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Development and Present Situation Analysis of Power Transformer State Maintenance

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Abstract. The pivotal status of power transformer in the power system is one of the most important equipment. The safety and reliability of its operation is directly related to the safety and stability of power system. Based on the analysis of the present situation of power transformer state maintenance in home and abroad, the paper points out the deficiency of the current method and provides a theoretical basis for further research, which has a certain guiding significance.

1. The state maintenance of power equipment
State maintenance is the mainstream of equipment maintenance in today's world. It has been used widely in the machinery, electricity, electronics, chemical, medical, automotive, metallurgy and other fields, which is recognized as the most efficient way of equipment maintenance. According to the definition of Steed. J.C, the state maintenance is a prediction method that characteristic use equipment and exist a life length before repairs are needed. This method makes full use of characteristics of some important parts of the life of equipment to predict the development trend of the equipment condition data collection and data analysis. On the basis of the condition monitoring, timely maintenance, which is called the state overhaul.

The development state of electrical equipment maintenance can be divided into three stages: CM (Corrective Maintenance) accident maintenance, regular maintenance TBM (Time Based Maintenance) and CBM (Condition Based Maintenance). The way mainly adopted is CM before 50s, which is repaired after equipment hitch or accident happened. It is no system like this network based on the large impact, so the surface is small when equipment occurred to be failure, and most of the equipment is relatively simple, margin design equipment and repair equipment outage is not easy, business activities for enterprises, people's dependence has not been so strong, at that time only simple daily maintenance and repair, maintenance did not carry out the system. Regular maintenance is a maintenance based on time its theoretical basis is: equipment can recovery to the new equipment through regular maintenance. Therefore, the content and periodic maintenance work are set in advance through the plan. regardless of the status of equipment, the time is to be coming to fix. The purpose is to prevent or delay faults and maximize the reliability of the equipment operation. But the regular maintenance management system is often at the expense of their own economic interests, the equipment has not yet occurred defects and the normal operation of the case for maintenance or replacement of equipment, resulting in unnecessary people, money, material waste. State maintenance
is a strategy and health equipment according to schedule maintenance and through the monitoring of equipment status. The equipment maintenance work condition maintenance in 60s American Airlines aircraft industry in 1970 by the U.S. DuPont Co I. D. Quinn first proposed, emphasis on equipment state overhaul began in 1978 as a benchmark, equipment maintenance is widely used in the United States Navy ships, in 80s, It is promoted the application in nuclear industry, and soon developed into electric power equipment the maintenance of the electric power industry, so the state overhaul is according to the actual operation of the equipment to determine maintenance time and position, targeted strong, economical and reasonable. According to the statistics, After the implementation of condition is repaired, equipment failure rate can be reduced by 75%, comprehensive maintenance costs can be reduced by 30%~50%, the practice of some domestic and foreign electric power enterprise application the equipment state maintenance can prove that the equipment maintenance management strategy has obvious social and economic benefits.

At the end of 70s, American Electric Power Research Institute (EPRI) research and applied on condition maintenance of electric power equipment, at present detection strategy has to reliability centered (RCM) development, as shown in Figure 1.1. Germany also used the state overhaul to improve repair efficiency. In recent years, the maintenance work of power plant is discussed. their views: the current development should be based on power plant equipment monitoring and diagnosis technology, the implementation of condition based maintenance, or in maintenance work to increase the state overhaul project. They think the main measures to improve the maintenance efficiency are: (1) state maintenance (CBM); (2) maintenance reliability centered (RCM); (3) the whole life cycle cost management strategy; (4) full maintenance; (5) slim maintenance management. Japan is to begin the implementation of state analysis and online detection based on state power equipment from 80s Overhaul and equipment inspection and life evaluation technology are adopted in the overhaul. However, most countries in Europe are also carrying out the overhaul system reform, the direction is also status maintenance.

![Fig1 Integrated system sketch for transformer substation of EPRI](image)

China began putting forward and studying CBM with the on-line monitoring technology and fault diagnosis technology in 1980s. The State Council pointed out that in the enactment of the national traffic management system all industrial equipment Ordinance in 1987: "methods should be based on equipment condition monitoring, and continuously improve the equipment management and maintenance of the level of modernization". our country also has some research units and enterprises in carrying out the theoretical research and application of the pilot work. at the beginning of 90s, the Northeast Power Group in Dalian Electric Power Bureau as the pilot implementation of state electrical equipment maintenance system, and has made certain achievements and experience. At present, the state of electrical equipment maintenance system is in power system, companies are also being actively carry out the pilot and extension. A national electric power equipment State maintenance
work experience exchange will be held in Wuhan in May 1998, the implementation of state maintenance workshop in Central China power grid power generation equipment in December 2001, state power company issued guidance on the implementation of "condition based maintenance of equipment in power plant, began to carry out CBM of electric equipment work in national power system. Although the development of state electric power equipment maintenance is still in the preliminary stage in our country, but with the continuous reform of computer network technology and the popularization and development of power system, electrical equipment maintenance and management level of our country's further development, the state power equipment maintenance will undoubtedly play a huge role.

