20-Foot Containerized Sodium-Ion Battery
Liquid-Cooled Energy Storage System

Technical Solution

Contents

1. Definitions of terms

name	paraphrase
Electrochemical energy storage station (EESS)	A power station that uses electrochemical cells as energy storage elements to store, convert and release electric energy.
Power conversion system (PCS)	A system for bidirectional energy conversion between energy storage battery and AC power grid.
A cell, Cell	An electrochemical device consisting of an electrode and an electrolyte, which constitutes the smallest unit of a battery module, can store the obtained electric energy in the form of chemical energy and convert the chemical energy into electric energy.
Battery module battery module	The battery assembly, which is composed of a single cell connected in series, parallel or series-parallel manner and has only one pair of positive and negative output terminals, may also include components such as a housing, management and protection devices.
Battery cluster battery cluster	The battery module is a battery assembly that is connected in series, parallel or series-parallel mode and can operate independently after being connected with the energy storage converter and ancillary facilities. It should also include battery management system, monitoring and protection circuit, electrical and communication interface and other components.
Battery stack Battery stack	A collection of batteries that can control the power input and output as a whole connected to the same power conversion system.
Battery management unit (BMU)	Manage a battery module, monitor the state of the battery (voltage, temperature, etc.), and provide communication interface for the battery.
Battery management system (BMS)	A system that monitors the state of the battery (temperature, voltage, current, charge state, etc.) and provides a communication interface and protection for the battery.
energy management system (EMS)	Manage an energy storage system. Monitor system overview, equipment monitoring, operation revenue, fault alarm, statistical analysis, energy management, etc.
coolant passage	Generally speaking, there are two forms of air cooling and liquid cooling. Air cooling, as a traditional cooling method, is mature in technology and widely used; the characteristics of liquid cooling are that it uses liquid cooling, which has higher cooling efficiency, and does not need air ducts, making the overall volume smaller and the energy ratio higher.

2. Overall solution of energy storage battery system

This scheme is a sodium ion electrochemical energy storage system, which adopts 20-foot container for easy lifting and transportation. The battery system has a high degree of integration and strong environmental adaptability, which effectively reduces the workload of on-site installation, debugging and later maintenance.

Energy storage battery system configuration: including battery cluster (including BMS battery management system), DC current collection system, automatic gas fire extinguishing system, liquid cooling temperature control system, video surveillance, communication system, container, in-box connection cable, lighting and power distribution, etc.

The 20-foot battery compartment is shown in Figure 1. The rated capacity of the entire DC side battery system is 1.08864MWh, and the design voltage level is 1500VDC.

The energy storage storage warehouse adopts a non-stepping design, which is convenient for equipment installation and maintenance, and meets the requirements of safe and reliable long-term operation of the entire energy storage system.

Figure 1 1.08864MWH liquid cooled battery compartment

3. Battery grouping design scheme for energy storage system

3.1 General introduction of energy storage DC side system group

The battery compartment is designed with a voltage level of 1500VDC, and the battery system has a rated voltage of 576VDC. It is designed for a charging and discharging power of 0.5P, integrating the energy storage batteries into a 20-foot non-enclosed container (or prefabricated cabin), making on-site installation convenient. The main parameters of the 1.08864MWh sodium-ion battery energy storage DC side are shown in Table 1. The topology diagram of the DC side of the energy storage system is shown in Figure 2.

Energy storage system containers, based on modular design, have high energy density and are integrated into container systems, reducing customers' investment costs and saving on-site construction costs and space. The battery system of this solution requires only simple infrastructure to complete one-stop installation; it just needs to connect power cables and secondary communication lines on site, making it convenient and quick, reducing engineering complexity, and saving costs.

Table 1 Main parameters of DC side of 1.08864WH lithium battery energy storage

Overall parameters of the battery system	
Type of battery cell	3.1V/210Ah, sodium ion
System battery configuration	One packet is 1P48S, and one cluster is 4 packets, a total of 9 clusters
Battery rated capacity	1.08864MWh
Battery voltage range	420V~1497.6V (monomer 2.0~3.9V)
Rated discharge power	0.5P/1MW
Overall parameters of liquid-cooled battery compartment	
Size of the site (length x width)	6058×2438mm
Maximum lifting and transportation weight and size of a single unit	33T ,L6058*W2438*H2896mm
levels of protection	IP54
Operating ambient temperature range	-30℃ ~ 50℃
Work altitude	Less than 2km (>2km requires design change and customization)
Battery temperature control mode	liquid cooling

fire extinguisher system	Battery box aerosol automatic fire extinguishing + automatic fire and fire extinguishing system (the agent can be selected according to the project area) + water fire extinguishing system
External system communication interface	Support RS485, Ethernet, CAN
External system communication protocol	Support Modbus RTU, Modbus TCP, IEC104, IEC61850

