Power Transformer Fault Diagnosis System Based on Internet of Things

Guoshi Wang[1*], Ying Liu[2], Xiaowen Chen[1], Qing Yan[1], Haibin Sui [1], Chao Ma[1], Junfei Zhang[1],
[1]Hainan Power Grid Co., Ltd, Haikou460100, Hainan, China
[2]Hainan Power Grid Co., Ltd. information communication branch, Haikou 460100, Hainan, China

E-mail: wanggs1@hn.csg.cn
[*Corresponding author]

Abstract: Transformer is the most important equipment in the power system. The research and development of fault diagnosis technology for Internet of things equipment can effectively detect the operation status of equipment and eliminate hidden faults in time, which is conducive to reducing the incidence of accidents and improving people's life safety index. Objective: To explore the utility of Internet of things in power transformer fault diagnosis system. Methods: A total of 30 groups of transformer fault samples were selected, and 10 groups were randomly selected for network training, and the rest samples were used for testing. The matter-element extension mathematical model of power transformer fault diagnosis was established, and the correlation function was improved according to the characteristics of three ratio method. Each group of power transformer was diagnosed for four months continuously, and the monitoring data and diagnosis were recorded and analyzed result. GPRS communication network is used to complete the communication between data acquisition terminal and monitoring terminal. According to the parameters of the database, the working state of the equipment is set, and various sensors are controlled by the instrument driver module to complete the diagnosis of transformer fault system. Results: The detection success rate of the power transformer fault diagnosis system model established in this paper is as high as 95.6%, the training error is less than 0.000l, and it can correctly identify the fault types of the non training samples. It can be seen that the technical support of the Internet of things is helpful to the upgrading and maintenance of the power transformer fault diagnosis system.

Keywords: Internet of Things, Power Transformer, Fault Diagnosis, Wireless Communication and Network

1. Introduction

In the power supply system, transformer plays an important role in power production and transmission. If the transformer breaks down suddenly in the process of operation, it will cause serious harm to human safety and economic property. Therefore, it is of great value to improve the specific monitoring and troubleshooting of transformers.

The application of the Internet of things to the power system can not only improve the basic network of power transmission and communication, but also enhance the security and stability of its transmission and communication network. As the main communication channel of distribution network, it can provide the functions that the current public and wireless networks lack. In addition, the Internet of things can withstand the power emergency in negative weather and improve the disaster resistance ability of the communication system. The Internet of things will become an important way for the rapid development of information technology in the future.

Di Renzo's research relied on modeling the location of the base station as the points of spatial Poisson point process, and carries out system level analysis by using random geometry. The trade-off between wireless information and power transmission is described by the concept of "feasible region", and quantified by the joint cumulative distribution function of average power and average rate. Di Renzo proposed a new mathematical method to analyze and optimize cellular low-energy mobile devices with wireless information and power transmission capabilities. The method is ingenious, but requires high accuracy, and needs to be improved in practical application [1]. In order to reduce the difficulty of data acquisition and transmission in the fault diagnosis system of mine hoist, and solve the problems of low efficiency of fault diagnosis and unreasonable reasoning process of mine hoist, a fault diagnosis method of mine hoist equipment based on Internet of things is proposed. Based on ZigBee short-range wireless communication technology, the collaborative acquisition system of key components of mine hoisting equipment is designed in the Internet of things. Juanli adopted remote wireless general packet radio service (GPRS) transmission mode to realize real-time data acquisition and network layer establishment. Juanli through the fault diagnosis test of mine hoist, the diagnosis method obtains complete diagnosis data, and the diagnosis result of this method has high accuracy and reliability [2]. Qian designed a relay with dual interface of wireless and PLC, which connects PLC and wireless sensor into an Internet of things network. In addition, the dual interface relay adaptively selects the interface to forward the message according to the channel state. Qian proposed a general mathematical model of the dual interface relay protection system. According to the statistical characteristics of PLC and wireless channel, Qian derived the probability density function of output signal-to-noise ratio (SNR). Qian's research has constructed the general mathematical model of double interface relay protection system. This method has high accuracy, but lacks feasibility [3]. Zikria connected the digital and physical worlds by combining energy-efficient microcontrollers, low-power transceivers, sensors, and actuators in so-called "small objects.". In general, intelligent objects are severely limited in computing, memory and energy resources. New verification methods and experimental tools are needed to study the intelligent object network, new software platform is needed to operate intelligent objects effectively, and innovative network models and protocols are needed to interconnect intelligent objects. Zikria's research connected the digital world with the physical world, which has many innovations, but needs more verification methods to support the accuracy of the research data [4].

In this paper, a total of 30 groups of transformer fault samples are selected, and 10 groups are randomly selected for network training, and the remaining samples are used for testing. The transformer fault diagnosis system model is established for each group of power transformers for four consecutive months, and the monitoring data and diagnosis results are recorded and analyzed. The communication network uses GPRS to realize the communication between the data acquisition terminal and the monitoring terminal. According to the parameters of the sample library, the working state of the equipment is set, and various sensors are controlled by the instrument driver module to complete the detection of the transformer fault system. The results show that the detection success rate of the power transformer fault diagnosis using this model is as high as 95.6, and the training error is less than 0.000l, and it can accurately identify the fault types of the samples in the non training set.

