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User Manual

(CDA-CAP® Energy Storage Modules)

For UPS / Backup & Renewable Energy Applications

DANGER - HIGH VOLTAGE HAZARD!

Never touch the power terminals as the module can be charged and cause fatal electrical shocks.

Always check that the module is fully discharged before manipulating the module.

1. Introduction

A supercapacitor energy storage module is a standalone energy storage device consisting of individual supercapacitor cells connected together via busbars. Cells can be connected in series (up to four) for higher operating voltage, in parallel for additional energy storage, or in series-parallel combinations for higher voltage and energy. Supercapacitor modules must not be connected to other types of modules in any way. The modules have built-in passive balancing.

2. Electrical

To avoid arcing and sparking, the energy storage module should be discharged during installation, and the system power supply should be disconnected. The module is discharged at the factory. Shorting wires should be removed before making electrical connections.

To provide the lowest possible equivalent series resistance (ESRDC), the high-power current paths within the module are unfused. Care should be taken to prevent excessive current in applications. Excessive current and/or abnormal duty cycles can cause module overheating, resulting in irreparable damage. Please refer to the specific data sheet for each module for current and duty cycle performance.

3. Electrical Connections

3.1 Series Connection (Voltage Boosting)

3.1.1 Series Connection Principle and Applicable Scenarios

A series connection connects the positive terminals of multiple supercapacitor modules to the negative terminals of the next module in sequence, ultimately creating a combined voltage equal to the sum of the individual module voltages. This is suitable for applications requiring higher voltages (such as high-voltage auxiliary systems in new energy vehicles).

3.1.2 Preparing for Series Connection

Module consistency screening: Modules in series must be from the same batch and model. Each module's capacity, internal resistance, voltage, and other parameters must be tested to ensure parameter deviations are $\leqslant$ 5%. Excessive parameter deviations can lead to uneven voltage distribution between modules after series connection, potentially causing overvoltage damage to some modules. Testing method: Use a professional capacitance tester to measure the capacity and internal resistance of each module under consistent test conditions (e.g., 25℃ ambient temperature, 10A discharge current). Simultaneously, use a multimeter to measure the no-load voltage.

Connecting Wire Selection: Based on the maximum current of the series circuit, select connecting wire with an appropriate cross-sectional area (usually copper conductor). The cross-sectional area is calculated as follows: $S = I \times L / (\gamma \times \Delta U)$ (where S is the cross-sectional area in mm^2; I is the maximum current in A; L is the conductor length in m; γ is the conductivity of copper, assumed to be 57S/m; ΔU is the allowable voltage drop within the conductor, typically $\leqslant$0.5V). The connecting wire must also have good insulation properties. Polyvinyl chloride or silicone rubber with a temperature resistance of 100° C or higher is recommended for the insulation layer.

3.1.3 Series Connection Procedure

Disconnect the main power supply of the application system and ensure that the series connection operation is performed in a power-free environment.

Place each module on a flat, insulated work surface. Connect the positive and negative terminals of each module using the prepared connecting wires, following the order of "module 1 negative terminal → module 2 positive terminal, module 2 negative terminal → module 3 positive terminal..." When connecting, ensure that the cables and connectors are in tight contact and not loose.

Insert a balancing resistor (resistance value determined by module capacity, typically 1kΩ-10kΩ, power $\geqslant$ 1W) in series with the series circuit to balance the voltage across the modules and prevent uneven voltage distribution after the series connection.

After completing the connection, use a multimeter to measure the voltage across each module and the total voltage of the entire series connection. Verify that the total voltage equals the sum of the individual module voltages and that the voltage deviation between modules is $\leqslant$2%.

3.1.4 Precautions After Series Connection

The maximum charge and discharge current of the series connection must not exceed the maximum charge and discharge current of a single module to avoid damage to the modules due to excessive current.

Check the voltage of each module regularly (recommended every 3-6 months). If a module voltage deviation exceeds 5%, replace it immediately to prevent further damage. Short circuits are prohibited in series circuits. Short circuits can cause instantaneous high currents and burn out modules and connecting cables. Therefore, fuses must be installed in the circuit (with a melting current of 1.2-1.5 times the module's maximum charge/discharge current).

