



# SPower 240o

## Operation & Maintenance Manual

Rongke Power Vanadium Flow Battery System

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## 1. Safety Precautions

### 1.1 Statement

Before transporting, storing, installing, operating, using, or/maintaining the equipment, please read this manual carefully, follow the instructions strictly, and adhere to all safety precautions indicated on the equipment and in the manual.

In this manual:

**"Equipment"** refers to the related products, software, components, spare parts, or/services, etc.

**"Our Company"** refers to the manufacturer (producer), seller, or/service provider of the equipment.

**"You"** refers to the entity responsible for transporting, storing, installing, operating, using, or/maintaining the equipment.

The terms **"Danger," "Warning," "Caution,"** and **"Notice"** in this manual do not cover all safety requirements. You must also comply with applicable international, national, or regional standards, as well as industry practices. Our company shall not be held liable for any consequences resulting from violations of safety operation requirements or breaches of safety standards in the design, production, or use of the equipment.

This equipment should be used in environments that meet the design specifications. Failures, malfunctions, or component damage caused by non-compliant conditions are not covered under the equipment's quality warranty. Our company shall not be liable for any personal injury, death, property damage, or other losses resulting from such circumstances.

All activities, including transportation, storage, installation, operation, use, and maintenance, must comply with applicable laws, regulations, standards, and specifications.

Reverse engineering, decompilation, disassembly, modification, implantation, or any other derivative actions on the equipment's software are strictly prohibited. You may not analyze the internal logic of the equipment, obtain the software source code, infringe on intellectual property rights, or disclose any performance test results of the equipment's software in any form.

- The company shall not be liable for any of the following circumstances or the consequences arising therefrom:
  - Damage to equipment caused by force majeure events such as earthquakes, floods, volcanic eruptions, mudslides, lightning strikes, fires, wars, armed conflicts, typhoons, hurricanes, tornadoes, extreme weather, etc.;
  - Operation outside the usage conditions specified in this manual;
  - Installation or usage environments that do not comply with relevant international, national, or regional standards;
  - Installation or use of the equipment by unqualified personnel;
  - Failure to follow the operating instructions and safety warnings provided in the product and documentation;
  - Unauthorized disassembly, modification of the product, or alteration of software code;
  - Damage caused by transportation conducted by you or a third party commissioned by you;
  - Damage resulting from storage conditions that do not meet the requirements specified in the product documentation;
  - Materials or tools provided by you failing to comply with local laws, regulations, or relevant standards;
  - Damage caused by negligence, intentional acts, gross misconduct, improper operation by you or a third party, or any reasons not attributable to the company.

### 1.2 Personal Safety

- **Danger**
  - Do not work on live equipment. Installing or removing cables while energized can cause arcing or sparks, leading to fire or serious injury.
  - Improper handling of live equipment may result in electric shock, fire, severe injury, or property damage.

- Remove all conductive objects (watches, jewelry, rings, necklaces, etc.) before working to avoid electric shock or burns.
- Use insulated tools rated for the appropriate voltage to prevent shock or short circuits. Tools must meet local electrical safety standards.
- Wear proper PPE, including insulated gloves, safety glasses, flame-resistant clothing, and dielectric footwear, when performing work.
- **General Requirements**
  - **Do not disable safety features** or ignore warnings, cautions, and precautions in the manual or on the equipment.
  - **If a malfunction occurs** that could cause injury or equipment damage, **stop operations immediately**, report it to the personnel responsible, and take appropriate safety measures.
  - **Do not power the equipment** until the installation is complete and verified by a qualified professional.
  - **Avoid direct contact** with energized equipment—do not use conductors, wet objects, or bare hands. **Always test for voltage** before touching any terminal or conductive surface to confirm it is safe.
  - **Keep fingers, tools, screws, and components away from running fans** to prevent injury or equipment damage.
  - **In case of fire**, evacuate the building or equipment area immediately and activate the fire alarm or call emergency services. **Never re-enter** a burning building or hazardous area.

### 1.3 Personnel Requirements

- **Only qualified professionals or trained personnel** are permitted to perform operations on the equipment.
  - **Professionals:** Individuals with expertise in equipment principles and construction, possessing training or operational experience. They must fully understand potential hazards and their severity during installation, operation, and maintenance.
  - **Trained personnel:** Individuals who have undergone relevant technical and safety training and possess necessary experience. They must recognize potential risks during operations and take measures to minimize hazards to themselves or others.
- **Installation and maintenance personnel** must receive rigorous training to master correct operational procedures, understand all safety precautions, and comply with applicable national/regional standards.
- **Only qualified professionals or trained personnel** are authorized to install, operate, and maintain the equipment.
- **Only qualified professionals** may remove safety devices or perform equipment repairs.
- **Specialized operations** (e.g., electrical work, working at heights, operating specialized equipment) require personnel to hold **locally mandated certifications**.
- **Replacement of equipment or components (including software)** must be performed by **authorized professionals**.
- **Unauthorized personnel must keep a safe distance** from the equipment during operation.

### 1.4 Electrical Safety

- **Danger**
  - Before making electrical connections, ensure the equipment is undamaged. Failure to do so may result in electric shock or fire.
  - Improper or incorrect operations may cause accidents such as fire or electric shock.
  - During operation, prevent foreign objects from entering the equipment. Foreign objects may cause short circuits, equipment damage, power supply derating or outages, and personal injury.
- **Warning**
  - For equipment requiring grounding:

