Electric Vehicle Safety Guide

China Association of Automobile Manufacturers (CAAM)

China Automotive Power Battery Industry Innovation Alliance

China Electric Vehicle Charging Infrastructure Promotion Alliance

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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	$0<U\leq60$	$0<U\leq30$
B	$60<U\leq1500$	$30<U\leq1000$

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.

1.1.3 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, 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 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 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.

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, 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.

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.

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 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, 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

(2) 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, 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, 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 contactor 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, evaluate the safety performance of the frontal collision high-voltage power of new energy. The test setting shall be in accordance with GB 20071, and the regulations of GB/T 31498 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, evaluate the safety performance of the frontal collision high-voltage power of new energy. The test setting shall be in accordance with GB 20072, and the regulations of GB/T 31498 Item 4 Technical requirements shall be met.

(Note: GB/T 31498 has not yet cited GB 20072, 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

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, 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.

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.

1.5 Vehicle EMC safety

The EMC radiation intensity regulations of the vehicle and 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, GB 34660 and GB/T 18387 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, 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 (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.

(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 output the motor temperature alarm or the motor temperature over-high signal to the vehicle controller through the vehicle CAN communication. The driver shall be prompted by the instrument panel of the vehicle controller.

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 output the controller temperature alarm or the controller temperature over-high signal to the vehicle controller through the vehicle CAN communication. The driver shall be prompted by the instrument panel of the vehicle controller.

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 in the vehicle shall be insulated and monitored. The air conditioning PTC shall have fault diagnosis function and 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 swappingdesign 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 have a floating follower mechanism, which can automatically follow the displacement change under the frequent vibration and creep caused by the vehicle travel to ensure 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.

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.

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	Generator
6	Steering motor
7	Air compressor
8	DC/DC converter (including isolated DCDC)
9	Controller (drive motor controller, generator controller, steering motor controller, 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 M_2 and M_3 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.

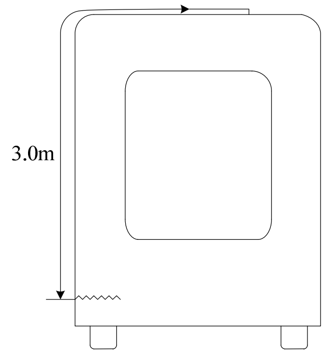


Figure 2-2 Shortest Path Measurement Schematic

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

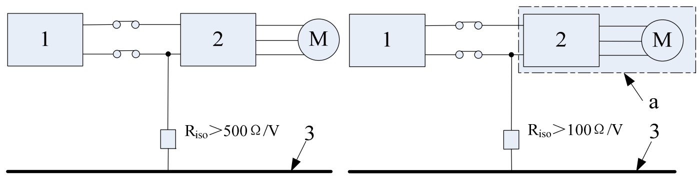
At the maximum working voltage, the minimum value of the DC circuit insulation resistance shall be at least greater than 100 Ω/V, and the AC circuit shall be at least greater than 500 Ω/V.

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.

(2) 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.

(3) 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.

2.4.3 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

Different fault handling mechanisms are developed for different fault levels.

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

Different fault display mechanisms are developed for different fault levels.

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 Requirements for disturbance and immunity caused by current harmonics and voltage fluctuation flicker along the power line during the vehicle's conduction charging process of the access grid

The current harmonic emission along the power line during the conduction charging process of the access grid shall meet the requirements in GB/T17625.8-2015, and the voltage fluctuation flicker shall meet the requirements in GB/T17625.7-2013.

2.7.4 Requirements for electromagnetic disturbance during vehicle induction charging

Radiation emission and conducted emission during induction charging shall comply with GB 34660, GB/T 18387 and GB/T 14023.

2.7.5 Safety requirements for vehicle occupants exposed to vehicle electromagnetic environment

When the vehicle occupants are exposed to vehicle electromagnetic environment, relevant requirements of GB 8702 shall be met.

2.7.6 Requirements for high and low-voltage harness design and layout

2.7.6.1 Requirements for high-voltage cable shielding

(1) The connecting bus between different B-level circuit units of the vehicle shall use at least a single layer of shielding cable and perform good multi-point grounding of the shielding layer; Other cables with special requirements, such as interconnection lines in the same unit, may not use shielding lines;

(2) Requirements for shielding layer: The shielding layer shall be woven with bare copper wire or tinned copper wire. The woven density single layer shall be not less than 90% or the multilayer shall be greater than 75%. The outer (or inner) of the woven shielding layer is allowed to be added with aluminum-plastic composite film tape. The overlap ratio shall not be less than 20%, and the aluminum-plastic composite film tape shall be in contact with and conductive with the woven layer whether it is inside or outside;

(3) The shielding layer needs to be well connected to the compression spring of the

shielding head at the inlet and outlet of the high-voltage components.

Requirements for vehicle routing and layout

(1) The high-voltage harness shall be connected to the low voltage data harness, and the signal transmission harness shall be kept away from the distance of at least 200 mm;

(2) The high-voltage AC harness cannot be bundled with the DC low voltage harness or the DC high-voltage harness, and the DC low voltage harness cannot be bundled with the DC high-voltage harness;

(3) The wiring of the high-voltage harness is not recommended to be looped;

(4) The reset signal and the low-voltage valid signal, the ground and the routing of the enable signal shall be kept at least 200 mm away from the strong interference source and the high-voltage harness.

Requirements for grounding

(1) The grounding system of the high-voltage components and the grounding system of the low-voltage components shall be separately set, and the same grounding point shall not be shared. The high-voltage grounding shall adopt the grounding system of the high-voltage components;

(2) Ensure that different grounding point resistance values in the grounding system of the high-voltage components are less than 0.1Ω;

(3) Routing shortest principle: Try to make the grounding point close to the battery installation side to ensure that the battery cathode is as equipotential as possible and reduce the influence of the wire loop on the grounding potential;

(4) Important sensitive devices need to be separately grounded to avoid interference, such as radio, EBS, ABS, vehicle controllers.

