Application and Research of Machine Learning Simulation Technology in Equipment Fault Monitoring under Smart Grid

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Abstract. Smart grid is increasingly becoming the development trend of grid technology. Smart grid is an important part of smart grid. Power equipment is the core part of smart grid, and the normal or not of power equipment directly affects the safety and stability of the entire power system. Smart grid usually has relatively complete fault diagnosis and self-healing functions to improve the stability and reliability of the grid. The application and development of a practical fault monitoring and early warning system for power equipment is to carry out predictive maintenance of power equipment so that the equipment can operate more safely and reliably. Due to the time-varying nonlinearity, stochastic uncertainty and local observability of smart grid, it is difficult for traditional power system modeling and analysis methods to fully reflect the steady-state and transient characteristics of power system in the new form. In this paper, based on machine learning simulation technology, through the research of power equipment fault monitoring system in smart grid, provide early warning information and solutions for equipment management personnel maintenance.

1. Introduction
In the urban power supply system, there are more and more power cables and the transmission distance of distribution lines is far. With the development of smart grid and ultra-high voltage technology, the normal operation of power equipment is particularly important to the reliability and stability of power system power generation and supply process [1]. Smart grid is a complex power network, which is usually composed of a series of facilities such as overhead lines, transmission cables, transformers and sectional switches connected to each other [2]. Smart grid plays a very important role in the power grid system and plays a very important role in the distribution of electric energy. Different from the original accident overhaul and regular overhaul, condition overhaul must be based on advanced online monitoring. Due to the high complexity of smart grid, faults will have a great impact, and fault location diagnosis and recovery are more difficult [3]. On-line monitoring, fault diagnosis and maintenance constitute the connotation of on-line condition maintenance of electrical equipment, and the construction of smart grid provides new development opportunities for on-line monitoring and fault diagnosis of electrical equipment [4]. The installation and usage of power equipment are increasing continuously, while the number of operation and maintenance personnel is limited. No matter what kind of power equipment fails, it will cause different degrees of economic losses and serious consequences [5]. The
power equipment fault monitoring and early warning system can feedback various status information of the power equipment in real time, so that the system user can grasp the parameter information of the power equipment and the running status of the equipment in the network client [6].

The significance of research and development of power equipment fault monitoring and early warning systems is to break the limitations of preventive maintenance. Users of the monitoring system can always see the monitoring parameter information of the equipment and the fault results and warning reports obtained by parameter processing analysis [7]. The power distribution system has a very close relationship with the transmission system, and it is different from the transmission system. In order to ensure the stability of the power supply system, the smart grid system is usually designed in a closed loop design in the design process [8]. State Grid Corporation firmly grasps the rapid development of the new generation of information and communication technology as an opportunity for the transformation of smart grid production methods and management models, actively promotes the construction of smart grids, closely tracks the development trend of new technologies, and carries out key technical research [9]. The time-varying nonlinearity, stochastic uncertainty and local observability of the smart grid make it difficult for the traditional power system modeling and analysis method to fully reflect the steady-state and transient characteristics of the power system under the new form [10]. This will make it difficult to plan, design, operate, maintain and protect the power grid. The intelligent terminal monitoring equipment monitors and collects line fault information and operating parameters in real time, and can be sent to the remote master station system for data interaction through GPRS and other communication methods [11]. Based on machine learning simulation technology, this paper finds the applicable algorithms for monitoring and fault diagnosis of different power equipments through the research of power equipment fault monitoring system under smart grid, and provides early warning information and solutions for equipment management personnel maintenance.

2. Characteristics of Equipment Fault Monitoring in Smart Grid

Smart grid refers to the intelligence of power grid, which is based on an integrated and high-speed two-way communication network. Smart grid achieves the goals of reliable, safe, economic, efficient, environment-friendly and safe use of power grid through the application of advanced sensing and measurement technology, advanced equipment technology, advanced control methods and advanced decision support system technology. Fault monitoring is the application of advanced sensor technology to obtain various parameters of power equipment, and then further analyze and process the data according to the regulation calibration and different diagnostic algorithms of power equipment to obtain diagnostic results, providing reasonable basis for condition-based maintenance. In normal operation, it is usually in a closed state, and the contact switch is usually used to connect nodes with other feeders. In the event of a fault in the smart grid, auxiliary power supply can be provided to the lost nodes by closing the contact switch [12]. The key problem of power equipment fault monitoring and early warning system is to find fault diagnosis algorithm suitable for equipment. According to the characteristics of equipment fault symptom parameters, the processing efficiency of existing artificial intelligence algorithm for equipment parameters is analyzed and compared. The introduction of artificial intelligence technologies such as deep learning into smart grid can alleviate the problems of mining high-dimensional complex data and feature extraction in smart grid on the one hand, and make up for the problems of insufficient training data and poor generalization ability of traditional machine learning methods in practical application on the other hand.