- During installation, the protective grounding wire **must be connected first**.
- During removal, the protective grounding wire **must be disconnected last**.
- **Caution**
  - Do not route cables through equipment air intake or exhaust vents.
  - Due to electrochemical corrosion risks between copper and aluminum, **direct connection of aluminum wires is strictly prohibited**.
- **General Requirements**
  - Installation, operation, and maintenance must strictly follow the procedures specified in the manual. Unauthorized modifications, additions, alterations to the equipment, or changes to the installation sequence are prohibited.
  - Erect temporary barriers or warning ropes in the work area with "No Entry" signs posted. Unauthorized personnel are strictly prohibited from entering.
  - Before installing or removing power cables, ensure the equipment and its upstream/downstream switches are powered off.
  - If liquid ingress into the equipment is detected, immediately cut off the power supply and discontinue use.
  - Prior to operation, verify all tools meet requirements and are logged. After completion, account for all tools to prevent them from being left inside the equipment.
  - Before installing power cables, confirm cable labels are correct and terminals are properly insulated.
  - Use a torque tool with the appropriate range to tighten screws during installation. When using a wrench, ensure it is not skewed and torque deviation does not exceed 10% of the specified value.
  - Secure bolts using torque tools and implement a dual-check system with color coding:
    - Installers mark tightened bolts in **blue**
    - Inspectors confirm and mark in **red** (lines must extend beyond bolt edges)
- To prevent electric shock, never connect Safety Extra-Low Voltage (SELV) circuits to Telecommunication Network Voltage (TNV) circuits.
- Ensure all slots are occupied by boards or blank panels to:
  - Prevent exposure to hazardous voltages
  - Maintain proper airflow
  - Control electromagnetic interference
  - Protect backplanes/baseboards from dust or debris
- After installation, verify all protective covers and insulation sleeves are properly installed to eliminate shock hazards.
- For permanently connected power inputs, install an easily accessible disconnecting device externally.
- For equipment with multiple power inputs, disconnect all sources and wait for complete power-down before servicing.
- When maintaining downstream equipment, disconnect the corresponding output switches of the power supply unit.
- During maintenance:
  - Tag upstream/downstream switches/breakers with "DO NOT CLOSE" signs
  - Post warning notices
  - Only restore power after resolving all faults
- For fault diagnosis requiring power interruption, follow this safety sequence:
  - Power off
  - Verify de-energization
  - Install grounding wires
  - Post warning signs and erect barriers
- Periodically inspect terminal screws to ensure proper tightness without looseness.
- Damaged cables must be replaced by qualified personnel only.
- Never alter, damage, or obscure equipment labels/nameplates. Replace illegible identification promptly.
- Do not clean electrical components (internal/external) with water, alcohol, oils, or other solvents.

- Always use designated protective gear and insulated tools to prevent electric shock or short circuits.

## 1.5 Mechanical Safety

- **Danger**
  - When working at heights, wear a safety helmet and safety harness/lanyard secured to a solid structural component. Never anchor to movable/unstable objects or sharp-edged metal surfaces to prevent hook slippage and fall accidents.
- **Warning**
  - Ensure all tools are complete and certified by professional institutions. Do not use damaged, unqualified, or expired tools. Verify tool integrity and never exceed load limits.
  - Before installing equipment into racks, confirm the rack is properly anchored. Unstable racks may tilt or collapse, risking installer injury and equipment damage.
  - Exercise extreme caution when sliding equipment out of racks. Unsecured or heavy devices may cause crushing or impact injuries.
  - Drilling into equipment is strictly prohibited. It compromises:
    - Environmental sealing
    - EMI shielding effectiveness
    - Internal components/cabling
    - Metal shavings from drilling may cause PCB short circuits.
- **General Requirements**
  - Any paint damage occurring during equipment transportation or installation must be promptly repaired. Long-term exposure of scratched surfaces is strictly prohibited.
  - Arc welding, cutting, or similar operations on the equipment are forbidden without prior evaluation and approval from our company.
  - Installation of additional equipment on top of the unit is prohibited without prior evaluation and authorization from our company.
  - When working in the space above the equipment, protective measures must be applied to the top surface to prevent equipment damage.
  - Always use appropriate tools and ensure proper handling techniques are followed.
- **Safe Handling of Heavy Loads**
  - When lifting heavy objects, prepare properly to bear the weight to avoid crushing injuries or strains.
  - When multiple people lift a heavy object together, consider factors like height to ensure proper team coordination and balanced weight distribution.
  - For two or more people lifting a heavy object, one person should give commands to synchronize lifting and setting down, ensuring uniform movement.
  - When using a forklift, position the forks centrally to prevent tipping. Secure the load with straps before moving, and assign a spotter during transport.
  - For transportation, prefer sea freight or well-maintained roads, and minimize jolts and tilting during transit.



## 1.6 Working at Heights Safety

- **General Requirements**
  - Any work performed 2 meters or more above ground level is considered working at heights and must be supervised by a safety monitor.
  - Personnel must undergo proper training and obtain certification before performing high-altitude work.
  - Suspend work at heights if surfaces (e.g., steel pipes) are wet or in other hazardous conditions. Resume only after safety inspectors and technicians verify all equipment is safe.
- **Safety Zones & Barriers**
  - Designate a restricted danger zone around the work area with clear warning signs. Unauthorized personnel are prohibited from entering.
  - Install guardrails and warning signs near edges and openings to prevent falls.
  - Keep the ground below clear—no scaffolding, planks, or debris allowed. Personnel must not stand or walk directly beneath an active work area.
- **Tool & Material Handling**
  - Secure all tools and equipment to prevent drops that could cause injury or damage.
  - Never throw objects between heights and ground. Use proper lifting methods (e.g., slings, baskets, cranes, or aerial lifts) for material transport.
- **Multi-Level Work & Dismantling**
  - Avoid simultaneous upper/lower-level work. If unavoidable, install protective canopies or barriers, and keep upper levels free of tools/materials.
  - When dismantling scaffolding, work top-down, one layer at a time. Never remove sections simultaneously—prevent collapse risks.
- **Behavioral Rules**
  - **No horseplay or loitering** in work-at-heights areas. **Resting mid-task is prohibited.**
  - **Strict compliance with safety protocols is mandatory. The company bears no responsibility for accidents caused by violations.**

## 1.7 Lifting Operation Safety

- **Personnel Qualification**
  - Only personnel who have received proper training and certification are permitted to conduct lifting operations.
- **Work Zone Isolation**
  - Clearly demarcate the lifting area with temporary warning signs or barriers to prevent unauthorized access.
- **Ground Requirements**
  - The working surface must provide adequate load-bearing capacity to support crane operations.
- **Pre-Lift Inspection**
  - Verify all lifting equipment is securely attached to load-rated anchor points or structural members prior to operation.
- **Safety During Operations**
  - Never walk under suspended loads or crane booms during lifting activities.
  - Do not drag wire ropes or rigging gear, and avoid striking them with hard objects.
  - Maintain the angle between two sling legs at  $\leq 90$  degrees throughout the lift.