2. Principle about Internet of Things and Fault Diagnosis System

2.1 Internet of Things

(1) Combination of Internet of things technology and smart grid

Since its successful development, the Internet of things has undergone many significant changes. From the logistics network mainly relying on radio frequency identification technology at the beginning, it has now been studied that a variety of information sensing equipment relying on Internet technology, sensing technology and computer technology can use Internet facilities for information exchange, coordination and processing, Then, it is an interconnection to meet the requirements of information exchange between people and objects in various regions or large areas [5-6]. The application of Internet of things technology in smart grid can realize the perception and exchange of advanced level, convenient operation and unified standard communication information, and complete the distributed intelligent information transmission, measurement and control. Using smart sensors to connect a variety of equipment and facilities as a whole, and then constitute an integrated information service system, not only can process and analyze a variety of information, but also can save costs through this way, and optimize the operation and control of power grid.

(2) The role of IOT technology in power maintenance

The periodic maintenance mode formulated in 1950s is used for the maintenance of power equipment in China. So far, the main maintenance mode is still the method [7-8]. There are two inevitable deficiencies in this method. One is the large-scale maintenance of normal equipment, the other is the equipment damage caused by accidents, which forces the regular maintenance to inevitably lead to a large amount of human and material resources consumption.

The primary problem to be solved by Internet of things technology is information acquisition. How to process information and how to realize overhaul decision should be scientifically planned [9-10]. As an independent management subject, maintenance management is inseparable from the advanced technology management system. A variety of maintenance systems are composed of various management objectives in many countries around the world. Under the condition of market factors and technical level, a maintenance management mechanism including conditional maintenance and flexible application of various methods is proposed. The addition of diagnosis expert system can make the reliability and safety of the system meet the level of people's needs, and optimize the maintenance plan and maintenance process.

2.2 Power Transformer

(1) Brief introduction

Power transformer is one of the key equipment of power system, and its reliable operation characteristic is the guarantee of the whole power mechanism to supply power safely. The fault of power transformer will directly interfere with the normal operation of the power system, and also cause serious harm to the economy of power companies and power users [11]. At present, the power system is developing rapidly in the direction of ultra-high voltage, large power grid and automation, and the influence and interference of transformer fault on the normal operation of power system is becoming more and more serious [12]. Because the improvement process of power transformer fault is related to the operating environment, load capacity and insulation level, it is difficult to find out some hidden faults immediately by using preventive maintenance means. Preventive maintenance not only needs high cost, but also does not have advanced level for development faults such as insulation. Therefore, it is very useful to detect the transformer running fault system on-line at any time. The combination of on-line detection technology and intelligent diagnosis of transformer fault can timely discover the hidden dangers in the development, reduce the probability of accidents, and do a good job of prevention.

(2) Application of power transformer

In the contemporary society, electricity is a particularly important energy, it has penetrated into every corner of human society. However, the power generated by power plants usually needs to be transported over long distances to reach the power area [13-14]. When the transmission power is fixed, because the voltage and current are in positive proportion, the current required for transmission decreases with the increase of voltage. Because the impedance of the transmission path is almost a fixed value, and the line loss is proportional to the square of the current, increasing the transmission voltage can greatly reduce the line voltage drop and line loss. At present, there are great difficulties in the manufacture of high-voltage generators. Therefore, special equipment must be used to boost the voltage before the voltage at the end of the generator is sent out. This special equipment is the transformer. In addition, at the receiving end, it is necessary to use step-down transformer to reduce the high-voltage to the distribution system voltage, so many distribution transformers are used to regulate the high-voltage to the exact application value. In the power system, transformers occupy a very important position, not only need a large number, but also have high efficiency and stable operation.

When the transformer is in operation, the transformer will fail due to various factors [15-16]. If the transformer fails, it will affect the output of the generator, reduce and interrupt the power supply of some users, and prolong the maintenance time of the transformer. If the accident can not be detected and solved immediately, it will cause serious harm to the conventional power supply and residents' property.

2.3 Power Transformer Fault Diagnosis System Based on Internet of Things

The decision level fusion in the system uses the extension theory to establish the fault diagnosis model, uses the correlation function to evaluate, and comprehensively diagnoses the transformer fault type [17-18]. The implementation process of decision level data fusion based on extension theory is as follows:

(1) Constructing matter element matrix

According to the concept of matter-element and the ratio code and fault type of each transformer, the transformer fault types are divided into nine levels: U={u1,u2,u4,u5,u6,u7,u8,u9}={I1,I2,I4,I5,I6,I7,I8,I9}. According to the three ratio codes of C2H2/C2H4,CH4/H2,C2H4/C2H6 and corresponding fault intervals, the three-dimensional matter-element matrix is constructed:

$$Z=\begin{bmatrix} \text{Transformer} & \text{Ratio of } C_2H_2/C_2H_4 & \text{Quantities of Failure Types } V_1 \\ \text{Fault Type} & \text{Ratio of } CH_4/H_2 & \text{Quantities of Failure Types } V_2 \\ \text{U} & \text{Ratio of } C_2H_4/C_2H_6 & \text{Quantities of Failure Types } V_3 \end{bmatrix} \quad (1)$$

