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Functional Safety Requirements and Testing Methods for Battery Management System of Electric Vehicles

电动汽车用电池管理系统功能安全要求及试验方法

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Functional Safety Requirements and Testing Methods for Battery Management System of Electric Vehicles

1 Scope

This Standard specifies the functional safety requirements and test methods for power battery management system (hereinafter referred to as “battery management system”) of electric vehicles.

This Standard is applicable to lithium-ion battery management system for electric passenger vehicles. Other types of power battery management systems and power battery management systems for other types of vehicles may take this as a reference.

2 Normative References

The following documents are indispensable to the application of this document. In terms of references with a specified date, only versions with a specified date are applicable to this document. In terms of references without a specified date, the latest version (including all the modifications) is applicable to this document.

GB 18384-2020 *Electric Vehicles Safety Requirements*

GB/T 19596-2017 *Terminology of Electric Vehicles*

GB/T 34590-2017 (all parts) *Road Vehicles - Functional Safety*

GB 38031-2020 *Electric Vehicles Traction Battery Safety Requirements*

GB/T 38661-2020 *Technical Specifications of Battery Management System for Electric Vehicles*

3 Terms and Definitions

What is defined in GB/T 19596-2017 and GB/T 34590.1-2017, and the following terms and definitions are applicable to this document. For ease of use, some terms and definitions in GB/T 19596-2017 are repeated listed.

3.1 Battery Management System; BMS

Battery management system refers to a system that monitors the state (temperature, voltage and state of charge, etc.) of a battery, and can provide communication, safety, cell balancing and management control for the battery, and provide a communication interface with application equipment.

3.6 Thermal Runaway

Thermal runaway refers to the phenomenon of uncontrollable rise of battery temperature caused by the exothermic chain reaction of secondary cell.

[GB 38031-2020, Definition 3.14]

3.7 Thermal Propagation

Thermal propagation refers to the phenomenon of continuous thermal runaway of the remaining secondary cells caused by the thermal runaway of one secondary cell in the battery pack or system.

[GB 38031-2020, Definition 3.15]

3.8 Explosion

Explosion refers to pressure waves or ejections generated by the sudden release of sufficient energy, which might cause structural or physical damage to the surrounding area.

[GB 38031-2020, Definition 3.10]

3.9 Leakage

Leakage refers to the leakage of electrolyte inside the battery to the outside of the battery shell.

[GB/T 19596-2017, Definition 3.3.3.13.7]

3.10 Venting

Venting refers to the release of gas through a pre-designed mode when the internal pressure in a secondary cell or battery pack increases.

[GB/T 19596-2017, Definition 3.3.3.13.8]

3.11 Overcharge

Overcharge refers to continuing to charge after the cell or battery is fully charged.

[GB/T 19596-2017, Definition 3.3.3.2.4]

3.12 Over Discharge

Over discharge refers to continuing to discharge after the cell or battery is fully discharged.

[GB/T 19596-2017, Definition 3.3.3.1.8]

3.13 Fire

Fire refers to the continuous combustion of secondary cells, modules, battery packs or any parts of the system (flame duration is greater than 1 s).

NOTE 1: "flame duration is greater than 1 s" refers to the duration of a single flame, rather than the cumulative time of multiple flames.

NOTE 2: sparks and arcs do not belong to combustion.

[GB 38031-2020, Definition 3.11]

4 General Requirements

Unless it is otherwise specified, the requirements for the functional safety technology development and process development of battery management system shall be implemented in accordance with GB/T 34590-2017 (all parts).

5 Definition of Related Items

5.1 General Rules

In accordance with the requirements of GB/T 34590.3-2017, related items shall be defined. Related items refer to systems or system groups that implement vehicle-level functions or partial functions.

NOTE: related items and their scope may be defined in accordance with specific conditions. Appendix A and Appendix B respectively provide examples of functional concepts that take battery management system and power battery system as related items, and boundaries and interfaces of related items.

