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Research on Monitoring Information of Substation Equipment Based on Big Data Technology and Power Server

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Abstract:

Aiming at the low precision and recall rate of the substation equipment intelligent inspection system of and the long delay of the system alarm, the substation equipment intelligent inspection system on the basis of the big data architecture is put forward and designed. The system is mainly composed of station-side monitoring system and substation equipment data integration and analysis system. In the system hardware part, the design is analyzed mainly by inspection task management unit, image monitoring unit and big data platform. The system mainly includes two aspects: intelligent inspection and signal intelligent monitoring. The system can not only help the supervisor to comprehend the meaning of the alarm signal adequately, but also make up for the hidden dangers caused by the uneven technical service level of the substation operator. It can also decrease the workload of the substation watchman and improve the precision and speed of the accident exception handling safe operation of the grid.

Keywords: *Big data technology, Power server, Substation equipment monitoring, Data integration.*

I. INTRODUCTION

Under the background of the State Grid Corporation's 'three episodes and five majors', substations of 500 kV and below voltage grades in various regions have gradually achieved unattended operation, and are turned into the monitoring and control teams at all levels for centralized monitoring. Substation is an important power system hub in various regions. Once a fault occurs, it will affect large-area power supply [1]. As the power grid develops and expands, the number of substations is increasing day by day, and the amount of information is increasing. The remote monitoring system and the alarm system are continuously upgraded and optimized, but the substation inspection still needs to be carried out manually, and the alarm signal processing depends on the monitor status greatly. As a result, it is necessary to incorporate more

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automation technologies based on the current monitoring system to assist the monitors in conducting business [2]. There are features of substation monitoring information as below: (1) large data size and high requirements on the time to process; (2) many types of data that consists of semi-structured and unstructured data, traditional processing techniques are difficult to meet; (3) source data to be processed. The big data research method can realize processing substation monitoring information data, which can help realize the intelligent monitoring of substation [3].

This paper first analyzes the current situation and existing problems of centralized monitoring of substations, and proposes improvement requirements based on this. Then, with the theory and method of big data, the substation intelligent monitoring scheme is proposed. The scheme cannot only implement the automatic inspection and result display of the remote control and remote measurement of the controlled station, but also provide various aspects of data and information, help the monitor comprehend the meaning of the alarm signal completely, and lay the basis for the correct disposal of the alarm information, which can make up Hidden dangers caused by uneven technical service levels of substation operators. This set of program research is significant to alleviate the workload of the substation watchman, improve the precision and speed of the accident handling, and guarantee that the power grid's operation is safe.

II. BASED ON BIG DATA AND POWER SERVER MONITORING SYSTEM DESIGN

2.1 Overall Structural Design

Carrying out intelligent grid monitoring and running the analysis of big data needs to dig deeper into the data value from the whole process and all-round perspective, and the relationships among data need to be found [4]. Relying on the existing cloud platform and varied business systems, the technology of big data is applied by the system to realize the overall architecture from data access to business application from the bottom up, as shown in Figure 1.

As can be seen from Figure 1, the overall structure of big data includes web services, non-renewable energy meters, renewable energy meters, and equipment control source changes. Through the change of equipment control source, renewable and non-renewable energy are respectively delivered to users, thus forming smart grid monitoring. Smart grid monitoring mainly includes data access layer, data storage layer, public service layer, business model layer and business application layer.

(1) Data access layer: The system integrates data sources including energy management system (EMS), production management system (PMS), dispatch management system (OMS), meteorological system, power distribution system and cloud platform. Types have structural, semi-structured and unstructured heterogeneous features. The system combines conventional JDBC, FTP, MQ, Web service and other data access methods with big data Sqoop, Kafka, Flume, etc. [5]. The number is combined with the verification rule engine and the data extraction conversion loading (ETL) tool to realize the cleaning and standardization of the

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extracted data. This kind of data access mode ensures the comprehensiveness, integration and high quality of the control related data, and is the upper layer data. The foundation of storage is laid.