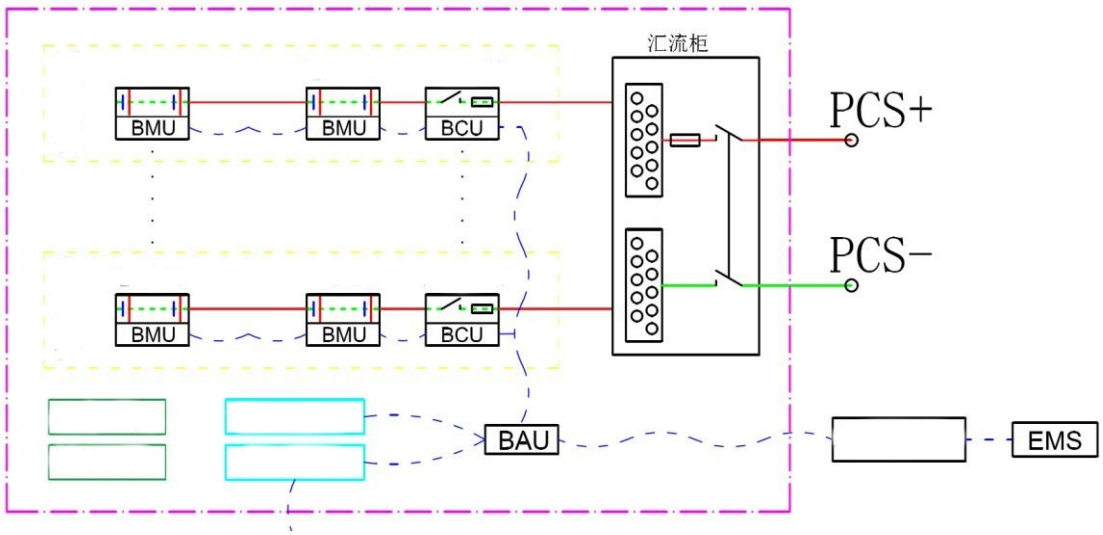


Figure 2 Topology diagram of 1.08864MWH DC side energy storage system

3.2 Design parameters of energy storage battery system

The group parameters of 1MWh battery system are shown in Table 2. It is equipped with a variety of communication interfaces to communicate with energy management system (EMS) and energy storage converter (PCS). After output from the battery system through the junction cabinet, it is connected to the storage

The converter PCS is connected with the PCS to form an energy storage subsystem that outputs AC power and connects to the grid.

Table 2 1MWH battery system grouping parameter

NO.	Item Description	Unit Topology	Rated Voltage (V)	Rated Capacity (Ah)	Store Electricity (Kwh)	Remarks
1	battery box (keep in the mouth BMU)		148.8	two hundred and ten	thirty one point two four eight	Cell 1 and 48 are connected in series 1 liquid cooled battery box, including fuse, temperature and voltage measurement.
2	Battery cluster (including BCMU)		576	210	120.96	4 battery boxes and 1 High voltage boxes are connected in series The 1P192S form a battery cluster.
3	Battery compartment (keep in the mouth BAU)		576	1890	1088.64	Nine battery clusters are connected in parallel to form the maximum rated energy 1.08864MWh@single cluster Four battery boxes

3.3 Battery cell

The battery system uses sodium ion square aluminum shell (210Ah/3.1V) battery cells, which have the characteristics of high specific energy, high life, low cost, safety and no pollution, etc., and has been widely used in the field of electrochemical energy storage.
Battery cells

The basic performance is shown in Table 3, the cell environmental adaptability performance table is shown in Table 4, and the cell safety and reliability performance table is shown in Table 5.

Table 3 Basic performance of battery cells

NO	Item	Performance	Remarks
1	Nominal capacity	210.00Ah@0.50C In the environment of 25.0±3.0℃	
2	Nominal voltage	3.1V	
3	Charging cut-off voltage	3.9±0.05V	
4	Discharge cutoff voltage	2.0±0.05V	
5	Internal resistance of the dc	≤0.5mΩ	
6	Charging temperature range	-20~45℃	
7	Discharge temperature range	-30~60℃	
8	Rated charging current	0.5C（25±2℃）	
9	Maximum charging current	1C（25±2℃）	
10	Rated discharge current	0.5C（25±2℃）	
11	Maximum discharge current	1C	
12	Cycle life	4000 times (25±2℃,0.5C/0.5C,70% EOL)	The calendar life is more than 10 years
13	Form factor of the battery	173.6X71.25X204.3±0.5mm	
14	Battery weight	4.50±0.50Kg	

Table 4 Battery safety performance table

order number	test item	performance criteria	Test conditions and methods
1	Vibration test	No fire, no explosion, no leakage	Reference: UL1642-16 After standard charging, the battery should withstand a vibration amplitude of 0.8mm and a vibration frequency Change at a rate of lHz/min within the range of 10-55HZ and vibrate for 60min.
2	Heat test	No fire, no explosion	Reference: GB 38031 8.1.5 After standard charging, the oven temperature was increased to 130℃ ± at 5 ± 2℃/min 2℃ Retain at this temperature for 30min and observe for 1 hour.

3	Short circuit test	No fire, no explosion	Reference: GB 38031 8.1.4 After standard charging, the positive terminal and negative terminal of the battery are connected at 25℃±3℃ The terminal is short-circuited externally for l0min (external line resistance <5mΩ), and observed for 1 hour time.
4	Overcharge test	No fire, no explosion	Reference: GB 38031 8.1.3 After standard charging, the battery is charged at 1C constant current to 5.0V at 25℃±3℃ Or stop charging after 120% SOC and observe for 1 hour.
5	Overexposure test	No fire, no explosion	Reference: GB 38031 8.1.2 After standard charging, the battery is discharged at 1C current at 25℃±3℃ When the discharge time reached 90min, observe for 1 hour.
6	Heavy impact	No fire, no explosion	Reference: UL 1642-14 After standard charging, a cylindrical rod with a diameter of 15.8mm is placed on the battery In the center, a 9.1Kg weight was dropped vertically from a height of 610mm The center of the battery.
7	fall-down test	No fire, no explosion	Reference: GB/T 31485 6.2.5 After standard charging, the positive and negative terminals of the battery sample are lowered from a height of Free fall to the cement floor at a height of 1.0m and observe for 1 hour.
8	Extrusion test	No fire, no explosion	Reference: GB 38031 8.1.7 After standard charging, the battery is placed between the two squeezing surfaces of the squeezing device, round The column battery core shaft is parallel to the extrusion plane, with an extrusion speed of less than 2m/s, Gradually increase the pressure until the deformation reaches 15% or the extrusion pressure reaches l00kN or 1000 times the weight of the battery, keep pressure for 10min and observe for 1 hour.
9	Low pressure test	No fire, no explosion	Reference: UL1642-19 After standard charging, the battery is stored for 6 hours under absolute pressure of 11.6Kpa and temperature of 20 ±5℃.

4. BMS battery management system

4.1 Overview of BMS system

The Battery Management System (Battery Management System, abbreviated as BMS), as a core component of the battery system, serves as a bridge between the battery pack and external devices. It determines the utilization rate of the battery, and its performance is crucial to the cost and safety of energy storage systems. The BMS collects,

processes, and stores critical information during the operation of the battery pack in real time, exchanges information with external devices, and provides real-time alerts and protection during the operation of the battery pack.

BMS generally adopts multi-level distributed architecture design, and the common three-level architecture is mainly composed of the master control unit (BAU), the master control unit (BCU), the slave control unit (BMU) and the corresponding wiring harness. The system has the characteristics of wide functional coverage, small size, strong anti-interference performance, safety and reliability.

