

1 Purpose

- To standardize the test items, test objectives, test methods, acceptance criteria, and judgment rules for liquid-cooled energy storage cabinets.
- To define the conditions and processes for liquid-cooled energy storage cabinets at each test stage (test task reception, test preparation, test execution, and test completion).
- To specify the basic principles for testing liquid-cooled energy storage cabinets, as well as the classification of non-conformance issues and quality judgment criteria.
- To inspect the various performances of liquid-cooled energy storage cabinets produced by the company, ensuring that the safety and reliability of the energy storage cabinets meet customer requirements.
- To identify obvious or potential quality issues, providing objective data support for improving product quality, safety, and reliability.

2 Scope of Application

Applies to the functions and performance of liquid-cooled energy storage cabinets produced by Hoenergy New Energy Technology Co., Ltd.

3 Referenced Standards

No.	Standard	Description
1	Product Technical Specification Requirements	Product Specification
2	IEC 62933-3-1:2018	(Energy storage system planning and performance evaluation) Operating and maintenance procedures for energy storage stations
3	IEC 62933-2-1:2017	(Unit parameters and testing) General technical requirements for electrochemical energy storage systems in power systems
4	IEC TS 62933-3-2:2023	(Energy storage system performance indicators) Operating indicators and evaluation of electrochemical energy storage stations
5	EN 50549-1:2019	(Generating plants connected to low-voltage grids) Technical specification for grid connection of electrochemical energy storage systems
6	EN 50549-10:2022	(Conformity assessment/testing) Test specification for grid-connected electrochemical energy storage systems
7	IEC 62619:2022	(Industrial lithium cells/batteries) Lithium-ion batteries for electrical energy storage
8	IEC TS 62933-3-2:2023	(Energy storage system performance indicators) Operating indicators and evaluation of electrochemical energy storage stations
9	IEC 62933-2-1:2017	(Unit parameters and testing) General technical requirements for electrochemical energy storage systems in power systems
10	EN 50549-10:2022	(Conformity assessment/testing) Test specification for grid-connected electrochemical energy storage systems
11	IEC 62477-1:2022	(Power electronic converter safety) Technical specification for energy storage converters of electrochemical energy storage systems

4 Term Definitions

- **EUT:** Equipment Under Test
- **AE:** Auxiliary Equipment

5 Testing Principles and Acceptance Criteria

5.1 Basic Testing Principles

Based on standards (international standards, national standards, industry standards), test specifications and specification documents, and combined with test data, evaluate the liquid-cooled energy storage cabinet from the user's perspective, and expose functional defects and potential failures during the testing phase.

The testing work is not affected by factors that interfere with the testing process, such as the attitudes and thinking of the project development team, and is independently executed in accordance with the testing process.

5.2 Problem Classification Principles and Standards

Classified by the severity of non-conformance with product quality characteristics:

- **Class A (Critical Defect):** Failure of basic functions, safety functions, etc.
- **Class B (Major Defect):** Failure to meet key indicators or items of key customer concern
- **Class C (Minor Defect):** Failure to meet general indicators
- **Class D (Acceptable Defect):** Defects acceptable based on current customer or company conditions

5.3 Quality Determination Criteria

If all inspection items meet the specified requirements, the product is determined to be qualified.

If any inspection item fails to meet the specified requirements, the inspection shall be suspended. The responsible unit shall analyze the non-conforming item, identify the cause, and take corrective measures before resubmitting for inspection. If the re-inspection passes, the product is still determined to be qualified. If the re-inspection still has items that fail to meet the specified requirements, the product is determined to be non-qualified.