3.2 Parallel Connection (Increasing Capacity)

3.2.1 Parallel Principle and Applicable Scenarios

Parallel connection involves interconnecting the positive and negative terminals of multiple supercapacitor modules, ultimately creating a combined capacity equal to the sum of the individual module capacities and a total voltage equal to the voltage of a single module. This is suitable for applications requiring higher capacity (such as emergency power storage systems).

3.2.2 Preparing for Parallel Connection

Module consistency screening: Similar to series connection, parallel modules must be from the same batch and model. The internal resistance and voltage parameters of each module must be tested to ensure internal resistance deviation is ≤5% and no-load voltage deviation is ≤2%. Excessive internal resistance deviation can lead to uneven current distribution between modules after parallel connection, potentially causing overcurrent damage to some modules.

Connecting Wire and Shunt Resistor Selection: The cross-sectional area of the connecting wire should be selected based on the total maximum current after parallel connection (calculation method is the same as for series connection). A shunt resistor (typically 0.1Ω-1Ω, power ≥5W) should be connected in series with the positive terminal of each module to balance the discharge current of each module.

3.2.3 Parallel Operation Procedure

Disconnect the main power supply of the application system to ensure no power is applied.

Connect the positive terminals of each module together with the connecting wires, and the negative terminals together with the connecting wires. Ensure tight contact at each connection point. Apply conductive paste (such as copper-based conductive paste) to reduce contact resistance.

Connect a shunt resistor in series between the positive terminal of each module and the total positive connection wire. Ensure that the shunt resistor is securely installed and the insulation is intact.

After completing the connection, use a multimeter to measure the total voltage of the parallel connection (which should be the same as the voltage of a single module). Use a clamp ammeter to measure the current on each module's connecting wire (the current should be close to zero when no-load, and the current deviation between each module should be ≤5% during charge and discharge).

3.2.4 Parallel Connection Precautions

The total voltage of the parallel combination must not exceed the rated voltage of a single module to avoid overvoltage damage.

Regularly (recommended every 3-6 months) test the internal resistance and current distribution of each module. If the current deviation of a module exceeds 10%, check the shunt resistor for damage or loose connections and promptly repair or replace it.

Fuses (with a breaking current of 1.2-1.5 times the total maximum charge and discharge current) must also be installed in the parallel circuit to prevent short-circuit accidents.

3.3 Series-Parallel Hybrid Connection (Simultaneously Increasing Voltage and Capacity)

3.3.1 Hybrid Principle and Applicable Scenarios

Series-parallel hybrid connection involves first connecting multiple modules in parallel (forming a "parallel group" to increase the capacity of each group), and then connecting multiple "parallel groups" in series (to increase the total voltage). This method is suitable for applications requiring both high voltage and large capacity, such as rail transit energy storage systems.

3.3.2 Parallel Connection Precautions

The modules within each parallel group must meet parallel consistency requirements. The total capacity and total internal resistance of each parallel group must have a deviation of ≤5% to ensure uniform voltage distribution across the parallel groups after series connection.

When connecting parallel modules, complete the connection of the parallel group and ensure it passes testing before connecting the modules in series. The series connection must meet all series connection requirements.

The total voltage of the parallel combination must not exceed the sum of the rated voltages of each parallel group, and the total maximum charge and discharge current must not exceed the maximum charge and discharge current of a single parallel group.

4. Connector Usage Precautions

4.1 Connector Type and Selection

Common connectors for supercapacitor modules include terminal blocks (such as screw-type and plug-in terminal blocks) and connectors (such as circular and rectangular connectors). The following principles should be followed when selecting connectors:

Current Matching: The connector's rated current must be greater than or equal to the module's maximum charge and discharge current to prevent overheating and damage. Typically, the connector's rated current should be at least 20% greater than the maximum charge and discharge current.

Voltage Matching: The connector's rated voltage must be greater than or equal to the module's rated voltage to prevent high voltage from breaking through the connector's insulation.