4.2 Functions and characteristics of BMS system

1）The working voltage of the system is 24V, which can meet the needs of various energy storage occasions, and has the function of anti-reverse connection;

2）The system has the function of collecting battery cell voltage and battery pack terminal voltage, with high accuracy and fast speed, and can ensure the reliability of collection by comparing the accumulation of cells and the collection at the terminal;

3）The system has the function of temperature collection and current collection, and can flexibly configure the number of temperature collection and electricity

The flow collection method (divertor or Hall collection) has the characteristics of high precision and high reliability;

4）The system has accurate insulation detection function to ensure the safety and reliability of the battery system;

5）The system uses the collected information of the battery and adopts the independent comprehensive algorithm to calculate the SOC and SOH of the battery in real time, which can obtain excellent accuracy under both dynamic and static conditions of the battery pack;

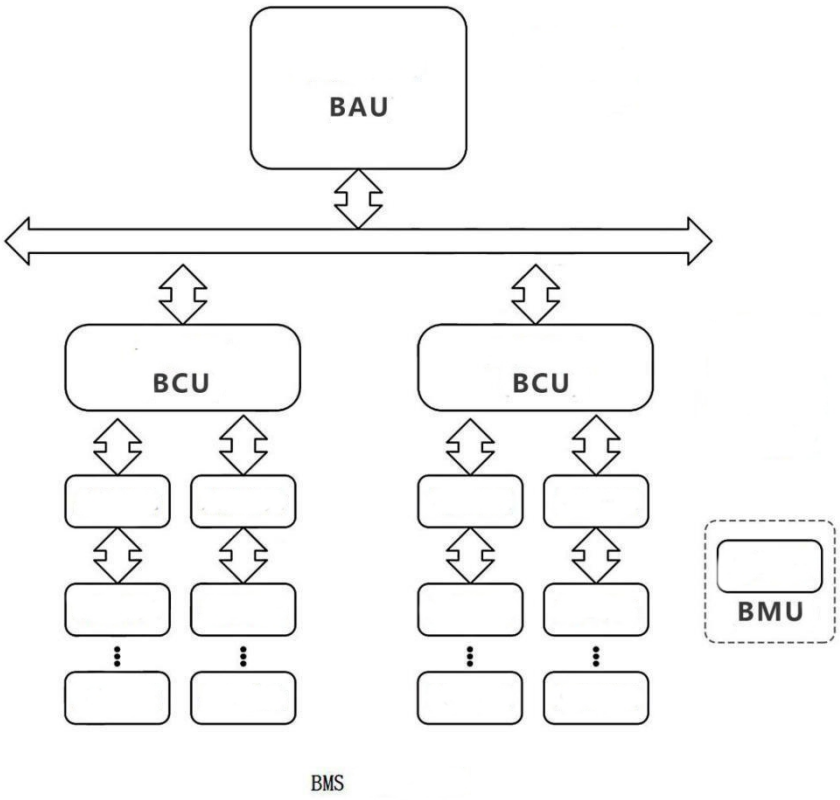
6）According to the collected and calculated information of the battery pack, the working state and fault level of the battery pack are judged in real time, so as to realize the alarm and protection function of the battery pack;

7）The system has rich interface functions, can meet the application of a variety of occasions, convenient to achieve battery pack charge and discharge control, battery pack temperature control and other functions;

8）The system has multiple CAN and RS485 communication interfaces, which can realize information exchange and control with PCS and EMS and other equipment, information transmission with display modules, remote information monitoring, control system and system upgrade functions;

9）The system selects automotive-grade devices and adopts multiple redundant protection measures. The system has high reliability, high stability and high anti-interference performance.

4.3 Principle of BMS system



3 BMS system topology

4.4 BMU From control unit

4.4.1 Overview of the controlled unit

The BMU control unit is a crucial component of the battery management system (BMS). It plays a decisive role in the safe application and extended lifespan of battery packs when used in series. The BMU precisely collects the voltage and temperature of each individual cell, enabling real-time monitoring of battery status. The module features reliable data communication capabilities, allowing it to communicate with the main control unit of the battery management system or other necessary devices during system operation. The latest collection technology is utilized in the design, ensuring high accuracy

The estimates of SOC provide a good physical basis.

4.4.2 Functions and characteristics of the controlled unit

- The battery cell voltage function has the characteristics of high collection accuracy and fast speed; it can be widely used in various types of batteries, compatible with lithium iron phosphate, lithium manganese oxide, lithium titanate, ternary batteries.
- Temperature sampling function: It has the characteristics of high precision and high reliability, supports 52 serial single battery sampling, and can sample up to 32 external temperatures.

■ Passive balancing function: can provide a maximum of 100mA balancing current.

■ isoSPI Communication: The sampled information is uploaded to the main control through isoSPI communication

■ Communication function: serial communication between master and slave is realized, which can be used for program upgrade, PACK fire control and diagnosis, automatic address allocation, etc.

■ 2 high-side output: the maximum sustainable output of a single high-side switch is 1A, and the output current is up to 2A when both channels are open at the same time. The internal status detection is set to realize hardware self-test.

■GPIO output and input: 2 IO open drain output, support PWM wave, two IO input.

■ It has rich self-diagnostic functions and supports functional safety certification requirements.

■ All materials are UL-94V0 flame retardant grade.

4.5 BCU main control unit

4.5.1 Overview of the main control unit

The BCU, the main control unit, is the core of the battery management system. It communicates with the slave units to monitor individual cell voltage and temperature, as well as the overall battery pack voltage, charging and discharging current, and ground insulation resistance. Using appropriate algorithms, it estimates and monitors the internal state of the battery (capacity, SOC, SOH, etc.). Based on this, it manages the charging and discharging of the battery pack, thermal management, insulation testing, cell balancing, and fault alarms. The BCU can exchange data with devices such as PCS, EMS, and human-machine interfaces via communication buses, and communicates with the BMU through a daisy chain.

