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The Design and Application of the Condition Monitoring and Management System of Power Transmission and Transformation Equipment under Information Technology

Jing Li[1*], Guangnian Xu[2], Jie Hong[2], Shangjun Wang[2]

[1] Zhejiang Huayun Electric Power Industrial Group Co. , Ltd. , Hangzhou 310008, PR China
[2] Zhejiang Huayun Information Technology Co. , Ltd. , Hangzhou 310008, PR China
Corresponding author(E-mail: puwen0614@163.com)

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Abstract

A monitoring and diagnosis system for power transmission and transformation equipment based on information technology is established to improve the stability of the power system to conduct real-time detection and management of power transmission and transformation equipment and establish a safe and stable power system. First, based on information technology, the power transmission and transformation monitoring management system is designed from three aspects: equipment information visualization platform, business integration management platform, and data acquisition platform. Second, the used intelligent diagnosis system for the condition of power transmission and transformation equipment is introduced. Because of the Fiore used for identification, the system processes excellent self-learning and self-optimization capabilities. It can optimize the results of fault diagnosis during identifying. Then, the designed monitoring management system is optimized through the group search optimizer to improve the stability of it in a complicated environment. At last, the designed condition monitoring and management system of power transmission and transformation equipment are tested. The results reveal that the average recognition accuracy of the designed power transmission and transformation monitoring and management system is 85.59%, so the classifier has excellent accuracy in the fault diagnosis of power transmission and transformation equipment. Moreover, the comparison of the used group search optimizer with the commonly used genetic algorithm and immune algorithm indicates that when the group search optimizer solves the problem, it has the least average number of iterations, and high optimization efficiency, in the case of the smallest population size. Therefore, the designed power transmission and transformation monitoring and management system can effectively manage power transmission and transformation equipment and provide technical support and safety guarantee for the safe operation of the power system.

Keywords: *power transmission and transformation equipment; condition monitoring; fault diagnosis; classifier;group search optimizer*

1. INTRODUCTION

The availability and stability of power transmission and transformation equipment in the power system affect the operating condition of this system. How to monitor the potential problems of power transmission and transformation equipment and eliminate them is an essential issue of concern with power companies. On the one hand, with the continuous improvement of China's economic strength, people's demand for the safety and stability of power is also increasing. On the other hand, the degree of informatization of power equipment is getting higher and higher, and traditional detection technology has been unable to adapt to the surge of current equipment operating data and test data. Therefore, it is imperative to establish an efficient and reliable fault diagnosis and monitoring system for power transmission and transformation equipment. The monitoring of power transmission and transformation equipment needs to meet the comprehensive, real-time, and accurate information acquisition

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requirements of power transmission and transformation equipment. By combining with information technology, the power transmission and transformation equipment is intelligentized. Then, it can carry out self-monitoring and diagnosis, and the efficiency of problem-solving is improved. The monitoring and diagnosis of power transmission and transformation equipment involve comprehensive problems, including high-voltage electricity, sensors, numerical analysis, and computer technology. The fault diagnosis of the monitoring of power transmission and transformation equipment is obtained by comparing and analyzing the characteristic data at a specific moment with historical monitoring conditions. Furthermore, the data are compared with the results of online monitoring, combined with the previous monitoring experiment data and the parameter changes of the operating voltage. First, whether the equipment is in a fault condition is determined. Then, the type of equipment fault is determined. Besides, the severity and cause of the fault areanalyzed, and the equipment maintenance method is given. Since the information transmission of the power transmission and transformation equipment monitoring system is of real-time, it is necessary to explore the performances of the communication network to improve the utilization rate of the equipment and the safety of the grid operation. The fault diagnosis of power transmission and transformation equipment is a prerequisite to ensure the stable condition of the equipment [1-3].

