Discussion on International Standards Related to Testing and Evaluation of Lithium Battery Energy Storage

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Abstract

With the massive penetration of distributed energy, energy storage has become an indispensable key link. Lithium battery energy storage is one of the most promising technologies in the field of energy storage. The discussion and Research on foreign lithium battery energy storage standards can better evaluate them to enter the international market. This article interprets some internationally representative test standards, and compares some key test items in accordance with international standards, aiming to promote domestic companies to understand international standards and ultimately produce products that meet international standards. It also points out the reqirements of reusing batteries and factories in the cascade utilization process stipulated by the UL 1974 evaluation standard. This paper provides technical support for the supervision and management of the entire life cycle of lithium batteries and also helps to promote the industry's circular low-carbon and sustainable development.

Keywords: Distributed energy, lithium battery energy storage, assessment, test items, echelon utilization, life cycle.

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Introduction

To implement the “double carbon” goal, the clean transformation of the power industry is imperative. Distributed Energy Systems (DES) will enter the fast lane of development, making the characteristics of the “double high” power system more prominent, And the grid connection of new energy is facing great challenges. The energy storage system is the best solution to the problem of grid connection of distributed power grid and the key technology to support the development of smart grid and new energy [1].

Due to the increasing shortage of energy, battery energy storage has been more and more widely used all over the world. To deal with the safety of energy storage, the test and evaluation standards need to be improved. At present, energy storage technology is developing rapidly, while China is lagging in updating the current standard due to a lack of guidance.

Standards are the important support for the development of technology and an important basis for measuring product quality. Research on foreign lithium battery energy storage standards can help domestic companies to fully understand the standards, better evaluate product performance, improve their R&D capabilities, and ultimately produce products that meet international requirements. Therefore, the study of foreign lithium battery energy storage standards is of important practical significance. Given this, this paper interprets some representative test evaluation standards in foreign countries and compares the key test items, to provide technical reference for the research and development, and production of related enterprises, as well as government supervision.

1 Standard Introduction

The international organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) are the most authoritative and influential standards organizations, as well as the most important international standard-setting organizations for lithium-ion batteries.

Foreign lithium battery energy storage test standards mainly include ISO 12405 series [2, 3], IEC 62660 series [4–6], IEC 62281 [7], IEC 62619 [8], and UL 1642 [9]. See Table 1 for details.

In addition to IEC 62660 series, other standards involve the test of battery pack or system.

UL (Underwriter Laboratories Inc.) is the most authoritative safety testing organization in the United States, and it is also the largest private

Table 1 Test standard of lithium battery energy storage abroad

Serial	Standard	Standard Name	Implementation Date	Main Content
1	IEC 62660-1:2010	Secondary lithium-ion cells for the propulsion of electric road vehicles-Part 1:Performance testing	2010-12-01	Requirements for electrical performance test
2	ISO 12405-1:2011	Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 1: High-power applications	2011-08-05	Requirements for electrical performance and environmental suitability of power batteries
3	ISO 12405-2:2012	Electrically propelled road vehicles – Test specification for lithium-ion traction battery packs and systems – Part 2: High-energy applications	2012-06-29	Requirements for electrical performance and environmental suitability of capacity batteries
4	IEC 62281:2016	Safety of primary and secondary lithium cells and batteries during transport	2016-12	Requirements for safety testing
5	IEC 62660-2:2010	Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 2: Reliability and abuse testing	2010-12-01	Requirements for reliability and safety testing
6	IEC 62660-3:2016	Secondary lithium-ion cells for the propulsion of electric road vehicles – Part 3: Safety requirements	2016-08	Requirements for safety testing

(*Continued*)

Table 1 Continued

Serial	Standard	Standard Name	Implementation Date	Main Content
7	IEC 62619:2017	Secondary cells and batteries containing alkaline or other non-acid electrolytes–Safety requirements for secondary lithium cells and batteries, for use in industrial applications	2017-02	Requirements for safety performance testing
8	UL 1642:2013	Standard for safety lithium batteries	2013-07-30	Requirements for safety performance testing

organization engaged in safety testing in the world. UL 1974:2018 [10] outlines how to evaluate reusable power batteries to ensure their safe and reliable continued use.

