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Professional Competency Requirements for Maintenance and Operation of Power Battery Systems

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ABSTRACT

The power battery system is one of the high-risk components for new energy vehicles, and standardized operation and maintenance is one of the effective measures to improve the safety of new energy vehicles. The operation and maintenance of the power battery system includes daily operation, first level maintenance, and second level maintenance. A combination of practical research and theoretical analysis is adopted to confirm different maintenance tasks, job contents, and technical requirements, in order to improve the standardization and safety of operations. Fault mode analysis is a continuation of fault maintenance and provides practical basis for the design and process improvement of power battery systems.

KEYWORDS

Power Battery, Maintenance and Operation, Professional Competency.

1. INTRODUCTION

In recent years, fueled by favorable policies worldwide, the global new energy vehicle (NEV) market has witnessed a rapid growth trend, with China's NEV performance particularly outstanding. The accelerated development of the NEV industry has not only led to significant changes in the automotive sector but also promoted a continuous low-carbon transformation in the transportation sector. From the beginning of 2024 to present, global NEV sales have maintained a high year-on-year growth rate. In the first quarter of this year, global cumulative NEV sales reached 3.175 million, representing a 24% increase year-on-year. The energy system of NEVs, comprising power battery systems, on-board chargers, and DC-DC converters, is one of the core systems, with the power battery system providing all the energy for battery electric vehicles (BEVs). Lithium-ion batteries, invented around 1990 and commercialized in 1991, have evolved into polymer lithium-ion batteries (using gel polymer electrolytes as separators and electrolytes) since 1995, which were commercialized in 1999. Currently, lithium batteries, mainly in the forms of lithium iron phosphate and ternary lithium batteries, are commonly used in new energy power batteries. However, the after-sales service system in the NEV industry is not yet perfect, with a scarcity of professional technical researchers in related industries. Additionally, there are instances of misguidance in the vocational education sector, such as in power battery operation and maintenance. According to research in the NEV maintenance industry, irregular high-voltage operations pose significant safety risks. Furthermore, the NEV and energy system industries have significant market potential, with shortages of personnel in maintenance, installation, testing, and repair operations. There is no shortage of job opportunities for skilled personnel in these areas.

2. POWER BATTERY OPERATION STATES

The power battery system consists of battery modules, heating systems, power cutoff systems, battery management units (BMS), housings, and accessories, as illustrated in Figure 1. The battery modules contain several cells, while the BMS comprises a main BMS and sub-BMS. The power cutoff system incorporates fuses, positive and negative contactors, pre-charge contactors, and pre-charge resistors. The power battery operation states include discharge, charging, and heating.

Discharge State: After pre-charging, the positive and negative contactors close, enabling the power battery system to supply power to the load. The sub-BMS monitors individual cell voltages, temperatures, and active balancing functions, transmitting information to the main BMS via CAN communication. The main BMS calculates remaining battery capacity, performs fault diagnosis, and communicates with the vehicle.

Charging State: There are two charging modes: slow charging through on-board chargers and fast charging via DC charging piles. During charging, the BMS monitors system operation.

Heating State: When temperatures are low, the power battery can heat itself through heating films, or the charging energy can be used to heat the battery through the heating films. The BMS oversees system operation during heating.