She (2020) analyzed the intelligentization process of the Internet of Things (IoT) for power transmission and transformation equipment to ensure the safe operation of the power network; the power transmission and transformation equipment was composed of a complicated structure; the IoT was a highly correlated and mixed network in the physical and information space; moreover, the IoT for power transmission and transformation equipment was based on information models and communication networks; by applying the IoT technology to the online monitoring system of power transmission and transformation equipment, the system processed exceptional reliability and flexible scalability to realize the free distribution of system functions and system expansion [4]. Mykoniatis (2020) explored a real-time condition monitoring system for low-voltage industrial motors based on the IoT, which could record and monitor the vibration and temperature conditions of industrial motors, transmit the data to the data recording center through a wireless network, identify the abnormal condition of the motor by analyzing the sensor input value that exceeded the predefined set value; when the motor was approaching an abnormal condition, the system would change the condition and notify the user through a mobile alarm; also, the motor management system required users to perform inspections mandatorily and the alarm system would remain active until the authorized person accessed the equipment; furthermore, the system could control the motor management systemremotely for users to visualize the current condition of the motor; the experiments on the system monitoring capability revealed that the intelligent predictive maintenance system could detect and predict specific motor faults [5].Pathirikkat et al. (2018) proposed an intelligent backup monitoring system to detect and classify the types of transmission line faults that occurred in the power grid; the transmission line faults in the power grid were analyzed and clarified by the measured values of the phasor measurement unit (PMU) of the generator bus; the location of any fault in the power grid was detected by the frequency spectrum analysis of the equivalent power factor angle change; moreover, with the help of artificial intelligence (AI) technology, the types of occurred faults were classified through spectral coefficients; the system could significantly assist the system protection centre to locate faults and restore the line as soon as possible; experiments conducted on the standard power system network indicated that the system could identify and classify the fault types of the power grid effectively [6].

To explore the application of information technology in the monitoring of power transmission and transformation equipment and establish a safe and reliable power system, a detection and management system is established for power transmission and transformation equipment under information technology to realize efficient and visual management of the equipment. Also, the classifier is employed to design the power transmission and transformation diagnosis system to add the self-learning and self-optimization ability to the system. Then, the group search optimization algorithm is used to optimize the power transmission and transformation monitoring and management system to improve the stability and reliability of the system under complicated environments. At last, relevant tests are carried out on the designed system to verify its reliability.

2. Method

2.1 Design of condition monitoring system for power transmission and transformation equipment

The stable condition of power transmission and transformation equipment is related to many factors. By sharing the condition of power transmission and transformation equipment with the production management information system, lightning location system, meteorological system, dispatching system, and other power network systems, an intelligent diagnosis system is established. Relevant data is stored in the database through the data acquisition platform. Then, the obtained data are stored, integrated, analyzed, and fused according to the information platform of the power transmission and transformation equipment to establish an efficient and comprehensive real-time information database of the power transmission and transformation equipment. With the help of information technology such as Geographic Information System(GIS), various data, quasi-real-time data, and static data are scanned and analyzed in real-time, to realize the functions of real-time display of power transmission equipment faults and real-time management of equipment condition [7-9]. The designed power transmission and transformation equipment monitoring and management system mainly include three aspects:

(1) Based on the information visualization platform for power transmission and transformation equipment of the Web Geographic Information System (WebGIS), corresponding data interfaces for data sharing and system integration are provided with the application of WebGIS technology to the construction process of visualized management of power transmission and transformation equipment condition. To realize the organic integration of power transmission and transformation equipment management and various information systems, including the management information

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systems, office management systems, supervisory control and data acquisition systems (SCADAS), and enterprise resource planning (ERP) systems. Besides, the goal of sharing various types of data and the interconnection of information can be achieved. Moreover, the maintenance of distributed power transmission and transformation equipment can be implemented to ensure the accuracy and unity of data sources. The structure of the WebGIS sharing platform is shown in Figure 1.

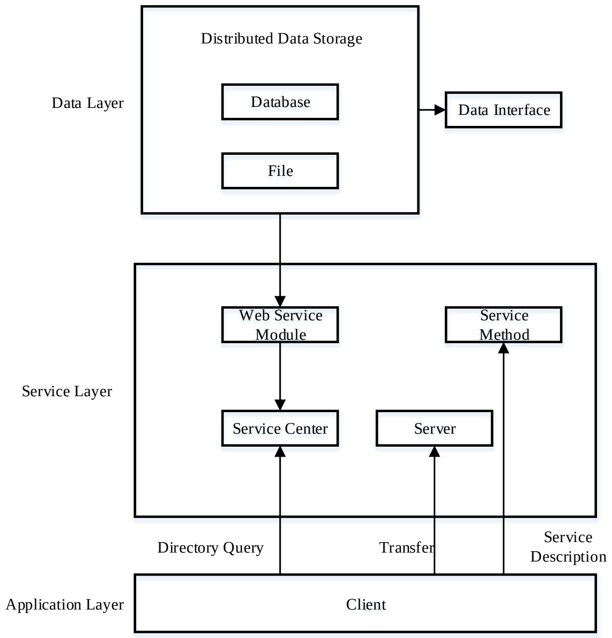

Figure. 1WebGIS sharing platform structure.

