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Structure and Working Principle of Power Battery

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Structure and Working Principle of Power Battery

The power battery system is the most important power component of new energy vehicles, and constitutes the "EIC" system together with the PMSM and the MCU. This course mainly explains the power battery system in the EIC system, and through this course, relevant personnel and professional maintenance personnel will have a basic understanding of the power battery system. The objectives of this cause are as follows:

- ✓ Understand the safety of power battery and the emergency response measures
- ✓ Understand the types, characteristics, basic structure of the power battery, as well as the basic functions of its core components
- ✓ Understand the basic working principle of the power battery
- ✓ Understand the operation and maintenance of power battery
- ✓ Understand the common faults and troubleshooting methods of power battery

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I. Overview to power battery system

1. Main functions of power battery

A power battery refers to a battery that provides energy for the powertrain of an electric vehicle. Inherently different from the battery on conventional vehicles, the power battery system mainly consists of battery modules, battery management system (BMS), manual service disconnect (MSD), sensors, electrical connectors, vent valves, battery structural components, and others, **and we can considered the power battery as the fuel tank in a conventional fuel vehicle.**

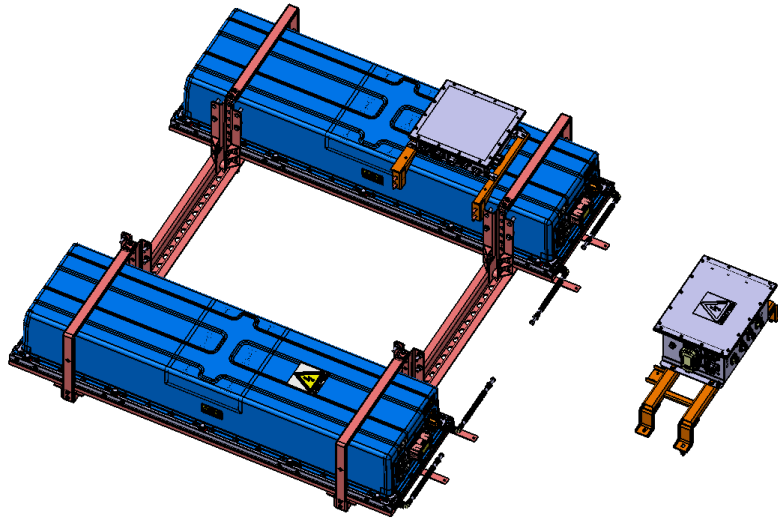


I. Overview to power battery system

2. Main parameters of power battery (taking M4 light truck as an example)

The battery system is adapted for local regulations and functions based on the original M4-6t CATL 81.14kwh battery system to meet the requirements for export to Poland.

The scheme of 81.14kwh battery system is as follows:



Item	Battery system scheme
Battery system capacity/kWh	81.14kwh
Cell Ah (LFP)	150Ah
Production condition of cell	Mass-produced
Assembly of standard battery pack	TX8 standard pack, 2 in series
Battery system scheme	1P168S
Dimensions of standard battery pack	1720*540*240
Energy density of standard battery pack/Wh/kg	> 135
Rated voltage (V)	540.96
Working voltage range (V)	420~613.2
Cooling/heating	Natural cooling/heating film heating with a heating rate of 0.25 °C/min
Max. continuous charging current (A)	150
Rated output current (A)	150
Weight/kg	--
Pack lifespan	5 years or 200,000 km

I. Overview to power battery system

2. Main parameters of power battery

IP rating of battery pack

IP rating: Protection of battery system includes equipment protection and personnel protection, and for equipment protection, the requirements are as follows:

IP XX against dust and water

Degree of protection against dust (the first X indicating ingress protection against foreign objects) 0- None

- 1- Test probe with a diameter of 50mm shall not penetrate completely
- 2- Test probe with a diameter of 12.5mm shall not penetrate completely
- 3- Test probe with a diameter of 2.5mm shall not penetrate completely
- 4- Test probe with a diameter of 1.0mm shall not penetrate completely
- 5- Dust shall only penetrate in quantities which do not impair performance and safety
- 6- Dust shall not penetrate

Degree of protection against water (the second X, indicating protection from harmful effects caused by water ingress)

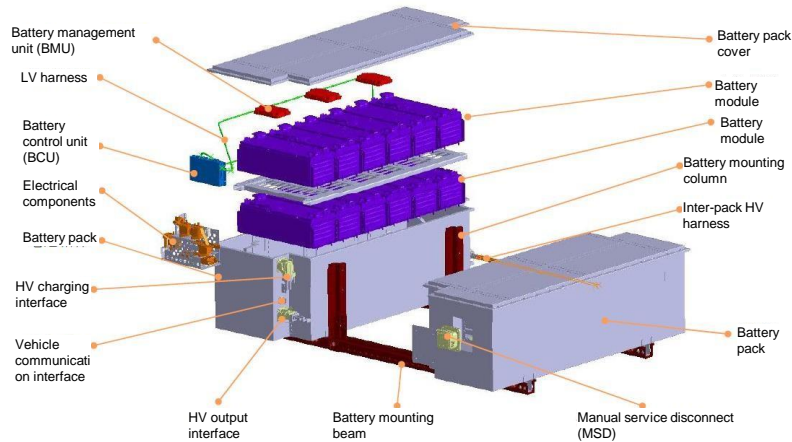
- 0- None
- 1- Vertical drips shall not have any harmful effects
- 2- Vertical drips shall not have any harmful effects when the enclosure is tilted at any angle up to 15° on either side of the vertical
- 3- Water spray at an angle up to 60° on either side of the vertical shall have no harmful effects
- 4- Water which splashes against the enclosure from any direction shall not have any harmful effects
- 5- Water which is directed against the enclosure from any direction as a jet shall not have any harmful effects
- 6- Water which is directed against the enclosure from any direction as a strong jet shall not have any harmful effects
- 7- Water shall not penetrate in a quantity cause harmful effects if the enclosure is immersed in water temporarily under specified pressure and time conditions
(the sample shall be immersed in the water for 30min with the bottom at least 1m away from the water surface)
- 8- Water shall not penetrate in a quantity causing harmful effects if the enclosure is continuously immersed in water under conditions which are agreed between manufacturer and user, but which shall be more severe than code 7 **(for CATL IPX8, it is defined that the sample is immersed in the water for 48h with the top 1m away from the water surface; and for MCU, Foton defines that the sample is immersed in the water for 24h with the top 1m away from the water surface)**

I. Overview to power battery system

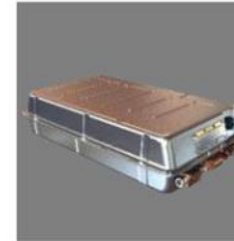
3. Structure and compositions of power battery

➤ **Battery system:** battery system is an energy storage unit consisting of battery cells or battery modules which are integrated together, battery management system (BMS), HV circuits, LV circuits (for control and communication), cooling system and mechanical assembly of the pack.

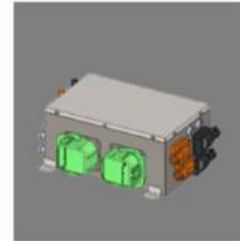
Structure of battery system



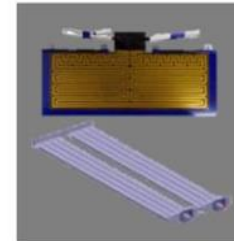
Battery pack



Battery distribution unit (BDU)



Thermal management accessories



HV/LV harness



I. Overview to power battery system

4. Differences between power battery and general battery



4. Differences between power battery and general battery

The battery can generally be classified by the following three methods:

Method 1: classify per type of electrolyte:

1. Alkaline battery, referring to battery which mainly applies potassium hydroxide solution as the electrolyte, for example, alkaline zinc manganese battery, cadmium nickel battery, nickel hydrogen battery, etc;
2. Acid battery, referring to battery which mainly applies sulfuric acid solution as the electrolyte, for example, lead–acid battery;
3. Neutral battery, referring to battery which applies saline solution as the electrolyte, for example, zinc manganese dioxide battery (also called as acid battery by some consumers), seawater activated battery, etc;
4. Organic electrolyte battery, referring to battery which mainly applies organic solutions as the electrolyte, for example, lithium battery and lithium-ion battery.

Method 2: classify per operation nature and storage method:

1. Primary battery, also called galvanic battery, referring to the battery that cannot be recharged, for example, zinc-manganese dry battery, lithium primary battery, etc;
2. Secondary battery, referring to battery that can be recharged, for example, nickel hydrogen battery, lithium-ion battery, cadmium nickel battery, etc; In actual practice, the storage battery traditionally refers to lead–acid battery, which is also a kind of secondary battery;
3. Fuel cell, referring to battery into which the active materials are continuously introduced from the outside only when it is working, for example, hydrogen oxygen fuel cell;
4. Reserve battery, referring to the battery for which the electrolyte is not filled until it is about to be put into use, for example, magnesium-silver chloride battery, also known as seawater activated battery, etc.

Method 3: classify per material of positive and negative electrodes:

1. Zinc series battery, for example, zinc-manganese battery, zinc-silver battery, etc;
2. Nickel series battery, for example, cadmium nickel battery, hydrogen nickel battery, etc;
3. Lead series battery, for example, lead-acid battery;
4. Lithium series battery, for example, lithium-magnesium battery;
5. Manganese dioxide series battery, such as zinc-manganese battery, alkaline manganese battery, etc;
6. Air (oxygen) series battery, for example, zinc-air battery.

5. Advantages of power battery

Advantages of lithium-ion battery:

1. High working voltage

The working voltage of lithium cobalt oxide battery, lithium manganese oxide battery, lithium iron phosphate battery and nickel-hydride/nickel-cadmium battery are 3.6V, 3.7V, 3.2V and 1.2V respectively.

2. High specific energy

The theoretical specific energy of the cathode material of lithium-ion battery is more than 200, but in actual use, the specific energy is lower due to irreversible capacity loss. Even so, the specific energy of lithium-ion battery will be still higher than 160, which is 3 times that of nickel-cadmium battery and lead-acid battery, and 1.5 times that of nickel-metal hydride battery.

3. Long cycle life

At present, the lithium-ion battery can be cycled over 1,000 times under deep discharge condition, and over 5,000 times under low-depth discharge condition, far better than other batteries.

4. Low self discharge rate

The self discharge rate of lithium-ion battery is only 3% -5% of the total capacity, greatly alleviating the loss of traditional secondary battery caused by self discharge when it is not working.

5. No memory effect

No memory effect is involved, and thus no activation is required during use.

5. Advantages of power battery

Advantages and disadvantages of lithium batteries

Type	Lithium iron phosphate (LFP)	Lithium manganese	Ternary lithium (Nickel-cobalt-manganese, NCM)
Advantages	<ul style="list-style-type: none"> Favorable environmental-friendliness Good safety Long cycle life (2,000+) Excellent high-temperature performance 	<ul style="list-style-type: none"> Low cost and zero pollution Good low-temperature performance Good safety Good rate capability Easy manufacturing process 	<ul style="list-style-type: none"> High energy density Small size Excellent low-temperature performance
Disadvantages	<ul style="list-style-type: none"> Poor low-temperature performance Low energy density Large size High manufacturing cost 	<ul style="list-style-type: none"> Low cycle life (1000+) Poor high-temperature performance Fast attenuation, and high swelling probability at high temperature 	<ul style="list-style-type: none"> Poor high-temperature performance Low safety High cost Low cycle life (1200+)

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Terminology and key characteristics of power battery

- Nominal voltage: also called rated voltage, the approximate voltage specified by the manufacturer to identify the type of battery, expressed in volts.
- Open-circuit voltage: the terminal voltage of a battery in an open circuit state (which is also called ideal power supply when no load is connected)
- Working voltage: the voltage displayed in the process of discharge after the battery is connected to the load. The working voltage at the initial stage of discharge is called the initial voltage. Then, after the battery is connected to the load, the working voltage of the battery, due to ohmic resistance and polarization overpotential, is lower than the open-circuit voltage.
- End-of-charge voltage: the max. battery voltage allowed during normal charging.
- End-of-discharge voltage: the min. battery voltage allowed during normal discharging.

Internal resistance: the resistance incurred by the battery when the current flows through the inside of battery, which will cause drop of battery working voltage, and also cause the terminal voltage to be lower than the electrodynamic potential and open-circuit voltage during discharging, and higher than the electrodynamic potential and open-circuit voltage during charging. Internal resistance is an extremely important parameter of a battery as it directly affects the working voltage, current, output energy, and power of the battery, and an internal resistance as low as possible is preferred.

Terminology and key characteristics of power battery

➤ Capacity (Ah)

Capacity refers to the amount of electricity that a battery can provide under certain discharge conditions, which is represented by the symbol C. Capacity is an important electrical performance indicator of battery, and is determined by the active substance in the electrode. The capacity is generally measured in amperes * hours (Ah) or milliamperes * hours (mAh) (if the rated capacity of the battery is 1Ah, it means that the battery can work continuously for 1h at a discharge current of 1A).

Battery capacity includes theoretical capacity, rated capacity and actual capacity

Theoretical capacity: the highest theoretical value calculated from the mass of active substances according to Faraday's law (which is only related to active materials).

Rated capacity: the minimum capacity that a battery is required to discharge under certain discharge conditions according to the national standards or the standards issued by relevant authorities, which is also called nominal capacity, and is an important technical indicator for the quality acceptance of a battery.

Actual capacity: the amount of electricity that a battery can output under certain conditions, which is equal to the product of discharge current and discharge time, expressed in Ah, and is generally lower than the theoretical capacity. Formula of battery capacity in case of constant-current discharge: $C=It$, i.e. Battery capacity (Ah)=Current (A) x Discharge time (h); Formula of battery capacity in case of variable current discharge: $C=\Delta I * dt$

The actual capacity of a battery mainly depends on the quantity and quality of active substances, and the utilization rate of active substances. The capacity of a battery is a function of range. Specifically. the higher the capacity, the longer the range, and the lower the capacity, the shorter the range.

Terminology and key characteristics of power battery

- Battery energy (battery level) (Wh): the amount of electricity (energy) stored by the battery, expressed in Wh

Meaning: The energy of a 3.7V, 15Ah cell is 55.5Wh, and the energy of a 37V, 10Ah battery pack is 370Wh. Battery energy is an important measure for the work done by devices driven by batteries.

Calculation formula of battery energy: Rated battery energy = Total battery voltage (number of battery strings * rated battery voltage) * Total battery capacity (number of batteries in parallel * rated capacity) ÷ 1000

(Taking a 25AH2P138S for example: $3.7 * 138 * 2 * 25 = 25530 \text{wh} \div 1000 \approx 25.5 \text{Kwh}$)

Measuring battery energy based on battery voltage is a simple but somewhat rough method, and for lithium-ion battery, the only advanced method to determine the battery energy is to measure with a Coulomb meter and calculate by applying the advanced algorithm.

- Power (KW): the energy output by the battery per unit time under a certain discharge condition, expressed in W or KW.
- Power density: also called specific power, the power output by the battery per unit mass or volume, which is expressed in W/KG or W/L. Specific power is an important indicator of the battery for evaluating its capability to support the acceleration and gradeability of a vehicle.

Terminology and key characteristics of power battery

➤ Energy density (Wh/Kg)

Energy density, also called **specific energy**, refers to the amount of energy stored per unit volume or mass, usually expressed in volumetric energy density (Wh/L) or mass energy density (Wh/kg).

- ✓ If a lithium battery has a weight of 325g, a rated voltage of 3.7V, and a capacity of 10Ah, its energy density is 113Wh/kg
- ✓ The table below lists the theoretical energy density of several types of batteries, which depends on the material density and structure.

Energy density	Lead-acid battery	Nickel–cadmium battery	Nickel–metal hydride battery	Lithium battery
Wh/kg	30~50	50~60	60~70	130~150
Wh/L	50~80	130~150	190~200	350~400

Terminology and key characteristics of power battery

- Discharge plateau: at the beginning of discharge, the voltage drops fast, and as the discharge progresses, the battery voltage hardly changes, or changes very little, which is called the discharge plateau voltage
- Discharge (charge) rate: a measure of the speed of discharge. 1C means that an 1AH battery is discharged from 100% to 0% in one hour

Taking the full charge of a 120Ah battery as an example:

- At a constant current of 120A (1.0C), the time for charging from 1% to 100% is 1 hour
 - At a constant current of 60A (0.5C), the time for charging from 1% to 100% is 2 hour
 - At a constant current of 240A (2.0C), the time for charging from 1% to 100% is 0.5 hours
-
- Charging method (CC-CV): the battery is charged first at constant current (the current remains constant for fast charging), then at constant voltage (voltage remains constant and current gradually decreases) and finally at trickle current (the battery is further charged at small current)

Terminology and key characteristics of power battery

➤ Battery life:

1. Calendar life: The calendar life of a lithium-ion battery refers to the period from the date of production to the end of the life of the battery measured by year, which covers shelving, aging, high/low temperature test, cycle, working condition simulation and other links. The end of life of a cell in a battery system often affects the operation of the whole system and causes malfunction of the system. Therefore, the correct estimation of battery state of health and the study of calendar life can provide further guidance for the operation of the battery.

2. Cycle life: The standard cycle life of a battery refers to the total charge and discharge cycles that the battery have been experienced before its capacity decays to the specified value under certain charge and discharge conditions.

For example, at a charge/discharge rate of 1C, the cycle life of a battery is 6,000, while at a charge/discharge rate of 3C, the cycle life drops down to about 2,000

3. Working condition life: this term is unusually applied to the power battery on the electric vehicles, and is mainly to test the service life of the power battery according to the working condition diagram, with a consideration that the conditions encountered by a vehicle, including terrains and traffic conditions, are more complex, and can affect the working condition of the battery. For example, the warranty period of a battery is 5 years or 200,000 km, whichever comes first.

Terminology and key characteristics of power battery

- SOC (state of charge): the percentage of the current available capacity in the rated capacity. A SOC of 0% indicates that the battery is completely discharged, and a SOC of 100% indicates that the battery is fully charged.

$SOC = Q_{\text{remain}} / Q_{\text{rated}} * 100\%$, where Q_{rated} is the rated charge of the battery, and Q_{remain} is the remaining charge in the battery.

- SOH (State of Health): a quantification of battery health. For the concept of SOH, "current battery capacity" is a widely applied and recognized external characteristic evaluation indicator that best reflects the deterioration of a power battery.

According to the working principle of lithium battery, lithium ions are constantly embedded and de-embedded, and with the repeated charge and discharge, the electrode active materials and reserved lithium ions are constantly consumed and lost, resulting in a continuous decline in capacity, charge/discharge power and other performance of the battery, gradual aging of battery and finally end of its life.

- DOD (depth of discharge): a measure of discharge degree, expressed as the percentage of battery discharge capacity to battery rated capacity.

On the contrary to SoC, a DoD of 100% indicates that the battery is fully discharged, and a DoD of 0% indicates that the battery is fully charged.

The DOD of a battery is 0 when it is fully charged, and 1 when it is fully discharged. In normal cases, the DOD of a battery is within 0~1, and the relationship of DOD and SOC is as follows: $DOD + SOC = 1$ Normally, the DOD of a power battery is 80% -90%. The smaller the DOD, the longer the battery life and the smaller the available capacity of the battery. SoC is generally used during use of the battery, and DOD is used to describe the cycle life of the battery.

Terminology and key characteristics of power battery

- **Internal short circuit:** a fault caused by contact between positive electrode and negative electrode, which is generally caused by (1) improper manufacturing in manufacturing process. Specifically, burrs on the surface of the electrode are not removed and pierce the separator, causing the positive electrode and negative electrode to be short, or metal chips are mixed in during the manufacturing and pierce the separator; (2) improper use in operation process. Specifically, sharp deposits (lithium dendrites) from chemical reaction will be generated after multiple charges and discharges, piercing the separator, or when the battery is overheating, the separator will contract and melt, resulting in a short circuit between the positive electrode and the negative electrode.
- **Micro short circuit:** Small sharp powder particles, metal chips, metal foreign matters and discharge at the tip during charging or discharging will melt the separator, causing small contact between the positive electrode and the negative electrode. Micro short circuit may sometimes be eliminated (broken) by high-current discharge, and if it occurs, will cause rapid voltage drop (self discharge) during long-term storage.
- **Self discharge:** a phenomenon of a battery that its voltage and charge reduce when it is not in use. The percentage of self discharge capacity in the original total capacity is referred to as self discharge rate.

Calculation method: When a battery is stored for 1 month after full charging, and then discharged to 3.0V at a discharge rate of 1C with the capacity at this point recorded as C2 and the original capacity recorded as C0, then the self-discharge rate of the battery in this month is: $(1-C2)/C0$.

The magnitude of self discharge is related to the internal structure and material properties of the battery. All batteries incur self discharge, but obvious self discharge is abnormal and needs your attention.

Terminology and key characteristics of power battery

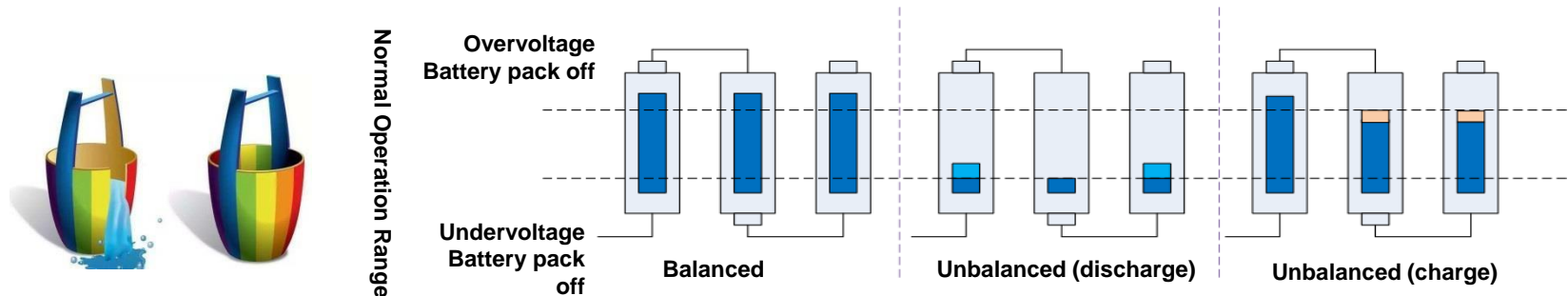
- **SOC jump: single SOC change greater than 1%** as indicated on the instrument panel during driving or charging. A SOC change **greater than 5%** constitutes a severe SOC jump.
- **SOC rapid drop:** a situation in which the change rate of **SOC** is 1% within **less than 12s** and a single SOC change is less than or equal to 1%.
- **Battery voltage difference: voltage difference of a cell with other cells in the battery system.** For batteries of different manufacturers, their voltage difference ranges are different due to difference in performance and temperature. The alarm threshold is accessible according to the vehicle protocol.
- **Battery temperature difference: temperature difference at one position with other positions in the battery system.** Normally, the temperature difference should be less than 10 °C, and the smaller the better. For batteries of different manufacturers, their temperature difference ranges are different due to difference in performance and temperature. The alarm threshold is accessible according to the vehicle protocol.

Terminology and key characteristics of power battery

- **Balancing:** Since a cell is unable to meet the needs of normal operation of electric vehicle due to limited voltage or capacity, it is required to connect multiple cells in series or parallel. However, those cells are not completely identical and may be different in internal resistance and capacity, and besides, when a cell is dead, other cells will charge the dead cell continuously and they may be damaged in the long term.

Balancing can control the voltage deviation of cells within a reasonable range, so as to ensure that each cell will not be damaged during normal operation. However, if balancing is unavailable, the voltages of cells will become more and more different from each other as the charge/discharge cycle increases, thus greatly shortening the service life of battery.

- Active balancing: a balance method in which a portion of the energy of the HV battery is returned to the battery circuit or directly to the LV battery through a converter, and by using a capacitor or an inductor as the energy storage unit and through repeated charging and discharging of the capacitor or the inductor, the basic balance is achieved among cells in the battery pack, i.e. **discharge at high voltage and charge at low voltage**.
- Passive balancing: a balancing method in which the balancer is connected in parallel on both ends of the cell to be balanced, so that when the voltage of the cell rises to a certain value due to charging, the start switch tube will close the discharge resistor to dissipate excess energy in the form of thermal energy, i.e. **discharge only**.



Terminology and key characteristics of power battery

➤ **Definition of cell consistency for lithium battery**

Cell consistency refers to a situation that the capacity, static internal resistance, static voltage, self discharge of cells made of the same raw materials through the same manufacturing process, as well as their changes of voltage/internal resistance/voltage during use are within the specified range.

For a battery system composed of multiple cells, the output energy, output power, and life of the system depend on the cell with worst performance.

➤ **The most intuitive parameters for assessing cell consistency mainly include capacity, voltage, internal resistance, and self discharge.**

● **There are many factors that affect the consistency of cells, which run through all links of the battery including design, manufacture, storage, and use.**

Differences in raw materials: many raw materials are expected to be used in lithium-ion batteries, and they are inherently inconsistent. Thus, the use of multiple materials together will result in significant cell inconsistency.

Differences in production process: dozens or hundreds of processes are required for manufacturing a finished cell from raw materials, and the whole production process, which takes 27-30 days in total, may involve many variable conditions and factors that will also lead to cell inconsistency.

Differences in production equipment: the inherent instability of production equipment will also lead to significant cell inconsistency in the production process.

Terminology and key characteristics of power battery

- **Impacts of voltage consistency on battery:**

Voltage consistency mainly affects the mutual charging of cells in a parallel battery pack. When the voltage of a cell is too low, other cells connected in parallel with it will charge this cell. However, due to the unavoidable differences in cell parameters, theoretical consistency is never possible among cells in the battery pack, which will not only accelerate the rapid decline of cell performance, but also cause substantial consumption of energy in the battery pack.

- **Impacts of internal resistance consistency on battery:**

For a series battery pack, current passing through the cells connected in series in the battery pack are the same, and if a cell incurs a high internal resistance, its voltage drop (voltage loss) and energy loss will be higher, and more heat will be produced, and as the heat produced increases, the temperature of the cell will increase, and then the internal resistance will further climb, pulling the cell into a vicious cycle. In addition, if the heat is not dissipated in time, some cells may incur thermal runaway (due to a poor heat dissipation system, heat will accumulate, the power of cell will reduce, and what's worst, the cell will catch fire or even explode), thus bringing safety hazards to the entire battery pack.

For a parallel battery pack, the charging current allocated to cells, due to internal resistance difference among them, is different, and in a cell with higher charging current, the voltage will rise faster. Therefore, charging is required to be stopped before most batteries are fully charged for the sake of safety, so that the actual total energy of the battery system is significantly lower than the design value.

Terminology and key characteristics of power battery

- **Impacts of self discharge consistency on battery:**

As the time when the battery pack is not connected to the external circuit increases, the capacity loss and voltage drop of cells with high self discharge rate will increase, increasing the inconsistency of the cells in the battery pack, speeding up the occurrence of inconsistent capacity, voltage and internal resistance, and even increasing the possibility of over discharge, posing a safety hazard thereafter.

- **Impacts of capacity consistency on battery:**

Provided that the operation conditions are the same, the depth of discharge of cells may vary due to a difference in capacity. Specifically, when a cell with high capacity is still in low-depth discharge state, the cell with low capacity has been in deep discharge stage; and when the cell with high capacity is in deep discharge, the cell with low capacity has no energy to be discharged any more and becomes a load in the circuit.

Though cells of same type have the optimum discharge rate, the discharge current of those cells, due to difference in capacity, will not be the same, so that for some cells, their discharge rate may be lower or higher than the optimum discharge rate.

In the process of charging, cells with low capacity will be fully charged earlier than the cells with high capacity, and if the charging continues at this point, a safety hazard may ensue.

As described above, cells with low capacity will be repeatedly pulled into a vicious cycle featuring overcharge/overdischarge and will be damaged prematurely, accelerating the deterioration of normal cells and affecting the performance and service life of the battery system.