## 1.8 Leakage Safety Guidelines

When aqueous vanadium electrolyte (typically a vanadium ion solution containing sulfuric acid) leaks from a VRFB, its strong acidity, oxidizability, and potential toxicity may cause chemical burns, environmental pollution, or equipment damage if mishandled. Key safety precautions are outlined below:

### I. Personnel Safety Protection

- **Personal Protective Equipment (PPE)**
  - **Protective clothing:** Acid/alkali-resistant suits (e.g., PVC or rubber) to avoid skin contact.
  - **Goggles/face shield:** Chemical splash goggles; full-face shield if necessary.
  - **Gloves:** Double-layer gloves (inner butyl rubber + outer acid-resistant gloves).
  - **Respiratory protection:** Acid gas cartridge respirator (use positive-pressure self-contained breathing apparatus for large leaks or confined spaces).
  - **Slip-resistant acid-proof boots:** Prevent electrolyte penetration to feet.
- **Prohibited Actions**
  - Direct skin contact with electrolyte or contaminated items.
  - Eating, drinking, or smoking in the leakage zone; avoid inhaling vapors or dust.

## II. Leak Site Management

- **Immediate Isolation & Warning**
  - Establish a ≥3-meter exclusion zone, evacuate non-essential personnel, and post "Corrosive Hazard" signs.
  - Cut off battery power to prevent short circuits or electric shock.
- **Leak Containment**
  - **Minor leaks:** Use explosion-proof pumps to transfer to acid-resistant containers or absorb with materials (e.g., diatomaceous earth, vermiculite) before cleanup.
  - **Major leaks:** Construct dikes (sandbags or dedicated barriers) to prevent spread to drainage systems or soil.
  - **Solid vanadium leaks:** Moisten before sweeping (to minimize dust), then seal in airtight containers.
- **Neutralization & Cleanup**
  - Neutralize slowly with sodium carbonate ( $\text{Na}_2\text{CO}_3$ ) or lime ( $\text{Ca}(\text{OH})_2$ ) to pH 6–8 to avoid splashing from violent reactions.
  - Collect neutralized wastewater; never discharge directly.

## III. Health Hazards & First Aid

- **Exposure Response**
  - **Skin contact:** Remove contaminated clothing immediately; rinse with copious water for ≥15 minutes; seek medical help.
  - **Eye contact:** Hold eyelids open; flush continuously with saline/water for 20 minutes; emergency medical care required.
  - **Inhalation:** Move to fresh air; administer oxygen if breathing is difficult; perform artificial respiration if needed.
  - **Ingestion:** Do NOT induce vomiting; rinse mouth and drink milk/egg whites to protect stomach lining; seek immediate medical attention.
- **Vanadium Toxicity Note**
  - **V<sup>5+</sup> (pentavalent vanadium)** may cause respiratory irritation and kidney damage; monitor urinary vanadium levels for chronic exposure.

## IV. Environmental & Equipment Protection

- **Pollution Control**
  - Lay impermeable mats under leak areas to prevent soil contamination.
  - Rinse contaminated tools ≥3 times; treat rinsate as hazardous waste.
- **Equipment Handling**
  - Leaked electrolyte may corrode stacks/pipes; post-repair, flush with deionized water and dry thoroughly.
  - Inspect peripheral equipment (e.g., cables, metal supports) for acid mist corrosion.
- **Recycling and Disposal**
  - Dispose of used batteries in compliance with local laws and regulations. Do not discard batteries as household waste. Improper battery disposal may cause environmental pollution or explosions.
  - If the battery leaks or is damaged, contact technical support or a battery recycling company for proper disposal.

- When the battery reaches the end of its service life, contact a battery recycling company for disposal.
- Avoid exposing used batteries to high temperatures or direct sunlight.
- Avoid storing used batteries in high-humidity or corrosive environments.
- Faulty batteries must not be reused. Contact a battery recycling company immediately for proper disposal to prevent environmental contamination.

## 2. Introduction

This manual provides detailed instructions for the operation, maintenance, and fault handling of the SPower 240o Vanadium Flow Battery System. Designed for safety, reliability, and long-term performance, the SPower 240o offers modular energy storage with features tailored for diverse energy needs. This manual includes key maintenance tasks and fault handling procedures necessary to maintain optimal performance.

Key Features:

- High Capacity: Rated at 240 kWh per module with 60 kW per module power output.
- Longevity: Over 25 years or 20,000 charge/discharge cycles under standard operating conditions.
- Robust Efficiency: DC efficiency rated at 80% (excluding self-consumption).
- Wide Operating Range: Ambient temperature range from -20° C to 50° C.
- Sustainability: Non-flammable electrolyte with zero degradation and modular design.



### 3. Tools and Assistant Devices Required

For both preventive and corrective maintenance, the following tools and materials are necessary:

- **General Tools:**
  - Multimeter, torque wrench, crimping tools, screwdrivers, and pipe wrenches.
- **Specialized Tools:**
  - Signal Generator: For testing faulty temperature and voltage sensors.
  - Ultrasonic Flowmeter: For diagnosing flow channel blockages in the electrolyte system.
  - Leak Detection Equipment: For monitoring electrolyte leaks in the system.
- **Instructions**
  - The tools listed in this table are for routine maintenance only. Prepare additional tools as needed.
  - When operating power equipment, ensure proper insulation protection. It is recommended to use insulated tools to prevent short circuits or electric shocks caused by improper operation.
- **Important Notice**
  - For maintenance, fault handling, component replacement, or modification work involving prefabricated modules, the presence of qualified engineers is mandatory during operations.