The classical domain element free matrix to determine the fault type is as follows:

$$Z_i = \begin{bmatrix} & U_1 & U_2 & U_3 & U_4 & U_5 & U_6 & U_7 & U_8 & U_9 \\ c_1 & [0,0.1] & [0,0.1] & [0,0.1] & [0,0.1] & [0,0.1] & [0,1.3] & [0.1,3] & [3,\infty] & [3,\infty] \\ c_2 & [0.1,1] & [1,\infty] & [1,\infty] & [0,\infty] & [0,0.1] & [0,1] & [3,\infty] & [0,1] & [1,\infty] \\ c_3 & [1,3] & [0,1] & [1,3] & [3,\infty] & [0,1] & [0,\infty] & [0,\infty] & [0,\infty] & [0,\infty] \end{bmatrix} \quad (2)$$

(2)Determine the matter element to be diagnosed

The analysis results of dissolved gas in transformer oil are represented by matter element Z0, and the following three-dimensional matter element matrix is obtained:

$$Z_0 = \begin{bmatrix} U_0 & \mathrm{c}_1 & V_1 \\ & \mathrm{c}_2 & V_2 \\ & \mathrm{c}_3 & V_3 \end{bmatrix} \quad (3)$$

(3) For the state information of each group of data, the steps of determining the objective weight of state information between components by the value method are as follows:

1) The ratio of state information value x_{ij} under state information quantity j is calculated:

$$P_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}} \quad (4)$$

2) Calculate the value h_j of state information j:

$$\mathrm{h}_j = -k\sum_{i=1}^{m}(p_{ij}\ln p_{ij}) \quad (5)$$

Where, $\mathrm{k} = \frac{1}{\ln(m)}$,k>1,and $0 \le h_j \le 1$.

3) The difference coefficient g_i of state information j was calculated:

$$\mathrm{g}_i = 1 - h_j (0 \le h_j \le 1) \quad (6)$$

(4) Data acquisition terminal

1) GPRS communication module

The GR47 module in Embedded TCP / IP protocol stack will be selected for online monitoring and diagnosis system. The GR47 module mainly includes GPRS communication module and IP module, which are used to complete the replacement of TCP / IP protocol, complete the sending and receiving of various information in turn, and provide data supply for GPRS [19-20]. In order to achieve various types of running state, this module also designs various types of interfaces to meet the work requirements. The adoption of the first mock exam module provides many users with many convenience, mainly because the protocol replacement process between TCP and IP does not need to send people to manual operation, and reduces the complicated handling time. The data transmission is more clear, and the data transmitted by the initiative can reach the terminal of the other network system directly after GR47's disposal, which greatly reduces the development time of the system.

2) Fault diagnosis module

After receiving the exact data information, the fault diagnosis module is fused and analyzed, and compared with the sample parameters in the diagnosis database, so as to judge whether the transformer is in good condition and its fault mechanism [21-22]. If the fault is of general type and the function is low, the diagnosis system will give a warning and let the user complete the simple equipment adjustment according to the given operation steps [23]. When the fault is more serious, the performance is worse. The diagnosis system will compare the collected data with the corresponding parameters of the transformer, comprehensively analyze the self inspection data and the important information in the technical reference library, and determine the modules that can be replaced after the fault occurs. After meeting the above requirements, the system will give the user specified repair steps. In this stage, the system technical guidance from the judgment of transformer fault type to the fault solution method is completed.

3) Transformer fault diagnosis based on Information Fusion Technology

Due to the complexity of the transformer manufacturing process and the instability of the operation state, the transformer fault causes are diverse, which is mainly reflected in that the same type of fault mode has different fault characteristics, and the same type of fault feature is the combination result of multiple fault modes [24-25]. Therefore, the relationship between fault modes and fault characteristics presents a variety of nonlinear relationships. Therefore, it is very important to determine the relationship in transformer fault diagnosis. Information fusion technology is to analyze and process the information and data from various information sources, make full use of all the fault characteristics of the transformer, get the multi information of the same object of the transformer from multiple angles, and integrate them to achieve more accurate and scientific online diagnosis. After the initial data evaluation and simple fault diagnosis analysis, the final results need to be clearly displayed on the monitoring site LCD screen, which is conducive to the direct collection of information and management planning.

3. Experiment and Analysis

3.1 Research Data and Experimental Design

(1) Data collection and determination of training samples

30 groups of transformer fault samples are selected, and 10 groups are randomly selected for network training, and the rest samples are used for testing. According to the designed transformer diagnosis system model, each group of power transformers are diagnosed for four months continuously, and the monitoring data and diagnosis results are recorded and analyzed.