From the above discussion, it is easy to see that the state maintenance system has the following advantages:

a) The lower the frequency of maintenance, prolong the overhaul time interval, shorten maintenance time, reduce outage losses, improve equipment reliability and operational availability, improve equipment utilization and productivity, save maintenance cost, reduce equipment life cycle cost.

b) Due to the state maintenance system is often on the basis of online monitoring results of equipment running condition for maintenance, it can forecast the fault occurrence time and the cause of the accident, and can effectively prevent the occurrence of accidents.

c) Condition monitoring can predict the influence and function of the existing hidden trouble on other parts of the equipment, and can eliminate the two damage caused by the existing fault of the equipment.

Because of the outstanding advantages of state maintenance, both domestic and foreign power industry and academia pay great attention to the research and popularize this maintenance system.

2. Development and present situation of power transformer CBM

The power transformer is the important equipment in power system. The current working state directly affects operation of the whole system. Improving the transformer operation and technical management level has become an important means to ensure the reliability of power supply. In order to make the transformer is always in good working condition, strictly monitoring and early finding any abnormality of transformer is very important. However, this alone preventive test regularly is unable to do. Therefore, we must be set up in the actual situation of the current transformer as the basis, through high-tech means of monitoring of the transformer longitudinal (history and status), transverse (operation condition of similar transformer) comparative analysis to identify early signs of failure. Besides, the fault location, severity and trend of fault judgment, to determine the optimal maintenance time maintenance mode of the transformer. CBM is developed for this demand.

Power transformer condition maintenance in general is divided into two parts: status assessment and maintenance decision. The state assessment mainly refers to the evaluation of transformer operation and health status and the result is the basis for the arrangement of maintenance work. The reliability assessment of the effect directly trust degree of state maintenance decision. So the key problem of the transformer CBM lie in condition assessment. but deterioration of the health status of the transformer operation performance for a variety of large and small transformer failure or malfunction. An important sign of safety hazard resulting in transformer operation to evaluate transformer's health status can meet the "safe production" the maintenance target and laid the foundation for the development of transformer condition evaluation state monitoring technology. The objective of the condition monitoring of transformer, transformer is based on the characteristics of the signal acquisition and analysis and identify the status of the transformer, in order to detect the early fault of transformer and state monitoring fault development trend. At present, the state monitoring of power transformer is one of the most international research objects and put forward a lot of different methods.

(1) Dissolved gas analysis in oil (Dissolved, Gas-in-oil, Analysis, DGA)
The gas analysis in oil is one of the methods of on-line monitoring of transformer insulation fault. Because of different transformer hitch will produce different gases, by analysing gas in the oil composition, content, gas production rate and the relative percentage can reach the diagnosis of transformer insulation. Several typical oil dissolved gases, such as H2, CO, CH4, C2H6, C2H4 and C2H2, are often used as the characteristic gas analysis. After the detection of the gas composition and content, they are often used the characteristic gas method or the Rodgers ratio method to the internal fault of transformer. such as partial discharge, spark discharge, overheating to discriminate.

(2) Partial discharge on-line monitoring technology (Partial, Discharge, PD)

There is a PD due to local field is too high, when the internal transformer happen to be failure or poor running conditions. Obvious changes of PD level and growth rate can indicate the changes taking place within the transformer or reflect the insulation due to some defects produced in the state, the metallic particles and air bubbles. Partial discharge occurs in addition to electrical information. at the same time, It is also accompanied by sound and a variety of non electrical information. Therefore, the detection of partial discharge in general can be divided into electrical measurement and non electric measurement method (including ultrasonic method, optical measurement method, decomposition method etc.). our country has engaged in many research units high-voltage electrical equipment about PD for a long time and has accumulated some experience and achieved remarkable results.

(3) Vibration analysis method

Short circuit and insulation aging may cause transformer winding deformation or lead structure offset disturbance. This transformer that has mechanical defects may cause a failure with the disastrous consequences of the insulation. Vibration analysis is a widely used method for monitoring the transformer fault effectively. To achieve the purpose of transformer condition monitoring through monitoring and analysis of vibration signal of transformer,. 

(4) Infrared temperature measuring technique

Infrared thermography is an infrared radiation signal of the measured target by infrared detector, amplified, converted into standard video signal, and then display infrared thermography through the TV screen or monitor. When the bad contact of transformer wire, coil conductor weld joints, overload operation conditions, they will cause the local overheating of conductive circuit, core multi point grounding will cause overheating. The accuracy of infrared thermal imaging technology core temperature is high, so it can be used in transformer monitoring. monitoring the temperature of the transformer by image analysis, and the data from vertical and horizontal comparison to make the judgement.

