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Guidelines for Safety Design of Lithium Ion Batteries

锂离子电池组安全设计指南

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Guidelines for Safety Design of Lithium Ion Batteries

1 Scope

This document provides guidance related to the safety characteristics of battery in the design of lithium ion battery, and suggestions for improving product safety characteristics from the aspects of cells, protection circuits, materials and components, thermal design, fire protection and installation, etc.

This document is applicable to the design of lithium ion battery, without distinguishing the fields of application.

2 Normative References

This document does not have normative references.

3 Terms and Definitions

The following terms and definitions are applicable to this document.

3.1 cell manufacturer

Cell manufacturer refers to the manufacturer of lithium ion cells.

3.2 battery manufacturer

Battery manufacturer refers to the manufacturer that assembles cells into batteries.

NOTE: under certain circumstances, battery manufacturer may also be the cell manufacturer.

3.3 lithium ion cell

Lithium ion cell refers to a device that relies on the movement of lithium ions between the positive and negative electrodes to realize the mutual conversion between chemical energy and electrical energy, and it is designed to be rechargeable.

NOTE 1: the device usually includes electrodes, diaphragms, electrolytes, containers and terminals, etc.

NOTE 2: hereinafter referred to as cell.

3.4 module

Module refers to a configuration with multiple cells connected in series or parallel, with or

without protection devices [for example, fuse protector or positive temperature coefficient thermistor (PTC)] and monitoring circuits.

[source: IEC 62619:2017, 3.9]

3.5 battery protection circuit module; PCM

battery management unit; BMU

battery management system; BMS

A circuit board, circuit module or electronic system with the core function of controlling the charging and discharging behavior of the battery to protect battery safety.

NOTE 1: usually in the simple application field of portable products, a separate battery protection circuit module is used to protect the cells, while in the component module of complex battery systems, the battery management unit is adopted to manage the cells in the module; in complex battery systems, for example, new energy vehicle power batteries, the battery management system is adopted to realize the management and protection of the cells.

NOTE 2: a complex battery management system may include cell voltage, temperature and current measurement, energy balance, SOC calculation and display, abnormal alarm, charge and discharge management, and communication, etc.

3.6 battery

Battery system

Battery system refers to a system consisting of one or multiple cells, modules or battery packs. It has a battery management system. If overcharge, overcurrent, over-discharge or overheating occurs, the battery management system will take action.

NOTE 1: if the cell manufacturer and the user reach an agreement, over-discharge cut-off is not mandatory.

NOTE 2: it may include cooling or heating devices, and some even include charge and discharge modules and inverter modules.

[source: IEC 62619:2017, 3.11]

3.7 large lithium ion battery

Large lithium ion battery refers to lithium ion battery with a total mass exceeding 12 kg.

[source: UN 38.3 (Sixth revised edition), 2.3]

NOTE: it is referred to as large battery in this document.

a relatively large nominal capacity shall be carefully selected to ensure the safety, and necessary protection devices shall be equipped.

6.3 Cell Consistency

Before assembly, the consistency of the cells needs to be screened (considering capacity, internal resistance and voltage, etc.); cells of the same brand, model and specifications should be used, otherwise, they must satisfy the safety requirements of international standards, national standards and industry standards related to cell consistency.

6.4 Cell Quantity

In order to reduce safety risks, the maximum quantity of cells connected in series or parallel in the battery respectively shall not exceed the quantity recommended by the cell manufacturer.

6.5 Cell Assembly Gap

In the structural design of the battery, for cells with square structures and polymer (including liquid flexible package) structures, sufficient expansion space shall be reserved on the largest surface of the cells. The reserved expansion space shall be at least greater than the minimum value recommended by the cell manufacturer.

6.6 Cell Safety

The safety of cells used by the battery manufacturer must satisfy the international standards, national standards and industry standards related to cells.

6.7 Cell Appearance

Before assembly, check the appearance of the cells. The appearance of the cells shall comply with the stipulations of the battery manufacturer. The surface shall be clean and without mechanical damage.

7 Protection Circuit

7.1 Overview

When lithium ion cells encounter abnormal conditions, such as: charging overvoltage, discharging undervoltage, charging overcurrent, discharging overcurrent and external short-circuit, etc., or are charged and discharged under extreme environmental conditions, or the charge and discharge rate exceeds their own capabilities in actual application environments, safety risks may arise. In the design of batteries, the above-mentioned risks shall be proactively addressed to protect the safety of the constituent cells.

The modes of dealing with the above-mentioned risks include actively stopping charging and discharging behavior or controlling charging and discharging behavior within the safety range specified by the manufacturer.

Priority should be given to the circuit function design to respond to the above-mentioned safety considerations, that is, to design a protection circuit that can control the charging and discharging behavior of the battery, for example, adding PCM/BMU/BMS to the battery.

