Research and Analysis of Nonlinear Model Identification Control Algorithm Based on Improved Neural RBF For Short Term Heat Load Forecasting of Heat Supply Network

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Abstract. Aiming at the mismatch between heat supply and demand of heating system, a nonlinear model identification control algorithm based on improved neural network for short-term heat load prediction of heat supply network is proposed by using the characteristics that heat load and temperature of heating system will not change dramatically in a short period of time. By using MATLAB simulation, short-term heat load rolling prediction is realized. From the experimental results, this algorithm is better than the traditional RBF neural network in the prediction accuracy, and can accurately predict the trend of heat load.

Keywords: Improved neural network; short-term heat load forecasting of heat supply network; nonlinear model; identification control algorithm; research and analysis.

1. Introduction
The heat supply process is a very complex dynamic system, and the energy and material transfer relationship are highly nonlinear. It is difficult to establish the mathematical model of heat load of heating system through physical models. Moreover, the heat supply network is a large lagging system. The effect of control will only take effect after a certain period of time [1-3], it is necessary to make short-term prediction of the load variation trend of heating network in advance, and to improve the parameters of the pre-regulation controller. In this way, the heating load forecast, especially the short-term load forecasting, can match the heating capacity of the heat source with the heat required by the user, and then the whole system can be coordinated and efficient operation.

The heat load forecasting methods in the field of heat supply network include outdoor temperature heating load curve [4-6], linear regression analysis [7,8-14], neural network [9]. The neural network method does not need to know the mathematical model between input and output in advance, so it is more suitable for the system which cannot establish accurate physical model [15-27].

In this paper, a nonlinear model identification control algorithm based on improved neural network for short-term heat load prediction of heat supply network is presented. A prediction model system based on improved neural network for short-term heat load prediction is established. The rolling
The prediction of short-term heat load is realized by MATLAB simulation. From the experimental results, this algorithm is better than the traditional RBF neural network in the prediction accuracy, and can accurately predict the trend of heat load.

2. Nonlinear model for short-term heat load forecasting of heat supply network

Nonlinear model for short-term heat load forecasting of heat supply network; Neural network, as is shown in Figure 5.

\[ R_i(X-C_i) = \exp \left( -\frac{\|X-C_i\|^2}{2\sigma_i^2} \right), \quad i = 1, 2, \cdots, k \]  

(1)

Fig. 1 Neural network.

Neural network is suitable for multivariable function approximation. As long as the radial basis function center is selected properly, only a few neurons are needed to obtain good approximation effect. The key problem of training RBF neural network is how to determine the center and weight coefficient of RBF neural network effectively.

\[ d_i = \min \|C_j-C_i\| \, , \quad \rho_i = a \cdot d_i \cdot C_k = \frac{1}{n+h-1} \sum_{(p) \in S_k} X_i^{(p)} \]  

(2)

Where: \( a \) is the overlap coefficient, and \( d_i \) is the distance between the \( i \) data center

The corresponding expected output is

\[ \hat{Y}_i = \Phi_{i-1} W_{i-1}, \quad Y_i = \hat{Y}_i + e \]  

(3)

\[ \min J_{i-1} = \|e\|_{F} = \|Y_{i-1} - \Phi_{i-1} W_{i-1}\|_{F} \]  

(4)

The output deviation matrix \( e \) in equation (7) is minimized, and the performance index function of neural network approximating the expected output is defined by norm.

3. Nonlinear model identification control algorithm based on Improved RBF

So, the vector, let’s call it

\[ \Phi_{i-1} = T_{i} \begin{bmatrix} Y_{i-1} \\ \varphi_{i} \end{bmatrix}, \quad \begin{bmatrix} R_{i-1} \\ \varphi_{i} \end{bmatrix} = T_{i} \begin{bmatrix} r_{i-1} \\ 0 \end{bmatrix} \]  

(5)
If $\lambda(j)=0$ are fixed, minimize $\Im(\theta)$, and according to

$$T_1^T \bar{Y}_{i+1} = \begin{bmatrix} \bar{Y}_{i+1} \\ \bar{Y}_{i+1} \end{bmatrix}, \quad T_2^T \begin{bmatrix} \bar{Y}_{i+1} \\ \bar{Y}_{i} \end{bmatrix} = \begin{bmatrix} \bar{Y}_{i} \\ \bar{Y}_{i} \end{bmatrix}$$

(6)

$$\|\bar{Y}_{i}\|_F^2 = \|\bar{Y}_{i}^T\|_F^2 + \|\bar{Y}_{i-1}\|_F^2$$

(7)

In the formula, $\|\bar{Y}_{i-1}\|_F$ is the error caused by $i-1$ data input; QR recursive decomposition can be performed by givens rotation transformation; $R_i$ is an upper triangular matrix, and the linear output weight matrix $W_i$ can be obtained by equation (8).

4. Steps of improving RBF neural network

Dynamic mean clustering and rlos algorithm are applied to RBF neural network to form improved RBF neural network. The algorithm steps are as follows:

Step 1: select $k$ historical data with large difference from heat network data as the initial cluster center $C_i$.

Step 2: each time a new training data vector $X$ is input, the distance $d$ between the new training data vector and the initial clustering is calculated to obtain the minimum $d_{\text{min}}$.

Step 3: after the network center is determined, the cluster radius can be recalculated by Equation (4) until all input vectors are assigned to the cluster.

Step 4: calculate the weight $W_i$ of prediction data output from hidden layer to output layer.

Step 5: output load forecast value.

Step 6: test the trained model and apply it to short-term rolling prediction.

5. Research and analysis

In this paper, based on the improved neural network, a nonlinear model identification control system for short-term heat load prediction of heat supply network is established, and the rolling prediction of short-term heat load is realized by MATLAB simulation. Our Lab, as are shown in Figure 2.

![Fig. 2 Our Lab.](image-url)
Comparative analysis of nonlinear model identification control based on Improved RBF.1, Comparative analysis of nonlinear model identification control based on Improved RBF.2, Comparative analysis of nonlinear model identification control based on Improved RBF.3, as are shown in Figure 3-6.

Fig. 3 Comparative analysis of nonlinear model identification control based on Improved RBF.1.

Fig. 4 Comparative analysis of nonlinear model identification control based on Improved RBF.2.

Fig. 5 Comparative analysis of nonlinear model identification control based on Improved RBF.3.

Nonlinear economic operation and management identification for anti-hail apple bagging.3. Comparative analysis of nonlinear model identification control based on Improved RBF.3, as is shown in Figure 4.
4. In Figure 2-5, a prediction model system based on improved neural network for short-term heat load prediction is established. The rolling prediction of short-term heat load is realized by MATLAB simulation. From the experimental results, this algorithm is better than the traditional RBF neural network in the prediction accuracy, and can accurately predict the trend of heat load.

6. Summary
In this paper, a nonlinear model identification control algorithm based on improved neural network for short-term heat load prediction of heat supply network is presented. A prediction model system based on improved neural network for short-term heat load prediction is established. The rolling prediction of short-term heat load is realized by MATLAB simulation. From the experimental results, this algorithm is better than the traditional RBF neural network in the prediction accuracy, and can accurately predict the trend of heat load.

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