The application diagram of the main control unit is shown in Figure 4:

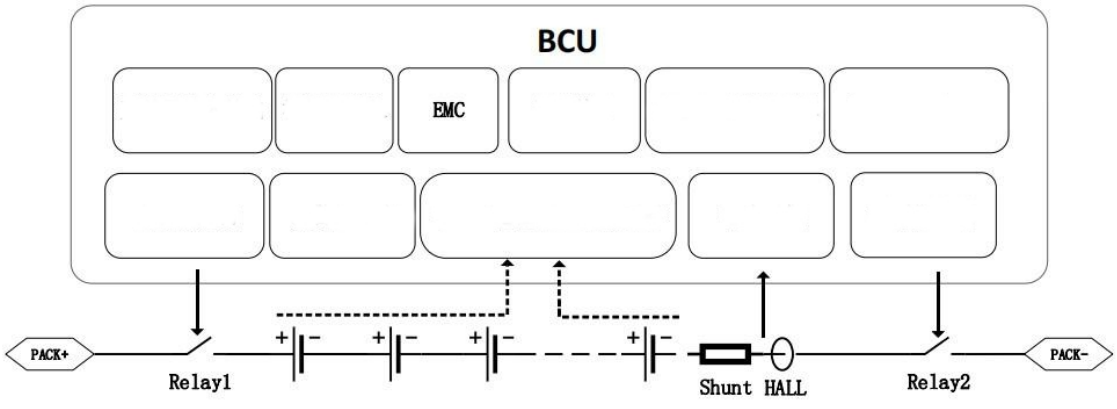


Figure 4 Application functions of the main control unit BCU

4.5.3 Introduction of main control unit function

1. Total battery voltage detection;

2. Battery pack charge and discharge current detection;

3. Battery insulation resistance to ground test;

4. Battery pack charge and discharge management;

5. Battery pack thermal management The system monitors the temperature of each cell during charging and discharging, and responds to the alarm of high temperature, low temperature, large temperature difference and sudden temperature change of each cell;

6. Real-time dynamic estimation of SOC and SOH;

7. BMS system self-test and fault diagnosis alarm;

8. Battery pack fault diagnosis and alarm;

9. Safety protection of various abnormalities and faults;

10. Communicate with other devices such as PCS and EMS;

11. Data storage, transmission and processing

The system can store the latest alarm information, reset information and sampling abnormal information, and export the stored information as required;

4.6 BAU master control unit

4.6.1 Overview of the master control unit

The BAU, or Battery Management Unit, is the control core of the battery management system. It communicates with the main control unit to monitor individual cell voltage and temperature, as well as the overall battery pack voltage, charge-discharge current, and ground insulation resistance. Using appropriate algorithms, it estimates and monitors the internal state of the battery (such as SOC and SOH). Based on this, it manages the charging and discharging, thermal management, insulation testing, cell balancing, and fault alarms for the battery pack. The BAU can also exchange data with devices like PCS, EMS, and human-machine interfaces via communication buses.

4.6.2 Composition of the master control unit

The main components of the control unit are as follows: auxiliary power conversion, MCU and peripheral circuits, real-time clock, CAN communication interface, RS485 communication interface, GPIO input, high and low side switches, dry contact and Ethernet communication interface.

4.6.3 Main features of the master control unit

1) Automotive design: The product software, hardware and structural design are designed according to automotive standards;

2) High security: complete protection function, with multiple redundant protection measures to protect the battery in various over-limit and accidental situations;

3) Strong anti-interference ability: the electromagnetic environment of high power and complex wiring of energy storage system is fully considered in the early stage of design, all components are selected to meet the requirements of automotive level, input and output interfaces and communication interfaces are effectively isolated and filtered, so as to meet the harsh electromagnetic environment of practical application;

4) Accurate signal acquisition and SOC estimation: Select high-precision sampling chips of international famous brands, combine the strengths of various SOC algorithms in the industry, and have intelligent learning function to ensure the accuracy of sampling precision and SOC estimation;

5) Rich external interfaces: rich switch quantities, a variety of communication ports and other input and output interfaces to meet the interface requirements of various projects;

6) Flexible configuration and upgrade. The product can be flexibly configured according to different application requirements by using the upper computer software, and the program can be quickly upgraded through CAN communication port;

4.6.4 Main functions of the master control unit

1） Battery pack charge and discharge management;

2） Battery pack thermal management;

Monitor the temperature of each cell during the process of system charging and discharging, and respond to the alarm of excessive temperature, low temperature, large temperature difference and sudden temperature change of each cell;

3） Real-time dynamic estimation of SOC and SOH;

4） BMS system self-test and fault diagnosis alarm;

5） Battery pack fault diagnosis and alarm;

6） Safety protection of various abnormalities and faults;

7） Communicate with other devices such as PCS and EMS;

8） Data storage, transmission and processing;

The system stores recent alarm information, reset information and sampling abnormal information, and can export the stored information as required.

9） Big data storage and processing (optional):

All the collected information, alarm information, reset information and various abnormal information are stored in the system,

It can be exported conveniently through TF-Card or directly read by Type-C according to needs.

10） Strong system self-inspection function to ensure the normal operation of the system;

11） Ethernet communication support IEC61850 (optional);

12） Support U disk upgrade.

5. Thermal management system

5.1 Design principle of liquid cooling system

The battery will generate heat in the process of charging and discharging, and the working environment has temperature requirements (the best working temperature is generally 20℃ ~30℃). Thermal management of energy storage system refers to the process of effectively controlling and regulating the working temperature of the battery through heating or cooling technology.

The battery compartment employs a liquid-cooling thermal management system, consisting of one liquid-cooling unit and a three-stage liquid-cooling piping system. Its temperature control principle is similar to that of an air conditioner, converting internal circulating air into cooling liquid. The cooling liquid is distributed through three stages of piping to the liquid-cooled plates at the bottom of each battery box, facilitating heat dissipation or absorption for individual battery cells.

5.2 Main functions of thermal management system

The temperature control system of the liquid cooling unit meets the working environment temperature-30℃-55℃; environmental humidity 5%-95%; applicable area altitude less than 4000m, the system design life is not less than 10 years.

The liquid cooling system has the refrigeration function, and can realize the constant temperature control of the coolant through its own regulation. The temperature adjustment range is 18℃~23℃.