(2) Information analysis and processing (flow chart)

GPRS communication network mode is used to complete the communication between the data acquisition terminal and the monitoring terminal. The data acquisition terminal transmits the detected data of transformer parameters to the monitoring terminal or receives the monitoring information from the monitoring terminal. The flow chart of inspection plan is shown in Figure 1:

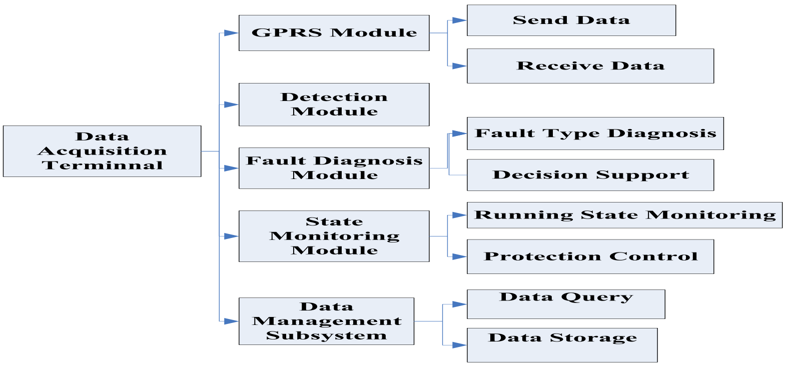


Figure 1 Maintenance Plan Flow Chart

(3) Detection and fault diagnosis module

The dissolved gas in transformer oil is measured respectively, and the monitoring and management system is used to compare with the standard parameters in the diagnosis knowledge base to judge the performance status and fault type of the voltage transformer, and give the operation steps of maintenance to the user. Finally, the fault type analysis of the transformer is completed, and the data support is provided to the technical personnel.

(4) State monitoring module and Internet of things Management System

According to the parameters of the database, the operation status of the equipment is set, and the instrument driver module is used to control multiple sensors to monitor the operation status of the transformer, and appropriate measures are taken to protect and control the transformer.

(5) The calculation formula of each module in the experiment

1) The correlation degree between the matter-element to be tested and the standard fault matter-element is calculated:

$$K(N_i)=\sum_{j=1}^{3} w_j \cdot K(v_j) \quad (7)$$

Where w_j is the weight coefficient, taking 1 / 3.

2) Standardization:

In order to facilitate the analysis of the diagnosis results, the correlation degree is standardized by the following formula:

$$K'(N_i)=\frac{2\times K(N_i)-K_{\min}-K_{\max}}{K_{\max}-K_{\min}} \quad (8)$$

3) The transformation formula used in this paper is as follows:

$$\bar{x}_i=\frac{x_i-x_{\min}}{x_{\max}-x_{\min}}\cdot(HI-LO)+LO \quad (9)$$

Among them, $\bar{x}_i$ represents the input after normalization, x_i is the input data, $x_{\min}$ is the minimum value of the data, $x_{\max}$ is the maximum value, HI = 0.9, LO= 0.1, the setting of HI and LO is conducive to reducing the error.

3.2 Analysis of Experimental Results

(1) Analysis of current and voltage in case of failure of voltage regulator

Explore the role of the Internet of things diagnosis module in the model to the voltage transformer, and detect the current and voltage when the voltage transformer fails. The results are shown in Figure 2:

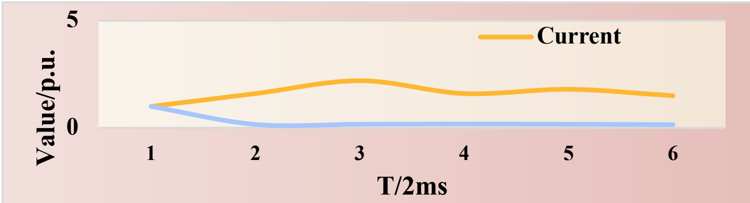


Figure 2 Current and Voltage Waveforms for Controlling Instant Aaction

It can be seen from Figure 2 that the average voltage of the transformer sample is not higher than 3V every 2ms. The fault location also has an impact on the current and voltage after the fault, but the DC line resistance is relatively small, so the fault location has little impact on the short-circuit current and voltage. Therefore, the diagnosis method of Internet of things technology comprehensively uses entropy method to weight each single diagnosis module, reduces the error interference, the diagnosis accuracy is much higher than the single diagnosis mode, can reflect the uncertain information of random variables, make full use of the obtained data information, eliminate the influence of subjective factors, and more objectively reflect the state of the system. Since the input and output power supply of the transformer is 5V, and the power supply of its core and internal and external devices is 3.3V, the system needs to use two groups of regulated power supply. The 220 V alternating current is first reduced by the step-down transformer, and the reduced alternating current is rectified into direct current through the rectifier bridge. After C1 filtering, it enters the lm7805 voltage stabilizing module, and finally outputs 5V DC after R1 voltage splitting. The IOT system diagnosed that the sample will be 5V DC and then use high-voltage output of 5.5V, then the equipment has the characteristics of small output current, low accuracy of output voltage and lack of stability. Combined with GPRS communication module and IP module, it is used to complete the replacement of TCP / IP protocol, complete the sending and receiving of various information in turn, and provide data supply for GPRS. 100 sensor nodes are randomly deployed in a 100 × 100 area, and the communication distance of all sensor nodes is set to 50m. The fault diagnosis of WSN nodes with failure rate of 0.05 ~ 0.30 in the sensing layer of the Internet of things is used to reduce the complex operation time and make the data transmission more clear, The active data can reach the terminal of the other network system after the processing of GR47, which greatly reduces the development time of the system. In this paper, the decision level fusion in the system is studied. The fault diagnosis model is established by using the extension theory, the matter-element matrix is constructed and the correlation function is used to evaluate. The fault type of power transformer can be comprehensively diagnosed.

