Power grid electricity prediction model in multi-dimensional scenarios

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Abstract. The prediction of power grid electricity is the key to ensure the reliable and economic operation of power system. In order to improve the accuracy of power grid electricity forecast, a new power grid electricity forecast model in multi-dimensional scenarios is proposed in this paper. The simulation results show that this method has higher prediction accuracy, and it provides a new idea for the research of power grid electricity prediction.

Keywords. Multi-dimensional scene; Grid electricity; BP neural network

1. Introduction

The development of electric energy is an important driving force for the development of modernization and for accelerating the pace of building a well-off society in an all-round way. In our country where power consumption is huge and the power industry is booming, accurate electricity sales forecasts are of great significance to the construction and planning of the national grid. According to incomplete statistics, each increase of 1% error in the forecast of electricity sales in some typical areas will result in an additional operating cost of about 17.7 million yuan [1]. It can be seen that every progress in the research on electricity sales forecasting has strong economic and practical significance.

In the power market environment, seasonal electricity forecasting for urban power grids is one of the basic tasks of power supply companies' marketing and line loss management [2]. Accurate electricity forecasting can promote the smooth development of marketing and line loss management. Therefore, for power supply companies, how to achieve fast, feasible and accurate electricity forecasting is the goal to be pursued [3]. However, in the actual electricity forecasting process, it was discovered that there were three urgent problems in the quarterly electricity forecast. (1) Electricity seasonal data has the nonlinear characteristics of volatility and trend. It is difficult for a single forecast model to describe this nonlinear change process, so it is difficult to meet the requirements of forecast accuracy. (2) Electricity seasonal data, which not only has its own law of change, but also has certain uncertainty due to internal and external factors; in the mathematical modeling process, if relevant variables cannot be introduced to reflect these two characteristics at the same time, It will cause the prediction model to fail to correctly reflect the true change process of the electricity data, and reduce the reliability of the prediction results. (3) Due to the randomness of the changes in electricity data, the prediction model with high fitting accuracy to historical data may not have the highest accuracy in predicting future electricity; the traditional model selection mechanism that selects the prediction model with fitting accuracy, if Abandoning other prediction models with less precision fitting may not get correct prediction results. These three problems make it difficult for the quarterly electricity data to meet the required accuracy requirements. Therefore, only by establishing a forecasting method that can reflect the changing law of electricity from multiple angles and introduce
external variables to describe the changing process of electricity can the forecast accuracy of quarterly electricity be improved.

The quarterly total electricity (electricity sales/power supply) data of the urban power grid has a dual trend of growth and seasonal volatility, and there are many influencing factors and uncertainties [4]. For seasonal fluctuation data, without introducing other variables, simply relying on a single electricity data change law to establish a forecast model for forecasting cannot fully reflect the impact of the change trend of industry power consumption within the urban power grid on the urban power grid. It cannot reflect the relationship between external economic and other related factors and the power supply of the urban power grid [5-6]. Therefore, the mathematical model of multivariate modeling can be used from multiple dimensions to make up for the shortcomings of single-dimensional forecasting methods.

According to the characteristics of electricity consumption, this article comprehensively analyzes related influencing factors such as electricity consumption by industry and economy: the electricity consumption of each industry reflects the changing law of power supply, and at the same time, economic data is introduced as the influencing factor of the total electricity of the urban power grid. Accurately model the amount of electricity to the greatest extent.

Therefore, if the existing social power industry can be classified in detail through a variety of methods, and a multi-dimensional scenario power prediction model can be studied to realize the power analysis and prediction of the entire region, and the medium and long-term load prediction methods can be improved and perfected, it will be a very pioneering work, it also meets the requirements of power market construction.

2. Electricity consumption classification and phase influencing factors of urban power grid industry

(1) Industry electricity consumption classification

Industry electricity is the basis for the supply and sale of electricity in the urban power grid. Each city has its own industry characteristics. The electricity consumption trends of different industries have different impacts on the electricity supply and sales of urban power grids. Even the electricity consumption trends of a certain industry can dominate the change trend of urban power grid electricity. Therefore, according to user types Industry classification of users; collect industry sample data and total electricity data, and select industry data based on the correlation between the two, and establish a prediction model based on the leading industry sample data; realize the use of small sample industry electricity data to compare cities Forecast of grid electricity. At present, according to the electricity price and the nature of the load, my country divides users into five types: large industrial users, ordinary industrial users, residential users, commercial users and other users (rice field irrigation and drainage, agricultural production), among which according to whether the capacity of the power receiving transformer reaches 315kVA divides industrial users into bulk industry and general industry.

