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Day-ahead Electricity Price Prediction Based on Improved ANN Information Fusion

Abstract. *A novel information fusion method is proposed based on the characters of day-ahead electricity price. An improved BPNN is used for its better performance as the core algorithm of information fusion. Using the information fusion ideas, a new modelling approach is proposed to establish the prediction model. The day-ahead electricity price prediction model is tested by the real data. The experiments demonstrate that the new prediction model established by improved BPNN information fusion method has better performance.*

Streszczenie. *W artykule przedstawiono nową metodę fuzji danych w oparciu o charakterystyki cenowe elektryczności z dnia poprzedniego. Algorytm oparto na sieci neuronowej BPNN. Jego działanie poddano badaniom, bazując na prawdziwych danych, których wyniki wskazują na skuteczność działania proponowanego rozwiązania. (**Jednodniowa predykcja cen elektryczność metodą fuzji danych z wykorzystaniem sieci neuronowych**).*

Keywords: Information fusion; electricity price prediction; BP neural network.
Słowa kluczowe: fuzja danych, predykcja cen elektryczności, sieć neuronowa BP.

Introduction

In electricity power market, the electricity price is closely related to the benefits of market participants. It also affects many aspects of society and economy. Therefore, the electricity price is a big focus problem of the society. For government, power enterprises and public, it is profoundly significant to predict the electricity price accurately. The electricity power market has the characters of big fluctuation of electricity price and big difference of electricity price among the different markets. There are many spikes during the whole period and no regularity. Consequently, it is difficultly to predict the electricity price accurately because above factors. The main methods of electricity price prediction could be divided into tow classes. One class is traditional mechanism method which computes the electricity price by modeling an electricity power market model of real operation [1, 2]. This kind of methods can reflect the real states of electricity power market and have a good performance of electricity price prediction in short-term. A lot of information should be supplied using this kind of methods. For example the units operating states of electricity power market, the operating states of power transmission network, the related information of neighboring electricity power markets, and so on. In addition, the system load flow, power economic dispatching and physical block also should be obtained for the mechanism model. Moreover, some of the information could be obtained very difficultly. Therefore, it is more difficult for general market participants to predict the electricity price using this kind of methods. The other class of methods is statistical method which establishes the electricity price prediction model by using the history electricity price information, power system information method and so on [3]. The statistical method is simple than the traditional mechanism. The information being used to establish the electricity price can be selected according to the need of user. A new information fusion method with improved BP neural network algorithm is proposed to establish the model. The experiments with real data demonstrate that the prediction mode based on information fusion has better accuracy.

The technique of information fusion

Information fusion is a new technique in the field of frontier science. Information fusion is the process of gathering, filtering, correlating and integrating relevant information from various sources into one representational format. This kind of information with various sources can reflect the characters of environments more perfect and more accurate, and the object being measured should be described comprehensively and accurately. The technique of information fusion is used by signal processing engineers and information operations specialists to help them make decisions involving tasks like sensor management, tracking, and system control [4, 5]. It is uncertainly for the information provided by different sources. Therefore, the process of uncertain information fusion is an uncertainly reasoning process actually. There are many information fusion methods and the neural network is one of famous methods. The neural network with good capability of self-adapt learning can accept the similarity of samples in system. It is because the neural network is consisted by a mount of interconnected neurons. Neural network also provide a methodology for solving many types of non-linear problems that are difficult to solve by traditional techniques. In neural network information fusion method, the neural network is used to obtain knowledge. Using neural network can avoid the process of feature extraction and modeling by traditional pattern recognition method. Therefore, the capability of system recognition should be improved and the real time recognition will be realized. The process of above neural network information fusion is showed as following: (1) Choose the structure of neural network according to the demands of system and information fusion. (2) The signal will be dealt with as an input function. (3) Obtain the weights by learning the output information of neural network information fusion system. Then the results of prediction will be obtained after knowledge acquisition and information fusion. Here, a new improved BP neural network algorithm will be used as core algorithm of information fusion to establish the prediction model.