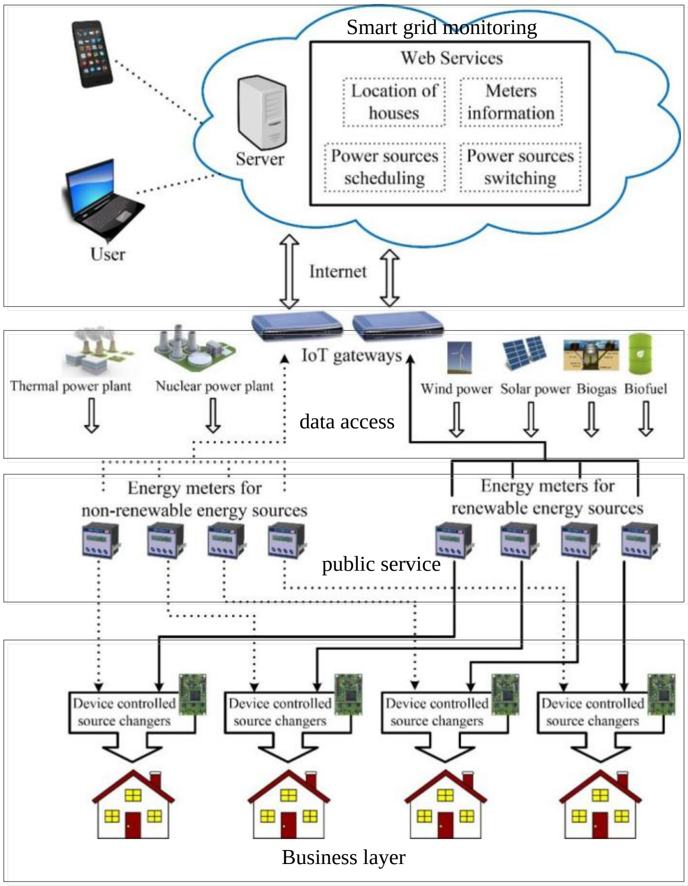

Fig 1: System overall structure

(2) Data storage layer: The system combines the traditional relational database with the memory database, uses the HSAP and the distributed file system HDFS in the big data Hadoop ecosystem, effectively stores the unstructured data of the standard service, and improves the scheduling efficiency of the monitoring information.

(3) Public service layer: The system is on the basis of the big data parallel computing framework. It integrates the public service components that the system business layer depends on through security, analysis, calculation, management and display. It provides user rights, transmission encryption and data backup. Security services; expert analysis, algorithm library and other analysis services; structured query language (SQL) computing, offline computing, batch processing, streaming computing services; meta data, operational monitoring, resources, configuration management services; search, Geographic information, interactive analysis, data instrument display services. The system introduces the big data parallel computing framework MR and Spark, and the corresponding streaming computing framework, which greatly improves the business computing performance, makes the correlation analysis and data mining between

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the business more effective, and greatly enriches the display and interaction of the business. The use of the system is more user-friendly [6].

(4) Business model layer: On the basis of the monitoring of actual business needs, the system integrates plenty of data mining algorithms such as preprocessing, classification, regression, clustering, and association rules, and performs multiservice modeling based on analysis and calculation units in the common service layer [7]. The 51 application models that form the five major businesses include the operational risk trend warning model, the monitoring equipment anomaly detection model, and the grid accident co-processing model [8]. Compared with the case where the business model other than EMS is relatively rigid, the system provides a maintenance entry for the model layer, and the model can be changed according to the business scenario change.

(5) Business application layer: Based on the analysis model, the system forms four major centers of big data according to different functional types, including data comparison statistical analysis center, equipment trend failure warning center, operation retrieval center, and visual display center.

2.2 Functional Analysis

(1) Statistical Analysis Center: With the standardization of data model and the integration of data collection, storage and governance, through the establishment of correlation statistics and analysis models, statistical analysis and mining of data related to multi-source heterogeneous structured power monitoring services, the existing system expands and enhances the dimension and quality of statistical data sources, and improves traditional data analysis from ‘single data point’ to ‘multi-point comparative correlation analysis’; with the combination of correlation analysis and causal analysis, realizing the inference of the normalized monitoring business and the cause of abnormal events, and the multi-dimensional comparative relevance comprehensive evaluation, compared with the traditional system mathematical statistics means, the detection method based on causality is introduced [9].

(2) Trend Warning Center: By applying big data analysis technology based on data mining, time series prediction, machine learning and deep learning, an application model for trend analysis of grid situation and equipment status is constructed. Compared with the detection methods of the passive problems of the existing systems, the equipment’s operational fault abnormality warning capability is transformed into the capability of active discovery, and the change of the grid security defense line from ‘post-mortem analysis’ to ‘pre-control’ is realized [10].

