2.5MW/5MWh Energy Storage System

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1. Solution Summary

Energy storage systems are a vital component and core technology supporting smart grids, renewable energy plants, and "Internet+" smart energy initiatives. These systems provide essential grid services including peak shaving, frequency regulation, emergency backup, black start capabilities, and demand-side response, serving as a key solution to enhance the flexibility, cost-effectiveness, and security of traditional power systems. Moreover, they significantly improve the integration of renewable energy sources such as wind and solar power into the grid.

The projects energy storage system has a configured capacity of 2.5MW/5MWh. It utilizes containers to house the complete lithium-ion battery system, bi-directional converter (PCS), battery management system (BMS), energy management system (EMS), AC/DC power distribution control system, environmental monitoring system, and fire protection system. The system is supported by core technologies in safety, integration, and intelligent information systems.

2. Design basis

NB/T33015-2014 Technical Regulations for the Connection of Electrochemical Energy Storage Systems to Distribution Networks

NB/T33016-2014 Test Regulations for the Connection of Electrochemical Energy Storage Systems to Distribution Networks

NB/T42089-2016 Technical Specifications for Power Conversion Systems in Electrochemical Energy Storage Power Stations

NB/T42090-2016 Technical Specifications for Monitoring Systems of Electrochemical Energy Storage Power Stations

NB/T42091-2016 Technical Specifications for Lithium-ion Batteries Used in Electrochemical Energy Storage Power Stations

DL/T1815-2018 Code for Reliability Evaluation of Equipment in Electrochemical Energy Storage Power Stations

DL/T1816-2018 Guidelines for Coding of Identification Systems in Electrochemical Energy Storage Power Stations

NB/T33013-2014 Specifications for the Control of Distributed Power Sources Operating in Isolated Mode

Q/GDW1564-2014 Technical Regulations for the Connection of Energy Storage Systems to Distribution Networks

Q/GDW10676-2016 Test Specifications for Energy Storage Systems Connected to Distribution Networks

Q/GDW697-2011 Functional Specifications for Energy Storage Systems Connected to Distribution Network Monitoring Systems

GB50065-2011 Code for Design of Grounding for AC Electrical Installations

DL/T5222-2005 Technical Regulations for the Selection and Design of Conductors and Electrical Appliances

GB/T14549-1993 Power Quality Harmonics in Public Power Grids

GB/T12326-2008 Voltage Fluctuation and Flicker of Power Quality

The fourth edition of Industrial and Civil Power Supply and Distribution Design Manual.

3. Conceptual design

3.1. Project Overview

This project features a total energy storage capacity of 2.5MW/5MWh, utilizing a 1500V DC system configuration. The battery system employs liquid cooling technology, with the energy storage module consisting of a 5MWh lithium iron phosphate battery container. The inverter system comprises a 2.5MW power unit inverter-boost integrated machine. A lithium battery container system is connected to this inverter-boost integrated machine for voltage elevation. After being boosted to 0.8kV, the energy flows into the low-voltage side of the container substation, where it is combined with photovoltaic power to reach 20kV for grid connection. Each battery container contains 12 battery clusters connected in series, with one PCS module corresponding to each battery cabinet. The energy storage system can integrate with renewable energy power stations to achieve wind-solar-storage convergence, energy transfer, and peak shaving/frequency regulation. Additionally, the system can respond to grid dispatching and participate in grid ancillary services.

3.2. System configuration

The energy storage system in this solution is configured with a capacity of 2.5MW/5MWh. It adopts a containerized integrated design, and the system employs a 1500V high-voltage liquid cooling method for integration.

The core components of the energy storage system comprise a battery system, energy storage converter, and step-up transformer. The 2.5MW/5MWh system consists of a single 2.5MW/5MWh energy storage unit.

The 2.5MW/ 5 MWh energy storage system consists of one 2.5MW inverter-boost integrated unit (featuring 12*215kW PCS modules) and one 5 MWh lithium battery container. Each container contains 12 battery clusters, with each cluster connected via DC switches to the 5MW inverter-boost unit for integration with the 215kW PCS.

This solution adopts 3.2V/ 314 Ah lithium iron phosphate batteries, with a cell capacity of 1.0048 kWh. It features safety, reliability, high system efficiency, and long cycle life. Each standard PACK box consists of 52 cells of 3.2V/314 Ah, with a PACK specification of 166.4 V/ 314Ah and a capacity of 52.2496kWh. Each battery cluster is composed of 8 PACK boxes connected in series and 1 high-voltage box, with a battery cluster specification of 1331.2V/ 314Ah and a single cluster capacity of 417.9968kWh.

Table 3-1: Unit Parameters of Energy Storage Battery System

Project	Rated voltage	Capacity	Energy	Burst mode
Cell	3.2V	314Ah	1.0048kWh	/
Cell PACK	166.4 V	314Ah	52.2496 kWh	1P 52 S
Battery pack	1 331.2 V	314Ah	417.9968 kWh	1P 416 S
Single 5MWh battery system unit	1 331.2 V	12* 314Ah	5015.96 kWh	12*1P 416 S