6 Test Instruments, Tools, and Environment

6.1 Test Equipment

No.	Equipment Name	Supplier	Model
1	Network Cable Tester	Pro'sKit (Taiwan)	MT-7028
2	Clamp Meter	Fluke	F393
3	Portable Pocket Thermal Imager	Fluke	PTi120
4	Temperature and Humidity Meter	Fluke	F971
5	Insulation Resistance Tester	Fluke	1535/1537
6	Power Quality Analyzer	Zhiyuan Electronic	PA5006H-P0600-242
7	Insulation Withstand Voltage Tester	Chroma	19053
8	CAN Box	Zhou Ligong	USBCAN-II+
9	USB to RS485 Module	Ningtai Technology	UT-8890

6.2 Test Environment

- The altitude of the test site shall not exceed 2000 m
- Atmospheric pressure: 86–106 kPa
- Ambient temperature during equipment operation: 20 ± 5 °C
- Daily average relative humidity: 45%–75%; the equipment shall have no condensation

7 Test Items, Test Methods, Acceptance Criteria, and Test Results

7.1 Appearance and Basic Component Inspection

Includes appearance inspection, equipment inspection, wiring inspection, door lock inspection, and dimension inspection.

7.1.1 Appearance Inspection

Test Method: Inspect the product nameplate, markings, logo, and housing appearance.

Acceptance Criteria: The nameplate, markings, and logo must be correctly and clearly displayed, and the housing must be free from damage and corrosion.

Test Results:

No.	Test Item	Acceptance Criteria	Result
1	Product front face	Nameplate, markings, and logo are correctly and clearly displayed; housing is free from damage and corrosion	Pass
2	Product left side	Same as above	Pass
3	Product right side	Same as above	Pass
4	Product back side	Same as above	Pass
5	Nameplate	Same as above	Pass
6	Logo	Same as above	Pass

7.1.2 Equipment Inspection

Test Method: Compare against the BOM checklist and the design installation drawings to check the installation positions and fastening status of the EMS, PCS, battery boxes, liquid cooling unit, power distribution cabinet, fire protection system, dehumidifier, and other components.

Acceptance Criteria: All equipment must be fixed in the correct position, secure, with no deformation or displacement; connecting screws must be tightened.

Test Results:

No.	Test Item	Acceptance Criteria	Conclusion
1	PCS	All equipment fixed in correct position, secure, no deformation or displacement; connecting screws tightened	Pass
2	EMS	Same as above	Pass
3	Battery Box	Same as above	Pass
4	Liquid Cooling Unit	Same as above	Pass
5	Power Distribution Cabinet	Same as above	Pass
6	Fire Protection Cabinet	Same as above	Pass
7	Dehumidifier	Same as above	Pass
8	Other Components	Same as above	Pass

7.1.3 Line Inspection

Test Method: Inspect item by item according to the electrical drawings:

1. The power cables, communication cables, and auxiliary power cables of each battery cluster are connected correctly and reliably;
2. The power cables, communication cables, and power cables of each combiner cabinet are connected correctly and reliably;
3. The PCS power cables, communication cables, auxiliary power cables, and cooling fan cables are connected correctly and reliably;
4. The EMS communication cables and auxiliary power cables are connected correctly and reliably;
5. The communication cables and power cables of the distribution cabinet are connected correctly and reliably;
6. The fire protection communication cables and power cables are connected correctly and reliably;
7. The grounding cables of each device are grounded correctly and connected reliably.

Judgment Criteria: Cables and copper busbar connections at all points are correct and reliable; the grounding cables and power cables are connected correctly as per the drawings, with clear and correct cable number identification.

Test Results:

No.	Test Item	Judgment Criteria	Conclusion
1	Battery cluster power cables / copper busbar	Cables and copper busbar connections at all points are correct and reliable; the grounding cables and power cables are connected correctly as per the drawings, with clear and correct cable number identification	Pass
2	Battery cluster signal cables	Same as above	Pass
3	High-voltage box power cables	Same as above	Pass
4	High-voltage box signal cables	Same as above	Pass
5	PCS power cables / copper busbar	Same as above	Pass
6	PCS signal cables	Same as above	Pass
7	EMS power cables	Same as above	Pass
8	EMS signal cables	Same as above	Pass
9	Liquid cooling unit power and signal cables	Same as above	Pass
10	Dehumidifier power and signal cables	Same as above	Pass
11	Fire protection power and signal cables	Same as above	Pass

7.1.4 Door Lock Inspection

Test Method: Use the key to unlock and lock each door lock one by one, and observe each door body.