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 CO_2 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 power steering pumps, electric blast pumps, high-voltage control cabinets, etc.
2	Check	Check the new energy high-voltage compartment	1) The door lock is valid and there is no dust or water leakage in the compartment. 2) No copper is exposed in the high-voltage line terminals, no loose or worn 3) Power battery box and each terminal are fixed reliably 4) The high-voltage compartment ventilation fan works normally and the compartment temperature is normal.
		Check motor water cooling system	1) Check the water level of the water tank, add when not enough 2) Check the pipeline for no bending, folding or water leakage
		Power battery	1) The box is fixed reliably, and there is no obvious dust, rust or deformation on the surface of the box 2) Dry and clean the battery compartment 3) The high and low voltage lines of each box are connected normally and fixed reliably without any looseness.
		Check drive motor, high-voltage generator and steering assist motor	1) The motor is firmly fixed 2) The motor has no abnormal noise and no fault 3) Check whether the steering pump and blast pump 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	Inspection items		Meet the operation requirements
2	High-voltage controller	View and fasten the controller box	(1) Controller is fixed firmly and no loose (2) Dust removal. Keep dry and clean (3) 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	(1) Check wiring conditions (2) Visual inspection and cleaning (3) Motor controller shell grounding detection (4) Check the low-voltage plug-in interface (5) Motor cooling water pipe	(1) The wiring is firm and not loose (2) Dust removal, keep dry and clean, no aging, deformation or leakage of cooling water pipes (3) The resistance between the motor controller shell and the vehicle body shall be less than 0.1Ω (4) Low-voltage plug-in interface is firmly connected, no terminal is loose (5) Water pipes and joints are reliable and without damage
4	DC/DC, DC/AC and all-in-one controller	(1) Visual inspection of each wiring pile (2) Visual inspection and cleaning	(1) Fixed and reliable, dry and clean surface (2) Each wiring pile head is not loose, not allowed to be bare
5	Power battery pack	(1) Inspect the battery box (2) Visual inspection of fixing and each terminal pile (3) Battery voltage and temperature (4) Insulation testing (5) Check the single cell dropout voltage	(1) Check the bottom of the battery box for abnormalities such as electrolyte and water (2) Each wiring pile head is not allowed to be exposed. (3) The voltage dropout voltage of the single cell shall not exceed the standard, and the temperature does not exceed the requirements of the specification. (4) The total anode and cathode insulation resistance to ground of the battery shall be greater than the standard value. (5) The voltage dropout voltage of the single cell shall not exceed the standard
6	Drive motor High-voltage generator	(1) Check U, V and W terminal wiring and shielding layer grounding (2) Visual inspection of motor input line and wiring box	(1) The U, V and W terminal wiring are firm without looseness. Check whether the motor casing grounding resistance is less than 0.1Ω (2) The insulation of the input wire is not damaged, and the wiring box is intact.

S/N	Inspection items	Operation contents	Technical requirements
		(3) Check the dust on the surface of the cleaning drive motor (4) Check the low-voltage plug-in interface (5) Check motor operation	(3) 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 (4) The low-voltage plug-in interface is not damaged, the resolver wire connection and the high-temperature sensor line are fixed and reliable, effective (5) Test run, no abnormal noise when the motor works
7	Electric blast pump assembly	(1) Visual inspection of the blast pump power line and the grounding line plug (2) Check the blast pumping oil level (3) Check and clean blast pump air filter motor insulation testing	(1) Blast pump assembly power line and grounding line are firm, no loose (2) Normal oil level (3) Cleaning blast pump air filter (4) Motor three-phase line to ground insulation resistance shall be greater than 2MΩ
8	Electric air conditioner	(1) Check air conditioning unit (2) 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	(1) Pipeline (2) Water pump (3) 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	(1) High-voltage control cabinet (2) Drive motor, high-voltage generator, booster pump high-voltage input line	(1) Resistance between high-voltage control cabinet high-voltage line and ground is higher than 2MΩ (2) 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 insulation between the power terminal and the outer casing, the power terminal and the signal terminal shall be no less than 1MΩ.

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.

2.10.2.2 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 LiFePO4 batteries, LiMn2O4batteries, $LiCoO_2$ 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 $LiCoO_2$, $LiMn_2O_4$, $LiFePO_4$,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 $liFePO_4$ and $LiMn_2O_4$ anode material. For passenger cars, it is recommended to use $LiFePO_4$,$LiMn_2O_4$ 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. It is necessary to ensure complete coverage of anode and cathode on the separator in extreme cases of environmental conditions, such as high temperature and high humidity.

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 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.

3.1.4.2.1 Overdischarge

The battery cell is over-discharged. During the use of the battery, the battery may be over-discharged due to the out of control of the BMS, the long-term running of the vehicle in the low SOC state of the battery, and the excessive power consumption of the BMS.

Overdischarge of the battery may cause the cathode current collector to dissolve and the anode to precipitate copper, which may lead to safety problems such as internal short circuit of the battery.

For testing method, please refer to GB/T 31485. The fully charged battery shall discharged at 1 C for 90 min and be observed for 1h to make sure it is free from fire outbreaks and explosion risks.

3.1.4.2.2 Overcharge

The battery may be overcharged due to faults such as instability in charging piles, BMS monitoring and grid.

When the battery is overcharged, the structure of the anode material is unstable due to excessive lithium ion elution, and metallic lithium is precipitated on the surface of the cathode. As the overcharge voltage increases, the lithium dendrites on the surface of the cathode will continue to grow, and a short circuit may occur inside the battery, causing safely failure to the battery cell.

Single cell overcharge evaluation:

(1) For testing method, please refer to GB/T 31485.

Charge the fully charged battery at 1C rate to 1.5 times manufacturer-specified termination voltage or 200% SOC, stop charging, and observe it for 1h to ensure that it is free from fire outbreaks and explosion risks.

(2) For testing method, please refer to the GB *Safety Requirements for Power Battery for Electric Vehicles* to be promulgated and implemented. Charge the battery at manufacturer-specified rate no less than 1I3 electric constant current to 1.1 times manufacturer-specified termination voltage or 115% SOC, stop charging, and observe it for 1h to ensure that the battery is free from fire outbreaks and explosion risks; s

It is recommended to try to use the method (1) for testing.

3.1.4.2.3 Short circuit

The battery will be short-circuited due to the short circuit of the anode and cathode during use; the power battery cell have a large capacity and a small internal resistance. When the battery is short-circuited, the current will become large, causing the battery to release heat sharply that safely failure to the battery cell.

For testing method of battery short circuit, please refer to GB/T 31485.

(1) Put the anode and cathode of the fully charged battery under external short-circuit for 10min with external line resistance less than 5 mΩ. Observe it for 1h to ensure the battery is free from fire outbreaks and explosion risks;

3.1.4.2.4 Extrusion

The extrusion testing is mainly to simulate the case of mechanical abuse or traffic accidents encountered by the battery. When the battery is deformed by certain external pressure, the battery can be safe, not igniting or exploding.

For testing method, refer to GB/T 31485.

(1) Extrude the fully charged battery by a semi-cylinder with a radius of 75 mm at a speed of 5 mm/s to a voltage of 0 or a deformation of 30% with a force of 100KN. Observe it for 1h to ensure the battery is free from fire outbreaks and explosion risks;

3.1.4.2.5 Thermal stability

The thermal stability testing mainly simulates the application of the battery in a harsh environment such as high temperature. No safety problem is allowed.

For testing method, please refer to GB/T 31485.

Place the fully charged battery in a high-temperature explosion-proof box. Raise the temperature inside the box from the test ambient temperature to 130℃±2℃ at a rate of 5±2℃/min, and stop heating after maintaining this temperature for 30 min. Observe it for 1h to ensure the battery is free from fire outbreaks and explosion risks;

3.1.4.2.6 Temperature cycle

The temperature cycle mainly simulates the application of the battery in the harsh environment where high and low temperature alternate repeatedly. No safety problem is allowed.

For testing method, please refer to GB/T 31485.

