Fault Diagnosis and Performance Analysis of Steam Turbine Thermal System based on Improved BP Algorithm

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Abstract. Steam turbine is an important tool in the growth of power generation work in power plants, and it is of great help to the growth of power generation work. The thermal power plant needs to constantly innovate the unit when generating electricity, and the steam turbine is an important part of the operation of the unit. Therefore, this paper proposes research on fault diagnosis and performance analysis of steam turbine thermal system based on improved BP algorithm. It mainly gives an overview of the steam turbine, and uses the improved BP algorithm scientifically, hoping to provide some help for the application of steam turbine.

Keywords: Improved BP Algorithm; Steam Turbine Thermal System; Fault Diagnosis and Prediction.

1. Introduction

With the rapid growth of computer technology, modern testing technology and signal processing technology, the fault diagnosis technology of equipment has also made great progress, including sonar, infrared temperature measurement and various non-destructive monitoring technologies [1]. At the same time, with the increasingly complex equipment system of modern large thermal power units, the investment in the system is also increasing, and the resulting damage and economic losses are bound to increase [2]. There are many reasons for the failure of thermal power units, and there is a coupling effect between them [3]. When various causes work together, the same fault will have different symptoms in different systems, and even multiple faults will appear in one system at the same time, which brings difficulties to the fault diagnosis of power equipment. In addition, coal power generation process should also take into account the use of the unit, if the unit operates normally, coal resources can be effectively utilized, thereby reducing the cost of coal power generation, and is conducive to environmental protection. As people attach more importance to environmental protection, people's attention to environmental protection is also increasing. Coal enterprises should take social responsibility in their work and actively participate in environmental protection work, which requires us to save energy and reduce emissions [4]. In order to achieve energy conservation and emission reduction, coal enterprises must increase investment and transform original equipment, thereby increasing their power generation costs. However, from the point of view of energy saving and emission reduction, when the circulating pump is actually used, the power difference between the power generation and the water pump must be increased to achieve the purpose of reducing pollution emissions. In the power plant, the steam turbine thermal system is a very important system, and its fault diagnosis and prediction are still in the exploratory stage. Therefore, this paper proposes research on fault diagnosis and performance analysis of steam turbine thermal system based on improved BP algorithm, which will have theoretical and practical significance for improving the operation level of thermal power units and coal-fired power generation.

2. Relevant Theoretical Analysis

2.1 Failure of the Steam Turbine Thermal System

The steam turbine unit is a large and complex system, which includes the steam turbine body, the steam turbine thermal system, the adjustment and safety system [5]. Due to the close connection between the unit equipment and the particularity of the operating environment, it has become a production system with high failure rate and high failure risk. Once a failure occurs, it will bring huge economic and social impacts to the enterprise. In order to monitor and diagnose the operation of the

steam turbine, it is necessary to analyze its fault characteristics in detail [6]. Through the analysis of the failure and propagation mechanism of the steam turbine unit system, we can know the characteristics of the steam turbine unit failure, as shown in Table 1.

Table 1. The characteristics of the failure of the steam turbine unit

Feature	Illustrate
Delay	A process from quantitative change to qualitative change, there is an accumulation process.
Hierarchical	It is determined by the hierarchy of the device structure.
Correlation	Refers to the "horizontality" of the fault diagnosis of the steam turbine unit, which is determined by the relationship between the parameters of the system.

The steam turbine thermal system is mainly composed of high- and low-pressure heaters, deaerators, condensers, feed pumps, condensate pumps, pipelines and valves, etc. Its operating characteristics are directly related to the thermal economy and safety of the unit [7].

The condensing unit occupies a very important position in the steam turbine unit. Due to reasons such as operation, maintenance, installation, design, etc., the vacuum degree of the condenser is very high during operation. If the vacuum degree of the condenser is too low, the effective pressure drop of the condensed water will be reduced, the thermal efficiency of the cycle will be reduced, and problems such as the rise of the exhaust steam temperature of the steam turbine, the deformation of the exhaust cylinder, and the vibration will be caused.

The failure of the feed water heater will directly affect the heat dissipation of the water-cooling wall, superheater, reheater and other components, and then affect the temperature distribution of each component, thereby affecting the combustion of the boiler, thereby reducing the overall work efficiency. The failure of the water heater to work normally will often endanger the safety of the host and other equipment, and even lead to major failures of the equipment. For example, the leakage of the water heater pipeline, or other reasons, the steam side of the heater is filled with water and enters the steam turbine, resulting in the deformation of the steam turbine cylinder, the change of the expansion difference, the vibration of the unit, the dynamic and static friction, the bending of the large shaft, and even the breakage of the blades. Among them, there are many problems in the operation, installation, design, and manufacture of high-pressure high-pressure heating furnaces, which lead to problems in equipment operation, installation, design, and manufacture, resulting in less equipment investment, which is the second largest factor affecting the equivalent availability factor of large units. Second only to boiler burst.