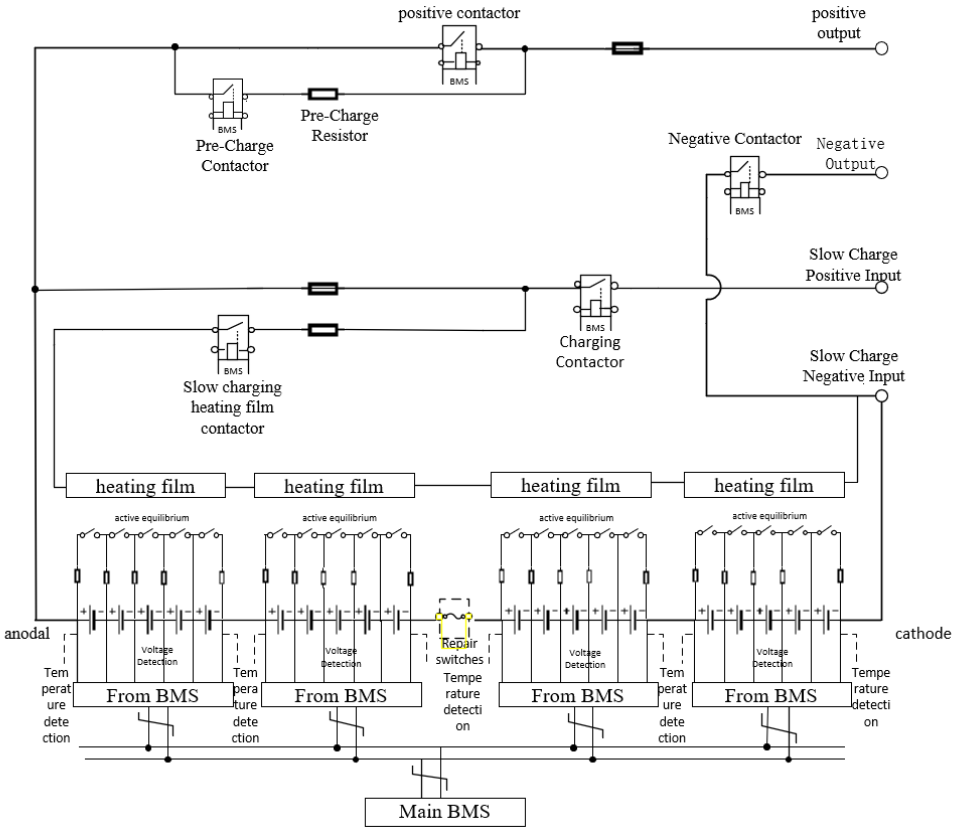


Figure 1: Schematic Diagram of Power Battery System

3. MAINTENANCE OF POWER BATTERY SYSTEMS

Similar to electromechanical products, power battery systems require regular maintenance, typically encompassing daily, first-level, and second-level maintenance.

3.1. Daily Maintenance

Daily maintenance involves the driver checking the vehicle's instruments before and after driving. If any instrument fault indicators related to the power battery appear, they should be addressed according to the recommended procedures. The instrument indicators related to the power battery are listed in Table 1.

Table 1: Instrument Indicators Related to Power Battery

Numble	Sign	Logo color	illustrate	Handling suggestions
1		green	Vehicle ready	—
2		red	Motor overheating fault	The whole vehicle is limited in power and needs to be repaired as soon as possible
3		yellow	High voltage system disconnection fault	High voltage system not powered on/failed to power on, check the high voltage system
4		red	Power battery malfunction	Immediate parking for maintenance
5		red	Power battery overheating	Immediate parking for maintenance
6		red	system failure	The vehicle has serious malfunctions and should be repaired immediately

3.2. First-Level Maintenance

First-level maintenance is conducted when the vehicle reaches a specified mileage or time limit as per the NEV manufacturer's requirements. It primarily involves checking the appearance, fixing points, and operating data of the power battery system. The items, contents, and technical requirements of the appearance inspection are detailed in Table 2.

Table 2: Items, Contents, and Technical Requirements of Appearance Inspection

operating item		Assignment Content	technical requirement
Power battery system	Tightening of bolts between the box and the frame	Inspection and fastening	Observe the anti loosening wire and recheck the bolt torque, ensuring that the torque meets the quality requirements.
	External wiring harness/connector inspection	Inspection and replacement	The appearance of the wiring harness is good, without wear and aging; There is no looseness or abnormal discoloration or blackening of the connector
	Outer cleaning	clean	The bottom PVC coating is intact, without deformation, corrosion, and dust is removed from the box to ensure good cleanliness, no scratches, and no damage
	Cooling system	Cooling fan working status	Working normally
		Ventilation cooling filter dust removal	The filter screen is not blocked, and there is no dust inside the box
		Tighten the connection end of the high-voltage wire harness	Secure and reliable connection
		Cooling water pump	Normal operation, no aging or leakage
		Cooling loop	No leakage in the loop