Place the fully charged battery under an environment where the temperature cycles between -40℃ and + 85℃ as shown in the following figure with 5 cycles, each lasting 480 minutes. Observe it for 1 h to ensure the battery does not ignite, explode, and leak.

3.1.4.2.7 Battery cell elastic modulus testing

A prismatic or pouch lithium-ion power battery will exhibit swelling deformation during use. Especially when being reused, its deformation and displacement will become increasingly serious, which has a great influence on the design of the subsequent module and pack. Therefore, it is necessary to test the elastic modulus of the single cells BOL, MOL and EOL under different SOC states, as well as the expansibility throughout the life cycle of the battery, in an effort to provide more reliability design parameters for the subsequent module structure design.

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 has 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	

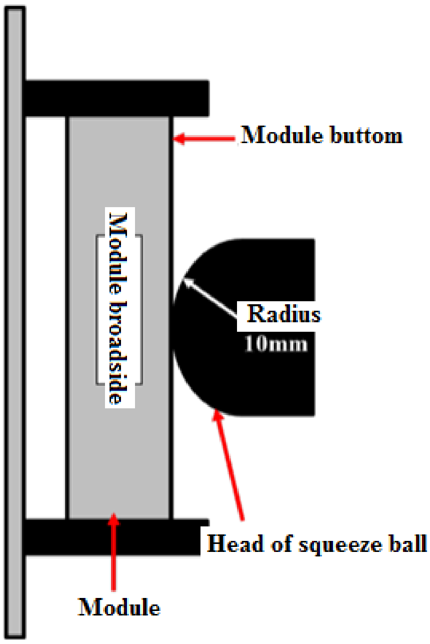


Figure 1 Module fixed installation

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.

(2) 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.

(3) 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.

(4) 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.

(5) 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.

(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.

4.1.2.2 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 torlerant 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 system from overcharging

• Prevent the battery system from being recharged after being overdischarged

• Prevent battery system from over-temperature

• Prevent battery system from overcurrent

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

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.

(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. When a single battery is required for thermal runaway, the system shall be designed to prevent thermal runaway incidents from spreading 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.

4.2.3 Electrical 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.

4.4.3.2.3 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, drop, rollover, simulated collision, extrusion, temperature shock, tepidity cycle, seawater immersion, external burning, salt fog, high altitude, over-temperature protection, short-circuit protection, overcharge protection and overdischarge protection, according to the requirements specified in GB 31467.3-2015

(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.

(4) 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.

(5) 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.

(6) 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. 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.

5.1 Charging safety mechanism

5.1.1 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.

5.1.2 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.

5.1.3 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.

5.1.4 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.

5.1.5 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.

5.2 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.

5.2.1 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.

5.2.2 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.

5.2.2.1 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.

5.2.2.2 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.

5.2.2.3 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.

5.2.2.4 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.

5.2.2.5 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.

5.2.3 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:

Requirements for touch current safety: Personnel touching current, voltage requirement, and residual current shall meet requirements for safety;

Requirements for grounding safety: Meeting relevant standards.

Requirements for electrical clearance and creep distance: Meeting relevant standards.

Requirements for electromagnetic radiation (electromagnetic exposure) safety: Damage to people and equipment and conducted interference shall meet relevant standards.

Current surge, voltage fluctuation: Meeting relevant standards.

In terms of 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.

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.

(1) 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.

5.2.4 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.

5.2.5 Charging connection testing

Charging connection implements requirements for interoperability, and shall comply with 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.

5.2.6 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.

5.2.7 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.

5.2.8 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.

5.3 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.

5.3.1 Ensuring the implementation of standard safety technical requirements for charging equipment.

5.3.1.1 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.

5.3.2 Electrical safety and protection

5.3.2.1 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. $100\Omega/V < R_t \leq 500\Omega/V$, 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.

(2) Earth leakage protection

Residual current protector shall meet the requirements specified in 3.6.7 and 10.3 of GB/T 18487.1-2015.

(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 33002-2010 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 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.

(8) Precharge function

Off-board charger shall have the precharge function to prevent excessive surge current generated during the process of starting charging. 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. 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 33001-2018.

(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 $R > 500\ \Omega/V$, 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.

(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.

5.3.2.2 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.

5.3.2.3 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.

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.

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.

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.

Emergency fault protection: It is recommended to 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.

5.3.2.4 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.

5.4 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.

5.4.1 Charge control and interoperability

The charging process shall meet the requirements for charging sequence of GB/T18487.1 and GB/T27930. 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.

The charging equipment shall have the dual protection function for the battery. 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), the charging equipment shall disconnect K1K2 within 1s and send an alarm prompt.

The short-circuit peak current of the charger does not exceed 10KA, and the short-circuit capacity shall not exceed 500000A2s. When an output short circuit occurs in the charging process, the charger shall stop charging within 1s.

5.4.2 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.

5.4.3 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.

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
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
		Battery cell voltage is too high
		Battery temperature is over high
		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.

5.5 Charging system and equipment function design

5.5.1 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.

(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) 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;

(6) 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 18487.1-2015.

(7) 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.

(8) 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.

(9) 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.

(10) 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.

(11) 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;

(12) 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.

(13) 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.

(14) 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.

(15) 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.

(16) 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.

(17) 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.

(18) 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.

(19) 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.

5.5.2 Requirements for interoperability

The charging equipment shall conduct interoperability locking device inspection, charging readiness testing, charge phase testing, charge connection control sequence testing, etc. according to the requirements of GB 34657.

Charging interoperability refers to the ability of power supply equipment and electric vehicles in the same or different models and versions to achieve charging interconnection through information exchange and process control. The charging process is mainly divided into the connection confirmation phase, self-test phase (DC charging), charging readiness phase, charging phase, and normal charging end phase.

5.5.2.1 DC charging process and communication interoperability

5.5.2.1.1 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.

5.5.2.1.2 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 after completing the self-test. 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.

5.5.2.1.3 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 $>\pm5\%$ 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.

5.5.2.1.4 Requirements for interoperability 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.

5.5.2.1.5 Interoperability 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.

5.5.2.1.6 Requirements for interoperability 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.

5.5.2.1.7 Interoperability 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).

5.5.2.2 AC charging process and communication interoperability

5.5.2.2.1 Requirements for interoperability 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.

5.5.2.2.2 Requirements for interoperability 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.

5.5.2.2.3 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.

5.5.2.2.4 Requirements for interoperability 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.

5.5.2.2.5 Requirements for interoperability 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.

5.5.2.2.6 Requirements for interoperability 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.

5.6 Charging interface safety

5.6.1 Requirements for charging interface safety

5.6.1.1 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.

5.6.1.2 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.

5.6.1.3 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.

5.6.1.4 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.

5.6.1.5 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.

5.6.2 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.

5.7 Charging equipment test and safety evaluation

Based on the requirements of GB 18487.1-2015, GB 20234.1-2015, GB 20234.2-2015, GB 20234.3-2015 and GB 34657-2017, the charging safety test methods and assessment methods are established and expanded.

