPa)	5 times as high as the design pressure (5 times for fuel cell stack)	No cracks, ruptures, denaturation or other visible physical damages
Air	Pneumatic	≥100kPa	1.3 times as high as the design pressure	No cracks, ruptures, denaturation or other visible physical damages
		＜100kPa	No requirement	No requirement
Coolant	Pneumatic	≥1.1MPa or ≥120℃	1.3 times as high as the design pressure	No cracks, ruptures, denaturation or other visible physical damages
		＜1.1MPa and ＜120℃	No requirement	No requirement

3.2.3.3 Fuel starvation test

The fuel cell system should be operated to a steady state with nominal power and normal operating parameters. The fuel flow is reduced to a level that represents the worst case to trigger fuel starvation. The worst case should be determined according to the risk assessment report provided by the fuel cell system manufacturer. The voltage monitoring system or other safety systems should provide a signal to switch the fuel cell system to a safe state before it reaches a dangerous state.

3.2.3.4 Oxygen/oxidant starvation test

The fuel cell system should be operated to a steady state with nominal power and normal operating parameters. The oxygen/oxidant flow is reduced to a level that represents the worst case to trigger oxygen/oxidant starvation. The worst case should be determined according to the risk assessment report provided by the fuel cell system manufacturer. The voltage monitoring system or other safety systems should provide a signal to switch the fuel cell system to a safe state before it reaches a dangerous state.

3.2.3.5 No-cooling/damaged-cooling test

When the fuel cell system is operated at the maximum allowable power output and under the stable conditions specified by its manufacturer, the coolant flow (if separated from the oxidant) is immediately stopped to simulate faults of no or damaged cooling system.

The fuel cell system should meet one of the following conditions:

(1) After the coolant is cut off, the fuel cell system can keep working for a period of time specified by its manufacturer.

(2) The fuel cell system is shut down due to performance degradation before the temperature of the structural material reaches the limit values.

(3) The fuel cell system operates until the safety system sends out a signal that switches the fuel cell system to a safe state before reaching a dangerous state.

3.2.3.6 Freeze/unfreeze cyclic test

This test is only applicable to PEMFC fuel cell systems with storage temperature or operating temperature below 0 ℃.

The fuel cell system should be turned off after normal operation in a stable manner. Then freeze the system at the lowest ambient temperature specified by the manufacturer. Then unfreeze the system according to the manufacturer's specifications until it reaches a minimum of 10 ℃. This freeze/unfreeze cycle should be repeated ten times, after which the leak test should be repeated.

3.2.3.7 Electrical overload test

The fuel cell power generation system should be able to withstand electrical overload. First make the fuel cell system achieve thermal stability at the rated current, then increase the output current to the manufacturer's permissible value and maintain it for a period specified by the manufacturer. The system should not be subject to fire, vibration, rupture, breakage, permanent deformation or other physical damage. There should be no burning, vibration, rupture, break, permanent deformation or other physical damages to the system during this period.

This test should not be performed if the manufacturer does not permit to operate the system at a higher current.

3.2.4 Fuel cell system electrical safety

3.2.4.1 Voltage ratings of circuits

Internal circuits of the power generation system are divided into different grades according to their working voltage (U) and that of the power generation system. For details, refer to the first chapter of the *Electric Vehicle Safety Guide*.

3.2.4.2 Signs

(1) Electrical equipment

If the voltage of the fuel cell system is close to the Class-B voltage, a sign of "Class-B-Voltage Device" should be marked nearby (as shown in Figure 1-1). Refer to the provisions of GB2893-2008, GB2894-2008 and GB/T5465.2-2008.

Other electrical equipment identification requirements refer to the first and the second chapter of the *Electric Vehicle Safety Guide*.

(2) Identification of Class-B-voltage wiring

The skin of Class-B-voltage cables and wiring harnesses should be orange to differentiate them from other wiring. The same method should be adopted for those inside the housing or behind the screen. Class-B-voltage connectors can be identified by the wiring harness to which they are connected.

3.2.4.3 Electric shock protection requirements

Normally, accessible conductive parts on the fuel cell system should not be charged. In order to prevent an electric shock caused by accidental contact with charged parts, the fuel cell system should adopt a suitable structure and be equipped with a protective casing, including both direct contact protection and indirect contact protection. For specific requirements, refer to the first and second chapter of the *Electric Vehicle Safety Guide*.

3.2.4.4 Insulation requirements

The insulation design of the fuel cell system should meet the requirements of GB/T18384-2015 or those of relevant enterprises. The insulation protection measures of the fuel cell system and its internal circuits should meet the following requirements:

(1)No insulation protection is required for circuits of Class A voltage.

(2)Insulation measures should be taken for live parts of any Class-B-voltage circuit to provide protection against hazardous contact, including but not limited to basic insulation or shields/casings or a combination of various insulation methods. No matter what method is adopted, it should meet the requirements stipulated by GB/T18384.3-2015.

(3)According to GB/T18384.3-2015, under the maximum working voltage, the insulation resistance of DC circuits should be at least more than 100Ω/V and that of AC circuits should be greater than 500Ω/V. If DC and AC Class-B-voltage circuits are electrically connected together, the insulation resistance should be greater than 500 Ω/V.

3.2.4.5 Clearance and creep-age distance

The insulator inside the fuel cell system should have sufficient voltage resistance, and breakdown or arcing should not occur during the voltage withstand test.

(1)Refer to GB/T16935.1-2008 for the high-voltage electrical clearance and creep-age distance of the fuel cell system. Its anode and cathode are not subject to these requirements.

(2)In the design of the fuel cell system, its electrical clearances can be determined according to the voltage withstand level and environmental pollution level.

(3)In the design of the fuel cell system, its creep-age distances can be determined according to the environmental pollution level, material CTI value, working voltage and working altitude.

(4)When the rated insulation voltage of the main circuit is different from that of the control circuit, their electrical clearance and creep-age distance can be selected according to their rated values respectively. When the rated insulation voltages of the conductive parts of the main circuit or those of the conductive parts of the control circuit are different, their electrical clearance and creep-age distance should be selected according to the highest insulation voltage.

3.2.4.6 Electrical connection reliability

(1)The electric connection part of each circuit in the fuel cell system should have an effective design. It is recommended to use thread glue to lock to ensure the reliability of connection impedance during the whole life cycle of the system.

(2)The connection impedance of the electrical connection parts of each circuit inside the fuel cell system should have clear indicators and testing so that tests can be performed during production and maintenance.

(3)The high and low voltage connection terminals of the wiring harness in the fuel cell system should be firmly connected with the wires.

(4)The connector should have a locking device to avoid separation or poor contact, and the high voltage connector should have the high voltage interlock.