The liquid cooling system also features heating capabilities and can control the coolant through its own regulation, with a temperature adjustment range of 18℃ to 30℃. The system heating uses PTC water heaters, which are connected in series in the liquid cooling system piping; the liquid cooling unit employs a dual-system parallel configuration to ensure operational reliability, using dual variable frequency compressors and variable frequency fans to reduce energy consumption.

The liquid cooling system uses 50% ethylene glycol deionized water solution as the cooling medium to ensure that no freezing occurs at the design ambient temperature. After the liquid-cooled unit is installed, it will not affect the sealing performance of the outdoor cabinet and ensures that the protection rating meets the IP55 requirement; the overall noise level of the liquid-cooling system at a distance of 1.0m should not exceed 78db(A) according to the test standard GBT21361. The liquid-cooled unit comes with a 4kw cooling capacity dehumidification function and has a dehumidification duct configured inside the container to ensure the operating temperature and humidity within the cabin, reducing the likelihood of condensation.

The liquid cooling unit uses the CAN communication protocol of the vehicle specification for communication, and the liquid cooling system control directly receives the BMS signal; in the case of BMS signal interruption, the liquid cooling system performs automatic control to ensure that the coolant temperature is maintained at 18℃.

5.3 Effect of liquid cooling temperature control system

The temperature control system works in conjunction with the battery management system to maintain constant temperature for lithium batteries, keeping them within safe parameters and preventing thermal runaway. The safety and capacity degradation of lithium batteries are significantly influenced by temperature. The liquid cooling temperature control system features high heat transfer coefficients, large specific heat capacities, fast cooling speeds, low energy consumption, and can quickly and effectively reduce temperatures. Additionally, it has a compact structure, takes up minimal space, is unaffected by altitude or air pressure, and offers a broader range of applications.

The liquid cooling temperature control system effectively addresses two major issues: first, the cost per unit of electricity, as temperature control can significantly help delay battery capacity degradation; second, safety, effective temperature control can prevent thermal runaway in batteries. The individual cells in the liquid-cooled system can achieve a temperature balance of around 3-5℃, effectively enhancing battery consistency and improving energy utilization throughout the entire lifecycle of energy storage, while reducing the risk of thermal runaway.

The simulation results of temperature rise during charging and discharging in battery box are shown in Figure 5.

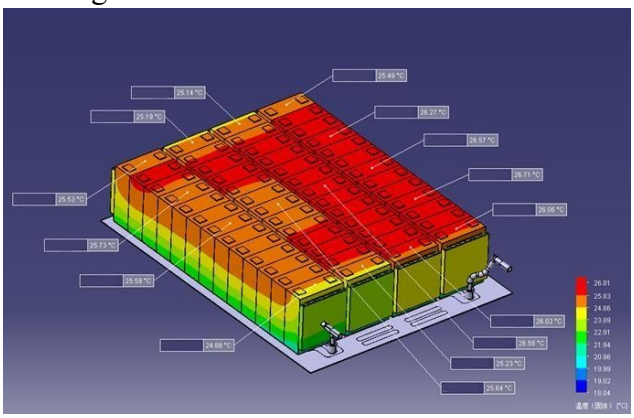


Figure 5 Simulation results of temperature rise during charging and discharging in battery box

6. Fire protection system

6.1 Fire safety system protection strategy

This fire protection scheme for the energy storage system adheres to the design philosophy of "combining prevention and firefighting, with multiple layers of protection."

It employs a multi-level fire protection system that includes mica sheet insulation at the cell level, aerosol fire suppression devices at the battery box level, automatic explosion-proof exhaust systems, and an automatic fire extinguishing system (the type of agent is selected based on specific requirements from overseas projects). The system also comprises early warning devices, automatic fire suppression devices, exhaust devices, and fire sprinkler systems. For a workflow diagram of the fire safety system protection strategy, see Figure 6.

1. The battery box is equipped with a built-in thermal start aerosol fire extinguishing device, and the BMU linkage management is used to realize the fire status monitoring of the battery box;

2. When any cell over-temperature and aerosol device is activated, the battery box level (PACK) aerosol fire extinguishing system starts to submerge protection, which will suppress the early state of thermal runaway in the battery pack;

3. When the thermal runaway in the battery pack cannot be controlled under extreme conditions and spreads to the container, the fire extinguishing system starts the full container flooding gas fire extinguishing function and sends fire alarm to the container;

4. If the fire in the container is rekindled, the fire water system of the power station can be manually connected to the fire hydrant interface reserved on the container wall to continuously spray water and put out the fire in the whole container, so as to ensure that the fire in the container will not spread outside the container.

Aerosol fire extinguishing at battery box level:

All battery boxes are equipped with aerosol fire suppression devices. The thermal trigger line is arranged along the pressure relief ports of the individual cells. When the temperature at the pressure relief port of an individual cell reaches the activation temperature of the thermal trigger line (170±10℃), the aerosol fire suppression device will respond within 1 second and complete the release of the fire extinguishing medium within 3 seconds to absorb heat and cool down, thereby suppressing the spread of thermal runaway inside the box. This process is managed through BMU linkage to monitor the fire status of the battery box.

The front panel of the designed battery box is reserved for fire extinguishing medium nozzle, and the position for detector installation is reserved in the box. The battery box level detector and fire protection scheme can be selected according to the actual needs of the project.

Automatic fire extinguishing system:

The "container level" fire protection of this scheme is designed for the full flooding cabinet automatic fire extinguishing system; the fire control host station is independently installed and displayed in this scheme;

The communication of the fire control host in this scheme is incorporated into the BMS network of the energy storage station or operates independently; the container of the energy storage station is reserved for the installation of pressure relief port (to discharge excess air and fire extinguishing agent).