## 4. Technical Requirements for Operation and Maintenance Personnel

Technical Domain	Competency Requirements	Qualification Standards
Power Supply & Distribution System	- Familiar with prefabricated module power distribution system configuration and core component operations	- Certified Power Distribution System Engineer
Hybrid Thermal Management (Passive + AC Cooling)	- Proficient in prefabricated module cooling system configuration and core component operations	- Certified Refrigeration Engineer
Management System	<ul style="list-style-type: none"> <li>- Solid knowledge of hardware/software systems</li> <li>- Understanding of basic communication protocols</li> <li>- Familiar with low-voltage system equipment interfaces</li> <li>- Proficient in NetEco management system operation</li> </ul>	- Certified Low-Voltage Systems Engineer
Fire Protection System	- Comprehensive knowledge of prefabricated module fire protection system configuration and core components	- Certified Fire Protection Engineer
Lighting & Structural Systems	- Thorough understanding of prefabricated module overall configuration and structural layout	- Prefabricated module maintenance experience required

## 5. Spare Parts and Critical Components

The following table outlines the spare parts that are typically needed during yearly maintenance, along with their corresponding order numbers and recommended quantities. This allows service organizations to plan ahead and stock the necessary parts.

<b>Component No.</b>	<b>Component Name</b>	<b>Quantity/Year</b>
02011101	Stack	2
05030219	Pump	1
05040270	DC Fan	2
05050135	Temperature sensor	1
05050170	Leakage sensor probe	4
05040267/05040268	Air Filters	2
05072377	Drive	1
05072805	Signal module	1
05072379	Core controller	1
05050620	Electric Heater (plastic casing)	2
05030234	Gas diaphragm pump	4
05040271	Industrial air conditioner	2

## 6. Routine Maintenance

- **Danger**
  - Always use dedicated protective equipment and insulated tools to prevent electric shock or short circuit hazards.
  - Smoking or open flames are strictly prohibited near batteries.
  - Never use wet cloths to clean exposed copper busbars or other conductive components.
  - Do not clean batteries with water or any solvents.
- **Warning**
  - Never perform maintenance on energized batteries. Operations such as torque verification/fastening of screws or battery module impedance measurements require complete power shutdown. These may only be performed after:
    - Explaining risks to the customer
    - Obtaining written customer consent
    - Implementing effective precautionary measures
  - Recharge batteries immediately after discharge to prevent damage from over-discharge
- **Caution**
  - Ensure battery circuits remain disconnected during installation and maintenance.
- **Notice**
  - Battery software upgrades must be performed with AC power input normally available to prevent service interruption.

### 6.1 Routine Maintenance requirements

Routine maintenance refers to a preventive maintenance approach where technicians periodically perform inspections and servicing on equipment during normal operation. This proactive process aims to:

- Detect and resolve potential alarms or faults at an early stage
- Eliminate hidden risks that may lead to equipment failures
- Prevent accidents before they occur
- Routine maintenance significantly impacts equipment performance. Perform maintenance on schedule. Before starting, thoroughly review all safety precautions and product documentation.
- Strictly comply with local safety regulations and laws to prevent accidents.
- The "**Note**," "**Caution**," "**Warning**," and "**Danger**" indicators in manuals do not represent all required safety measures, but serve as supplemental safety reminders for specific operations.
- Personnel responsible for installing or maintaining RKP equipment must:
  - Complete rigorous training
  - Fully understand all safety precautions
  - Demonstrate proper operational procedure before performing any installation, operation, or maintenance.
- All operations must strictly adhere to:
  - Equipment-specific precautions provided by RKP
  - All safety instructions

Note: Safety warnings in manuals only cover known risks. RKP is not liable for consequences resulting from:

- Violations of general safety practices
- Non-compliance with safety standards for design, manufacturing, or equipment use
- Most maintenance requires powered-off equipment. Never energize during maintenance. Exceptions (e.g., current/pressure/temperature measurements during operation):
  - Ensure complete equipment connection before power-on
  - Immediately de-energize after maintenance
- Electrical maintenance requires protective measures:
  - Wear insulated gloves
  - Use insulated footwear
- Exercise extreme caution for specialized maintenance. Consult customer service for guidance.

- When replacing components:
  - Never lean materials against equipment racks
- Routine maintenance significantly impacts equipment performance. Perform maintenance on schedule. Before starting, thoroughly review all safety precautions and product documentation.
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- Electrical maintenance requires protective measures:
  - Wear insulated gloves
  - Use insulated footwear
- Exercise extreme caution for specialized maintenance. Consult customer service for guidance.
- When replacing components:
  - Never lean materials against equipment racks

## 6.2 Routing maintenance Items

To ensure the long-term and stable operation of the flow battery energy storage system, it is recommended to perform routine maintenance as described in this section.

- **Warning**
  - Before performing maintenance tasks such as system cleaning, electrical connection checks, internal battery compartment inspection, door opening, or grounding reliability verification, ensure the system is powered off. All battery "**SWITCH**" positions must be set to "**OFF**," and the battery should be in a **fully discharged** state before proceeding.
  - If it is necessary to open the maintenance compartment door during rain or snow, **take protective measures** to prevent moisture or snow from entering. **Do not open the maintenance compartment door** in such weather conditions if proper protection cannot be ensured.

Maintenance Item	Frequency	Operation Guide	Exception Handling
BMS	Based on actual operation conditions.	"All graphic display units on the screen are operating normally, all power parameters are within the normal range, and no faults or alarm messages appear in the displayed records."	Check if it is in working status and whether there are any abnormal alarms.
Battery Operating Status	Based on actual operation conditions.	The screen displays the operating status as charging or discharging, with no faults or alarm messages in the displayed records.	Check and handle abnormal messages.