(2) Business integration management platform: The business integration platform is mainly responsible for the access and maintenance of business components, whose responsibilities consist of dynamic online management of system functions, real-time monitoring of equipment operation conditions, and providing the platform for overall security management and maintenance.The business integration management platform is developed in the form of component-architecture, and Mandatory Running Control technology is used to ensure the safety and stability of the platform.As the core part of the business integration platform, business process management takes the workflow engine as the foundation. It drives the instructions to manage and analyze the modeling, deployment, automatic operation, operation control,and monitoring and tracking of the process. Moreover, a closed-loop process management system is set up. The functional system of business process management is shown in Figure 2.

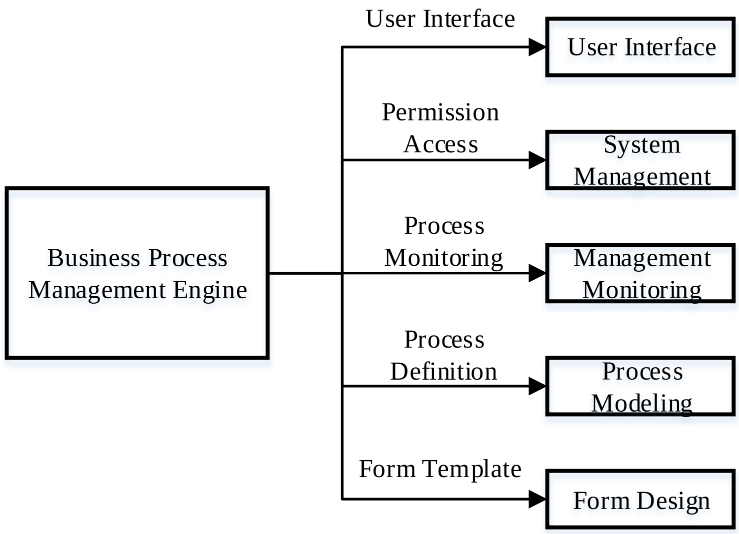

Figure. 2The functional system of business process management.

(3) A data acquisition platform of power transmission and transformation monitoring based on multi-agent technology:A complete equipment information database required as data support in the establishment of a power transmission and transformation equipment monitoring and management system. A comprehensive data center for power transmission and transformation equipment is established through the data acquisition and sharing platform to provide data for the monitoring management system.The data source of the data acquisition and sharing platform are independent databases. According to the requirements of the power transmission and the monitoring management system of transformation equipment, data acquisition, conversion, and storage for different forms of data sources in different application systems are achieved bythe data acquisition platform. The data acquisition and sharing platform include a real-time data information integration platform and a data-sharing platform. Thesoftware bus technologyis used in the subsystems of the two platforms to call each other data. The real-time data, other document format data, and business data are collected and stored them the target database by data acquisition adapter. Besides, they are provided to the power transmission and transformation equipment monitoring, management system. The structureofthe data acquisition and sharing platform is shown in Figure 3.

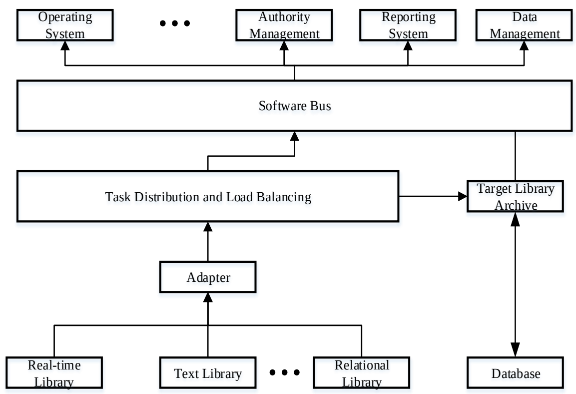

Figure. 3 Data acquisition and sharing platform structure.

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The monitoring and management system for power transmission and transformation equipment mainly involves functions such as overall real-time monitoring, intelligent, comprehensive diagnosis, real-time risk scanning, in-depth data analysis, 3D visualization, and report summary. It can perform various technical operations such as condition monitoring, fault diagnosis, production management, and statistical analysis of power transmission and transformation equipment.A fault library is established bycondition diagnosis system of power transmission and transformation equipment through the basic parameters of the equipment, fault data, historical operation data, external environment data and the fault types of the power transmission and transformation equipment.The fault classifier is optimized and trained based on the classification learning of the vector machine to perform fault classification. According to the fault library, the fault classifier is trained to form the fault recognizer, which is used to judge the operation condition of power transmission and transformation equipment. The example learning model of intelligent diagnosis of power transmission and transformation equipment condition is shown in Figure 4.