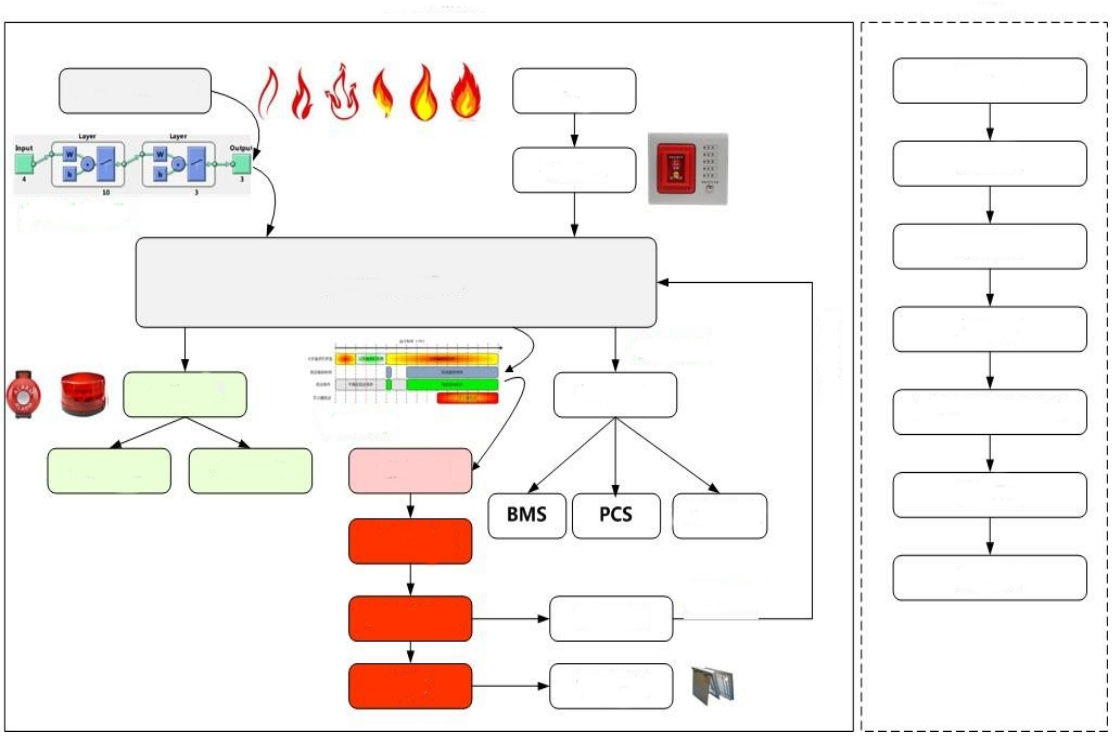


Figure 6 Fire system workflow diagram

6.2 Working mode of fire protection system

1、Alarm and delayed start

Before the fire extinguisher is started, in order to ensure the safety of personnel, the system sets a delay start function for personnel to evacuate safely.

The system detects the fire, starts the external sound and light alarm, gas spray indicator light, delays for 30 seconds, and then starts the fire extinguisher.

2、Automatic manual mode

The system has two working modes: automatic and manual, which can be switched by the "automatic/manual switch".

The design principle is that the fire extinguisher will not be activated when personnel enter.

In automatic mode, the system detects a fire and automatically starts the extinguisher.

In manual mode, the system detects the fire and only alarms without starting the fire extinguisher.

When personnel enter, the system can be set to manual mode; when personnel leave the station, the system can be set to automatic mode.

3、Force start and emergency stop

In automatic or manual mode, when the personnel presses the "forced start button", the system starts the external sound and light alarm and gas spray indicator, delays for 30 seconds, and then starts the fire extinguisher.

At this time, press the "emergency stop button", the system will not start the fire extinguisher, and close the station sound and light alarm, the station outside sound and light alarm, gas spray indicator light.

6.3 Fire protection system function

1、The audio-visual alarm system has the functions of early warning and fire warning. The early warning is carried out by the "external audio-visual alarm", and the fire warning is carried out by the "external audio-visual alarm".

2、Fire intelligent judgment

The system uses detectors (integrating smoke, heat, and gas sensors) for intelligent fire detection. It employs various methods such as fixed thresholds, multi-sensor fusion, and sensor trend analysis to make judgments. When the highly sensitive gas sensor detects an abnormal "thermal runaway gas concentration" or the smoke sensor detects "visible smoke," or when multiple sensors (gas, smoke, and temperature) collectively indicate an anomaly, it will issue a warning. Under the premise of a warning, if the temperature sensor detects an abnormal "temperature characteristic value" with a clear upward trend, it will trigger a fire warning. The conditions for a fire warning are as follows:

（1）When the temperature sensor measures the temperature above 90℃, it is a fixed threshold for fire warning;

（2）The temperature sensor test is above 65℃ and 1℃/S;

In addition, in order to ensure the accuracy of early warning, the judgment of fire warning level needs to last for a continuous time. Among them, the judgment of early warning needs to last for 15 seconds, and the fire warning lasts for 10 seconds. When the system judges that there is a fire, but does not reach the duration of fire warning, it will also immediately give early warning.

3、delayed start

The system has a strict start-up sequence to ensure that there is enough time for the sound and light alarm before the fire extinguisher starts, so that the staff of the energy storage station have enough time to escape.

4、Intra-station communications

The RS485 communication is realized with BMS according to the corresponding communication protocol. The system operating status, warning status and fire control status can be displayed on the LCD screen of the energy storage station control cabinet.

5、Fire control host

As the main fire control system in the station, the fire control host has the functions of collecting detector data, starting fire extinguishers, audio and light alarm control, and communication with the main host in the station.

6、Detector

The detector integrates smoke, temperature, electrolyte gas (H2, CO combustible gas, etc.) and temperature into one. The "power battery thermal runaway model" is used to analyze and process the current thermal runaway parameters to determine whether thermal runaway and fire detection warning occur. The detector is installed on the top of the battery container space.

7、Pipe network fire extinguishers

The gas fire extinguishing agent storage bottles of the pipe network fire extinguishing system are usually placed in the special cylinder room and connected through the pipe network. In case of fire, the fire extinguishing agent will be transported from the cylinder room to the protection area that needs to be extinguished and sprayed out through the nozzle.

8、Explosion-proof exhaust

When the concentration of combustible gas detected by the combustible gas detector in the battery compartment reaches the set threshold (usually set to

When the gas fire extinguishing system is started, the fan stops running when the gas pack alarm host sends out a signal and starts the explosion-proof fan in conjunction. (5%LEL or less)

9、Pressure relief port

When the pressure of fire extinguishing agent in the protection area rises to a certain value, part of air and fire extinguishing agent are released to the outside of the protection area through the pressure relief port in time to ensure the safety of the protective structure.