Acceptance Criteria: The door lock function is normal, with no deformation or damage.

Test Results:

No.	Test Item	Acceptance Criteria	Conclusion
1	Door Lock Appearance and Function	The door lock function is normal, with no deformation or damage	Pass

7.1.5 Dimensional Inspection

Test Method: Use a tape measure to measure the dimensions of the cabinet in all directions and compare them with the design drawings.

Acceptance Criteria: Refer to ISO 2768-1:1989 "General Tolerances — Part 1: Tolerances for Linear and Angular Dimensions":

Table 1 Limit Deviations for Linear Dimensions (mm)

Tolerance Class	0.5–3	>3–6	>6–30	>30–120	>120–400	>400–1000	>1000–2000	>2000–4000
Fine (f)	±0.05	±0.05	±0.1	±0.15	±0.2	±0.3	±0.5	—
Medium (m)	±0.1	±0.1	±0.2	±0.3	±0.5	±0.8	±1.2	±2
Coarse (c)	±0.2	±0.3	±0.5	±0.8	±1.2	±2	±3	±4
Very Coarse (v)	—	±0.5	±1	±1.5	±2.5	±4	±6	±8

Length direction deviation $\leq \pm 1.2$ mm; width direction deviation $\leq \pm 1.2$ mm; height direction deviation $\leq \pm 2$ mm.

Test Results:

No.	Test Item	Acceptance Criteria	Conclusion
1	Length Direction	Equipment dimensional deviation ≤ 10 mm	Pass
2	Width Direction	Equipment dimensional deviation ≤ 10 mm	Pass
3	Height Direction	Equipment dimensional deviation ≤ 10 mm	Pass

7.2 Functional Test

7.2.1 Battery Cluster Power-On Inspection

Test Method:

1. Measure the B+/B- voltage of each battery PACK and the high-voltage box;
2. Close the circuit breaker of the high-voltage box;
3. Use a CAN box to connect the computer to the high-voltage box, open the main controller, and read the battery cluster data information.

Acceptance Criteria: PACK voltage, battery cluster voltage, and maximum voltage difference shall comply with the standards (PACK voltage 134.4–172.8 V, voltage difference <0.5 V; battery cluster voltage 672–864 V, voltage difference <2 V). The high-voltage box shall be powered normally with no alarms. The voltages of each battery cluster, each PACK, and each cell shall be normal, and the data from each temperature sensor shall be normal.

Test Results:

Item	Standard Value	Sample	PACK No.	Min. Value	Max. Value	Voltage Difference	Conclusion
Battery Cluster Inspection	134.4–172.8 V	1	#1	Vout (V)	Vout (V)	—	Pass
Battery Cluster Inspection	672–864 V	1	—	Vout (V)	Vout (V)	—	Pass
PACK Max. Voltage Difference Inspection	Difference 0–0.5 V	1	—	Vout (V)	Vout (V)	0–0.5	Pass

7.2.2 Power-On Process Inspection

Test Method:

1. Close the AC-side circuit breaker;
2. Close the circuit breakers of the liquid cooling unit, fire protection, fan, 24V power supply, socket, lighting, high-voltage box power supply, etc.;
3. Close the battery cluster switch.

Acceptance Criteria: The system operates normally, with no alarms and no protection actions during the startup process.

Test Results:

No.	Test Item	Acceptance Criteria	Conclusion
1	Power-on Process	The system operates normally, with no alarms and no protection actions during the startup process	Pass

7.2.3 EMS Data Inspection

Test Method: After the system is powered on, log in to the EMS local platform and the cloud platform respectively to view platform data.

Pass Criteria: The data on both the EMS local platform and the cloud platform remains normal at all times.

Test Results:

No.	Test Item	Pass Criteria	Conclusion
1	EMS Data Inspection	The data on both the EMS local platform and the cloud platform remains normal at all times	Pass

7.2.4 Battery Cluster Information Check

Test Method:

1. Log in to the EMS local platform and the cloud platform;
2. Check the cluster voltage, cluster current, cluster SOC, chargeable capacity, dischargeable capacity, single-charge capacity, single-discharge capacity, cumulative charge capacity, cumulative discharge capacity, maximum cell voltage, minimum cell voltage, average temperature, maximum cell temperature, minimum cell temperature, cell SOH, insulation R+, insulation R-, average SOC, and other information.