(2) Analysis of transformer chromatographic data in case of fault

Test the diagnosis effect of transformer fault diagnosis system model for transformer. Analyze the chromatographic data of 10 groups of transformer fault, as shown in Figure 3:

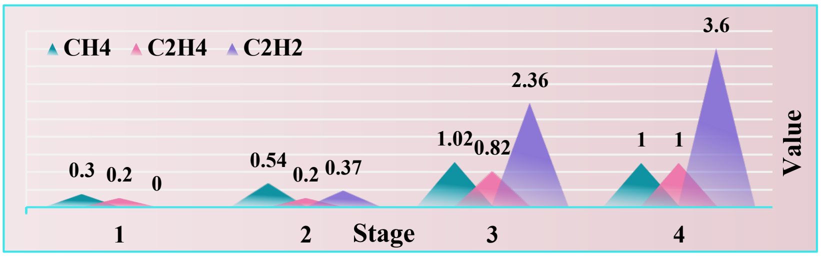


Figure 3 Chromatographic Data of Transformer in Case of Fault

It can be seen from Figure 3 that the content of C2H2 in transformer exceeds the attention value (attention value ≤ 5), and obvious fault occurs inside the transformer, and the fault is determined as arc discharge. According to the data in Figure 3, we can see that the diagnosis decision result of node module fault type based on perception of node fault symptoms has high accuracy, and the node fault diagnosis accuracy is high. In this system, the Internet of things network has strong self-learning ability, good robustness and anti-interference ability, and can determine the redundant test sample data. Therefore, the model constructed in this paper has more excellent characteristics when applied to transformer fault diagnosis. These parameters are sensed and acquired by Internet of things technology, that is, the multi-component gases dissolved in transformer oil are collected in real time by wireless data acquisition terminal, and the data are analyzed, preprocessed and data fusion is carried out. The fault diagnosis results of transformer can be obtained automatically, and the characteristics can be optimized and the volatile coefficient change pheromone can be adaptively searched, The detection ability of the algorithm is optimized, and the robustness and convergence of the network are enhanced. The composition and content of dissolved gas in transformer oil is closely related to fault type and fault severity. The Internet of things model combines qualitative and quantitative aspects to study the law and method to solve the contradiction problem. By establishing the matter-element evaluation model with multi index parameters, the comprehensive quality level of things can be fully reflected.

(3) Research on model processing effect after diagnosis

The treatment effect of fault diagnosis system model for transformer system diagnosis is compared and analyzed. The chromatographic data of 10 groups of transformer after diagnosis are calculated as shown in Figure 4:

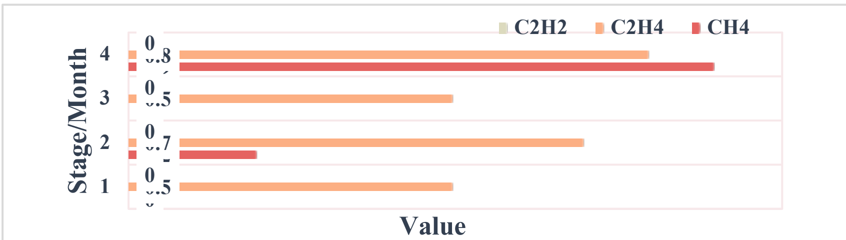


Figure 4 Chromatographic Data of Transformer after Diagnosis

It can be seen from Figure 4 that there is no significant difference between the values of grounding current and total grounding current between the core and clamp and the same kind of transformer, indicating that the discharge defect has been eliminated. The key of transformer fault diagnosis is to determine the fault diagnosis standard. At present, the chromatographic analysis of dissolved gases in transformer oil is often used to diagnose the potential faults in transformers. The results show that the gas ratio analysis has the advantages of less oil sample and faster analysis speed, and is an effective method for transformer fault diagnosis. The transformer works on the principle of electromagnetic induction. Therefore, its structure is: two (or more) mutually insulated windings are sheathed on a common iron core, and they are connected with each other through magnetic circuit coupling. In this paper, the specific fault diagnosis samples are used for analysis. The diagnostic accuracy of the combined diagnosis method is better than that of the single diagnosis method, which verifies the effectiveness of this method. The Internet of things diagnosis technology is a new research direction. It can effectively combine different diagnosis methods and ideas, make full use of known information, so as to improve the accuracy and stability of diagnosis. The method in this paper is not limited to transformer fault diagnosis, but also can be used in other equipment fault diagnosis. Combined diagnosis method is a new method in transformer fault diagnosis, which needs to be further explored to further improve the diagnosis accuracy.