2.2 Performance of Steam Turbine and its Thermal System

A steam turbine is a mechanical device that converts steam into mechanical energy [8]. The steam turbine has many advantages, the first is cost reduction, the more powerful the turbine is, the more steam can be converted into mechanical energy, thereby reducing the investment of power plants and other companies. With the growth of the economy, the demand for electricity is increasing, and the requirements for power plants are also getting higher and higher. The use of water turbines in power plants can improve the efficiency of power generation and improve the economic benefits of enterprises. It is precisely because of the above characteristics that it is increasingly used in power plants.

First of all, for the integrity of the data, it is necessary to consider not only the general process parameters of the main spoke machine, but also some special parameters that are difficult to detect, such as the steam turbine exhaust enthalpy; secondly, the accuracy of the data requires both to ensure the change trend of the process parameters, but also to ensure the numerical accuracy of the process parameters. For example, the requirements for the measurement accuracy of the main steam flow; finally, the consistency of the main process parameters and the main process parameters, such as the consistency of the main steam flow and the unit load. These parameters will have a great influence on the thermal characteristics of the steam turbine.

Factors affecting the operation of the unit include external factors, own factors and operating factors. External factors refer to external environmental factors such as temperature, humidity, and load during the operation of the unit. The steam turbine must run at a suitable temperature. If the temperature is too high or too low, it will adversely affect the work of the unit; the same is true for the load adversely affect operation. Its own factors refer to the heat dissipation efficiency, water pump efficiency, etc. during operation. During operation, a large amount of heat will be generated, which will cause the temperature around the turbine to rise, thus affecting the thermal performance of the entire unit. If the heat dissipation is good, which can quickly dissipate heat, reduce damage to the turbine, and prolong the service life of the turbine. Operating parameters refer to various influences on the operation of the unit during the operation of the unit. For example, an unreasonable sliding pressure curve will affect the stability of the unit and then affect the performance of the unit. Various factors have different effects on the performance of the unit, but it is precisely because of the existence of these factors that the operating stability of the unit needs to be further improved.

2.3 Performance Analysis

The steam turbine generator set and its thermal system are an important part of the power plant. It is of great significance to establish a thermal energy model and quantitatively analyze its characteristics.

The economic diagnosis of the unit is mainly to determine whether the operating parameters and operating modes of its main, auxiliary and thermal systems are reasonable, and to qualitatively analyze whether the operating mode and operating parameters are reasonable. necessary [9].

The earliest application of economic diagnosis is the "small indicator analysis method". Due to its simplicity and convenience, it has been widely used, but its quantitative results are rough and the accuracy is not high. In the 1960s, the "thermal deviation analysis" method has been adopted in Western Europe and North America. In the United States thermal power plant, the thermal deviation method is used for quantitative diagnosis. This method has also been widely promoted in China since the 1980s. Compared with the small index analysis method, the thermal deviation method belongs to a relationship between "point" and "line". In the quantitative analysis, the thermal deviation method takes into account the influence of operating conditions and quantitative deviations on economic indicators under various operating conditions. But its disadvantage is that most of these data come from experience data. Since the 1980s, based on the equivalent heat drop method, a set of thermal and economical diagnostic methods suitable for thermal power plants have been established. This method utilizes the principle of "equivalent start to fall" to decompose the deviations of economic indicators layer by layer. Finally, the economic impact of each operating deviation is obtained. It is characterized in that the interaction of various influencing factors is taken into account in the economic analysis of the thermal system.

Quantitative analysis of the thermal system of the power plant is an important part of the economic diagnosis of the unit, and it is also an effective method. The early calculation method of thermal power system of thermal power unit is "Lightning gauge heat balance method", after simple calculation and improvement, it has developed into "direct heat balance method", which has become the traditional calculation method of thermal system. The calculation results of this method are reliable, but the calculation process is cumbersome and the speed is slow. The current problems are as follows:

(1) Since the operation of the unit is a dynamic process, the entire thermal system is more complicated.

(2) There are still many problems in thermal calculation that have not been completely solved, or have not been solved well.

