Acqirement of the Basic Value of Heat Deviation Parameters Based on the Generalized Regression Neural Network

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Keywords: Heat Deviation Analysis, Generalized Regression Neural Network.

Abstract. Acquirement of the basic value of heat deviation parameters is the key to application of heat deviation analysis. This paper put forward a method of acquirement of the basic value of heat deviation parameters based on generalized regression neural network (GRNN), which cannot fully understand the conditions of process mechanism, through the study of process data and modeling, excavating implicit relationship between the process parameters and approaching the process mechanism. Finally, take the main steam pressure for instance, the results show that the maximum predicting error of GRNN is 0.06%, and that of BPNN is 1.91%. It is visible that GRNN has a better predictive ability than BPNN, even if lack sample data, it indicates that GRNN prediction model is suitable for small samples. Besides, the design of GRNN model is simple and it has a fast convergence which improves the real-time processing and the prediction ability of reflecting the latest operation condition parameters.

Introduction

Heat deviation analysis is the continuous supervision and analysis of the key parameters of the unit operation and compare the actual operation value of these parameters with the optimization target values, according to some of heat deviation analysis model to calculate the effect of unit coal consumption while these parameters deviate from the optimal target value, thereby optimize the operation management unit, determine the influence reasons, parts and energy-saving potential for affecting the operation economy of unit equipment. It follows that heat deviation analysis is one of the necessary theoretical work for realizing optimal operation and save energy of thermal power units.

At present, the research of heat deviation analysis for thermal power plant is focused on the problem for confirming the basic value of heat deviation, only real-time and accurate confirm the basic value of heat deviation parameters, can the optimal adjustment of operation parameters be more reliable, so minimize the sum of system heat deviation is achieved. Therefore, this paper puts forward a method for
acquiring the basic value of heat deviation parameters based on Generalized Regression Neural Network (GRNN).

**Confirmation Method for the Basic Value of Heat Deviation Parameters in Consumption**

At present, the optimization target values of internal heat deviation analysis system mainly uses the non-real-time reference value, less consider about the change of environmental parameters and the transform of the unit performance with large working condition change, while monitoring and optimizing systems in abroad have been able to dynamically provide control values for operators to reduce energy-loss. Visibly, compared with foreign countries, the performance monitoring and optimization operation technology of thermal power unit in our country still has certain gap.

**Three Methods for Acquiring the Basic Value of Heat Deviation Parameters:**

1) **Design Value, Test Value and Statistics Value.** They often need a large number of test or theoretical calculation, and with the running time of unit goes on, some optimization target value will gradually deviate from the actual performance of system, it is difficult to play the role of guiding operation.

2) **The Mechanism Modeling.** Confirming basic value of heat deviation parameters is essentially the solving process of following optimization problem:

\[
\begin{align*}
\min f(x) &= b' \\
\text{S.t} & \quad g_i(x) \geq 0, \quad i=1, 2, \ldots, m \\
& \quad h_j(x) = 0, \quad j=1, 2, \ldots, l
\end{align*}
\]

(1)

where, the objective function \( f(x) \) represents the coal consumption of the unit; constraint condition \( g_i(x) \) and \( h_j(x) \) respectively represent the basic principle and law of thermoelectric conversion that operation parameters follows; \( x \) represents some controllable operation parameters.

However, confirming basic value of heat deviation parameters is a high-dimensional and multiple constrained complex optimization problems, it is difficult to solve and the optimization model cannot be established in the actual complex process of thermal which leading to the incapable acquirement of theoretical optimal decision variables.

3) **Intelligent Modeling.** Neural network is an excellent intelligent learning method which can excavate the implied relationship of process parameters and approach the process mechanism by studying and modeling with process data while lack knowledge of process mechanism.

This article chooses the generalized regression neural network which has good nonlinear mapping ability, less modeling samples and less artificial parameters.

**The Sliding Pressure Operation Mode of the Steam Turbine**

Constant pressure operation: Boiler following turbine, steam turbine change electric load by changing the position of control valve, boiler maintain steam pressure.

Sliding pressure operation: Turbine following boiler, Boiler change electric load by changing the main stream pressure, the steam turbine maintain the position of control valve.
To define the working condition of the unit with four high control valves, assume that the open order of control valves is GV2 and GV3, then GV1, finally GV4, that is GV2 and GV3 firstly open at the same time, according to the size of tone overlap degree, when GV2 and GV3 is about to fully open then open GV1. With the increase of load, GV2, GV3 and GV1 continue to turn up, when GV2 and GV3 is fully opened, GV1 is close to full open then open CV4. High-pressure control valve of indigenous generating units may have a different practical open order, but have almost the same open method. According to open case of control valve and the size of the main steam pressure, we make definition and classification about working conditions of constant sliding pressure operation as following:

1) the rated working pressure: main steam turbine side maintain the rated pressure, regardless of the state of the speed control valve, so there are multiple rated working pressure for different load points.