Pass Criterion: The battery cluster information is correct.

Test Result:

No.	Test Item	Pass Criterion	Conclusion
1	Battery Cluster Information Check	The battery cluster information is correct	Pass

7.2.5 Battery Cluster Terminal Voltage Measurement Accuracy Test

Test Method:

1. Use a multimeter voltage range to measure the battery PACK terminal voltage V1;
2. Read the battery PACK terminal voltage V2 from the EMS local/cloud platform;
3. Calculate the terminal voltage measurement error $(V2-V1)/V1$;
4. Take the maximum error calculated during the test.

Acceptance Criteria: Measurement error $\leq \pm 5\%$.

Test Results:

Item	Standard Value	Sample	PACK No.	Measured Value Vout (V)	EMS Data Vout (V)	BMS Master Vout (V)	Voltage Difference	Conclusion
PACK Voltage Accuracy Test	-0.50%~+0.50%	1	#1	-0.50%	-0.50%	—	—	Pass
Same as above	Same as above	2	—	—	—	—	—	Pass
Same as above	Same as above	3	—	—	—	—	—	Pass
Same as above	Same as above	4	—	—	—	—	—	Pass
Same as above	Same as above	5	—	—	—	—	—	Pass
Battery Cluster Voltage Accuracy Test	-0.50%~+0.50%	1	—	-0.50%	-0.50%	—	—	Pass

7.2.6 PCS Terminal Voltage Accuracy Test

Test Method:

1. Use a multimeter voltage range to measure the PCS DC-side voltage V1 and the AC-side three-phase voltages VA1, VB1, VC1;
2. Read the PCS DC-side voltage V2 and the AC-side three-phase voltages VA2, VB2, VC2 from the EMS local/cloud platform;
3. Calculate the terminal voltage measurement errors $(V2-V1)/V1$, $(VA1-VA2)/VA1$, $(VB1-VB2)/VB1$, $(VC1-VC2)/VC1$;
4. Take the maximum value of the errors calculated during the test process.

Acceptance Criteria: Measurement error $\leq \pm 5\%$, refer to the PCS specification.

Test Results:

Item	Standard Value	Sample	Category	Measured Value	Platform Data	Voltage Difference	Conclusion
PCS Terminal Voltage Accuracy Test	-0.50%~+0.50%	1	Phase A Voltage	-0.50%	0.50%	—	Pass
Same as above	Same as above	1	Phase B Voltage	—	—	—	Pass
Same as above	Same as above	1	Phase C Voltage	—	—	—	Pass
Same as above	Same as above	1	DC Voltage	—	—	—	Pass

7.2.7 Lighting Inspection

Test Method: Open and close the battery compartment door, and observe the lighting status.

Pass Criteria: Lighting functions normally.

7.2.8 PCS Cooling Fan Inspection

Test Method:

1. Start the PCS operation;
2. If the PCS heat sink temperature exceeds the set value, observe the PACK fan action;
3. Stop the PCS operation;
4. Observe the fan action again.

Judgment Criteria: When the PCS charge/discharge active/reactive power is below the set value (e.g., 1% of rated power), the fan starts when the PCS heat sink temperature exceeds the set temperature (80 °C), until the heat sink temperature drops to the set temperature (60 °C); when the PCS charge/discharge active/reactive power is above the set value (e.g., 1% of rated power), the fan starts when the PCS heat sink temperature exceeds the set temperature (60 °C), until it drops to the set temperature (50 °C).

Test Results:

No.	Test Item	Conclusion
1	Fan airflow direction	Pass
2	Fan control logic	Pass

7.2.9 Liquid-Cooling Unit Data Inspection

Test Method:

1. Observe the cooling start temperature value / heating start temperature value of the liquid-cooling unit;
2. Compare the liquid-cooling data on the EMS local interface with that on the cloud;
3. Manually adjust the cooling start temperature value / heating start temperature value of the liquid-cooling unit and observe the operating status.