Terminology and key characteristics of power battery

- **Impacts of connection method and structure/device on consistency of battery pack:**

For a large energy storage system, a large number of cells will be connected in series/parallel to meet the requirements for output energy and power, and thus a large number of connection circuits, controls and other devices are required between cells and modules. Since the energy consumption at connection points, and the performance and aging rate of devices or structures are different, their impacts on the battery are also different.

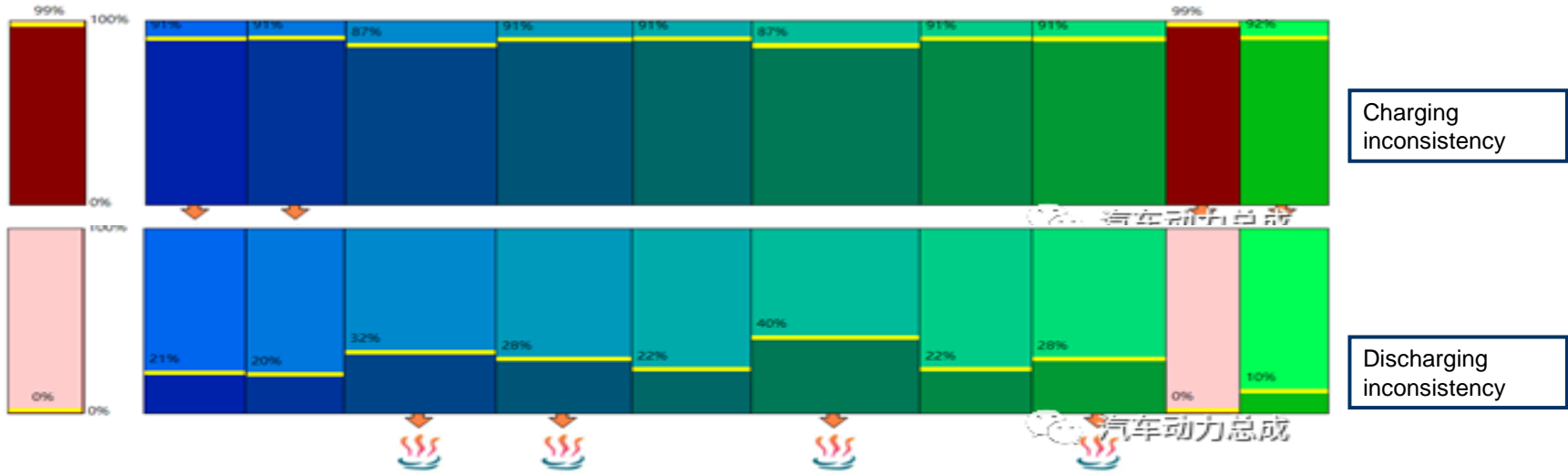
- **Impacts of working condition and environment on consistency of battery pack:**

The environment of cells in the battery pack, due to the assembly design characteristics and operation environment characteristics, will be inevitably different. For example, the ambient temperature, stress and other conditions exposed to cells in the middle of module are different from those exposed to the cells at the outboard of the module (especially the temperature difference), and in this case, the charging/discharging rate, aging rate, and other characteristics of the cells are substantially changed, resulting in an increasing difference in the deterioration rate of the cells, and further accelerating the death of the battery system.

II. Terms and definitions

Terminology and key characteristics of power battery

In a battery system, inconsistency is absolute, while consistency is relative. To increase the performance and service life of the battery system, the common practice at present is to actively manage and maintain the cells in the system. In fact, over half of the life of a battery pack depends on the management and maintenance of the system. By active balancing management and control through external circuits, all cells in the battery system will be kept in the same environment and same conditions as much as possible, thereby achieving consistence of cells in working status and pace, and making the performance and life of the battery pack closer to the performance and life of cells.



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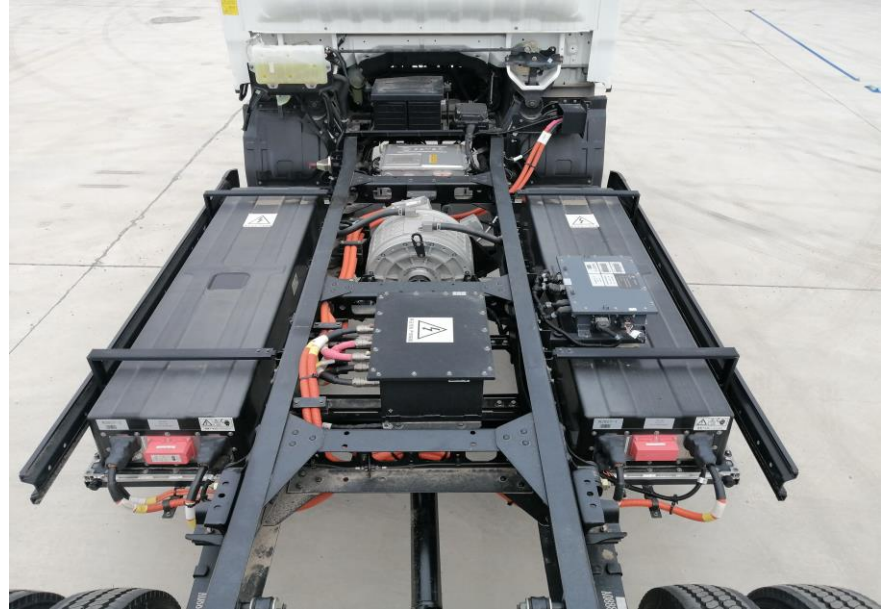
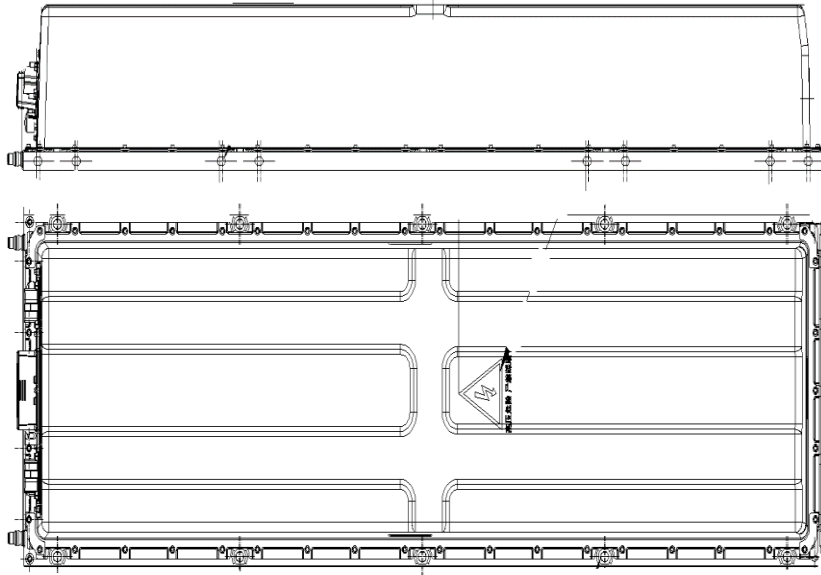
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III. Structure, composition and working principle of battery pack

1. Structure of pack

Pack: an energy storage system consisting of cells or modules integrated together, BMU, HV circuits, LV circuits, cooling device and mechanical assembly.



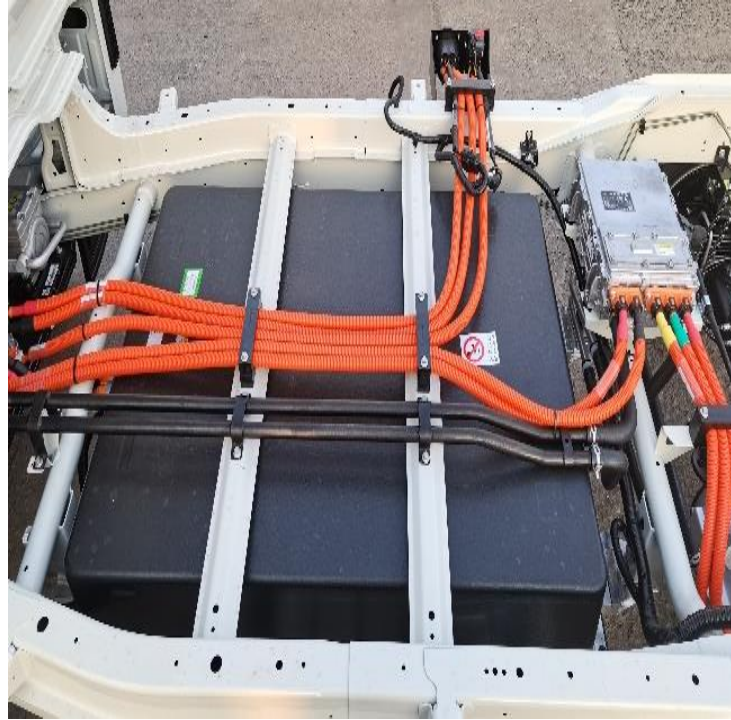
Light truck

III. Structure, composition and working principle of battery pack

1. Structure of pack



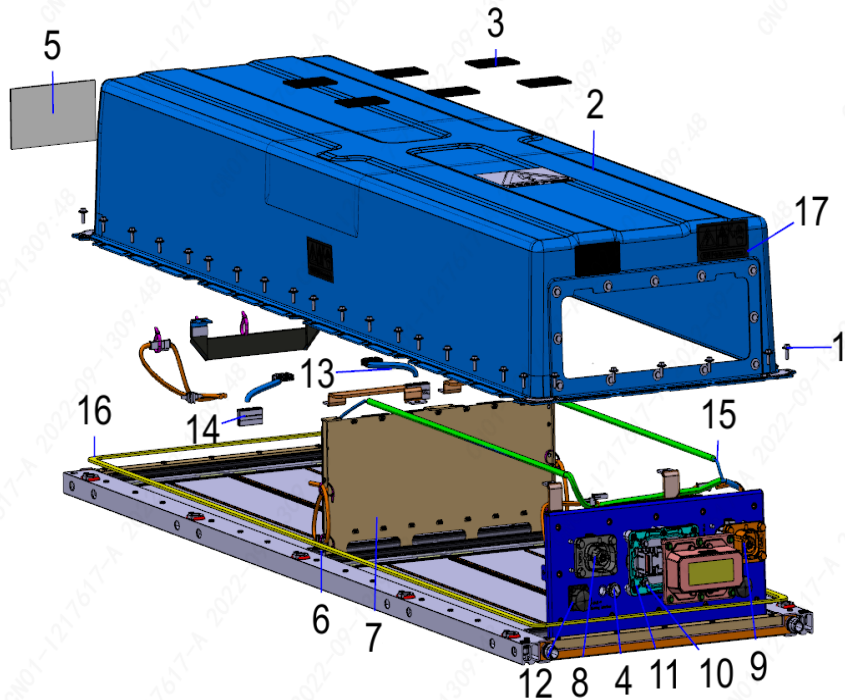
VAN



Mini truck

III. Structure, composition and working principle of battery pack

2. Main components (including external electrical interfaces)



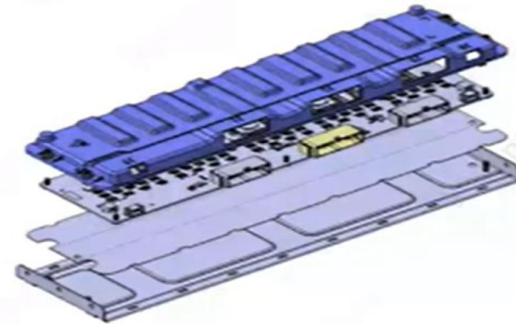
1. Combined hex head bolt_ M5x16_coated with adhesive
2. Battery pack cover_molding TX8
3. Upper cover buffer foam_240Ah_01
4. Balancing valve_M12_valve plate
5. Hygroscopic tablet
6. M5 hex flange nut
7. Ebus CSC assembly_7.0_LT_6_84S_BPC_B3-V2
8. HV connector socket
9. HV connector socket
10. Hex flange bolt_M5x10mm
11. MSD mounting
12. Pack internal HV harness
13. Pack internal LV harness
14. Pack internal LV harness
15. Pack internal LV harness
16. Gasket_T8_150
17. Gasket_TX8_panel

III. Structure, composition and working principle of battery pack

2. Main components (including external electrical interfaces)

Cell Supervision Circuit (CSC): an electronic unit which **collects heat and electricity data** related to battery cells (integrated) or modules (integrated), and transmits them to the battery control unit

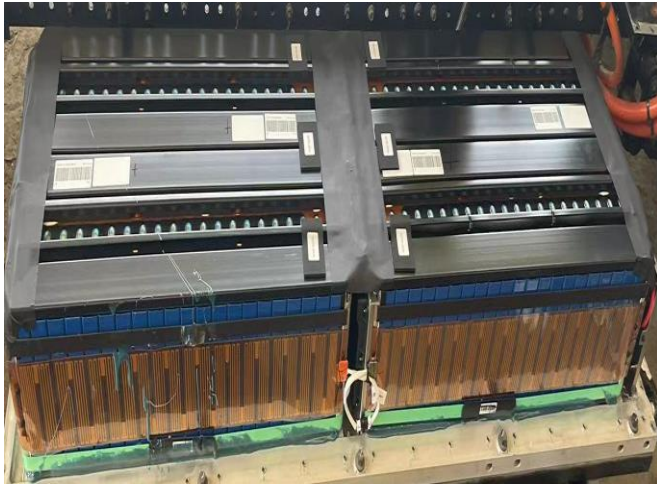
- Data collected: cell voltage and temperature.
- Battery active/passive balancing.



III. Structure, composition and working principle of battery pack

3. Module

Module: a group of cells connected in series and/or parallel with only one pair of positive and negative output terminals for use as a power source.



Light truck



VAN

Note

At present, on all overseas models, the power battery is fixed by laser welding and adhesive at the bottom, and each cell and module cannot be disassembled for repair individually, and in case of any problem, the power battery needs to be replaced as a whole.

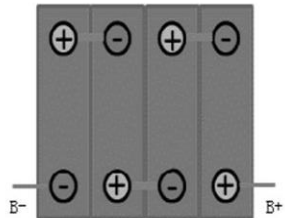
III. Structure, composition and working principle of battery pack

3. Module

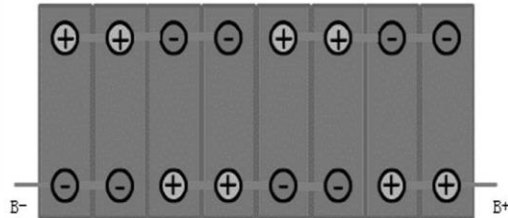
Module series/parallel connection modes

Cells are directly housed in the shell, with the **temperature sampling point** and **voltage sampling point** as shown in the figure.

1P4S

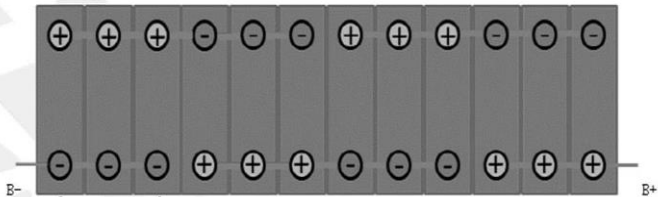


2P4S

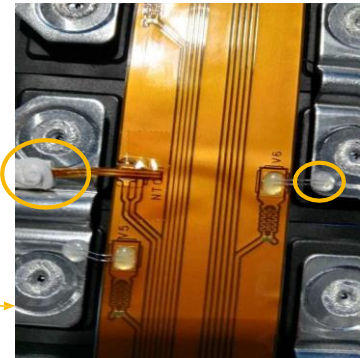
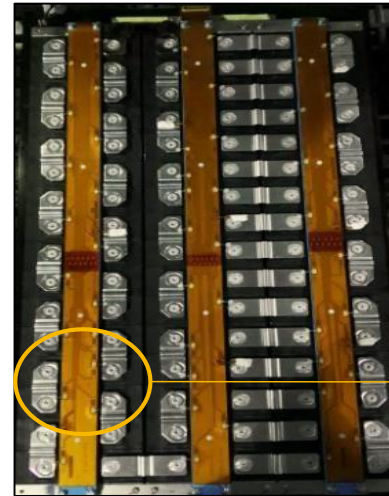


These two cells are considered as one cell (parallel)

3P4S



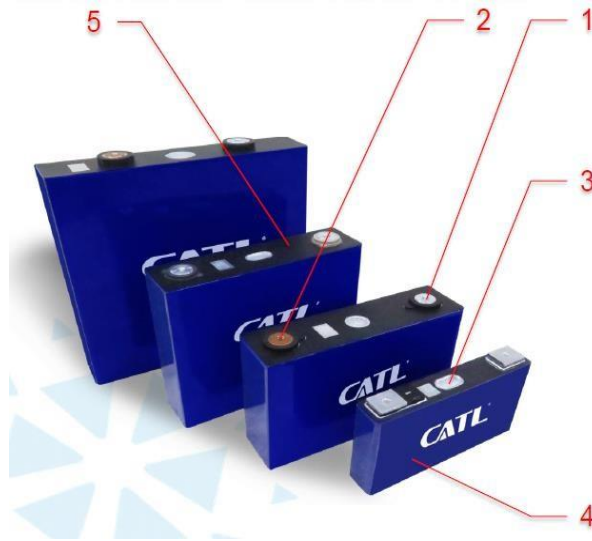
These three cells are considered as one cell (parallel)



III. Structure, composition and working principle of battery pack

4. Cell

Cell: a basic unit that directly converts chemical energy into electrical energy and designed to be rechargeable, which consists of electrode, separator, electrolyte, shell and terminal.

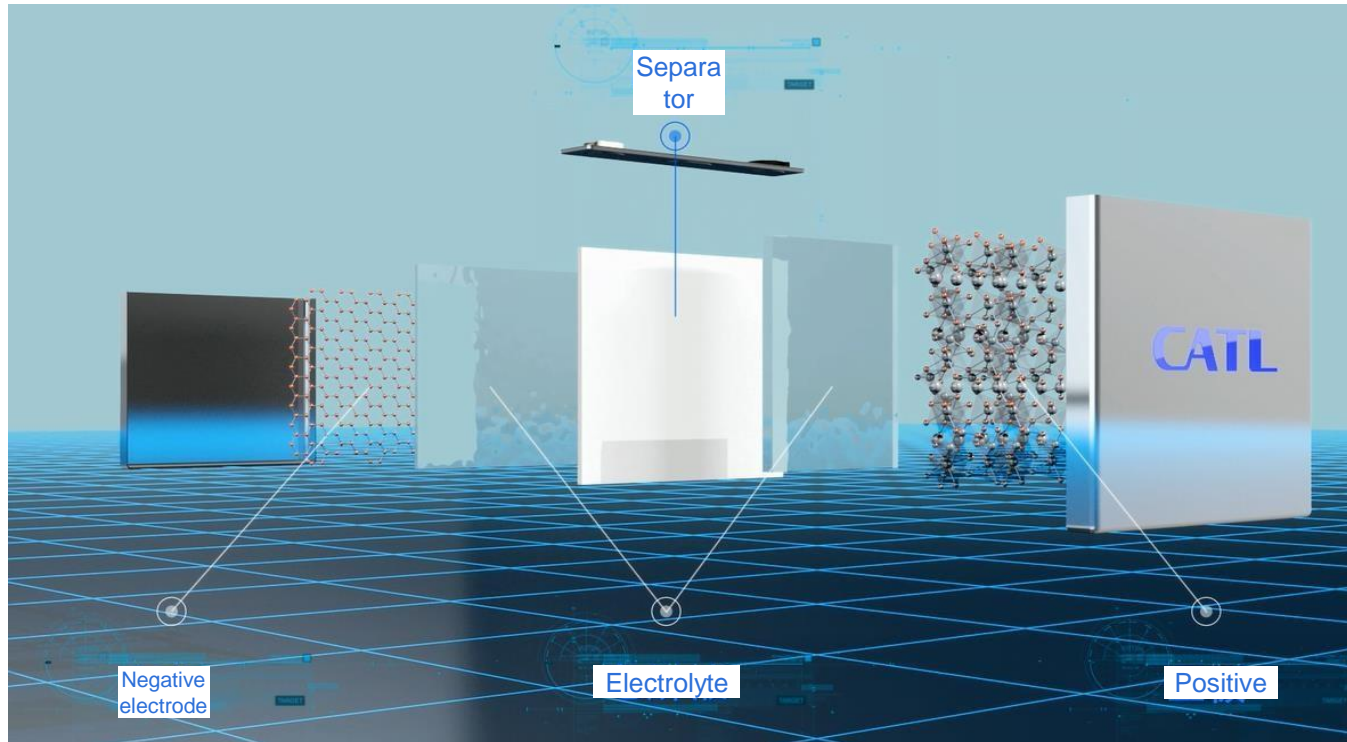


1. Positive pole
2. Negative pole
3. Vent
4. Shell (Al)
5. Insulating film

III. Structure, composition and working principle of battery pack

5. Charging and discharging principles of lithium battery

Composition of lithium-ion battery



III. Structure, composition and working principle of battery pack

5. Charging and discharging principles of lithium battery

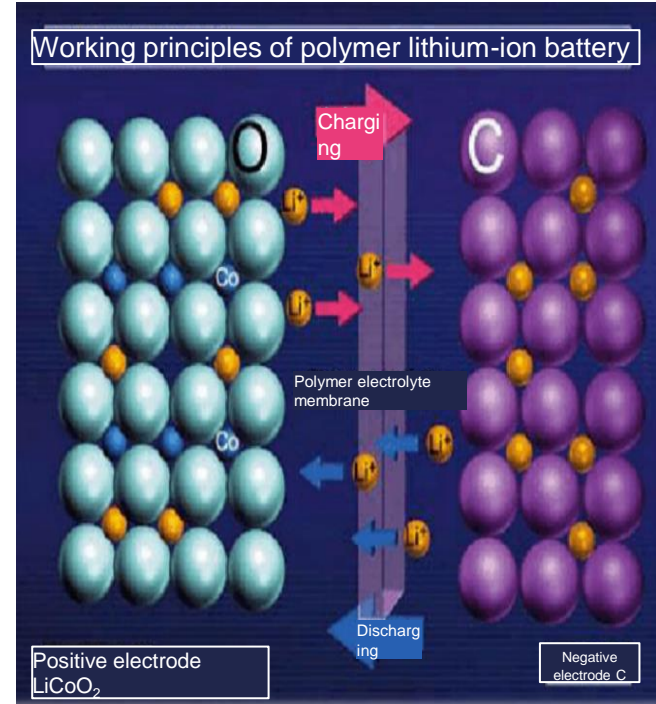
✓ During charging

When the battery is being charged, the lithium metal oxide at the positive electrode undergoes a chemical reaction to produce lithium ions, and then lithium ions are carried by organic electrolytes through the separator to the negative electrode, and run into the pores on the graphite of the negative electrode with a layered structure. The more lithium ions embedded in the pores, the higher the charging capacity. In the charging process, the lithium ions at positive electrode decrease, while the lithium ions at negative electrode increase, manifested externally as a normal rise in the terminal voltage of the battery.

✓ During discharging

When a battery is being discharged, the chemical reaction is opposite to that during charging, lithium ions are separated from the negative electrode and return to the positive electrode to combine with lithium metal compounds, so the lithium ions at the positive electrode increase, the lithium ions at the negative electrode decrease, and the battery energy decreases, manifested externally as a decrease in the terminal voltage of the battery.

Generally, the charging current of lithium battery is set between 0.2C and 1C. The higher the current, the faster the charging, and the more the heat generated by the battery. Moreover, if the charging current is too high, the capacity will not be fulfilled enough because certain time is required for electrochemical reactions inside the battery. Just like pouring beer into a cup, foam will be produced at a high pouring speed, but the cup is not fulfilled.



III. Structure, composition and working principle of battery pack

5. Charging and discharging principles of lithium battery



整车课件

Contents

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II. Terms and definitions
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IV. Structure, composition and working principle of battery distribution unit (BDU)
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VII. Power-on/off process
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IX.

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X.

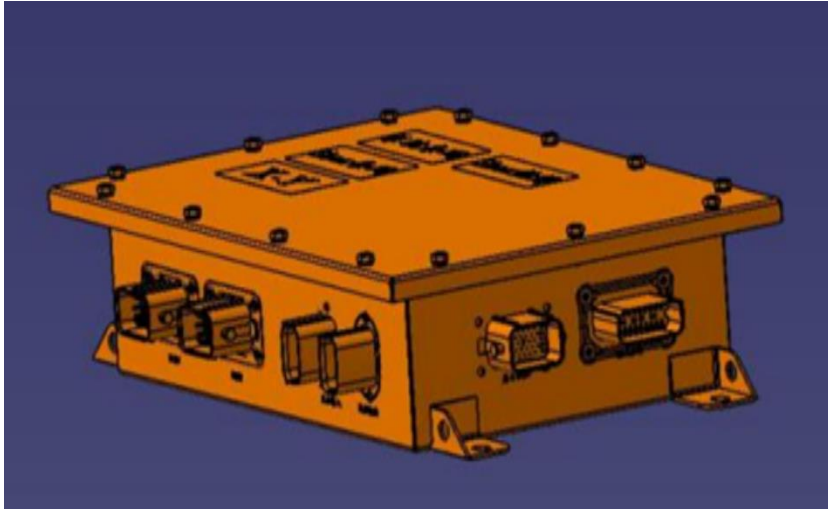
XI. Common faults and troubleshooting methods
XI.

IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

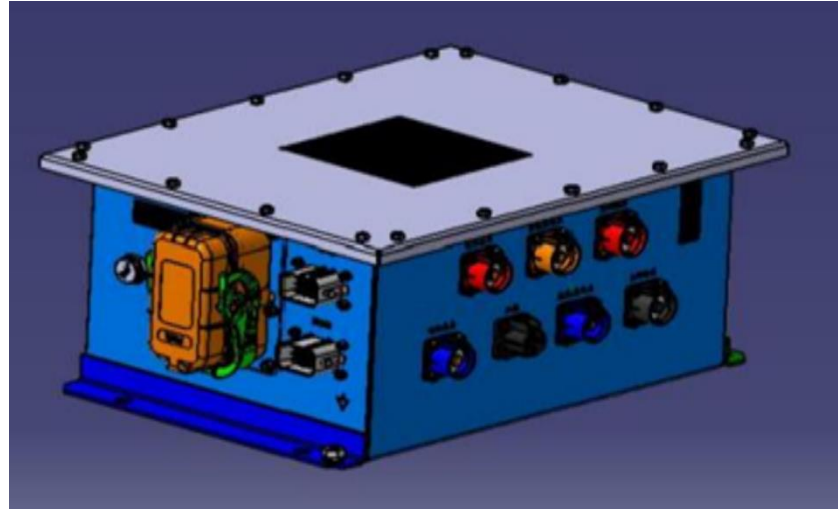
1. Structure of battery distribution unit (BDU)

➤ Battery Distribution Unit (BDU): a unit generally consisting of relays, current sensor, fuses, pre-charge resistor, etc., mainly for transferring or transmitting energy from HV battery to other HV systems.

CATL, also known as S-BOX, is usually divided into integral type and split type. Foton light trucks are adopted with the split BDU.