(3) The prediction and verification of real-time data is not accurate enough, and the data collected by the operation optimization system often has errors. The calculation results of, have a large error, and the reliability of the performance calculation is not high, and it cannot truly reflect the actual working conditions.

2.4 Improved BP Algorithm

The BP neural network is divided into three layers, namely the input layer, the middle layer and the output layer [10]. Neurons at all levels are completely interconnected without any feedback, neurons at all levels have no connection, and there is no interval feedforward, each node can feed forward to all nodes in the next layer. Figure 1 is the basic structure of a neuron, and Figure 2 is a schematic diagram of a typical three-layer feedforward neural network.

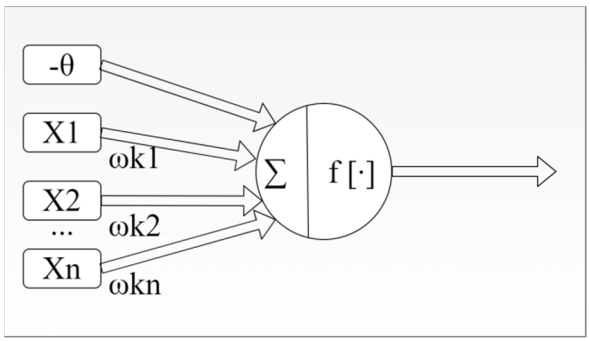


Figure 1. Basic structure of neurons

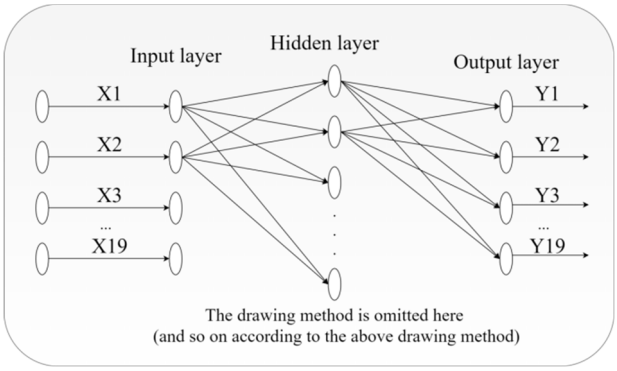


Figure 2. Schematic diagram of the three-layer feedforward neural network

At the input end, the signal is transmitted to the hidden layer through the input layer, and is transmitted to the output layer through the excitation function of the hidden layer node. After the processing of the output layer, the output of the output end is obtained.

The training of the BP network usually adopts the batch algorithm, which is based on the total sample error to represent its learning error, and its calculation formula is:

$$E=\sum_{q=1}^{Q}E_q=\frac{1}{2}\sum_{q=1}^{Q}\sum_{l=1}^{L}\left(t_{ql}-y_{ql}\right)^2 \tag{1}$$

After optimization and improvement, the following formula is obtained:

$$E(v_l)=\frac{1}{Q}\sum_{q=1}^{Q}\left(t_q-v_l^T o_q\right)^2 \tag{2}$$

$$\frac{\partial E(v_l)}{\partial v_l}=0 \tag{3}$$

3. Fault Diagnosis and Performance Analysis of Steam Turbine Thermal System based on Improved BP Algorithm

In the research, the BP algorithm is analyzed and compared, as shown in Figure 3.

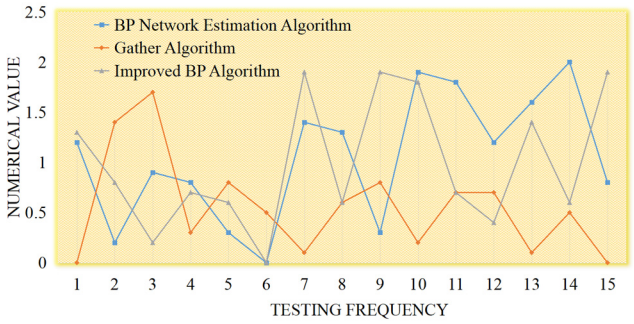


Figure 3. Error comparison chart of the algorithm

By constructing the fitness function of its fault diagnosis evaluation index system, the dynamic search of the optimal evaluation scheme is carried out under the premise of dimension direction and multi-objective constraints. The experimental simulation shows that comparing the algorithms, the numerical errors of the improved BP algorithm in this paper are basically within 1, while the other algorithms are within 2. It shows that the algorithm has better evaluation accuracy and execution efficiency.