Judgment Criteria:

1. When the PCS is operating: cooling starts when the maximum temperature ≥ 35 °C; water-circulation heat preservation is entered when the temperature ≤ 20 °C; heating starts when the temperature ≤ 5 °C; water-circulation heat preservation is entered when the temperature rises back to 15 °C.
2. When the PCS is not operating: cooling starts when the maximum temperature ≥ 40 °C; TMS stops when the temperature ≤ 35 °C; heating starts when the temperature ≤ 5 °C; TMS stops when the temperature rises back to 15 °C.

Test Results:

No.	Test Item	Judgment Criteria	Conclusion
1	Liquid-Cooling Unit Data Inspection	Control logic is correct	Pass

7.2.10 Fire Protection Inspection

Test Method: Observe the fire protection system status and feedback information on the EMS local/cloud platform.

Acceptance Criteria: The fire protection system operates normally and the feedback is correct.

Test Results:

No.	Test Item	Conclusion
1	Operating Status	Pass
2	Fault Feedback	Pass

7.2.11 Emergency Stop Switch Inspection

Test Method:

1. Issue a charge/discharge command at the system rated power via the local/cloud EMS;
2. Press the emergency stop switch;
3. Observe the system operating status and indicator light status.

Pass Criteria: After the emergency stop switch is pressed, the system stops charging/discharging and the emergency stop indicator lights up; after the emergency stop switch is released, the system resumes charging/discharging and the emergency stop indicator goes off.

Test Results:

No.	Test Item	Conclusion
1	Status feedback is correct	Pass
2	Logic is correct	Pass

7.2.12 Simulated BMS Alarm Test

Test Method:

1. Observe the current BMS charge/discharge current, cell voltage, and cell temperature values;
2. Set the host-configured alarm value lower than the current value;
3. Observe the operating status of the entire system;
4. Set the host-configured alarm value higher than the current value;
5. Observe the operating status of the entire system.

Acceptance Criteria: Meets the technical standards.

Test Results:

No.	Alarm Type	Acceptance Criteria	Conclusion
1	Cell Overvoltage	Meets the technical standards	Pass
2	Cluster Overvoltage	Meets the technical standards	Pass
3	Cell Over-Discharge	Meets the technical standards	Pass
4	Cluster Over-Discharge	Meets the technical standards	Pass
5	Discharge Overcurrent	Meets the technical standards	Pass
6	Charge Overcurrent	Meets the technical standards	Pass
7	Charge Overtemperature	Meets the technical standards	Pass
8	Discharge Overtemperature	Meets the technical standards	Pass
9	SOC Alarm	Meets the technical standards	Pass

7.2.13 Simulated PCS Alarm Test

Test Method:

1. Simulate PCS undervoltage alarm;
2. Simulate PCS phase reversal alarm;
3. Observe PCS status and charge/discharge status.

Acceptance Criteria: When the alarm occurs, the system stops charging and discharging; once the alarm is cleared, normal charging and discharging resume.

Test Results:

No.	Alarm Type	Acceptance Criteria	Conclusion
1	Undervoltage	Meets technical standards	Pass
2	Phase Reversal	Meets technical standards	Pass

7.2.14 Simulated BMS and EMS Communication Alarm Test

Test Method:

1. Disconnect the communication cable between BMS and EMS;
2. Observe the EMS status locally or in the cloud;
3. Restore the communication cable between BMS and EMS;
4. Observe the EMS status locally or in the cloud.

Pass Criteria: The system stops charging and discharging and generates a system alarm when the communication cable is disconnected; the system resumes normal charging and discharging after the communication cable is restored.

Test Results:

No.	Test Item	Pass Criteria	Conclusion
1	Simulated BMS and EMS Communication Alarm	Disconnect → stop operation and alarm; reconnect → resume	Pass

7.2.15 Simulated PCS and EMS Communication Alarm Test

Test Method:

1. Disconnect the communication cable between the PCS and the EMS;
2. Observe the EMS status locally or on the cloud;
3. Restore the communication cable between the PCS and the EMS;
4. Observe the EMS status locally or on the cloud.

