Research on Multi-node Frame Early Warning System of Power Grid Based on Abnormal Data Extraction

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Abstract: Nowadays, the collection of electrical energy measurement data is mainly completed by smart meters, electrical energy data monitoring equipment and electrical energy data management equipment. Due to system defects, equipment failures and human factors, it is prone to abnormal data collection. The design concept of online early warning system for extracting abnormal features of electrical energy data based on multi-node real-time computing framework is proposed in the paper to analyze the hardware and software of the online early warning system for extracting abnormal features of electrical energy data.

1. Introduction
The electric energy collection and billing system is a subsystem supported by smart grid operation, which is the basis for economic operation, scientific dispatching, assessment and settlement of the grid. What is more, the traditional solution to the abnormal alarm of electrical energy data is to store the received whole-day electricity data in the database at 24:00 on the day, and then the relevant formula data and balance data are calculated by querying the original electricity data in the database. From these calculation results, it is analyzed whether there are abnormal power consumption data. However, throughout the process, the obtained formula data results are lagging. Meanwhile, for a large amount of real-time power data, the traditional architectural approach is not applicable. Therefore, how to realize the online early warning of abnormal electrical energy data and timely solve the hidden dangers that affect the safety of electrical energy data will be an urgent problem to be solved in the design and development of the power grid[1-3].

2. Early Warning System Software Design
Based on multi-node big data framework, early warning system software is developed with the help of Java language programming. Moreover, the whole can be divided into three layers, and each layer is further divided into multiple modules and multiple sub-processes in detail. What is more, each module contacts and interacts with each other to form an online analysis system based on the network topology, that is, the software running network. The software design of early warning system is shown in Figure 1[4].
As can be seen in Figure 1, the early warning system software is mainly divided into data acquisition layer, data transmission layer, and data analysis layer the three levels. What is more, the data collection layer compresses the data that will be written to the multi-node message bus including data producers and data consumers through regularly reading the offline data of the database, analyzing and processing the interactive file data with CIM/E format in real time, as well as handling the collected communication message data timely. Moreover, data collection layer is the data producer of the message bus, and data analysis layer monitors and consumes the data, which pushes the consumption data into the Storm multi-node computing framework to perform online calculation based on the established abnormal data recognition model topology. Additionally, multi-node cache for static data throughput is designed to speed up the calculation speed, where is no need to save the data in the entire analysis process, and the analysis result is stored in the database as the end node of the calculation[5-6].

Whether the electrical energy is abnormal is judged by the bus power report, and the abnormal electrical energy needs to be judged at different voltage levels. For example, the standard given for the power unbalance rate is as in the line environment of 220kV and 110kV, and the normal unbalance rate is ±2%. The method for calculating the standard unbalance rate is shown below.

$$\lambda = \frac{C_i - R_i}{R_i}$$  (1)

In formula (1), $\lambda$ represents the standard unbalance rate, $C$ refers to the total output power, and $R$ is the total input power. Additionally, $i$ indicates the variable at a specific voltage level.

Both the total input power $R$ and the total output power $C$ represent the total power input and output generated in the bus at the same voltage level $i$. In other words, the total output power is the total output energy of each outlet at a specific time point on the basic bus of the set voltage level, and the total input power refers to the total electrical energy input by each incoming line at a specific voltage level and time point[7].

The standard electrical energy value, which is known, is compared with the collected data, and when the result is greater than the normal value, the platform will edit the warning information and release the warning information through 3 information release methods.

3. Abnormal Characteristics Database of Electric Energy Data
The data mining library for abnormal characteristics of electric energy data performs large data mining and cluster analysis on the abnormal characteristics of electric power in various aspects such as grid models, measurement data, electric energy data, and balance data through extracting and dispatching EMS system data, TMR system data, power consumption information data, and subdividing models of various data indicators. Meanwhile, according to the contribution of various measurement checkpoint
assessment indicators, the trend of power change, and the degree of abnormal deviation, the abnormalities are divided into model, data, balance, and maintenance four categories, as shown in Table 1. In addition, for different dimensions, the characteristics of its abnormal data is analyzed to provide differentiated and personalized services[8-10].

| Category 1          | Category 2                     | Model class                        | Relationship problem                                                                 |
|---------------------|--------------------------------|------------------------------------|--------------------------------------------------------------------------------------|
| Consistency problem | Model conflict                 | Consistency problem                | No corresponding voltage registration found                                         |
|                     | Naming convention              | The key value is empty             | The first and last stations on the line are the same                                 |
|                     | The key value is empty         | Factory station can't find area    | The definition of the first end of the line does not exist                           |
|                     | Model conflict                 | Relationship problem               | The meter cannot find the corresponding device                                        |
|                     | Naming convention              | Model matching problem             | The main transformer is not matched when matching the winding                        |
|                     | The key value is empty         | Name matching failed               | Name matching failed                                                                 |
|                     | Factory station can't find area| Auto association failed            | Auto association failed                                                               |
|                     | Relationship problem           | Model matching problem             | Meter wiring error                                                                   |
|                     | Model conflict                 | Abnormal collected data            | Zero base code is empty                                                              |
|                     | Consistency problem            | Name matching failed               | Suspected table change                                                               |
|                     | Consistency problem            | Auto association failed            | Incorrect acquisition parameters                                                     |
|                     | Consistency problem            | Model matching problem             | Calculation battery error                                                            |
|                     | Consistency problem            | Data class                         | Incorrect mother level configuration                                                 |
|                     | Model conflict                 | Abnormal collected data            | Incorrect mother level configuration                                                 |
|                     | Consistency problem            | Data class                         | Start and stop service                                                               |
|                     | Consistency problem            | Abnormal collected data            | Location                                                                             |
|                     | Consistency problem            | Abnormal collected data            | Maintenance class                                                                    |

The abnormal types in Table 1 are associated with the repair function software functional modules of system design, where Model class abnormality corresponds to the edit module of model management and parameter maintenance.

Data abnormality correspond to functional modules such as data reprocessing, data recall, data editing, meter rotation, magnification change, and parameter editing.

Balanced abnormality corresponds to functional modules such as calculation configuration, model maintenance, and recalculation; Maintenance class abnormality corresponds to the operation and
maintenance interface of the underlying platform, which includes functions such as starting and stopping services and log positioning.

Through the closed-loop governance process from finding abnormal tags to putting them into the corresponding data, a set of plug-in data governance system is established, which continuously and iteratively optimizes the abnormality identification and processing capabilities to provide reliable data quality guarantee for business systems.

4. Online Analysis and Detection Process of Abnormal Electricity Driven by Real-time Data
The online early warning system based on multi-node real-time computing framework for electrical energy data anomaly feature extraction has realized the real-time drive of collecting electricity data with the help of TMR, EMS-CIME file based on EMS system and event message based on marketing system. Besides, the system calculates the relevant electricity formula data and balance data online. In addition, by verifying the rationality of the data and analyzing the balance results, the data on abnormal electrical energy is judged and pushed to the warning server in real time.

![Figure 2 Multi-node real-time computing framework online warning real-time processing flow](image)

Figure 2 is the online warning real-time processing flow based on TMR’s daily freezing of collected power data under the framework of multi-node real-time computing.

5. Conclusion
Based on the design of the collected data index characteristics during extracting abnormal data, a multi-node framework early warning system for the power grid is established in the paper to avoid the occurrence of electric power safety accidents, so that the online early warning function for extracting abnormal features of electric energy data can be realized. Moreover, data flow test proves that the system proposed in the paper has practical effect, which provides reference and improvement suggestions for the early warning system currently being applied.
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