(2) Introduction of influencing factors

This article mainly studies the influence of economic factors on the changes in electricity supply/sales of urban power grids, that is, using economic data to build electricity forecasting models. The main economic indicators are: regional GDP, primary industry GDP, secondary industry Gross production value, tertiary industry gross output value, industrial added value, total foreign trade exports, etc.

3. Mathematical model of multi-dimensional forecasting method based on industry power consumption and related factors

At present, BP neural network is one of the most widely used and successful ANN methods in dealing with nonlinear problems. It is a predictive model based on the "backstepping" learning method of multilayer networks. Figure 1 shows the structure of a 3-layer BP neural network.
This paper selects a three-layer forward network BP neural network to predict and analyze the electricity of the urban power grid. The three-layer neural network is the input layer, the hidden layer and the output layer, and each layer is fully connected. The prediction process of the BP neural network includes two steps; first, when the learning sample is input into the network from the input layer, the activation value of the neuron propagates from the input layer through the hidden layer to the output layer; then, to reduce the target output and actual power data. The error is the goal, from the output layer to the hidden layer, each connection weight is corrected layer by layer, and finally back to the input layer. This algorithm is called "error back propagation method", that is, BP algorithm. Repeated error back propagation to correct each connection weight until the preset error accuracy is met, thereby improving the fitting accuracy of the BP neural network. The model can be summarized as:

(1) Forward propagation process of signal
The input of the I-th node of the hidden layer is \( net_i \):
\[
net_i = \sum_{j=1}^{M} w_{ij}x_j + \theta_i \tag{3-1}
\]

In the formula, \( w_{ij} \) represents the weight between the i-th node in the hidden layer and the j-th node in the input layer; \( \theta_i \) represents the threshold of the i-th node in the hidden layer.

The output of the i-th node in the hidden layer:
\[
y_i = \phi( net_i ) = \phi( \sum_{j=1}^{M} w_{ij}x_j + \theta_i ) \tag{3-2}
\]

In the formula, \( \phi(x) \) represents the activation function of the hidden layer, and an S-shaped function is used.

The input \( nets \) of the kth node of the output layer:
\[
nets = \sum_{i=1}^{q} w_{ki}y_i + a_k = \sum_{i=1}^{q} w_{ki}\phi( \sum_{j=1}^{M} w_{ij}x_j + \theta_i ) + a_k \tag{3-3}
\]

In the formula, \( w_{ki} \) represents the weight between the kth node of the output layer and the ith node of the hidden layer, \( i=1,\ldots,q; \) represents the threshold value of the kth node of the output layer, \( k=1,\ldots,L \).

The output \( a_k \) of the kth node in the output layer:
\[
a_k = \psi( nets ) = \psi( \sum_{i=1}^{q} w_{ki}y_i + a_k )
\]
\[
= \psi( \sum_{i=1}^{q} w_{ki}\phi( \sum_{j=1}^{M} w_{ij}x_j + \theta_i ) + a_k ) \tag{3-4}
\]
In the formula, $\psi(x)$ represents the activation function of the hidden layer, and $\psi(x)$ uses a linear function in this paper. For each sample $p$, the quadratic error objective function is $E_p$:

$$E_p = \frac{1}{2} \sum_{k=1}^{L} (T_k - o_k)^2$$

(3-5)

In the formula, $T_k$ is the target output value. Accumulate the sum of squared errors of a single sample, and the objective function of the total error is:

$$E = \frac{1}{2} \sum_{p=1}^{P} \sum_{k=1}^{L} (T_k^p - o_k^p)^2$$

(3-6)

$E$ is used to evaluate the learning state of the entire network. When $E$ and the pre-given error value meets $E - \varepsilon \leq 0$, the algorithm ends, otherwise it shifts to error direction propagation calculation.