5.2 Functional Concept

In order to satisfy the safe operation of a vehicle and ensure the safety of the internal and external personnel of the vehicle, and the vehicle environment, the battery management system shall monitor and protect the safe operation of the power battery. The functional requirements of the battery management system shall also satisfy GB 18384-2020, GB 38031-2020 and GB/T 38661-2020.

NOTE 1: Appendix A provides a description of the functional concept of charge management and discharge management of the battery management system. Appendix B provides a description of the functional concept of the power battery system for charging and discharging.

NOTE 2: the state of charge includes external charge, internal charge (for example, vehicle braking energy recovery), etc. The state of discharge includes driving discharge

parties through negotiation.

7.2.5 Alarm and degradation concept

After the battery management system detects an over-discharging fault of secondary cell, it shall warn the driver through warning signals or prompt messages.

If there are scenarios where the power battery cannot immediately enter or maintain the safe state, a degradation function (for example, limitation of charging power and prohibition of the use of braking energy recovery function) shall be designed to put the vehicle into the emergency operation mode.

7.3 Prevent Thermal Runaway Caused by Over-temperature of Secondary Cell

7.3.1 General requirements

The battery management system shall monitor the temperature of secondary cell. When the temperature of secondary cell exceeds the safety threshold, the power battery system shall be put into a safe state within FTTI. When the over-temperature fault withdrawal and elimination conditions of the secondary cell are not satisfied, the power battery system shall not exit the safe state.

Fault detection, response and handling shall be completed within FTTI.

The safety threshold shall be provided based on the battery system manufacturer's over-temperature test results.

The temperature of the temperature measurement point in the battery system shall be able to represent the highest temperature of secondary cell in the battery system.

7.3.2 Operation mode

The battery management system shall be in a working state.

7.3.3 FTTI

The FTTI for over-temperature of secondary cell shall be provided based on the battery system manufacturer's over-temperature test results.

NOTE: the method of determining FTTI for over-temperature of secondary cell shall take Appendix C as a reference. See Figure 4 for the schematic diagram.

parties through negotiation.

7.4.5 Alarm and degradation concept

After the battery management system detects an overcurrent fault of the power battery system, it shall warn the driver through warning signals or prompt messages.

If there are scenarios where the power battery cannot immediately enter or maintain the safe state, a degradation function (for example, limitation of charging and discharging power, and prohibition of the operation of some non-safe-operation-related functions) shall be designed to put the vehicle into the emergency operation mode.

8 Verification and Confirmation of Functional Safety

8.1 General Rules

The verification of functional safety is to verify the completeness and correctness of the functional safety requirements. The confirmation of functional safety is to confirm that the safety goals are thoroughly realized, and that the occurrence of hazardous events can be relieved or avoided at the system and vehicle level.

The verification of functional safety shall verify the functional safety requirements and design at the level of the battery management system. The verification methods include review, walk-through, inspection, model check, simulation, engineering analysis, certification and testing. The purpose of verification is to prove the functional safety requirements:

a) Consistency and compliance with the results of verification activities;

b) Correctness of realization.

This Standard mainly provides test-based functional safety verification methods. The tests may be carried out in a simulated environment or a real environment.

The confirmation of functional safety requires confirmation of the realization of functional safety goals at the power battery system level or the vehicle level. The confirmation methods include inspection and testing. The purpose of confirmation includes:

a) Prove that the realization of the safety goals at the vehicle level is correct and complete, and that the safety goals are fully realized;

b) The safety goals can prevent or mitigate the hazardous events and risks identified in hazard analysis and risk assessment.

This Standard mainly provides test-based functional safety confirmation methods.

d) The test shall monitor the process of the battery management system entering a safe state (such as: safety threshold, time and state switching);

e) The test shall monitor the conditions, under which, the battery management system exits the safe state.

8.2.1.4 Test end conditions

8.2.1.4.1 When any of the following conditions is met, end the test under the simulated environment:

a) The test object enters the safe state within FTTI and does not accidentally exit the safe state;

b) The test object enters the safe state within FTTI and accidentally exits the safe state;

c) The test object does not enter the safe state within FTTI.