3.2.5 Fuel cell system safety monitoring requirements

Various failures and/or accidents that may occur during normal or abnormal use should be considered during the design and manufacture of the fuel cell system, and appropriate measures should be taken to avoid them. The corresponding risk assessment and reliability analysis should be carried out in accordance with GB/T 7826-2012.

For unavoidable safety risks, safety warning signs and handling instructions should be provided, as well as sound, light and other warnings and automatic and/or manual handling measures.

The control system should be designed to monitor the operation of the various functional subsystems of the fuel cell system and to prevent the deterioration to dangerous conditions due to a single failure of the system components.

Manual controls should be clearly labeled and designed to prevent accidental adjustments and starts.

3.2.6 Shock, vibration and collision

Vibration is a test of the durability of structural parts. Different from traditional vehicles, the excitation source of the fuel cell system mainly comes from the unevenness of the road surface during the driving process. The excitation frequency of the road surface is mostly low, based on which the overall natural frequency of the fuel cell system should be considered in its design.

The fuel cell system should have certain shock vibration resistance, so as to ensure that shock vibration generated during normal use, transportation or storage will not cause damage to various parts of the system.

(1)During the design of the fuel cell system, the maximum deformation of its protective housing and internal structures (the fuel cell stack, high- and low-voltage wire harnesses and auxiliary systems) during the collision should be analyzed, and the safety risks during shock, vibration and collision should be judged based on the principle of priority protection of the fuel cell stack.

(2)According to space requirements, the protective housing can be designed with reinforcing ribs or corrugated plates to improve the overall structural strength.

(3)The structure design with energy absorption effect can be considered based on the layout of the whole vehicle. The plastic requirements of the corresponding materials should be considered during the design.

(4)The reliability of electrical connections should be considered to avoid the occurrence of wire shedding or wire collision of electrical components and short circuit caused by vibration.

(5)Improve the structural strength of the hydrogen supply system and thermal management system, and increase protection design, so as to avoid hydrogen pipeline damage, hydrogen leakage and coolant leakage caused by shock, vibration and collision.

3.2.7 Electromagnetic compatibility

The fuel cell system should, through reasonable layout arrangement and shielding protection design, withstand the electromagnetic radiation interference of the standard emission power field intensity level of the on-board transmitter under working/non-working state without any deviation of functions or safety degradation. Test verification should be carried out for the working frequency ranges of different transmitters in accordance with GB/T33012.3-2016.

The fuel cell system should be able to resist the electromagnetic interference in the working environment. The collection of voltage, temperature and other signals, the normal operation of communication and opening and closing of the solenoid valve should be ensured when the system works in the preset environment. Moreover, during the normal operation, the electromagnetic interference above the specified level will not be generated.

The high-voltage wiring harness of the fuel cell system should be equipped with EMC shielding, and its arrangement should not enhance EMC radiation. The signal acquisition control wiring harness should be as perpendicular as possible to the high-voltage wiring harness to avoid the radiation crosstalk of the high-voltage wire harness. The shield layer of the high-voltage wiring harness should be effectively connected with the conductive shell of high-voltage components.

4. Operation, maintenance and infrastructure of fuel cell vehicle

4.1 User's guide and manual

Complete fuel cell vehicle manufacturer shall provide a user's manual, which specifies the automobile's specific operation, fuel and safety features. The manual shall at least comprise of safe operation procedures, including the operating environment and precautions regarding the fuel, coolant and other substances for storage and use on the automobile.

4.1.1 Storage of fuel cell vehicle

(())A hydrogen fuel cell vehicle must be parked in an open-air place if hydrogen gas has been filled in its gas tank. Make sure to keep the place and passageway well ventilated. After meeting the requirements for test of complete vehicle in a closed space, a fuel cell vehicle may be parked in an indoor space, where hydrogen gas leakage detection system and interlinked exhaust system should be deployed at the highest location.

(2)Make sure the parking space is well ventilated and the passageway between vehicles is free of obstruction of any sundry item. The parking space should be far away from gasoline refueling station, gas refilling station, heat source, dampness, inflammable facility/inflammable substance stacking area, corrosive gas and dusty places. At the same time, try to prevent any other vehicle or moving object from colliding or crushing the vehicle and avoid secondary impact of the accident.

(3)A dedicated carpark should be well drained and well ventilated, and the extreme flooding height in the place shall not be higher than the maximum height of water level for a vehicle to enter into.

(4)During the storage period, the hydrogen filler of a vehicle must be covered with a cap to prevent invasion of rain and dust. At the same time, make sure the door of the hydrogen filler is locked.

(5)It is inevitable for a hydrogen fuel cell vehicle under daily operation to enter into an underground carpark or other general indoor place which is a relatively closed environment. It is suggested the vehicle operator to shut off the fuel cell system before entering into any of these places and drive the vehicle in the electricity mode only. The hybrid mode of the fuel system should not be turned on again until the vehicle leaves the above places.

4.1.2 Daily safety inspection during operation of a fuel cell vehicle

(1)Visually check if there is any damage to the surface of the high-pressure hydrogen cylinder. Under the condition where hydrogen is supplied in the pipeline, use soap water or leakage detection liquid to check the air tightness of the hydrogen system. Check the main parts including the filler, the filler pressure meter, main electromagnetic valve, pressure relief valve, safety valve, air release valve and all connectors, and at the same time check if the connecting pipelines are in complete and good condition.

(2)Visually check if there is any crack, deformation or other abnormal phenomena in the frame of the hydrogen system.

4.1.3 Safety precautions for refueling hydrogen to a fuel cell vehicle

(1)The hydrogen gas for use in a fuel cell vehicle must meet the requirements for the national standard GB/T 37244-2018, “Hydrogen Gas as a Fuel for Use in Proton Exchange Membrane Fuel cell vehicle”.

(2)When the vehicle arrive at the parking space for hydrogen refueling, turn off the fuel cell system, pull the hand brake, and turn off the lighting at night.

(3)The driver should get off the vehicle, open the hydrogen tank filler cap, and then wait in the safety area.

(4)Hydrogen refueling for the vehicle shall be performed by the qualified professional hydrogen refueling personnel at the hydrogen refueling station.

(5)Upon completion of hydrogen refueling, the driver should confirm if the hydrogen refueling gun and the antistatic grounded wire are removed, the hydrogen filler pressure meter reads within a normal range and the hydrogen filler dust cover is in place, and lock the hydrogen filler tank door.

(6)After getting on the vehicle, the driver should first check dashboard and see if the cylinder pressure and temperature data are normal and if there is any failure alarm. After confirming that there is no failure, the driver should start the vehicle and drive away from the hydrogen refueling station.

