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A monitoring and early warning platform for energy storage systems based on big data analysis

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Abstract. This article focuses on the safe operation of lithium battery energy storage power stations and develops a data monitoring and safety warning platform for energy storage systems. The background, architecture, implementation methods, and main functions of the platform development are introduced in sequence. This platform significantly improves the safety of energy storage stations by implementing active safety monitoring and early warning, which is of great significance for the large-scale application and promotion of lithium battery energy storage stations.

1.Introduction

Building a power system dominated by new energy is beneficial for reducing environmental pollution and achieving the "dual carbon" goal. Energy storage can regulate peak and valley electricity demand, alleviate fluctuations caused by integrating new energy generation forms into the power grid, and improve the safety and stability of the power grid [1]. Lithium ion battery energy storage technology benefits from its higher cycle life and lower cost, and occupies a dominant position in the application of new energy storage in power systems [2].

However, serious safety accidents such as combustion and explosion of lithium-ion batteries often occur, so solving the safety issues of lithium-ion batteries is the primary task for the construction and further development and application of lithium-ion battery energy storage stations [3]. The safety prevention and control of energy storage power stations run through multiple key links such as battery manufacturing, power station design and construction, power station operation and maintenance, and post-accident fire protection [4]. Currently, the safety prevention and control of energy storage power stations in China are mainly concentrated in the design and construction stage and the fire protection stage [5]. The battery will gradually age during operation, and the testing conducted during the design phase cannot guarantee the long-term safe operation of the power station [6]. However, the fire prevention and control measures during the fire protection phase are taken after accidents occur, which cannot fundamentally prevent safety accidents in energy storage power stations [7]. Therefore, it is necessary to conduct online status monitoring based on real-time operating data during the operation of energy storage power plants, to identify and warn of safety hazards and early failures of the energy storage system [8]. By implementing active safety warnings for energy storage stations, the safety of energy storage stations can be greatly improved, which is of great significance for the large-scale application and promotion of lithium battery energy storage stations [9].

This article researches the auxiliary decision-making system for the full life cycle safety analysis of energy storage power stations. A set of active safety warning and intelligent operation inspection systems and energy storage system monitoring and warning platform based on big data analysis is developed for newly built energy storage power stations. Real-time monitoring of the battery body and battery management system is carried out to understand the internal causes of accidents promptly after accidents occur, accurately and quickly achieve accident warning and diagnosis, and ensure the safe and stable operation of energy storage power stations.

2.Platform Architecture

2.1.Overall architecture

This article analyzes the massive operational data of energy storage power stations to evaluate the real-time health status of battery equipment. We have developed an active safety warning and intelligent operation and detection system suitable for new energy storage power plants, to achieve active warning of external hazards such as battery thermal runaway and early battery failure.

The intelligent operation and maintenance system of energy storage power stations is implemented in an overall architecture of the platform layer and advanced application layer. In principle, the intelligent operation and inspection system in energy storage power stations should not add new sensing points, and utilize existing data and information channels in the partition layer,

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without affecting the computer monitoring function of the energy storage power station. The system structure is shown in Fig. 1.