Diagnosis and analysis of Internet of things joint information fusion technology

After training on the training set data, the forward propagation network within the error range is obtained, and then the test set is input to verify the training results. The test set data is shown in Figure 5:

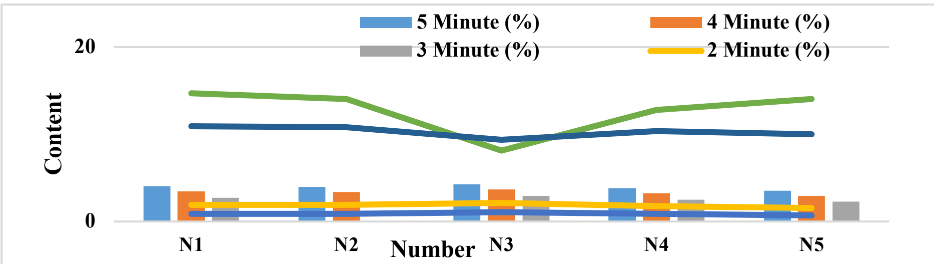


Figure 5 Comparison of Partial Optimized Test Sets

As can be seen from Figure 5, on the basis of information fusion technology added to the Internet of things, the fault diagnosis system constructed in this paper can quickly obtain sample data within 5min, which can better cooperate with the terminal data acquisition and improve the actual effect. In this paper, the transformer fault on-line diagnosis is taken as an example. If the traditional Internet of things measurement system is used, it will take more than 20 minutes to get the final fault parameters. In this way, the measurement time will be very long, which is a waste of time and cost. Therefore, we use the extension theory to train the data samples of the Internet of things to meet the convergence conditions And applied to the data processing server. Through the information fusion technology, the information and data from various information sources are analyzed and processed. By using all the fault characteristics of the transformer to the maximum extent, the multi-faceted information of the same object of the transformer can be obtained from multiple angles, and the integrated use can realize more accurate and scientific online diagnosis. After the initial data evaluation and simple fault diagnosis analysis, the final results need to be clearly displayed on the monitoring site LCD screen, which is conducive to the direct collection of information and management planning. The Internet of things can reasonably solve the terminal and communication problems in the distribution network. Only by connecting the equipment and its accessories in the distribution network with the Internet, the communication work of the distribution network can be completed, and the automation technology of the distribution network such as remote signaling, telemetry and remote control can be realized. It can be seen that the Internet of things can well deal with the problem of more distribution terminals and frequent changes.

(5) Training sample statistics

In this paper, the data of one day to more than one day are collected in the field. In the training model, one transformer data is selected every hour to remove the invalid test point data. Two thirds of the data are selected as the training samples and the remaining one third are the verification samples. The statistics of the sample database are shown in Table 1:

Table 1. Training Sample Statistics

	Normal	Ageing	Fault
Number of Transformers	17	10	10
Sample Size	302	150	150
Training Sample	203	102	102
Validation Sample	101	53	53

It can be seen from Table 1 that the samples in this paper have been screened for many times, and the detection success rate of the power transformer fault diagnosis system model designed by the Internet of things is as high as 95.6%. The transformer fault diagnosis method based on Internet of things has good pattern recognition ability, which can diagnose transformer fault quickly, effectively and accurately, and improve the fault diagnosis ability of the whole system through the self-learning function of the network. The network structure and network parameters selected in this paper are reasonable, and the training error is less than 0.0001, which can accurately identify the failure types of samples in non training set. It is of great significance for the safe operation of power system to study the efficient fault diagnosis method of power transformer. In this paper, data fusion and extension theory are also applied to power transformer fault diagnosis. In the single sensor system, batch estimation data fusion technology is adopted, which improves the reliability of single sensor data acquisition, but does not involve the heterogeneity of data among multiple sensors. The effective processing of the monitoring data of multiple sensors can effectively solve the problem that a single sensor can not diagnose the safety state of the transformer, as well as the problem that the coding rules are not complete or there are multiple state types.

(6) Research on diagnosis results

According to the model of transformer fault diagnosis system and input of fault parameters, the diagnosis results are shown in Table 2:

Table 2. Diagnosis Results

Serial Number	Fuzzy Closeness	Cause of Actual Sample Failure	Serial Number	Fuzzy Closeness	Cause of Actual Sample Failure
1	0.976	Discharge and Overheating	6	0.932	High Temperature Overheating
2	0.965	High Energy Exothermic	7	0.923	Low Temperature Overheating
3	0.960	High Temperature Overheating	8	0.865	Spark Discharge
4	0.961	High Energy Heat Release and Overheating	9	0.864	Low Energy Discharge and Heat Release
5	0.954	High Energy Discharge	10	0.831	Medium Temperature Overheating

It can be seen from Table 2 that most power transformers are prone to high temperature overheating when faults occur. The diagnosis results show that the fault type of most power transformers is high energy discharge, which is consistent with the actual fault type. Transformer is the most important component in the power system. For low-energy discharge and overheating, it is decomposed into the combination of low-energy discharge and medium temperature overheating, mainly considering the high probability of low-energy discharge and medium temperature overheating. For the same reason, high energy discharge and overheating are decomposed into the combination of high energy discharge and high temperature overheating. In this system, the realization process of the data module involved in diagnosis is: decompose the diagnosis results, calculate the scores of overheating fault and discharge fault respectively after weighting (accuracy), score according to the rounding principle, and then judge the level according to the score, and finally get the fault type. If a diagnosis module fails (no diagnosis result) or no fault is diagnosed, the diagnosis module will automatically exit the comprehensive diagnosis. In this way, it is easy for two modules to think that there is discharge (or overheating), only one module thinks that there is both overheating (and discharging), and the diagnosis result will be discharge and overheating fault. This is mainly from the perspective of causing enough attention from users. Therefore, using the combination diagnosis model to diagnose transformer fault, the misjudgment rate of each fault type is far lower than that of using a single diagnosis module. Therefore, the effect of using Internet of things and its series of methods to diagnose power transformer fault is better than the traditional diagnosis method, which can effectively improve the accuracy of fault diagnosis.