5.8 Manufacture of charging equipment

Implement the quality control of charging equipment and facilities in the production process, implement certification of suppliers of raw materials, strictly control import quality, and carry out product form test in accordance with rules for safety items and delivery inspection of handover products to ensure the consistency of products.

5.9 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.

5.9. 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.

5.9.1.2 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* (GB50229-2006) and *Code for Fire Protection in Architectural Design* (GB50016-2014);

(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.

5.9.2 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.

5.9.3 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.

5.9.4 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.

5.9.5 Subsidiary building

5.9.5.1 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.

5.9.5.2 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).

5.9.6 Clear safety identification

Charging facilities shall be equipped with obvious safety signs to ensure smooth and safe operation process.

5.9.7 Weak current and monitoring system

5.9.7.1 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.

5.9.7.2 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.

5.9.7.3 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.

5.9.7.4 Safety and protection monitoring

5.9.7.4.1 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.

5.9.7.4.2 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.

5.9.8 Fire safety

5.9.8.1 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.

5.9.8.2 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 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.

5.9.8.3 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.

5.9.8.4 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.

5.9.8.5 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) 2) 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.

5.9.8.6 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.

5.9.8.7 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.

5.9.9 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.

5.9.9.1 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.

5.9.9.2 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.

5.9.9.3 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.

5.10. Safety requirements for operation and maintenance of charging facilities

5.10.1 Safety risk identification and preventive measures

5.10.1.1 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.

5.10.1.2 Safety protective measures

5.10.1.2.1 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.

5.10.1.2.2 Information safety risk prevention and control

5.10.1.2.2.1 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.

5.10.1.2.2.2 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

5.10.1.2.2.3 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.

5.10.2 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.

5.10.3 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.

5.10.4 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.

5.10.5 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.

5.10.6 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.

5.10.7 Safety management of charging facility operation

5.10.7.1 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.

5.10.7.2 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.

5.10.7.3 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.

5.10.7.4 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.

5.11 Information safety

5.11.1 Information safety guarantee of charging operation

1. The general requirement of information safety protection is for divided regions, secure access, secure and credible, dynamic perception, lean management and comprehensive protection.

2. Information safety protection is divided into 11 aspects

(1) Technical requirements: According to the requirements of different levels of safety protection, it is necessary to carry out technical protection from the aspects of physical safety, terminal safety, application safety, network safety, host safety and data safety;

(2) Requirements for management: According to the requirements of different levels of safety protection, it is necessary to manage from the aspects of safety management system, safety management organization, personnel safety management, system construction management, system operation and maintenance management, and network safety management.

5.11.2 Safety software selection and management

(1) The safety software used in charging infrastructure shall be authorized and evaluated by the production and operation enterprises of charging infrastructure, and the safety software with corresponding safety measures shall be selected for charging infrastructure based on risk assessment;

(2) Establish anti-virus and malware intrusion management mechanism, and take safety precautions such as virus detection and killing for equipment temporarily accessed by charging infrastructure;

(3) Mobile terminal APP adopts safety software with safety protection measures, and related safety software needs to be authorized and evaluated by charging infrastructure production and operation enterprises;

(4) Operating platform safety software needs to be authorized and evaluated by charging infrastructure operation enterprises. It has the safety capability to support charging infrastructure and requirements for mobile terminal safety protection, and forms an integrated defense system.

5.11.3 Configuration and patch management

(1) Establish and maintain the configuration list of charging infrastructure system, keep access logs of boundary equipment and key charging business logs for no less than 6 months, and audit configuration regularly;

(2) Make change plans for major configuration changes and make impact analysis, carry out strict safety testing before implementation of configuration changes;

(3) Pay close attention to major safety loopholes in charging infrastructure and take timely patch and upgrade measures. Before patches are installed or upgraded, strict safety assessment and testing verification are required for patches or upgrades;

(4) In order to upgrade remotely, the upgrade process needs to be carried out under the condition of system safety, with the ability of communication safety, anomaly monitoring and response, confirmed by users, and log information shall be completely recorded during the upgrade process.

5.11.4 Boundary safety protection

(1) Separating the development, testing and production environment of isolating charging infrastructure;

(2) In the design of charging infrastructure architecture, network segmentation and isolation technology are used. Different network segments are subject to boundary control and data and files of internal control network of charging infrastructure shall be subject to safety control and safety monitoring;

(3) Charging infrastructure accesses the external communication in the secure mode, divides services, and accesses the network through different secure communication subsystems;

(4) Operating platform shall have safety functions such as firewall and intrusion detection.

5.11.5 Physical and environmental safety

(1) Configure all access points of charging infrastructure and restrict access;

(2) Remove unnecessary interfaces on the host.

5.11.6 Identity authentication

(1) Identity authentication management is adopted in the process of charging infrastructure start-up login, mobile terminal login, operation platform access, etc. In key business scenarios, multi-factor authentication is adopted;

(2) User registration real-name system;

(3) Enhance the login accounts and passwords of charging infrastructure, mobile terminals and access points, force the change of default passwords, avoid weak passwords, and update passwords regularly;

(4) Identity authentication mechanism is adopted in data communication between charging infrastructure systems.

5.11.7 Remote access safety

(1) The charging infrastructure needs to strictly control remote access ports and close unnecessary ports;

(2) The key business scenarios of remote access need to be strengthened by safety measures to control the access time limit, and adopt the mechanisms of identity authentication, data safety transmission, access control, etc.;

(3) It is necessary to retain access logs for charging infrastructure system and conduct safety audit for operating procedures.

5.11.8 Safety monitoring and emergency pre-plan drilling

(1) Establish the safety monitoring system in charging infrastructure to detect, report and deal with network attacks or abnormal behavior in time;

(2) Charging infrastructure shall have the functions of package monitoring and data monitoring to restrict illegal operation;

(3) Formulate early warning of safety incident response. When the charging infrastructure is abnormal or fault due to safety threats, it is necessary to take emergency protective measures immediately to prevent the expansion of the situation and report it to the local authorities step by step, and pay attention to protecting the site for investigation and evidence collection;

(4) It is necessary to drill the emergency response plan of charging infrastructure system regularly, and revise the emergency response plan if necessary.

5.11.9 Asset safety

(1) Establish a list of assets for charging infrastructure, clarify the person responsible for the assets, and the rules for the use and disposal of the assets;

(2) Redundant configuration of key equipment and components.

5.11.10 Data safety

(1) Collect, transmit and store data in charging infrastructure system, and periodically carry out risk assessment. Key business data and user information shall be stored and transmitted with safety mechanism, and access control strategy shall be adopted in the process of use;

(2) It is necessary to regularly copy key business data, payment and settlement data;

(3) The acquisition, storage, transmission and use of user information must be clearly authorized by the user.

5.11.11 Supply chain management

(1) When choosing suppliers of charging infrastructure planning, design, construction, operation, maintenance or assessment, products and services, it is necessary to give priority to products that pass safety assessment, enterprises and institutions with safety service experience, and require suppliers to do a good job of confidentiality to prevent the leakage of sensitive information;

(2) It is necessary to carry out safety assessment before the charging infrastructure system is put into operation or when major changes occur, and carry out regular safety assessment for the charging infrastructure in operation.