4.1.4 Other general precautions in fuel cell vehicle operation

(1)The fuel cell vehicle should be operated in strict compliance with the operating manual for the complete vehicle product.

(2)It is strictly forbidden use any open fire in the vehicle. Do not place any inflammable or explosive item inside the vehicle.

(3)Servicing operation should not be performed until the fuel cell system comes to a complete stop and the high voltage end is free of any voltage.

(4)After hydrogen refueling, cover the hydrogen filler dust cap to keep clear of other things.

(5)No hydrogen refueling should be performed when the power system is on.

(6)Upon completion of installation and inspection of the hydrogen gas pipeline, blow the hydrogen gas pipeline to keep other thing from entering into the fuel cell system.

4.2 Coping with emergency in a fuel cell vehicle

4.2.1 Coping with accidental leakage of hydrogen gas

4.2.1.1 Several signs of possible hydrogen gas leakage in a fuel cell vehicle

(1)Loose hydrogen gas pipeline;

(2)Continuously declining number in the pressure meter;

(3)Hydrogen gas leakage alarm;

(4)Hydrogen system low pressure alarm;

(5)Depressurizing pipeline safety valve;

(6)Depressurizing hydrogen cylinder PRD;

(7)Deforming hydrogen gas pipeline;

(8)Deforming valve;

(9)Damage occurring to the surface of the hydrogen cylinder;

(10)Displaced or dislocated hydrogen cylinder or valve.

4.2.1.2 Measures for coping with hydrogen gas leakage emergency

In case of any hydrogen gas leakage, evacuate the personnel in the vehicle as soon as possible, switch off the hydrogen valve, turn off the key to the vehicle, switch off the power rocker switch, open all windows for ventilation, set up warning signs, and inform the after-sales personnel of the complete vehicle factory to arrive at the site in time.

In case of leakage or accumulation of a large amount of hydrogen gas, first make the alarm call and take the following measures at the same time: cut off the gas source in a timely manner and evacuate the personnel in the leakage polluted area to the windward place; ventilate the polluted leakage area for diluting the leaked hydrogen gas. If the gas source cannot be cut off in a timely manner, dilute it with water mist to prevent accumulation of hydrogen gas and forming of explosive gas mixture; highly concentrated hydrogen gas makes people suffocating, the suffocated personnel should be moved to a well-ventilated place in a timely manner for artificial respiration and sent for medical treatment quickly.

In case of hydrogen gas leakage and fire, the following measures shall be taken: cut off the gas source in time; if the gas source cannot be cut off immediately, use a large amount of water to forcibly cool down the equipment on fire; take measures to prevent fire from spreading, such as using a large amount of water mist to spray on other ignition substances and adjacent equipment; and, since the hydrogen flame is not easily detected by naked eyes, the fire fighters should wear self-contained breathing apparatus and electrostatic clothing when entering into the site and avoid any burn on the exposed skin.

4.2.1.3 Other precautions in case of hydrogen gas leakage in a fuel cell vehicle

Emergencies related to a hydrogen system shall be coped with by specially trained service personnel. The service personnel shall wear anti-static clothes and shoes and remove the static electricity from their bodies.

Hydrogen gas is an inflammable and explosive gas. At the emergency site, the service personnel shall always be aware of not having any spark, high temperature heat source or open fire in their operation that may easily ignite the hydrogen gas, and it is not allowed to use any electric tool, electric welding tool or non-explosion-proof tool.

It is strictly forbidden to disassemble or hit the hydrogen gas pipeline and hydrogen cylinder without permission, and it is strictly forbidden to operate with voltage on.

4.2.2 Coping with accidental vehicle combustion

When any part of fuel cell vehicle is on fire, first turn the key switch to OFF, evacuate the passengers, and make the alarm call according to the on-site situation.

After the firefighters arrive at the scene, clearly point out the location of major hazard sources such as hydrogen gas cylinder, fuel cell system and power cell for the firefighters, and provide information about the number of cylinders and the remaining amount of hydrogen gas in the cylinder.

Under the circumstance that personal safety is guaranteed, if condition allows, perform the following operations:

(1)If the vehicle harness has smoke and fire, the rescue personnel may wear simple personal protective equipment (such as filter-type self-rescue respirator, fire gloves) and use dry powder fire extinguisher, carbon dioxide fire extinguisher or water-based fire extinguisher to spray on the fire point, and water-based fire extinguisher is preferred.

(2)If the power cell box is on fire, contact the fire department in a timely manner and spray with a high pressure water gun at a place more than 5 meters away from the fire box; at the same time, it is necessary to spray at the hydrogen gas cylinder to prevent the pressure relief device (PRD) at the mouth and bottom of the cylinder from opening due to high temperature and discharging a large amount of hydrogen gas. In case of fire on a large number of cells or on the cell system, try to set up at least three water gun positions as soon as possible and continuously spray a large amount of and sufficient water to the fire battery box. After the fire is put out, continue to spray water at the cell system that has been burned or baked by fire to reduce the temperature and to prevent after-combustion. For other safety measures related to the power cell box, please refer to Chapter 3 of the Electric Automobile Safety Guidelines.

(3)In case of fire during the charging process, make sure to stop charging immediately before taking any action to put out the fire.

(4)If any person breathes in smoke carelessly, please move him away as soon as possible and send for medical treatment.

(5)If condition allows, have professional personnel operate and disconnect the manual service switch.

4.3 Fuel cell vehicle servicing and maintenance

4.3.1 Precautions for fuel cell vehicle servicing(1)Inspection and servicing on non-hydrogen system: if there is no need to use fire at work, the inspection and servicing work may be performed as long as ensuring good circulation of air in the surroundings. If servicing work is performed indoor, make sure that the internal clearance height of the plant is not less than 8 meters. If there is any need to use fire at work, the hydrogen gas in the vehicle must be fully discharged or the hydrogen system must be completely disassembled before any fire is used.

(2)Before using any fire at work on the hydrogen system, make sure that the volume score of hydrogen gas inside the system and in the fire working area is within the safe range. The servicing or inspection facilities shall be in a good and reliable condition, and personal protective products shall be worn in accordance with requirements. Prevent any open fire or other exciting energy from entering into the no-fire area. It is prohibited to use any electric furnace, power drill, furnace, blowtorch or any other tool and hot object that generate open fire and high temperature. Copper tools should be used for inspection and servicing work where fire is used.

(3)For all inspections using fire, make sure that no other irrelevant hydrogen fuel system exists within 3 meters around the open fire.

4.3.2 Safety matters related to fuel cell vehicle servicing

(1)During the maintenance of pipe and valve in the hydraulic system, choose a well-ventilated place and empty the hydraulic gas in the pipeline before performing maintenance on the parts.