2 Test Standard

Standard Content

Table 2 below introduces the content of the test standards from two aspects: test items and test types.

Table 2 Introduction of standard content

Standard	Test Topic	Test Type
IEC 62660-1:2010	Charge retention and recovery capability, Cycle life	Life test
ISO 12405-1:2011 ISO 12405-2:2012	Capacity, Power, Internal resistance, Energy efficiency	Performance testing
IEC 62281:2016 IEC 62660-2:2010 IEC 62660-3:2016 IEC 62619:2017 UL 1642:2013	Vibration, Mechanical shock, Extrusion, Temperature cycling, High temperature charge holding capacity, External short circuit, Overcharge, Forced discharge	Security or abuse testing

Table 3 Comparison of charge retention and resilience test items

Standard Code	IEC 62660-1:2010	ISO 12405-1:2011	ISO 12405-2:2012
Clause	7.6.1 Storage test-charge retention test	7.5 Storage capacity loss/7.4 No load capacity loss	7.6 Storage capacity loss/7.5 No load capacity loss
Level	Cell	With/without BMS battery system	With/without BMS battery system
Storage cycle	28 days/checkup 28 days	30 days/checkup 1,7 and 30 days	30 days/checkup 1,7 and 30 days
Condition	25°C ± 2K	25°C ± 2K	25°C ± 2K
Test Temperature	45°C ± 2K	45°C ± 2K/25°C and 40°C ± 2K	45°C ± 2K/25°C and 40°C ± 2K
Capacity	50%	50%/80%	50%/100%
Determination method	1C	1C	0.33C

2.1 The Key Test Items Comparison

According to the eight standards in Table 2 above, a comparison is conducted among the key test items involved in life test, performance test, safety or abuse test.

Life Test

The charge retention and recovery ability, mainly affected by the battery manufacturing process, materials, and storage conditions, is an important parameter to measure battery performance. (See Table 3 for the comparison of related standard test items.)

One charge and one discharge is called a period or a cycle. Cycle life refers to the number of times that a battery can withstand charging and discharging before its capacity decreases (decays) to a specified value under a certain charging and discharging system. (See Table 4 for the comparison of related standard test items.)

2.1.1 Performance Test

Capacity is one of the important performance indicators to measure the performance of a battery. The comparison of relevant standard test items is shown in Table 5.

Generally, the smaller the battery capacity is, the greater the internal resistance is. The comparison of power and internal resistance-related standard test items is shown in Table 6.

Table 4 Comparison of cycle life test items

Standard Code	IEC 62660-1:2010	ISO 12405-1:2011	ISO 12405-2:2012
Clause	7.7.X Cycle life test	7.9 Cycle life	7.7 Cycle life
Level	Cell	Battery system	Battery system
Environment condition	Convective cooling at 45°C ± 2K	Active cooling at 25–40°C ± 2K	Active cooling at 25–40°C ± 2K
Capacity	20%–100%/25%–80% (Defined by switching voltage)	30%–80%	20%–100%
Storage cycle	28 days at 25°C ± 2K	28 days at 25°C ± 2K	28 days at 25°C ± 2K

Table 5 Comparison of capacity test items

IEC 62660-1:2010	ISO 12405-1:2011		ISO 12405-2:2012	
Cell	Battery Pack	Battery System	Battery Pack	Battery System
BEV:1/3C	BEV:1C		C/3, 1C, 2C	
HEV:1C	HEV:10C and 20C			
Temperature: 0, 25, 45°C	Temperature: −25, RT, 40°C		Temperature: −18, −10, 0, RT, 40°C	

Table 6 Comparison of power and internal resistance test items

IEC 62660-1:2010	ISO 12405-1:2011		ISO 12405-2:2012	
Cell	Battery Pack	Battery System	Battery Pack	Battery System
10 second pulse and 10 minute pause				
Capacity: 20, 50, 80%	Capacity: 80, 65, 50, 35, 20%		SOC: 90, 70, 50, 35, 20%	
Temperature: 40, 25, 0, −20°C	Temperature: −25, RT, 40°C		Temperature: −25, −18, −10, 0, RT, 40°C	

The requirements of ISO 12405-1:2011 and ISO 12405-2:2012 for battery energy test are the same as the capacity test; In IEC 62660-1:2010, it is pointed out that the energy is only evaluated at 25°C.