5.11.12 Responsibilities mechanism

(1) Establish charging infrastructure safety management mechanism and information safety coordination group, define the head of information safety management, implement the safety responsibility system, and deploy safety protection measures;

(2) According to the requirements of different levels of safety protection, it is necessary

to manage from the aspects of safety management system, safety management organization, personnel safety management, system construction management, system operation and maintenance management, and network safety management;

(3) Establish the assessment system of network safety protection for charging infrastructure, adopt self-assessment as the main method and check and assessment as the supplementary method, and establish the information safety management system for charging infrastructure network.

5.12 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.

5.12.1 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).

5.12.2 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.

5.12.3 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.

5.12.4 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.

5.12.6 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.

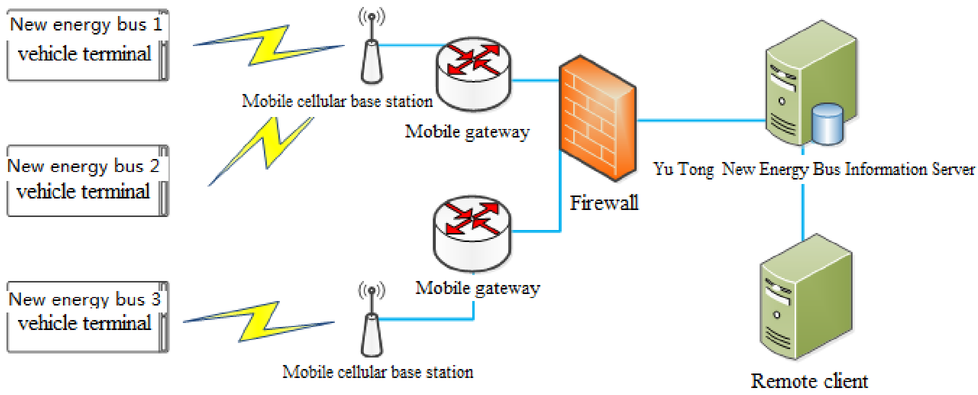
6. Data monitoring and management

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.

6.1 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.



6.1.1 Data collection

Data collection parameters range includes but is not limited to GB/T 32960.3 (see Table 6-1). The collection frequency of real-time data shall not be less than 1/s.

Table 6-1

Drive motor data		**Vehicle location**	**Extreme data**		**Alert data**	
Number of drive motor	Speed of drive motor	Location status	Maximum voltage battery subsystem number	Maximum temperature subsystem number	Maximum alarm level	List of drive motor fault codes
List of drive motor assembly information	Drive motor torque		Maximum voltage battery cell code	Maximum temperature probe unit code	General alarm sign	Number of engine faults N3
No. of drive motor	Drive motor temperature	Longitude	Battery cell maximum voltage	Maximum temperature value	Total number of faults of rechargeable energy storage devices N1	List of engine fault codes
			Minimum voltage battery subsystem number	Minimum temperature subsystem number		
Drive motor status	Input power of drive motor controller	Latitude	Minimum voltage battery cell code	Minimum temperature probe subsystem code	List of fault codes for rechargeable energy storage devices	Total number of other faults N4
Drive motor controller temperature	DC bus current of drive motor controller		Minimum battery cell voltage	Minimum temperature	Number of drive motor faults N2	List of other fault codes

Table 6-2

<table>
<tr><th>Engine data</th><th colspan="2">Data of whole vehicle</th><th>Cell voltage</th><th>Cell temperature</th></tr>
<tr><td rowspan="2">Engine state</td><td>Vehicle state</td><td>Total voltage</td><td>Number of rechargeable energy storage subsystems</td><td rowspan="2">Number of rechargeable energy storage subsystems</td></tr>
<tr><td>Charging status</td><td>Total current</td><td>Rechargeable energy storage subsystem number</td></tr>
<tr><td rowspan="2">Crankshaft speed</td><td rowspan="2">Mode of operation</td><td>SOC</td><td>Rechargeable energy storage device voltage</td><td rowspan="2">Rechargeable energy storage device subsystem number</td></tr>
<tr><td>DC-DC state</td><td>Rechargeable energy storage device current</td></tr>
<tr><td rowspan="2">specific fuel consumption</td><td rowspan="2">Vehicle speed</td><td rowspan="2">Gear</td><td>Total number of single cell</td><td rowspan="2">Number of temperature probes for rechargeable energy storage</td></tr>
<tr><td>Starting battery number of frame</td></tr>
<tr><td rowspan="3">/</td><td rowspan="2">Accumulated mileage</td><td rowspan="2">Insulation resistance</td><td>Total number of single cell of frame</td><td rowspan="3">Temperature values detected by temperature probes in the rechargeable energy storage subsystem</td></tr>
<tr><td>Voltage of single cell</td></tr>
<tr><td>Accelerated pedal travel value</td><td>Brake pedal status</td><td>Voltage of single cell N</td></tr>
</table>

6.1.2 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.

6.1.3 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.

6.1.4 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.

6.1.5 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.

6.2 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.

6.3 Vehicle information security

6.3.1 Vehicle hardware information security

The information security objectives 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.

6.3.2 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.

6.3.3 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.

6.4 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.

6.4.1 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.

6.4.2 Information data is storaged 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).

6.4.3 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.

6.5 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.

7. Repair and maintenance

7.1 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.

7.1.1 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.).

7.1.2 Requirements for pre-operation

Before overhaul and maintenance, it is necessary to cut off the high-voltage power supply according to the specifications, set the power supply main switch handle of the low voltage power supply to the "OFF" position, and close the key switch, and the key shall be kept by the maintenance personnel. It is necessary to keep in mind that there is high-voltage inside the battery system. After 15 minutes disconnecting all the manual maintenance switches (MSD) on the battery box and high-voltage box, it is necessary to confirm that there is no voltage at the high-voltage end with the multi-meter and then carry out relevant operations. After the operation is completed, it is necessary to ensure that it is re-installed in place.

7.1.3 Requirements for operational process

(1) Insulating shoes, gloves and goggles shall be worn for operation.

(2) It is strictly forbidden to wear metal jewelry such as gold and silver jewelry or watches.

(3) In any case, the positive and anode and cathode poles of the battery box cannot be touched at the same time.

(4) All the bundles of orange bellows are high-voltage harness and cannot be sheared under any circumstances.

(5) Any part connected with the orange wire harness shall not be touched at will.

(6) Close the high-voltage cabin door when the repair and maintenance are completed. Non-professionals are not allowed to open it at will.

7.1.4 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.

7.2 Requirements for repair and maintenance of power batteries

7.2.1 Maintenance requirements for power batteries

7.2.1.1 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. When driving normally, if SOC is less than 10%, it is necessary to charge it. If SOC is less than 5%, it is necessary to charge it as soon as possible, otherwise the battery overdischarge will affect the service life of the battery.

7.2.1.2 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 overdischarge, 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

7.2.2 Repair of power battery

Power batteries need to be repaired by professionals because of high-voltage characteristics.