Priority shall be given to design of the above-mentioned protection circuit in the battery. If the above-mentioned protection circuit is only designed in the system equipment circuit and a battery without its own protection circuit is used, then, it is not appropriate to design the system's battery as a user-replaceable structure.

In order to achieve a complete protection function, considerations may be given to adding necessary information collection devices to the battery. Necessary communication and control buses can be added to the connection between the battery and the equipment. In certain scenarios (for example, on the premise of ensuring personal and property safety), the system control circuit can respond to the protection strategy.

7.2 Voltage Management

The protection circuit of the battery should have an overvoltage charging protection function, so as to prevent any cell from being charged to beyond its upper limited charge voltage.

The protection circuit of the battery should have an undervoltage discharging protection function, so as to prevent any cell from being discharged to below its discharge cut-off voltage.

For a multi-cell lithium ion battery connected in series, even if the total voltage does not exceed the safety range of the battery, a certain single cell may be overvoltage or undervoltage due to poor consistency of the constituent cells. Therefore, it is quite necessary for multi-cell battery connected in series to manage the voltage of each cell or each parallel-connected cell block.

For multi-stage lithium ion battery connected in series, proper balancing design can reduce the probability of charging overvoltage or discharging undervoltage caused by the inconsistency of the constituent cells. However, the battery should not rely solely on the circuit balancing function to prevent the hazard of charging overvoltage or discharging undervoltage.

If the upper limited charge voltage or discharge cut-off voltage of the battery or its constituent cells is closely related to the ambient temperature, then, in addition to having reliable voltage protection, it is also advisable to control any constituent cell during charging and discharging to not exceed its upper limited charge voltage and discharge cut-off voltage at the current ambient temperature.

For protection circuits designed with measures to protect cells from being charged or discharged to beyond the safe voltage range, the voltage management requirements can be reduced.

7.3 Current Management

The protection circuit of the battery should have a charging overcurrent protection function, so as to prevent the charging current of any cell from exceeding its maximum charging current.

The protection circuit of the battery should have a low-temperature protection function, so as to prevent the battery from being charged below the lower limit of charging temperature of the constituent cells.

The temperature collection of the battery should cover every constituent cell as much as possible, and its surface temperature shall be monitored. It is advisable to monitor the surface temperature of the cell where it is most likely to generate heat. If necessary, it is advisable to manage the temperature difference between the constituent cell with the highest temperature and the constituent cell with the lowest temperature in the battery, so as to reduce the possibility of cell failure or accident.

7.5 Consistency Management

Multi-stage battery connected in series should have a certain cell balancing function.

For large-scale lithium ion batteries, it is advisable to have the function of monitoring the status information of the constituent cells of the batteries. In addition, the battery should have the capability of reporting cell status information to the system equipment through the battery interface.

The system equipment should be able to detect the consistency of the constituent cells of the battery through communication signals, and promptly notify the user or manufacturer of unacceptable cell consistency problems.

7.6 Multi-level Protection

It is recommended that the battery adopts a Level-2 or above overcharge protection design, so as to increase the redundancy of electrical safety protection.

If the battery adopts an integrated circuit device that integrates the charging management circuit and the protection circuit, in order to prevent the failure of this single integrated circuit device from causing over-range charging and discharging behavior of the cell, and it is crucial to adopt a Level-2 or above cell protection design.

7.7 Protection Reliability

The protection circuit of the battery needs to be able to initiate protection actions as expected throughout the battery's entire life cycle. For example, key devices that perform the battery protection function, in addition to being able to initiate overvoltage charging protection as expected, also need to withstand foreseeable sustained high-voltage inputs. The antistatic capacity of cell protection devices is also one of the reliability factors that need to be considered.

When designing a battery with a software-controlled protection circuit, it is also advisable to design a hardware protection circuit as the final safety protection.

7.8 Other Considerations

For the battery of certain equipment, if the charging and discharging loops are directly cut off,

it may cause derivative hazards, and this risk is more unacceptable than the cells being overcharged or over-discharged. For example, if the cell used in a balance bike is directly cut off and discharged, the rider may fall and be injured. For this type of battery, it should be considered to advance the Level-1 protection settings of the battery and equipment to the system equipment, and leave a certain threshold, so that the system equipment can actively limit charging and discharging behavior to protect the cell.

For high-voltage batteries with an upper limited charge voltage exceeding 60 V, the protection against the hazard of electric shock is also a factor that needs to be considered. For lithium ion batteries, please refer to the requirements related to electric shock safety of information technology equipment products in GB 4943.1.