Environmental Adaptability: Select a protection level (such as IP65 or IP67) based on the installation environment. For humid and dusty environments, choose connectors with a high protection level. For high-temperature environments, choose connectors with a temperature resistance of 120° C or higher (such as ceramic connectors).

Connection Reliability: Prefer connectors with a locking mechanism (such as snap-on or threaded locks) to prevent vibration-induced loosening.

4.2 Connector Connection Operation

Cleaning: Before connecting, wipe the connector pins and contact surfaces with anhydrous ethanol to remove any oxidation and dirt, ensuring good contact. If the pins are severely oxidized (such as blackened or rusted), lightly sand them with fine sandpaper before cleaning.

Polarity Verification: Connect strictly according to the module markings (usually "+" for positive and "-" for negative) and the connector polarity markings. Reverse polarity is prohibited. Reverse polarity can cause a short circuit in the module and damage the protection circuit and connector.

Connection Force Control: When connecting screw-type terminal blocks, use a screwdriver to tighten the screws. The tightening torque must meet the connector manual (usually 1-3 N • m). Too little torque will result in poor contact, while too much can damage the screws and pins. When connecting pluggable connectors, insert and remove them smoothly. Confirm the connector is fully locked when you hear a "click" sound. Insulation Protection: After completing the connection, wrap the connector joints with insulating tape (such as high-temperature-resistant insulation tape) or install an insulating protective cover to prevent foreign objects from contacting and causing short circuits.

4.3 Connector Maintenance and Inspection

Regular Inspection: Check the connectors monthly for looseness, deformation, or signs of heat (such as discoloration or melting of the plastic casing). If looseness is detected, retighten or plug and unplug them immediately. If signs of heat are detected, check whether the current is excessive or the connector is mismatched, and replace the connector if necessary.

Moisture and Rust Prevention: Apply a small amount of anti-rust oil (such as silicone-based anti-rust oil) to the metal contact surfaces of the connectors quarterly, but be careful not to contaminate the insulation layer. In humid environments, the inspection interval should be shortened and moisture-proof measures should be increased.

Replacement Requirements: Connectors must be replaced immediately if: ① Pins are irreparably broken or bent; ② The insulation layer is damaged or cracked; ③ The contact resistance is increased (measure the contact resistance with a multimeter; it should generally be ≤50mΩ; if it exceeds 100mΩ, replacement is required); ④ The locking mechanism fails after repeated plugging and unplugging.

5. Daily Use and Maintenance

5.1 Charging and Discharging Specifications

Charging Requirements: Use a dedicated charger compatible with the module. The charging voltage must not exceed the module's rated voltage, and the charging current must not exceed the module's maximum charging current. Monitor the module temperature during charging. If the temperature exceeds 65℃, pause charging and wait until the temperature returns to normal before resuming.

Discharging Requirements: The discharge current must not exceed the module's maximum discharge current, and the discharge termination voltage must not fall below the module's minimum discharge voltage (typically 30% of the rated voltage). Excessive discharge can cause permanent capacity degradation.

Charge and Discharge Frequency: Avoid frequent charging and discharging (e.g., more than 5 times per minute). Frequent charging and discharging can increase internal module heat and shorten the module's service life. It is recommended that the interval between charge and discharge cycles be 10 minutes or longer.

5.2 Transportation and Storage

During transportation, avoid severe vibration, impact, and compression. Protect from sunlight and rain, and do not invert.

During loading and unloading, handle with care and avoid dropping, tumbling, or heavy pressure.

Storage Environment: Store the product in a clean, dry, and well-ventilated place with an ambient temperature of -20℃ to 40℃ and a relative humidity no greater than 64%. Avoid direct sunlight.

Store the product out of direct sunlight, avoid contact with corrosive media, and keep away from sources of fire and heat.

Place the capacitor module on electrically insulating material.

6. Safety Warnings

6.1 Electrical Safety

When operating the module, you must wear insulating gloves and insulating shoes. If the module's rated voltage is ⩾36V, you must also wear goggles to prevent burns from high-voltage arcs. Do not touch conductive parts such as connectors and cables while the power is on. After powering off, wait 5-10 minutes (for any residual charge in the module to dissipate) before operating again.