Acceptance Criteria: When the communication cable is disconnected, the system stops charging and discharging and generates a system alarm; after the communication cable is restored, the system resumes normal charging and discharging.

Test Results:

No.	Test Item	Acceptance Criteria	Conclusion
1	Simulated PCS and EMS communication alarm	Shutdown and alarm on cable removal, recovery on cable restoration	Pass

7.2.16 Simulated BMS–PCS Communication Alarm Test

Test Method:

1. Disconnect the communication line between the PCS and the BMS;
2. Observe the local or cloud status of the EMS;
3. Restore the communication line between the PCS and the BMS;
4. Observe the local or cloud status of the EMS.

Pass Criteria: When the communication line is disconnected, the system stops charging and discharging and generates a system alarm; after the communication line is restored, the system returns to normal charging and discharging.

Test Result:

No.	Test Item	Pass Criteria	Conclusion
1	Simulated BMS–PCS Communication Alarm	Disconnection triggers stop-and-shutdown alarm, reconnection restores operation	Pass

7.2.17 Simulated Communication Alarm Test Between BMS and Liquid Cooling Unit

Test Method:

1. Disconnect the communication cable between the air conditioner and the BMS;
2. Observe the EMS local or cloud status;
3. Restore the communication cable between the air conditioner and the BMS;
4. Observe the EMS local or cloud status.

Pass Criteria: When the communication cable is disconnected, the system stops charging/discharging and generates a system alarm; after the communication cable is restored, the system resumes normal charging/discharging.

Test Result:

No.	Test Item	Pass Criteria	Conclusion
1	Simulated Communication Alarm Between BMS and Liquid Cooling Unit	Disconnect triggers shutdown and alarm; reconnect restores operation	Pass

7.2.18 Insulation Test

Test Method: Measure the insulation resistance between the input/output terminals of the integrated cabinet and the enclosure, as well as the insulation resistance between the B+/B– terminals of the high-voltage box and the enclosure, at 3110 VDC @ 10s.

Acceptance Criteria: The insulation resistance shall not be less than 1 MΩ.

Test Results:

Item	Standard Value	Sample	Category	Measured Value (Ω)	Conclusion
Insulation Test	≥1 MΩ	1	B+ to enclosure	—	Pass
Insulation Test	≥1 MΩ	1	B– to enclosure	—	Pass

7.2.19 Withstand Voltage Test

Test Method: Measure the leakage current between the input/output terminals of the integrated cabinet and the enclosure, as well as the leakage current between the high-voltage box B+/B- and the enclosure, at 3110 VDC for 60 s.

Acceptance Criterion: Leakage current < 1 mA.

Test Results:

Item	Standard Value	Sample	Category	Leakage Current (mA)	Conclusion
Withstand Voltage Test	<1 mA	1	B+ to Enclosure	—	Pass
Withstand Voltage Test	<1 mA	1	B- to Enclosure	—	Pass

7.2.20 SOC Calibration Test

Test Method:

1. The EMS local/cloud control system charges at 1/2 of the rated power;
2. Observe the BMS SOC data until the BMS over-discharge protection is triggered.

Acceptance Criteria: The calibrated SOC value at full charge is 100%.

Test Results:

No.	Test Item	Acceptance Criteria	Conclusion
1	SOC Calibration Test	SOC calibrated to 100%	Pass

7.2.21 Full Power Test

Test Method:

1. Discharge at full power load through the local/cloud EMS control system until the cut-off condition, followed by full-power charging until the cut-off condition;
2. Observe the operating status of the entire system throughout the process.

Pass Criteria: No alarms and no protective actions occur during the full-power charge and discharge process, and the charge/discharge process is not interrupted.

Test Results:

No.	Test Item	Pass Criteria	Conclusion
1	Full Power Test	No alarm or protective action during the charge/discharge process, and the process is not interrupted	Pass

7.2.22 Charge/Discharge Efficiency Test

Test Method:

1. The EMS local/cloud control system discharges at full power to the cut-off condition, then charges at full power to the cut-off condition, and then discharges at full power to the cut-off condition again;
2. Use a power quality analyzer to read the full-capacity charge quantity W1 and the full-capacity discharge quantity W2;
3. Calculate the average efficiency $\eta = W2/W1 \times 100\%$.