(2)Before operation of releasing hydrogen gas, the operation personnel shall set up warning signs or isolation belts, and touch the electrostatic releaser to remove static electricity on the body.

(3)Personnel shall receive training and pass the exam before performing any operation of gas discharge.

(4)It is forbidden to bring mobile phones, lighters, non-explosion-proof walkie-talkies, matches and other fire sources and items that are prone to generate static electricity into the safety area at the site where gas is discharged.

(5)It is forbidden to use any open fire within 30 meters of the safety area at the site where gas is discharged.

(6)It is strictly forbidden to wear any clothes and shoes with nails that are prone to generate static electricity at the site where gas is discharged.

(7)The tools used in the safety area of the site where gas is discharged shall be explosion-proof tools.

(8)The area where gas is discharged shall only be used for the operation of gas discharge. It is strictly forbidden to carry out other operational activities in the same area.

(9)During the process of gas discharge, the power supply, doors and windows of the vehicle shall be closed, while all roof windows shall be opened.

(10)During the process of gas discharge, no personnel except those who are designated to perform gas discharge will be allowed to enter.

(11)After hydrogen gas is discharged from the vehicle, it is necessary to test and make sure no gas remains around the vehicle, in the tank and inside the vehicle before drive the vehicle away.

(12)It is forbidden to perform any operation of gas discharge in thunderstorm weather.

(13)If the modification work that needs to use fire is required for the hydrogen fuel cell vehicle, the hydrogen gas needs to be discharged before operation.

4.4 Operation and management of hydrogen gas filling facilities

4.4.1 Operation and maintenance of hydrogen refueling

After completion of construction of the hydrogen refueling station, training and regular inspection shall be carried out respectively for the operation personnel and equipment, and the safety management system, risk management system and accident emergency plan shall be established to maintain the stability of the facilities in the hydrogen refueling station; the subject that operates the hydrogen refueling station shall standardize the records of its operation information, and keep real-time records of the operation maintenance, inspection, emergency accidents and personnel and save the records for a certain period of time. It is forbidden to park any vehicles, stack any item or carry any kindling within the safe distance between the hydrogen storage tank and the oxygen compressor.

Training on and requirements for operators:

(1)Personnel need to be trained, including certificate training, three-level education training, daily training, etc.

(2)Equip with safety protection equipment such as goggles, helmets, work clothes and safety shoes.

(3)The safety work of the whole operation process shall be supervised and managed by the person in charge on site, and the process of operation with gas shall be strictly implemented.

(4)It is strictly forbidden for the operating personnel to bring kindling into the site. Anti-static clothing should be worn for access. Do not use any steel operation tools that may generate electrostatic sparks.

(5)Working personnel shall be responsible for patrol inspection on the site (with on-site warning signs, etc.). It is strictly forbidden to allow any unauthorized person to enter the work site. All personnel entering the work site must switch off their mobile phones. It is strictly forbidden to use any open fire and generate electrostatic sparks.

(6)It is strictly forbidden to use any flash light or news light and have any personnel irrelevant to commissioning existing at the site during operation.

(7)The operation personnel shall be familiar with the use of fire equipment and facilities and understand safety knowledge.

Regular inspection and maintenance of hydrogen refueling station:

(1)The fire equipment must be equipped in strict accordance with the quantity and specification required by the design and placed in the specified place, and the fire extinguisher shall be checked regularly to see whether it meets the use requirements.

(2)Establish a process for inspection on hidden danger investigation process (including comprehensive, seasonal, holiday, daily and professional inspection processes).

(3)Establish a system for hazard source identification, risk assessment and control management, and establish a system for emergency management (emergency plan, emergency drill and drill evaluation).

(4)Establish a process for accident (incident) investigation and report management.

(5)It is not allowed to conduct kindling operation on the site of hydrogen refining station which has been put into operation. In the event that fire needs to be used in operation under special circumstances, the operation shall not be performed until relevant procedures are completed with the competent safety department.

(6)All operation machinery and equipment components must meet explosion-proof requirements.

(7)All sealing points shall be inspected regularly, and the production area shall be free of oil and water leakage.

(8)Check all kinds of valves regularly to ensure they function properly.

(9)Avoid continuous discharge of nitrogen gas in the closed area, so as not to cause any hazard of suffocation. Intermittent discharge should be adopted in the process of blowing operation.

(10)Operation shall be stopped in thunderstorm and heavy rain weather. If operation is required in light rain weather, rainproof measures shall be taken at the connection interface and on electrical facilities.

4.4.2 Hydrogen refueling station quality management system

It is suggested that the hydrogen refining station should meet the requirements of ISO 9001:2015 and iatf16949:2016 quality management system. The combination of the two standards uses process method plus the plan-do-check-action (PDCA) cycle and risk-based thinking, as shown in Figure 4-1, to keep its quality management system consistent or integrated with the requirements of other management system standards, which is conducive for the hydrogen refueling station operator to attract customers, develop new products and services, reduce waste or improve productivity.

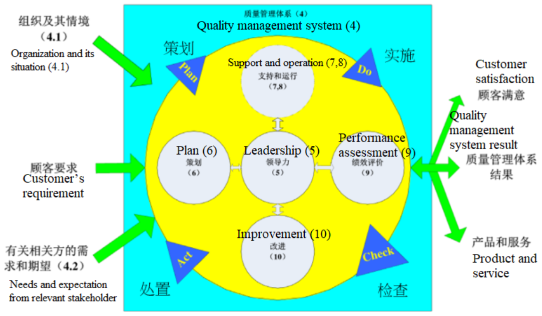


Figure 4-1 Operation mode of plan-do-check-action (PDCA) management method

4.4.3 Measurement and charging system

In order to improve the operation efficiency of each hydrogen refueling station, it is suggested that the operator establish a central management platform and collect data analysis on each hydrogen refueling station through the Internet of Things. Each hydrogen refueling station has its own management sub-platform, which collects information of each hydrogen refueling gun and vehicle to obtain accurate hydrogen refueling time, weight hydrogen refueling, price and other information

4.4.4 Project construction

4.4.4.1 Hydrogen refueling station construction

(1)Methods of transportation of hydrogen gas: high pressure hydrogen gas long tube trailer, hydrogen cylinder group cylinder transportation, pipeline transportation, or self-made hydrogen system can be used at the hydrogen refueling station.

(2)Types of hydrogen refueling station: hydrogen refueling station can be built jointly with gas refilling station or gasoline refueling station, and relevant specifications shall comply with Technical Standards for Hydrogen Refueling Station (GB 50516-2010) and Safety Technical Standards for Hydrogen Refueling Station (GB/T 34584-2017). The above standards also regulate hydropower vehicles. The above standards also provide safety and technical requirements for the transportation of hydrogen gas on hydrogen vehicles from the hydrogen refueling station, production of hydrogen inside the station, and the storage, compression and filling of hydrogen gas.