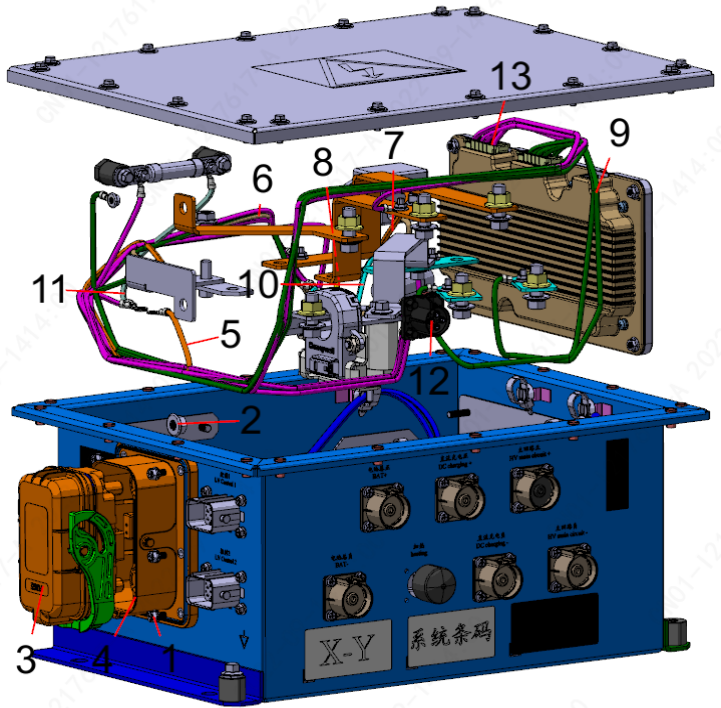
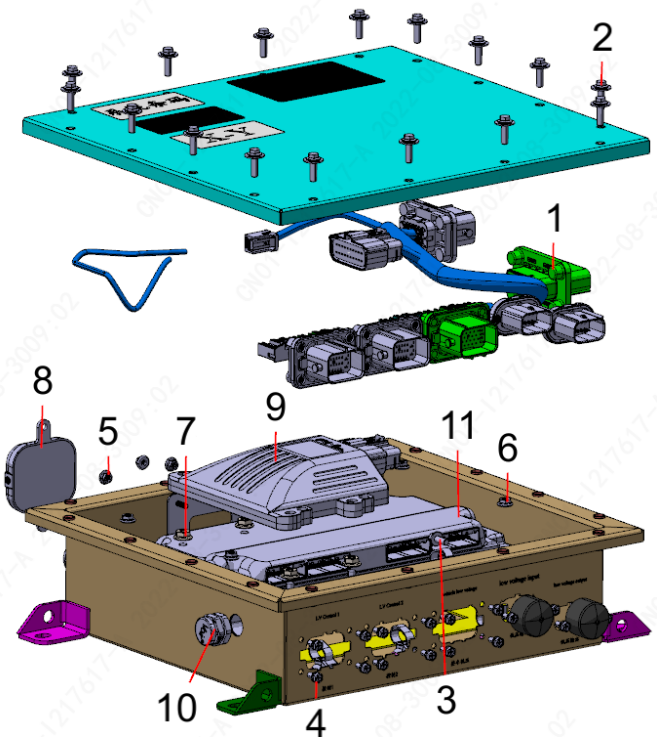
LV BCU



HV BDU

IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

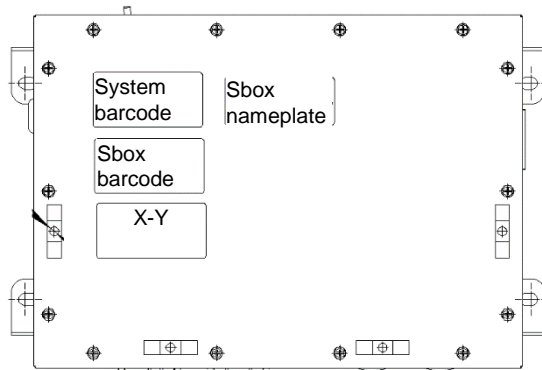
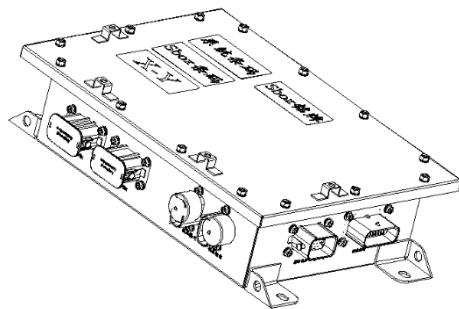
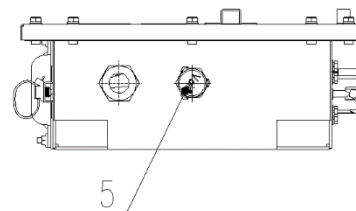
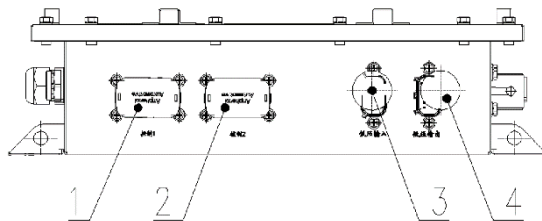
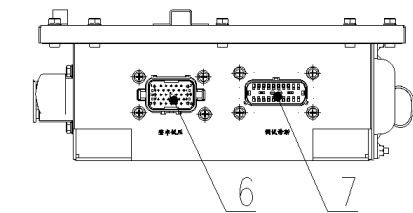
1. Structure of battery distribution unit (BDU)



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

LV BCU



- 1. Interface 1 of control;
- 2. Interface 2 of control;
- 3. Low voltage input;
- 4. Low voltage output;
- 5. Vent valve ;
- 6. Vehicle control interface;
- 7. Adjusting interface.

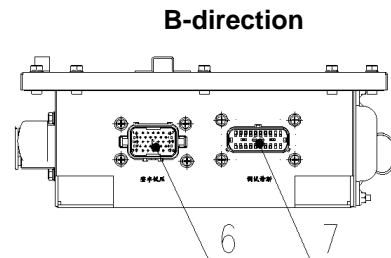
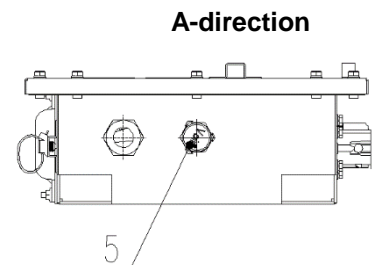
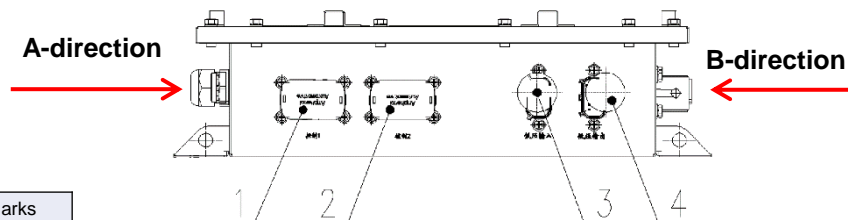
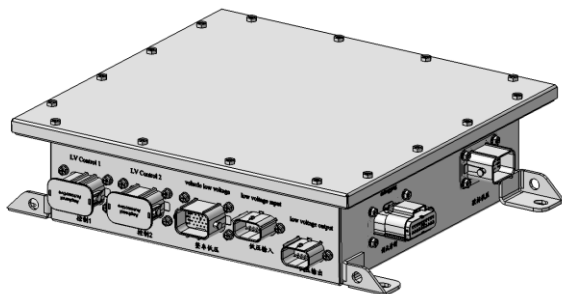
IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

LV BCU

List of LV connectors

Name	Socket model	Plug model	Remarks
Control 1	Amphenol_ BSMB0320	Changzhou MPS02-BSFB032S	32p
Control 2	Amphenol_ BSMA0320	Changzhou MPS02-BSFA032S	32p
Vehicle low voltage power	Amphenol HC08B-P32R	Amphenol HC18B-S32	32p
EU low voltage power	Amphenol HC08A-P32R	Amphenol HC18A-S32	32p
Low voltage input	Recodeal 3.653.601004R	Recodeal 3.663.601002R	12p
Low voltage output	Recodeal 3.653.601003R	Recodeal 3.663.601001R	12p
Adjusting	THB 1540101		20p

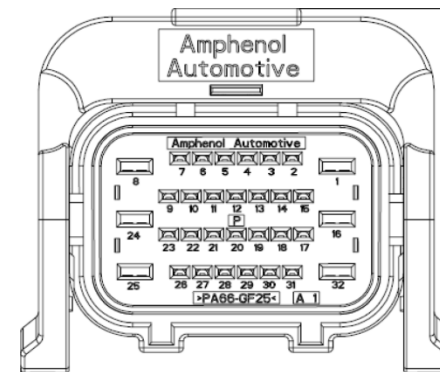


IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Interface 1 of control

Amphenol MPS02-BSMB0320



PIN	Definition	Description	PIN	Definition	Description
1	N/C	N/C	7		DC B/AC positive contactor high output
2		Main negative contact low output	8		Spare contactor high output
3		Main negative contactor high output	9		Pre-charge/pre-test contactor high output
4		Main positive contactor high output	10		DC B/AC negative contactor high output
5		DC A positive contactor high output	11		Heating film positive contactor high output
6		Heating negative contactor high output	12		DC A negative contactor high output

IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Interface 1 of control

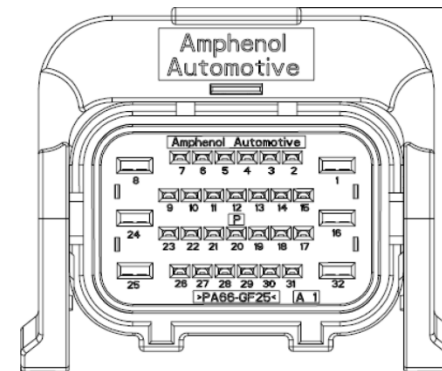
PIN	Definition	Description	PIN	Definition	Description
13		TMS positive contactor high output	23		Heating film positive contactor high output ground
14		Reserve contactor high output	24		Collector positive contactor high output
15		Main positive contactor high output ground	25		Collector negative contactor high output
16		Reserve contactor high output ground	26		Collector positive contactor high output ground
17		DC A positive contactor high output ground	27		DC A negative contactor high output ground
18		Heating negative contactor high output ground	28		Collector negative contactor high output ground
19		DC B/AC positive contactor high output ground	29		TMS positive contactor high output ground
20		Spare contactor high output ground	30		BDU high voltage interlock output
21		Pre-charge/pre-test contactor high output ground	31		BDU high voltage interlock input
22		DC B/AC negative contactor high output ground	32	N/C	N/C

IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Interface 2 of control

Amphenol MPS02-BSMA0320



PIN	Definition	Description	PIN	Definition	Description
1		Current sensor power supply 1	7		Electronic lock locking signal 2
2		Collector charge temperature detecting 1-	8		ANSI CC signal
3		Collector charge temperature detecting 1+	9		Current sensor power supply 2
4		Electronic lock feedback signal 2	10		HV sampling module power supply
5		Electronic lock feedback signal 1	11		Electronic lock unlocking signal 1
6		Electronic lock unlocking signal 2	12		Electronic lock locking signal 1

IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Interface 2 of control

PIN	Definiton	Description	PIN	Definition	Description
13		Collector charge temperature detecting 2-	23		Spare temperature detecting 2+
14		Spare temperature detecting 1-	24		Current sensor ground 1
15		Spare temperature detecting 2-	25	N/C	N/C
16	N/C	N/C	26		Current sensor ground 2
17		Currency CAN_H return	27		HV sampling module ground
18		Current CAN_L return	28		Hall current sampling feedback1
19		Current CAN_H	29		Hall current sampling feedback2
20		Current CAN_L	30		Hall current sampling feedback3
21		Collector charge temperature detecting 2+	31		Hall current sampling feedback4
22		Spare temperature detecting 1+	32	N/C	N/C

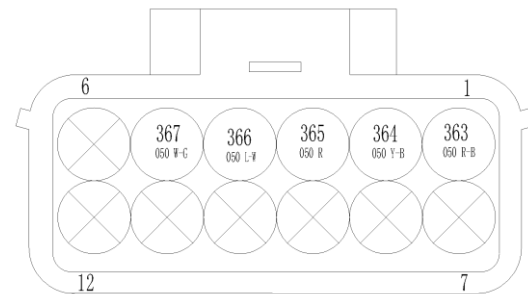
IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Low voltage input interface

PIN	Definition	Description
1		Battery Telecom input Tx+
2		Battery telecom input Tx -
3		Battery pack high voltage interlock input
4		Battery Telecom input Re+
5		Battery telecom input Re -
6~12	N/C	N/C

601004R



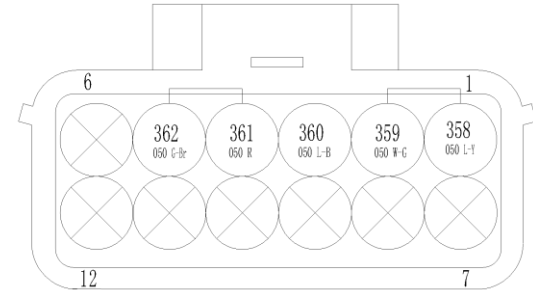
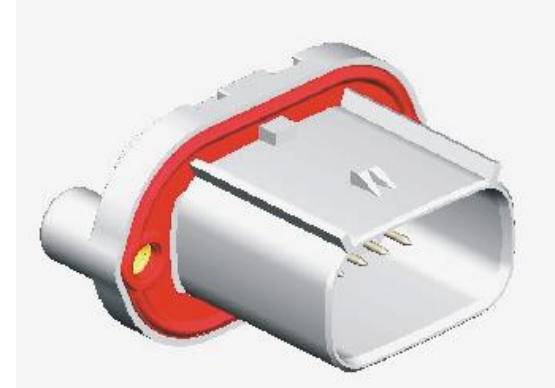
IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Low voltage output interface

PIN	Definition	Description
1		Battery Telecom output Tx+
2		Battery telecom output Tx -
3		Battery pack high voltage interlock output
4		Battery Telecom output Re+
5		Battery telecom output Re-
6~12	N/C	N/C

601003R



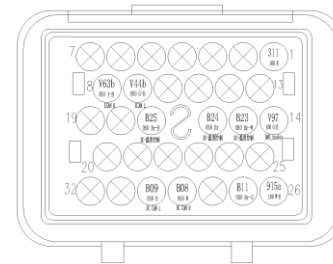
IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Vehicle control interface



HC08B-P32R



PIN number	Definition	Property	Effective value	Remarks
1	24V+ power supply	Input	High	
2	Remote update CAN_H	CAN	/	
3	Remote update CAN_L	CAN	/	
4	CC signal CC	/	/	Not used by Foton
5	High active signal	/		Not used by Foton

IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Vehicle control interface

PIN number	Definition	Property	Effective value	Remarks
6	Wakeup	/	/	Not used by Foton
7	TMS ground	/	/	Not used by Foton
8	Power CAN_H input	CAN	/	
9	Power CAN_L input	CAN	/	
10	Coolant control low voltage power supply	/	/	Not used by Foton
11	Power CAN_H output	/	/	Not used by Foton
12	Power CAN_L output	/	/	Not used by Foton
13	Coolant wakeup	/	/	Not used by Foton
14	BMS enabled by VCU	Input	High	VCU output PIN 97
15	Charge socket temperature detecting 1+	Input	Analog	DC charge socket output PIN 7

IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Vehicle control interface

PIN number	Definition	Property	Effective value	Remarks
16	Charge socket temperature detecting 2+	Input	Analog	DC charge socket output PIN 9
17	Charge socket temperature detecting 1&2-	Input	Analog	DC charge socket output PIN 8
18	Charge socket temperature detecting 3&4-	/	/	Not used by Foton
19	DC LV battery power supply A+	/	/	
20	Charge socket temperature detecting 3+	/	/	Not used by Foton
21	Charge socket temperature detecting 4+	/	/	Not used by Foton
22	N/C	/	/	Not used by Foton
23	Low active signal	/	/	Not used by Foton
24	N/C	/	/	Not used by Foton
25	AC charge pilot signal CP	/	/	Not used by Foton

IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Vehicle control interface

PIN number	Definition	Property	Effective value	Remarks
26	24V- ground	Input	Low	
27	CC2_1	Input	Low	DC charge socket output PIN 4
28	CC2_2			Not used by Foton
29	DC charge CAN_H	CAN	/	250KBPS
30	DC charge CAN_L	CAN	/	250KBPS
31	N/C	/	/	
32	N/C	/	/	

IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Battery diagnosis interface

This interface is mainly intended for CATL battery manufacturer to perform fault diagnosis and troubleshooting, and is usually blocked with a plug. When this interface is to be used, it is only required to connect the diagnosis harness to it.



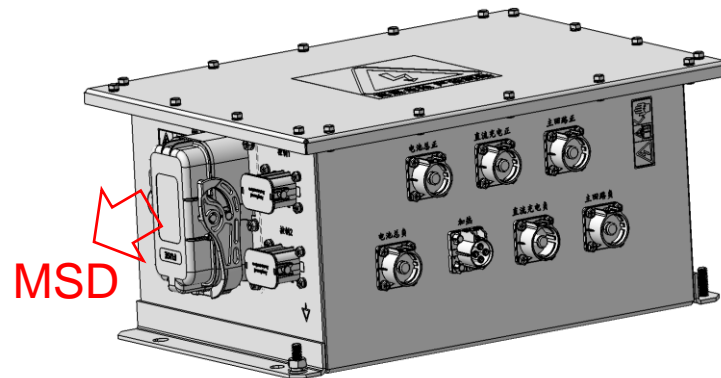
IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

HV BDU

List of HV connectors

No.	Name	Socket model	Plug model
1	Heating interface	L61-B2469-001-X	L61-B2470-001-X
2	Battery positive	Amphenol:PL00W-301-10D10-M	Amphenol:PL18W-301-35-M
3	Battery negative	Amphenol:PL00T-301-10D10-M	Amphenol:PL28T-301-35-M
4	Main positive	Amphenol:PL00U-301-10D10-M	Amphenol:PL18U-301-35-M
5	Main negative	Amphenol:PL00Y-301-10D10-M	Amphenol:PL18Y-301-35-M
6	DC charge positive	Amphenol:PL00X-301-10D10-M	Amphenol:PL18X-301-70-M
7	DC charge negative	Amphenol:PL00V-301-10D10-M	Amphenol:PL18V-301-70-M

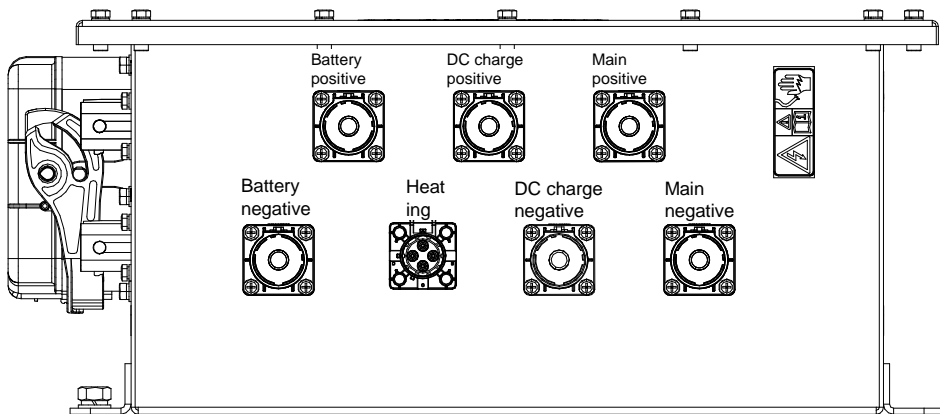


IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

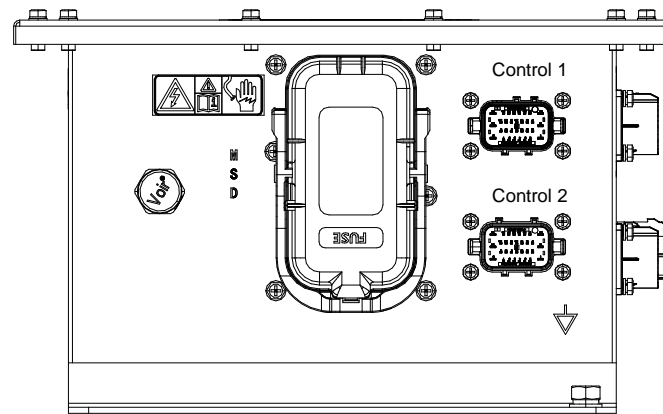
2. Main components (including external electrical interfaces)

HV BDU

Front view



Side view

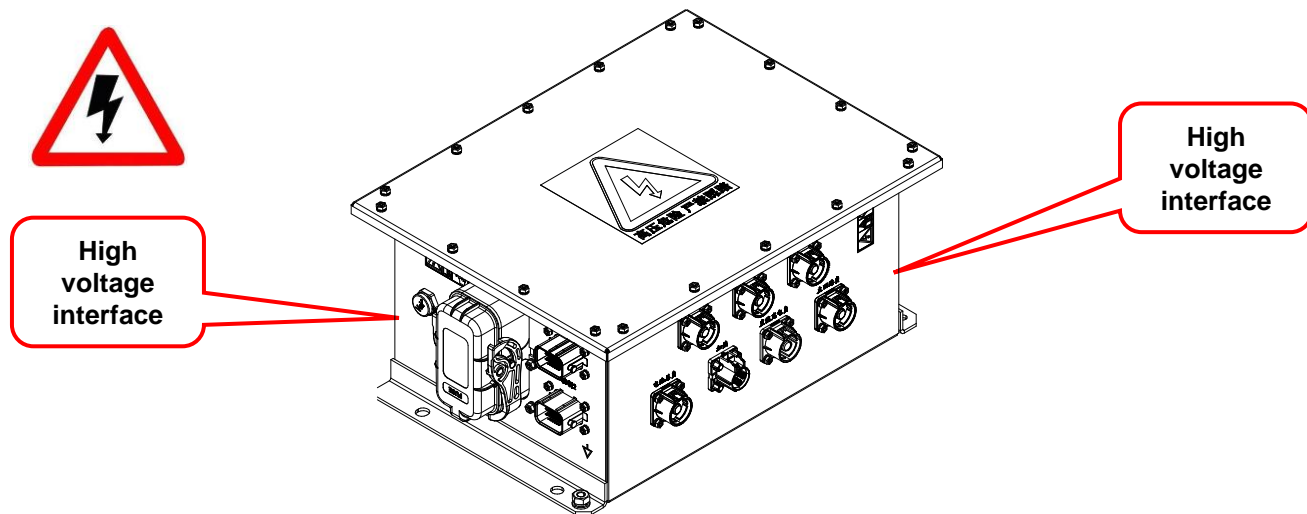


IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

HV BDU

The interfaces of battery distribution unit (BDU) include high voltage interfaces and low voltage interfaces.



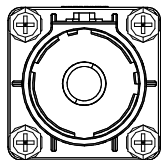
IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

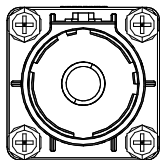
HV BDU

The high voltage interface of high voltage distribution unit (BDU) includes: battery positive interface, battery negative interface, heating interface, DC charge positive interface, DC charge negative interface, main positive interface and main negative interface. Except for heating interface, the others are single core interface.

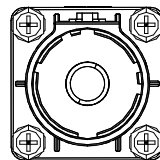
Battery positive



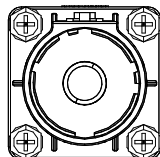
Charge positive



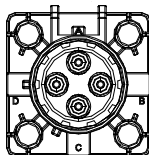
Main positive



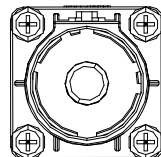
Battery negative



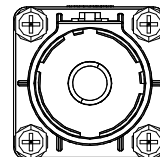
Heating



Charge negative



Main negative



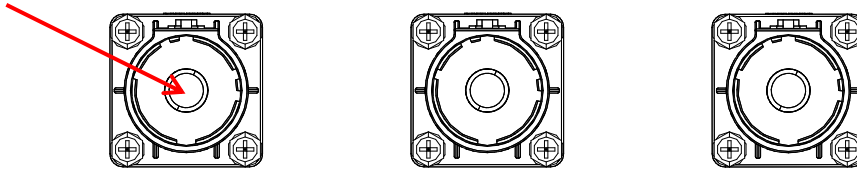
IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

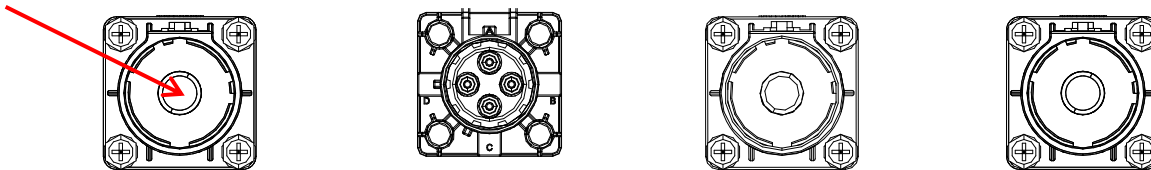
HV BDU

The battery positive and negative interfaces are respectively connected to the positive and negative output terminals of the battery pack, which are the output channels of the high voltage DC power.

Battery positive



Battery negative

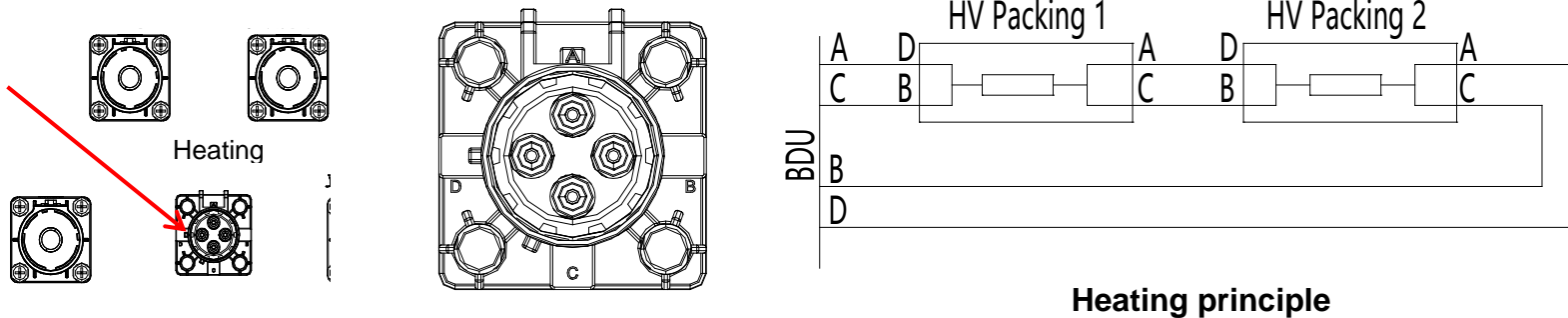


IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

HV BDU

The heating interface is directly connected to the heating connector of battery pack to heat the HV battery. The heating voltage is about 270V, the heating current is about 6A. It is a series relationship for heating of two HV batteries.



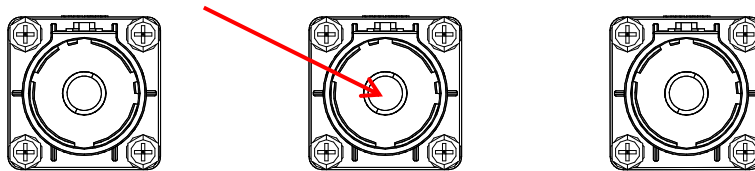
IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

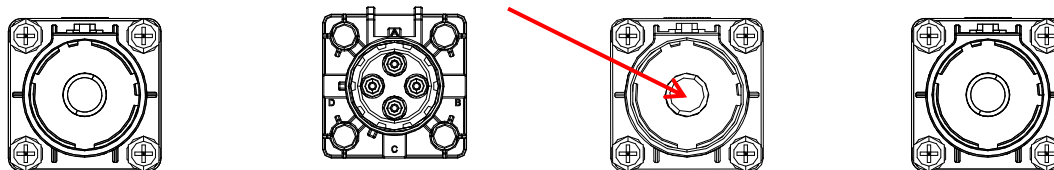
HV BDU

The DC charge positive and negative terminals are directly connected to DC charge interface to receive electric energy provided by DC charger.