The energy efficiency of a battery refers to the percentage of discharged power and charged power, and the assessment is the utilization efficiency of energy resources. The comparison of relevant standard test items is shown in Table 7.

Table 7 Comparison of energy efficiency test items

IEC 62660-1:2010	ISO 12405-1:2011		ISO 12405-2:2012	
Cell	Battery Pack	Battery System	Battery Pack	Battery System
Discharge at room temperature				
SOC: 100, 70%	SOC: 35, 50, 65%		·SOC's: Increase by 10% SOC	
Temperature: 45, 0, −20°C	Temperature: RT, 40, 0°C		Temperature: Tmin, 0, RT°C	

Safety or Abuse Test

In terms of safety or abuse testing, comparative studies were carried out from mechanical, thermal, and electrical aspects. The mechanical safety test focuses on vibration, mechanical shock, and extrusion. The thermal safety test focuses on the comparison of temperature cycling and high-temperature charge holding capacity. The electrical safety test focuses on the comparison of external short circuits, overcharge, and forced discharge. The comparison of relevant standard test items is shown in Table 8.

IEC 62619:2017 divides safety performance tests into product safety and functional safety. Product safety performance test is applicable to single cells (battery cells), battery packs, and battery systems. The functional safety performance only tests the safety of the battery management system, disinvolving vibration, mechanical impact, extrusion, and temperature cycle test items.

3 Evaluation Criteria

Every year, large-scale power batteries are scrapped. It is urgent to discuss and study how to evaluate and determine the feasibility of carrying out cascade utilization, give full play to the residual value of power batteries, and improve resource utilization. This article briefly introduces UL 1974 Ed. 1-2018 (Standard For Evaluation For Repurposing Batteries). It points out the reuse requirements of batteries and factories in the echelon utilization process, provides a reference for promoting the standardization of domestic power battery echelon utilization, ultimately leading to its healthy and orderly development.

3.1 Batteries for Echelon Utilization

UL 1974 specifies that the battery for echelon utilization should meet the relevant requirements specified in the standards matching the actual application

Table 8 Comparison of safety or abuse test items

Standard Code/ Test Name	IEC 62281:2016	IEC 62660-2:2010	IEC 62660-3:2016	IEC 62619:2017	UL 1642:2013
Vibration	7–200 Hz, 12 h, 1 to 8 g_n	10–2000 Hz, 24 h, 27, 8 m/s^2	10–2000 Hz, 8 h, 27, 8 m/s^2		10–55 Hz, 0, 8 mm, 95 min
Mechanical Shock	150 g_n, half sine of 6 ms, 18x(cell)	500 m/s^2, half sine of 6 ms, 30x(cell)	500 m/s^2, half sine of 6 ms, 60x(cell)		shock from 75 to 150 g_n, 3X
Crush	crushing surfaces with 1,5 cm/s until 13 kN, 50% deformation or 100 mV voltage drop	crushing bar or sphere, until 1000X cell weight, 15% deformation or voltage drop of 1/3 of Vinit	crushing with a 150 mm diameter extrusion plate at a speed of 6 mm/min or less, 15% deformation or voltage drop of 1/3 of Vinit		crushing surfaces with 1,5 cm/s until 13 kN
Temperature cycling	−40 to 72°C, 10X	−40 or Tmin from manufacturer to 85°C or Tmax from manufacturer, 30X, with or without electrical operation	−40 to 85°C, 30X		−40 to 72°C, 10X
High temperature endurance		130°C, 30 min	130°C, 30 min	85°C, 3 h	≥130°C, ≥10 min, depending on cell's temperature specification
External short circuit	<0, 1 Ohm, @55°C, >1 h	<5 mOhm, 10 min	<5 mOhm, 10 min	30 mOhm, 6 h	80 mOhm until 0, 2 V
Overcharge	$2I_{max}$ (provided by the manufacturer) charging lasts for 24 h or reaches the end of charging state specified by the manufacturer	1It (BEV) or 5It (HEV) until 200% SOC equivalent or 2 Vmax	$1I_{t(BEV)}$ or $5I_{t(HEV)}$ until 1,2 V_{max} or 130% SOC equivalent	charge until max. voltage of charger that lost control, except if double protection is used	$3I_{max\ .charge\ by\ manufacturer}$, for 7 h or reaching end of charge condition by manufacturer
Forced discharge	12 V source in series	discharging a discharged cell at $1I_t$ for 90 min.	discharging a discharged cell at $1I_t$ for 30 min. Until <0, 25 V_{nom}	discharging a discharged cell at $1I_t$ for 90 min. The current is reduced depending on the number of available protections	discharging a discharged cell by the number of charged cells in the application in series and an 80 mOhm resistor until V_{tot} <0, 2 V