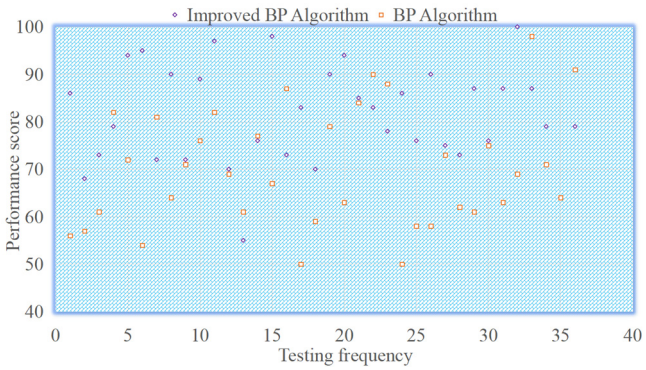


Figure 4. Comparison of performance scores between BP algorithm and improved BP algorithm

As can be seen from Figure 4 above, the overall trend of the performance scores of the two algorithms is similar, both within the range of 50-100 points. However, there are still some differences in the performance scores of the two algorithms. The performance score of the improved BP algorithm is higher than that of the BP algorithm, up to 36 points higher, most of which are higher than 10 points. It is also the other way around. The performance score of the BP algorithm is higher than that of Group A, up to 29 points higher. But the average performance score of the improved BP algorithm is 81.36, while the average performance score of the BP algorithm is 70.08. It can be seen that the analysis effect of the steam turbine thermal system performance based on the improved BP algorithm is very good and has been well confirmed.

4. Conclusion

Due to many characteristics of steam turbines, it can effectively reduce the operating costs of power plants and improve the economic benefits of power plants, so it has been widely used in power plants. In actual use, the operation of the thermal performance system is affected by many factors, including its own and external factors, thus reducing its performance. Therefore, in the optimization process, we should start from improving the operating environment, improving the energy efficiency of the unit, and creating a good operating environment, so as to improve the operating efficiency of the unit. Electricity is an important part of the economy. People's daily life and industrial production are inseparable from electric energy. Therefore, in the future growth, in-depth research and optimization should be carried out. No job is smooth sailing, and the same is true for the growth of

steam turbine units, so the growth of the unit should be fully prepared so that the problems in growth can be solved in time. Therefore, the following strategies are proposed.

(1) Create a good operating environment

When optimizing the thermal performance system of the steam turbine, a better working environment must be created. When the unit is working normally, the operation will bring a certain load to the unit, thus affecting the working performance of the unit. When performing optimization operations, two aspects should be considered: First, select appropriate operating parameters. When determining the operating parameters, many factors such as temperature, humidity, load, energy efficiency, etc. should be considered, and various influencing factors should be considered comprehensively to ensure the rationality of each parameter. When the optimal operation is carried out, the operating parameters must be strictly controlled. The operating parameters are affected by many factors, so that the external environment during the operation changes, and the operating parameters deviate, which must be adjusted in time. Second, lower the temperature to spray. The use of desuperheating spray can reduce the temperature of the unit, but it will increase the humidity of the air around the unit, so other methods must be taken to adjust the working temperature of the unit.

(2) Monitoring the operating environment of the steam turbine

When optimizing, the external environment of the unit must be checked to determine whether its external environment is suitable. When the external environment changes, corresponding adjustments must be made to ensure its normal operation. When monitoring the external environment, the load of the unit must be detected, otherwise the unit will be overloaded during operation, thereby shortening the service life of the unit; on the contrary, if the load pressure is too low, the unit will not be running enough. power, thereby reducing the power generation efficiency of the unit. Only when the load pressure is properly controlled, can it function better. Finally, if the external temperature is too high during the detection, it must be cooled down, so as to ensure the normal operation of the unit. When monitoring, it is also necessary to detect the humidity to keep it within a reasonable range to ensure the normal operation of the unit.

(3) Enhance its own energy efficiency

Finally, by optimizing the thermal characteristics of the unit, the energy efficiency of the unit can be improved, and the energy-saving effect of the unit can be improved. It is necessary to strengthen the technical transformation of the unit, improve the overall performance of the unit, and ensure the operation of the unit. Secondly, it is necessary to regularly maintain the steam turbine to see if there is any potential danger in order to improve the life of the steam turbine. In terms of improving the energy efficiency of the steam turbine, its potential must be fully tapped. If the shaft seal clearance is too large, it will cause the system to leak air during operation and affect its work efficiency. The poor vacuum sealing performance of the condenser or the low working efficiency of the vacuum pump will have a certain impact on the exhaust steam of the coal-fired thermal power unit, and thus have a certain impact on its power consumption. Therefore, these problems must be controlled and developed effectively to improve their energy efficiency.

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