BMS Configurable Parameters Check	Based on actual operation conditions.	Verify output voltage level, frequency, number of battery cells, battery capacity, etc.	Correct parameter settings if abnormal.
U-shaped Tube	Based on actual operation conditions.	Ensure normal water level in the U-shaped tube.	Add water if necessary.
U-shaped Tube	Based on actual operation conditions.	Ensure the liquid is colorless and transparent.	Replace or refill if necessary.
Rodent Prevention Check	Based on actual operation conditions.	The equipment room has rodent prevention measures, such as rodent barriers or traps.	Repair according to inspection standards if abnormal.
Filter Screen	Quarterly	Ensure the filter screen is not clogged.	Clean the filter screen (preferably with water).
Filter Screen	Quarterly	Ensure the filter screen is not damaged or deformed.	Replace the filter screen.
Fan	Quarterly	Ensure the indoor fan grille is not deformed.	Repair or replace the grille.
Fan	Quarterly	Ensure the indoor fan blades are undamaged. Replace the fan assembly if necessary.	Ensure the indoor fan blades are undamaged. Replace the fan assembly if necessary.
Fan	Quarterly	Ensure the indoor fan operates without abnormal noise. Replace the fan assembly if necessary.	Ensure the indoor fan operates without abnormal noise. Replace the fan assembly if necessary.
Fan	Quarterly	Ensure the fixing screws of the indoor fan are not loose.	Ensure the fixing screws of the indoor fan are not loose.
Electric Heater	Quarterly	Ensure the electric heater is securely fixed. Tighten the heater and its switch.	Ensure the electric heater is securely fixed. Tighten the heater and its switch.
Electric Heater	Quarterly	Check for corrosion on the electric heater surface. Replace the heater if necessary.	Check for corrosion on the electric heater surface. Replace the heater if necessary.
Cables	Quarterly	"Cables are intact, with no damage to the insulation layer. Cable connection screws are tight, with no displacement of the tightening marks. Cable connection points show no signs of blackening or arcing."	Replace the corresponding cable.
Leak Sensor	Quarterly	Ensure the leak sensor cables are securely fixed.	–
Power/Capacity Unit	Quarterly	Check for strong acidic odors or electrolyte leakage around the unit.	Analyze the cause, tighten, replace seals, or replace the unit.
Power/Capacity Unit	Quarterly	Check for strong burnt smells around the unit.	Analyze the cause and replace.
Equalizer & Bus Cabinet	Quarterly	Check for strong burnt smells or abnormal internal noises around the SOC equalizer.	Analyze the cause and replace.
Equalizer & Bus Cabinet	Quarterly	Verify whether the working status is effective and accurate.	Repair or replace.
Chiller	Quarterly	Check for strong burnt smells or abnormal internal noises around the chiller.	Check for strong burnt smells or abnormal internal noises around the chiller.
Chiller	Quarterly	Check for abnormal noises during operation or unbalanced fan rotation.	Replace.

Pipes	Quarterly	Ensure no abnormal bending, swelling, or shrinking of pipes.	Replace or repair.
Pipes	Quarterly	Ensure no cracks, seepage, or leakage in pipes, flanges, valves, or unions.	Replace or repair.
Pipes	Quarterly	Ensure valves are fully open under normal conditions.	Repair.
Pipes	Quarterly	Ensure mixing valves are fully closed under normal conditions.	Repair.
Sensors	Quarterly	Ensure sensors are intact with no alarms.	Replace.
Sensors	Quarterly	Ensure temperature sensors are intact, display normal readings, and show no leakage.	Replace.
Sensors	Quarterly	Ensure pressure sensors are intact, display normal readings, and show no leakage.	Replace.
Sensors	Quarterly	Ensure leak sensors are correctly positioned and show no corrosion.	Replace.
Magnetic Pump	Quarterly	Ensure current values are normal.	Replace.
Magnetic Pump	Quarterly	Ensure the pump head is intact with no leakage.	Replace.
Magnetic Pump	Quarterly	Ensure normal operation with no abnormal noises.	Replace.
Storage Tank	Quarterly	Ensure no leakage in the storage tank.	Repair or replace.
Storage Tank	Quarterly	Check for liquid leakage around the manhole cover and ensure bolts are tight.	Repair or replace.
Storage Tank	Quarterly	Check for kinks or water accumulation in the gas vent pipe.	Repair or replace.
Electrode Stack	Quarterly	Ensure no leakage in the electrode stack.	Repair or replace.
Electrode Stack	Quarterly	Ensure no breakage or detachment of spring clamps.	Repair or replace.
Electrode Stack	Quarterly	Ensure no breakage or detachment of 巡检线 (inspection lines).	Repair or replace.
SOC Battery	Quarterly	Ensure no leakage or cracks at pipe connections.	Repair or replace.
SOC Battery	Quarterly	Ensure no leakage in the SOC battery.	Repair or replace.
SOC Battery	Quarterly	Ensure SOC values are normal (0–100%).	Repair or replace.
Electrolyte Sampling & Analysis	Annual	Perform sampling and analysis.	Requires manufacturer assistance for analysis.
Ground Wire Check	Annual	Ensure the ground wire is securely connected to the equipment room's grounding bar, with screws tightened.	Tighten screws if abnormal.
Battery Connection Reliability Check	Annual	"With the equipment powered off, check the reliability of each battery connection point in a fixed sequence from positive to negative. Use a torque wrench to verify each battery screw's torque meets the manufacturer's requirements. After verification, mark the screws for future inspections."	Repair according to inspection standards if abnormal.
Dust in Battery Distribution Cabinet	Annual	Check for dust on the distribution cabinet panels.	Clean the distribution cabinet.
Check for Oxidation on Battery Metal Parts	Annual	Ensure no metal rust is present.	"If severe oxidation is found, perform derusting or replacement. If painted, repaint after derusting."

## 7. Component Replacement & fault handling

### 7.1 SOC Battery Fault Handling

- **Fault Information:**  
The BMS system displays "System SOC high or low fault."
- **Fault Phenomenon:**  
An OCV (Open-Circuit Voltage) indicator error causes inaccurate SOC values, leading to a system shutdown.
- **Fault Analysis:**
  - Wiring Problems: Loose or disconnected terminal wiring, or damage to the safety tube.
  - Voltage Transmitter Fault: A faulty transmitter leads to inaccurate SOC readings.
  - Pipeline Problem: Abnormal pressure in the SOC battery's inlet/outlet pipeline causes damage and leakage.
- **Fault Handling:**
  - Wiring Problems: Reconnect and fasten loose terminals. Replace the safety tube if damaged.
  - Voltage Transmitter Failure: Check power supply voltage and replace the transmitter if faulty.
  - Pipeline Problem: Inspect and replace damaged pipelines.