(3)If a natural gas refilling station or a gasoline refueling station is also built with the hydrogen refueling station, relevant provisions of the Standards for Urban Gas Design (GB 50028-2016) and the Standards for Design and Construction of Gasoline and Gas Refueling Station for Automobiles (GB 50156-2012) shall be met respectively.

(4)When a hydrogen self-production system or a mobile hydrogen refueling facility is equipped, relevant provisions of Standards for Design of Hydrogen Refueling Station (GB 50177-2005), Technical Requirements for Water Electrolysis Hydrogen System (GB/T 19774-2005) and Technical Requirements for PSA Purification Hydrogen System (GB/T 19773-2005) shall be met.

(5)Anti-static measures: special attention shall be paid to prevent the occurrence of electrostatic fire in the hydrogen refueling station. Therefore, for hydrogen gas system, control circuit and components, the station shall be equipped with electrostatic eliminators and relevant personnel shall be required to wear anti-static clothes, and relevant measures shall comply with the Safety Standard for Intrinsic Safety Human Body Electrostatic Eliminators (SY/T354-2017) and the Standards for Explosive Environment Part 4: Intrinsic Safety “i” Protected Equipment (GB 3836.4-2010).

(6)Hydrogen refueling stations can be classified into different levels as in the table below.

Table 4-1 Classification of hydrogen refueling station levels

Level of Classification	Hydrogen Storage Tank Capacity	
	Total Capacity kg	Single Tank Capacity kg
Level 1	4000-8000	≤2000
Level 2	1000-4000	≤1000
Level 3	≤1000	≤500

4.4.4.2 Hydrogen refueling infrastructure design and safety requirements

The following matters shall be noted with regards to the design and safety requirements of hydrogen refueling station infrastructure design and safety requirements:

(1)The hydrogen refueling station and all kinds of combined hydrogen refueling stations should be in the fire hazard category A.

(2)The hydrogen refueling station and all kinds of combined hydrogen refueling stations with explosion hazard room or zone should be in the explosion hazard level zone 1 or zone 2.

(3)The fire resistance level of buildings in the hydrogen refueling station and all kinds of combined hydrogen refueling stations should be no lower than level 2.

(4)The classification of hydrogen refueling station, hydrogen and gas refueling station and hydrogen and gasoline refueling station should conform to the relevant provisions in GB 50516-2012.

(5)When a hydrogen refueling station and a charging station is built together, the design of the charging process and facility should comply with the relevant provisions in GB 50966-2014 and GB/T 29781-2013.

(6)When forced ventilation is adopted, the ventilation capacity of the ventilation equipment should be greater than 12 times per hour during the operating period of the process equipment and 5 times per hour during the non-operating period of the process equipment. The technical specifications and design of the ventilation equipment shall conform to the relevant provisions in the Standards for Design of Electric Device in the Environment with Explosion hazard (GB50058-2014).

(7)When natural ventilation is adopted, the total area of the vent should not be smaller than 300 cm2/m2 (ground), the air change frequency should be no lower than 5 times per hour, and it shall be configured near the place where hydrogen gas accumulates.

(8)An additional forced ventilation device should be used for emergency ventilation, and the frequency should be no lower than 15 times per hour.

(9)In case of any failure or accident, the fuel system needs ventilation and exhaust, and gas should flow in the direction and to the place far away from people, electricity and fire source.

(10)Trees, oily plants and various plants that are easy to form oxygen accumulation and easily inflammable shall not be planted in the working area of hydrogen refining station.

(11)No catering, accommodation and entertainment facility operations should be provided in the hydrogen refueling station. It is strictly forbidden to set up workplaces for car washing or repair. The building of the hydrogen refueling station can be built together with its auxiliary service area, but a solid wall without any doors and window and the waterproof limit of no lower than 3h shall be configured between the station building and the auxiliary service facility.

(12)The classification of the area with explosion risk shall be defined in compliance with relevant provisions of the current Standards for Design of Electric Device in the Environment with Explosion hazard (GB50058-2014).

(13)The hydrogen refueling machine zones with explosion hazards shall be classified in compliance with the following rules: the internal space of the hydrogen refueling machine is Zone 1, and the round table shape space with the external contour line of the hydrogen refueling machine as the interface, the ground area with a radius of 4.5m as the bottom and the 4.5-meter dome of the hydrogen refueling machine as the top is Zone 2, as shown in Figure 4-2.

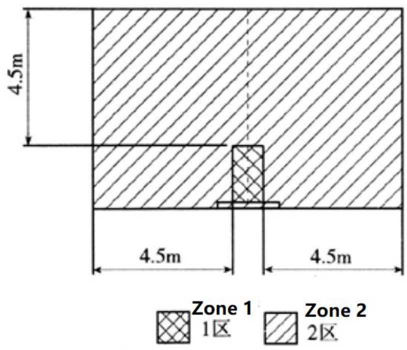


Figure 4-2 Classification of the zone with explosion hazard in a hydrogen refueling machine

(14)A canopy is needed for the hydrogen refueling station, and the canopy should be sloping up from the inside to the outside to avoid accumulation of hydrogen gas. The equipment itself is Zone 1, and the space from the ground area and the top space with a radius of 4.5m and with the external contour of the equipment as the interface is Zone 2.

(15)The vent pipes of the equipment shall be centralized. Around the hydrogen gas vent pipes, the space with a radius of 4.5m and the space of 7.5m above is Zone 2, as shown in Figure 4-3.

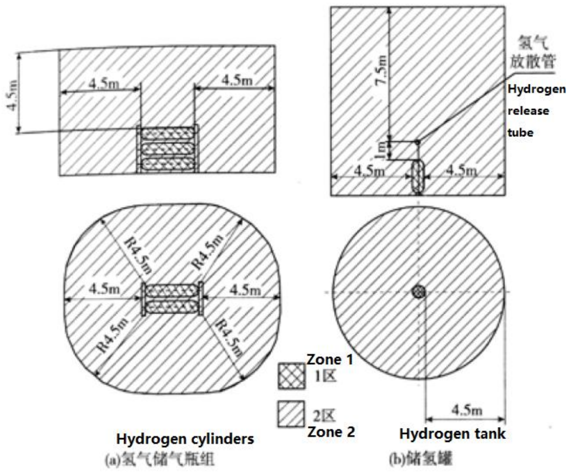


Figure 4-3 Division of areas with explosion hazard related to hydrogen tank or hydrogen cylinders outdoor or under the awning

The fire safety distance between hydrogen gas process facilities in the hydrogen refueling station and the buildings and structures outside the station shall be no less than the distance specified in the table below.