DC charge positive



DC charge negative



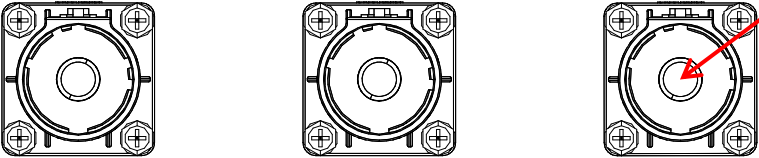
IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

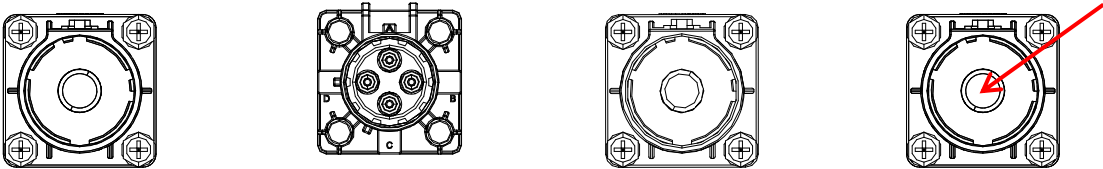
HV BDU

The HV main positive and negative terminals are directly connected to PEU, and are the energy output interfaces of the HV battery.

Main positive



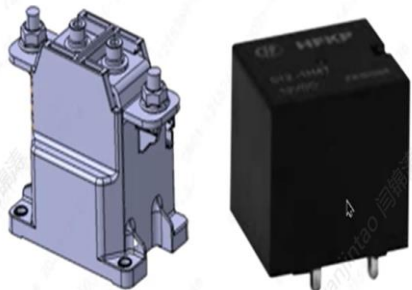
Main negative



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

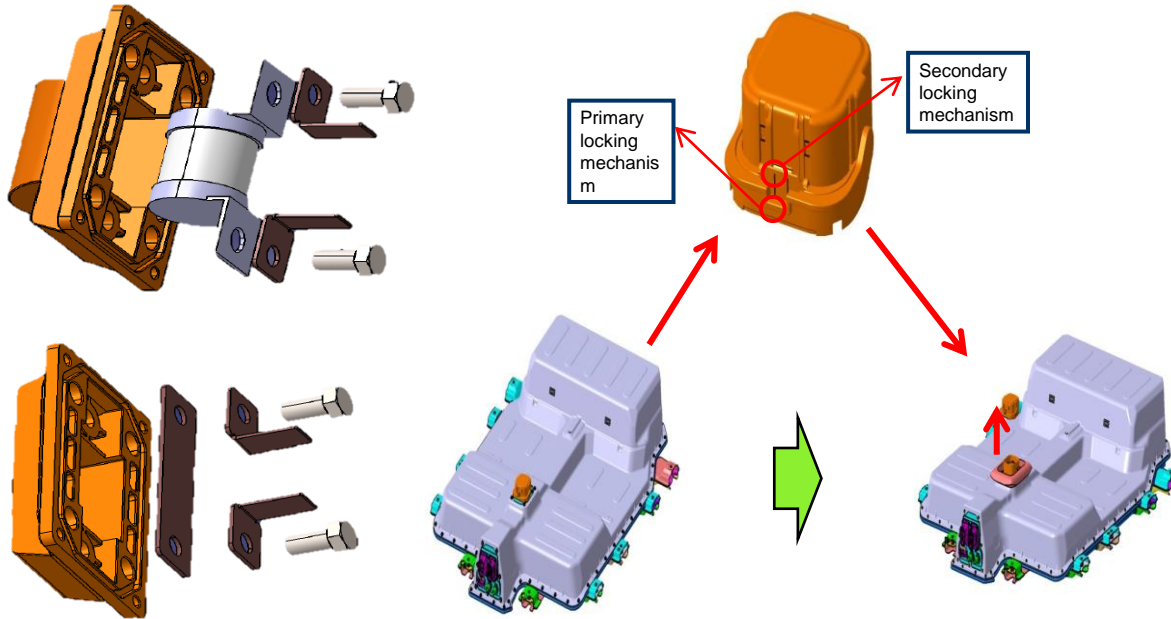
DC contactor is a contactor in which the control coil is applied with DC current, and the load at its main circuit end may be DC current or AC current. The core of DC contactor is different from the AC contactor as there is no vortex current in the DC contactor. Since the coil of DC contactor is applied with DC current, the DC contactor is free of start current with impact and heavy core impact, and therefore, it has a longer service life, and is suitable for situations involving frequency start and stop.



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

- Manual service disconnect (MSD): In order to protect the safety of technician repairing electric vehicles in high voltage environments or handle emergency events, MSD allows for **quick disconnection of HV circuit**, making maintenance safe enough. For protection in case of external short-circuit, the high voltage circuit must be disconnected during maintenance.



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

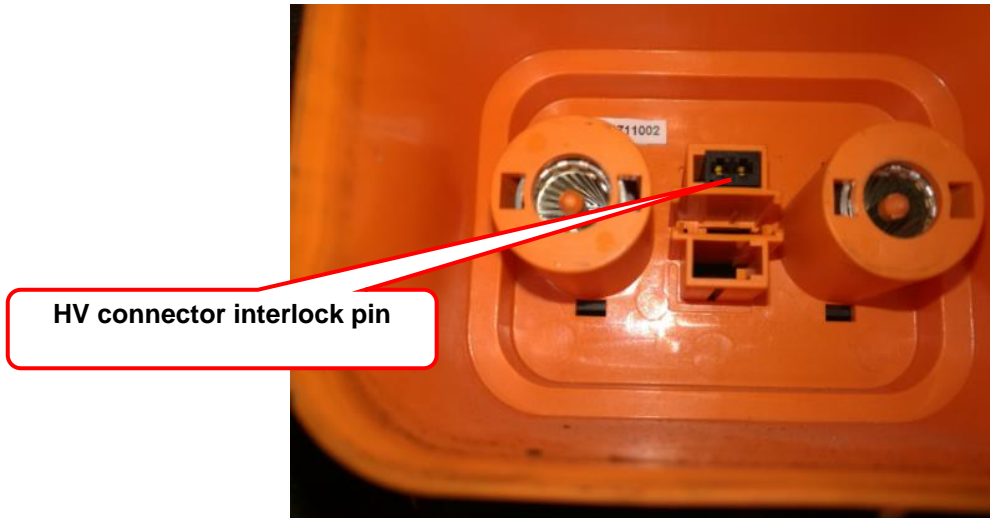
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IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

MSD is designed with a high voltage interlock concept, so that when the MSD is not installed in place, the high voltage interlock loop will not be closed, and the high voltage power output is impossible.



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

Removal and installation video of MSD

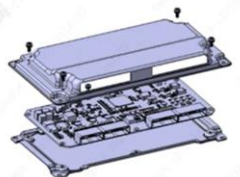
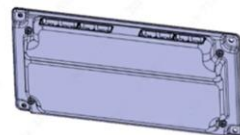


IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

➤ **Battery Management Unit (BMU):** an electronic control unit that controls or manages the electrical or thermal performance of the battery system and can interact with other control units on the vehicle.

- Data collected: busbar current, busbar total voltage, insulation resistance, etc.
- Data processing: fault diagnosis, parameter calibration
- SOC/SOH estimation.
- Control of charging and discharging status of the battery system, and control of charging and discharging power.
- CAN communication with VCU
- CAN communication
- Control of ON/OFF of high-voltage power supply
- Detection of contactor coil and contact status
- Cell balancing
- Thermal management control



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

CAN communication (CATL includes three CAN channels, namely C-CAN, A-CAN, and CH-CAN, and for new product, D-CAN, S-CAN, and T-CAN are added)

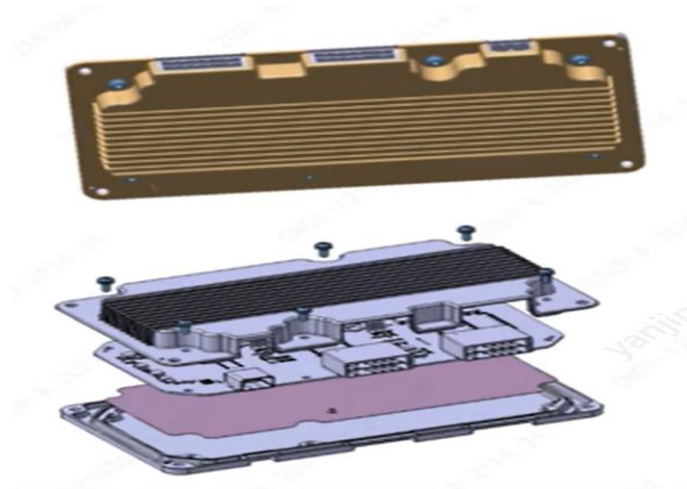
- ✓ Through C-CAN, the BMU communicates with multiple CSCs to obtain the voltage, temperature, and working status of each cell from CSCs. Through C-CAN, the BMU controls the CSC to enter the balancing state when the conditions for balancing are met.
- ✓ Through A-CAN, the BMU communicates with the VCU, and receives commands and occurrence status information from HCU.
- ✓ Through CH-CAN, the BMU communicates with the charger.
- ✓ Through S-CAN, the BMU communicates with HVB and CSU (current sampling unit).
- ✓ Through D-CAN, the BMU communicates with the RDB (remote data base).
- ✓ Through D-CAN, the BMU communicates with the remote update module.



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

- High voltage sampling unit (HVB): As a high-voltage link component of BMS, HVB is intended for voltage sampling from high-voltage positive and negative contactors, and insulation sampling monitoring, and communicates through S-CAN



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

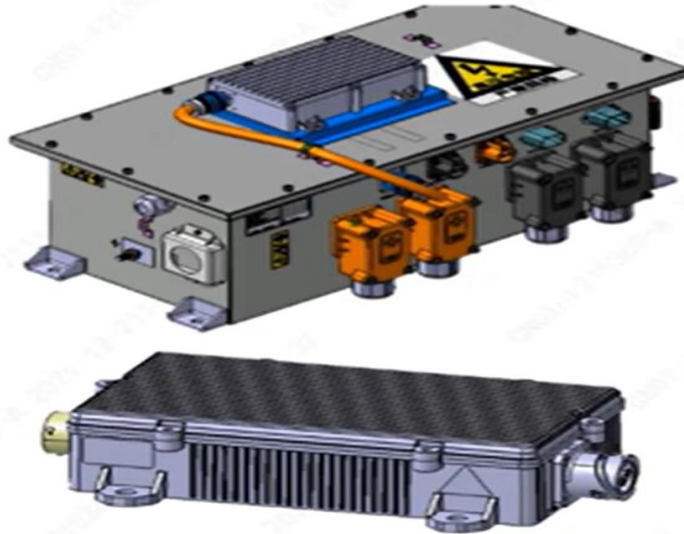
- Hall current sensor: this sensor collects real-time battery current through a magnetic flux gate and sends it to the BCU through S-CAN



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

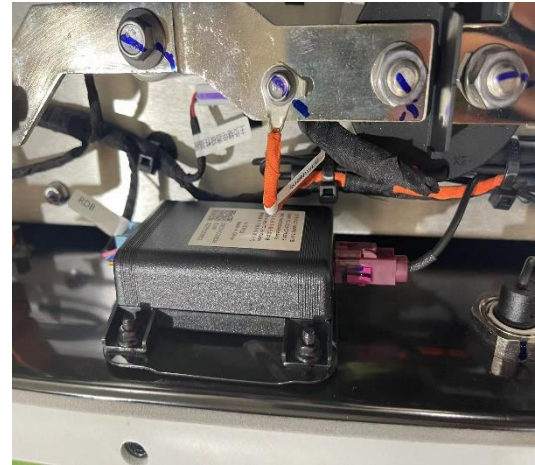
- **DCDC converter:** The DC-DC converter in BMS is mainly designed for converting the high voltage of the battery into low voltage during charging to supply power to the BMS, and it will power up and wake up the BMS on regular basis to achieve timed monitoring.



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

2. Main components (including external electrical interfaces)

- **Remote Data Base (RDB):** this system is intended for real-time monitoring and storage of battery data, and supports remote monitoring and data reading/download data when necessary.



3. Concept of BMS

➤ Battery management system (BMS): Battery management system (BMS) is a control system to protect the safe operation of power battery. The controller of the battery management system is called battery management unit. The BMS constantly monitors the operation status of the battery and mitigates the inconsistency of the battery pack through necessary measures, well protecting the operation safety of high-voltage battery packs on new energy vehicles. It is divided into software and hardware by nature, and into data acquisition unit and control unit by function.

- ① Hardware: master control board, slave control board, BDU, and electronic devices for collecting voltage, current, temperature, etc.
- ② Software: logic programs for monitoring battery voltage, current and temperature, calculating SOC, communicating with VCU/charger, and controlling the charging and discharging of battery system.

IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

3. Concept of BMS

Power supply management

- Sleep and wake-up
- Power supply voltage detection
- Power sequential control

Battery safety management

- Thermal management
- Thermal management
- Charging and discharging management

Troubleshooting

- Fault detection and preprocessing
- System self-test and diagnosis

Battery parameter detection

- Voltage detection
- Current detection
- Temperature detection

Balance management

- Cell balancing

Information management

- CAN communication
- Diagnosis and calibration
- Program updates

SOC&SOH estimation

- SOC estimation
- SOH estimation
- Energy estimation

HV safety management

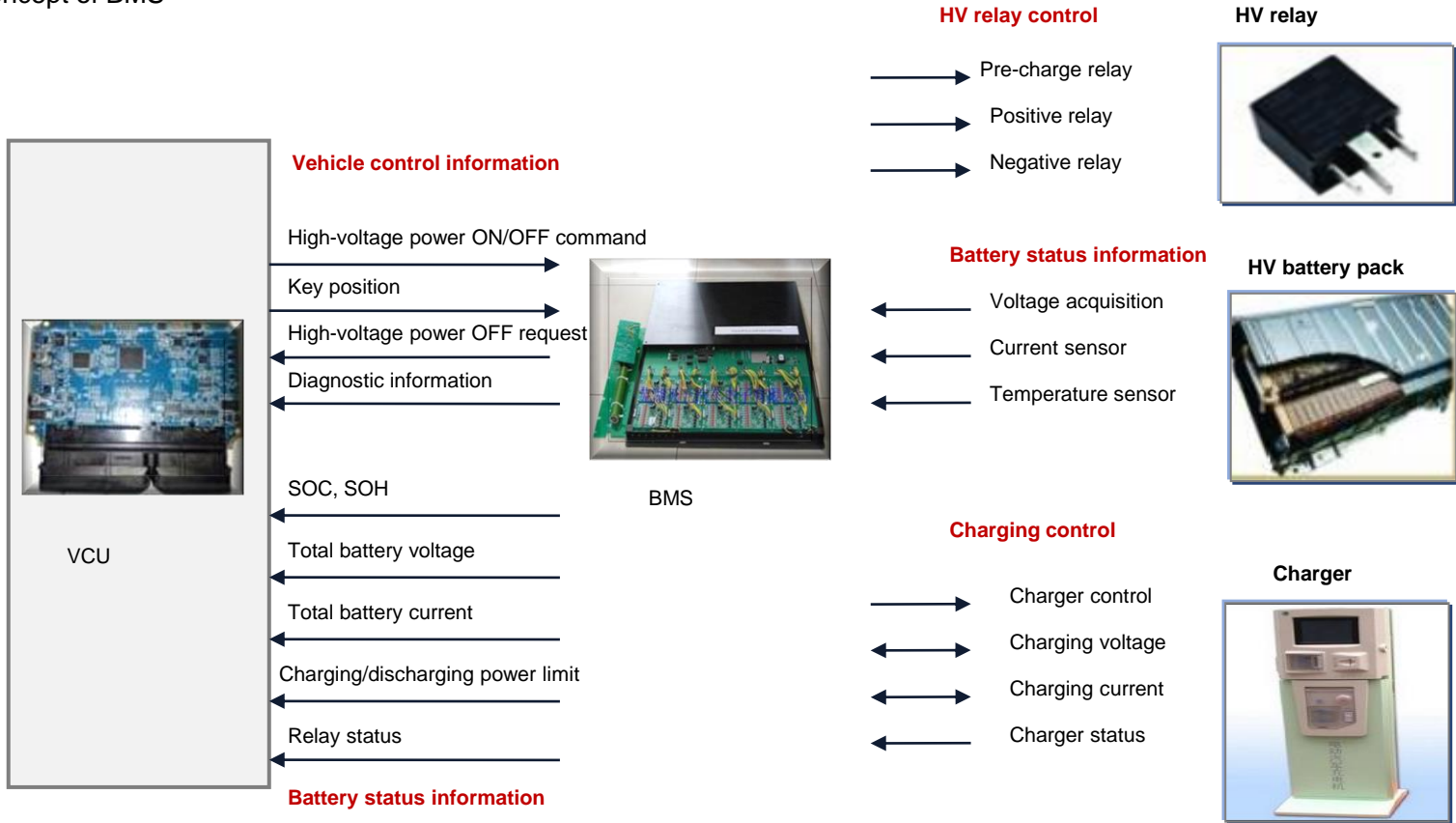
- High voltage interlock
- Insulation detection
- Relay control

Data storage

- Key data of cells
- Product application data
- Cell ID traceability

IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

3. Concept of BMS



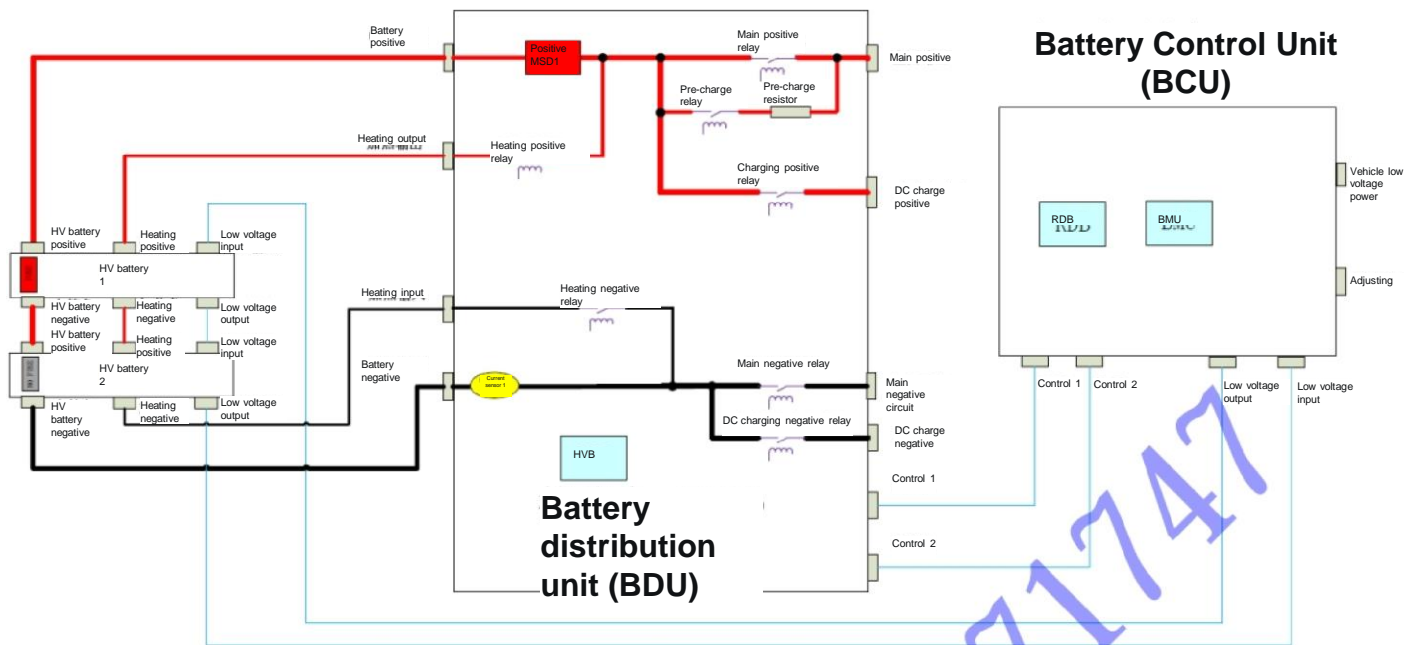
3. Concept of BMS

- | ➤ Level 1 fault | ➤ Level 2 fault | ➤ Level 3 fault |
|--|--|--|
| ● Fault alarm (reporting without handling) | ● Emergency fault (power limitation to 50% -0%) | ● Critical fault (immediate disconnection of high-voltage power) |
| ● Overhigh/overlow voltage | ● Overhigh/overlow voltage (relatively severe) | ● Overhigh/overlow voltage (severe) |
| ● Large voltage difference | ● Large voltage difference (relatively severe) | ● Large voltage difference (severe) |
| ● Overhigh/overlow temperature | ● Overhigh/overlow temperature (relatively severe) | ● Overhigh/overlow temperature (severe) |
| ● Large temperature difference | ● Large temperature difference (relatively severe) | ● Large temperature difference (severe) |
| ● Overhigh/overlow SOC | ● Overhigh/overlow SOC (relatively severe) | ● Overhigh/overlow SOC (severe) |
| ● TMS offline | ● Low insulation resistance | ● TMS offline |
| | ● Current above limit | ● Low insulation resistance (severe) |
| | | ● Current above limit (severe) |
| | | ● Contactor failure |

Alarm → Power Limitation → Standby (Power 0) → Prohibition of High-voltage Power ON, Charging, and Energy Recovery → Immediate Disconnection of High-voltage Power

4. HV battery system circuit principle

High voltage principle of battery system

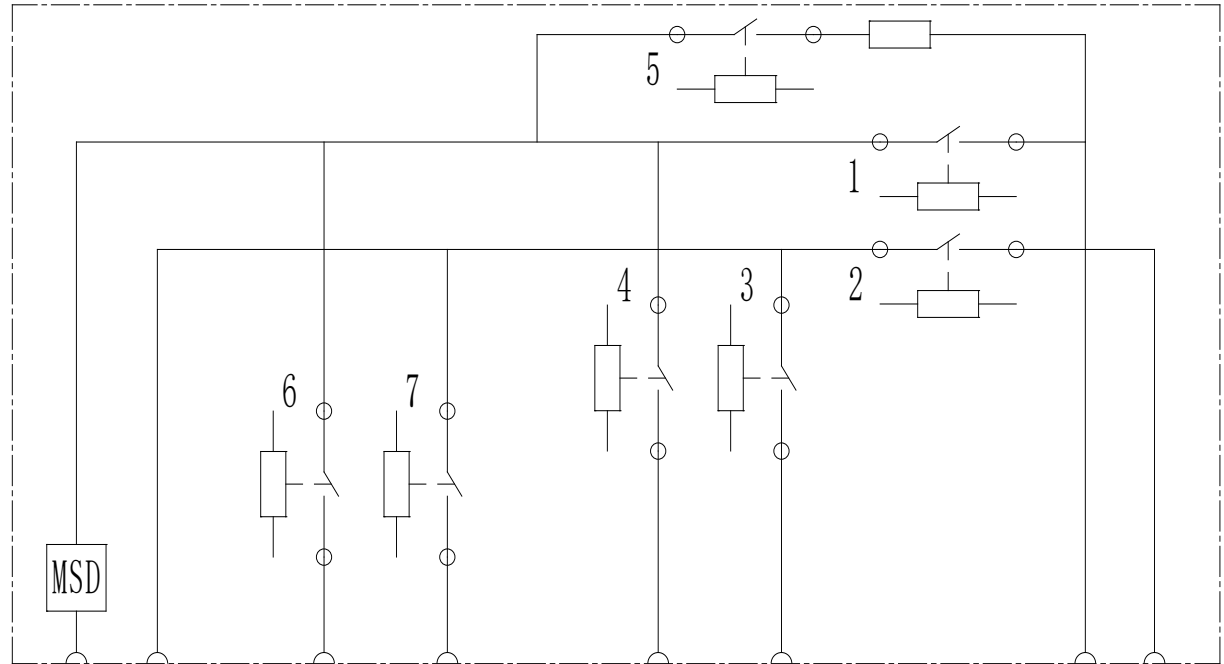


IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

4. HV battery system circuit principle

High voltage circuit principle:

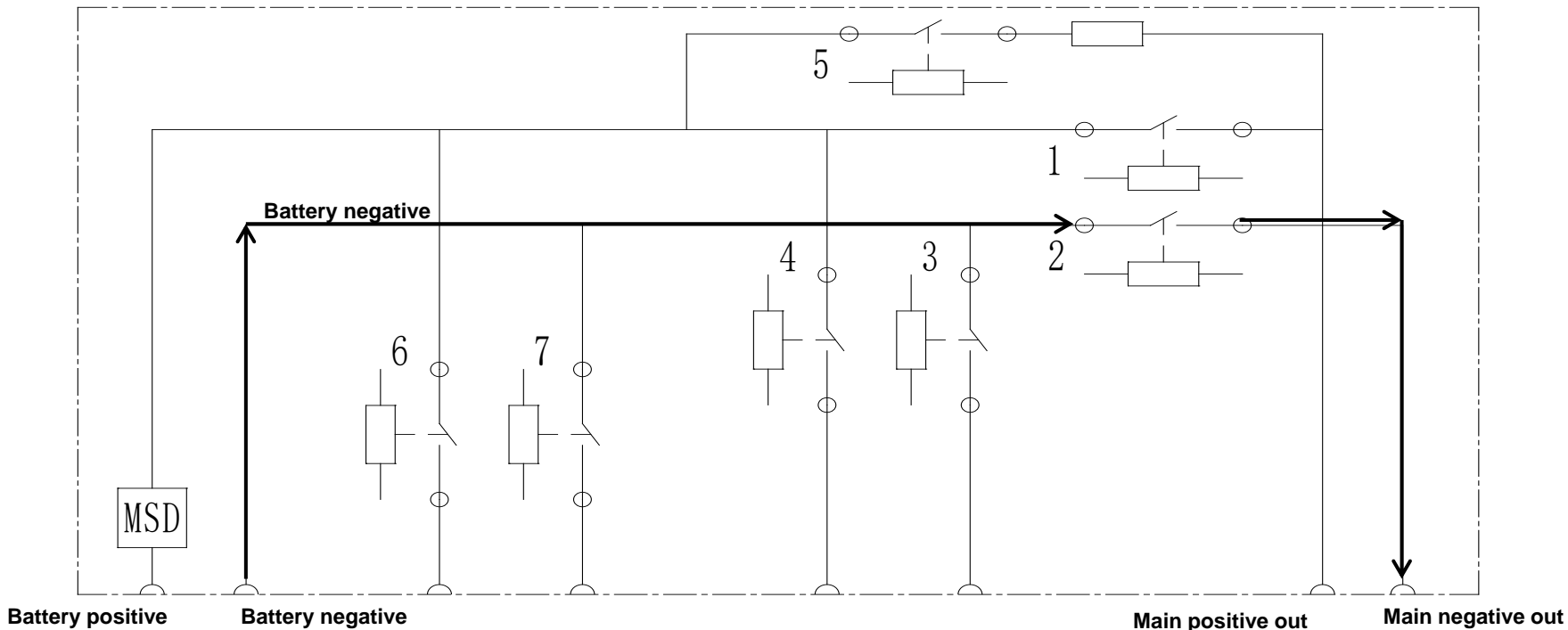
No.	Name
1	Main positive contact
2	Main negative contactor
3	Heating negative contactor
4	Heating positive contactor
5	Pre-charge contactor
6	AC charge positive contactor
7	AC charge negative contactor