10、External sound and light alarm

This is an explosion-proof sound and light alarm, installed on the outside of the container, to warn of fire.

11、Fire sprinkler system

If the fire in the container is rekindled, the fire water system of the power station can be manually connected to the fire hydrant interface reserved on the container wall to continuously spray and extinguish the fire in the whole container. A water sprinkler head is arranged above each battery cluster and located inside the hatch, which can act quickly to ensure that the fire in the container will not spread outside the container.

7. Battery compartment structure and auxiliary system scheme

7.1 Battery compartment structure

The battery compartment of this project adopts a 20-foot high container, and the 2MWh liquid-cooled battery compartment layout is shown in the figure

7. The main functions and characteristics of the container are as follows:

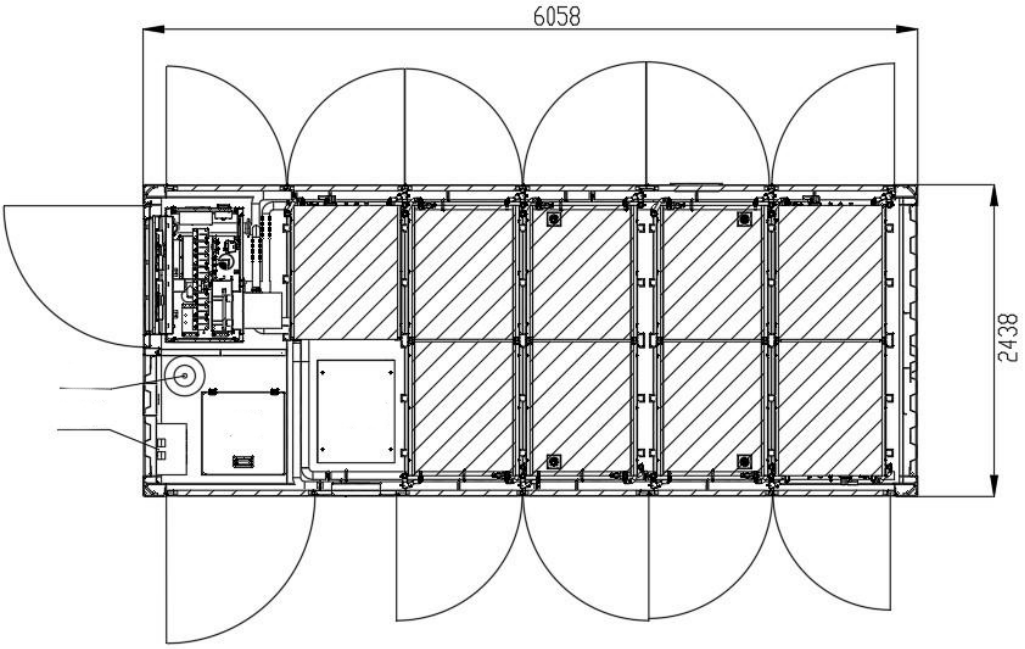


Figure 7 1MWH liquid cooled battery compartment layout

1） Equipped with excellent anti-corrosion, fireproofing, waterproofing, dustproofing (windproof), shockproofing, UV protection, and theft prevention functions, the container will not malfunction due to corrosion, fire, water, dust, or UV factors for 20 years. Structural material selection: The steel used in the battery compartment (container) is SPA-H (weathering steel), with the grade of steel profiles being no less than Q235B, and the main load-bearing parts no less than Q345B.

2） Corrosion protection function: the protective layer of the designed container will be adjusted according to the actual temperature and humidity and salt spray degree of the project site to ensure

In 20 years, the appearance, mechanical strength and corrosion degree of containers meet the requirements of actual use;

- Corrosion treatment of the tank: service life> 20 years;
- The metal parts of the cabin are treated with over-weight protection system and painted;
- The corrosion protection design grade C3~C5 is determined according to the actual project site.

3） Fire protection function: the container shell structure, thermal insulation materials, internal and external decorative materials are all flame retardant materials;

4） Selection of insulation layer material specifications: container ceiling and side wall: rock wool insulation, thickness 50mm; container floor

Surface: rock wool insulation, thickness 100mm; rock wool density is more than 100kg/m^3; flame retardant grade: A grade.

5） Waterproof function: ensure that the top of the box is not waterlogged, not seepage, not water leakage, the side of the box is not rain, the bottom of the box is not seepage;

6） Dustproof (wind and sand) function: standard ventilation and filter screens that can be easily replaced are installed in the air inlet and outlet of the container and the air inlet of the equipment. At the same time, when encountering strong wind and sand, dust can be effectively prevented from entering the interior of the container;

7） Seismic function: ensure that the mechanical strength of containers and their internal equipment meets the requirements under transportation and earthquake conditions, and no deformation, abnormal function, vibration and non-operation faults occur;

8） The anti-uv function ensures that the properties of the materials inside and outside the container will not deteriorate due to uv exposure and will not absorb the heat of uv.

7.2 Container auxiliary system

Container auxiliary systems include security systems (video surveillance, access control systems), lighting systems and power distribution and grounding systems, etc.

7.2.1 Battery compartment security design

The security design of battery compartment (container) mainly includes video surveillance system, access control system, etc.

The prefabricated cabin is equipped with video surveillance and access control alarm functions. The video equipment ensures comprehensive monitoring inside the cabin, allowing real-time observation of the equipment conditions. When someone forcibly attempts to open the cabin door, an alarm signal is generated, which triggers a threat alert via Ethernet remote communication to the monitoring backend. This alarm function can be disabled by the user. The video surveillance equipment and access control host signals support integration with the intelligent auxiliary control system in the main control cabin.

The camera technical requirements are shown below.