Pass Criteria: The average efficiency shall be greater than the system design requirement.

Test Results:

Item	Standard Value	Sample	Category	Charge Quantity	Discharge Quantity	Efficiency	Conclusion
Charge/Discharge Efficiency Test	Meets design requirement	1	Full power	—	—	—	Pass

7.2.23 Temperature Difference Test

Test Method:

1. The EMS local/cloud control system discharges at full power to the cut-off, then charges at full power to the cut-off, and then discharges at full power to the cut-off again;
2. Record the temperature values of each temperature sensor;
3. Calculate the temperature difference.

Acceptance Criterion: The maximum temperature difference shall not exceed 10 °C.

Test Results:

Item	Standard Value	Power (kW)	Battery Cluster No.	Max Temperature (°C)	Min Temperature (°C)	Temperature Difference (°C)	Conclusion
Temperature Difference Test	<10 °C	Full Power	#1	—	—	—	Pass

7.2.24 Pressure Difference Test

Test Method:

1. The EMS local/cloud-based control system discharges at full power to the cutoff, then charges at full power to the cutoff, and then discharges at full power to the cutoff again;
2. Record the voltage of each cell and calculate the maximum pressure difference.

Acceptance Criteria: The maximum pressure difference shall not exceed 200 mV.

Test Results:

Item	Standard Value	Power (kW)	Battery Cluster No.	Maximum Cell Voltage (mV)	Minimum Cell Voltage (mV)	Pressure Difference (mV)	Conclusion
Pressure Difference Test	<200 mV	Full Power	#1	—	—	—	Pass

7.2.25 SOC Accuracy Test

Test Method:

1. The EMS local/cloud control system discharges at full power to the cutoff, then charges at full power to the cutoff, and then discharges at full power to the cutoff;
2. Use a power quality analyzer to calculate the charging SOC and discharging SOC, and compare them with the BMS data.

Pass Criteria: The SOC error shall not exceed 5%.

Test Results:

Item	Standard Value	Power	Measured Value	Calculated Value	Deviation	Conclusion
SOC Accuracy Test	<5%	Rated Power	—	—	—	Pass

7.2.26 Capacity Test

Test Method:

1. The EMS local/cloud control system discharges at full power until cut-off, then charges at full power until cut-off, and then discharges at full power until cut-off;
2. Use a power quality analyzer to calculate the charge capacity and discharge capacity;
3. Calculate the capacity difference.

Pass Criterion: Capacity shall be no less than 95% of the rated capacity.

Test Result:

Item	Standard Value	Power	Measured Value	Conclusion
Capacity Test	>95%	Rated Power	—	Pass

7.2.27 Software Version Number Verification

Test Method:

1. Verify the main control software version;
2. Verify the slave control software version.

Acceptance Criteria: The version numbers are correct.

Test Results:

No.	Category	Version Number	Conclusion
1	BMS Main Control	—	Pass
2	BMS Slave Control	—	Pass

7.2.28 BMS OTA Upgrade Test

Test Method:

1. Upgrade the BMS main control program and slave control program through the EMS cloud platform, observe the upgrade process and the phenomenon after the upgrade, and repeat 10 times;
2. Upgrade the BMS main control program and slave control program through the BMS main control host software, observe the upgrade process and the phenomenon after the upgrade, and repeat 10 times.

Pass Criteria: The program upgrades normally and runs normally after the upgrade.

Test Results:

No.	Test Item	Conclusion
1	Cloud platform upgrade normal	Pass
2	BMS host software upgrade normal	Pass

7.2.29 Noise Test

Test Method: Measure the noise of the equipment during full-load operation at horizontal distances of 1 m and 1.2 m from the equipment using a sound level meter, and record the maximum value.

Acceptance Criterion: Refer to IEC 62933-2-1:2017 (Unit parameters and testing): Noise shall not exceed 80 dB.