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

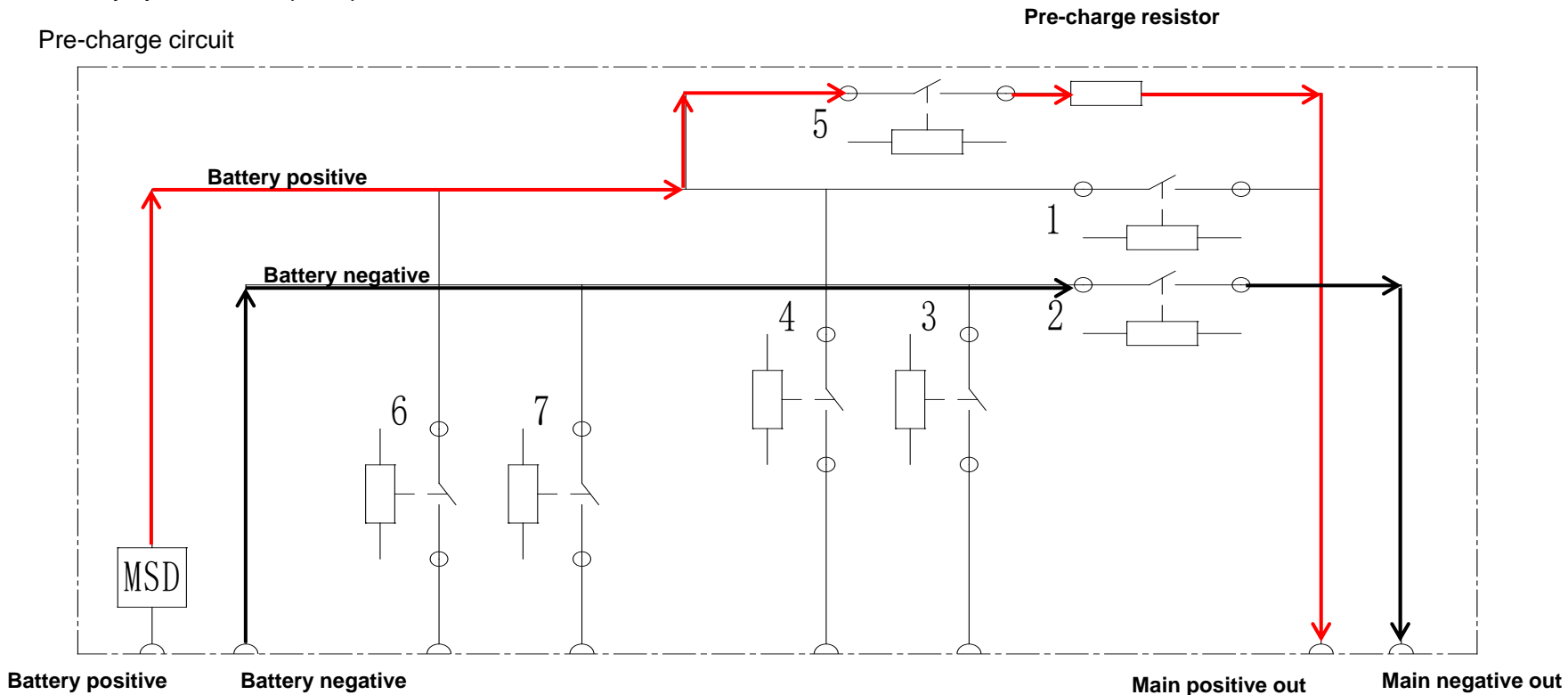
4. HV battery system circuit principle

Negative circuit



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

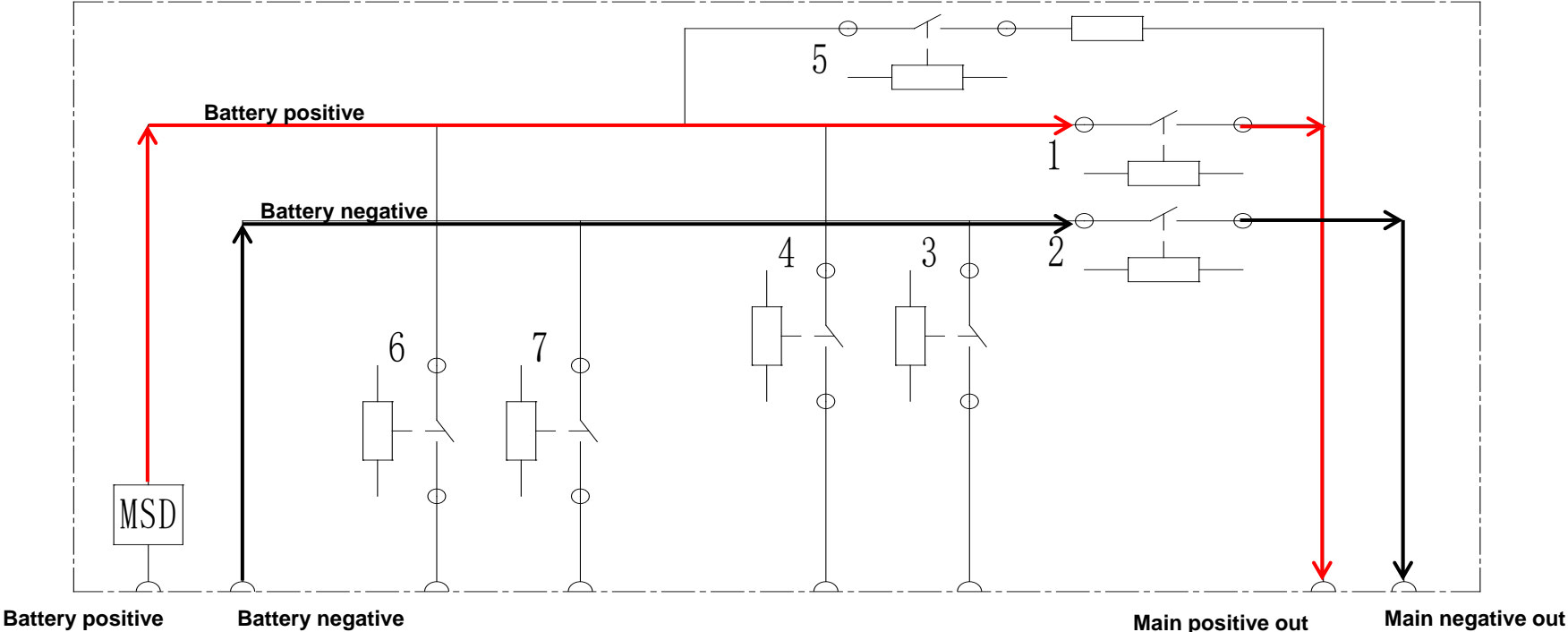
4. HV battery system circuit principle



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

4. HV battery system circuit principle

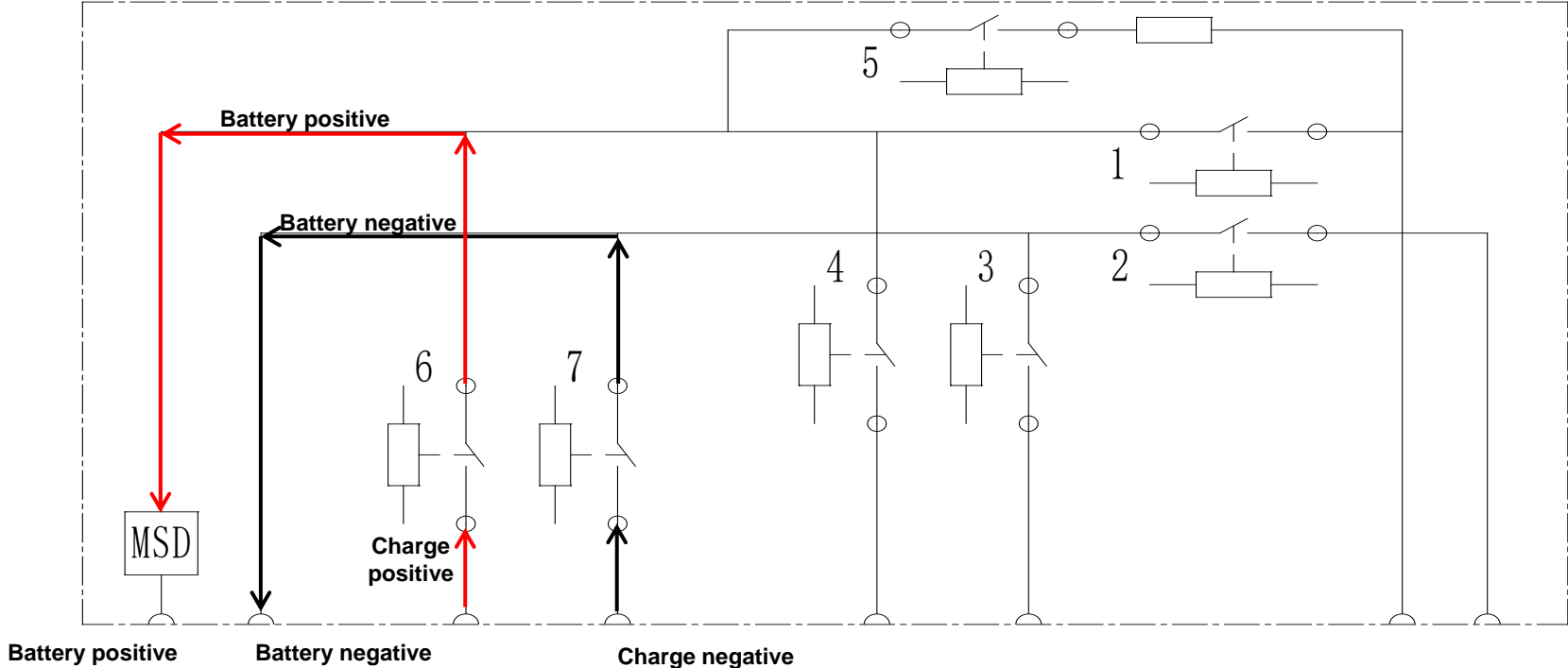
Positive circuit



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

4. HV battery system circuit principle

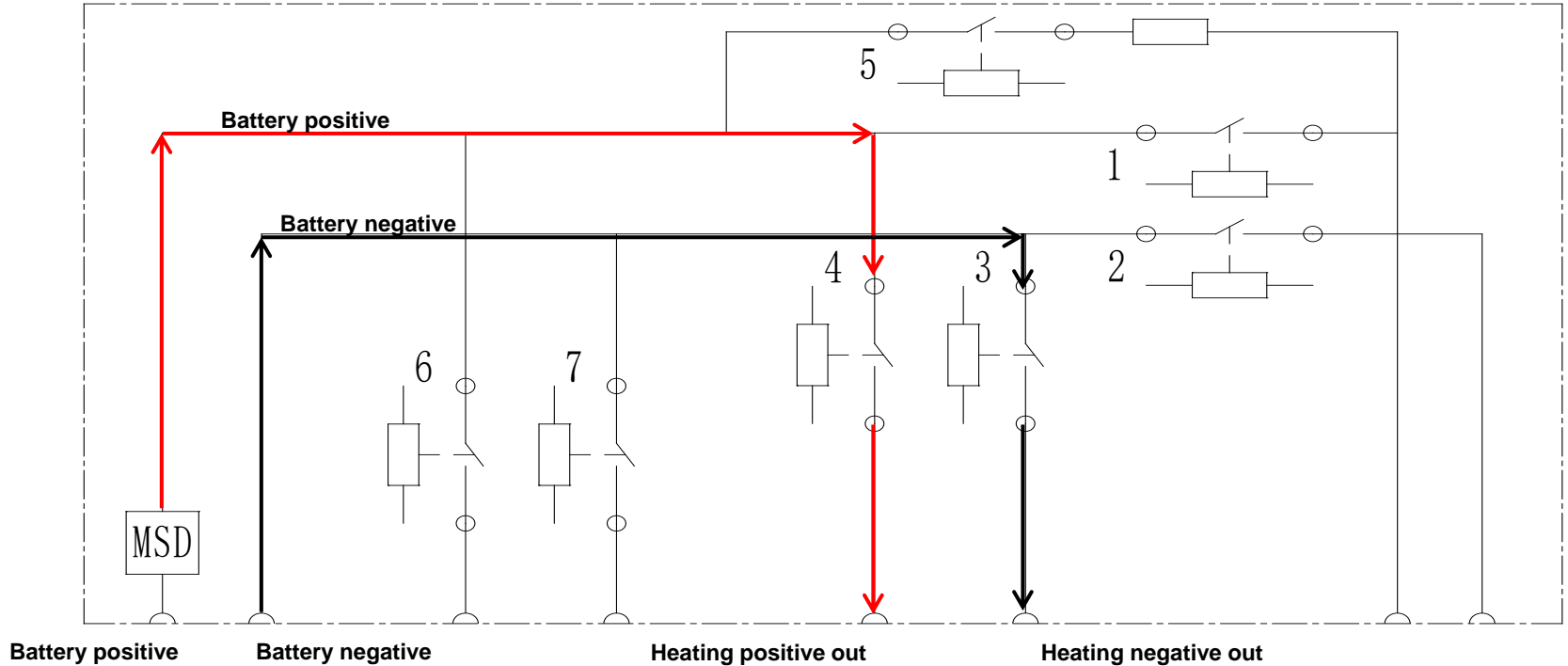
Charge circuit



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

4. HV battery system circuit principle

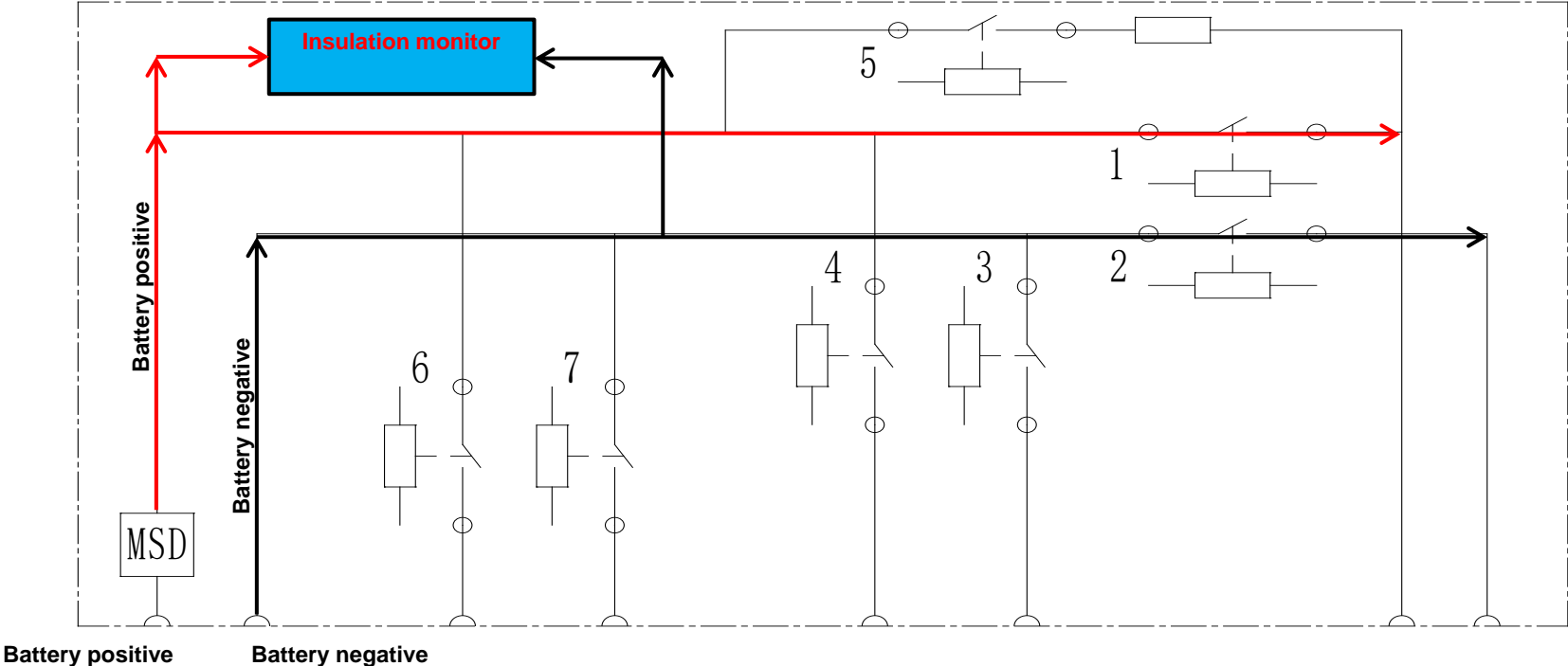
Heating circuit



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

4. HV battery system circuit principle

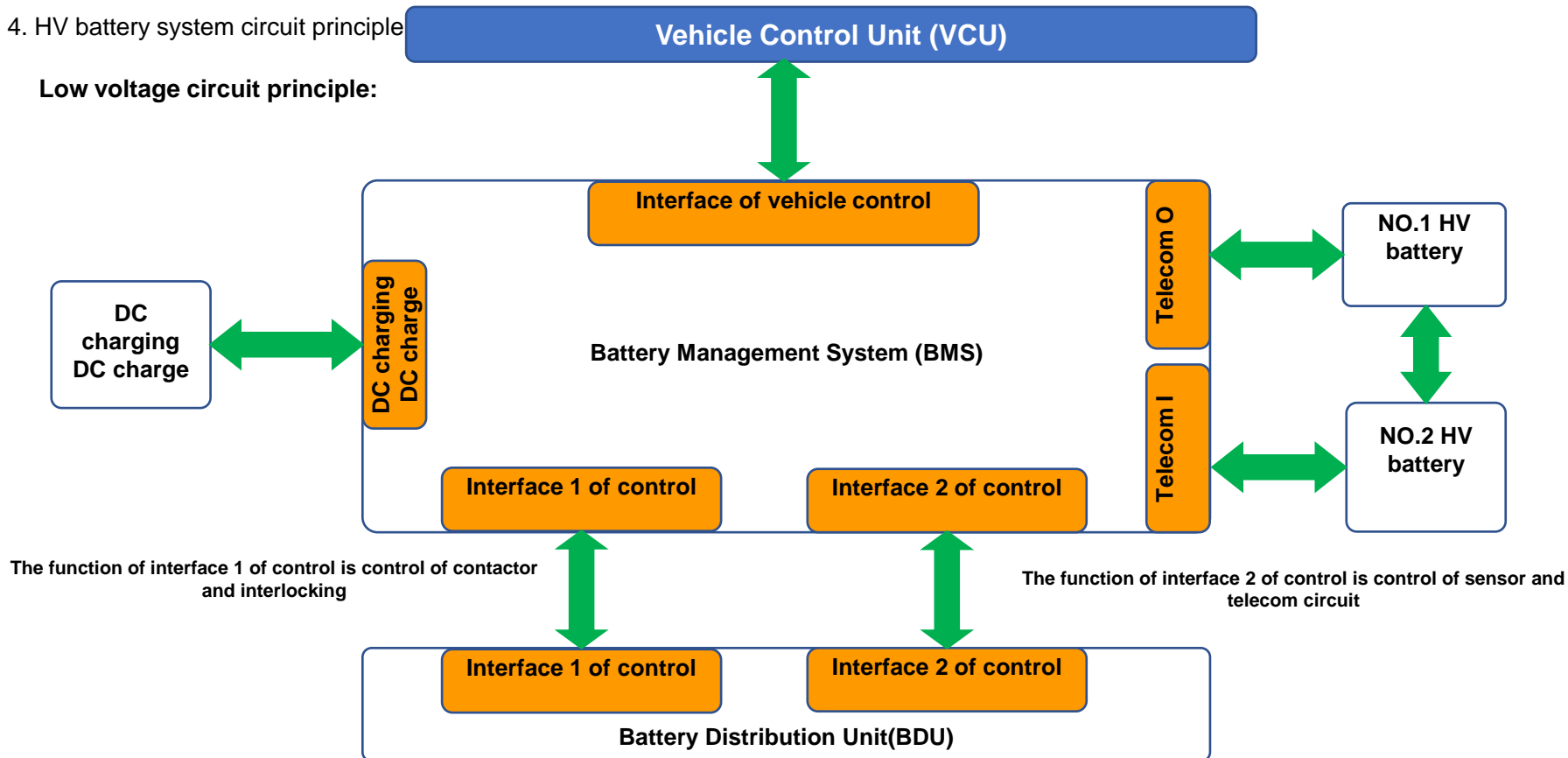
Insulation monitoring circuit



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

4. HV battery system circuit principle

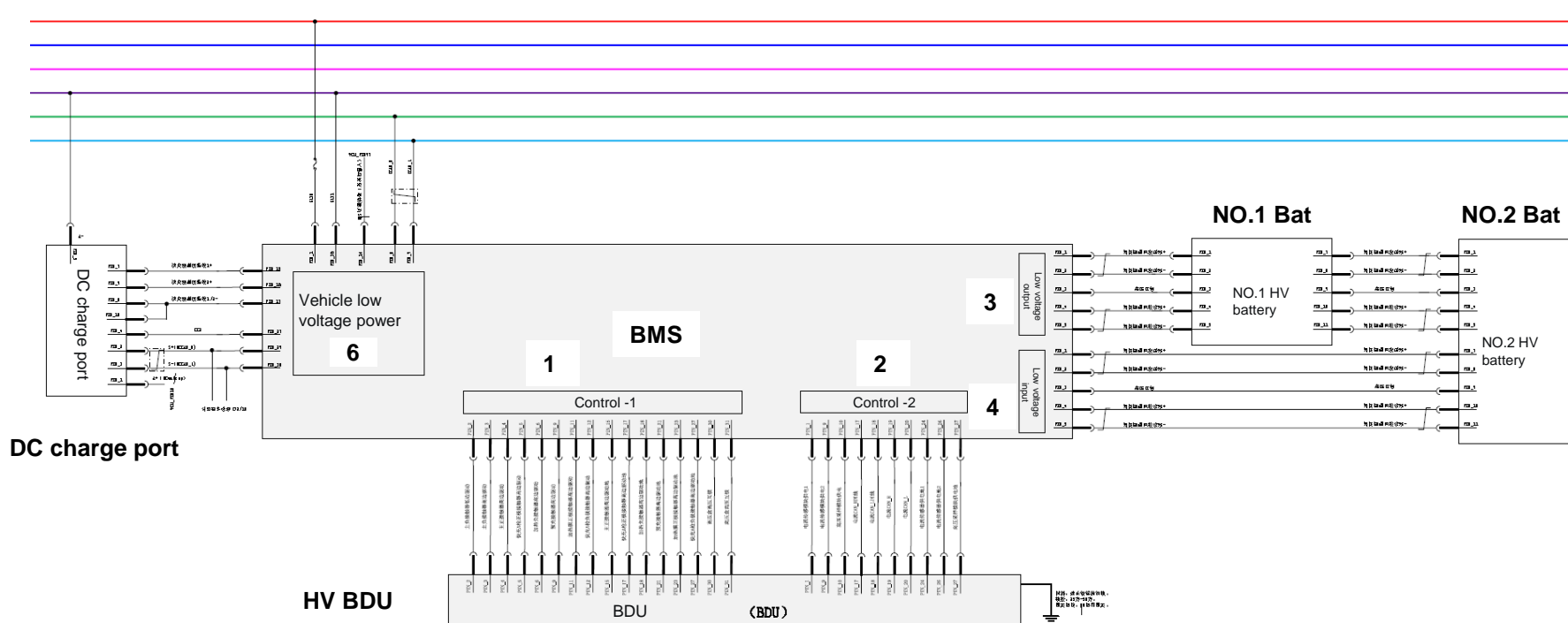
Low voltage circuit principle:



IV. Structure, composition and working principle of battery distribution unit (BDU) FOTON

4. HV battery system circuit principle

Low voltage circuit principle:



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1. Composition of thermal management system

The thermal management of power battery includes heating and cooling.

At present, most of power batteries are applied with PTC technology or “PTC+liquid cooled plate” technology for heating, and cooling technologies usually adopted include natural cooling, air cooling, water cooling, and silicone oil cooling. In the early development stage, air cooling and silicone oil cooling were more commonly applied, but due to technology update and obvious shortcomings of these two cooling methods, natural cooling and water cooling are more commonly adopted at present.

Since the power battery will produce a large amount of heat during charging, the traditional cooling solution of “electronic fan+cooling tank” are often unable to meet the cooling needs when the vehicle is stationary. Therefore, the A/C refrigerant is often adopted as the coolant of the power battery system. For A/C cooling of power battery, two solutions are available, namely integration with vehicle A/C system, and provision of an independent battery A/C system.

Taking the CATL power battery on Aumark M4 as an example, the PTC heating system and integrated A/C water cooling system are adopted for heating and cooling of the battery.

Heating system: composed of BMU, control circuit (including high-voltage contactor and high-voltage fuse), high-voltage harness, and PTC heating plate.

Cooling system: composed of BMU, control circuit (including high-voltage contactor and high-voltage fuse), high-voltage harness, circulating water pump, A/C system, expansion tank, and coolant.

2. Introduction to main components

Cooling system:



water pump



Expansion tank, coolant



Liquid cooling pipe (quick joint)

2. Introduction to main components

Heating system:



Heating film



High-voltage connector

3. Function of thermal management system

- The BMS continuously collects the temperature of the battery pack, and adjusts the working mode of the thermal management system according to the temperature of the battery. So that the battery is always kept at the best working temperature.
- Thermal management working modes include heating, self-circulation, cooling.
- The start and stop of the cooling pump of the battery system is controlled by the BMS that works in a LV circuit. Heating and cooling modes are controlled by HV circuits. Controlled by the BMS
- During driving or charging, if the battery temperature is too high, the A/C system will be forced to activate, and this action is not controlled by the driver. When the battery temperature drops, the A/C will automatically stop working.
- The coolant in the expansion tank should be kept above the minimum scale to avoid too high battery temperature or temperature imbalance due to insufficient coolant



4. Principle of thermal management system

Thermal management control logic (example)

1. Heating strategy

	Temperature condition for cell activation	Temperature condition for cell deactivation
Heating during driving	$T_{min} \leq 12^{\circ}\text{C}$ and $T_{max} \leq 28^{\circ}\text{C}$	$T_{min} \geq 15^{\circ}\text{C}$ or $T_{max} \geq 30^{\circ}\text{C}$
Heating during charging	$T_{min} \leq 17^{\circ}\text{C}$ and $T_{max} \leq 28^{\circ}\text{C}$	$T_{min} \geq 20^{\circ}\text{C}$ or $T_{max} \geq 30^{\circ}\text{C}$

2. Liquid cooling strategy

- Cooling strategy requirements are as follows:
- Temperature for activation of cooling during charging: $T_{max} \geq 30^{\circ}\text{C}$ and $T_{mean} \geq 26^{\circ}\text{C}$
- Temperature for deactivation of cooling during charging: $T_{max} \leq 26^{\circ}\text{C}$ or $T_{mean} \leq 24^{\circ}\text{C}$.
- Temperature for activation of cooling during driving: $T_{max} \geq 30^{\circ}\text{C}$ and $T_{mean} \geq 26^{\circ}\text{C}$
- Temperature for deactivation of cooling during driving: $T_{max} \leq 26^{\circ}\text{C}$ or $T_{mean} \leq 24^{\circ}\text{C}$
- Driving mode + cooling mode request water temperature: 15°C
- Charging mode + cooling mode request water temperature: 10°C

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1. Composition of harness system

There are two types of harnesses for electric vehicles: LV harness and HV harness. The installation and layout of the LV harness is explained in the vehicle electrical course, and only the HV harness is explained in this course. The HV harness is a harness used to transmit high voltage, which is quite different from the LV harness. The main difference lies in the insulation and withstand voltage of the cable.