As far as China’s power system is concerned, the level of distribution network is far behind that of transmission network, both in terms of automation degree, intelligence degree and network self-healing and optimization ability. The dynamic part of the unified information model mainly stores a message format template of real-time collected data by sensor nodes, and analyzes and updates the real-time collected data according to the template to form data consistent with the storage format of the data service system. The test preparation data for the delivery accuracy of screened power dispatching data,
the delivery speed of power dispatching data, and the safety level detection of power dispatching data are shown in Table 1.

Table 1. System sampling analysis map information

| Project                                      | First time | Second time | Third time |
|----------------------------------------------|------------|-------------|------------|
| Power dispatch data security level detection | 35%        | 36%         | 39%        |
| Delivery accuracy of power dispatch data     | 65%        | 60%         | 73%        |
| Power dispatch data delivery time            | 7          | 8           | 6          |

As the wires of smart grid are usually very long, the resistance and reactance values of the wires themselves are very large, and the power loss caused by the heating of the wires in the transmission process is also relatively large. In the process of generator fault diagnosis, the corresponding relationship between fault feature quantity and fault information is complicated, which is difficult to be accurately expressed by mathematical expressions. Therefore, a fault diagnosis algorithm with multiple inputs and multiple outputs must be selected. The fault recovery of smart grid is a complicated problem, which is difficult to be summarized by human experience. Based on the definition of big data industry chain, the key technologies of big data include not only core technologies such as data analysis technology, but also important technologies such as data management, data processing and data visualization. When dealing with this problem, the traditional shallow model has limited ability to express complex nonlinear functions, and it is easy to be under fitted when dealing with complex classification, prediction and other problems. In order to improve the learning efficiency and performance, it is necessary to innovate the learning mechanism of the shallow model. Deep learning learns more useful features by building machine learning models with multiple hidden layers and massive training data, so as to improve the accuracy of classification and prediction. Because each diagnosis algorithm has its own advantages and limitations, it is necessary to combine a variety of intelligent technologies to achieve the diagnosis goal in the equipment fault diagnosis, so as to avoid the defects and limitations brought by using a single diagnosis algorithm.

3. Application of Fault Detection Technology in Smart Grid

Due to the lack of sufficient prior knowledge and the limitation of manual experience, it is difficult to manually label the types of fault information and fault recovery scheduling schemes. Moreover, due to the large scale of smart grid, there are many types of possible fault information. In order to meet the requirement of quick power supply recovery in case of fault, smart grid usually adopts closed loop design. When the line is in normal operation, the data collector and the digital fault indicator communicate through the set communication mode and send real-time data to DCU. Data extraction is carried out on massive various data in the integrated information system database, and the data are stored in the data warehouse of the system in real time. The data is mainly used for analysis, and the data design is designed according to the principle of business-oriented design [13]. Data is automatically and periodically extracted from each integrated system through a data extraction tool. The extracted data is filtered according to different business requirements to filter out dirty data and incomplete data to form data that can be used for power analysis. In order to introduce the current research situation of deep learning in power system, it is necessary to summarize their application models, data sources and technical principles.

In order to realize the system monitoring and fault early warning for different equipment and improve the analysis results of different equipment monitoring methods, the system needs to have certain expansibility for the power equipment monitoring and early warning methods. The ring network power supply smart grid shown in Fig. 1 is a typical closed-loop design, and its power supply lines can form a closed ring, which can be represented by the smart network model according to the structure of Fig. 2.
The benefit of using a closed-loop design is that the smart grid can be powered in both directions. If a branch fails, the affected node can be powered in the other direction of the network loop, minimizing the impact of the fault.