When testing the module's voltage or resistance, use a multimeter with a matching range (DC voltage range ⩾1.5 times the module's rated voltage). Do not use the AC or current range to directly measure the module's positive and negative terminals to avoid damaging the instrument or causing a short circuit.

If the module leaks (usually electrolyte, a pale yellow or colorless, transparent liquid), stop using it immediately. Cover the leaked area with dry baking soda to neutralize the acidity. Wear a respirator and acid- and alkali-resistant gloves to clean the area. Avoid direct skin contact with the leaked liquid. After cleaning, perform an insulation test on the area.

7. Module Decommissioning and Environmentally Friendly Disposal

7.1 Decommissioning Criteria

A module shall be deemed decommissioned and prohibited from further use if the following conditions occur:

The module casing is severely damaged or deformed, exposing internal components;

The module must be decommissioned after fire, flooding, or severe impact, even if there is no obvious external damage (the internal structure may be damaged, posing a safety hazard);

The capacity has decreased by more than 30% (after professional testing), or the internal resistance has increased by more than 200%, failing to meet the performance requirements of the application system;

The protection circuit has been completely burned out and cannot be repaired.

7.2 Decommissioning Process

Residual Charge Discharge: Before decommissioning, the module must be fully discharged. This can be done by connecting a matching discharge resistor (resistance value determined by the module capacity, typically 100Ω to 1kΩ, power ≥10W) for ≥2 hours. After discharge, use a multimeter to check the module voltage to confirm that the voltage is ≤1V to ensure there is no residual charge.

Disassembly and Sorting: After discharge, professional personnel will disassemble the module, separating the outer casing (metal materials are recyclable), supercapacitor cells, protective circuit components (such as resistors, capacitors, and chips), and connecting cables. Supercapacitor cells must be collected separately and must not be mixed with regular trash.

Environmentally Friendly Disposal:

Metal casings and copper connecting cables can be recycled at authorized waste recycling centers for resource reuse.

Supercapacitor cells must be sent to a facility certified for hazardous waste disposal (such as a hazardous waste treatment center designated by the local environmental protection department). The electrolyte within them contains corrosive substances and is therefore considered hazardous waste and must not be discarded carelessly.

Damaged circuit boards, chips, and other electronic components must be disposed of by electronic waste recycling companies to prevent heavy metal (such as lead and mercury) contamination.

8. Other Usage Precautions

To ensure proper use of capacitors, please read these instructions carefully before use:

- Do not crush, smash, or disassemble capacitors.
- Do not operate or use capacitors outside the specified operating voltage and temperature ranges.
- During long-term storage, avoid high temperatures, high humidity, direct sunlight, shock, vibration, and direct contact with water, corrosive and toxic substances, or other chemicals.
- Do not immerse capacitors in water. When not in use, store them in a cool, dry environment.
- Do not use or store capacitors near heat sources such as fire or heaters.
- When using this product, use only dedicated charging and discharging equipment.
- Do not use this product if the explosion-proof valve is damaged or cracked.
- Do not physically impact, vibrate, knock, throw, or step on the product. Do not pierce the capacitor with nails or other sharp objects. Do not use this product if it is deformed.
- In the event of a malfunction, the metal casing of the capacitor may be electrically charged. Arc current or human load current can cause harm. Do not place any objects or tools on top of the capacitor. When near capacitors, be sure to remove any metal objects such as rings, watches, or clothing.
- If the product becomes dirty, wipe it clean with a dry cloth before use. Failure to do so may result in poor contact and malfunction.
- Do not use capacitors with modified or damaged charging and discharging equipment or devices.
- Do not use with other different types of products.
- Do not use in areas with strong static electricity or magnetic fields, as this may damage the product's safety features and pose a safety hazard.
- Do not use products that are leaking, dropped, short-circuited, or otherwise damaged.
- If the product develops an odor, becomes hot, leaks, changes color, deforms, or exhibits any other abnormalities during use or storage, immediately remove it from the holder or device and discontinue use.
- If a capacitor leaks and electrolyte enters your eyes, do not rub them. Rinse with clean water and seek medical attention immediately if necessary. Failure to do so may cause eye damage.