scenarios, mainly including the structure requirements, material selection, shell design, conductor and connection terminal, insulation design, and BMS design; The regulation also specifies that battery test items should meet the needs of terminal standards, including battery protection function test, insulation performance test, temperature rise test, heating/cooling system fault simulation, environmental test, mechanical performance test, and anti combustion characteristics.

3.2 Echelon Utilization Enterprise

The technical requirements for echelon utilization enterprises in UL 1974 are as follows: (1) Establish the required procedure documents at all levels. (2) The quality control requirements are regulated from three aspects: feed control, manufacturing process and data collection, non-conformity management, and control. (3) Safety and environmental control requirements are mainly put forward from the four aspects of the storage environment, environmental control in the manufacturing/processing process, sufficient safe operation documents, and effective fire protection measures. (4) Regular maintenance and calibration of testing equipment. (5) The key elements of battery screening include the curriculum vitae of cells/batteries and related accessories and the situation where abnormal batteries need to be included in the scope of unqualified products/rejection. (6) Battery screening means (7) Necessary testing equipment/means. In addition, the screening and grading of reusable batteries by echelon utilization enterprises should follow the Six Sigma law for process control. Manufacturers should establish a long-term data analysis mechanism, analyze and optimize the reuse process and key product parameters, and establish remanufactured finished battery inspection procedures, waste/damage battery disposal procedures, and transportation/packaging requirements.

4 Conclusion

Other countries, regions, and relevant organizations have also issued important safety requirements and test specifications in lithium battery energy storage, especially TUV and other safety assessment institutions, which pay special attention to energy storage safety. Distributed energy technology is an important development direction of world energy technology in the future. Discussion and research on foreign lithium battery energy storage standards can better evaluate battery performance, help improve and improve domestic standards, facilitate the operation of energy storage users, and make the operation more scientific and reasonable, thereby comprehensively improving the performance of lithium battery energy storage systems. Security will ultimately promote the sustainable development of distributed energy.

Echelon utilization of power battery recycling is a necessary measure to give full play to the life cycle value of lithium batteries. The evaluation of recycled batteries is the first stage of the echelon utilization process [11]. When formulating domestic lithium battery energy storage testing and evaluation standards, it is necessary to integrate echelon utilization into the battery design and manufacturing process, to improve the efficiency of echelon utilization of retired batteries.

This paper introduces some representative test evaluation standards abroad and compares the contents of test standards from two aspects: test items and test types. It also points out the requirements for reuse of batteries and factories using echelons specified in the UL 1974 evaluation standard, which contributes to the green and environmental protection, low-carbon cycle, and sustainable development of distributed energy. It also provides technical support for the supervision and management of the whole life cycle of a lithium battery.

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