8.2.1.4.2 When any of the following conditions is met, end the test under the real environment:

a) The test object enters the safe state within FTTI and does not accidentally exit the safe state;

b) The test object enters the safe state within FTTI and accidentally exits the safe state;

c) The test object does not enter the safe state within FTTI;

d) The battery system where the test object is located has leakage, venting, fire or explosion.

8.2.1.5 Test pass criteria

The test object enters the safe state within FTTI and does not accidentally exit the safe state.

8.2.2 Prevent thermal runaway caused by recharging after over-discharging of secondary cell

8.2.2.1 Test purpose

The battery management system shall monitor the voltage of secondary cell. When the voltage of secondary cell is lower than the safety threshold, the power battery system shall be put into a safe state within FTTI. When the over-discharging fault withdrawal and elimination conditions of the secondary cell are not satisfied, the power battery system shall not exit the safe state.

the safe state;

b) The test object enters the safe state within FTTI and accidentally exits the safe state;

c) The test object does not enter the safe state within FTTI.

8.2.2.4.2 When any of the following conditions is met, end the test under the real environment:

a) The test object enters the safe state within FTTI and does not accidentally exit the safe state;

b) The test object enters the safe state within FTTI and accidentally exits the safe state;

c) The test object does not enter the safe state within FTTI;

d) The battery system where the test object is located has leakage, venting, fire or explosion.

8.2.2.5 Test pass criteria

The test object enters the safe state within FTTI and does not accidentally exit the safe state.

8.2.3 Prevent thermal runaway caused by over-temperature of secondary cell

8.2.3.1 Test purpose

The battery management system shall monitor the temperature of secondary cell. When the temperature of secondary cell is higher than the safety threshold, the power battery system shall be put into a safe state within FTTI. When the over-temperature fault withdrawal and elimination conditions of the secondary cell are not satisfied, the power battery system shall not exit the safe state.

8.2.3.2 Test object

The test object is the battery management system.

8.2.3.3 Test requirements

8.2.3.3.1 Under a simulated environment, the test shall satisfy the following requirements:

a) All equipment that affects the functions of the test object and is related to the test results shall be in normal operation state;

b) The test shall be aimed at the operation mode specified in 7.3.2;

f) The test shall monitor the process of the battery management system entering a safe state (such as: safety threshold, time and state switching);

g) The test shall monitor the conditions, under which, the battery management system exits the safe state.

8.2.4.3.2 Under a real environment, the test shall satisfy the following requirements:

a) All equipment that affects the functions of the test object and is related to the test results shall be in normal operation state;

b) The test shall be aimed at the operation mode specified in 7.4.2;

c) The battery system where the test object is located shall be charged and discharged by gradually increasing the charging and discharging current at the change rate of the charging and discharging rate permitted by the battery system manufacturer, until the current exceeds the safety threshold;

d) The test needs to consider parameters that affect the safety threshold of current, for example, temperature;

e) The test shall monitor the process of the battery management system entering a safe state (such as: safety threshold, time and state switching);

f) The test shall monitor the conditions, under which, the battery management system exits the safe state.

8.2.4.4 Test end conditions

8.2.4.4.1 When any of the following conditions is met, end the test under the simulated environment:

a) The test object enters the safe state within FTTI and does not accidentally exit the safe state;

b) The test object enters the safe state within FTTI and accidentally exits the safe state;

c) The test object does not enter the safe state within FTTI.

8.2.4.4.2 When any of the following conditions is met, end the test under the real environment:

a) The test object enters the safe state within FTTI and does not accidentally exit the safe state;

b) The test object enters the safe state within FTTI and accidentally exits the safe state;

f) The confirmation shall monitor the conditions, under which, the power battery system exits the safe state;

g) After the confirmation is completed, observe at the ambient temperature of confirmation for 1 h.

8.3.1.4 Confirmation end conditions

When any of the following conditions is met, end the confirmation:

a) The confirmation object enters the safe state within FTTI and does not accidentally exit the safe state, and the battery does not have leakage, venting, fire or explosion;

b) The confirmation object enters the safe state within FTTI and accidentally exits the safe state;

c) The confirmation object does not enter the safe state within FTTI;

d) The confirmation object has leakage, venting, fire or explosion.