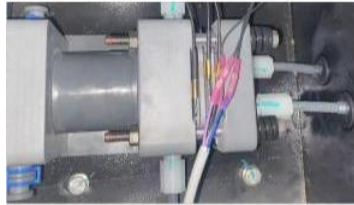


Fig.7.1 SOC

### 7.2 Magnetic Pump Fault Handling

- **Fault Information:**  
The magnetic pump malfunctions, reducing electrolyte flow or pressure.
- **Fault Phenomenon:** High or low system pressure due to pump inefficiency.
- **Fault Analysis:**
  - Bearing Damage: Worn or damaged pump bearings restrict movement.
  - Air Binding: Air trapped in the pump causes inefficiency.
  - Electrical Fault: Wiring or connection issues lead to pump malfunction.
- **Tools and Instruments:**
  - Multimeter
  - Clamp ammeter
  - Wrench
  - Screwdriver
- **Fault Handling:**
  - Replacement: Inspect and replace damaged bearings if the pump shows signs of excessive noise or reduced efficiency.
  - Air Release: Remove trapped air from the pump and inspect for any air blockages that may be causing performance issues.
  - Electrical Fault Repair: Test the electrical connections and check for any loose wiring or malfunctioning components. Repair or replace as necessary.



Fig.7.2 Magnetic Pump

### 7.3 Temperature Sensor Fault Handling

- Fault Information: The temperature sensor displays inaccurate readings.
- Fault Phenomenon: System temperature measurements become unreliable, leading to improper regulation of hybrid thermal management (Passive + AC Cooling).
- Tools and Instruments:
  - Signal generator
  - Multimeter
  - Infrared thermometer
- Fault Handling:
  - Sensor Testing: Test the temperature sensor using a signal generator to check its accuracy. Replace the sensor if readings are inconsistent.
  - Wiring Inspection: Inspect the wiring and connections to the temperature sensor, ensuring no loose or corroded terminals.
  - Replace Faulty Sensors: If the temperature readings continue to be inaccurate, replace the faulty sensor with a new one.



Fig.7.3 Temperature Sensor

### 7.4 Pipe Fault Handling

- Fault Information: Pipe blockages or leaks affect electrolyte flow, causing reduced efficiency or system downtime.
- Fault Phenomenon: Electrolyte flow rates decrease due to obstructions, or the system experiences leakage from damaged pipes.
- Tools and Instruments:
  - Ultrasonic flowmeter
  - Pressure gauge
  - Pipe wrenches
  - Sealant or pipe replacement parts
- Fault Handling:

- Blockage Removal: Use an ultrasonic flowmeter to detect any blockages in the electrolyte pipelines. Remove or clear any obstructions affecting flow.
- Leak Repair: Inspect pipes for leaks. Tighten or replace faulty pipe sections and use sealant where needed.
- Pressure Check: Monitor pressure levels in the pipeline to ensure that the system is operating at the required levels. Adjust as necessary.



Fig.7.4 Pipe

## 7.5 U-Pipe Fault Handling

- Fault Information: A U-pipe fault disrupts the system's ability to maintain proper electrolyte flow.
- Fault Phenomenon: Electrolyte flow becomes inconsistent due to blockages or damaged seals, causing pressure imbalances.
- Fault Analysis
  - Blockages: Crystallization or debris blocks the U-tube, affecting electrolyte flow.
- Fault Handling:
  - Blockage Removal: Use an ultrasonic flowmeter to detect reduced flow rates in the U-tube. Manually clear any blockages or flush the system to remove debris.
  - Seal Replacement: Inspect the U-tube seals for wear or damage. Replace damaged seals and tighten any loose connections to restore proper pressure regulation.
- Prevention Tip: Regularly inspect the U-tube for signs of blockage or seal wear to prevent electrolyte flow issues.



Fig.7.5 U-pipe

## 7.6 Hybrid Thermal Management (Passive + AC Cooling) Fault Handling

- Fault Information: The cooling system fails to regulate the electrolyte temperature, causing system overheating.
- Fault Phenomenon: Electrolyte temperature exceeds safe operating thresholds, leading to system shutdown or efficiency loss.
- Fault Analysis
  - Cooling Fan Failure: Cooling fans are blocked or damaged, preventing proper heat dissipation.
  - Heat Exchange System Malfunction: The heat exchange system isn't effectively reducing electrolyte temperatures.

- Tools and Instruments:
  - Multimeter
  - Fan testing tools
  - Infrared temperature gun
- Fault Handling:
  - Fan Replacement: Test the cooling fan using appropriate tools to check for operational efficiency. Replace faulty or damaged fans to restore cooling.
  - Heat Exchange System Repair: Check the heat exchange system for blockages or flow interruptions. Clear any obstructions and ensure the system is functioning correctly.
- Prevention Tip: Regularly inspect the U-tube for signs of blockage or seal wear to prevent electrolyte flow issues.



Fig.7.6 Hybrid Thermal Management (Passive + AC Cooling)

## 7.7 Leakage Sensor Fault Handling

- Fault Information: The leakage sensor provides inaccurate readings or fails to detect leaks in the system.
- Fault Phenomenon: Leaks go undetected, leading to potential safety hazards or electrolyte loss.
- Fault Analysis
  - Sensor Degradation: The sensor may have degraded over time, affecting its accuracy.
  - Wiring Issues: Loose or disconnected wiring can lead to faulty sensor readings.
  - response. Replace the sensor if it shows erratic or inaccurate readings.
  - Wiring Inspection: Inspect the sensor wiring for loose or disconnected terminals. Reconnect and secure the wiring.
- Prevention Tip: Regularly inspect leakage sensors for signs of degradation and test them for accurate readings.



Fig.7.7 Leakage Sensor

## 7.8 High Stack Voltage Fault Handling

- Fault Information: The stack voltage exceeds safe operating limits, triggering a system shutdown.
- Fault Phenomenon: The system detects abnormally high voltage differences between stacks, which can damage components.
- Fault Analysis
  - Wiring Problems: Loose or disconnected wiring causes voltage fluctuations.
  - Safety Tube Damage: Damaged safety tubes can cause voltage to exceed safe levels.
  - Voltage Transmitter Failure: A faulty transmitter results in inaccurate voltage readings, causing the system to misinterpret stack conditions.
- Tools and Instruments:
  - Multimeter
  - Screwdriver
  - Torque wrench
- Fault Handling:
  - Wiring Inspection: Inspect and reconnect loose wiring in the stack to ensure consistent voltage readings.
  - Safety Tube Replacement: Replace damaged safety tubes to prevent voltage spikes.
  - Voltage Transmitter Testing: Test the voltage transmitter using a multimeter. Replace the transmitter if it produces inaccurate readings.
- Prevention Tip: Perform regular checks of wiring connections and safety tubes to avoid voltage inconsistencies.