2) the 3 point sliding pressure condition: GV2 and GV3 fully open, GV1 valve position control in GV4 is about to open the opening.

3) 2 points by sliding pressure conditions: GV4 fully close, GV2 and GV3 valve position control is set to open when opening GV1.

4) composite sliding pressure condition: control valve not fully open, the main steam pressure not the rated conditions, the opening of the control valve is set with the current actual sliding pressure curve.

![Figure 1. The sliding pressure parameters curve.](image)

The unit number of a Hebei power plant is N600-16.7/537/537, when the load of the unit at or below 300 MW, the steam turbine is rated working pressure, the main steam pressure is set to 10 MPa; when the load of the unit at or above 420 MW, the steam turbine is also rated working pressure, the main steam pressure is set to 16.7 MPa; when the load of the unit is between 300 MW and 420 MW, main steam pressure is proportional to the load, that is sliding pressure operation. Figure 1 is the setting curve of sliding pressure parameter.
Confirming the basic value of main stream pressure in the sliding pressure operation should combine the valve location and open order, otherwise the obtained basic value of the main steam pressure is difficult to implement in DEH control system. Through optimizing the experiment, Hebei electric institute obtain a conclusion that when the unit run in the sliding pressure operation, the unit keep in a 2 point sliding pressure condition, when the opening of GV2 and GV3 is 33% ~ 34%, the heat consumption rates of the unit is the lowest, this is took as the valve state for obtaining the basic value of main steam pressure when the unit is running in sliding pressure operation.

**Generalized Regression Neural Network**

![GRNN Diagram](image)

Figure 2. The topological structure of GRNN.

Generalized Regression Neural Network (GRNN) is a kind of Radial Basis Function (RBF) neural network, it is consisted of three layers, input layer nodes only input signals to the hidden layer, the transfer function of hidden layer nodes is a gaussian function, the output layer nodes is usually a simple linear function. The hidden layer node function (primary function) responds the input signal in a local, when the input signal close to the central range of the primary function, the output of hidden layer nodes will be large, so the GRNN has local approximation ability. Figure 2 is the topological structure of GRNN.

**Based on the GRNN to Acquire the Basic Value of Parameters in Model Design**

Take main steam pressure in the above a certain power plant in hebei for instance analysis, this paper mainly analyzes the basic value of main steam pressure on the sliding pressure operation, so the load range for 300 MW to 420 MW, medium have lignite coal, anthracite coal and lignite coal and anthracite coal mixed, environmental temperature is divided into four stages \([-10 \, ^\circ\text{C} \text{ to } 0 \, ^\circ\text{C}], [0 \, ^\circ\text{C} \text{ to } 10 \, ^\circ\text{C}], [10 \, ^\circ\text{C} \text{ to } 20 \, ^\circ\text{C}], [20 \, ^\circ\text{C} \text{ to } 30 \, ^\circ\text{C}].\)
This paper selects coal, environment temperature, load as input variables, the basic value of main steam pressure and the basic value of the power supply coal consumption as the output value.

**Spreading constant choices**

For the generalized regression neural network, when model of learning samples is affirmative, the corresponding network structure and connection weights between neurons is determined, the training of the network is actually the process of spreading constant is determined. Different from the traditional BPNN, learning algorithm of GRNN need not change the weights of connections between neurons in the process of training, but spread constant change, thus adjust the transfer function of each unit in the model layer, in order to obtain the best regression estimation results.

Visible, the choice of spread constant has a great influence to the creation of GRNN. By adjusting the threshold of hidden layer nodes b1, can adjust the spread constant of the network approximating function, so that the effect of network approximating function is better.

Made a generalized regression neural network function approximation, the spread constant were set to 0.1, 10, and 1, function approximation results as shown in figure 3.

When the spread is 0.1, the curve fitting results will be appeared eligibility, fitting curve appear many peaks that should not have.

When spread for 100, the curve fitting results will be discomfort, the error of the fitting curve is very large.

And spread to 1, curve fitting effect is better, to be able to expect the input and output sample to accurately fitting.

![Figure 3. Spread constant impact on the function approximation.](image-url)

Figure 3 show that the choice of spreading constant has a great influence to function approximation effect of GRNN. MATLAB simulation of acquisition of basic
value of the main steam pressure based on the generalized regression neural network, when the Spread constant is set to 0.07, the curve fitting results neither seen eligibility, also won't appear discomfort, curve fitting effect is better.