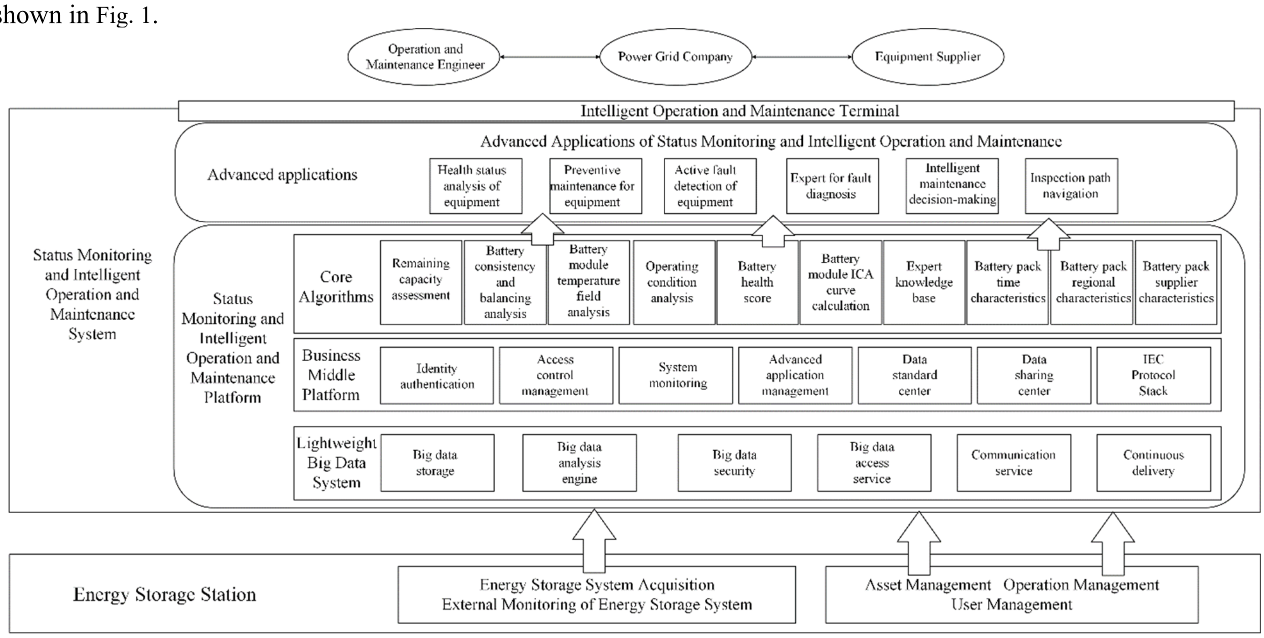

Fig. 1. Structure diagram of intelligent operation and inspection system

Following the principle of moderate isolation between the main control system and auxiliary systems in energy storage power stations, the intelligent operation and inspection system requires the addition of equipment data and application servers, as well as intelligent operation and inspection terminals, based on utilizing existing monitoring system equipment.

2.2.Implementation of early warning platform

The intelligent operation and inspection system for energy storage power stations can process massive operational and status data of energy storage inverters and batteries in the power station, providing an in-depth analysis of the critical operating status of equipment. At the same time, by combining the equipment fault map library and expert transportation diagnosis, provide equipment warning message analysis, improve the efficiency and accuracy of fault diagnosis, and achieve maintenance assistance decision-making. The key function jump relationship of the intelligent operation and inspection system is shown in Fig. 2.

After the intelligent operation and inspection system generates multi-level messages based on the multi-dimensional device health status assessment algorithm, click on the warning message in the wiring diagram of the device status monitoring page to enter the preventive maintenance or active fault warning page. Select the message in the message bar on the page and display the analysis of the operating status and fault status of the corresponding device. Click "Start Diagnosis" in the operation suggestion to enter the fault expert diagnosis page. Based on the expert diagnosis module and remote expert support, confirm the cause of the fault. After obtaining the cause of the fault, click on the 'Issue Work Order' button on the fault expert diagnosis page to enter the intelligent maintenance assistance page.

2.3.Implementation of data processing

In terms of data processing, the system adopts the Internet data processing architecture, which is mainly divided into pre-data collection, core algorithm processing, and advanced application display according to the process.

2.3.1.Data acquisition

The system data is mainly collected by BMS and PCS and can receive second-level data. After pre-collection and processing, it is resampled according to algorithm requirements. The resampling period includes 10 seconds, 1 minute, and 5 minutes. After resampling, it is stored in the collection database, and all collected data is saved for 1 year.

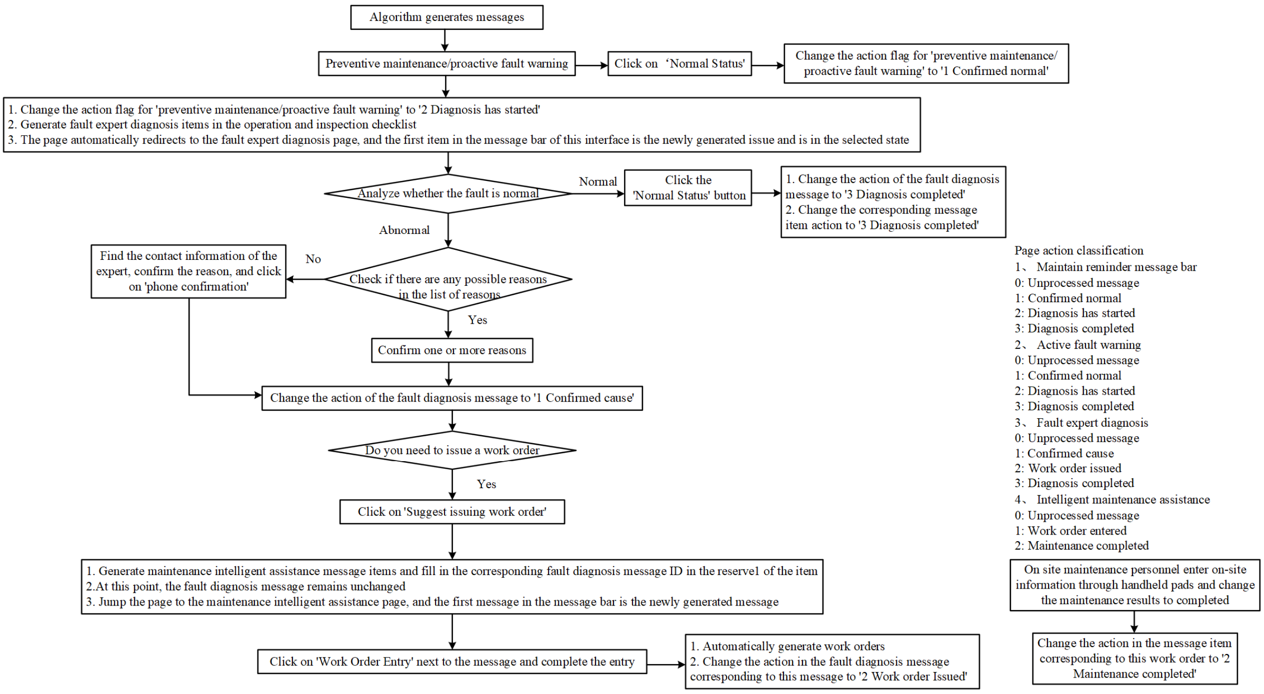

Fig. 2. Key functional jump relationships of intelligent operation and inspection system

2.3.2.Core algorithm

The core of the system includes equipment health evaluation, battery abnormal failure analysis, battery remaining life analysis, voltage inconsistency analysis, temperature inconsistency analysis, module capacity variance analysis, etc. The core algorithm is based on data collection, analyzing fixed periods of data, and outputting analysis results. The algorithm data is stored for 3 years.