8.3.1.5 Confirmation pass criteria

The confirmation object enters the safe state within FTTI and does not accidentally exit the safe state, and no leakage, venting, fire or explosion occurs during the observation.

8.3.2 Prevent thermal runaway caused by recharging after over-discharging of secondary cell

8.3.2.1 Purpose

Confirm that the safety goal of “preventing thermal runaway caused by recharging after over-discharging of secondary cell” is correctly realized, and that the occurrence of thermal runaway due to recharging after over-discharging of secondary cell can be effectively prevented.

8.3.2.2 Confirmation object

The confirmation object is the power battery system.

8.3.2.3 Confirmation requirements

The confirmation shall satisfy the following requirements:

a) All equipment that affects the functions of the confirmation object and is related to the confirmation results shall be in normal operation state;

b) The confirmation shall be carried out at the vehicle level, including at least the real battery system, and the actual operating conditions or the simulated

c) The confirmation object does not enter the safe state within FTTI;

d) The confirmation object has leakage, venting, fire or explosion.

8.3.3.5 Confirmation pass criteria

The confirmation object enters the safe state within FTTI and does not accidentally exit the safe state, and no leakage, venting, fire or explosion occurs during the observation.

8.3.4 Prevent thermal runaway caused by overcurrent of power battery system

8.3.4.1 Purpose

Confirm that the safety goal of “preventing thermal runaway caused by overcurrent of power battery system” is correctly realized, and that the occurrence of thermal runaway due to overcurrent of power battery system can be effectively prevented.

8.3.4.2 Confirmation object

The confirmation object is the power battery system.

8.3.4.3 Confirmation requirements

The confirmation shall satisfy the following requirements:

a) All equipment that affects the functions of the confirmation object and is related to the confirmation results shall be in normal operation state;

b) The confirmation shall be carried out at the vehicle level, including at least the real battery system, and the actual operating conditions or the simulated operating conditions of the vehicle;

NOTE 1: the actual operating conditions of the vehicle include at least the most severe operating conditions in the hazard analysis and risk assessment.

c) The confirmation shall include typical failure modes that violate the safety goals;

NOTE 2: the typical failure modes include functional abnormalities derived from the safety goal in the hazard analysis and risk assessment, for example, charging at a current beyond the expectation.

d) The confirmation needs to consider parameters that affect the safety threshold of current, for example, temperature;

e) The confirmation shall monitor the process of the power battery system entering a safe state (such as: safety threshold, time and state switching);

f) The confirmation shall monitor the status of the power battery system;

Appendix A

(informative)

An Example of Hazard Analysis and Risk Assessment (HARA) with Battery Management System as a Related Item

A.1 Definition of Related Items

A.1.1 Functional concept

A.1.1.1 Charge management

This function aims at putting the power battery in a safe state during the charging process through the control and management of the battery management system. During the charging process of the power battery, the battery management system controls and optimizes parameters, such as: charging voltage, charging current and detectable battery temperature, so as to ensure the safety of the power battery during the charging process.

A.1.1.2 Discharge management

This function aims at putting the power battery in a safe state during the discharging process through the control and management of the battery management system. During the discharging process of the power battery, the battery management system controls and optimizes parameters, such as: discharging voltage, discharging current and detectable battery temperature, so as to ensure the safety of the power battery during the discharging process.

A.1.2 Boundaries and interfaces of battery management system

In accordance with the requirements of 5.4.2 in GB/T 34590.3-2017, define the boundaries and interfaces of related items of the battery management system and other related items.

Example: Figure A.1 is a reference example of boundaries and interfaces of BMS related items. Other related items are: power battery system, finished-vehicle low-voltage battery, finished-vehicle power control system (vehicle controller and motor controller, etc.), high-voltage component (service switch, etc.) and charging interface (for electric vehicles with external charging function).

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