NOTE: in the standards on the safety of home appliances, DC voltage exceeding 42.4 V is regarded as dangerous voltage, which requires electric shock safety-related tests and assessments. When the upper limited charge voltage of the battery used in portable home appliances exceeds 42.4 V, the protection against the hazard of electric shock must also be considered.

8 Components and Materials

8.1 Installation of Overcharging and Over-discharging Protection Devices

Overcharging and over-discharging will destroy the cells in the battery, causing potential dangers, such as: fire, explosion and leakage.

In addition to the protection circuit, its main component is the metal-oxide semiconductor field-effect transistor (MOSFET). The battery can also be equipped with corresponding protection devices in the charging and discharging loops, such as: thermostats (interrupt the current), positive temperature coefficient thermistors (PTCs), as well as thermal fuses, etc. The key components of safety need to comply with the relevant requirements of battery standards or component standards.

8.2 Connector / Connecting Piece Connection

When cells are connected in series and parallel, the connecting pieces cannot be directly welded to the cells through welding with high heat input. For example, soldering can easily cause overheating of the cells. Although overheating damage is invisible, it will probably trigger leakage, rupture, fire, or even explosion. In order to avoid overheating damage, it is recommended to use welding modes with low heat input, such as: ultrasonic welding, resistance welding and laser welding, to connect the cells. Use the welding modes with low heat input to firmly weld the cells, so as to prevent insufficient welding and falling off.

For cells connected by nickel strips, the structural design must ensure that the nickel strips do not come into contact with any other cell nodes that are not connected, or that short circuits will not be caused by the insulating coat on the cell surface being punctured by the edge burrs of the nickel strips.

electrolytes, high temperatures, physical shock and other hazards during use. Battery designers choose materials for wire insulation, cell insulation and battery casing, etc. that can withstand electrolytes and high temperatures. The resistance and strength shall be adapted to the specific location and mode of usage. Taking all possible uses into consideration is quite important in battery design.

8.7.3 Insulation materials

The insulation materials used in the battery (such as: insulation tapes and wire sheaths, etc.) shall have sufficient insulation properties and corresponding voltage resistance capabilities, and with good chemical, electrochemical, mechanical and thermal stability within the expected temperature ranges of storage and usage.

9 Safety Thermal Design

9.1 Thermal Protection Design

The battery can be equipped with structural protection devices and thermal management (for example, ventilation) to avoid overheating of the cells caused by the working process or the surrounding environment. Large-capacity battery modules are generally realized through dense assembly of small cells. Therefore, when using them at high voltage or large capacity, the specific energy and thermal behavior characteristics of small cells need to be taken into consideration. The failure of individual units in the battery will affect the operation of the entire system. Generally, the mode of ventilation cooling or liquid cooling is adopted for the thermal management of the battery, or phase-change materials can be used. In order to avoid overcooling of the cells caused by the surrounding environment, the mode of supplementary heating can be adopted to raise the temperature of the surrounding environment of the cells.

9.2 Location of Cells in the Battery

During the structural design of the battery, components that may generate heat shall be placed as far away from the cells as possible, so as to prevent the cells from being affected by high temperatures; power devices that may easily generate heat in the battery management system should be placed as far away from the cells as possible in design, so as to prevent the high temperature of the heating elements from being transmitted to the cells.

9.3 Location of Battery in the Equipment

The location of the battery in the equipment needs to consider the impact of other heat sources on the cell temperature. A proper thermal diffusion environment is conducive to the mitigation of temperature rise.

10 Fireproof Design

10.1 Flame Retardancy of Materials

The flame-retardant requirements of the protective circuit board (PCB), casing, wire sheath and insulation materials used in the battery need to satisfy the requirements of relevant standards.

10.2 Anti-burning Design

Large-scale batteries have the capability of avoiding or delaying system fires in the event of thermal runaway of the cells and satisfy the requirements of relevant standards.

11 Installation

11.1 Prevention of Mechanical Damage

During the assembly process, take protective measures for the cells to prevent scratches, bumps and other damage to the cells. During the process of loading the battery into the battery holder, a sufficient positioning accuracy shall be set to prevent the cells from being squeezed, and the protective board or terminals from being bent or deformed, etc.; during the assembly process, prevent screws and other foreign objects from falling into the battery holder.

11.2 Prevention of Drop Injuries

Make sure that the battery is securely installed on the equipment, so as to prevent the battery from sliding inside the equipment, or even being ejected if the equipment is dropped or subject to a sudden impact. Necessary cushion pads can be configured to avoid damage to the cells and battery due to collision.

11.3 Embedment in Other Equipment

If the battery is embedded in other equipment, the battery shall not be designed as a closed structure, and shall have a pressure relief device.

For applications where water logging may be encountered, the battery must have a corresponding level of structural waterproof design.

11.4 Installation Direction

Install the cells or battery in accordance with the direction recommended by the cell manufacturer.

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