Table 6 Camera technical parameters

NO.	Specification name	**Parameter**
1	Parameter	2 million 1/2.7" CMOS ICR day and night hemispherical network camera
2	Adjust the angle	Level: 0°~360°; Vertical: 0°~ 75°; Rotation: 0°~360°
3	Day and night conversion mode	ICR infrared filter type
4	Wide dynamic range	Digital wide dynamic
5	Digital noise reduction	3D digital noise reduction
6	Video compression standard	H.264/MJPEG
7	Frame rate	50Hz: 25fps （1920×1080,1280×960,1280×720)；
8		60Hz: 30fps (1920×1080,1280×960,1280×720)
9	Memory function	NAS (NFS, SMB/CIFS supported)
10	Interface protocol	ONVIF,PSIA,CGI,ISAPI,GB28181
11	Warning notice of intelligence	Mobile detection, dynamic analysis, occlusion alarm, network cable break, IP address conflict, memory full, memory error
12	Warning notice of intelligence	Boundary detection, regional intrusion detection, scene change detection, face detection, virtual focus detection
13	Support protocols	TCP/IP,ICMP,HTTP,HTTPS,FTP,DHCP,
14		DNS,DDNS,RTP,RTSP,RTCP,NTP,UPnP,
15		SMTP,IGMP,802.1X,QoS,IPv6,Bonjour
16	Communication interface	1 RJ45 10M / 100M adaptive Ethernet port
17	Working temperature and humidity	-30℃~60℃, humidity less than 95% (no condensation)
18	Power suppl	DC12V±25% / PoE(802.3af)
19		(DS-2CD2320D-I does not support PoE)
20	Power dissipation	5.5W MAX (7.5W when ICR is switched)
21	Levels of protection	IP67
22	Infrared irradiation distance	EXIR: 20-30 meters
23	Infrared temperature measurement function	Thermal imaging type

The electrical area of the battery compartment is a walk-in maintenance zone, equipped with a maintenance door and an access control system. The access control system includes an access host (a card-swiping fingerprint reader), a door lock, and an open button, which can communicate with the backend via an open protocol. The access host provides power lines and communication network cables to the control panel, with reserved network cable interfaces. To enter from outside to inside, maintenance personnel must use their fingerprints or swipe a card to unlock the magnetic lock and rotate the door handle to enter; to exit from inside to outside, they need to press the door button on the side of the door and push the fire extinguisher lever to lock the maintenance door.

In the fire alarm state, the power supply of the auxiliary distribution cabinet is cut off. At this time, the access control fails, and the indoor personnel can directly push the fire push lock to open the maintenance door.

7.2.2 Lighting scheme

The battery compartment is equipped with normal lighting and emergency lighting. When the door is opened, the normal lighting is turned on; when the door is closed, the normal lighting is turned off; when the door is opened and the normal lighting is cut off, the emergency lighting is turned on, and the emergency lighting time is guaranteed to be no less than 30 minutes.

The lighting system uses explosion-proof lamp tubes with a voltage of 220V and a frequency of 50Hz, capable of operating between-60℃ and 50℃. The lighting system is easy to install and maintain, with a service life exceeding 10 years on a replaceable basis. Each door is equipped with a control switch to turn on all internal lighting. To ensure safe evacuation, emergency lighting devices are installed at each door.

7.2.3 Distribution and grounding systems

The power supply of the distribution system is taken from the isolation transformer inside the PCS container.

Under the condition that the distribution cabinet, communication cabinet, battery rack, air conditioner and other equipment maintain their own good grounding, the total grounding of all equipment is connected to the grounding network to ensure the continuity of the grounding of the whole system. The maximum resistance of the whole grounding system to the earth does not exceed 4Ω.

The auxiliary power unit provides air conditioning, communication cabinets, fire protection, video surveillance, access control system and lighting for the container

The branch circuit for the standby lighting lamp and socket is used to supply power to each equipment with a main circuit voltage of AC380V.

8. Battery compartment hoisting scheme

The full load weight of the 20-foot battery compartment is about 35 tons, and the box has the load-bearing and lifting capacity. When loading and unloading in the following states, there will be no permanent deformation or other abnormal deformation that affects the use.

In the case of full or empty boxes, the hoist with a hook, unhook or twist lock is used to lift vertically on the top corner piece, as shown in Figure 8; in the corner piece at the top of the bottom, the steel wire rope with an end fitting is used to lift at any Angle between 45° vertically, as shown in Figure 9.

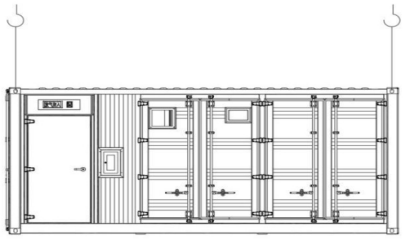


Figure 8 Schematic diagram of lifting from the top (vertical lifting)

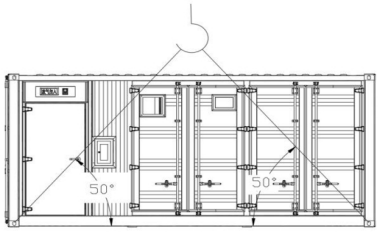


Figure 9 Schematic diagram of lifting from the bottom

9. List of major equipment

Table 7 List of major equipment

NO.	Name	Main parameter	Unit	Qty	**Remarks**
1	1.08864MWh energy storage system	1.08864MWh	set	1	It consists of one 20-foot battery compartment with a capacity of 1.08864MWh per battery compartment
1.1	Battery cluster	576VDC/210Ah	set	9	Each cluster contains 4 battery boxes, 1 cluster battery high voltage box, and corresponding battery racks and cables
1.1.1	Battery pack (PACK box)	1P48S 210Ah	pcs	4	Including BMU, battery cell, liquid cooling plate, fuse, etc
1.1.2	Battery cluster high voltage box	1500V 250A	pcs	1	Contains BCU, fuse, precharge contactor, etc
1.2	DC junction box	1500VDC 1600A	pcs	1	Including BAU, fuse, circuit breaker, etc
1.3	Temperature controlling system	Cooling capacity 45kw	pcs	1	Liquid cooling temperature control, with dehumidification function
1.4	Fire extinguisher system	/	set	1	Aerosol fire extinguishing + automatic explosion-proof exhaust + automatic fire extinguishing system + water fire sprinkler
1.5	20-foot containers	custom made	set	1	It includes monitoring, UPS, power distribution, lighting and communication management with auxiliary control system