7.2.2.1 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.

7.2.2.2 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.

7.2.2.3 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 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.

7.3 Requirements for repair and maintenance of motor controller

7.3.1 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.

7.3.2 Repair requirements for motor controller

7.3.2.1 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.

7.3.2.2 Inspection and replacement of motor controller

(1) Disassembly of the complete unit: It is necessary to remove the bolts of the MCU and take down the MCU.

(2) Repair is carried out by professionals according to MCU fault diagnosis and treatment methods.

(3) Re-install MCU 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 MCU 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) The waterproof level of the controller is IP67. Do not wash the controller with high-voltage water gun or other tools. If you need to wash it, you shall wipe the controller with soft and dry cotton cloth or other cloth. Do not wipe it with alcohol or organic solvent.

(13) 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.

7.4 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.

7.4.1 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.

7.4.2 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 ≤36V 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.

7.5 Requirements for repair and maintenance of high-voltage electric connections

7.5.1 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.

7.5.2 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.

7.5.3 Requirements for repair and maintenance of AC/DC charging sockets

7.5.3.1 Requirements for maintenance of AC/DC charging sockets

It is suggested that AC and DC charging sockets shall be cleaned regularly.

7.5.3.1.1 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.

7.5.3.1.2 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.

7.5.3.2 Requirements for repair of AC/DC charging sockets

7.5.3.2.1 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

7.5.3.2.2 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.

7.5.3.2.3 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.

7.5.4 Requirements for repair and maintenance of charging guns

7.5.4.1 Requirements for maintenance of charging guns

It is recommended that the charging gun be cleaned regularly.

7.5.4.1.1 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.

7.5.4.2 Requirements for repair of charging guns

7.5.4.2.1 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

7.5.4.2.2 Charging gun maintenance requirements

Non-work state.

7.5.4.2.3 Repair, inspection and replacement of charging gun

The charging line assembly needs to be replaced.

7.6 Requirements for repair and maintenance of high-voltage components of power electronics

Power electronic components include vehicle chargers, DCDC converters, DC/AC inverters, etc.

7.6.1 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.

7.6.2 Requirements for repair of high-voltage components of power electronics

7.6.2.1 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.

7.6.2.2 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.

8. 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.

8.1 Summary of graded utilization and recycling of power battery

8.1.1 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.

8.1.2 Power battery graded utilization and recycling process

According to the relevant specifications and requirements of electric vehicles, the power battery graded utilization and recycling process is shown in Fig. 1.

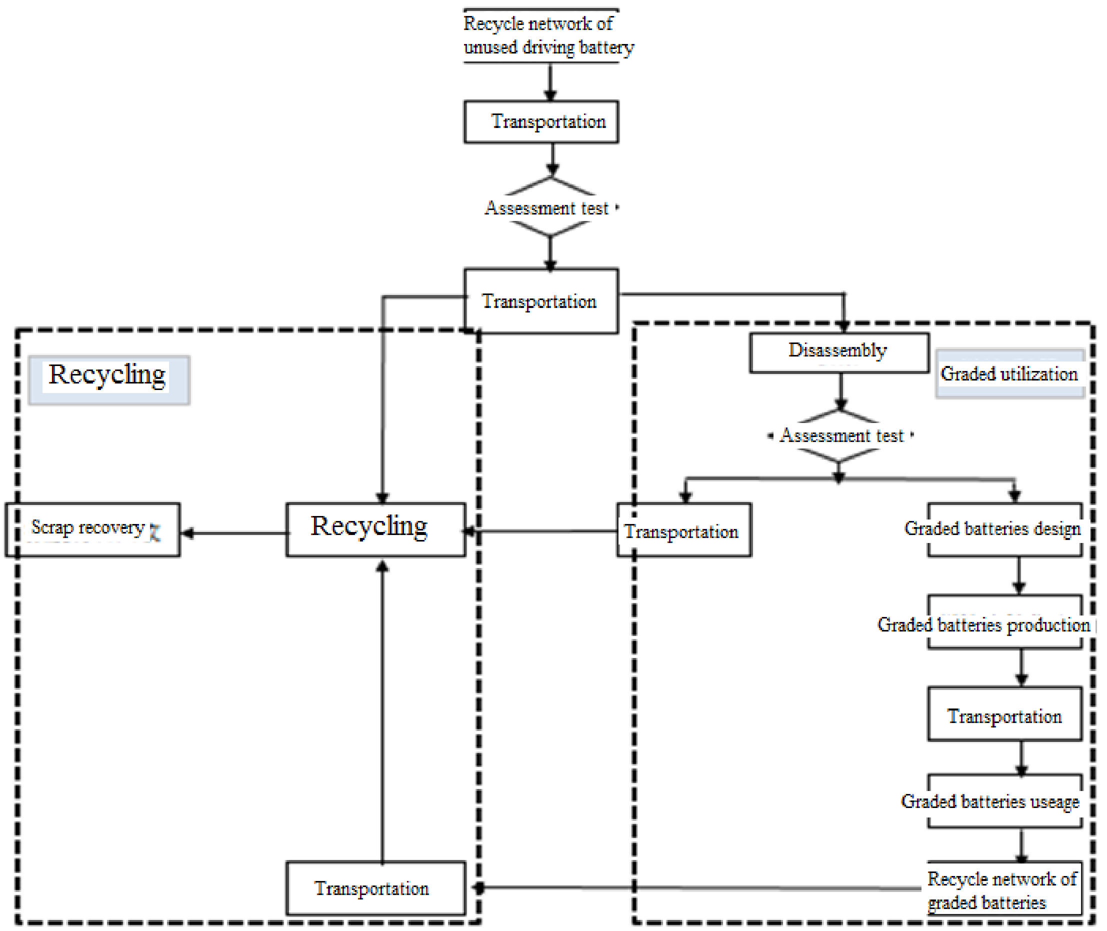


Figure 1

8.1.3 Environmental safety

8.1.3.1 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 engaged in comprehensive utilization and graded utilization shall regularly carry out safety and environmental protection training, assessment, supervise and implement safety and environmental protection system, eliminate hidden dangers of safety and environmental protection.

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.

8.1.3.2 Requirements for environmental safety and qualification of responsible enterprises

Enterprises engaged in comprehensive utilization and graded utilization of power batteries shall follow the following requirements in environmental safety and qualification:

(1) Enterprises engaged in comprehensive utilization and graded utilization shall formulate detailed rules for the implementation of environmental safety in various departments;

(2) Enterprises engaged in comprehensive utilization and graded utilization shall formulate procedures for personnel training, competence and qualification identification of various departments.

8.2 Recovery network and storage and transportation safety of power batteries

8.2.1 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:

8.2.1.1 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.

8.2.2 Disposal requirements for battery system before transportation of recycledrecycled 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.