4. Conclusion

This paper mainly expounds the combination of Internet of things and smart grid technology and the role of Internet of things technology in power maintenance, analyzes the use of power transformer and its fault diagnosis system, and focuses on GPRS communication module and fault diagnosis module in data acquisition terminal, and deeply explores transformer fault diagnosis and data management subsystem based on information fusion technology. It can be seen that GPRS communication network combined with Internet of things technology can effectively diagnose the fault system of power transformer.

The research results of this paper: 30 groups of transformer fault samples are selected, and 10 groups are randomly selected for network training, and the remaining samples are used for testing. The transformer fault system diagnosis model is established for each group of power transformers for four consecutive months. This paper studies the detection success rate of power transformer fault diagnosis system model based on the Internet of things the training error is less than 0.000l, and it can accurately identify the fault types of non training samples.

Although many scholars have made outstanding achievements in the research of power transformer fault diagnosis system and Internet of things technology, but at the same time, in view of some limitations of this study, we hope that the Internet of things and transformer fault diagnosis technology should also consider other problems that are easy to be ignored while meeting the demand, so as to better improve the fault diagnosis technology and more widely Use it. If the fault system diagnosis technology can be further improved and applied to power transformer better, it will greatly improve the safety of people's life.

List of Abbreviations

PLC: Programmable Logic Controller
SNR: Signal Noise Ratio
IOT: Indexed Organized Table
TCP: Transmission Control Protocol
IP: Internet Protocol
LCD: liquid crystal display
DC: direct current
GPRS: General Packet Radio Service

Declarations

Consent for publication: Approved.

Competing interests

There is no potential competitive advantage in our paper. All the authors have reviewed the manuscript and agreed to submit it to your magazine. We confirm that the contents of the manuscript have not been published or submitted for publication elsewhere.

Funding

This work was supported by Digital grid platform (Hainan) construction project. (number：072900HQ42190001)

Author's contributions

All authors take part in the discussion of the work described in this paper.

Acknowledgements

The authors thank the editor and anonymous reviewers for their helpful comments and valuable suggestions.

References

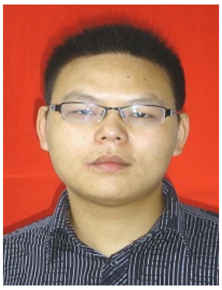
1) Di, Renzo, M., Lu, W. (2017) System-level analysis/optimization of cellular networks with simultaneous wireless information and power transfer: stochastic geometry modeling. IEEE Transactions on Vehicular Technology, (3):1-1.
2) Juanli L , Jiacheng X , Zhaojian Y , et al. Fault Diagnosis Method for a Mine Hoist in the Internet of Things Environment. Sensors, 2018, 18(6):1920-.
3) Qian Y , Yan J , Guan H , et al. Design of Hybrid Wireless and Power Line Sensor Networks With Dual-Interface Relay in IoT. Internet of Things Journal, IEEE, 2019, 6(1):239-249.
4) Zikria Y B , Yu H , Afzal M K , et al. Internet of Things (IoT): Operating System, Applications and Protocols Design, and Validation Techniques. Future Generation Computer Systems, 2018, 88(NOV.):699-706.
5) Zungeru A M , Subashini S , Vetrivelan P . Wireless Communication Networks and Internet of Things Volume 493 || NR-DCSK-Based MIMO Chaotic Communication System. 2019, 10.1007/978-981-10-8663-2(Chapter 22):207-215.
6) Zungeru A M , Subashini S , Vetrivelan P . Wireless Communication Networks and Internet of Things Volume 493 || Throughput Analysis of MacroUE for Varied Transmit Power of Small Cell

in Heterogeneous Network. 2019, 10.1007/978-981-10-8663-2(Chapter 17):161-170.