VI. Structure, composition and working principle of harness system

2. Introduction to main components

Take the electric light truck M4 as an example: it has a total of 10 harnesses:

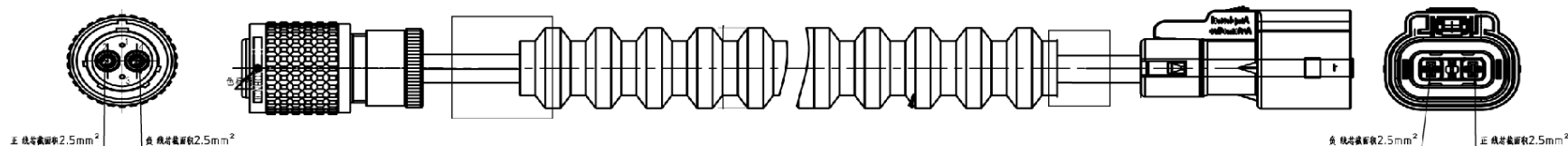
No.	Name	Remark
1	PTC heater harness assembly	
2	Air compressor harness assembly	
3	AC charge HV harness assembly	
4	Motor harness assembly	
5	Inter-pack power HV harness assembly of power battery	
6	Inter-pack heating HV harness assembly of power battery	
7	DC charge HV harness assembly	
8	Power battery output HV harness assembly 1	
9	Power battery output HV harness assembly 2	
10	PEU output HV harness assembly	

2. Introduction to main components

Heating harness assembly:

To PTC

To PEU

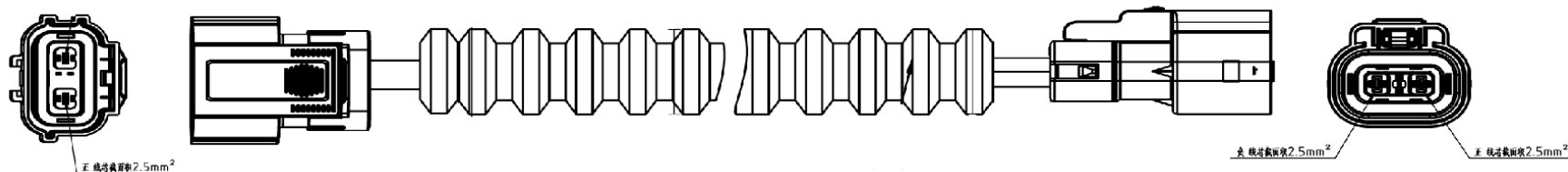


2. Introduction to main components

Air compressor harness assembly:

To air compressor

To PEU

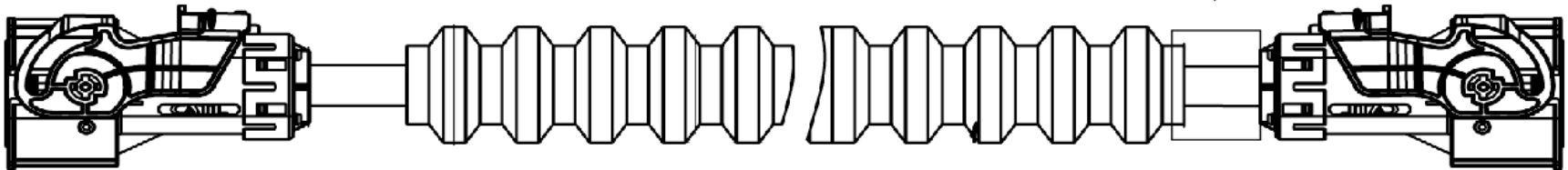


2. Introduction to main components

Inter-pack power HV harness assembly of power battery:

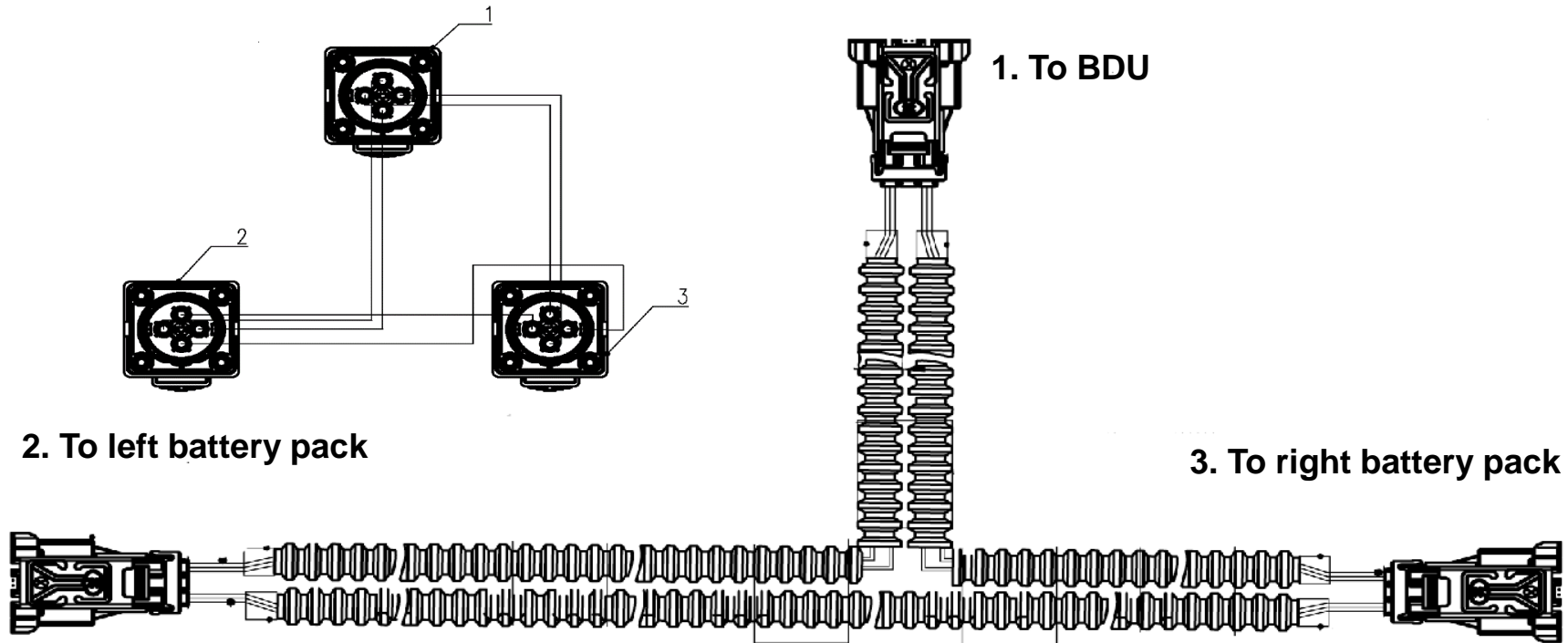
To left battery pack+

To right battery pack-



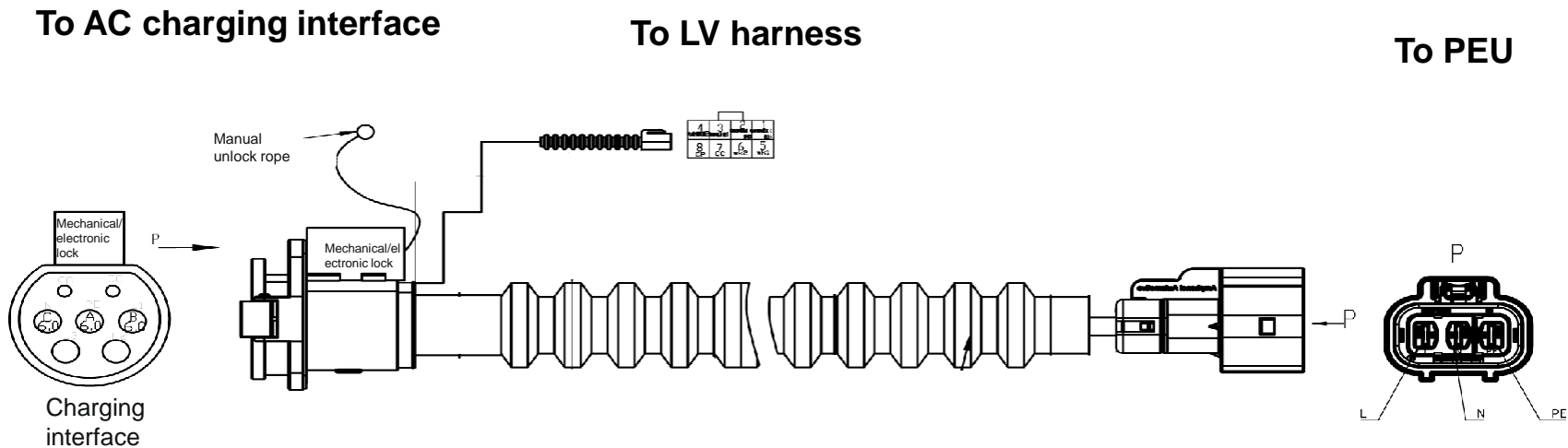
2. Introduction to main components

Inter-pack heating HV harness assembly of power battery:



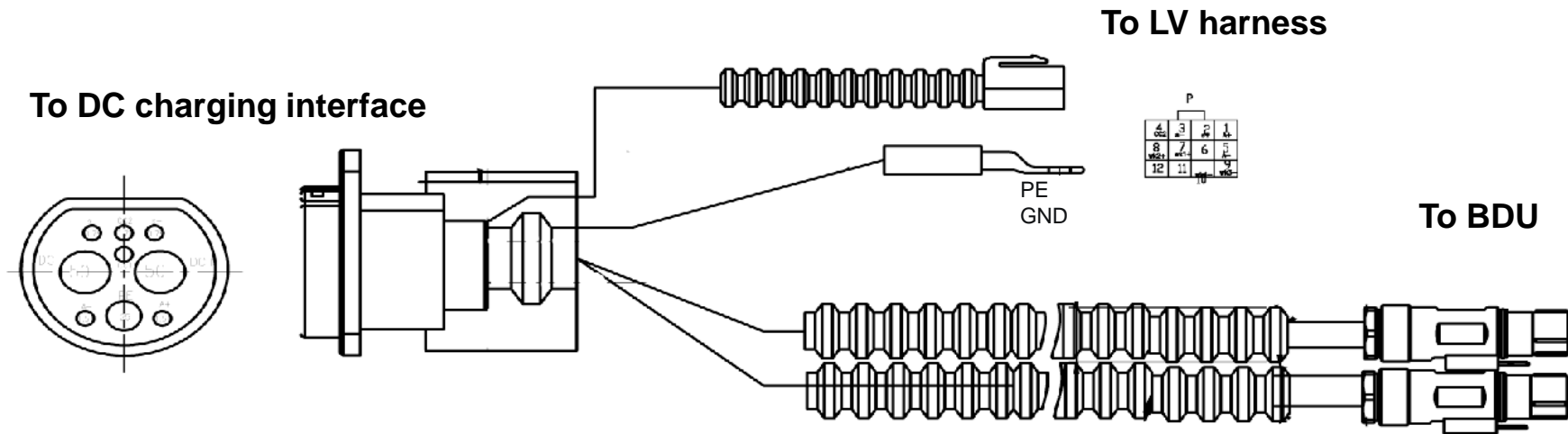
2. Introduction to main components

AC charge input HV harness assembly:



2. Introduction to main components

DC charge HV harness assembly:

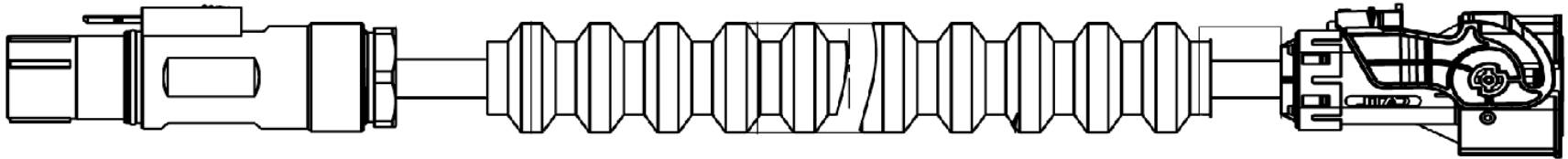


2. Introduction to main components

Power battery output HV harness assembly 1:

To BDU battery pack positive

To right battery pack positive

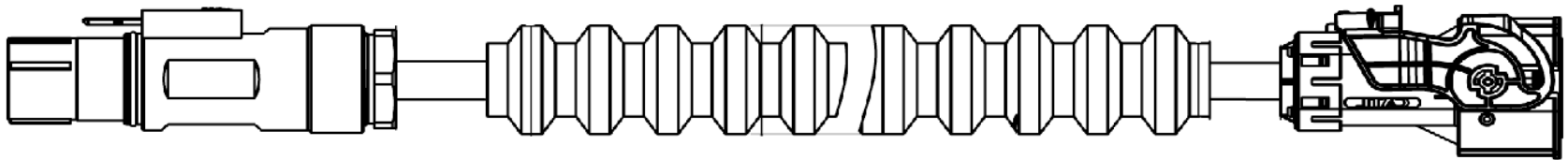


2. Introduction to main components

Power battery output HV harness assembly 2:

To BDU battery pack negative

To left battery pack negative

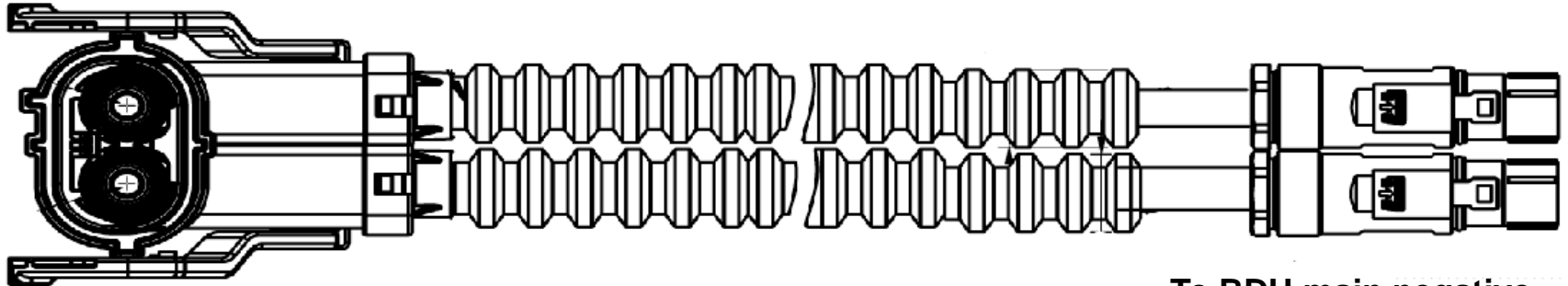


2. Introduction to main components

PEU input HV harness assembly:

To PEU power battery

To BDU main positive



To BDU main negative

2. Introduction to main components

Power battery output HV harness assembly 2

Inter-pack power HV harness assembly of power battery

Power battery output HV harness assembly 1

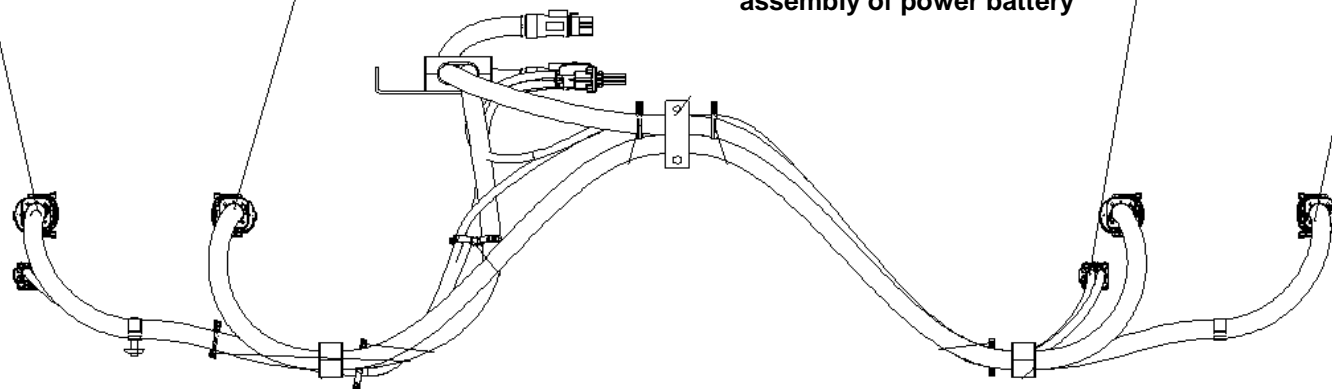
L121400000199
动力电池输出高压线束总成

L121400000195
动力电池箱同电源高压线束总成

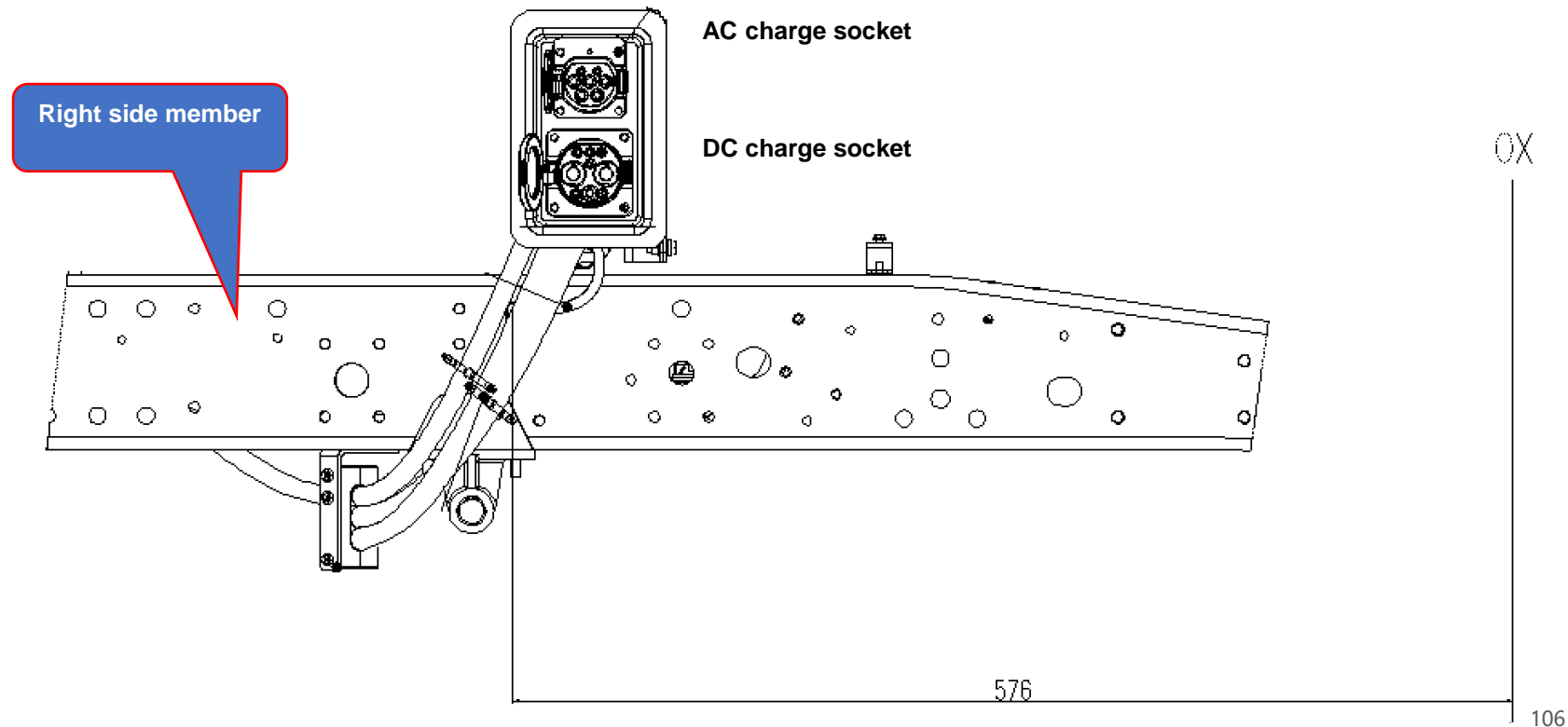
Inter-pack heating HV harness assembly of power battery

L121400000196
动力电池箱同加热高压线束总成

L121400000198
动力电池输出高压线束总成



2. Introduction to main components



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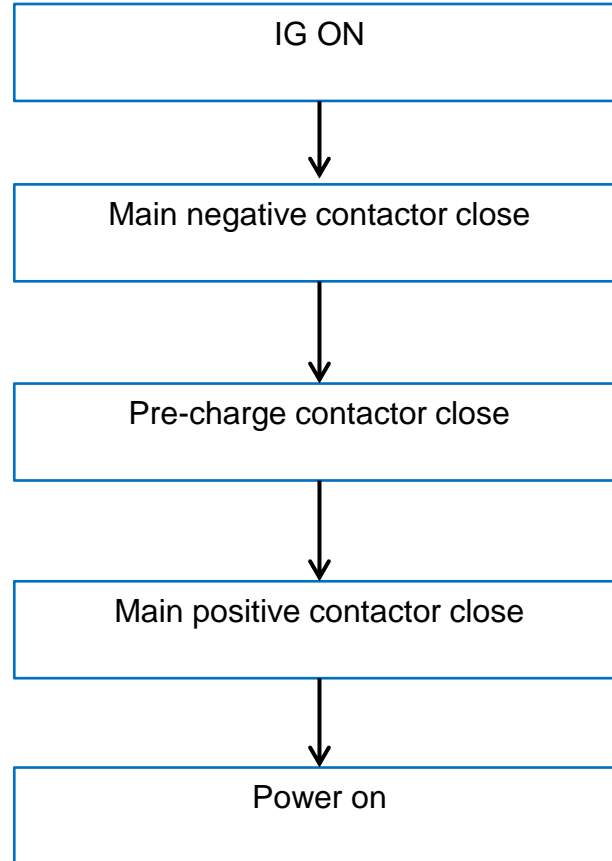
X.

XI. Common faults and troubleshooting methods

XI.

VII. Power-on/off process

1. Introduction to the process of powering on and off



1. Introduction to the process of powering on and off

Process of main negative contactor closing:

S1: VCU receives key ON signal valid;

S1:

S2: VCU doesn't receive "level 2 insulation alarm" of insulation detection module;

S2:

S3: BMS doesn't send "main contactor disconnect request";

S3:

S4: The logic relationship is "and" if the MCU has no fault of level four or above;

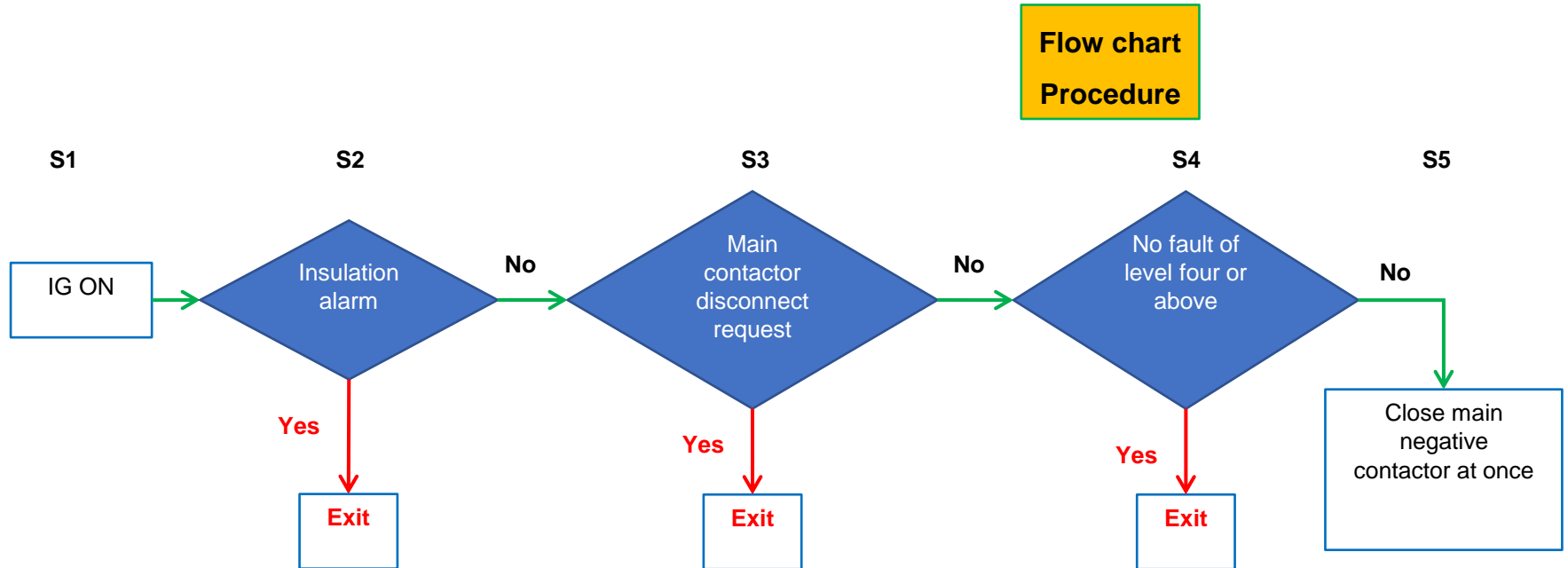
S4:

S5: If above conditions are effective, then close main negative contactor at once.