Table 4-1 Fire safety distance between hydrogen process facilities in the hydrogen refueling station and the buildings and structures outside the station (m)

Item name		Hydrogen storage tank Level 1	Hydrogen storage tank Level 2	Hydrogen storage tank Level 3	Hydrogen compressor, hydrogen refueling machine	Vent pipe
Important public building		50	50	50	50	50
Location with open fire or emitted spark		40	35	30	20	30
Civil building protection category	Protected building category 1	35	30	25	20	25
	Protected building category	30	25	20	14	25
	Protected building category	30	25	20	12	25
Factory and warehouse fire-resistance level	Level 1 & 2	25	20	15	12	25
	Level 3	30	25	20	14	
	Level 4	35	30	25	16	
Class-A Item Warehouse, Class-A, B and		35	30	25	18	25

C Liquid Storage Tank and Inflammable Material Storage Yard						
Outdoor Transformer and Power Distribution Station		35	30	25	18	30
Railway		25	25	25	22	40
Urban Roads	Expressway, Trunk road	15	15	15	6	15
	Secondary trunk road, branch road	10	10	10	5	10
Overhead communication line	National Level 1 & 2	No crossing, and no less than 1x higher than the bar				
	General					
Overhead power line	＞380V	No crossing, and no less than 1.5x higher than the bar				

In addition, if hydrogen self-preparation system and mobile hydrogen refueling facility are included, the following requirements shall be met:

(1)Environment and building safety of hydrogen making room: the space between buildings shall comply with the provisions of the Standards for Design of Hydrogen Gas Station (GB 50177-2005). The structural design and installation requirements of hydrogen making room shall comply with the requirements of the Standards for Fire Prevention in Architectural Design (GB50016-2014). The main unit for hydrogen production, cooling water pump and water tank, water pump and water tank for adding electrolyte shall be installed inside the hydrogen making room, and installation of the water pump for the non-explosion-proof motor is not allowed.

(2)Power supply safety of the hydrogen system: the power supply device of the water electrolyte hydrogen production room must comply with the provisions of the Standards for Design of Electric Device in the Environment with Explosion Hazard (GB50058-2014), the Standards for Construction and Acceptance of Electric Device Installation Project (GB50254-2014), and the Standards for Construction and Acceptance of the Grounded Device in Electric Device Installation Project (GB 50169-2016) code for construction and acceptance of grounding device in electric device installation engineering. The space within the hydrogen production room and the hydrogen gas tank storage area should be classified as Hazardous Zone 1 with explosive gas environment, and the area including the floor and space with a radius of 4.5m outside the edge of the doors and windows of the hydrogen production room and outside the external wall of the hydrogen gas storage tank, the space with a radius of 4.5m around the hydrogen gas discharge outlet and the area 7.5m above should be classed as Zone 2.

(3)Safety of lightning protection facility for hydrogen production system: lightning protection device must be installed in the water electrolysis hydrogen production room and equipment, and grounding grid must be installed to prevent static electricity from being generated in the production process of the water electrolysis hydrogen production equipment, so as to ensure good grounding of equipment. The grounding device and lightning protection facility must comply with the Standards for Construction and Acceptance of Grounded Device in the Electric Device Installation Project (GB50169-2016) and the Standards for Lightning Protection Design in a Building (GB50057-2010).

(4)Hydrogen gas detection and safety response system: within the area with fire and explosion hazard in the hydrogen production system (the hydrogen gas room and the hydrogen gas storage tank), a combustible gas (hydrogen gas) detection alarm need to be set, in compliance with the relevant requirements of the Standards for Design of Combustible Gas and Toxic Gas Detection Alarm in Petrochemical Industry (GB 50493-2009).

(5)The fire safety distance between the parking space of the long pipe trailer of the hydrogen gas and the buildings and structures in the station shall be determined according to the fire safety distance of the hydrogen gas storage tank in the Technical Standards for Hydrogen Refueling Station (GB 50516-2010).

4.4.4.3Hydrogen refueling station acceptance and safety evaluation

The construction unit shall carry out the inspection for acceptance of the project upon completion in a timely manner after all the projects within the scope specified in the contract are completed. The construction unit shall be responsible for the inspection for acceptance of the project upon completion, and organize the construction, design and supervision units to jointly carry out the project inspection. After the project is accepted, the acceptance procedure upon completion shall be completed immediately. When the project is inspected for acceptance, the completion acceptance documents submitted by the construction unit are the basis of the project completion acceptance and the basis of "life-long" quality of the project. Random inspection or test should be performed when necessary. The construction unit shall submit the following documents:

(1)For the overall project: technical document as description of project completion, commencement report, certificate of project completion, record of joint examination of drawings, list of modified design and the corresponding sign-and-prove documents, material and equipment quality certification documents and the re-inspection report.

(2)For the construction project: Project positioning survey record, foundation trench inspection record, reinforced steel bar inspection record, concrete engineering construction record, concrete/mortar specimen test report, records of inspection on items with allowable deviation in the equipment foundation, equipment foundation settlement record, steel structure installation record, steel structure fireproof layer construction record, waterproof project water test record, filling soil material and filling soil compaction test record, qualified welder registration form, concealed works record, anticorrosion works construction inspection record.

(3)Qualified welder registration form, concealed works record, equipment unpacking inspection record, static equipment installation record, equipment cleaning, inspection, blowing, replacement and sealing record, equipment installation record, single equipment operation record, valve pressure test record, safety valve adjustment test record, pipeline system installation and inspection record, pipeline system test record, pipeline system blowing / replacement Records, equipment and pipeline system anti-static grounding record, cable laying and insulation inspection record, alarm system installation and inspection record, grounding body, grounding resistance and lightning protection grounding device installation and measurement record, electrical lighting installation inspection record, explosion-proof electrical equipment and installation inspection record, instrument commissioning and system test record.

(4) Completion drawings.

(5)Visual inspection record form.

Monitoring of hydrogen gas system

A hydrogen refueling station should set up a central monitoring and data collection system shall be established for the hydrogen refueling station, and the system should be able to connect with the information from different hydrogen refueling stations and allow relevant data to be accessible by customers. By collecting big data, establishing an optimized management system and applying client-end software, the station can improve its efficiency. The data will be collected and uploaded to the data analysis database. The system-monitored data specific to the hydrogen fueling station include the following:

(1)Pressure monitoring, including detection on whether the pipeline and the hydrogen storage cylinder are over-pressurized and judgment on the amount of hydrogen stored in the hydrogen storage cylinder

(2)Monitoring of hydrogen gas flow.