The operation data of the power battery system usually needs to be read from the current state data stream and historical fault data through a fault decoder. If there is a fault in the current state or a historical fault, fault repair is required. The operational data of the power battery system is not completely consistent among different vehicle manufacturers, mainly including voltage related physical quantities, temperature related physical quantities, current related physical quantities, cut-off circuit status, heating system, and other states of the power battery. Among them, voltage related physical quantities include each individual voltage, voltage difference, total battery voltage, charging voltage, individual voltage acquisition circuit status, total voltage acquisition circuit status, etc; Temperature related physical quantities include the temperature of each temperature sensor, temperature difference, temperature rise, temperature acquisition circuit status, charging station temperature, etc; Current related physical quantities include charging current, discharging current, balancing current, current sensor status, current acquisition circuit status, etc; The communication status includes internal communication status, external communication status, etc; The cut-off circuit status includes positive contactor status, negative contactor status, pre charging contactor status, fuse status, pre charging resistor status, charging contactor status, etc; The heating system includes the status of the heating element, the status of the heating contactor, etc; Other states of the power battery include SOC、SOH、 Insulation resistance, interlocking, etc., contact resistance.

3.3. Second-Level Maintenance

According to the requirements of new energy vehicle manufacturers, second level maintenance should be carried out when the driving mileage or time reaches the limit. Second level maintenance includes first level maintenance content, and also requires testing of capacity, insulation, and airtightness. The second level maintenance work items, work content, and technical requirements are shown in Table 3.

Table 3 Secondary Maintenance Tasks, Job Content, and Technical Requirements

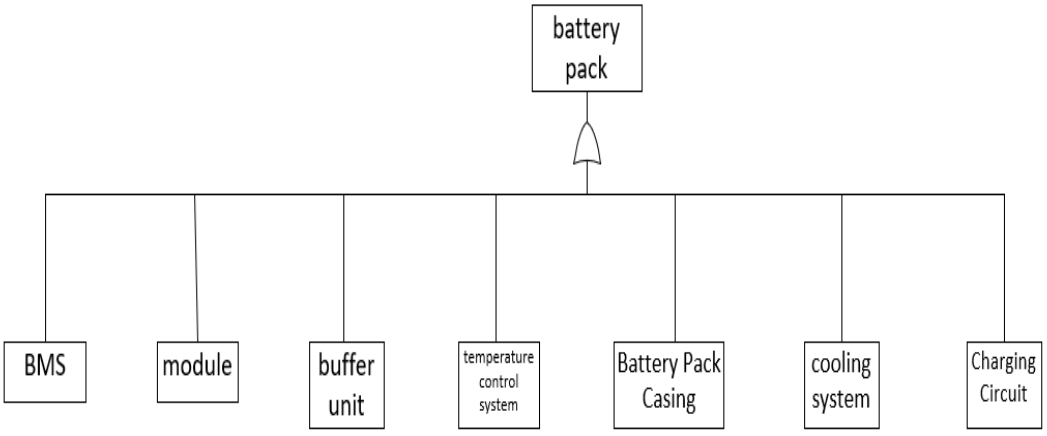
operating item		Assignment Content	technical requirement
Power battery system	Battery system	System Connection	Each part of the circuit is fixed reliably and neatly
		temperature	Temperature collection data is normal
		Individual voltage	The individual voltage set data is normal, and the voltage is within the specified range.
		Total voltage	The total voltage of the system is within the specified range.
	Capacity Test	Power battery system status	Use dedicated power battery maintenance equipment (or external charging) to maintain the consistency of individual batteries
		Power battery system SOC value calibration	Using specialized diagnostic equipment for power batteries (or external charging) to calibrate the system SOC value
	Insulation inspection	Positive (input, output) insulation resistance to the vehicle body	≥5MΩ
		Negative pole (input, output) insulation resistance to the vehicle body	≥5MΩ
	High voltage distribution box	Working status of high-voltage components	High voltage components are working properly
	Air tightness test	Check the airtightness of the box before opening it	The airtightness of the box meets the standard

The notice issued by the Ministry of Industry and Information Technology on the special investigation of safety hazards in new energy passenger vehicles and cargo vehicles should confirm the unpacking maintenance inspection in combination with the battery design scheme and past situation. The unpacking maintenance inspection work items, work content, and technical requirements are shown in Table 4.