In order to ensure the safe, economical and efficient operation of smart grid, open-loop operation is usually adopted in the operation of power grid. Although smart grid sometimes has closed loop operation, power distribution will produce excessive circulation impact when the grid is closed loop operation, thus causing relay protection action to cause closed loop failure. In order to carry out early warning of equipment failure, there must be enough basic data of equipment, and the basic parameters of equipment must be collected and stored. For the basic information of power equipment, the production manager can manage it timely and dynamically. As can be seen from Table 2, the error between the natural frequency of power equipment obtained by numerical simulation and that calculated by finite element method is less than 5%. The comparison between the two proves the accuracy of the description of elastic deformation.

### Table 2. Comparison of results

| Order number | Numerical simulation frequency (Hz) | Calculate modal frequency (Hz) |
|--------------|------------------------------------|-------------------------------|
| 1            | 16.625                             | 16.844                        |
| 2            | 88.547                             | 85.523                        |
| 3            | 182.153                            | 185.842                       |
| 4            | 255.565                            | 270.695                       |

The farther the fault distance is, the smaller the zero sequence voltage is. Therefore, the inductor current on the arc suppression coil, that is, the zero-sequence current on the bus side, also decreases as the fault distance increases. The failure detection of the system model method can be defined as the sample path of product performance degradation, namely:

\[
RSRP_{n,n} + (\lambda_j - \lambda_R) = RSRP_{n,m}
\]

Assume that for any one sample, there is the following non-stationary process:
\[ (\alpha_{MMSR}, \beta_{MMSR}) = \left( \frac{M}{k}, \frac{M}{k(d-k+1)} \right) \]  

(2)

Use the Poisson process to approximate this process. Then there are:

\[ A^T G = \sum_i A_i^T G_i \]  

(3)

For a fixed time indicator, the parameters of the Poisson process are:

\[ S^* = \arg \max \{ f(S) \} = \sum_{i=1}^n \max \left\{ \left( T_{s_m,j,m} - D_{s_m,j} \right), 0 \right\} \rightarrow \min \]  

(4)

The extraction of fault features is mainly applied to health assessment and fault prediction. Therefore, the fault characteristics obtained by different methods are applied to the health assessment in the experiment, and the results of the health assessment are observed to verify the fault extraction results. The primary fault feature deviation curve is shown in Fig. 3.

![Deviation distance index](image)

**Figure 3.** Primary selection fault characteristic deviation curve

Equipment failure monitoring refers to the parameter information of each monitored equipment can be seen in the system. The input items of the system are the type and code of equipment, and the output items of the system are the parameter information of equipment. Deep learning adopts a hierarchical structure similar to that of neural networks, but its training mechanism is significantly different from that of neural networks. Its models include generation model, discrimination model and hybrid model. In a relational database, data are stored in two-dimensional tables, each table representing different data information. The equipment information table includes equipment number data, fault data, historical data and online monitoring data. In order to ensure the integrity and security of the database, each attribute of each table in the database sets the data type and uniqueness according to the actual function
of the database. Historical data query refers to the input device type, device code and query time, and the system displays the historical data of the device. Big Data classifies, plans, designs, and deploys data from different angles such as data characteristics, data sources, data acquisition methods, and data acquisition frequencies. For the system behavior with dynamic characteristics, the data can be extracted through unsupervised training to reflect the intrinsic characteristics of the system behavior, and then the expression of the characteristics can be improved through supervised training.

4. Summary
Smart grid fault location and on-line monitoring system is mainly used on medium and high voltage transmission and distribution lines. It can detect and indicate short circuit and ground faults, and can monitor the normal operation and fault occurrence process of lines in real time. The fault recovery technology of smart grid plays a certain role in promoting the development of smart grid technology and the safe operation of smart grid. The use of machine learning technology in fault recovery of smart grid is of great significance to the fast and autonomous implementation of fault recovery scheme of smart grid. Machine learning is the core content of artificial intelligence technology. Smart grid is a typical information physical integration system. It uses a large number of sensing devices and complex communication networks to form a complex system of real-time sensing, information service and dynamic control. Different equipment is suitable for different diagnostic algorithms. Further research and testing should be carried out on the diagnostic algorithms. In addition, the functions of the system should be further improved according to the actual situation. The realization of power equipment fault monitoring and early warning system is conducive to the predictive maintenance of equipment, and is also a major supplement and extension to the traditional offline preventive tests. It can be predicted that with the rapid development of smart grid technology, smart grid fault online monitoring has a good development prospect.

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