(a) 60-minute data analysis: Equipment health evaluation, battery abnormal depletion analysis, and battery remaining life analysis algorithms need to obtain data within 60 minutes, perform continuous calculations, and store the analysis results in the algorithm library;

(b) 30-minute data analysis: Voltage inconsistency analysis, temperature inconsistency analysis, and module capacity variance analysis algorithms need to obtain data within 30 minutes, perform continuous calculations, and store the analysis results in the algorithm library.

2.3.3.Advanced application display

Store algorithm output results and call them, configure a graphical display interface, and output key analysis results such as dynamic state evolution and state distribution.

3.Platform functions

3.1.Identification of battery safety risk sources

By real-time analysis of the operating data of the energy storage power station system, potential risk sources that may cause safety accidents can be identified and appropriate measures can be taken in advance to eliminate the risk sources.

3.2.Status monitoring and intelligent operation inspection

The intelligent operation and maintenance system in energy storage power stations mainly serves grid operation and maintenance personnel. Its functions include equipment health status analysis, equipment preventive maintenance, proactive fault warning, fault expert diagnosis, intelligent maintenance decision-making, daily equipment inspection, and inspection path navigation.

3.2.1.Overall monitoring of transportation and inspection status

The system homepage contains basic information, operating status, health status, system wiring diagram, rolling information, statistical data, fault and maintenance data of energy storage stations/devices.

3.2.2.Analysis of Equipment Health Status

The intelligent operation and inspection system of the energy storage power station has established a database of equipment health status, which can analyze the health status of devices such as batteries and battery management systems in real-time. This module displays the health status of energy storage plants or equipment. Display the health score of energy storage power plants or equipment in the form of a curve graph, which includes marked information such as preventive maintenance reminders, fault warnings, fault alarms, and maintenance operations for energy storage power plants or equipment.

3.2.3.Analysis of abnormal battery failure

This project conducts research on the internal mechanisms of abnormal failure of lithium iron phosphate batteries under different aging paths, establishes a diagnostic mechanism of "external features internal mechanisms", and achieves early feature extraction and diagnosis of battery abnormal failure faults.

3.2.4.Equipment proactive warning

The intelligent operation and inspection system can use data mining technology to detect abnormal states of devices such as batteries and battery management systems in advance, effectively compensating for the shortcomings of energy storage power station monitoring systems. It can perform SOC calibration and preventive maintenance, active warning analysis based on voltage, temperature, and module capacity consistency, and active warning analysis based on IC analysis for abnormal attenuation.

3.2.5.Fault expert diagnosis

The intelligent operation and inspection system has the function of fault expert diagnosis, which is used for identifying the nature of faults, analyzing the root cause of faults, locating faulty components in energy storage power stations, and transmitting the diagnosis results to the intelligent operation and inspection terminal for reference by operation and inspection personnel. For components with excessive state variables or deteriorating health status, the intelligent operation and inspection system first preliminarily determines the approximate type of fault based on collected information such as temperature, current, and voltage, and then analyzes it using a diagnostic expert knowledge base to determine the fault situation and state trend, and finally achieves fault localization and analysis.

3.2.6.Intelligent maintenance decision-making

The intelligent operation and inspection system analyzes real-time data such as temperature, current, and voltage of energy storage battery pack equipment and massive historical data to comprehensively evaluate the health status of the equipment. Based on this, it comprehensively considers the diagnosis results of fault experts and generates the optimal equipment maintenance plan (including fault description, maintenance tasks, maintenance operation methods, diagnostic testing operations, maintenance precautions, safety protection measures, etc.).

4.Conclusion

With the large-scale application of lithium-ion battery energy storage power stations, ensuring the safe and reliable operation of energy storage power stations is particularly important for their development. This article introduces the data monitoring and warning platform for energy storage systems developed based on active safety warning technology and comprehensive performance evaluation methods for energy storage power stations. The intelligent operation and maintenance system of the energy storage power station achieves pre-data collection through an intelligent operation and maintenance platform and evaluates the results through core algorithms such as equipment health evaluation, battery abnormal failure analysis, battery remaining life analysis, voltage inconsistency analysis, temperature inconsistency analysis, module capacity variance analysis, etc. It outputs key analysis results such as dynamic state evolution and state distribution in advanced application displays. The intelligent operation and inspection system can identify three types of battery safety risk sources and eliminate hidden dangers. Through this energy system data monitoring and warning platform, the safety warning capability of energy storage power stations can be effectively improved.

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