Test Result:

Item	Standard Value	Measured Value	Conclusion
Noise Test	≤80 dB	—	Pass

7.2.30 Waterproof Test

Test Method: IPX4: Use a spray head with 121 spray holes of 0.5 mm diameter, with water flow set to 10 L/min, sample-to-nozzle distance of 300–500 mm, and a test duration of 10 min.

Pass/Fail Criteria: No water ingress damage inside the equipment; generally, even if water enters, it shall not be sufficient to affect normal operation or compromise safety. Refer to IEC 60529:2013.

Test Conditions:

- Ambient temperature: 15–35 °C; ambient humidity: 25–75% RH; atmospheric pressure: 86–106 kPa
- Test equipment: ZC1207 IPX3-X6 waterproof grade testing machine
- Inspect the enclosure for water ingress after the test

Reference Standard: IEC 60529:2013

Test Result: After the IPX4 test, the louver side of the equipment was exposed to spraying, and obvious water marks were found inside the equipment.

7.2.31 Anti-Reverse-Power Test

Test Method:

1. Set the anti-reverse-power threshold P_{nl} and the operating time T_d (to meet the test requirements);
2. The system implements two operating modes — peak shaving and valley filling, and real-time dispatch — each of which must be tested under both charging and discharging states;
3. Under the above four operating conditions, adjust the electronic load power so that the electronic load operates within the range of 0–50 kW;
4. The reverse-power duration shall be no less than 5 s;
5. Use a power quality analyzer to record parameters such as the active power at the energy storage grid-connection point and the PCC point.

Acceptance Criteria: The anti-reverse-power operating time shall not exceed 2 s.

Test Results:

Mode	Average Operating Time (s)	Conclusion
Peak Shaving and Valley Filling (Charging)	1.581	Pass
Peak Shaving and Valley Filling (Discharging)	1.931	Pass
Real-Time Dispatch (Charging)	1.897	Pass
Real-Time Dispatch (Discharging)	1.663	Pass

7.2.32 Anti-Overload Test

Test Method:

1. Set the anti-overload power point P_{gz} and the action time T_d (meeting the test requirements);
2. The system implements three modes: peak shaving and valley filling, dynamic expansion, and real-time scheduling. Each mode needs to operate in both charging and discharging states;
3. Under the six operating conditions mentioned above, adjust the electronic load power so that the electronic load operates in the range of 0–50 kW;
4. The overload duration shall not be less than 5 s;
5. Use an analyzer to record parameters such as active power at the energy storage grid-connection point and the PCC point.

Acceptance Criteria: The anti-overload action time shall not be greater than 2 s.

Test Results:

Mode	Average Action Time (s)	Conclusion
Peak Shaving and Valley Filling (Charging)	1.663	Pass
Peak Shaving and Valley Filling (Discharging)	1.651	Pass
Dynamic Expansion (Charging)	1.710	Pass
Dynamic Expansion (Discharging)	—	Pass
Real-Time Scheduling (Charging)	—	Pass
Real-Time Scheduling (Discharging)	—	Pass

7.2.33 Stability Test

Test Method:

1. Configure the power station electricity price parameters on the cloud platform and generate a planned power curve, then dispatch it to the local EMS;
2. The operating parameters include anti-reverse-flow parameters, anti-overload parameters, power station capacity, SOC upper and lower limits, meter configuration, communication configuration, etc.;
3. Start the power station so that the energy storage system participates in on-site peak shaving and valley filling. Use the power station power quality analyzer to record parameters such as the active power of the energy storage system and the grid-connection point;
4. Where conditions allow, manually tune the overload and reverse-flow parameters so that the conditions for triggering the protection function are satisfied.

Pass Criteria:

1. Both the cloud platform and the local system operate normally, including whether the energy storage system charge and discharge satisfy the planned peak shaving and valley filling operation;
2. All levels of protection functions operate normally, including SOC, overload, and reverse-flow protections;
3. Power station data monitoring is normal, including real-time electrical parameters, cloud platform interface information, and power data;
4. The power equipment and monitoring equipment experience no crashes or freezes, and access is normal.