8.2.3 Packaging requirements for recycledrecycled power batteries before transportation

8.2.3.1 Specification for packaging and stacking of recycledrecycled 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) Protective packaging mainly includes leak-proof packaging, insulation packaging, fire-proof packaging, shock-proof packaging, cushioning packaging, etc. Appropriate protection methods shall be selected according to the characteristics of different types

of power batteries;

(3) 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;

(4) Battery packages shall be labeled with "lithium batteries to be processed" or "lithium batteries to be recycled";

(5) The packages of treated batteries shall be labeled with "damaged/defective lithium batteries or lithium battery packs";

(6) Emergency contact information shall be attached to the packages of batteries.

8.2.3.2 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.

8.2.4 Requirements for information traceability for recycling power batteries

Enterprises engaged in comprehensive utilization and graded utilization of power batteries shall follow the following requirements in information traceability:

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.

8.3 Detection, classification and disassembly safety of power battery recycling

8.3.1 General requirements

8.3.1.1 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 fire fighting 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.

8.3.1.2 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.

8.3.1.3 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 labour 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.

8.3.1.4 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.

8.3.1.5 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.

8.3.2 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.

8.3.3 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.

8.3.4 Inspection safety in the process of disassembly and separation of enterprises engaged in graded utilization

8.3.4.1 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 labour 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.

8.3.4.2 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.

8.3.5 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.

8.4 Safety requirements for design of battery pack by recycled power batteries

8.4.1 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.

8.4.1.1 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.

8.4.1.2 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.

8.4.1.3 Design requirements for flame retardant structure

Fire prevention and flame retardant can be considered from two aspects: 1) Passive fire prevention and flame retardant; 2) Active fire prevention and flame retardant.

Passive fire prevention and flame retardant refers to the use of high flame-retardant grade or non-combustible materials for the components of battery system in design. The plastic parts inside the battery system shall reach some certain flame-retardant grade, and the high and low voltage harness shall be of high flame retardant level. It is recommended to choose high and low voltage harness with temperature resistance above 125℃. Refer to GB/T 2408-2008 *Plastics - Determination of Burning Characteristics - Horizontal and Vertical Methods*.

Active fire prevention and flame-retardant design can be considered from two aspects: Firstly, in the design of battery system, fire protection structure is added to prevent the exterior flame from entering the inside of the box directly. Secondly, in the design of battery system, fire fighting system is added inside the box.

8.4.1.4 Design requirements for thermal management

Thermal management design of power batteries include two important parts:

(1) The temperature in and between batteries shall be balanced.

(2) In order to control the absolute temperature of batteries within the reasonable range, the thermal management design of graded batteries shall meet the environmental temperature conditions of different industries.

8.4.1.5 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.

8.4.1.6 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.

8.4.2 Safety requirements of lithium battery management system

8.4.2.1 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.

8.4.2.2 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;

8.4.2.3 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.

8.5 Safety requirements for production of batteries by recycled power batteries

8.5.1 Detection

8.5.1.1 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.

8.5.1.2 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.

8.5.2 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.

8.5.3 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.

8.5.4 Warehousing

(1) The charged batteries in the finished product warehouse meet the requirements for safe storage and transportation of batteries. The batteries in the finished product warehouse shall be stored differently according to different quality states;

(2) When finished batteries are stored for a long time, it is recommended that they shall be regular inspected for safety;

(3) Battery packs of different state products shall be stored in the storage space of effective isolation zones and not mixed with other materials. The warehouse shall adopt remote or on-site monitoring measures, installed with smoke and temperature alarms;

(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.

8.6 Safety requirements for use of graded batteries

8.6.1 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.

8.6.2 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.

8.6.3 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.

8.6.4 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.

8.6.5 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.

8.6.6 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.

8.7 Safety requirements for recycling and utilization of power battery materials

8.7.1 General requirements

8.7.1.1 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.

8.7.1.2 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.

8.7.1.3 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.

8.7.1.4 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 (HG30014-2013);

(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.

8.7.1.5 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.

8.7.2 Safety requirements for recycling process

8.7.2.1 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.

8.7.2.2 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.

8.7.3 Requirements for warehousing

(1) Reference 8.2.3.1 and 8.5.4.1;

(2) It is strictly forbidden to dump the waste directly, and it shall be centrally stored and handed to the manufacturer with recycling qualification.

8.8 Requirements for safety data control for recycling of power batteries

8.8.1 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.

8.8.1.1 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.

8.8.1.2 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.

8.8.2 Big data analysis and operational management

8.8.2.1 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.

8.8.2.2 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.

8.8.3 Data application in safety accidents

8.8.3.1 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.

8.8.3.2 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.

9. Accident handling

9.1 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.

9.1.1 Collision rescue

9.1.1.1 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.

9.1.1.2 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 are 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.

9.1.1.3 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.

9.1.1.4 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.

9.1.2 Water accident rescue

9.1.2.1 Investigation

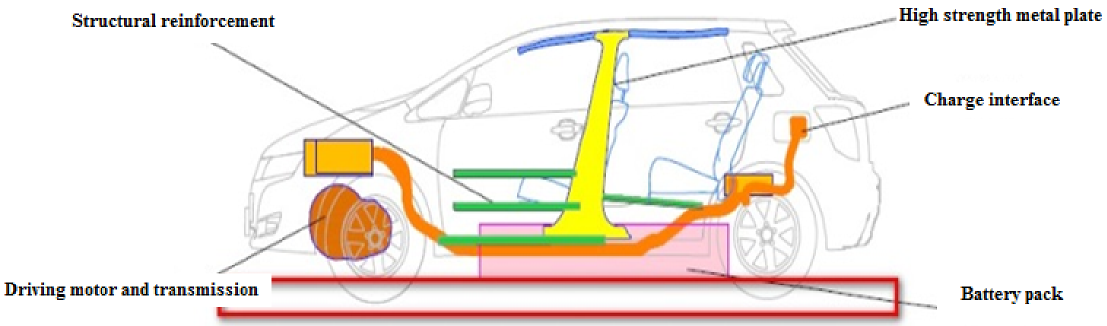
Investigate the depth of water of vehicle and take rescue measures according to different depth of water. It shall be noted that the power battery system will also ignite and explode in the water. Pay attention to safety in the rescue process.

(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.