7) Manogaran G , Chilamkurti N , Hsu C H . Emerging trends, issues, and challenges in Internet of Medical Things and wireless networks. Personal and Ubiquitous Computing, 2018, 22(5-6):879-882.
8) Mahmoud M S , Mohamad A A H . A Study of Efficient Power Consumption Wireless Communication Techniques/ Modules for Internet of Things (IoT) Applications. Advances in Internet of Things, 2016, 06(2):19-29.
9) Krueger S . Critical theory of communication: new readings of Lukács, Adorno, Marcuse, Honneth and Habermas in the age of the internet. Information Communication & Society, 2018, 21(11-12):1808-1812.
10) Zungeru A M , Subashini S , Vetrivelan P . Wireless Communication Networks and Internet of Things Volume 493 || Dependency Analysis of Control Parameter Configuration on ISD and Random Mobility of UE in LTE-A Network. 2019, 10.1007/978-981-10-8663-2(Chapter 16):151-159.
11) Ma Z , Xiao M , Xiao Y , et al. High-reliability and Low-latency Wireless Communication for Internet of Things: Challenges, Fundamentals and Enabling Technologies. IEEE Internet of Things Journal, 2019:1-1.
12) Zungeru A M , Subashini S , Vetrivelan P . Wireless Communication Networks and Internet of Things Volume 493 || Modelling and Performance Analysis of Wi-fi Offloading. 2019, 10.1007/978-981-10-8663-2(Chapter 4):33-39.
13) Zungeru A M , Subashini S , Vetrivelan P . Wireless Communication Networks and Internet of Things Volume 493 || Enhancement of QOS Parameters in Cluster-Based Wireless Sensor Network Using Cooperative MIMO. 2019, 10.1007/978-981-10-8663-2(Chapter 20):187-195.
14) Arya K V , Bhadoria R S , Chaudhari N S . Emerging Wireless Communication and Network Technologies || Realizing the Wireless Technology in Internet of Things (IoT). 2018, 10.1007/978-981-13-0396-8(Chapter 10):173-192.
15) Rana M M , Xiang W . IoT Communications Network for Wireless Power Transfer System State Estimation and Stabilization. IEEE Internet of Things Journal, 2018:1-1.
16) Vinel A , Chen W S E , Xiong N N , et al. Enabling wireless communication and networking technologies for the internet of things . IEEE Wireless Communications, 2016, 23(5):8-9.
17) Zungeru A M , Subashini S , Vetrivelan P . Wireless Communication Networks and Internet of Things Volume 493 || Efficient Relaying for Enhanced Network Longevity for E-health IOT Services in Medical Body Area Networks. 2019, 10.1007/978-981-10-8663-2(Chapter 2):13-19.
18) Ramezani P , Jamalipour A . Toward the Evolution of Wireless Powered Communication Networks for the Future Internet of Things. IEEE Network, 2017, PP(6):12-19.
19) Ejaz W , Anpalagan A , Imran M A , et al. Internet of Things (IoT) in 5G Wireless Communications. IEEE Access, 2017, 4:10310-10314.
20) Junqing Z , Trung D , Roger W , et al. Securing Wireless Communications of the Internet of Things from the Physical Layer, An Overview. Entropy, 2017, 19(8).
21) Gao S , Tian G , Dai X , et al. A Novel Distributed Linear-Spatial-Array Sensing System Based on Multichannel LPWAN for Large-Scale Blast Wave Monitoring. IEEE Internet of Things Journal, 2019, 6(6):9679-9688.
22) Freschi V , Lattanzi E . A Study on the Impact of Packet Length on Communication in Low Power Wireless Sensor Networks under Interference. IEEE Internet of Things Journal, 2019:1-1.

23) Kaiwartya O , Abdullah A H , Cao Y , et al. Virtualization in Wireless Sensor Networks: Fault Tolerant Embedding for Internet of Things. IEEE Internet of Things Journal, 2018, 5(2):571-580.
24) Hu P , Zhang J . 5G-Enabled Fault Detection and Diagnostics: How Do We Achieve Efficiency?. IEEE Internet of Things Journal, 2020, 7(4):3267-3281.
25) Yang G , Yuan D , Liang Y C , et al. Optimal Resource Allocation in Full-Duplex Ambient Backscatter Communication Networks for Wireless-Powered IoT. IEEE Internet of Things Journal, 2018:1-1.

Guoshi Wang was born in 1986. He received the Master degree from Beijing University of Posts and Telecommunications, P.R. China. Now, he working in Information and Communications Branch of Hainan Power Grid Co., Ltd.His research is in power information system construction and maintenance..
E-mail: wanggs1@hn.csg.cn



Ying Liu was born in 1987. He received the bachelor‘s degree from Chongqing University of Technology, P.R. China. Now, he working in Hainan Power Grid Co., Ltd.His research information planning and construction.
E-mail: liuy4@hn.csg.cn

Xiaowen Chen was born on July,1987, graduated from South China University of technology and worked in the information and communication branch of Hainan Power Grid Co., Ltd. his research direction is computer technology.
E-mail:chenxw3@hn.csg.cn

Qing yan was born in 1983. graduated from automation major of Nanchang University, he working in Information and Communications Branch of Hainan Power Grid Co., Ltd.His research is in power information system construction and maintenance.
E-mail:yanq1@hn.csg.cn

Haibin Sui was born in 1983. He received the Master degree from Changchun University of Science and Technology. Now, he's working in Information and Communications Branch of Hainan Power Grid Co., Ltd.His research is in Data asset management ,power information system construction and maintenance.
E-mail:suihb@hn.csg.cn

Chao Ma was born in 1989. He received the bachelor‘s degree from Northeast Dianli University, P.R. China. he working in Information and Communications Branch of Hainan Power Grid Co., Ltd.His research database and bigdata.
E-mail:mac@hn.csg.cn

Junfei Zhang was born in 1990.He Graduated from North China Electric Power University, working in the information and communication branch of Hainan Power Grid Co., Ltd., the research direction is network maintenance.
E-mail:zhangjf2@hn.csg.cn

Figure: