Power Load Forecasting Based on BP Neural Network

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Abstract. Load prediction of power system plays an important role in real-time control and ensuring economic, safe and reliable operation of power system. At the same time, the variation of power load system parameters is affected by many factors, which will lead to the nonlinear development of load curve. In this paper, a prediction method based on BP neural network is proposed. The biggest advantage of this method is that it has adaptive function to a large number of nonlinear characteristics and non-accuracy laws. This paper mainly focuses on the application of BP neural network in short-term load prediction of power system to do further research, and through MATLAB BP neural network design, simulation results show that the application of BP neural network in short-term load prediction is feasible, can better reflect the nonlinear characteristics of load prediction. However, because this paper does not consider the effects of climate, temperature, holidays and other factors, there is still a certain gap between the simulation results and the ideal results, but it is certain that BP neural network is still better than the traditional prediction method, is a very promising new research and development field.

Keywords: power load prediction, BP neural network, power storage, power dispatching.

1. Introduction

The prediction of electric load plays an extremely important role in the process of electric power production and use. Through the high accuracy of load prediction, the unit can be economically and reasonably arranged to start and stop, reduce the rotating reserve capacity, reasonably arrange the maintenance plan, reduce the cost of power generation and improve the economic benefit[1]. Therefore, the theory of load prediction of power system is developed, especially in the process of forming electricity trading market, the research of load prediction is of great significance.

One of the characteristics of electric energy is that it cannot be stored in large quantities, that is, the generation, transmission, distribution and consumption of electric energy are carried out simultaneously, so the available power generation capacity in the system should be able to meet the requirements of the load in the system at any time under normal operating conditions[2]. If the generating capacity is insufficient, necessary measures shall be taken to increase the generating set or import the necessary power from the adjacent network; On the contrary, if the power generation capacity is surplus, necessary measures should also be taken, such as selective shutdown or output of excess energy to the neighboring network. Therefore, the prediction of the trend and characteristics of the load change in the future is one of the basic information that must be possessed by the dispatching department and planning and design department of the power network. Under the current market operation conditions, due to the more frequent electricity transactions and the differences between operating entities, there will be various uncertain factors, and the sensitivity of load to electricity price is gradually enhanced with the improvement of the market, which also brings new difficulties to load forecasting. As the market parties attach more importance to the acquisition of information and the economy of operation, accurate forecasting plays a direct role in improving the operating benefit of the main body of power operation, and the importance of short-term load forecasting becomes more prominent[3].

2. Review of existing power load forecasting methods

In the past, load forecasting often relied on the dispatching personnel's work experience to make intuitive judgment, that is, according to the existing data and experience, to compile load forecasting curve. In recent years, many scholars have studied on this, put forward many kinds of forecasting methods, and timely applied the latest advances in mathematics to forecasting, so that the level of forecasting has been rapidly improved, and the research on load forecasting has made great progress.

The existing load forecasting methods can be divided into classical methods and intelligent technology. Classical methods are mainly time series models based on various statistical theories, while intelligent technologies include artificial neural networks and expert system methods[4]. Specific prediction methods are as follows:

2.1 Regression analysis method

Regression prediction is a common method of load prediction, which is to find the regression equation between independent variables and dependent variables according to the change rule of historical data, determine the parameters of the model, and make prediction based on it. It is divided into unary linear regression, multiple linear regression, unary nonlinear regression and multiple nonlinear regression.

2.2 Time series method

Time series models include autoregressive (AR), moving average (MA), autoregressive moving average (ARMA) and other models. The time series method usually involves sequence partial leveling, model identification, model order determination, model parameter estimation, model testing and load prediction. Because the time series method assumes that the load curve is a stable time series, but in fact the power system load is not a stable time series, so when it is used to predict the weekend, holiday or seasonal variation cycle, the prediction accuracy will be relatively poor. Meanwhile, the model is relatively complex and the huge amount of calculation is also its shortcoming[5].

2.3 Neural network prediction method

Neural network load forecasting is a widely used load forecasting method in recent years. Its advantage is that it has adaptive function to a large number of non-structural and non-accurate laws. Among them, BP neural network has strong nonlinear fitting ability, especially convenient for weather, temperature and other factors in the prediction.

The main task of using artificial neural network to predict the load of power system is to simulate the running law of load by using artificial neural network which can approximate the characteristics of any nonlinear process with any precision[6].

The advantage of using neural network technology for power load prediction is that it has adaptive function to a large number of non-structural and non-accurate laws, and has the characteristics of information memory, independent learning, logical reasoning and optimal calculation. Its self-learning and self-adaptive functions are not possessed by conventional algorithms and expert systems.

2.4 Principle of BP neural network

According to the direction of network information transmission, neural network can be divided into feedback network and forward network. Error back propagation neural network is called BP network. BP neural network can learn and store a large number of input-output mode mapping relations, is a one-way propagation multi-layer forward network, before storing information without revealing the mapping relationship of mathematical equations. The input layer, output layer and hidden layer constitute the topology of BP neural network model. Widely used in adaptive control, image processing, pattern recognition, optimization calculation, system identification, optimal prediction, function fitting and other fields. Figure 1 is a schematic diagram of BP network[7].

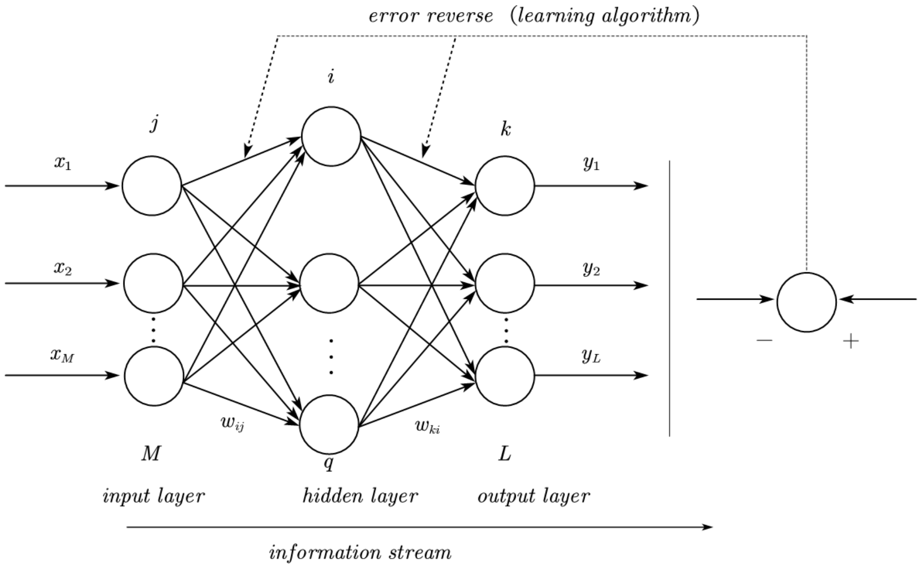

Figure 1 Diagram of the BP neural network

Forward propagation and back propagation constitute the algorithm learning process of BP neural network.

In the forward propagation process, the network information passes through the hidden layer from the input layer to the output layer. During transmission, the state of the basic neural units in each layer only affects the state of the basic neural units in the next layer. If the desired output results cannot be obtained at the output layer, then reverse propagation will be carried out. The system error signal will return along the original connection path, and the weight of neurons at each layer will be modified to minimize the error signal[8].

As shown in Figure 1, there are M input nodes in the structure diagram of BP network, and the input of each input layer node is equal to the output of this node. The hidden layer has Q neurons and L output nodes, W_{ki} is the connection weight between the hidden layer and the output layer, W_{ij} is the connection weight between the input layer and the hidden layer. The weighted sum of the outputs of the nodes in the previous layer is the total number of inputs of the nodes in the hidden layer and the output layer, the excitation function of the node, and the input signal and determine the excitation degree of the node[9].

3. The main function

Given N training samples, it is assumed that the input/output mode of sample P carries out network training for X_p and $\{d_{PK}\}$, and the input of the ith neuron of the hidden layer under the action of P is:

$$net_{pi} = net_i = \sum_{j=1}^{m} w_{ij} o_j \tag{1}$$

The output of the ith neuron is:

$$o_i = f\left(net_i\right), \tag{2}$$

Where the excitation function is:

$$f\left(net_i\right) = \frac{1}{1+\exp\left[-\beta . net_i\right]} \tag{3}$$

As the value of β approaches infinity, the excitation function approaches the step function, and the value of β is set to 1.

Substitute β=1 into Formula (3) to obtain the derivative:

$$f'\left(net_i\right) = f\left(net_i\right)\left[1-f\left(net_i\right)\right] \tag{4}$$

Through the weighting coefficient W_{ki}, the output of the ith node propagates forward to the kth neuron and serves as one of the inputs of the kth neuron[10]. The total input number of the kth neuron in the output layer is:

$$net_k = \sum_{j=1}^{q} w_{ki} o_i \tag{5}$$

Thus, the total output number of the kth neuron in the output layer is:

$$o_k = f\left(net_k\right) \tag{6}$$

If the desired output of a given model dk do not agree with the output of the neural basic unit, the error signal will back propagation along the route from the output end, and in the process of transmission, modifying neurons weighting coefficient, makes the output maximum possible close to the d_k of the weighted coefficient of sample P adjustment is completed, and then into the next sample model for similar operations, Until you've done N samples of training[11].

4. The example analysis

In this paper, based on the number of power loads in the past few years, the BP neural network is used to predict the power loads of the following year, and the results of the power loads of the New Year are obtained. Then the data of the New Year are added to the training set to obtain the power load data of the next year.

A large number of repeated operations are required to make prediction using the above methods. Here, we only take out a group of training results for analysis.

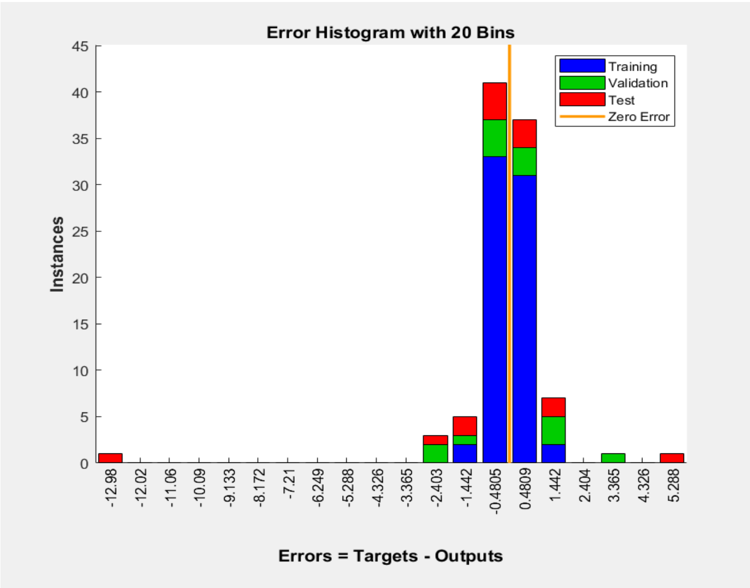

Figure 2 Error distribution diagram

Figure 2 shows the prediction results of power load data in 2022 based on the power load data from 2014 to 2021. It can be seen that most of the predicted results are located near the zero-cut error line, so it can be seen that the error predicted by this method is within the tolerable range.

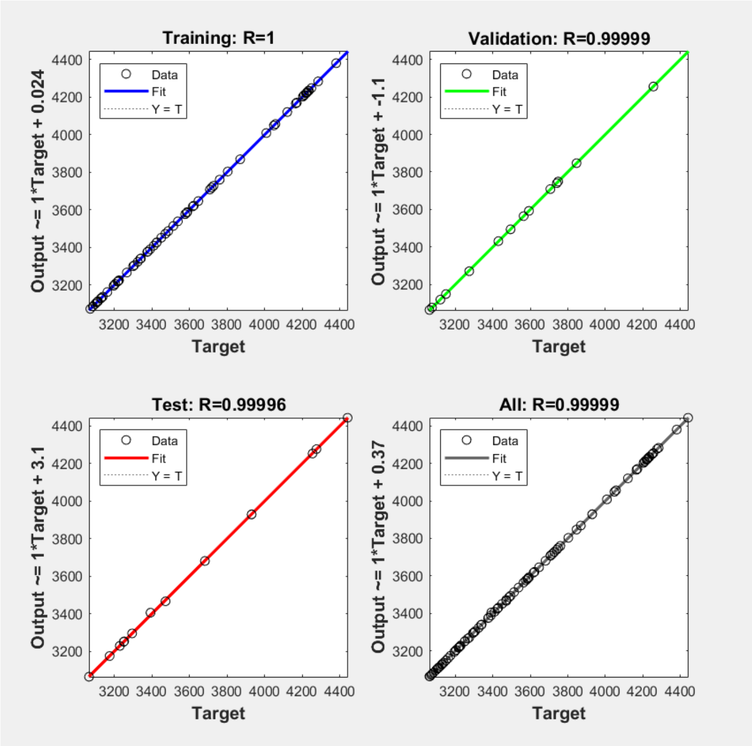

Figure 3 Correlation coefficient diagram

It can also be seen from Figure 3 that the results predicted by BP neural network are highly consistent with the training set, and the correlation coefficient is as high as 0.99999. It can be considered that the error of the results obtained by this method is almost zero.

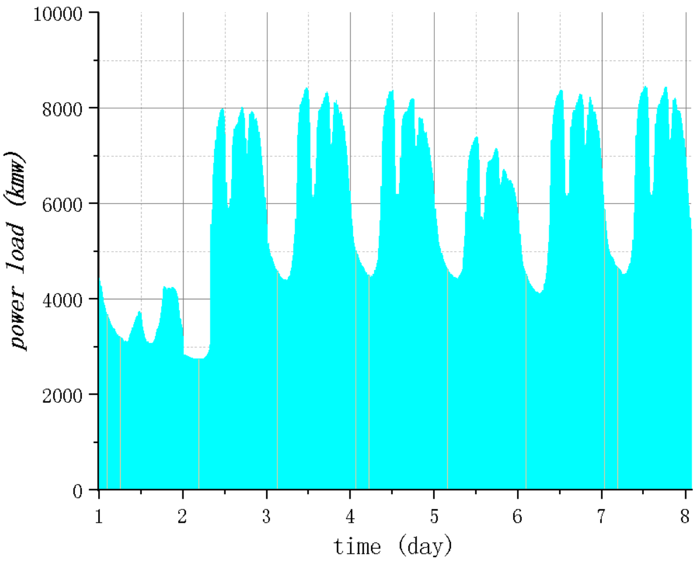

Figure 4 Power load forecast for the first week of 2022

By using BP neural network algorithm to predict the power load data in the first week of 2022, Figure 4 is drawn and analyzed. It can be found that the power load on the first day of 2022 is very low. The characteristics of China can be analyzed as most factories and enterprises are on holiday on the first day, so the power load ratio decreases. After the first day, the power load start area is stable and the daily power load trend, peak value and valley value are almost the same. The peak daily power load is approximately 8000kMW, and its daily trough value is approximately 4500kMW.Next, the image of a day after the power load leveled off was extracted for a more detailed analysis.

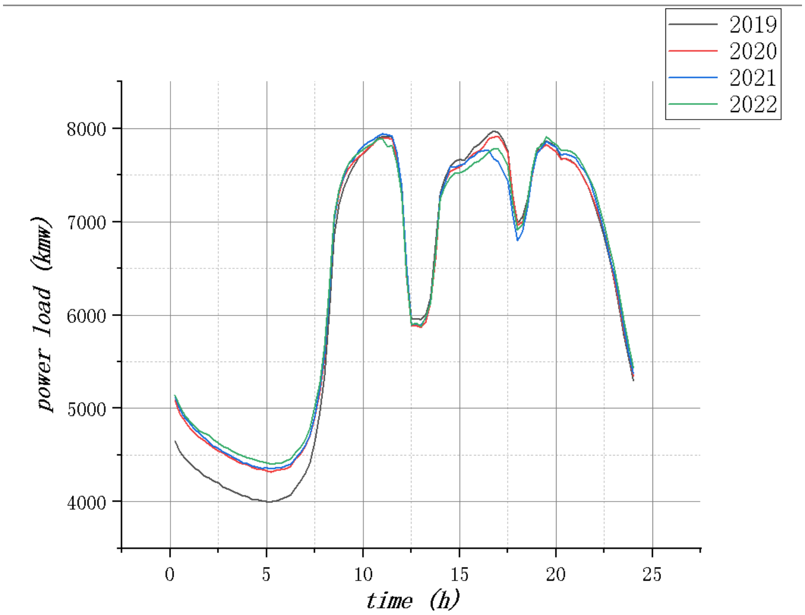

Figure 5 Third day power Load comparison chart for each year 2019-2022

The data of the third day of the first week of 2019-0222 were taken out to draw a multi-y-axis graph, as shown in Figure 5. It can be seen from the graph that the trend of power load on the same day in these four years was roughly the same without too serious error. By analyzing the overall image, it can be found that the overall power load from 20:00 to 5:00 in the morning shows a trend of mutual decline. It can be analyzed that most people are resting during this period, and the power load level is naturally at a low level. From 5:00 to 11:00, the overall power load is at an increasing level, and during this period, the power load is rising during working hours. At about 12:30, the power load level reached the underestimate again. At this time, it was in the lunch break and the power load level was low. The power load level rises again after 12:30, corresponding to the working time in the afternoon; At 5:30 p.m., the power load reached its lowest level again, just before the end of the workday. After that, the power load level increases again, which can be analyzed as the power load level rises again after sunset due to the activation of electric appliances such as lights. However, the power load level starts to decrease again after 20:00 when some people fall asleep.

In Figure 4 we have found that a year on the first day of the power load is small, the first day of a year for the first day of the New Year the majority of people are at home to rest, at this time of power load can be thought of as a family of electricity power load levels, we can through in recent years, the first day of the power load analysis in recent years the trend of electricity load.

Figure 6 is drawn by extracting the power load data of the first day of each year from 2009 to 2022. It can be found that the household electricity consumption increased steadily from 2009 to 2014, and the power load level began to stabilize after 2014. From this, it can be inferred that the household electrical appliance level of residents was at a high development speed from 2009 to 2014.After 2014, the level of household appliances was in a saturation state of development, so the power consumption level began to be stable in the region.

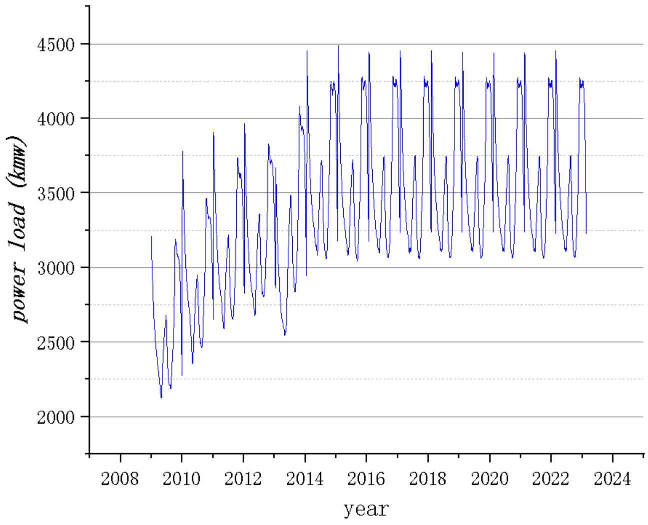

Figure 6 Comparison of power load on the first day of each year, 2009-2022

Figure 7 is drawn to analyze the broken line chart of the peak value of a certain power load level on each day from 2017 to 2022. It can be clearly analyzed from the Figure that the power load level from 2017 to 2022 increases year by year. A careful observation of the actual starting point of each year shows that they are the minimum value of the power load level of each year. This can be well interpreted with Tuhaha (the first day of each year in 2017-2022 has no obvious growth trend).

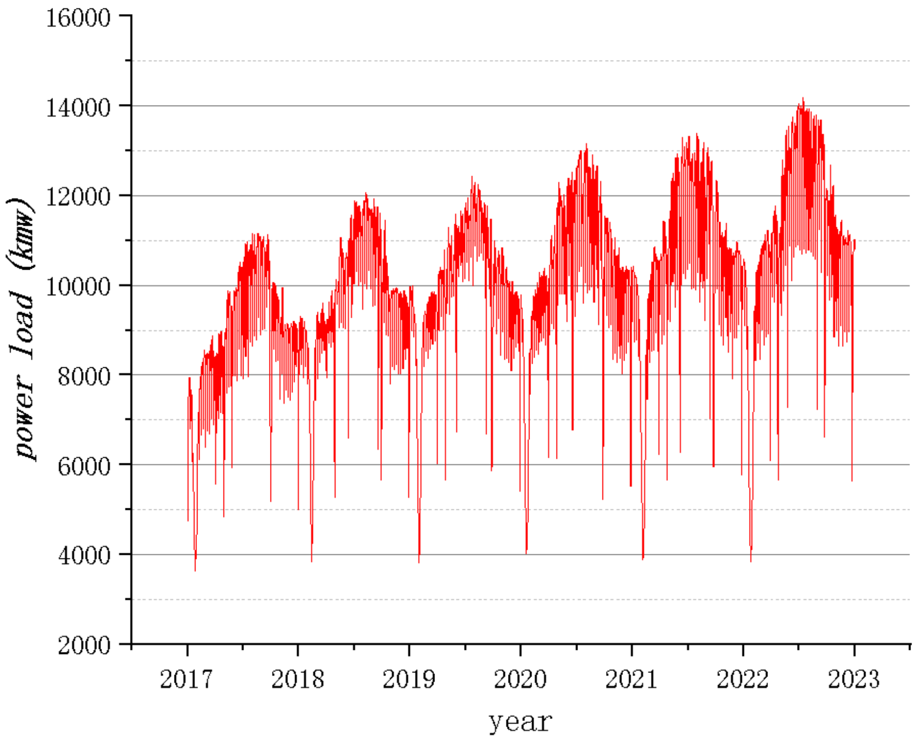

Figure 7 Comparison of power load peaks from 2017 to 2022

Through the above analysis, it can be concluded that in recent years, the overall annual power load level is in a steady rise and the peak value is also in a rising state; The trend of power load in 2022 is almost the same as that in 2021, and there is no significant difference. The power load is in a rising state from the beginning of the year to the middle of the year, and then begins to decline after the middle of the year. Based on the above analysis, the excess power at the beginning of the year and the end of the year can be stored in pumped storage, compressed air energy storage and other ways until the mid-year when the power load is high. The power load trough at the beginning of each year has not changed significantly in the past six years, and is roughly at 4000kMW.

5. Conclusion

This paper studies the application of BP neural network to load forecasting. This paper introduces the knowledge of neural network, and takes The Chinese load as an example to predict the load.

Load forecasting is the basis of power system operation, and it is very important to the decision-making process of power department, so the accuracy of load forecasting is required more and more high. According to this paper, neural network has learning function, has incomparable advantages in solving nonlinear problems, and has good development prospects in load prediction. Forecasting is one of the most potential applications of power system, and load forecasting is the most suitable field of neural network in power system application.

However, there are still some problems to be solved when neural network is used for load prediction. BP algorithm has three familiar essential shortcomings: first, it is slow in convergence speed. BP algorithm is usually used to solve a network with four or five components. Secondly, the fault tolerance of the network is poor. Again, the algorithm is incomplete.

At present, China is in a serious period of power shortage, so it is necessary to rationally dispatch power resources to reduce the economic loss caused by power shortage as far as possible, especially in the current situation of energy market deregulation. Neural network for load forecasting needs further research to provide more accurate predictive values for power department decision-making and power dispatching.

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