(5) Winding deformation

In recent years, measurement of transformer winding deformation are actively carried out around the world, but they are basically using off-line testing. low frequency response method recommended in the standard. The domestic is organizing the relevant units to prepare guidelines for the measurement of transformer winding deformation, which is mainly related to low frequency response method. At present, the method of summarizing transformer short-circuit reactance measurement system has existed. Monitoring and diagnosis of transformer winding deformation on-line is running and the measurement accuracy can be achieved 1%. It can given instructions according to the measured short-circuit impedance of winding deformation and warned that not the existing variable shaped transformer until the exit operation. Besides, It can provide the basis for the implementation of the state overhaul of power transformer and the experimenter does not depend on the experience.

(6) Pump / fan operation monitoring

The most frequent failure mode of transformer cooling system is the pump and fan. The continuous on-line analysis of pump and fan determine whether they are in the running state when the set or closed. It can be realized by current and measuring the flow through the pump and fan control associated with the temperature of the cooling system can be realized; by measuring pump / fan current and upper oil temperature. Rotation accuracy of the normal operation mode can indicate the fan and pump impeller, the abnormal operation of these devices is usually the control coil abnormal results.
In addition, the monitoring of transformer core grounding current, the leakage inductance of the winding test, humidity test oil, commonly used method of resistance testing, which are state monitoring of transformer insulation. But transformer oil water, winding temperature distribution (with the hot temperature winding) and aging parameters of paper insulation (such as furfural) online monitoring, there is no good solution. Both at home and abroad are actively exploring. In terms of the present situation in our country, implementation is to assess the health state of transformer preventive test based, because the requirement of on-line monitoring technology is higher. Economy, technology and hardware facilities exist more or less difficult to considerable part of the substation. However, the transformer condition evaluation technique with the basis of condition monitoring is the state overhaul of the direction of development, which will continue with the popularization and improvement of state monitoring technology and Broken development

3. Development stage of transformer condition based maintenance

As the sensor technology, computer hardware and software and digital signal processing technology, artificial neural network, expert system, fuzzy set theory and integrated intelligent system used in the condition monitoring and fault diagnosis of transformer, the transformer condition maintenance will undergo 4 stages:

1)original state overhaul stage

The use of a few transformer state data dispersion, through simple empirical analysis, the status of transformer rough judgment to determine the maintenance strategies. This stage also can't replace state maintenance regular maintenance, condition based maintenance and regular maintenance coexist, and still dominated by regular maintenance, only replenish regular maintenance.

2)primary stage overhaul stage

The state data comprehensive summary of the obtained (transformer operation data, preventive test data etc.) is in progress a preliminary classification, sorting, and finally the experts analys and judge to determine the health status of the transformer to determine the maintenance strategy according to the operation experience of the state data.

3)state overhaul stage of the system

Overall, the state data collection system for transformer; obtaining a more continuous and more accord with the actual state of the data with on-line monitoring test means instead of part of power. The initial state data of all transformer conduct a comprehensive, systematic processing, the formation of state data system by computer. The establishment of computer auxiliary expert judgment system preliminary the state, data analysis and judgment so as to obtain maintenance strategies. This stage is a cumulative improvement process (Figure 2).

4)perfect state overhaul stage

Through long-term practice to determine a complete set of state variables and health status reflect the transformer effectively, the continuous state information in a mature way of online access to the transformer, and the real-time processing of state data of computer system improve the expert system for data analysis to determine the exact complex, health status and maintenance strategy that transformer.

At present, the research and application of domestic transformer maintenance has been in full swing. However, the transition phase transformer condition maintenance are most in the primary condition based maintenance to condition based maintenance system in the actual operation of the power grid. The full implementation of transformer state maintenance is a huge systematic project, which is the equipment management mode change, and monitoring technology, diagnosis technology and maintenance technology of organic unity. It need scientific management technical support. The power transformer maintenance in the initial exploration stage both at home and abroad, the key problem is that the equipment condition evaluation, evaluation of health status of equipment condition monitoring and fault diagnosis based on is the way to solve this problem practical. With the all-round development of state monitoring technology, the state evaluation problem is successfully solved. The
state of maintenance will be for on behalf of the traditional planned overhaul system and bring huge economic benefits for power enterprises

![Systematic stage of CBM](image)

**Fig2** Systematic stage of CBM

### 4. Conclusion

The condition assessment of power transformer is one of the important content of electric power equipment maintenance work. From the domestic and foreign research situation, the research on transformer condition maintenance work has got great results. But in general, more attention focused on the specific parameters of the electrical or mechanical monitoring and CBM method based on a single or a small number of parameters of the macro, and lacking of an effective method to characterize the operation state of transformer and various testing, operation conditions, comprehensive relationship.

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