(3) Intelligent Search Center: Provide flexible and comprehensive information acquisition means, increase the intelligent push ability of important events and user reservation information relative to existing systems; introduce semantic analysis and reasoning technology, use big data deep learning algorithm, correlation analysis Method and discrete event analysis method, analyze and mine user behavior, obtain user preference model, greatly improve the humanization and practicability of the system in search, and realize the change of information search from ‘object retrieval’ to ‘behavior retrieval’.

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(4) Visualization Exhibition Center: The display results of the statistical analysis center, the trend warning center and the intelligent search center are visualized by using two-dimensional plane panorama, three-dimensional real-view virtual and video data virtual reality synthesis technology, and constructed on the time scale. Real-time and non real-time integrated application in the measurement of multiple signals. Compared with the traditional system, in the display factor, through the mining of related business and professional habits, the multimodule, cross-business, multi-database joint full-factor perspective display method is realized, thereby improving the control of grid statistics, system operation and equipment status. Level, the realization of data display changes from ‘single mode weak expression’ to ‘multi-mode strong expression’.

III. HARDWARE AND SOFTWARE FACILITIES

3.1 Inspection Task Management Unit

The inspection task management unit in the intelligent inspection system of the substation equipment includes functions such as new task creation and saving and deletion, and functions such as manual release command and timing operation. The unit can create and delete inspection tasks in the human-computer interaction interface, and the operator can independently adjust the system running time [11,12]. For the development of the inspection task, the main nature of the inspection work is mainly the guidance center. After obtaining the corresponding feedback, the base station starts the corresponding work task.

3.2 Image Monitoring Unit

The image monitoring unit of the substation equipment intelligent inspection system belongs to the function class, and its main function diagram is shown in Figure 2.

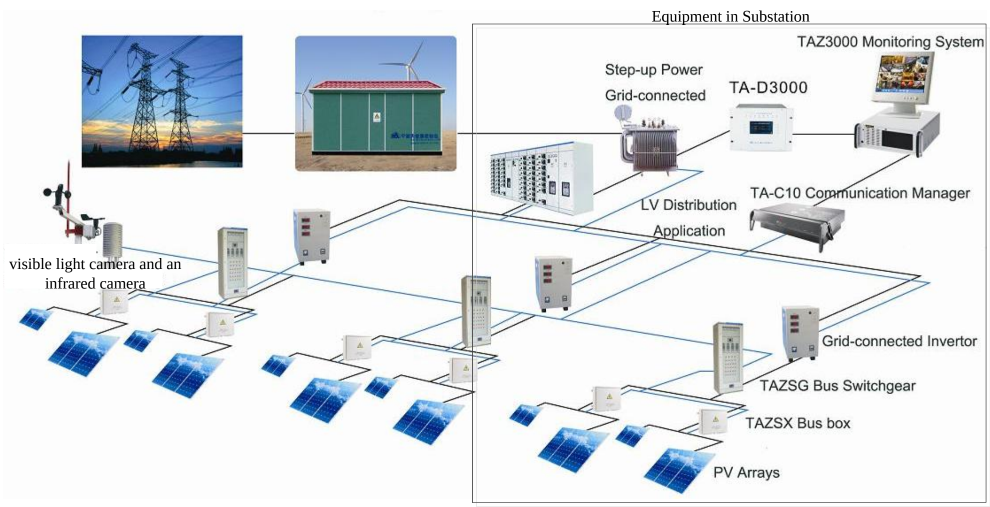

Fig 2: Schematic diagram of the image monitoring unit

In Figure 2, the module consisting of a visible light camera and an infrared camera is an image monitoring unit in the substation equipment intelligent inspection system [13]. The visible light camera can encapsulate the video service device in essence, and the analog video

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output by the system can pass. The device is implemented. The infrared camera is used for non-destructive collection of various information of each equipment in the substation. The combination of the two can monitor the operation of the substation equipment timely to improve the recall and precision of the intelligent inspection of the substation equipment.

3.3 Big Data Platform

The big data platform is the pivotal part in the design of the intelligent inspection system for substation equipment [14]. It combines the non-electrical quantity data information of time, weather and geology with the status of the substation equipment and the station end detection data such as relay maintenance to quickly and accurately detect substation equipment failures and issue safety warnings to maintain the safe operation of substation equipment as much as possible. The data source in the substation equipment intelligent inspection system with big data architecture is the measured data and the time and weather information data, and the data integrated data flow in the substation equipment inspection system can be divided into several categories.

IV. INTELLIGENT PATROL DATA PROCESSING OF SUBSTATION EQUIPMENT

4.1 Switch Current Data Processing

Calculate the current three-phase deviation. On the basis of the data collected currently, calculate the maximum deviation ratio as the formula (1), and the concrete data of the switch with the deviation ratios larger than 50% is saved.

$$\sigma_{\max} = \frac{I_{\varphi\max} - I_{\varphi\min}}{I_{av}} \times 100\% \tag{1}$$

Where: $\sigma_{\max}$ is the maximum deviation ratio; $I_{\varphi\max}$ is the maximum phase current; $I_{\varphi\min}$ is the minimum phase current, and I_{av} is the three-phase average current.

4.2 Bus Voltage Automatic Patrol

The bus voltage source data is compared with the top and bottom limits of the bus voltage running curve, and the formula for calculating the specific information of the over-limit device is stored as shown in Equation (2).

$$\alpha\% = \frac{U_0 - U_{\lim it}}{U_{\lim it}} \times 100\% \tag{2}$$

Where: $\alpha\%$ is the bus voltage crossover ratio; U_0 is the operating voltage; $U_{\lim it}$ is the bus voltage limit.

4.3 Line Load Automatic Inspection

Calculate the power device load rate and store device data with a load rate larger than 90%. The line and main transformer load rate are calculated with the formula as shown in equations (3) and (4), respectively.

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$$\eta_{l\text{int}} = \frac{I_0}{I_n} \times 100\% \tag{3}$$

Where: $\eta_{l\text{int}}$ refers to line load rate; I_0 refers to the line actual current; I_n refers to the line rated current.

$$\eta_t = \frac{P_0}{P_n} \times 100\% \tag{4}$$

Where: η_t is the main variable load rate; P_0 is the main variable actual load; P_n is the main variable rated power.

Based on the three parameter information of switching current, bus voltage and line load, check whether the geographical location is good [15]. After the line is loaded, take bus voltage as the reference, measure the current amplitude of each phase and the angle between each phase current and the reference voltage, and judge the correctness of current polarity by comparing the current of each phase.

V. ANALYSIS OF EXPERIMENTAL RESULTS

A correlation experiment was conducted for the purpose of verifying the performance of the substation equipment intelligent inspection system based on big data architecture. The experimental reference object is a large substation in a province. The experimental indicators are: (1) full inspection rate; (2) inspection accuracy; (3) real-time inspection alarm. Verify the real-time performance of different systems with the length of the alarm delay. In TABLE I, A represents the equipment fault point number. B represents the power patrol system alarm delay based on 3D end path self-learning navigation. Relative to the three-dimensional vector of the location and direction of the patrol object, the center point of the motion track is depicted. The map is separated into n * m grids, each grid has k directions, and the search space of the path is set to cover the patrol location area. According to the location of patrol equipment and the topological relationship between patrol personnel, the network data set is established and the path is planned. C represents the alarm delay of the substation equipment intelligent inspection system based on the big data architecture. TABLE I shows that the power patrol system based on the 3D end path self-learning navigation has an average alarm delay of 1.6 μs and the substation equipment intelligent patrol system on the basis of the big data architecture has an alarm delay of 0.18 μs on average. It can be seen from the results that the proposed system is time-sensitive and feasible. The reason why the proposed system and the current system have a large gap in alarm delay is that the proposed system adopts MapReduce distributed computing form and real-time stream computing mode in the data processing process, which effectively improves the real-time performance of the system. The api voice play function in the bottom layer of Windows is used to implement the alarm function, which further ensures the real-time performance of the system.

TABLE I. Comparison of different system alarm delays

A	B	C
1	1.5	0.1
2	1.6	0.2
3	1.5	0.1
4	1.4	0.2
5	2	0.3

VI. CONCLUSION

In conclusion, the big data analysis and intelligent decision-making system of equipment monitoring signal is used to correlate the accident signal and record the data of telemetry, remote signaling, remote control, network trend and other aspects related to the current accident signal. Before the accident, the grid operation record is convenient for the confirmation and early prediction of the current accident alarm. For example, if the accident trips, there will be a total signal of the switch interval accident, the current is instantaneously 0, the opening state, etc., and the big data platform will analyze and judge the current accident event. And the accident handling is to push the expert disposal suggestions in real time and confirm the startup equipment monitoring defect disposal process.

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