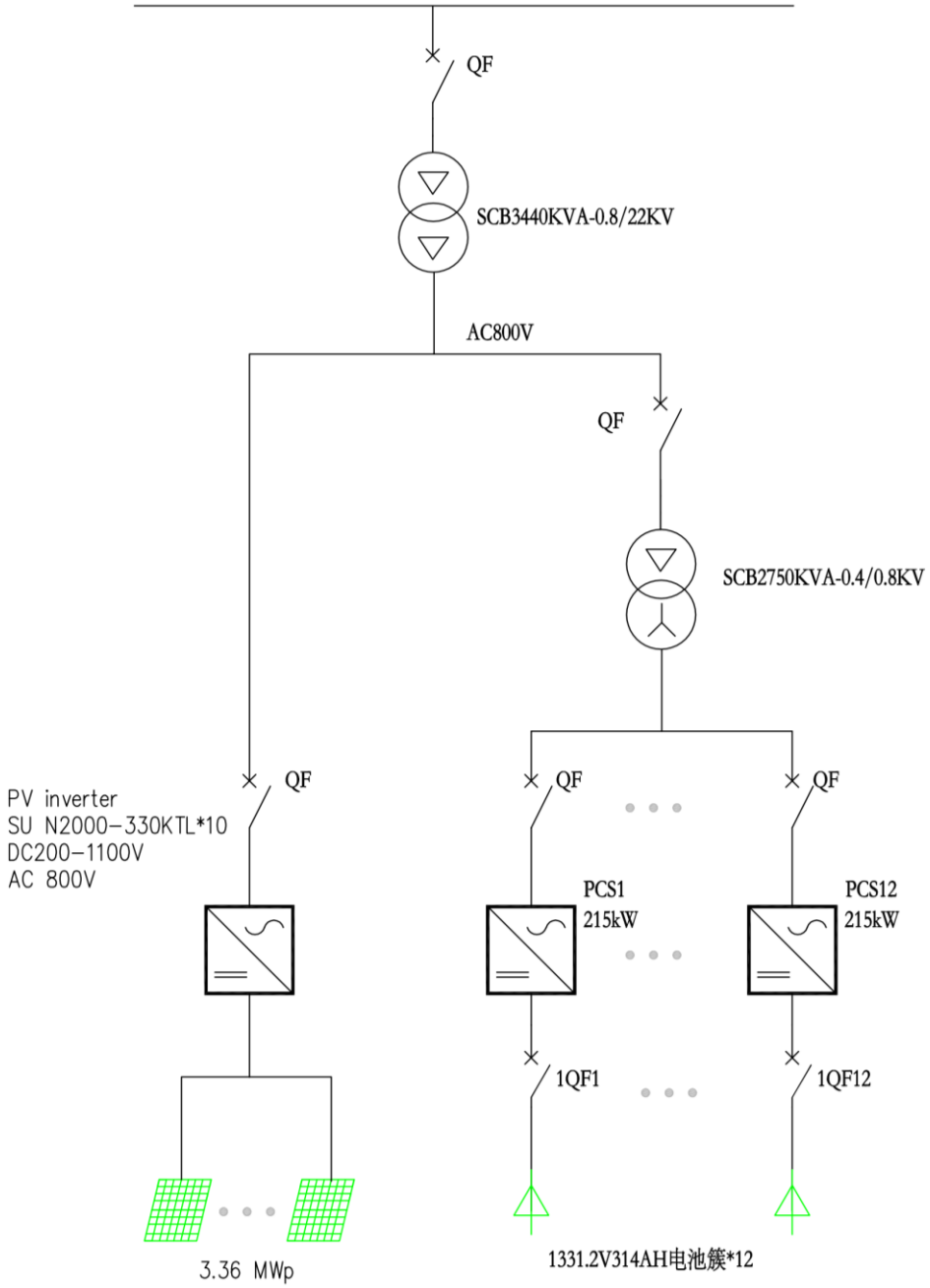


Table 3-1 2. Main topology diagram of 2.5MW/5MWh energy storage unit

3.3. System access topology

The energy storage system consists of lithium iron phosphate battery systems, battery management systems (BMS), power conversion systems (PCS), energy management systems (EMS), and step-up transformers.

When the power system operates with dual-circuit power supply, the energy storage system runs in grid-connected mode. During off-peak hours, it charges the storage batteries, while during peak hours, the batteries discharge to meet load demands and absorb excess solar power. This system participates in grid peak shaving and valley filling, helping users save on electricity bills through peak-valley arbitrage.

3.4. Layout

3.4.1. Overall layout design requirements

The on-site installation of energy storage systems primarily follows these principles:

(1) Maintain a minimum 4-meter clearance between DC system equipment for transportation and maintenance access.

(2) The doors on both sides of DC and AC system equipment shall operate independently without interference, ensuring a minimum 3-meter clearance for equipment transportation and maintenance access.

(3) The station layout plan should take into account local design standards, station arrangement, fire escape routes, and road spacing requirements.

3.4.2. Schematic diagram of the appearance of energy storage products

(1) Complete sets of equipment for DC systems

The DC side employs next-generation energy storage system solutions with specialized cells, significantly enhancing the systems energy density, safety, maintainability, flexibility, lifespan, and efficiency. Simultaneously, it effectively reduces energy consumption, costs, and footprint. With its exceptional cell performance and ultra-long lifespan, the solution delivers reliable energy storage that puts customers minds at ease.

The battery system features a non-intrusive design. Each energy storage container comprises 12 battery clusters, a power distribution control unit, a combiner unit, a thermal management system, and a fire suppression system. The modular design of the containers facilitates system maintenance and allows flexible scalability. The power distribution control unit handles electrical

distribution, communication, and control functions. The DC switching unit employs 12 branch molded case circuit breakers with fuses for DC output, enhancing system maintenance safety. The thermal management system integrates liquid cooling and heating (HVAC) systems to maintain optimal operating temperatures for battery performance, effectively extending cycle life. The fire suppression system incorporates fire detection, automatic alarms, gas extinguishing (using perfluorohexanone), and water-based fire suppression modules. Each container is constructed with fire-resistant steel plates, providing "fireproof + isolation" protection. This comprehensive approach safeguards the system through fire compartmentation, explosion-proof fire detection, explosion-proof ventilation, and fire suppression mechanisms.

DC system battery cabinet with IP5 5 protection rating. Its pre-assembled integrated design for transportation streamlines on-site installation and wiring by eliminating manual wiring.

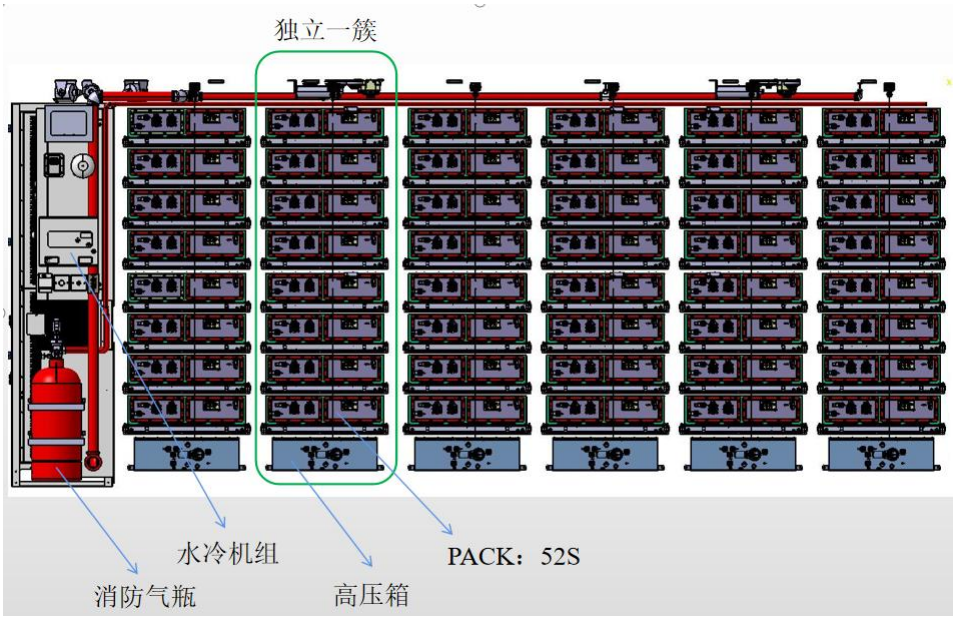


Figure 3-4: Container rendering of the battery system

(2) Complete sets of equipment for the communication system

The 2.5MW Inverter-Step-Up Integrated System is a highly integrated medium-to-high voltage power solution, combining 12×215kV PCS modules, intelligent distribution systems, and step-up transformers. Featuring modular design with DC string connections, it integrates inverter, step-up, and power distribution functions into a single unit. Compared to traditional discrete systems, this solution significantly reduces footprint and simplifies wiring. Its core modules employ digital control technology for efficient energy conversion and dynamic optimization, with built-in

overvoltage/overcurrent protection mechanisms to ensure stable operation. The fully insulated and sealed distribution system adapts to complex environments. Designed for renewable energy grid integration, industrial power upgrades, and microgrid development, the system supports rapid deployment, online maintenance, flexible scalability, and enhanced redundancy, delivering a reliable and efficient integrated solution for medium-to-high voltage power applications.

The AC system adopts an outdoor-integrated design with an IP55 protection rating. Its pre-installed modular design simplifies on-site installation and wiring work.



Figure 3-5 Schematic diagram of the inverter-boost integrated machine

4. Key equipment parameters and functions

4.1. Battery system

The energy storage battery system features a modular design, with cells, modules, clusters, and systems organized into distinct layers. This architecture ensures a clear structure and comprehensive functionality, including battery racks, a battery management system (BMS), temperature control, lighting, fire detection and suppression, security, and emergency systems.

The technical specifications of a single 5MWh battery container are detailed in the table below:

Table 4-1 Technical Parameters of 5 MWh Battery System Container

Item	Project	Parameter	Remarks
1	nominal voltage	1 331.2 V	
2	nominal capacity	5010 kWh	
3	voltage range	1123.2V～1497.6V	
4	Recommended SOC window	10%~90%	
5	maximum charging power	0.5p	
6	maximum discharge power	0.5p	
7	operating ambient temperature	-30~+55℃	
8	heat management	liquid cooling	
9	communication mode	CAN/Ethernet/RS485	
1 0	System IP level	IP5 5	container
1 1	weight	Approximately 45.5 tons	
1 2	System size	6058*2438*2896 mm	20-foot container
1 3	storage temperature	0~35℃	No more than 6 months
1 4	storage humidity	＜70%RH	

The battery system is equipped with a comprehensive battery management system (BMS) featuring a three-tier architecture: module-level, battery cluster-level, and system-level. This architecture enables full control, management, and protection of the battery system, ensuring its safe and stable operation.

4.1.1. Cell technology

The battery cell is a mature 314Ah cell with high energy density, long cycle life and high safety.

Table 4-2: Battery Cell Parameters Table

Item	Parameter	Size of product	Remarks
1	Chemical materials for batteries	Lithium iron phosphate (LFP)	/
2	initial cell capacity	314Ah	/
3	primary energy	1004.8 Wh	/
4	voltage range	2.5V~ 3.65 V	/
5	weight	5±0.2 kg	/

4.1.2. Battery box technology

The battery module adopts the form of battery plug box, with a specification of 166.4V 314Ah, and is composed of 52314Ah cells, collection harness, BMU module, explosion-proof valve, fuse, liquid cooling plate, MSD and other related electrical and structural parts.

Design features of battery box:

1) The battery module is configured in a 1P52S configuration, with individual cells connected in series. Each aluminum busbar is laser-welded to the cells positive and negative tabs, ensuring both mechanical reliability and electrical conductivity.
2) Each battery module contains multiple temperature monitoring points.
3) The battery module is externally connected via bolted joints with front wiring, facilitating maintenance and inspection by technicians.
4) The front panel of the battery module integrates a BMU (Battery Management Unit) that collects voltage and temperature data from individual cells. The BMU receives this information through a dedicated data cable, enabling real-time monitoring and transmission of cell-specific voltage and temperature metrics.
5) 20-foot standard container: designed for comprehensive transportation and installation, meeting international shipping requirements.
6) High safety features: The domestic version features a PACK-level liquid cooling safety technology solution.

Table 4-3 Battery Box Parameter Table

Item	Description	Parameter	Remark
1	nominal voltage	166.4V	
2	nominal capacity	314Ah	
3	nominal energy	52.2496 kWh（@25℃±2）	

4	productiveness		≥94%@0.5P at room temperature	
5	charge and discharge terminal voltage difference		≤ 350mV	
6	maximum continuous charge and discharge power		0.5P	
7	rated charge and discharge current		0.5C	
8	operating voltage range		130 V ~18 9 .8 V	
	Maximum operating temperature range	charge	0℃~55℃	
9		discharge	-30℃~55℃	
	optimal operating temperature range	charge	20℃~35℃	
10		discharge	20℃~35℃	
	Temperature for transportation and storage (battery at 30% or 50% SOC, after one charge-discharge cycle)	Within 1 month	-20℃~45℃	
11		6 months	-20℃~45℃	
12	Maximum temperature of a fully charged cell in a national standard cycle		35℃	
13	Maximum temperature difference for a fully charged cycle cell according to the national standard		5℃	
14	insulating property		Resistance value ≥ 500MΩ@1000VDC	
16	IP grade		IP67	
17	ambient humidity		<95%RH (no condensation)	
18	cooling-down method		cold plate liquid cooling	

4.1.3. Battery pack technology

This solution adopts lithium iron phosphate battery clusters, with a single cluster specification of 1331.2V/ 314Ah. It consists of 8 battery boxes and 1 high-voltage box. The battery cluster cells are grouped in a 1P416S configuration, with 8 battery boxes connected in series. The battery boxes and high-voltage box are arranged sequentially on the battery rack. The power circuit is connected in series through plugs and power cables on the front panel. Each battery module BMU collects the voltage and temperature of the battery cells and transmits them to the BCMU in the high-voltage box via communication cables. The BCMU collects and analyzes the data and reports it to the BAMS,

while also receiving control commands from the BAMS.

Table 4-4 Battery Cluster Parameter Table

Item	Description		parameter	remarks
1	nominal capacity		3 77 h	/
2	nominal voltage		1 331.2 V	/
3	nominal capacity		417.9968 kWh	
4	series-parallel mode		1P 416 S	8 battery modules in series
5	constant power charging	maximum continuous charging power	0.5 P	/
6		charge cutoff voltage	1 497.6 V	
7	discharge	maximum continuous discharge power	0.5 P	/
8		discharge cutoff voltage	10 40 V	
9	charging interval	standard charge	2 .0h	
10		quick charge	2.0h	
11	insulation resistance		＞500 MΩ/V	
12	Recommended SOC window		SOC:10%~90%	/
13	Working temperature under charging conditions		0~ 60℃	/
14	Operating temperature under discharge conditions		- 30~ 60℃	/

- **High-voltage compartment**

The high-voltage cabinet contains the main positive contactor, main negative contactor, pre-charging circuit contactor, fuse, and fan cooling circuit, with all contactors controlled by the battery management system.

- **Product Features**

(1) The battery cluster cable adopts a bottom-in bottom-out configuration with independent switches;

(2) Temperature sampling points are set in the battery cluster, and liquid cooling is adopted to ensure the heat transfer efficiency;

(3) The battery cluster adopts a frame structure for easy maintenance and replacement, with the frame surface treated by electrostatic spraying for corrosion resistance.

(4) Strong and weak current systems and wiring are arranged separately in the battery cluster

to avoid interference and ensure system safety.

(5) Each battery cluster can independently perform battery system capacity calibration, SOC calibration, and battery management system parameter configuration through the energy storage bidirectional inverter (PCS) in accordance with control commands from the energy storage station monitoring system.

4.2. PCS system

This project utilizes a 2.5/5MW integrated inverter-boosting system featuring bidirectional converter technology with specialized performance capabilities. The energy storage PCS enables automated operation with high visual transparency, incorporating a display screen as the human-machine interface. Through touchscreen or button controls, it provides clear real-time monitoring of operational metrics, fault data, and historical records.

The integrated inverter and step-up system comprises: 12/2 4 sets of 215kW energy storage converter modules with supporting components, a dry-type transformer, a high-voltage switchgear, and a low-voltage distribution and communication cabinet. The Power Conversion System (PCS) manages AC/DC conversion and bidirectional energy flow. A 35kV transformer converts the grids 35kV voltage to the PCSs 690V operating level. The high-voltage incoming cabinet connects to the grid, while the low-voltage distribution and communication cabinet handles auxiliary power distribution, measurement and control devices, and external communication interfaces. The battery container houses the battery system, fire protection system, temperature control system, lighting system, Battery Management System (BMS), and monitoring system.

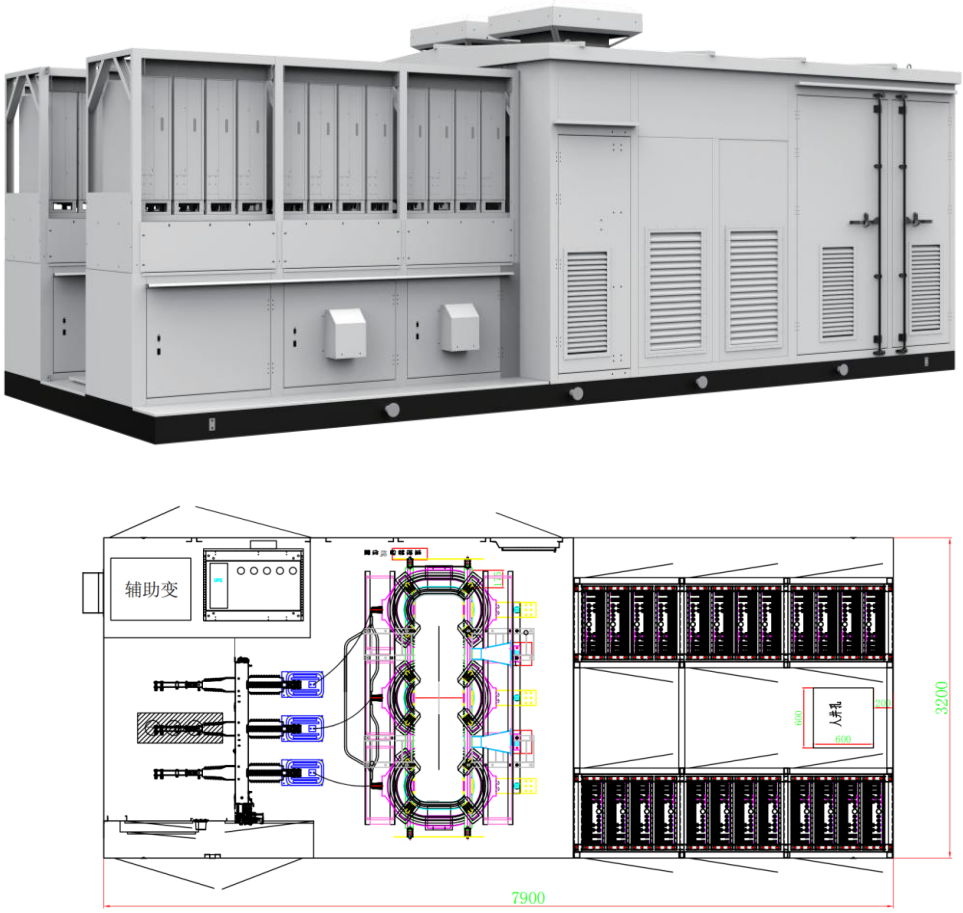


Figure 4-5 Energy storage bidirectional converter

4.2.1. Circuit block diagram

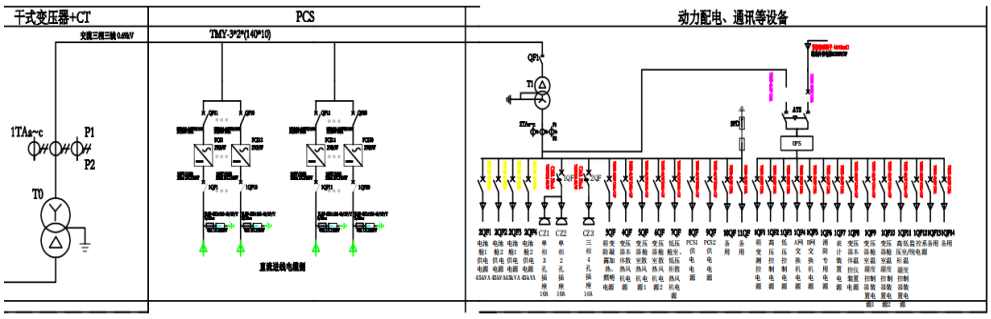


Figure 4-6 Energy storage unit topology

4.2.2. Technical parameter

Table 4-5 **Parameters of 2.5MW Inverter Boost Integrated Machine**

Model grade		**CRES- 25 00**
DC side parameters	voltage range	DC950V～DC1500V
	direct current channel	12
	single channel rated current	275A
AC low-voltage parameters	output line system	3W+PE
	power rating	2500KVA
	rated voltage	AC690V
	rated current	2100A
	voltage range	-15%～+10%
	rated frequency	50Hz/60Hz
	frequency range	±2Hz
	power factor range	-0.9~+0.9
	output current harmonics	≤3% (rated power)
High-voltage AC parameters	Rated power of the transformer	2750 KVA
	voltage ratio	0.69/0.8kV
	Type of transformer	dry type transformer
environment	working temperature	-20℃ to 55℃ (rated below 45℃)
	storage temperature	-40℃ to 70℃ (without battery)
	relative humidity	0% RH to 95% RH, no

		condensation
	working altitude	4000m; (use at reduced capacity for>2000m)
	noise	＜75dB
else	communication mode	CAN/485/LAN
	levels of protection	The converter has an IP66 rating, while the entire machine frame has an IP55 rating.
	cooling-down method	Air cooling, smart fan speed control
	Maximum conversion efficiency of the converter	98.6%
	size W*D*H	6058*2438*2896 mm
	weight	16t

4.2.3. Product function

4.2.3.1. Active power control

（1）When the active power command is set to a fixed value, the Power Conversion System (PCS) delivers a constant power output. Under normal operating conditions, the active power remains stable regardless of frequency or voltage fluctuations, with the control accuracy meeting the requirements of the GB/T34120 standard.

（2）The PCS (Power Control System) regulates the active power output of the energy storage station according to the monitoring systems commands. In thermal standby mode, the response time from receiving the power dispatch command to outputting power does not exceed 100ms.

4.2.3.2. Voltage/ reactive power regulation

（1）When the reactive power is constant, the PC S outputs a constant power value, and the reactive power does not change with the frequency and voltage.

（2）The PCS tracks and adjusts the reactive power output in real time based on control commands from the energy storage station monitoring system.

（3）The dynamic reactive power support capability meets the requirements of GB/T34120 standard.

4.2.3.3. Voltage unbalance on the AC side

After grid connection, the three-phase voltage unbalance at the common connection point shall comply with the limits specified in GB/T15543-2008 "Power Quality-Three-phase Voltage Unbalance". The negative sequence voltage unbalance shall not exceed 2% under normal conditions and 4% during short-term surges. For PCS-induced negative sequence voltage unbalance, the limit is 1.3%, with a maximum of 2.6% during short-term surges.

4.2.3.4. Protections

（1）internal short circuit protection

When a short circuit occurs in the PCS (e.g., IGBT bypass or DC bus short circuit), the electronic circuits, protective fuses, and AC contactors within the PCS will operate swiftly and reliably.

（2）communication fault protection

①The PCS is equipped with communication fault protection for both the local monitoring station and battery management system. It can detect communication interruptions between the PCS and these systems. When communication with the local monitoring station is interrupted, the PCS immediately shuts down. For communication with the battery management system, a delayed shutdown can be configured.

②Redundant communication redundancy: The PCS is equipped with redundant operation capability with the battery management system (BMS) during communication interruption. When communication between PCS and BMS is interrupted, the system determines whether to continue operation based on the normality of the emergency stop contact signal sent by BMS. The emergency stop signal must simultaneously connect to both normally closed and normally open contacts. Upon detecting any action, PCS immediately initiates protective shutdown.

（3）overheat and over moisture protection

The PCS features overheat protection mechanisms, including internal temperature safeguards against overheating (e.g., from fire-induced overheating) and critical component temperature

thresholds. It also provides basic humidity monitoring, automatically shutting down when condensation is detected. In such cases, the PCS implements effective measures to eliminate the condensation.

（4）Flame retardancy and environmental adaptability of the whole machine

The PC S system employs flame-retardant wires and cables, with flame-retardant materials used for cable trays and wire number marking sleeves. The rated operating temperature of internal cables must not fall below 125°C, while the rated temperature rise should not exceed 20°C. To ensure optimal insulation performance, the long-term operating temperature of internal cables is precisely matched to the working temperatures of connected components, with full consideration given to the temperature effects at cable joints. The system incorporates environmental temperature and humidity control relays, along with protective relays, to enhance overall environmental control and protection capabilities.

（5）downgrading warning

When temperatures exceed safe limits, the PCS does not shut down immediately but enters a derated operation mode. If the system automatically enters this mode due to overheating, it displays warnings on its local screen and sends alerts to the backend through its communication interface.

（6）The PCS system features comprehensive protection functions including AC phase sequence error, grid voltage imbalance, overcurrent, over/under voltage, over/under frequency, cooling system failure, and DC component exceedance, all meeting standard requirements.

4.2.3.5. Other features

（1）The voltage fluctuations and flicker generated during the grid-connected operation of energy storage PCS comply with the requirements of GB/T12326.

（2）The energy storage PCS is equipped with DC motor circuit breakers, AC motor circuit breakers, and emergency shutdown operation switches. Each PCSs AC output side features a circuit breaker and a step-up transformer on the low-voltage side, ensuring safety isolation.

（3）The PCS energy storage systems DC busbar supports simultaneous connection of multiple DC battery cluster input branches. The terminal dimensions are designed to meet integration requirements. The busbar and combiner bar are equipped with insulated heat-shrink

sleeves, with no exposed copper bars inside.

（4）The PCS energy storage system connects to the transformers low-voltage side via copper busbars on its AC side.

（5）The PCS DC side features a pre-charging circuit. During each system startup for charging or discharging, the pre-charging circuit activates automatically to maintain the DC sides surge current below 10A.

（6）PCS Human Machine Interface

The PCS features a high-quality display and control panel with a wide temperature range, enabling on-site manual operation by operators. The display shows all operational and historical data, including running parameters, status, fault information, historical power consumption, and instantaneous power generation.

（7）Display and Alarm of PCS

The display parameters of the display include: DC voltage, DC current, DC power, AC voltage, AC current, output frequency, power factor, current power generation.

The fault signals include: output voltage too high, output voltage too low, output frequency too high, output frequency too low, output voltage unbalanced, DC voltage too high, overload, overheating, short circuit, radiator overheating, AC side DC component exceeds the standard, communication failure, etc.

（8）Historical data acquisition and storage in PCS

The PCS features data storage capability, enabling continuous recording of operational data and fault logs throughout its service life. It maintains second-level accuracy for fault reports, alarm triggers, and abnormal event data.

（9）The system supports off-grid operation mode to enable full-standby black start capability. When a sudden mains power failure occurs, EMS detects the power loss and trips both the mains circuit breaker and load circuit breaker. Simultaneously, it issues a VF (Voltage Frequency) control mode command to PCS, switching it from PQ (Power Quality) mode to VF mode to stabilize voltage and frequency. After stabilization, the load circuit breaker is closed to restore power supply to the load.

（10）The system can rapidly switch operating modes, with the transition time from

grid-connected charging to discharge at rated power not exceeding 100ms.

（11）The system features multiple protection functions including low-voltage ride-through (LVRT), high-voltage ride-through (HVRT), anti-islanding protection, AC overcurrent/short-circuit protection, AC overvoltage/undervoltage protection, AC overfrequency/underfrequency protection, AC incoming line phase sequence error protection, DC overcurrent/short-circuit protection, DC overvoltage/undervoltage protection, DC polarity reversal protection, overtemperature protection, power module (IGBT) protection, communication fault protection, cooling system fault protection, and DC current component over-limit protection.

（12）It has bidirectional inverter and four-quadrant independent operation.

4.3. 20 kV step-up unit (transformer substation)

4.3.1. Basic function

（1）The transformer is a three-phase synchronous non-excited voltage-regulating transformer with a voltage regulation range of 20 k V ±2% (2.5% per phase). The high-voltage side features a tap changer with clearly marked tap positions and reliable positioning mechanisms to prevent improper operation. Manual and lock mechanisms ensure proper tap setting, guaranteeing smooth system integration. The energy storage system is normally connected to the mains. The Energy Management System (EMS) monitors the power supplys PT and CT signals, then applies the Power ID (PID) algorithm to dispatch reactive power to the Power Control System (PCS), thereby regulating the mains voltage.

（2）The transformers low-voltage side is connected to the PCS through a cable.

（3）The transformer can be put into operation at any time and can be put into operation directly after a period of time after stopping operation. It can bear 80% of the sudden load under normal ambient temperature.

（4）Transformer short-circuit withstand capacity:

At any tap position, the transformer can withstand external short circuit for 4 seconds without component damage or winding deformation, with the average winding temperature not exceeding 250° C during short circuit.

4.3.2. Technical parameter

20/0.69kV The step-up transformer (box transformer) mainly combines the 800VAC energy output of the energy storage and the 800V output of the photovoltaic to step up the voltage and transmit it to the 20kV bus section of the platform.



Schematic diagram of a step-up transformer

The transformers detailed specifications are shown in the table below.

Table 4-7 Transformer Parameter Table

Item	Project	Parameter	Remarks
1	Rated operating temperature range	-20~45℃	
2	height	1000m	
3	type	resin cast dry / oil-immersed transformer	
4	Rated voltage (high/low)	20±2×2.5%kV/0.8 kV	
5	model	SCB1 1	
6	rated capacity	3440 kVA	Supports 1.1x long-term overload
8	pressure regulating	unexcited voltage	

		regulation	
9	overload capacity	Air-cooled, IP00 protection rating, designed for long-term operation at 110% load	
10	rated frequency	50Hz	
11	Link Group	Dy11	
12	impedance voltage	8%	
13	climatope	C2	
14	Environmental grade	E2	
15	combustion performance class	F1	
16	cooling-down method	AN/AF	
17	insulation endurance class	H	
18	sound power level	≤80dB（1m，AN）	
19	open circuit losses	Meet the requirements of national standards.	
20	Load loss (115℃) kW	Meet the requirements of national standards.	
21	total losses	bias ≤±10%	
22	temperature rise	100K	
23	Winding material (high voltage/low voltage)	Copper/copper	
2 5	level of partial discharge	≤10pC	
2 6	communication	RS485 Interface/MODBUS Communication	
2 7	fan	full dose	
28	Temperature control and display system	1	
29	Alarm and trip of winding	Group 1	

	temperature		
3 0	material quality	allotungsten	

4.3.3. Technical feature

- The high-voltage coil of the transformer is wound with copper wire and cast with epoxy resin, while the low-voltage coil is wound with copper foil and formed by high-temperature curing. Its insulation class is F, and the temperature rise is tested at 100K. The transformer has a service life of no less than 25 years.
- It can be put into operation at any time, and after a period of time, it can be directly put into the power grid without drying for safe operation.
- It has good flame retardancy, is non-combustible, and does not produce harmful gases when exposed to a fire source.
- The product has good heat dissipation and high mechanical strength, and the coil surface will not crack due to temperature change during transformer operation life.
- comprehensive measurement, alarm and control signal

(1) Three-phase monitoring (displaying A, B, C phase temperatures every 2 seconds) and maximum value display (automatically showing peak temperature and phase sequence);

(2) Overtemperature alarm: When the maximum temperature exceeds the preset threshold, the system triggers both audible and visual alarms, with the alarm output contacts closing to enable the user to connect the secondary alarm circuit.

(3) Overtemperature trip (when the maximum temperature exceeds the preset value, the trip alarm light illuminates, and the trip output contacts close, providing users with a trip control circuit. The overtemperature trip output includes normally closed dry contacts and normally open dry contacts, which are used for emergency shutdown of electrical equipment inside the container).

(4) the alarm of the broken wire of the sensor element;

(5) The fan automatically starts and stops (temperature adjustable);

(6) With a temperature controller installed on the front of the low-voltage side of the transformer housing, the controller provides signal output contacts. It features remote transmission, permanent memory for power loss, automatic fault detection, and alarm functions.

(7) The thermostat is equipped with an RS485 communication interface for external configuration.

4.4. Battery Management System (BMS)

The battery management system (BMS) is a real-time monitoring system composed of electronic circuitry. It effectively monitors battery voltage, current, cluster insulation status, state of charge (SOC), and the status of battery modules and individual cells (including voltage, current, temperature, and SOC). The system manages the charging and discharging processes of battery clusters, issues alarms and provides emergency protection for potential faults, and optimizes the operation of battery modules and clusters to ensure safe, reliable, and stable battery performance.