**The Simulation Results and Discussion**

Simulation using GRNN and BPNN respectively, and compare the two the simulation results.

312 groups of sample data come from the history database in the above a certain power plant in hebei in table 1, the input vector of the load values for 300 MW, 310 MW,... 420 MW from which I took 26 values; Lignite coal, lignite coal mixed with anthracite coal and anthracite notes for 0, 1, 2 respectively; Environmental temperature is divided into four stages\([-10 ^\circ C \text{ to } 0 ^\circ C],[0 ^\circ C \text{ to } 10 ^\circ C],[10 ^\circ C \text{ to } 20 ^\circ C],[20 ^\circ C \text{ to } 30 ^\circ C]\) notes for 1, 2, 3, 4 respectively.

| load / (MW) | Coal kind | temperature | Main steam pressure / (MPa) | coal consumption / (kg/(kW-h)) |
|-------------|-----------|-------------|----------------------------|-------------------------------|
| 420         | 0         | 1           | 16.70                      | 0.319                         |
| 420         | 0         | 2           | 16.69                      | 0.318                         |
| 420         | 0         | 3           | 16.70                      | 0.319                         |
| 420         | 0         | 4           | 16.70                      | 0.318                         |
| 420         | 1         | 1           | 16.70                      | 0.317                         |
| 420         | 1         | 2           | 16.70                      | 0.316                         |
| 420         | 1         | 3           | 16.69                      | 0.317                         |
| 420         | 1         | 4           | 16.70                      | 0.316                         |
| 420         | 2         | 1           | 16.70                      | 0.315                         |
| 420         | 2         | 2           | 16.70                      | 0.314                         |
| 420         | 2         | 3           | 16.69                      | 0.315                         |
| 420         | 2         | 4           | 16.70                      | 0.314                         |
| 300         | 0         | 1           | 12.20                      | 0.346                         |
| 300         | 0         | 2           | 12.20                      | 0.346                         |
| 300         | 0         | 3           | 12.21                      | 0.346                         |
| 300         | 0         | 4           | 12.20                      | 0.345                         |
| 300         | 1         | 1           | 12.19                      | 0.344                         |
| 300         | 1         | 2           | 12.20                      | 0.344                         |
| 300         | 1         | 3           | 12.20                      | 0.344                         |
| 300         | 1         | 4           | 12.20                      | 0.343                         |
| 300         | 2         | 1           | 12.20                      | 0.342                         |
| 300         | 2         | 2           | 12.20                      | 0.342                         |
| 300         | 2         | 3           | 12.21                      | 0.342                         |
| 300         | 2         | 4           | 12.20                      | 0.341                         |

Table 1. The main steam pressure to acquire the basic value of samples.

In a certain situation that the load, coal and the environmental temperature keep certain, basic value of the main steam pressure is main steam pressure value of the power supply coal consumption is the most smallest; basic value of the power supply coal consumption value is the minimum value of the power supply coal consumption.

The MATLAB simulation is as follows:
Compared figure 4 with figure 5, prediction ability of GRNN is better than BPNN. BPNN often requires multiple iterations for obtaining better prediction effect, the results of this paper is obtained after 3018 iterations, training time is about one minute. But GRNN has much faster convergence speed than BPNN, training proceed is
almost instant, so GRNN can satisfy the need of the training data update consistently and real-time processing.

![GRNN relative error curve](image1)

**Figure 6.** GRNN relative error curve.

![BPNN relative error curve](image2)

**Figure 7.** BPNN relative error curve.

Compared figure 6 with figure 7, the relative error of GRNN is smaller than BPNN, the maximum relative error of GRNN is 0.06%, but the maximum relative error of BPNN is 1.91%, so the accuracy of GRNN prediction is higher.
Besides, compared with BPNN, when lack of sample data, prediction effect of GRNN prediction model is better. GRNN requires much less sample size while get the same results as BPNN, so in the case of difficult to get enough sample size, GRNN is should be a priority. Figure 8 is the GRNN prediction relative error curve when the study sample was reduced to a quarter.

![Relative Error Curve](image)

**Figure 8. Small sample GRNN prediction relative error curve.**

**Conclusions**

Because the generalized regression neural network has good nonlinear mapping ability, less modeling samples and less artificial parameters. this paper proposes a GRNN prediction model to acquire the basic value of heat deviation parameters, which has faster convergence speed and higher convergence precision than BPNN model in the aspect of function approximation. The results show that the GRNN model can better adapt to predict the characteristics of the basic value of heat deviation parameters, confirmed the feasibility and effectiveness of the prediction model.

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