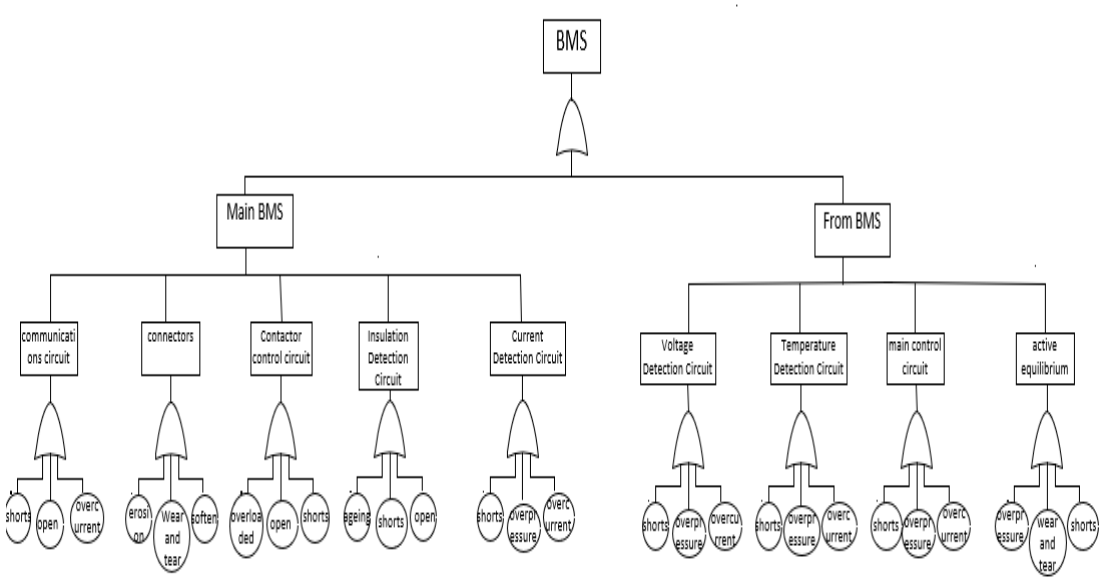
Table 4 Items, contents, and technical requirements for unboxing maintenance and inspection operations

	operating item	Assignment Content	technical requirement
Power battery system Unpacking inspection and replacement of parts	Replace the sealing ring	Component replacement	N/A
	Check if there is condensation on the inside of the upper cover	Visual inspection	The appearance of the inner side of the upper cover is good and there is no condensation water
	Check the appearance of the low-voltage wiring harness inside the box and the connection of the connectors	Visual inspection	The appearance of the wiring harness is good, without wear and aging, and the connectors are not loose
	Check the high-voltage wiring harness inside the box (including copper bars)	Visual inspection	There is no wear on the insulation skin of the wiring harness, and there is no abnormal discoloration or blackening of the copper bar
	High voltage copper bar bolt torque inspection	Tool detection	The bolt drawing line has no displacement; Detect residual torque of bolts and record it; Tighten the bolt torque to the factory quality requirement torque
	Check the appearance of the water-cooled plate	Visual inspection	1) The soft/hard connections of the water-cooled pipes are good; 2) The water-cooled plate has no deformation
	Check the cleanliness of the box	Visual inspection	Good internal cleanliness and no residual impurities

4. POWER BATTERY FAULT DIAGNOSIS



Power battery fault tree



BMS Fault Tree

5. CONCLUSION

The power battery system is the most core component of new energy vehicles and also one of the components with a high probability of failure. Adopting standard technical requirements for primary and secondary maintenance of the power battery system can effectively improve its service life. Selecting the method of obtaining power battery fault information based on actual working conditions, fault mode analysis is the practical basis for design verification and process verification.

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