Fig.7.8 Stack Wiring

## 7.9 BMS System Faults

### 7.9.1 Current Limit Fault of Electrolyte Circulating Pump

- Fault Information: The BMS system displays "Electrolyte circulating pump current is high/low."
- Fault Phenomenon: The system fails to stop and sends out a fault signal.
- Fault Analysis
  - Possible circulating pump failure
  - Faulty frequency converter
- Tools and Instruments:
  - Screwdriver
  - Wrench
  - Multimeter
  - Clamp ammeter
  - Signal generator
  - Insulation resistance meter
- Fault Handling:
  - Check the circulating pump current using a clamp ammeter or via the frequency converter.
  - Verify HMI interface settings for the circulating pump current.
  - If the issue persists, inspect and repair or replace the circulating pump or frequency converter.

- Prevention Tip: Perform regular checks of wiring connections and safety tubes to avoid voltage inconsistencies.



Fig.7.9 Frequency Converter

### 7.9.2 Fault of Current Difference between Positive and Negative Electrolyte Circulating Pumps

- Fault Information: The BMS system displays "High current difference between positive and negative electrolyte circulating pumps."
- Fault Phenomenon: The system fails to stop and sends out a fault signal.
- Fault Analysis
  - Loose wiring
  - Circulating pump failure
  - Faulty frequency converter
- Tools and Instruments:
  - Screwdriver
  - Wrench
  - Multimeter
  - Clamp ammeter
  - Signal generator
  - Insulation resistance meter
- Fault Handling:
  - Fasten or rewire the loose connections.
  - Replace the circulating pump if faulty.
  - Replace the frequency converter if it is malfunctioning.

### 7.9.3 High Temperature Fault of Positive Electrolyte

- Fault Information: The BMS system displays "High temperature of positive electrolyte."
- Fault Phenomenon: The system fails to stop and sends out a fault signal.
- Fault Analysis
  - Ambient temperature exceeds requirements
  - Refrigeration system failure
  - Overflow or liquid mixing failure
  - Serious internal leakage in the stack
- Tools and Instruments:
  - Screwdriver
  - Multimeter
  - Thermometer
  - Clamp ammeter
- Fault Handling:
  - Measure the temperature of the positive electrolyte using a thermometer.
  - If the temperature sensor is faulty, replace it immediately.

- Check HMI interface settings for start/stop temperatures.
- Inspect the refrigeration system for operational issues and repair as necessary.
- Check for electrolyte leaks and repair any damage to pipes or tanks.

#### 7.9.4 High Stack Voltage Fault

- Fault Information: The BMS system displays "High stack voltage."
- Fault Phenomenon: The system fails to stop and sends out a fault signal.
- Fault Analysis
  - Stack voltage exceeds safety limits
  - HMI interface setting error
  - Possible electrical fault or false alarm
- Tools and Instruments:
  - Screwdriver
  - Multimeter
- Fault Handling:
  - Measure stack voltage using a multimeter and compare with the BMS readings.
  - Inspect the stack voltage transmitter module for malfunctions or loose wiring.
  - Check HMI interface settings for incorrect voltage configurations.
  - Replace the stack if confirmed faulty.

#### 7.9.5 SOC Value High/Low Fault

- Fault Information: The BMS system displays "SOC high/low."
- Fault Phenomenon: The system fails to stop and sends out a fault signal.
- Fault Analysis
  - SOC value exceeds 100% or drops below 0%
  - HMI interface calculation errors
  - Possible OCV battery failure
- Tools and Instruments:
  - Screwdriver
  - Multimeter
- Fault Handling:
  - Check HMI interface settings for the correct SOC range (0% to 100%).
  - Inspect SOC calculation settings in the HMI interface.
  - Check for OCV battery malfunctions and replace faulty components.

### 7.10 Electrolyte Faults

#### 7.10.1 Vanadium Pentavalent Precipitation Fault

- Fault Information: Brown-red floc precipitates in the electrolyte.
- Fault Analysis
  - Excessive electrolyte temperature
  - Impurities in the electrolyte
  - Unqualified factory electrolyte
- Tools and Instruments:
  - Laboratory tests
- Fault Handling:
  - Verify electrolyte temperature and reduce if it exceeds operational limits.
  - Test the electrolyte for impurities in a laboratory, and return it to the factory if unqualified.



Fig.7.10 Storage Tank

### 7.10.2 Vanadium Bivalent Crystallization Fault

- Fault Information: Sky-blue crystals appear in the electrolyte.
- Fault Analysis
  - Low electrolyte temperature
  - Impurities in the electrolyte
  - Unqualified factory electrolyte
- Tools and Instruments:
  - Laboratory tests
- Fault Handling:
  - Heat the electrolyte or increase temperature to dissolve the crystals.
  - Test the electrolyte for impurities and return it to the factory if unqualified.

### 7.10.3 Reduced Capacity Efficiency

- Fault Information: Charging and discharging times become shorter, with inconsistent SOC readings.
- Fault Analysis
  - Low electrolyte temperature
  - Low electrolyte flow rate
  - Imbalance in vanadium concentration or valence states
- Tools and Instruments:
  - Thermometer
  - Ultrasonic flowmeter
  - Laboratory tests
- Fault Handling:
  - Check vanadium concentration and valence state in a laboratory, and adjust or restore capacity as needed.
  - Increase electrolyte flow rate to ensure consistent operation.