The battery management system (BMS) consists of a battery module management unit (BMU), a battery cluster management unit (BCMU), and current/temperature monitoring units. The BMS provides high-precision analog signal detection and reporting, fault alarms, data upload and storage, battery protection, parameter configuration, passive balancing, battery pack state-of-charge (SOC) calibration, and communication with other devices.

4.4.1. Topological graph

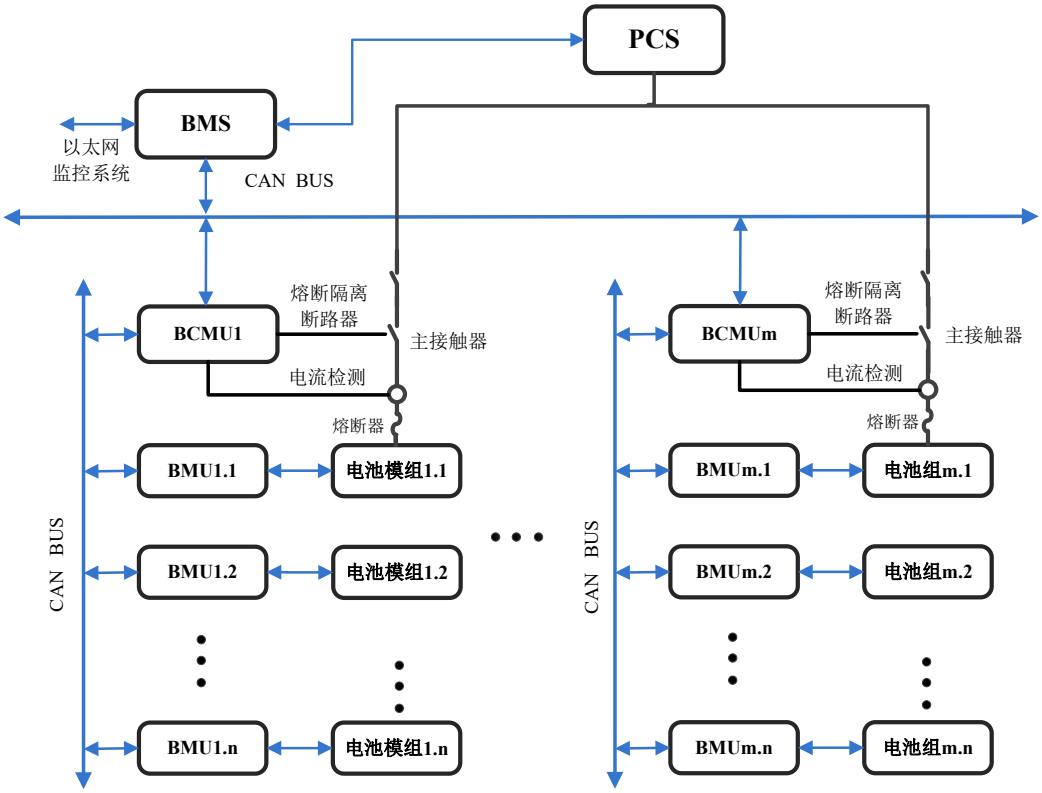


Figure 4-7 BMS system topology diagram

4.4.2. Product function

BMS has the following functions:

(1) High-precision monitoring function of battery analog quantity

At the BMU level, real-time monitoring of single-module voltage is performed. The MBMS tracks battery cluster charge/discharge currents, system total voltage, and insulation status.

(2) SOC estimation

The system achieves basic SOC estimation through current integration, with full-charge and discharge calibration functions to significantly improve accuracy. Under BAMS management, it independently performs capacity and SOC calibration. Using proprietary algorithms, it generates corrected battery system capacity and SOC calibration values, which serve as the basis for subsequent charge/discharge management. This approach minimizes SOC value errors and prevents their amplification over extended periods.

（3） Alarm and protection function of battery system

When the analog quantity of battery system such as voltage, current and temperature exceeds the safety protection threshold, the battery management system will isolate the fault, withdraw the problem battery cluster from operation, report the protection information and display it locally.

BMS features a three-tier software protection system, with the detailed breakdown as follows:

Table 4-7 Three-level software protection items

primary protection	secondary protection	three level protection
Level 1: High voltage alarm for individual units Level 1 monomer voltage low alarm Level one: Alarm for large voltage difference in the single unit Level 1 high total pressure alarm Level 1 low total pressure alarm	Level 2: High voltage alarm for individual units Level 2 single unit voltage low alarm Alarm for large voltage difference in secondary single units Level 2 high total pressure alarm Level 2 Total Pressure Low Alarm	Level 3 single-unit high voltage alarm Level 3 single unit voltage low alarm Level 3: Alarm for large voltage difference in the single unit Level 3 high total pressure alarm Level 3 Total Pressure Low Alarm

Level 1 high temperature alarm Level 1 low temperature alarm Level 1: Alarm for significant temperature differences Large charging current for the first charge; an alarm is triggered. High discharge current alarm at the first level Level 1 insulation low alarm	Secondary temperature high alarm secondary temperature low alarm Alarm for significant temperature difference at secondary level Alarm for high charging current in secondary charging mode High secondary discharge current alarm Secondary insulation low alarm	Three-level high temperature alarm Three-level low temperature alarm Three-level temperature difference alarm Three-level charging current alarm High discharge current alarm for Level 3 Low alarm for three-level insulation

Note: Level 1 and 2 alarm faults will automatically resolve once they disappear. However, Level 3 alarms cannot be automatically resolved and require manual troubleshooting and system restart.

(4) Charge and discharge management

During system operation, the BMS continuously monitors individual cell voltages and battery pack temperature. When a cell voltage reaches the maximum charging voltage, the BMS automatically triggers the relay to cut off power, protecting the battery. Similarly, if a cell voltage drops below the minimum discharge voltage, the BMS will immediately trip the relay to safeguard the battery.

(5) Equilibrium function

The battery management system (BMS) uses passive balancing strategy to maintain the consistency of the battery pack.

(6) Operational parameter configuration (enableable after debugging and connecting to the host computer)

This battery management system allows local modification of various operational parameters. The parameter settings include:

Maximum charging voltage for a single battery

Lower discharge voltage of a single cell

Maximum operating temperature of the battery

Minimum operating temperature of the battery

Battery pack overcurrent threshold

The batteries temperature rises too quickly within a short period of time.

(7) Faulty operation mode

When partial battery failures occur in the systems battery pack requiring maintenance, the low-voltage power supply to the faulty MBMS high-voltage box can be disconnected. After rebooting the system, it automatically enters a fault mode with self-diagnosis, applying current limits to prevent prolonged system downtime during battery repairs.

When the voltage difference between battery packs is excessive, the system can automatically activate specific pack relays via the host computer, while the PCS performs manual small-current charging/discharging for the entire pack to reduce the voltage difference, thus simplifying on-site maintenance.

(8) System status display

This battery management system can display various operational statuses of the battery system locally, including (configurable after connecting and debugging the host computer):

Battery Cell Voltage/Temperature Query and Display

Battery voltage and temperature query and display

Battery Cell Current/SOC/SOH Query and Display

Alarm message displayed

Other error messages

Battery System Capacity Calibration and SOC Calibration

Table 4-8 BMS Parameter Table

item	project	specifications
1	system power supply	DC24V
2	Voltage detection range (V) for a single cell	0V～5V
3	Voltage detection accuracy of a single cell (mV)	±5mV
4	Temperature range (°C)	-40°C～85°C
5	Temperature measurement accuracy	±1°C

	(°C)	
6	Total voltage detection range (V)	0V～1 5 00V
7	Total voltage detection accuracy (%)	1%FSR
8	Insulation detection	Supports a maximum voltage of 1,800V with a detection error below 10%.
9	Current measurement range (A)	-300A-300A
10	Current measurement accuracy (%)	1.0%FSR
11	SOC accuracy （%）	6%
12	equalizing current （A）	100mA
14	communication mode	CAN or 485
15	show	Industrial display
16	Indicator light, buzzer alarm	Equipped with red and green indicator lights and a buzzer alarm
17	protect	Features include overcharge, overdischarge, overheating, and short-circuit protection, with adjustable protection thresholds.