(3)Monitoring on the temperature of pipeline and hydrogen storage tank.

(4)Monitoring and analysis on the number of refueling in the hydrogen refueling machine, the amount of hydrogen refueled, and the amount of money from hydrogen refueling.

(5)The information such as the number of refilling and the amount of hydrogen refueling into the hydrogen storage cylinder on the vehicle may be sent back to the management center of the hydrogen refueling station.

(6)Safety information is transmitted in a real time manner and response is given in a timely manner, so as to reduce safety risk.

(7)Uninterrupted video monitoring should be set up for the entrance and exit, hydrogen gas storage area, gas storage area, hydrogen gas refueling area, gasoline and gas refilling area, charging area, main control room and general electricity power distribution room of the hydrogen refueling station and different types of combined hydrogen refueling stations, and the monitoring videos shall be uploaded to the data collection system for data backup.

(8)It is ideal to set up a surrounding alarm device around the hydrogen refueling station and various types of combined hydrogen refueling stations, and the alarm signal should be included in the monitoring system.

(9)All alarm signals of the hydrogen refueling station and various combined hydrogen refueling stations and their processing results shall be recorded in the database of the system.

(10)Uninterrupted backup power should be supplied to all core units in the monitoring and data collection system of the hydrogen refueling station and various combined hydrogen refueling stations, and the backup power can maintain power supply within 60 minutes after power failure.

(11)The real-time information about the hydrogen refueling in customer's hydrogen refueling station should be available through use of the client-end software, so as to reduce the waiting time for hydrogen refueling, automatically calculate the distance and time from the hydrogen refueling station, and give timely reminder to the customer.

Appendix I：Relevant Specifications of Electric Vehicles Safety Guide （2019 version）

1. Alarm Requirements for Battery Overheating of Electric Passenger Vehicles

2. Safety Design Specification for Electric Passenger Vehicles

Appendix II： Electric Vehicle Safety Guide （2019 Version） Compilation Committee

1、Leading Organizations:

Department of Equipment and Industry of Ministry of Industry and Information Technology of the People's Republic of China

Department of Electric Power of National Energy Administration of the People's Republic of China

Department of High and New Technology of Ministry of Science and Technology of the People's Republic of China

Department of Industry of National Development and Reform Commission of the People's Republic of China

Department of Economic Development of Ministry of Finance of the People's Republic of China

2、Expert Groups:

Leader: DONG Yang (China Association of Automobile Manufacturers)

Members:

WANG Binggang (Senior Experts for the 863 program or "State High-Tech Development Plan" for China's new energy vehicle)

LI Jun (Member of China Engineering Academy, Tsinghua University)

OUYANG Minggao (Academician of the Chinese Academy of Sciences, Tsinghua University)

SUN Fengchun (Member of China Engineering Academy, Beijing Institute of Technology)

WU Feng (Member of China Engineering Academy, Beijing Institute of Technology)

ZHENG Heyue (Vice Director of Department of Equipment and Industry of Ministry of Industry and Information Technology of the People's Republic of China)

LI Kaiguo (China Automotive Engineering Research Institute Co., Ltd.)

XIAO Chengwei (Tianjin Institute of Power Sources)

WANG Zhenpo (Beijing Institute of Technology

WEI Xuezhe （Tongji University）

WANG Zidong （China Power Battery Industry Innovation Alliance）

WANG Fang (China Automotive Technology and Research Center Co., Ltd.)

XU Yanhua (China Association of Automobile Manufacturers)

HOU Fushen (China Society of Automotive Engineers)

CAI Wei (Automotive Electronic Drive Control and System Integration Engineering Research Center of Ministry of Education)

SHAO Zhehai (Potevio New Energy Co., Ltd.)

LIU Yongdong (China Electricity Council)

GAO Buwen (China Tower Corporation Limited)

JIANG Yanji (China Tower Corporation Limited)

3、Drafting Groups

Leader: XU Yanhua (China Association of Automobile Manufacturers)

Deputy Group Leader: WANG Zidong（China Power Battery Industry Innovation Alliance）

（1）DRAFTING LEADERS OF EACH CHAPTER:

KANG Huaping (SAIC Motor Corporation Limited)

PU Jinhuan (SAIC Motor Corporation Limited)

WANG Deping (FAW Group Co., Ltd.)

ZHOU Anjian (Chongqing Changan Automobile Co., Ltd.)

YANG Zifa (Beijing Electric Vehicle Co.Ltd.)

LI Gaopeng (Zhengzhou Yutong Bus Co., Ltd.)

LIU Jihong (Beijing Auv Bus Beiqi Foton Motor Co., Ltd.)

DING Zhaoshi (Tianjin Lishen Battery Co., Ltd.)

MENG Xiangfeng (Contemporary Amperex Technology Limited)

GUO Xiaodong (Neusoft Reach Auto Technology Co., Ltd.)

ZHANG Wenyu (Beijing Pride Power Technology Co., Ltd.)

LAO Li (Octillion Energy Holdings Inc.)

HONG Munan (Chongqing Changan New Energy Automobile Co., Ltd.)

DENG Xiaojia (NIO Inc.)

SHAO Zhehai (Potevio New Energy Co., Ltd.)

CHEN Xiaonan (State Grid Electric Vehicle Service Co., Ltd.)

JU Qiang (Qingdao Teld New Energy Co., Ltd.)

LI Desheng (Wanbang New Energy Investment Group Co., Ltd.)

GAO Jian (China Tower Corporation Limited)

ZHENG Yun (Zhangjiagang National Remanufacturing Industry Institute)

CAI Wei (Automotive Electronic Drive Control and System Integration Engineering Research Center of Ministry of Education)

(2) MAIN PARTICIPATING ORGANIZATIONS:

COMPLETE CAR COMPANIES

SAIC Motor Corporation Limited

FAW Group Co., Ltd.

Chongqing Changan Automobile Co., Ltd.

Dongfeng Motor Corporation

Beijing Electric Vehicle Co.Ltd.

GAC GROUP

BYD Automobile Co.Ltd.

Zhejiang Geely Holdings Inc.

Beiqi Foton Automobile Co., Ltd.

JAC NEVs Technology Co., Ltd.

Anhui Jianghuai Automobile Group Corp., Ltd.

NIO Inc.

China National Heavy Duty Truck Group Co., Ltd.

Zhengzhou Yutong Bus Co., Ltd.

Beijing Auv Bus Beiqi Foton Motor Co., Ltd.

Xiamen King Long United Automotive Industry Co., Ltd.

Suzhou King Long United Automotive Industry Co., Ltd.

Zhongtong Bus Holding Co., Ltd.