S5:

VII. Power-on/off process

1. Introduction to the process of powering on and off



1. Introduction to the process of powering on and off

Process of pre-charge contactor closing:

S1: Main negative contactor feedback signal is valid;

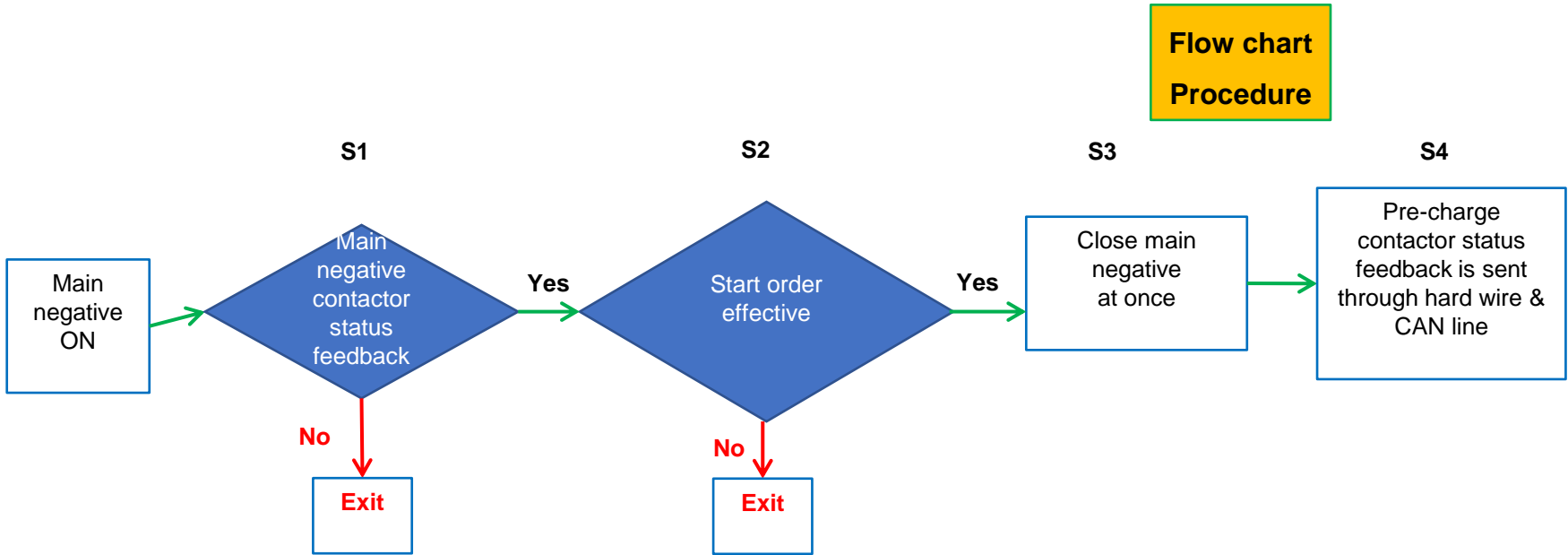
S2: The Key Start signal sent by the VCU is received, and the above logical relationship is "and";

S3: If the above conditions are all valid, close the pre-charge contactor;

S4: Status feedback signal of pre-charge contactor is sent (message sending is valid in case of hard wire output), and the above logical relationship is "AND";

VII. Power-on/off process

1. Introduction to the process of powering on and off



1. Introduction to the process of powering on and off

Process of main positive contactor closing:

S1: Main negative contactor status feedback = 1 valid;

S2: Pre-charge contactor status feedback is valid;

S3: Compare with the VCU, and check whether the bus voltage of the MCU reaches 95% or more of the current voltage of the power battery, and whether the voltage of the power battery and the voltage at both ends of the MCU is greater than 300V; the main positive contactor will be closed if the above conditions are valid, and the main positive contactor will not be closed if they are invalid;

S4: After the main positive contactor is closed, the status feedback of the main positive contactor is sent out (the hard wire output is valid for message sending);

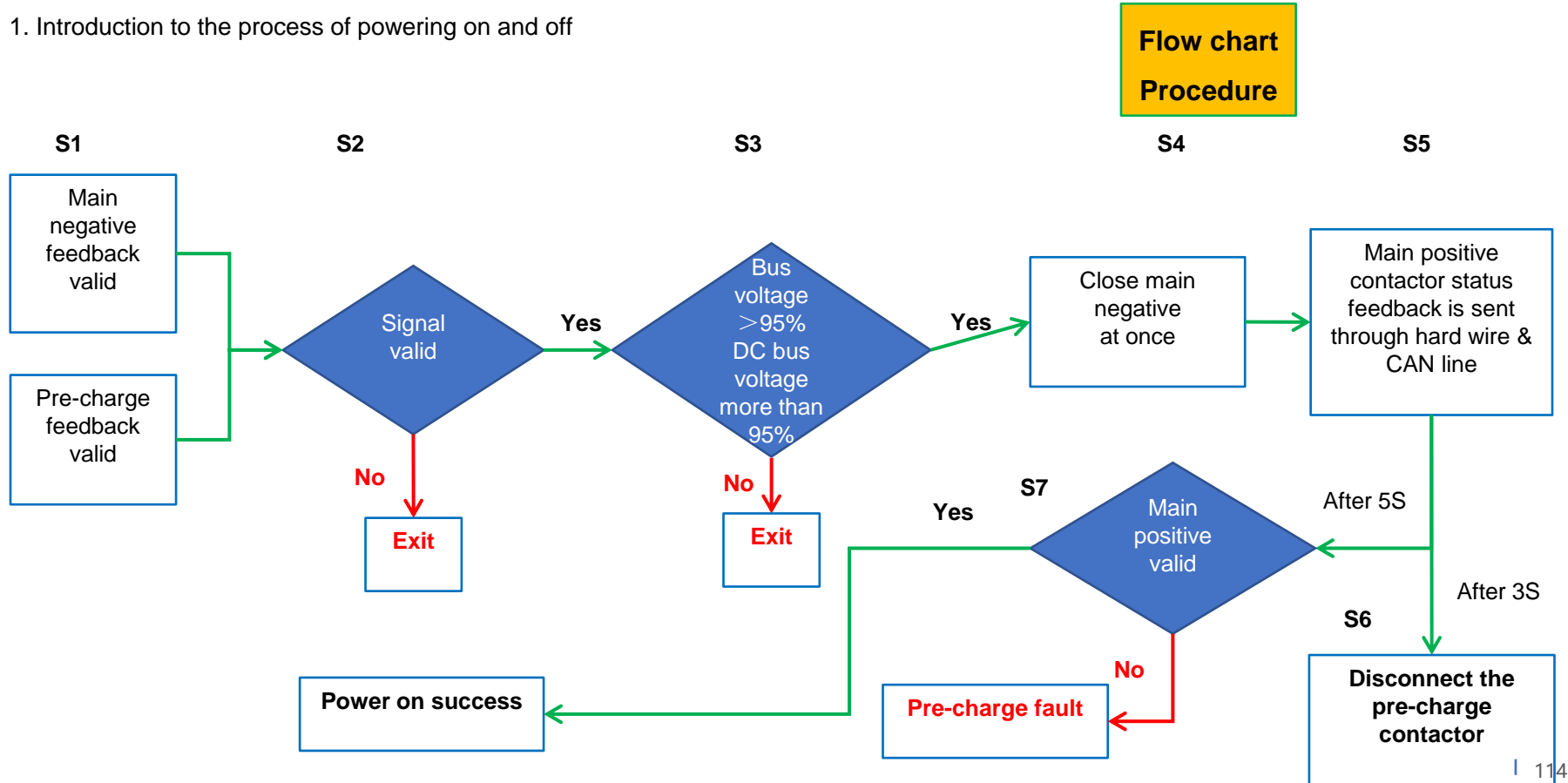
S5: The output water pump control hard wire and DC / AC hard wire can be enabled after the main positive contactor is closed for 1s;

S6: After the closing feedback of main positive contactor is valid for 3s, the pre-charge contactor is disconnected;

S7: If the main positive contactor is not closed within 5s, the pre-charge timeout will be reported;

VII. Power-on/off process

1. Introduction to the process of powering on and off



1. Introduction to the process of powering on and off

Normal positive and negative power off strategy:

S1: VCU has received Key Off signal;

S2: After delay 2s, disconnect the main positive contactor, and send the status feedback of the main positive contactor through the message;

S3: After delay 2s, disconnect the main negative contactor, and send the status feedback of the main negative contactor through the message;

S4: After delay 1s, VCU goes into a dormant status.

1. Introduction to the process of powering on and off

Non-normal positive and negative power off strategy:

S1: VCU receives Key ON signal valid;

S2: VCU receives "level 2 insulation alarm" of insulation detection module;

Or the message from the insulation detection module node cannot be received for 1min;

Or the BMS sends a "disconnect main contactor" request;

Or the BMS message cannot be received for 1min;

Or the MCU has level 4 fault;

Or the MCU message cannot be received for 1min;

1. Introduction to the process of powering on and off

Non-normal positive and negative power off strategy:

The logical relationship above is “OR”; if one of all is valid, VCU will perform actions below: 1. VCU resets the accelerator pedal aperture (or request torque) and brake pedal aperture; 2. After the enable signal of DC/DC and DC/AC is valid for 50S, VCU stops output; 3. VCU stops output of water pump control hardware; 4. VCU does not respond pre-charge or other request signals;

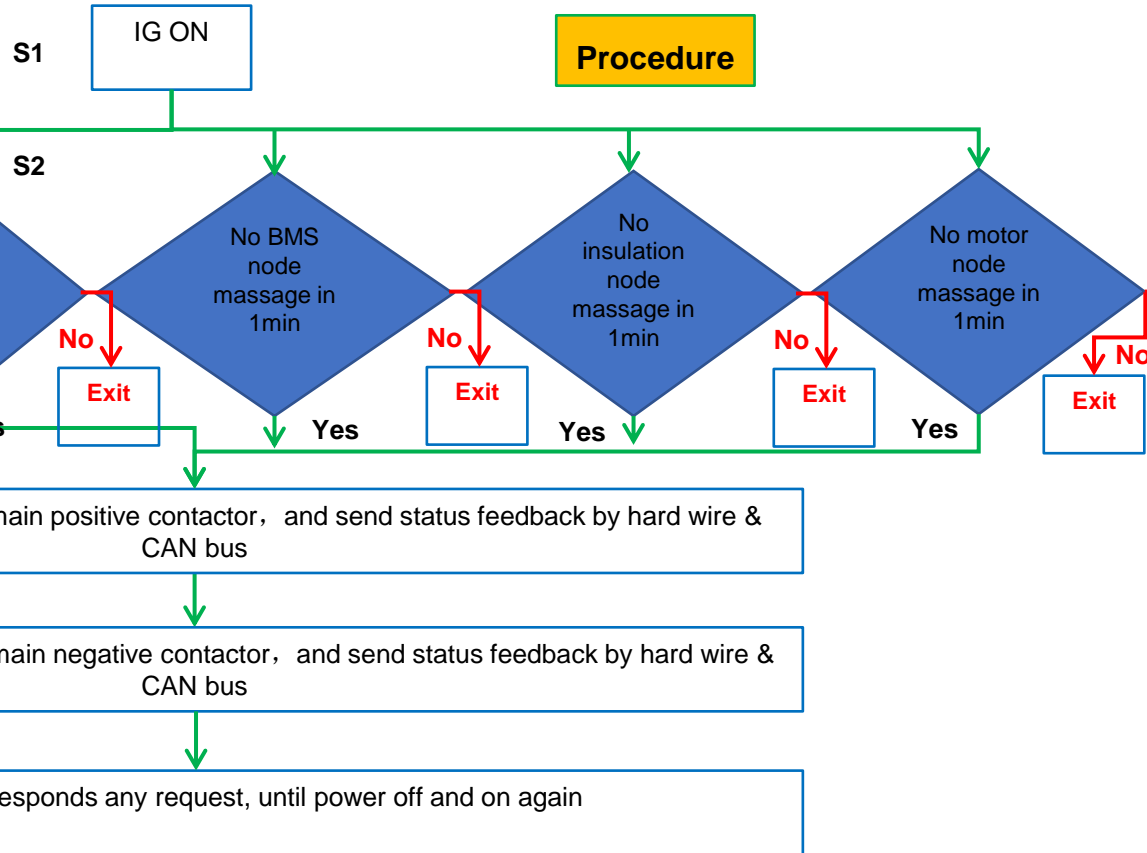
S3: After the fault is valid 1s, disconnect the main positive contactor, and send its status feedback out (if main positive contactor isn't closed, then keep current status);

S4: After the fault is valid 55s, disconnect the main negative contactor, and send its status feedback out;

S5: VCU no longer responds any request, until power off and on again.

VII. Power-on/off process

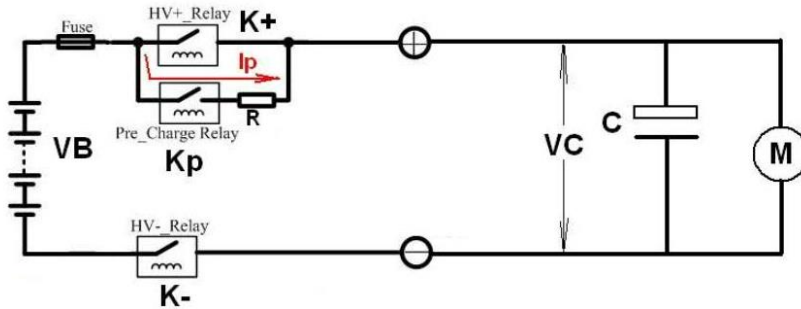
1. Introduction to the process of powering on and off



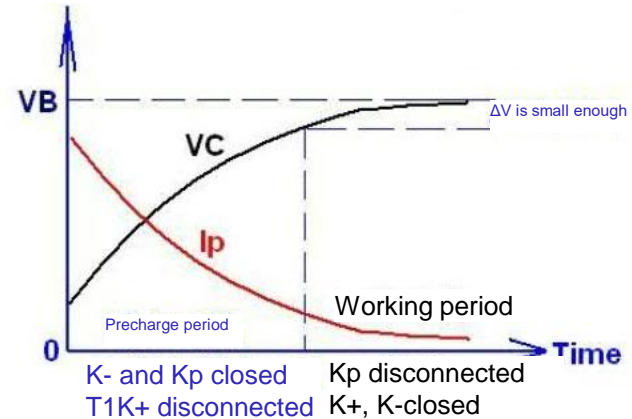
2. Pre-charge principle

For components with a large number of capacitive loads, a large impact current will be formed when the high voltage is connected if no pre-charge device is provided. During use, frequent power-on and power-off may lead to the risk of local overheating and failure of the component, forming an arc on the contactor, or even contact adhesion that cannot be disconnected and controlled again, which directly affects the safety of the HV system.

In order to avoid the hidden dangers of HV safety caused by the above risks, it is necessary to add a pre-charge circuit, add a pre-charge resistor, and calculate a reasonable pre-charge time during design to avoid this phenomenon. For example, when the HV DC main contactor is closed, a pre-charge resistor can be added to extend the service life of the fuse.



Schematic diagram of HV system pre-charge



HV system pre-charge voltage and current characteristic curve

3. Precautions for power on and off

Precautions for power on and off operations:

When the new energy vehicle is powered on, be sure to wait in the ON position until the instrument lights up, and the vehicle can be started after all systems are normal upon self-test. It is forbidden to start the vehicle directly after IG ON. When the power is switched off, be sure to wait until the instrument completely goes out before powering on again. Do not repeat rapid power on and off in a short time.



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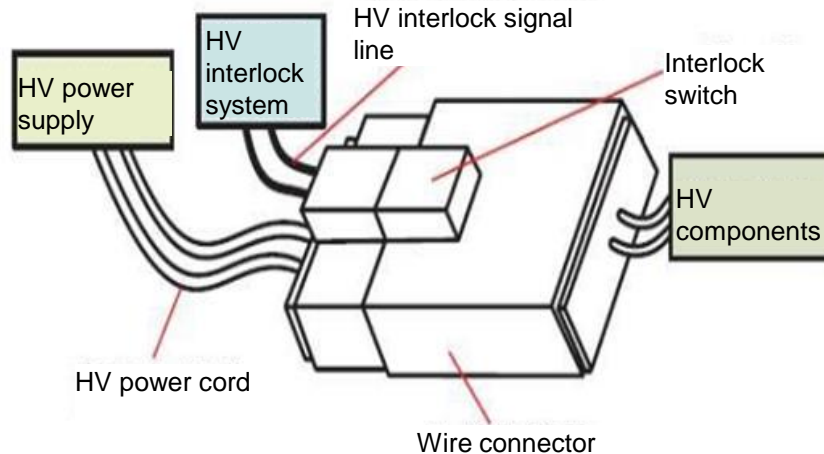
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VIII. High voltage interlock

1. Concept of HV interlock

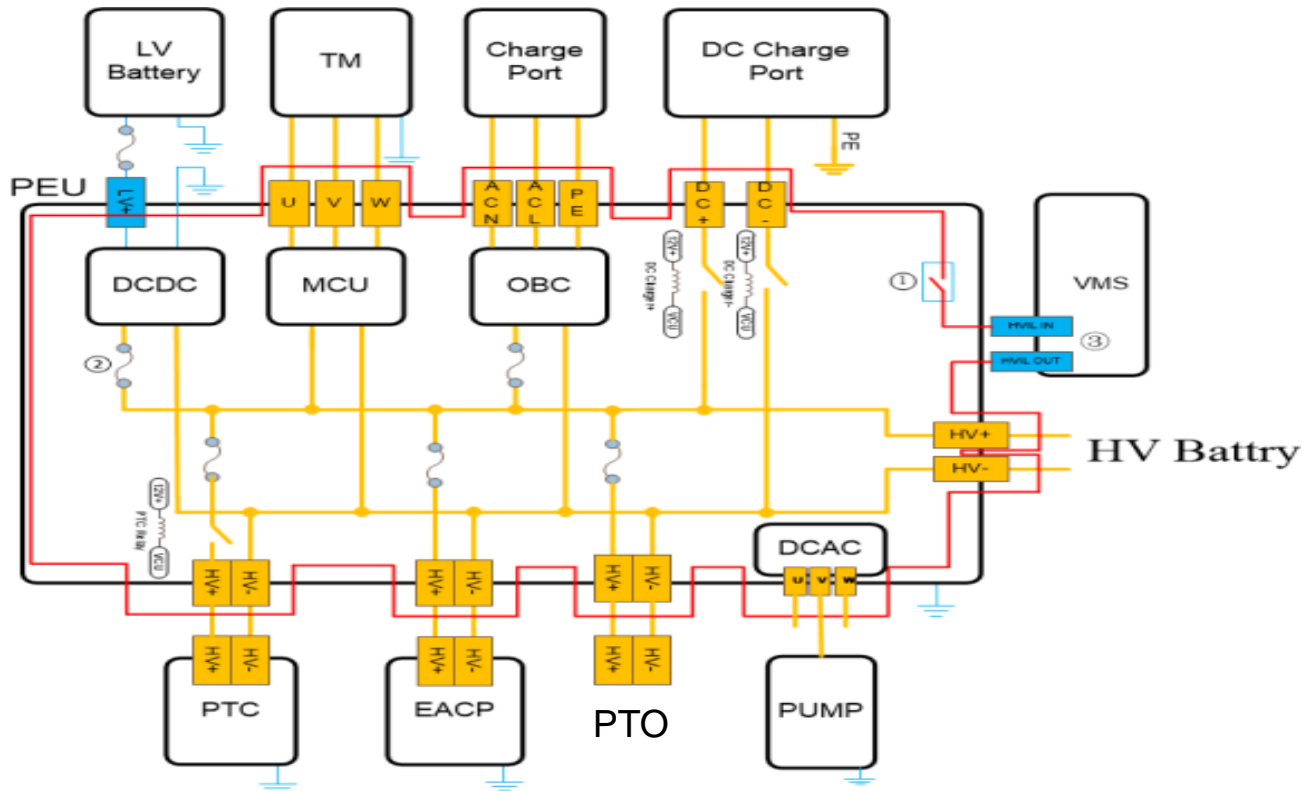
When any HV component is disconnected, removed or not reliably connected, and the HV power switch is not disconnected in time, the HV live terminals may be exposed in accessible parts or connected to conductive objects, endangering the safety of operators.

In order to avoid unplugging the HV terminal to make the HV live terminal exposed in an accessible position, HV harnesses, HV connector terminals, HV components and their covers are all designed with electrical signal detection to ensure the integrity of electrical connections. As shown in the red line in the figure, when the HV safety system detects that a certain connection is disconnected, unreliably connected, or the cover is opened, it will cut off the output of the relevant HV power supply directly or through the vehicle control system, and send an alarm until fault is eliminated.



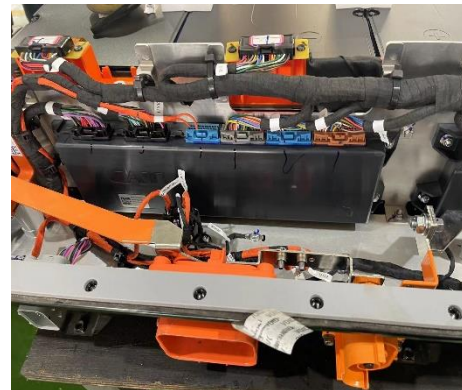
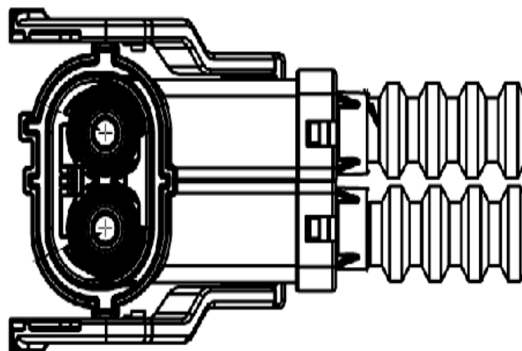
VIII. High voltage interlock

2. Working principle of HV interlock



VIII. High voltage interlock

3. Components involved in HV interlock (battery system)



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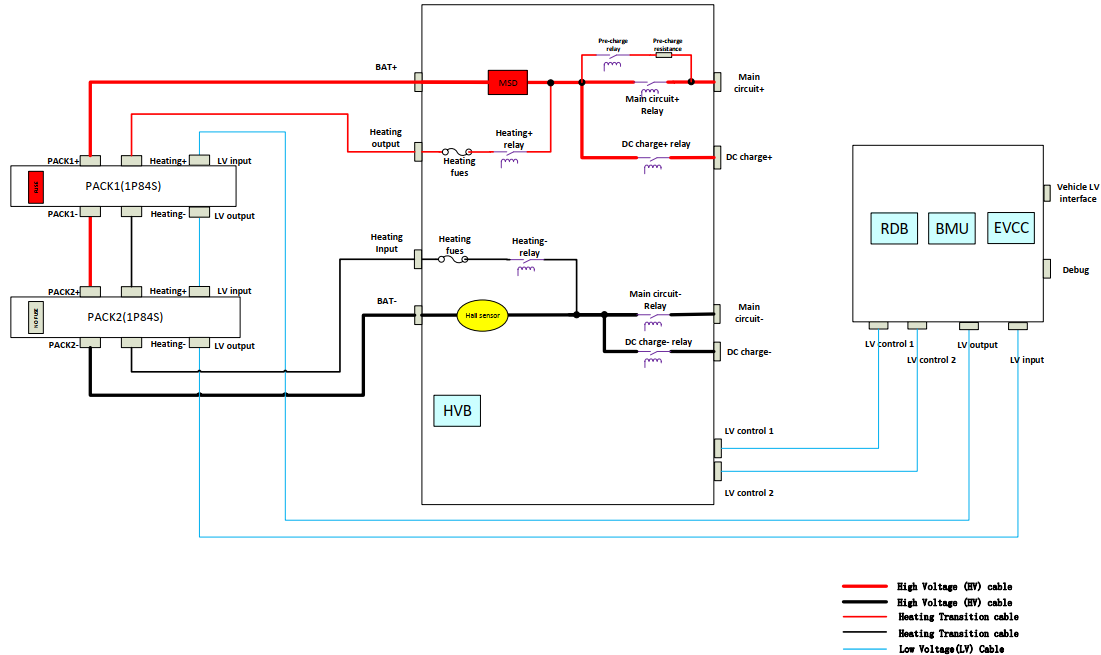
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System schematic diagram

CATL adopts single-branch BDU, which integrates charge relay, positive and negative relays, pre-charge relay, Hall effect relay, heating relays and other components inside.



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X. Specification for daily use of power battery

1. Safety precautions

1) Technician qualification






- Possess the Special Operation Certificate (Low-Voltage Electrician Certificate) issued by the State Administration of Work Safety;
- Be trained by the company and pass the assessment;



X. Specification for daily use of power battery

1. Safety precautions

2) Preparation before maintenance

List of PPEs			
Insulating gloves			Insulating anti-smash shoes
Work clothes		Guard cable	
		Insulating rescue hook	

X. Specification for daily use of power battery

1. Safety precautions

2) Preparation before maintenance

- Maintenance personnel must wear PPEs (work clothes, insulating gloves, etc.), and are not allowed to wear items that are not related to work (such as necklaces, rings, watches, etc.) on the work site.
- All metal tools should be insulated for safe working conditions.



X. Specification for daily use of power battery

1. Safety precautions

3) Maintenance site

- Dedicated maintenance station.
- Dedicated battery removal lift
- Clean, dry and well ventilated.
- Please set safety isolation warning sign before maintenance
- The maintenance station must be equipped with PPEs and fire-fighting equipment.
- There are fire hydrants and fire bunkers near the maintenance site.
- Avoid irrelevant personnel and customers from approaching.



X. Specification for daily use of power battery

1. Safety precautions

4) Maintenance process

- Before the maintenance of the system, turn off the ignition switch, and set the "Inspecting and Repair" sign, and have the HV capacitor discharge for 5min.
- Remove the key, disconnect the main power switch of the 12/24V battery negative cable, and turn the lever to the "OFF" position.

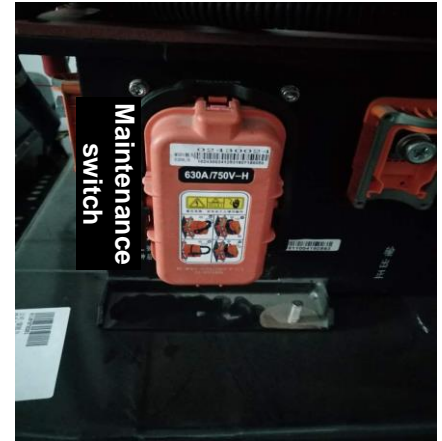


X. Specification for daily use of power battery

1. Safety precautions

4) Maintenance process

- During maintenance, unplug the MSD on the BDU and the HV power line between packs;
- When inspecting and repairing the insulation fault of the battery system, be sure to wear insulating gloves and disconnect the connecting harness of each pack to prevent electric shock.

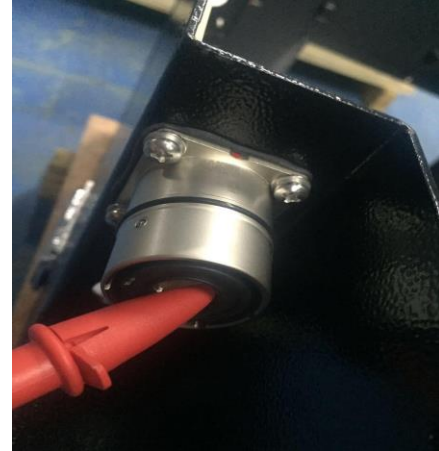


X. Specification for daily use of power battery

1. Safety precautions

4) Maintenance process

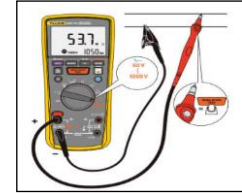
- When using a multimeter or an insulation meter to measure the connector, be sure to use the protective cover for the probe to prevent the probe from touching other parts.
- During inspection and maintenance of the battery system, under no circumstances should the positive and negative poles of the battery pack be touched at the same time, and the points of the battery compartments in series in the pack cannot be touched at the same time.
- It is strictly forbidden to step on or put tools, testing equipment and various metal objects on the battery.



X. Specification for daily use of power battery

1. Safety precautions

4) Maintenance process



X. Specification for daily use of power battery

1. Safety precautions

4) Maintenance process

- When using a forklift for removing the battery pack, ensure that the external circuit of the battery pack is disconnected and the center of gravity of the battery is stable. Maintenance operations in mid-air are strictly prohibited. The use of forklifts should be in accordance with the *Regulations on Safe Forklift Operation*.
- For vehicles with a battery system installed at a high position, such as the overhead battery, the maintenance technician needs to wear a guard cable.
- During hoisting the battery pack/module, it should be ensured that the hoisting center of gravity is stable, the hoisting rope is solid and reliable, and no one is allowed to stand under the sling.



X. Specification for daily use of power battery

1. Safety precautions

4) Maintenance process

- When dismantling the HV wires of the assembly, wrap the HV and LV harnesses with insulating tapes at least 3 layers and cover the metal part at least 1cm to avoid short circuits.
- The batteries (modules, cells) dismantled for inspection and repair should be placed in a relatively open place. It is strictly forbidden to place the modules on the metal box to avoid short circuits. Places for modules and cells should be laid with insulating materials more than 1cm to avoid short circuit and stabbing.



X. Specification for daily use of power battery

1. Safety precautions

5) After maintenance

- If maintenance of liquid-cooled battery pack is completed, the specified coolant must be added to prevent the mixing of different coolants from causing deterioration, blockage, and corrosion of the liquid cooling system.
- After maintenance is completed, the battery pack and liquid-cooled system should be tested for air tightness.
- When maintenance of the battery pack is completed, an anti-tear label must be attached to the connection of the battery pack case cover.



X. Specification for daily use of power battery

1. Safety precautions

5) After maintenance

- After replacing the HV components, be sure to tighten the bolts in place to ensure the torque, and measure whether the insulation resistance is normal.
- The cable interface must be tightened according to the standard torque, and the connector must be connected in place.
- After maintenance is completed, before powering on for a test run, reconfirm that the vehicle is unmanned.
- Supply LV power to the battery before switching on HV power supply, connect the battery detection harness, and check whether there are any faults (voltage, temperature) inside the battery through the BMU or by reading messages.
- After full switching on HV power supply of vehicle, recheck that the battery fault has been repaired correctly through the BMU or by reading the message again, and select different working conditions to test the vehicle.
- After the tested vehicle has been completely repaired, charge the vehicle and test whether there is any problem in the battery charging system. If the customer picks up the vehicle for a short time, decide how much to charge according to the customer's needs. If the customer cannot pick up the vehicle for a long time, full charge and standing for 1 hour should be done for the battery, and then discharge it to about 50% SOC for storage.

X. Specification for daily use of power battery

2. Daily use requirements and precautions

- ① Check the instrument panel to confirm that there is no abnormal alarm information.
- ② Before driving the vehicle, please ensure that the SOC is not less than 50%. If conditions permit, it is recommended to perform a full charge before driving. If SOC is not greater than 30%, it means the SOC is low. Charge the battery as soon as possible. When the SOC indicator bar on the meter is in the red warning grid, it indicates that the SOC of the power battery is low and the battery should be charged in time. When the ambient temperature is lower than 0° C, the charging time is longer than that under normal temperature, and the charging capacity is low. The specific charging time should be based on the time displayed on the meter. When the temperature is low, it is recommended to charge the battery in time at the end of operation of vehicle. The recommended SOC values for battery charging at different temperatures are as follows:

Temperature	<-20°C	[-20°C, -10°C)	[-10°C, 0°C)	>0°C
SOC	≥30%	≥25%	≥20%	≥15%

	Lithium iron phosphate (LFP)
Battery working temperature range	-35°C~65°C
Battery storage ambient temperature range	-35°C~55°C
Optimum charge and discharge temperature range	25°C~35°C

2. Daily use requirements and precautions

- ③ The daily accumulated charged power should not exceed 1.5 times of the current SOC as much as possible. The battery system may be overheated after repeated charging and discharging, which will affect the charging time, power performance and battery cycle life.
- ④ Non-professional maintenance personnel are strictly prohibited from plugging and unplugging the maintenance switch and any connectors on the batter pack.
- ⑤ For liquid-cooled battery systems, it is strictly forbidden to mix different models of coolants.
- ⑥ For electric vehicles with a battery system fire extinguishing device, when the battery fire is confirmed and the alarm activation switch has an early warning signal, immediately open the protection cover of the alarm activation switch, press and hold the fragile button for 3s, and activate the fire extinguisher.
- ⑦ It is strictly forbidden to wash the battery pack and its connectors directly with water to prevent the battery pack from being damaged by water.
- ⑧ When charging, please do not remove the gun while power supply is not switched off. When the vehicle power is switched to ON, it is strictly forbidden to plug and unplug the maintenance switch and any connector on the battery pack;
- ⑨ The battery maintenance must be carried out at least once a year to prevent damage to the battery.
- ⑩ Electric battery vehicles should be fully charged automatically at least once every three days.