4.5. Energy Management System

The Energy Management System (EMS) and monitoring system serve as the core of coordinated control and a critical component for system operation. They are essential tools and safeguards for achieving efficient, stable, and secure system performance while maximizing renewable energy utilization. The monitoring system for energy storage power stations automatically monitors and regulates electrical equipment, including the power station and control power supply system, in real-time according to system requirements and operational modes. The EMS integrates monitoring software for both the battery PCS and the battery itself, enabling simultaneous monitoring of the battery and PCS functions. The battery storage monitoring platform oversees and controls the battery storage system, coordinates its operation and system integration, and facilitates the application of the battery storage system. The topology diagram of the EMS is shown below.

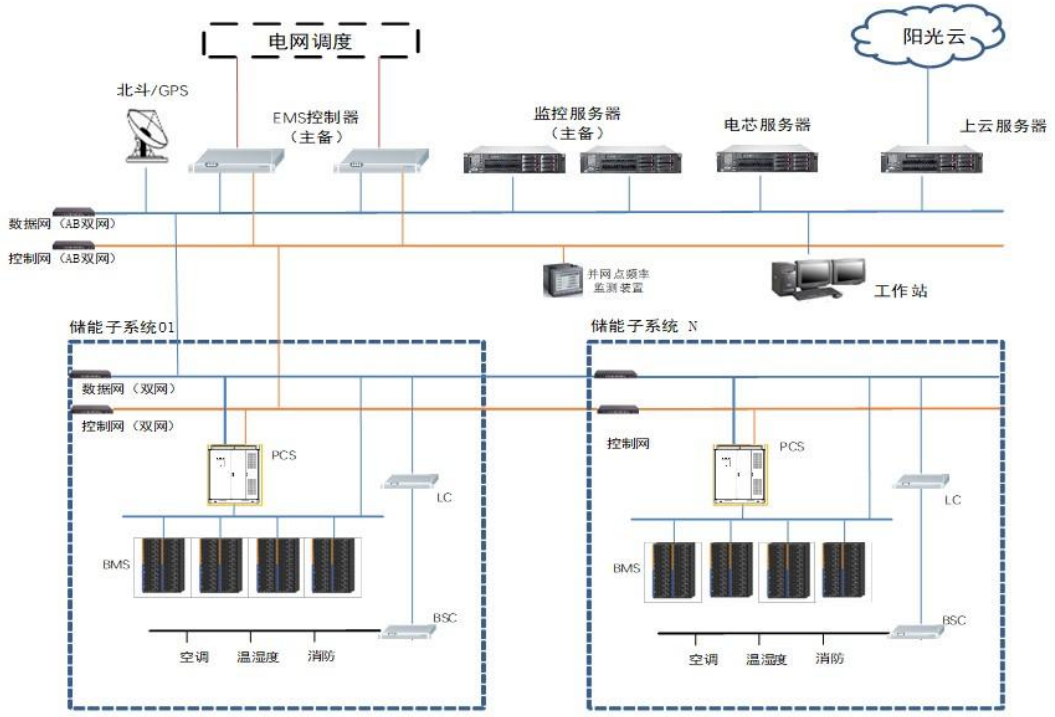


Figure 4-8:

BMS Energy Management System Topology Diagram

4.5.1. Main functions of the system

(1) The energy management functions planning curve supports flexible local operation scheduling configuration in monitoring systems, utilizing

The monitoring systems remote adjustment function delivers preconfigured operation plans to controlled systems, enabling flexible customization. Additionally, the plan curve function can receive and parse remote plan curves in various formats from different dispatch master stations. By controlling remote/local status, it facilitates switching between different plan curves. The power control system manages energy storage operations, featuring active/reactive power coordination, emergency discharge modes, SOC automatic maintenance, abnormality-triggered regulation, lockout regulation, and remote/local switching among other control functions and operational modes.

(2) Power Control Function The energy storage monitoring and control system integrates an Active Power Coordination Control (AGC) module and a Voltage/Reactive Power Coordination Control (AVC) module. It automatically processes dispatch instructions or locally stored planning curves, employing safe, economical, and optimized control strategies. By regulating the Power Conversion System (PCS), the system effectively controls the active and reactive power outputs of

the battery bank, establishing a comprehensive control framework for active power and voltage/reactive power.

a) The AGC-controlled energy storage system can rapidly respond to active power control objectives by employing optimized control strategies and distributed control.

The allocation algorithm enables real-time control of PCS devices to rapidly and accurately adjust the active power at the grid connection point. It supports both capacity-proportional allocation and SOC balancing allocation methods.

b) The AVC control function enables the energy storage system to rapidly respond to voltage/reactive power target commands, utilizing an optimized control strategy.

The system employs a distributed algorithm to dynamically adjust both the stations reactive power design and the reactive power of individual PCS devices, enabling rapid regulation of the grid-connected points reactive power while precisely tracking the bus voltage target. The allocation algorithm utilizes...

The reactive power reserve is distributed according to the equal method.

c) The system peak-shaving dispatching master station schedules energy storage stations based on load conditions, issuing operation plans to implement peak-shaving. During peak load periods, it controls battery discharge to maintain load at optimal levels. When load is low, it selects appropriate time slots for charging through suitable methods.

d) SOC (Social Security) automatic maintenance function

The power control system continuously monitors the SOC (State of Charge) readings from each battery pack provided by the BMS (Battery Management System). When a battery packs SOC deviates from the normal range, the system activates its automatic SOC maintenance mode. By employing controlled slow charging and discharging strategies, it executes maintenance-level power regulation commands from the PCS (Power Conversion System) to restore the SOC to a healthy range. Once the SOC returns to normal, the system reactivates the battery pack for participation in power tracking allocation.

(3) Monitoring Functions a) Battery Monitoring Function Battery monitoring data includes battery status, current, voltage, power, temperature, and State of Health (SOH).

a) Measurement data including SOC, battery anomalies, and protection action triggers; BMS system status data; along with the group and cell numbers of battery units with peak and minimum voltage, as well as those with peak and minimum temperature.

b) Monitoring of energy storage converters

The energy storage converter monitors PCS topology, active/reactive power, voltage/current measurements, operational status, fault reports, protection actions, and module temperature data.

c) The auxiliary control system provides monitoring functions for air conditioning and fire safety, displaying measurement data such as temperature, along with status, anomalies, and fault information.

(4) Database Management The database management features include:

a) Enables fast access to both resident memory and hard disk data, ensuring real-time performance in concurrent operations;

b) Allow different programs to access the same dataset in the database concurrently, ensuring the databases integrity and consistency under concurrent access;

c) It demonstrates excellent scalability and adaptability, automatically accommodating the continuous expansion of data scale while providing diverse interfaces for various applications to access;

d) When generating or modifying databases online, the database management system must update all relevant data on all workstations simultaneously to ensure data consistency.

e) The computer system can return to its pre-failure state once the malfunction is resolved;

f) Enables convenient interactive queries and calls, with response times meeting engineering requirements;

g) Real-time mirror function.

4.5.2. Energy Management System Equipment Configuration

The EMS system employs an open hierarchical distributed architecture, consisting of a station control layer and an interval layer. The station control layer equipment is installed in the secondary equipment compartment of the booster station, while the interval layer equipment is deployed as needed in integrated energy storage converters or battery containers. The station control layer primarily includes EMS controllers (primary/backup), monitoring servers (primary/backup), cell servers (optional), operator-engineer workstations, fast-frequency devices, and switches. The interval layer equipment mainly comprises local controllers (LC100), battery system controllers (BSC), and switches.