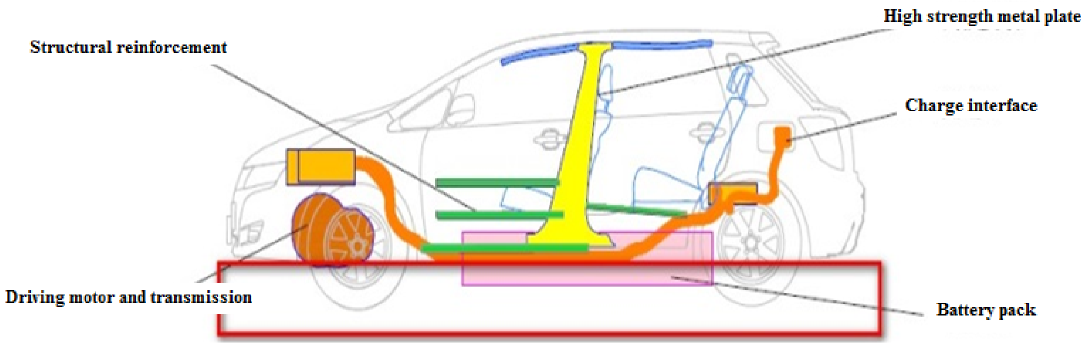


(2) Water at or near the threshold (as shown below)

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;

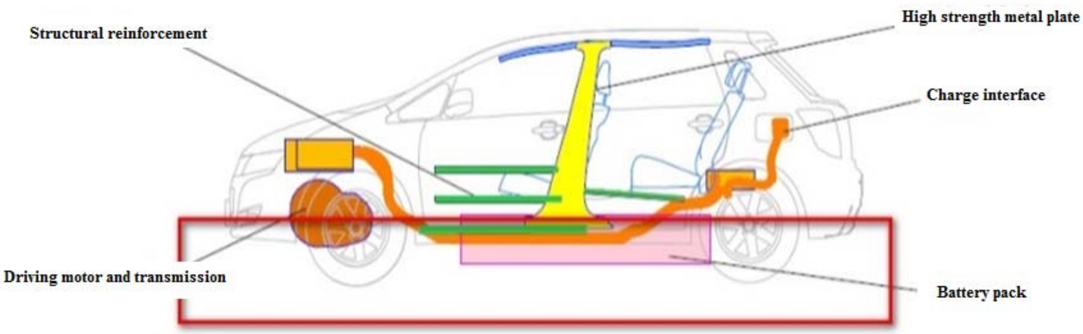
b. In case of anything abnormal, call for rescue;

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.



9.1.2.2 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) Condcut 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.

9.1.2.3 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.
9.1.2.4 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.
9.1.3 Fire rescue
9.1.3.1 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 when 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.

9.1.3.2 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.

9.1.4 Treatment of electric shock accident

9.1.4.1 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.

9.1.4.2 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.

9.1.4.3 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.

9.1.5 Treatment of electric charging accident

9.1.5.1 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.

9.1.5.2 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.

9.2 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.

9.2.1 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.

9.2.2 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.

9.2.2.1 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.

9.2.2.2 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.

9.2.2.3 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.

9.2.2.4 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.

9.2.2.4.1 Collision accident

9.2.2.4.1.1 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.

9.2.2.4.1.2 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.

9.2.2.4.1.3 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.

9.2.2.4.2 Water accident

9.2.2.4.2.1 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.

9.2.2.4.2.2 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 driving which lead to vehicle accidents in the water area.

During the parking process, water accidents occur because of the change of external environmental factors.

9.2.2.4.2.3 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.

9.2.2.4.3 Fire accident

9.2.2.4.3.1 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.

9.2.2.4.3.2 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.

9.2.2.4.3.3 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.
9.2.2.4.4 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.
9.2.2.4.4.1 People under electric shock
9.2.2.4.4.1.1 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.
9.2.2.4.4.1.2 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.
9.2.2.4.4.1.3 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.

9.2.2.4.4.2 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.

9.2.2.4.4.2.1 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.

9.2.2.4.4.2.2 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.

9.2.2.4.4.2.3 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.

9.2.3 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.

9.3 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.

9.3.1 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:

9.3.1.1 Analysis of technical reasons

(1) Correct location

Specify 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.

9.3.1.2 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.

9.3.2 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.

9.3.3 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.

9.3.4 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);

9.4 Requirements for accident reporting

Accident reports are compiled according to Table 9-1:

Table 9-1

<table>
<tr><td>Occurrence time of accident</td><td colspan="2">Accident location</td><td colspan="2">Casualties</td><td>Type of accident</td></tr>
<tr><td></td><td colspan="2"></td><td colspan="2"></td><td>Fire/water/collision/other</td></tr>
<tr><td>Accident vehicle manufacturer</td><td>Accident vehicle brand</td><td>Accident vehicle type</td><td colspan="2">Power type of accident vehicle</td><td>Battery supplier of accident vehicle</td></tr>
<tr><td></td><td></td><td></td><td colspan="2"></td><td></td></tr>
<tr><td>Accident description</td><td colspan="5">1 Description of occurrence
2 Description of rescue process
3 Result description</td></tr>
<tr><td rowspan="2">Accidents cause</td><td colspan="3">Subjective reason</td><td colspan="2">Objective reason</td></tr>
<tr><td colspan="3"></td><td colspan="2"></td></tr>
<tr><td>Rectification measures</td><td colspan="5"></td></tr>
<tr><td>Accident investigation team
List of members</td><td colspan="5"></td></tr>
<tr><td>Other instructions</td><td colspan="5"></td></tr>
</table>

10. Operational safety

10.1 Operational guidance training and qualification certification system

10.1.1 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.

10.1.2 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.

10.2 General requirements for operational guidance of electric vehicles

10.2.1 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.

10.2.2 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.

10.3 Preparation before operation

10.3.1 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.

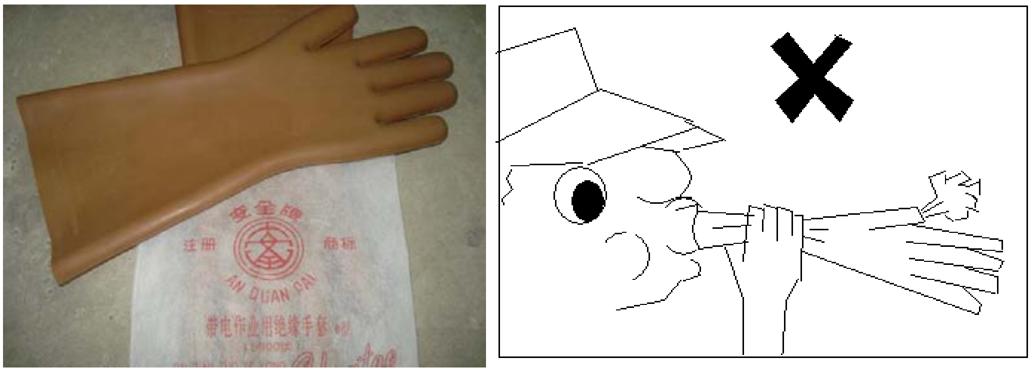


Figure 10-1 Inspection of insulating gloves

10.3.2 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.

10.3.3 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.

10.3.4 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.

10.4 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.

10.5 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.

11. 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.

11.1 General requirements for electric operating vehicles

11.1.1 Operation certificate handling

Operating certificates shall be handled according to the requirements for the local operating vehicles and the operation certificate handling procedures.

11.1.2 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.

11.1.3 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.

11.2 Safety requirements for electric operating vehicle configuration

11.2.1 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.

11.2.2 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.

11.2.3 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.

11.2.4 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.

11.2.5 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.

11.2.6 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.

11.3 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.

11.4 Safety requirements for remote monitoring of electric operating vehicles

11.4.1 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.

11.4.2 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.

11.4.3 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.

11.5 Requirements for safety accident handling for electric operating vehicles

Electric vehicles must first meet the requirements of Chapter 9 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.

11.6 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.

11.7 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.

11.8 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.