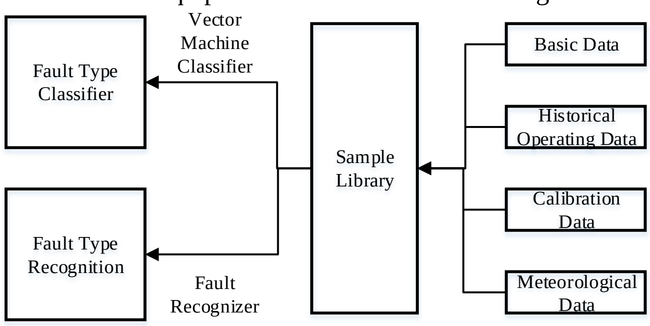

Figure. 4 Example learning model for intelligent diagnosis of power transmission and transformation equipment condition.

The equipment condition example library is the basis of thedesigned intelligent diagnosis system for the condition of power transmission and transformation equipment. After the historical operating data, necessaryinformation, meteorological data, and calibration parameters of the power transmission and transformation equipment are setas a sample library of the power transmission and transformation equipment, the data of the power transmission and transformation equipment is processed and analyzed accordingly. Then, the fault type of the equipment is judged, and afault library of equipment fault categories is obtained.Then the obtainedfault library is used as the learning object to train the fault type classifier. The fault recognizer of power transmission and transformation equipment is established based on the fault library of electrical output equipment.While the intelligent diagnosis model is appliedto the power transmission and transformation equipment, the current operating condition of the power transmission and transformation equipment is monitored, andthe data are filtered and normalized. Furthermore, the model of power transmission and transformation equipment is constructed to form the sample of equipment condition to be tested.A diagnosis diagram tree of equipment fault is composed through the fault classifier to classify the samples and determine the fault type of the sample. Moreover, the fault recognizer of the corresponding fault type is used to identify the fault of the sample. The fault condition with the highest degree of fit by comparing with the sample is the fault condition of the fault sample [10-13].

After the equipment diagnosis result is given by the power transmission equipment monitoring and diagnosis system, the result is evaluated. Also, the fault identifier of power transmission and transformation equipment is further optimized; the diagnosis condition of the equipment is enhanced at the same time; the example is supplemented tothe library.Therefore, the designed monitoring management system of the power transmissionand transformation equipment processesparticular self-learning and self-optimizing capabilities. Self-learning ability means that after the fault diagnosis of power transmission and transformation equipment, the system can be improved, and the current monitoring condition of the equipmentwill be saved to the example library. During the diagnosis, new monitoring samples can be continuously added according to the situation.Self-optimization capability refers to that after the equipment fault is diagnosed, the evaluation results may need to be further improved. Also, the fault classifier can be optimized accordingly to enable it to identify the fault more accurately.The learning stage of the power transmission and transformation equipment monitoring and management system is the core of the system. Through continuous classification and learning, the recognition accuracy of the power transmission and transformation monitoring and management system can be continuously optimized.

2.2 The optimization of the monitoring system based on group search optimizer

The monitoring and management system of power transmission and transformation equipment is susceptible to complex environmental conditions such as network delay and reliability, data packet error analysis, and resource limitations. Therefore, a group search optimizer is employed to optimize the monitoring system. The swarm search optimization algorithm is a random algorithm established by simulating the foraging behavior of the animals, and it does not have an initial condition. Its calculation speed is fast, and it can provide the best solution to the whole situation effectively. This algorithm is a stochastic optimization algorithm suitable for structural optimization design. In dealing with the optimization of spatial structure, it is mainly used for the articulated structural system, continuous variable structural design, and discrete variable structural. The group search optimizer is more straightforward than other algorithms and has higher operating efficiency. Its special search mode can avoid much unnecessary structural re-analysis, and is especially suitable for the optimization and application of complicated engineering structures. Combined with the power transmission and transformation monitoring management system, intelligent monitoring is further improved. The characteristics of the data and transmission point of the monitoring management systemare analyzed in a specific range. Moreover, a multi-path sensing system is established through the data transmission and monitoring conditions, and the stability of the system is enhanced. The group search optimizer can improve the optimization direction accurately and quickly, increase the convergence speed of the algorithm, and reduce the dependence on the initial population. Furthermore, it can avoid the algorithm from premature convergence effectively, and ensure that the algorithm can converge to the optimal global solution with a considerable probability [14,15].