Warm reminder:

1. When the temperature is below 0° C, the operating vehicle should be charged as soon as possible at the end of operation, so as to prevent the charging time from prolonging when the battery temperature is too low, which will affect the operation.
2. In hot weather in summer ($\geq 35^{\circ}$ C), recharge during the daytime should not be carried out more than twice, and the recharge duration each time does not exceed 30min. If the recharge duration exceeds 30min, only recharge once is allowed. Therefore, impact of battery high temperature on normal operation can be avoided.

3. Requirements for use of the vehicle not used for a long time

1. Under normal circumstances, vehicles that have been stored for more than 15 days are defined as vehicles that have not been used for a long time.
2. Before the battery is stored, the SOC should not be lower than 40%.
3. Before vehicle use for the first time after storage for a long time, "battery maintenance" should be done at least once to activate the battery system to restore its performance to the best state.

Warm reminder:

If the battery is not used for a long time, and the battery balance maintenance is not carried out, the battery system will have inaccurate SOC, virtual power and other phenomena, which may affect the normal use of the vehicle .

X. Specification for daily use of power battery

4. Use and precautions of the charger

- ① Charging temperature range: charge according to the temperature range required by each battery supplier; there is no abnormal alarm on the instrument panel;
- ② During charging, avoid excessive temperature around the vehicle. It is recommended to charge the vehicle in a ventilated and cool place.
- ③ Before charging, ensure that the charging interface and charging gun are free from water, snow or foreign objects, and that the charging device is not damaged, rusted or corroded; it is forbidden to charge on outdoor exposed EVSEs in rainy, snowy or wet weather.
- ④ During charging, several "clicks" of relay pull-in may be heard in the PDU, which is a normal phenomenon.
- ⑤ It is recommended to charge on the EVSE recommended by Foton. If the output power of the charging pile is insufficient, the charging time will be extended. The specific charging time is based on the time displayed on the meter.
- ⑥ For the convenience of use, the meter will prompt the estimated full charge time. Under different temperature, power, charging facilities, etc., there may be a certain deviation in the full charge time, which is a normal phenomenon.
- ⑦ If an unusual smell or smoke coming out of the vehicle is found during charging, stop charging immediately.
- ⑧ After charging, please do not disconnect the charger with wet hands or standing in water.
- ⑨ Make sure the charging connector is disconnected from the charging interface before driving the vehicle.



X. Specification for daily use of power battery

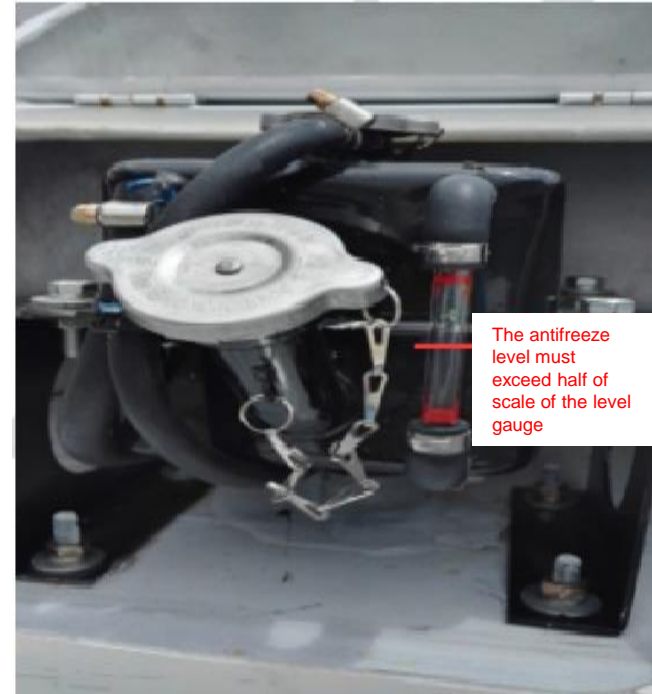
5. Maintenance method of the battery

Battery external vehicle part inspection items:

- The HV and LV power supplies must be disconnected before inspection and maintenance;
- Check the vehicle exterior ventilation louvers for foreign matters. Clean up foreign matters in time if any.
- Check whether the coolant level of the water-cooled unit reaches the scale (or more than 2/3 capacity of the radiator). If not, add coolant in time. The model of coolant must be the same, and then switch on the power supply to check whether the coolant circulation is normal;
- The inspection frequency is recommended to be at least once a month, and a checklist should be made.

Note

For models equipped with water-cooled units, if the average temperature of the battery is found to be above 52° C during high-temperature operation in summer and this phenomenon continues, which is abnormal. In this case, please check the water-cooled unit as required. If the fault still cannot be solved, please contact the after-sales service department or the service agent of Ningde Times for help.



X. Specification for daily use of power battery

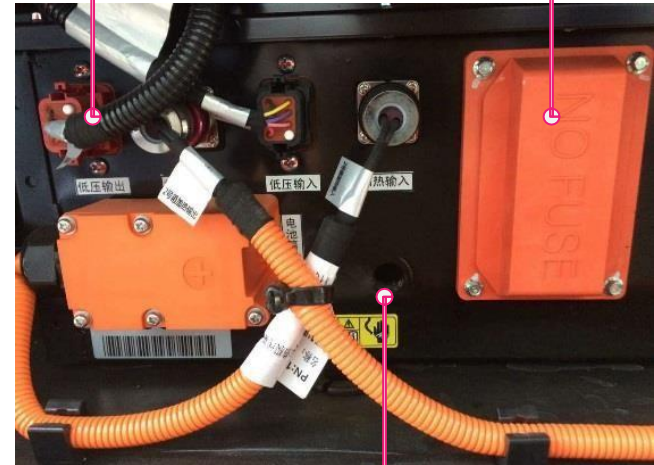
5. Maintenance method of the battery

Inspection items of battery pack:

- Check whether the MSD is loose or overheated, and whether the fixing screws are loose.
- Check whether the balance valve of the battery pack is normal.
- Check whether the battery pack is deformed or damaged. Check the surface for oxidization, peeling off, and whether the installation position is offset
- Check the harness connector for looseness.
- Check the conductive copper cores and pins of the HV and LV connectors for burns, pitting, oxidation, deformation, etc.
- Check whether the battery pack for peculiar smell or leakage of unknown liquid.
- Check the surface of the pack for dust, and clean the surface. It is recommended to use an air gun to blow away the dust on the battery pack, and it is forbidden to use a high-pressure water gun or a large amount of water to wash it.
- Check whether the battery pack is icy (in winter)
- Check that no water is in the battery compartment

Harness connector

Check whether the MSD is loose or overheated, and whether the screws are loose



Check whether the balance valve is normal

X. Specification for daily use of power battery

5. Maintenance method of the battery

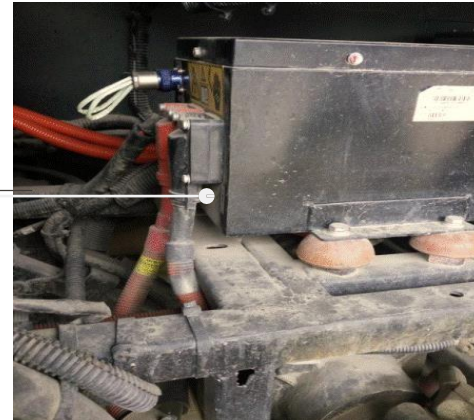
Inspection items of BDU:

- Check whether the MSD is loose or overheated.
- Check whether the BDU terminal is loose or overheated.
- Check whether the BDU is deformed.
- Check the HV harness for aging or damage.
- Check Whether the fixing screw is loose.

MSD



HV terminal



X. Specification for daily use of power battery

5. Maintenance method of the battery

Maintenance process of battery system of operating vehicle:

- ① Turn the key to the "ON" position to check the SOC value
- ② Adjust the SOC below 20%
- ③ Stop the vehicle (device) stably, turn the key to the "OFF" position, and turn off the vehicle (device). Do not operate them more than 1 hour, and no additional operation is required during this period.
- ④ A full charge is required after standing.
- ⑤ The maintenance period should be in accordance with the vehicle maintenance manual.

Note

During Step 3, the use of vehicle or any electrical consumer is prohibited.

X. Specification for daily use of power battery



5. Maintenance method of the battery

Maintenance process of battery system of stored vehicle:

- ① Turn the key to the "ON" position to check the SOC value
- ② Adjust the SOC below 20%
- ③ Stop the vehicle (device) stably, turn the key to the "OFF" position, and turn off the vehicle (device). Do not operate them more than 1 hour, and no additional operation is required during this period.
- ④ A full charge is required after standing.
- ⑤ Adjust the SOC to 40%-60% and continue storage.
- ⑥ Stored vehicles need to be fully charged every three months. Stored vehicles after standing need to be maintained before they can be used for the first time.

Note

During Step 3, the use of vehicle or any electrical consumer is prohibited.

X. Specification for daily use of power battery



6. Maintenance method of the independent battery in the storage room

1. Storage conditions:

- The optimal SOC range for the stored battery should be 40%~60%.
- Lithium-ion batteries should be stored in a clean, flat, dry, ventilated indoor place protected against exposure to direct sunlight and rain and kept away from heat sources, with a temperature of -20-45°C and a relative humidity of no more than 75%.
- The positive and negative poles of the battery pack should be free of ingress of any conductive dirt such as metal materials and should be protected by insulating materials.
- The battery pack should be protected against shock and stress from mechanical equipment.
- The battery maintenance of the vehicle stored for a long time must be carried out every three months to prevent battery damage.
- Before vehicle use for the first time after storage for a long time, "battery maintenance" should be done at least once to activate the battery system to restore its performance to the best state.

6. Maintenance method of the independent battery in the storage room

2. Maintenance frequency & method:

1. Adjust the SOC to below 20%.
2. Stand for 1 hour. Monitor the battery by the BMU through professional connection equipment.
3. SOC corresponding to the measured average cell voltage through the monitoring by the BMU: SOC_{VAG}, and SOC corresponding to the minimum cell voltage: SOC_{min}
 - If "SOC_{VAG}-SOC_{min}>5%," it is necessary to perform unpacking equalization maintenance. After the maintenance is completed, fully charge the battery, discharge it to 40%-60% SOC, and continue storage.
 - If "SOC_{VAG}-SOC_{min}≤5%," fully charge the battery, discharge it to 40%-60% SOC, and continue storage.



Note

1. Since the stored battery cannot be discharged independently, it is recommended to use special equipment (charge and discharge integrated machine) to cooperate with BMS to perform reasonable charge and discharge operations. It is strictly forbidden to carry out blind charge and discharge of the battery.
2. Unpacking equalization operation, if required, should be carried out after professional training. Blind operation is prohibited; otherwise, safety risks may be caused.

7. Handling methods of emergencies

1) Traffic accident

Step 1: Stop the vehicle, apply the parking brake, open the door to evacuate the passengers, After that, turn the key to OFF and turn on the emergency lamps; set the warning sign at the accident site, and prepare fire extinguishers in advance; if conditions permit or necessary, turn off the main power switch and unplug the MSD.

Step 2: Handle the traffic accident according to local traffic regulations and procedures.

Step 3: Notify the vehicle dealer and relevant units as soon as possible, and drag the faulty vehicle to the designated safe area for further inspection, repair or scrapping according to the dealer's instructions. Do not use the vehicle before the relevant parties give the battery safety judgment result.



X. Specification for daily use of power battery

7. Handling methods of emergencies

2) Fire

Step 1: Leave the vehicle quickly and make a fire emergency call according to the situation on the spot.

Step 2: Perform the following operations under the condition of ensuring personal safety:

- ① If the HV/LV harness catches a fire, cut off the power supply as soon as possible, and use sand to bury it, or use carbon dioxide or dry powder fire extinguisher to spray onto it (do not use water fire extinguisher).
- ② If a fire occurs inside the battery, the on-board fire extinguisher, if equipped, should be first used to extinguish the fire. If the thermal runaway is serious, the power battery pack catches fire inside, and there is a lot of smoke and open flames, spray water on the fire area to cool it down. Stop spraying water until there is no possibility of re-ignition inside the power battery pack, and keep the water spraying equipment in standby. During water spraying, it is recommended that personnel be more than 2m away from the fire source.
- ✓ Under the premise of ensuring the safety of on-site personnel, transfer other vehicles and flammable and explosive materials.
- ✓ For fires that are difficult to control, on-site rescuers must keep a certain safe distance and set up a warning area to prevent accidental explosion of the power battery.

When the firefighters arrive at the scene, they should inform the on-site conditions such as the articles on fire and whether there are flammable and explosive materials around.

③ If any person accidentally inhales smoke, please perform transfer and seek medical attention as soon as possible.

Step 3: Notify the after-sales personnel to obtain further handling opinions.

Note: If a fire occurs during the charging process, please be sure to power off the charging device before the fire extinguishing.



X. Specification for daily use of power battery

7. Handling methods of emergencies

3) Wading

When driving on waterlogged roads, please pay attention to the following:

Depth	Speed	Time
≤35cm	≤10km/h	≤10min



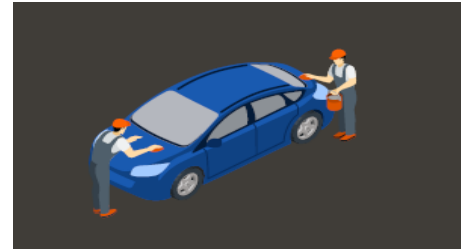
Note: If the depth of water on the road exceeds 35cm, it is forbidden to drive the vehicle on this road; if little water has invaded into the vehicle, first drive the vehicle away from the waterlogged area and then clean up the water immediately; if the vehicle stops in a waterlogged area due to water ingress, immediately cut off the power supply; if the vehicle is seriously flooded, evacuate the occupants to a safe location as soon as possible, and call for rescue according to the severity of the accident.

7. Handling methods of emergencies

4) Immersion

If the vehicle gets into the water or is submerged in stagnant water due to accidents, please pay attention to the following:

- ✓ Power-on is prohibited
- ✓ Notify the auto service provider
- New energy vehicles submerged in stagnant water are prohibited from being started and should be handled by professionals. Professionals should wear special PPE to disconnect the MSD and all HV/LV harnesses of the battery pack, and tow the vehicle to the repair shop.
- When the battery pack is damp or flooded, it is strictly forbidden to charge and discharge the battery pack. Professionals should disassemble, test and repair the battery, then restore the battery pack, and then test the insulation of the battery pack. The battery pack can only be used if its insulation is normal.



Note: Due to weather or special reasons, when the vehicle is submerged in stagnant water, it is forbidden to power on the vehicle, otherwise it may cause safety risks or secondary damage to the vehicle.

7. Handling methods of emergencies

5) Precautions for towing

After the above emergencies occur, notify the vehicle dealer and relevant units as soon as possible, and drag the faulty vehicle to the designated safe area for further inspection, repair or scrapping according to the dealer's instructions. When towing the vehicle, pay attention to the following:

- If the vehicle suffers overheat, smoke or fire, dry powder fire extinguisher or water should be used to extinguish the fire, and the vehicle can only be towed after cooling down without safety risks.
- Before towing, turn the key to OFF, and move the shift lever to N.
- When the towing speed is higher than 15Km/h, it is necessary to disconnect the axle shaft to prevent the motor from recovering electric energy and burning the motor or the internal components of the PEU.
- If the axle shaft cannot be removed, tow the vehicle with a faltbed semi-trailer.
- The vehicle that suffer leaks, serious deformation, smoke or fire must be dragged to an open area. Vehicles are not allowed to be parked within 5m of the surrounding area. Warning signs must be placed to avoid people watching and touching.
- The towing vehicle needs to carry fire extinguishing equipment to respond to accidents such as fire during towing.

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List of common faults

Phenomena	Tool to be used
No HV output	Service tools, multimeter, BMU or diagnostic scan tool
Abnormal cell voltage	Service tools, multimeter, BMU or diagnostic scan tool
Abnormal cell temperature	Service tools, multimeter, BMU or diagnostic scan tool
Insulation fault	Service tools, insulation meter, BMU or diagnostic scan tool
Charge failure	Service tools, multimeter, pcan, computer, BMU
Abnormal heating function	Service tools, multimeter, BMU or diagnostic scan tool

XI. Common faults and troubleshooting methods

1) No HV output



Power battery fault indicator lamp



HV off indicator lamp

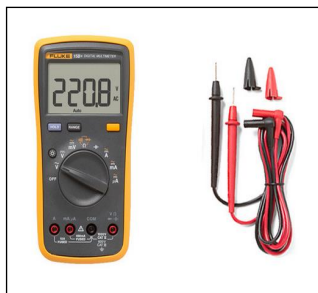


Low SOC indicator lamp



System fault indicator lamp

Tools preparation:



Multimeter



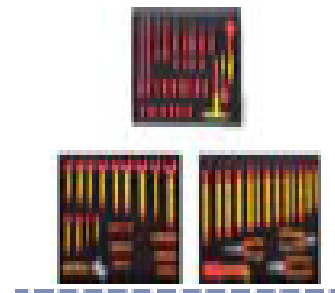
Upper computer



Diagnostic harness



Diagnostic scan tool



Service tools

1) No HV output

Cause 1: The HV circuit is open (the instrument panel or the BMU shows that the HV voltage is 0v)

- The BDU/battery pack MSD is not connected securely or is blown
- The inter-pack HV harness is loose
- The HV terminal is not connected properly
- The HV sampling harness is abnormal

Solutions:

- Check whether the BDU/battery pack MSD is not connected securely or is blown
- Check whether the inter-pack HV harness is connected properly or loose
- Check whether the HV terminal is damaged
- Check whether the HV sampling harness is connected properly or loose

1) No HV output

Cause 2: pre-charge failure (pre-charge failure causes the main contactor not to pull in)

- During pre-charging, the vehicle load works ahead of schedule, resulting in too long pre-charge time
- During pre-charging, there is an external short circuit, which causes the pre-charge current too high
- The pre-charge resistor or the pre-charge contactor is faulty and damaged

Solutions:

- Check whether any HV short circuit of the vehicle occurred.
- Check whether the external load of the vehicle works ahead of schedule during pre-charging, causing the voltage to fail to meet the pre-charge completion conditions. (electrical load contactor sticking)
- Check whether the pre-charge contactor is damaged through the BMU or dismantling the BDU
- Disassemble the BDU and check whether the pre-charge resistor is faulty
- If all tests are ok, replace the BCU (BMU) and test again.

1) No HV output

Cause 3: contactor fault (main positive/negative contactor fault)

- HV contactor sticking or fault
- Software misreporting

Solutions:

- Use a diagnostic scan tool such as BMU or FT700/710 to execute forced disconnection and closing commands and check whether the contactors are active (this operation cannot close all contactors at the same time, and the contactors must be closed and disconnected one by one. If the positive and negative contactors need to be closed at the same time, it is necessary to disconnect the load)
- If no action is performed after forced disconnection and closing, 1. Check whether the power supply of the contactor is normal, check and replace the contactor if the power supply is normal.
 2. If the power supply is abnormal, check the power supply module according to the drawings.
 3. Disassemble the BDU and check whether the contactor is stuck

2) Abnormal cell voltage



Power battery fault indicator lamp



System fault indicator lamp



Remove the power battery equipment

Tools preparation:



Multimeter



Upper computer



Diagnostic harness



Diagnostic scan tool



Service tools

2) Abnormal cell voltage

Cause 1: Cell overvoltage/undervoltage alarm

- The cell is overcharged, overdischarged or damaged
- The battery voltage acquisition harness is abnormal
- The BMU (CSC) is faulty

Solutions:

- Unpack and check whether the battery voltage is overvoltage or undervoltage. If the overvoltage or undervoltage is serious, replace it.
- If the actual voltage is normal, check whether the voltage acquisition module BMU (CSC) and the voltage harness are normal
- For occasional overvoltage and undervoltage, collect vehicle dynamic data and analyze whether the data is caused by vehicle discharge or feedback current exceeding the limit.
- If the high charge voltage and low discharge voltage are caused by serious battery capacity attenuation, replace it.

2) Abnormal cell voltage

Cause 2: Poor consistency alarm of cell voltage

- Poor cell consistency
- Battery capacity attenuation
- Loose voltage sampling harness
- The BMU (CSC) is faulty

Solutions:

- Refer to the OCV curve to evaluate the soc of the cell. When the difference between soc values is large, remove battery pack and recharge it until the values reach a balanced level. In case of serious inconsistency, replace the battery.
- In case of large occasional voltage difference, collect vehicle dynamic data, analyze and evaluate whether the vehicle discharge and feedback exceed the limit
- If the high charge voltage and low discharge voltage are caused by serious battery capacity attenuation, replace it.

3) Abnormal cell temperature



Power battery fault indicator lamp



System fault indicator lamp



Power battery overtemperature warning



Remove the power battery equipment

Tools preparation:



Multimeter



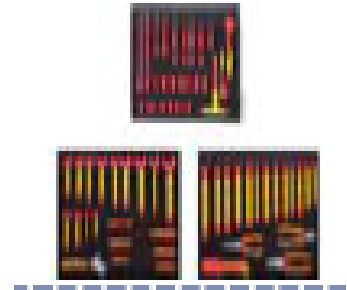
Upper computer



Diagnostic harness



Diagnostic scan tool



Service tools

3) Abnormal cell temperature

Causes: The cell temperature is too high or too low, and the temperature difference is large

- There is an abnormal heat source around the cell
- The cell is damaged and generates a lot of heat
- Temperature sampling is abnormal
- The thermal management system is abnormal
- The BMU (CSC) is faulty

Solutions:

- Connect to the BMU to collect temperature distribution
- It is found that individual temperature values jump abnormally, which may be a sampling fault, and in this case, check whether the temperature sampling harness and sensor are normal
- It is found that the temperature difference between packs is abnormal, check the distribution of the battery, find the abnormality, and relevant personnel evaluate the unreasonable heat distribution of the vehicle.
- If the cell temperature is abnormal, according to the voltage data analysis, check whether the cell is leaking, causing any risk
- Check the acquisition module BMU (CSC), check whether the slave control is damaged, and replace it if it is damaged.

4) Insulation fault



System fault indicator lamp



Insulation warning lamp



Power battery fault indicator lamp

Tools preparation:



Multimeter



Insulation meter



Service tools



Remove the power battery equipment¹ 168

4) Insulation fault

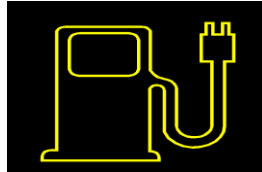
Cause:

- Water in battery
- Battery leak
- Too much dust
- Too high connector humidity
- HV harness is damaged
- Insulation fault of vehicle components

Solutions:

- Disconnect the HV connection between the battery and the vehicle, and check the insulation status when the PACK is independent. If the battery insulation is abnormal, check carefully the packs, sections and parts to confirm the abnormal point and deal with it after finding it. If no abnormality is found, replace the insulation module.
- If the insulation at the battery end is normal, check the insulation status of other HV components at the vehicle end.

5) Charge failure

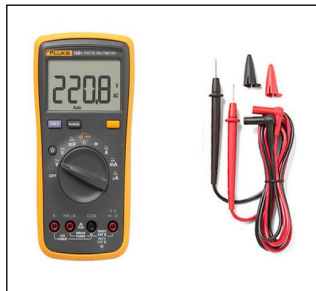


Charge fault indicator lamp



CAN data recorder

Tools preparation:



Multimeter



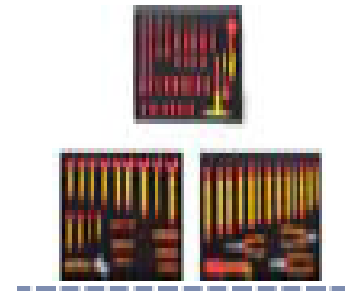
Upper computer



Diagnostic harness



Diagnostic scan tool



Service tools

5) Charge failure

Cause:

- The charging gun is not connected firmly
- The battery system is faulty
- The charger is faulty

Solutions:

- Check whether the vehicle is running normally, use diagnostic scan tool to check the vehicle fault, and deal with the fault first if any.
- Check whether the connection between the charging gun and the charge socket is abnormal
- Check whether the EVSE can charge the normal vehicle
- Check whether the vehicle can be charged at other EVSEs
- Confirm the EVSE model
- Collect charging messages from EVSEs and further analyze the causes of charge failure

6) Abnormal heating function



Power battery fault indicator lamp

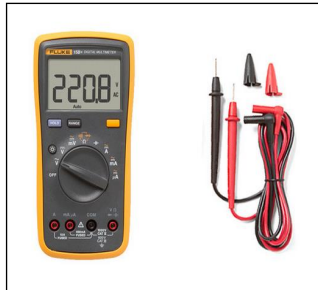


System fault indicator lamp



Power battery overtemperature warning

Tools preparation:



Multimeter



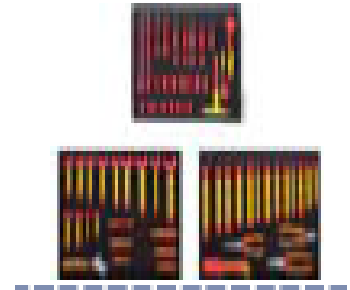
Upper computer



Diagnostic harness



Remove the power battery equipment



Service tools

6) Abnormal heating function

Cause:

- Failure to reach the temperature condition for activation
- Heating circuit open
- Heating film open

Solutions:

- Confirm temperature condition for activation
- Use the diagnostic scan tool such as BMU or FT700/710 to execute the forced closing and heating commands, and observe whether the current parameters change, and whether the contactor is working normally. If not, disassemble the BDU and check the heating contactor, heating fuse, and heating harness status.
- Measure the resistance of the heating film of the battery pack, and compare it with the resistance of the vehicle battery. If the resistance is abnormal, the heating film may be burnt out. Further disassemble the pack for confirmation.

XI. Common faults and troubleshooting methods



Special tools

1	Auxiliary installation and removal tools	FT-FZAZ-bx001	FT-FZAZ-bx001	Fork truck	Digital multimeter (FLUKE F17B+)	Measuring tools
2				Power battery storage rack	HV insulation tester (FLUKE 1587FC)	
3				Power battery lift truck	HV insulation tester (FLUKE 1508)	
4				Power motor disassembly tray		
5	Power battery service tools	FT DCWX-bx001	FT-DCWX-bx001	Air tightness testing equipment	Current clamp (FLUKE 319)	
6				Ningde Times airtight tooling	Non-contact infrared thermometer (FLUKE MT4MAX+)	
7				Power battery balancer	Milliohm meter (HIOKI RM3548)	
8				DC HV 1000V discharge tooling		
9	Installation tools	FT-CL-bx001	FT-CL-bx001	New energy vehicle service kit	ZLG CAN USBCAN-II	
10				Battery service truck	FT710	
11	Other tools	FT-QT-bx001		Insulating mat	BMU monitoring software (rental)	
12				Fire fighting equipment (dry power, water-based, sandbox)	Debugging cable	
13						
14				Insulating equipment (insulating shoes, insulating gloves)	PCAN-USB (USB to CAN bus adapter)	Acquisition tools
15				Goggles	Vehicle multi-channel CAN-bus data recorder (CANDTU-400EWGR)	
16				Temperature and humidity indicator		
	Fire blanket					

THANKS