Weltmeister Motor Technology Co.,Ltd.

Chongqing Changan New Energy Automobile Co., Ltd.

Xiaopeng Motors

SAIC MAXUS Co., Ltd.

POWER BATTERY COMPANIES

Tianjin Lishen Battery Co., Ltd.

Contemporary Amperex Technology Limited

Gotion Inc.

China Automative Battery Research Institute Co., Ltd.

Shenzhen BYD Lithium Battery Co., Ltd.

Tianjin Ejeeve Power Industry Co., Ltd.

Huzhou Microvast Power Co., Ltd.

Jiangsu Tafel New Energy Technology Limited

Neusoft Reach Auto Technology Co., Ltd.

Shanghai Jieneng Automobile Technology Co., Ltd.

Beijing Pride Power Technology Co., Ltd.

Hefei Octillion Energy Technology Co., Ltd.

Shenzhen BAK Power Battery Co., Ltd.

Luoyang Aviation Industry Lithium Technology Co., Ltd.

CHARGING FACILITIES & OPERATING COMPANIES

Potevio New Energy Co., Ltd.

State Grid Electric Vehicle Service Co., Ltd.

Qingdao Teld New Energy Co., Ltd.

Wanbang New Energy Investment Group Co., Ltd.

Beijing Electric Vehicle Co.Ltd.

Xi'an TGOOD Intelligent Charging Technology Co.,Ltd.

Avic Jonhon Optronic Technology Co.Ltd.

POWER BATTERY RECYCLING COMPANIES

China Tower Corporation Limited

Zhangjiagang National Remanufacturing Industry Institute

Zhangjiagang Tsingyan Test Technology Co.Ltd.

Zhejiang Huayou Recycling Technology Co.Ltd.

Jiangmen Ronda Group

Dongguan FB Tech New Energy Co.Ltd.

Jiangsu Rich Power Technology Co.Ltd.

Shenzhen Broad New Energy Technology Co., Ltd.

FUEL CELL SYSTEM COMPANIES

Shanghai Re-Fire Technology Co.,Ltd.

Guangdong Sino Synergy Power Co., Ltd.

Foshan Yunfu Hydrogen Energy Standardization Innovation R&D Center

VEHICLE HYDROGEN STORAGE & HYDROGEN SUPPLY COMPANIES

Zhangjiagang Furui Hydrogen Power Equipment Co., Ltd.

Zhangjiagang Qingyun New Energy Research Institute Co., Ltd.

VEHICLE OPERATING COMPANY

Shanghai Hydrogen Vehicles Operating Co., Ltd.

Motor System And Electric Drive Assembly Enterprise

Jingjin Electric Technology Co., Ltd.

Shanghai Edrive Co., Ltd.

Corun Hybrid Power Technology Co., Ltd.

Hefei JEE Power system Co., Ltd.

CRRC Electric Vehicle Co., Ltd.

Huawei Technologies Co., Ltd.

Shanghai Branch, Zhejiang Founder Motor Co., Ltd.

Xiamen Faratronic Co., Ltd.

UNIVERSITITES & INSTITUTES

China North Vehicles Research Institute

China Electric Power Research Institute

Beijing Jiaotong University

Tongji University

Shanghai University

Harbin University of Science and Technology

Institute of Electrical Engineering, Chinese Academy of Sciences

Zhejiang University

China Automotive Technology and Research Center Co., LTd.

China Automotive Engineering Research Institute Co., Ltd.

(3) MAIN PARTISPATING TALENTS:

ZHANG Peng, JIA Hongtao, LV Zhiwei, LIN Fu, CHEN Dong, FU Hong, SONG Fang, LONG Jianqi, LI Zunjie, HUANG Min, LIU Shuang, SUN Quan, WU Gang, ZHANG Guoxing, LI Boyu, XIONG Jinfeng, LIU Baokun, FAN Zhixian, KUANG Yong, WANG Hongjun, SU Liang, LIU Chaohui, WEI Changhe, WEI Wenbo, SONG Guangji, LIU Heping, DU Weibin, ZHAO Yonggang, SHI Hong, ZHANG Zheng, CUI Yi, JIANG Wenfeng, GAO Xiulin, FANG Weifeng, WANG Zhenxing, SUN Long, WANG Shuaifeng, LI Wenbin, JIN Huifen, JIANG Bin, ZHANG Shuo, ZHAO Xinghua, SU Qianye, TIAN Xiujun, ZHANG Youqun, YANG Yong, LIN Zhihong, LIANG Jian, YI Binxi, LIU Deyun, ZHU Suran, YANG Zhenpeng, LU Zhipei, ZHU Yulong, WANG Shuyang, JIANG Guanghui, QIU Zhipeng, YIN Jinsong, BAO Wei, ZHENG Bowen, TU Qiang, LIU Xixin, LI Gang, HAN Jingke, LV Chao, WANG Yan, TIAN Cuijun, TIAN Wei, DENG Chi, RU Yonggang, ZHOU Qiang, FANG Ming, WU Shangjie, SANG Lin, ZHANG Xuan, LIU Wenzhen, BAI Ou, ZHANG Caiping, GU Wenwu, CHEN Baojiang, HU Jinyong, ZHOU Xiarong, SHANG Guoping, LIU Mulin, ZENG Tao, WANG Chengye, WANG Qing, WANG Haibin, WEN Yandong, HAO Bin, GU Dongping, DAI Zhonghua, CAI Chunxia, PEI Zhengqiang, LIANG Yafei, WANG Jian, SUN Chunzhe, KONG Qingbo, ZHANG Zhouyun, HUANG Bingjian, LIU Jihong, ZHANG Qinglu, XU Qiang, ZHANG Liangliang, LIU Chuankang, LING Xinliang, Cai Wei, ZHOU Dongsheng, WU Lixun, YAN Xiqiang, WANG Duolin, BU Qingyuan, ZHAO Jishi, CHEN Wenfeng, MAI Jiaming, MA Tiancai, ZHOU Wei, YANG Daijun, LIU Andong, ZHANG Yi, WANG Xuesheng, YAN Yan, WANG Meiyan, ZHU Ling, ZHU Ziyan.

(4) OVERALL COORDINATORS & MODERATORS:

WANG Yao, ZOU Peng, WEI Youliang, MA Xiaoli, GAO Lei, LIU Yan, ZHANG Fan, LI

Kang, QIN Xueliang

Contact:

China Association of Automobile Manufacturers, ZOU Peng, +86 18610920317

China Industry Technology Innovation Strategic Alliance for Electric Vehicle, MA Xiaoli, +86 13683507578

China Electric Vehicle Charging Infrastructure Promotion Alliance, ZHANG Fan, +86 13810280098