(2) Back propagation process of error

Error back propagation, that is, the output layer starts to calculate the output error of each layer of neurons layer by layer, and then adjusts the weight and threshold of each layer according to the error gradient descent method, so that the final output of the modified network can be close to the expected value.

According to the error gradient descent method, the output layer weight correction amount $\Delta w_i$; the output layer threshold correction amount $\Delta a_k$; the hidden layer weight correction amount $\Delta w_j$; the hidden layer threshold correction amount $\Delta \theta_l$; their calculation formula is as follows:

$$\Delta w_i = \eta \sum_{p=1}^{P} \sum_{k=1}^{L} (T_k^p - o_k^p) \cdot \psi'(net_i) \cdot y_i$$

(3-7)

$$\Delta a_k = \eta \sum_{p=1}^{P} \sum_{k=1}^{L} (T_k^p - o_k^p) \cdot \psi'(net_i)$$

(3-8)

$$\Delta w_j = \eta \sum_{p=1}^{P} \sum_{k=1}^{L} (T_k^p - o_k^p) \cdot \psi'(net_i) \cdot w_j \cdot \phi'(net_l) \cdot x_j$$

(3-9)

$$\Delta \theta_l = \eta \sum_{p=1}^{P} \sum_{k=1}^{L} (T_k^p - o_k^p) \cdot \psi'(net_i) \cdot w_j \cdot \phi'(net_l) \cdot \phi'(net_l)$$

(3-10)

among them $\frac{\partial \psi}{\partial net} = \phi'(net_l)$

$$\frac{\partial \theta_l}{\partial net_i} = \phi'(net_l)$$

In this way, as long as the parameters of the model are initialized with a small random number, model training, learning and prediction can be carried out. The prediction flow chart of BP neural network is shown in Figure 2.
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Figure 2 Forecasting flowchart of BP neural network

4. Simulation

(1) BP neural network prediction model

The input of the BP neural network prediction model is the electricity consumption of the automotive industry, the electricity consumption of the electronics industry, the electricity consumption of the food and drug industry, the electricity consumption of the metal processing industry, the electricity consumption of light industry daily chemicals, the gross regional product (GDP), industrial value-added and total import and export, therefore, the input neuron of the neural network is 8; and the output value is the power supply, so the output neuron is 1. The selection of the number of neurons in the hidden layer is based on an empirical formula, which is:

\[ M = \sqrt{n + m + a} \]  \hspace{1cm} (4-1)

In the formula, \( n \) is the number of neurons in the input layer; \( m \) is the number of neurons in the output layer; \( a \) is an integer \( 1 < a < 10 \).

(2) Predictive analysis and results

In this paper, after calculating multiple neural network models with \( M \) values, it is believed that when \( M \) is set to 12, the network is optimal; therefore, the number of hidden layers of the neural network is set to 12. The choice of learning rate tends to choose a smaller value in general to ensure stability. This article takes the learning rate as 0.01. In actual application, it is found that when using BP neural network to predict the power supply, the training error accuracy should not be set too high, because too high error accuracy will lead to network over-learning and data over-fitting, and the fitting effect is good. The phenomenon of large prediction errors; therefore, the training error accuracy selected in this article is 0.01. It can be seen from Figure 3 that in the BP neural network, a small number of predicted values have large deviations, and the
remaining predicted values have good accuracy. Therefore, as long as appropriate prediction samples are provided, the BP neural network can be used to predict and analyze the power supply.

![Figure 3 Fitting Graph of BP Neural Network](image)

**5. Conclusions**

This paper mainly solves the problems that need to be solved in the actual work of electricity forecasting, and constructs a multi-dimensional forecasting method based on industry electricity consumption and related factors. This method includes reflecting the change of electricity supply itself. The result of the law also includes the result that reflects the influence of industry power consumption and economic factors on the power supply. Through the neural network prediction model, the prediction result is better than the single-dimensional model, which verifies the effectiveness of the algorithm and guides the output of generators and transformers. Economic operation and grid planning provide reliable electricity forecasts, and also provide a new idea for quarterly electricity forecast research.

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