4.6. Thermal management system

Based on the operation condition of the whole battery system, the cooling and heating demand of the whole system is analyzed, and the reasonable system layout and the selection of liquid cooling unit and pipeline are carried out.

The temperature control system for a single battery system container consists of a liquid cooling unit and its associated liquid cooling pipeline system. Under the operation and control of the liquid cooling system and the control system, the temperature control system can achieve both cooling and heating inside the container. The control system automatically adjusts the liquid cooling systems operation based on the containers internal and external temperature and humidity, utilizing the liquid cooling system to perform battery cooling and heating functions. This ensures the battery equipment inside the container operates within the optimal working range of 15°C to 35°C.

The thermal management system of this project employs liquid cooling to regulate the battery systems temperature. By utilizing an integrated liquid cooling unit within the container and a well-designed piping system, it effectively controls the internal temperature of the battery cells, ensuring the energy storage system operates within an optimal environment. This approach not only extends the systems lifespan but also enhances its operational safety and reliability.

The liquid-cooled unit should have the following six working modes: cooling, heating, self-circulation, standby, fault, and dehumidification. Cooling mode: The compressor is activated, and the high-temperature, high-pressure refrigerant is discharged from the compressor and enters the condenser to condense and release heat.

After temperature adjustment, throttling is applied to reduce pressure. The refrigerant then enters the battery cooler for evaporation and heat exchange with the coolant. In the plate heat exchanger, the refrigerant absorbs heat and evaporates before returning to the compressor, completing one refrigeration cycle. The water pump activates while the PTC remains inactive. The cooled coolant flows into the battery packs liquid-cooling plates to cool the batteries.

Heating mode: The compressor is turned off, while the water pump and PTC heater are activated. The coolant is heated by the PTC heater and then flows into the battery packs liquid-cooling plate to warm the battery.

In self-circulation mode, the compressor, fan, and PTC are turned off while the water pump is activated. The coolant circulates between the battery packs liquid-cooled plates and the unit, effectively removing heat. This mode is ideal for low-load battery charging and discharging operations.

Standby mode: All devices are turned off and operate based on BMS signals.

Fault mode: Feedback fault information to BMS and execute policies based on fault severity.

Dehumidification mode: This mode activates when the containers humidity exceeds the dew point temperature for its corresponding temperature setting, and can operate in conjunction with the cooling mode.

4.7. Energy storage system safety assurance

4.7.1. System configuration

The battery container is equipped with fire fighting equipment, which consists of smoke sensor, sound and light alarm, perfluorohexanone fire extinguisher, ultra-fine dry powder fire extinguisher and water spray.

The PFOS fire protection system has the following characteristics:

(1) The system features three control modes: automatic, manual, and emergency start/stop.

(2) The system is designed to be fully automatic, which can effectively prevent the occurrence of misoperation events.

(3) Perfluorohexane does not contain chlorine or bromine, it does not damage the ozone layer, it does not damage the battery system, it does not leave residue or oil stain after release, and it can be discharged through normal exhaust channel.

(4) Install smoke detectors, temperature sensors, and fire sprinklers in the battery cluster to ensure the safety of electrical equipment and battery systems.

(5) A fire emergency mechanical starting device is installed outside the container to activate the gas cylinder spray extinguishing system in emergencies.

(6) The fire protection system must respond within 10 seconds to ensure rapid and targeted response.

(7) All cables for power supply, control, and networking in the fire protection system are

independently routed using galvanized steel pipes.

(8) The interlock control will cut off the power supply for air conditioning and ventilation, as well as the batterys DC power supply, before activating the gas fire extinguishing system.

The PCS booster chamber is equipped with fire protection systems comprising smoke detectors, a fire alarm host, and ultra-fine dry powder fire extinguishers. When smoke detection in the PCS booster chamber activates, the alarm host triggers both audible and visual alerts, and the dry powder extinguishers are deployed to suppress the fire. Upon alarm activation, the energy storage system and ventilation cooling system are immediately deactivated to ensure uninterrupted fire suppression.

4.7.2. Technical Parameter Table

Table 4-1 0 Technical Parameters of Fire Protection Systems

Item	project	Performance/Parameters
1	source	AC220V
2	communication mode	CAN, RS485, dry contact
3	working temperature	0℃～+50℃
4	Fire detection methods	temperature and smoke detector
5	fire extinguishing method	full-automation
6	Types of fire extinguishing agents	perfluorohexane
7	dosage	70kg
8	design concentration	≥9%
9	starting mode	Automatic, manual, and emergency start/stop
10	product certification	3C, Fire Safety Certification

4.7.3. Fire control plan

Fire system workflow diagram:

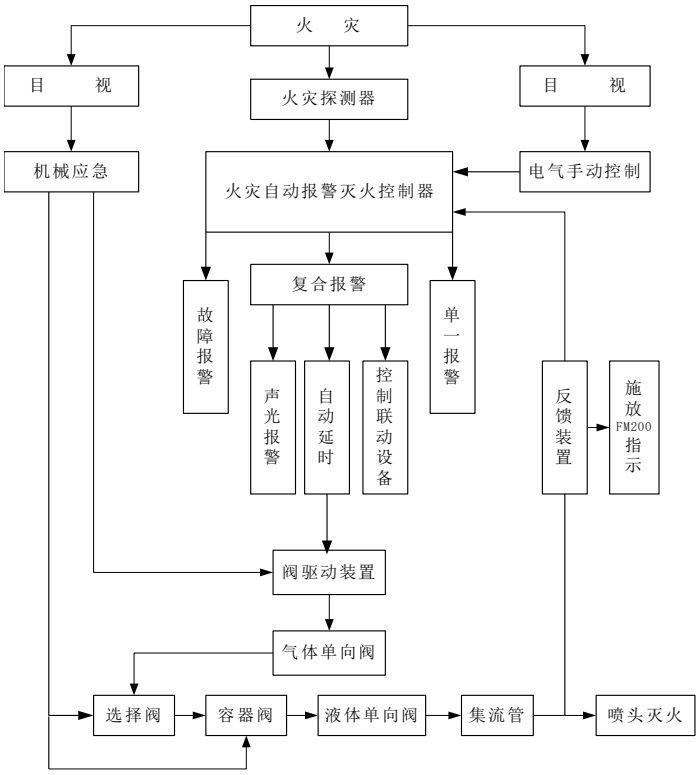


Figure 4-9 Block diagram of fire extinguishing system operation procedure

The fire system features both automatic and manual control modes as follows:

(1) Automatic control

Under normal conditions, the fire protection system operates in automatic mode. When a fire breaks out in the battery compartment, the fire detector triggers an alarm signal. The fire alarm controller then activates audible and visual alerts while issuing a linkage command to shut down ventilation equipment such as air conditioners and fans. After a delay, it sends a fire suppression instruction (prompting immediate evacuation of personnel). The alarm host then activates the fire suppression signal, which triggers the container valve electromagnetic starter to open the valve on the fire extinguishing agent storage tank, releasing perfluorohexanone to extinguish the fire.

(2) Manual control

When personnel are present in the battery compartment, the fire alarm controller operates in manual mode, activating the fire suppression system. In case of a fire, pressing the activation button will trigger the automatic fire suppression system to extinguish the flames. Alternatively, after confirming all occupants have evacuated, the emergency activation device may be deployed to release fire extinguishing agents after a preset delay. If the fire alarm is triggered but no immediate

activation of the fire suppression system is required during the delay period, the emergency stop device can be activated to terminate the suppression process.