## 8. Contingency Plan

### 8.1 Electrolyte Splashing or Large Outflow

- **Emergency Response:**

The primary goal is to control the electrolyte leakage. The following measures should be taken immediately:

  - Close the relevant valves at the leakage site to control the leakage.
  - Use cofferdams or similar containment items to prevent the spread of the leak.
  - Use suitable containers (e.g., electrolyte suction trucks, magnetic pumps) to collect and contain the leaked electrolyte.
- **Safety Precautions:**
  - **Personnel Safety:** Ensure the safety of all personnel before beginning any emergency repair. Only trained personnel with proper protective equipment should remain in the area. Evacuate non-essential personnel to a safe location.
  - **Protective Gear:** Emergency responders should wear gas masks if necessary and avoid direct contact with the electrolyte without proper protective measures (e.g., gloves, goggles, acid-resistant suits).
- **Tools and Instruments:**
  - **Tools:** Electrolyte suction truck, magnetic pump, cubic barrels, cofferdams.
  - **Safety Gear:** Gas masks, acid-resistant gloves, protective suits.
- **Emergency Repair Procedure:**
  - Cut off the source of the leak and isolate the area.
  - Inspect the equipment to determine the cause and extent of the leak.
  - Carry out emergency repairs with appropriate spare parts and tools to prevent the issue from escalating or spreading further.
- **Post-Emergency Procedures:**
  - Ensure the quality of the repairs by conducting tests and inspections.
  - Prevent secondary accidents by addressing risks such as electric shock, chemical burns, or mechanical injuries.
  - Clean up the site, dispose of the recovered electrolyte appropriately, and inspect other similar equipment to avoid recurrence. In cases of minor spills, neutralizing agents should be used to prevent further chemical reactions.

### 8.2 Electrolyte Temperature Exceeds the Standard

- **Emergency Response:**
  - When the electrolyte temperature falls below 0°C or exceeds 47°C, the following emergency measures must be taken to prevent equipment failure:
  - Restore ambient temperature as quickly as possible.
  - If unable to restore the temperature, carry out a series of controlled operations to ensure the safety of the equipment and electrolyte.
- **Immediate Actions:**
  - For High Temperature (>40° C): Start the heat exchange system to cool the electrolyte.
  - For Low Temperature (<6° C): Turn on the heating system to maintain appropriate temperature. If the heating system fails, begin charging and discharging the battery system to generate heat.
- **Preventive Measures:**
  - Install temperature monitoring and alarm systems to alert operators when the electrolyte is approaching critical temperature thresholds, allowing for early intervention.
- **Long-Term Storage Precaution:**
  - If the energy storage system needs to remain inactive for an extended period and the electrolyte temperature is below 6° C, it is necessary to mix the anode and cathode electrolytes until the

total voltage approaches 0V. After that, continue mixing for another 30 minutes. This operation helps increase the electrolyte temperature by dissipating stored energy, but it should be done when the system is in a SOC state below 10% to minimize energy loss.

- Post-Repair Checks:
  - Ensure that the system is operating within the correct temperature range, and test Hybrid Thermal Management (Passive + AC Cooling) to avoid similar issues in the future.

### 8.3 Object Strike and Mechanical Injury

- Emergency Response:

In the event of an object strike or mechanical injury, immediate action should be taken to ensure the safety of personnel and to manage the situation:

  - The person in charge must organize on-site rescue operations and call emergency services.
  - Administer first aid as needed, including stopping bleeding and dressing wounds.
- Equipment Considerations:
  - If the accident does not threaten the normal operation of equipment, continue operating the system while ensuring that personnel are kept away from hazardous areas.
- Preventive Measures:
  - Reinforce the use of enhanced personal protective equipment (PPE) to reduce the chance of injury from falling objects or other mechanical risks.
- Post-Incident Procedures:
  - Conduct a comprehensive inspection of the scene, isolate any faulty equipment, and implement preventive measures to avoid future accidents. Provide safety training to all personnel involved in the incident.

### 8.4 Electric Shock Accident

- Emergency Response:

If an electric shock occurs, the immediate goal is to remove the victim from the power source and provide first aid.

  - For Low Voltage Accidents: Cut the power by pulling the nearest switch or unplugging the device. Use insulated tools to move the victim away from the power source.
  - For High Voltage Accidents: Notify the relevant departments to shut off the power. Use high-voltage insulated tools to remove the wire from the victim.
- First Aid:
  - Administer artificial respiration or chest compressions if the victim's breathing or heartbeat has stopped. Transport the victim to the hospital immediately.
- Preventive Measures:
  - Regularly inspect electrical systems and ensure that Ground Fault Circuit Interrupters (GFCI) are in place and functioning properly. Regular audits and electrical safety training for personnel should also be part of preventive strategies.
- Post-Incident Actions:
  - Inspect all similar equipment to avoid recurrence of electric shock accidents and carry out safety training with all personnel. Use shock prevention checklists to ensure proper procedures are followed in daily operations.

### 8.5 Chemical Exposure (Electrolyte Contact)

- Emergency Response:

In the event of unwanted contact with electrolyte or other chemicals:

  - Immediately remove contaminated clothing and rinse the affected area with clean water for 10–15 minutes.
  - If the chemical comes into contact with the eyes, flush thoroughly with clean water, ensuring the eyelids are open.

- First Aid:
  - Avoid applying any ointments or covering the area with bandages. Seek medical attention for more serious injuries or if irritation persists.
- Washing Facilities:

While larger facilities may have dedicated emergency wash stations, for smaller installations, ensure that a readily available source of clean water (e.g., a portable eyewash bottle or running water) is accessible for rinsing affected areas.

- Post-Incident Care:
  - After initial first aid, follow up with a healthcare professional for further evaluation and treatment as needed.

## 8.6 Post-Incident Review and Reporting

After the implementation of emergency protocols, the following steps should be taken:

- Incident Review: Conduct a detailed review of the incident, assessing its cause and the effectiveness of the response.
- Reporting: Prepare an incident report, outlining the actions taken, the root cause, and preventive measures for future occurrences.
- Training and Education: Provide training to all personnel involved, addressing areas where improvements are.

## 9. Glossary of Terms

- **BMS** (Battery Management System): The system responsible for monitoring and controlling battery performance, safety, and communication.
- **SOC** (State of Charge): A measurement of the battery's current charge level.
- **MODBUS**: A communication protocol used for connecting industrial electronic devices.
- **CANBUS**: A robust vehicle bus standard designed to allow microcontrollers and devices to communicate with each other without a host computer.
- **OCV** (Open-Circuit Voltage): It refers to the potential difference between the positive and negative terminals of the battery in the absence of current passing through. This voltage reflects the ability of the chemical energy inside the battery to be converted into electricity.



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