3. Results and discussion

3.1 Fault diagnosis test of power transmission and transformation equipment

The classifier in the system is trained to test the designed power transmission and transformation equipment better and verify the accuracy and rationality of the monitoring management system. Nine hundredpieces of equipment operating data are selected for the experiment, of which consist 624 pieces of normal data and 276 pieces of fault data. Part of the datais selected for training and the remaining data for testing. A total of 5 classification tests are performed. The results are shown in Figure 5.

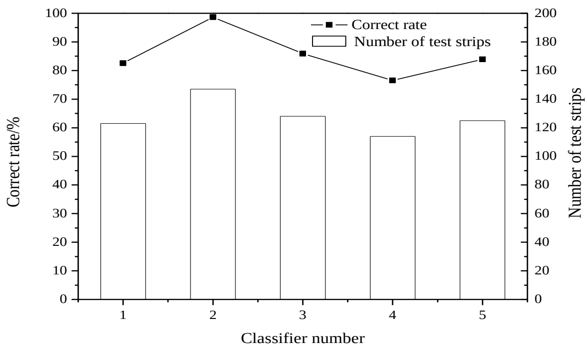

Figure 5.The accuracy of fault identification in the monitoring and management of power transmission and transformation equipment.

Figure 5indicates that after testing the equipment operating data, the highest test classification accuracy rate is 98.66%; the lowest is 76.51%; the average is 85.59%. There is a specific relationship between the identification accuracy and the number of test items. The more the number of tests is, the higher the accuracy is. Therefore, the classifier has good accuracy in fault diagnosis of power transmission and transformation equipment.

3.2 The comparison of algorithms' performances

The usedgroup search optimizer is compared with the commonly used genetic algorithm and immune algorithm, and the result is shown in Figure 6. In the process of the group search optimizer solving the power transmission and transformation problem, in the case of the smallest population size, the average number of iterations is the least, and the optimization efficiency is high.

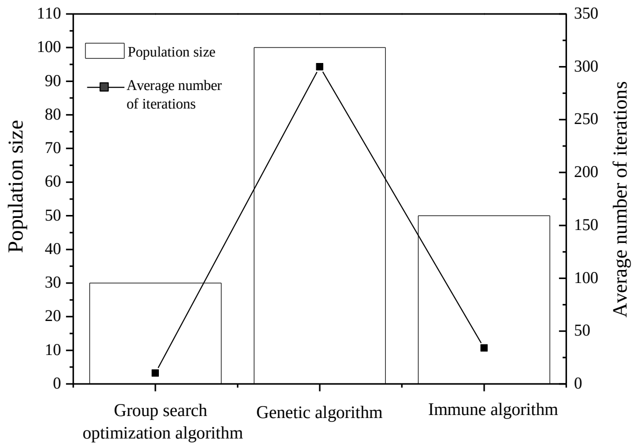

Figure. 6The comparison of algorithms' performances.

In summary, the average recognition accuracy of the power transmission and transformation monitoring and management system is 85.59%, indicating that the monitoring and management system has excellent accuracy in fault diagnosis. Moreover, the used group search optimizer is compared with the commonly used genetic algorithm and immune algorithm. The results suggest that when the group search optimizer solves the problem, in the case of the smallest population size, its average number of iterations is the smallest, and the optimization efficiency is high. Therefore, the designed power transmission and transformation monitoring and management system can manage power transmission and transformation equipment effectively.

4. CONCLUSION

To explore the application of the power transmission and transformation equipment condition monitoring and management system in the power transmission network, a power transmission and transformation equipment monitoring and management system based on information technology is designed, which can be divided into three parts: a visualization platform, a management platform, and a data acquisition platform. Also, the three parts are introduced, respectively. Besides, a fault diagnosis system for power transmission and transformation equipment is proposed based on the classifier. The system has particular self-learning and self-optimization capabilities, which can improve the accuracy of fault identification. Then the monitoring management system is optimized through the group search optimizer to improve its operating stability in complicated environments. Finally, the monitoring and management system is tested. The results reveal that the system has significant accuracy in fault diagnosis of power transmission and transformation equipment. Moreover, by comparing the used group search optimizer with the commonly used genetic algorithm and immune algorithm, the results prove that when the group search optimizer solves the problem, in the case of the smallest population size, the average number of iterations is the least, and the optimization efficiency is high. Therefore, the designed monitoring and management system of the power transmission and transformation can manage power transmission and transformation equipment effectively. However, there are still some shortcomings. The self-learning and self-optimization abilities of the fault diagnosis system need to be further analyzed, whose ability is mainly reflected in the evaluation of diagnosis results and the increase of new examples. The evaluation methods of diagnosis results and the conditions for adding new examples have not been explored thoroughly, so in-depth analysesare needed in future works.

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