The improvment of the BP neural network

The BP neural network is one of the most extensively applied algorithm among all artificial neural network algorithms, its structure is simple, algorithm is mature, and it can search optimum value accurately, etc. But traditional BP algorithm has some shortcomings, such as the algorithm falls into local minimum easily, convergence speed is slow and causes oscillating sometimes probably. It can be improved by following methods. Therefore, genetic algorithm (GA) is used to overcome the shortages of BP network. Genetic algorithm has the very strong global optimization performance, so genetic algorithm is combined with BP network here. Genetic algorithm is used to optimize

weight and bias values of BP network when training , after searching space becomes smaller BP network begins to run to obtain exact solutions, thus global optimization is realized quickly and efficiently [6, 7].

Encoding

Because weights' learning of neural network is a large and complicated parameters system optimizing process, if binary-encoding is adopted, codes will be longer, and codes have to be decoded for real numbers, the solution's precision will be influenced. A conclusion can be drawn that the stability of GA with binary-encoding is not as good as real-encoding additionally. So real-encoding is adopted here. A population containing M individuals is produced randomly: $X=\{X_1,X_2,\cdots,X_m\}^T$, each individual $X_i=\{x_1,x_2,\cdots,x_n\}$ denotes a distribution of initial weights and bias of neural network, each gene value in X_i denotes connection weight and bias, individual size n is the number of weight and bias values, namely

$$n=r\times s_1+s_1\times s_2+s_1+s_2 \tag{1}$$

Where, r denotes input layer number; s1 denotes hidden layer number; s2 denotes output layer number.

Fitness function

The error square sum between the output of network and the output of expectation is an important capability of BP neural network. So the error square sum is selected as individual fitness function f:

$$f=1/E+1 \quad E=\frac{1}{2}\sum_{k=1}^{N}(y_k-\hat{y}_k)^2 \tag{2}$$

where, $(x_k,y_k)(k=1,2,\cdots,N)$ represent leaning samples, $\hat{y}_k$ is actual output of the network.

Rank selection method is used. The fitness value is ignored in this method. The probability of survival is obtained by the rank of individuals. The rank selection can make the individual with big fitness value obtained a high probability. At the same time, this method can prevent some super individuals from controlling heredity process too fast.

Crossover

Arithmetic crossover is used in this paper. This method can keep the filial generation's character of closing. In other words, the linear combinations of any two individuals in the solution space are still in this space. Two individuals X_i and X_j in population are selected randomly to act as crossover parents, random number λ yields in [0, 1], the initial crossover bit l is a random number, then:

$$X_i'(k)=\begin{cases}X_i(k) & 0\le k<l\\ \lambda X_i(k)+(1-\lambda)X_j(k) & l\le k<n\end{cases}$$

$$X_j'(k)=\begin{cases}X_j(k) & 0\le k<l\\ \lambda X_j(k)+(1-\lambda)X_i(k) & l\le k<n\end{cases} \tag{3}$$

$$(l=1,2\cdots n_c)$$

Where, X_i' , X_j' are two new individuals.

Mutation

Mutation provides new information for population and thereby keep the variation of population genome, namely weight values have already gone beyond original space and search toward broader space to avoid precocious phenomenon occurrence. The generation produced from father generation mutation X_l' is:

$$X_l'=\begin{cases}X_l+h(X_l) & sign=0\\ X_l-h(X_l) & sign=1\end{cases} \tag{4}$$

sign yields 0or1 randomly. Where,

$$h(X_l)=y\left[\lambda_m\left(1-\frac{g_c}{g_{\max}}\right)\right]^b$$

$$y=\begin{cases}b_r-X_l & sign=0\\ X_l-b_l & sign=1\end{cases} \tag{5}$$

sign yields 0or1 randomly. g_c denotes current evolution generation numbers; $g_{\max}$ denotes maximum evolution generation numbers; $\lambda_m\in$ [0, 1] is random number; b denotes the shape coefficient to measure disturbance, b_r , b_l are upper and lower limit of the variable correspondingly.

The BP network training

We choose the three layers BP network with high adaptability in this paper. Optimized weights from genetic algorithm are used as initial weights. The functions of activation in the hidden layer are of log-sigmoid nature and in the output layer the functions have a linear nature. The data are not at the same scale, so they should be normalized before training [1, 1]. Maximum & minimum function is used to normalize the data. Target function is

$$E=\frac{1}{2}\sum_{k=1}^{N}(y_k-\hat{y}_k)^2 \tag{6}$$

Where, $(x_k,y_k)(k=1,2,\cdots,N)$ are learning samples, $\hat{y}_k$ is network output.

Prediction of Day-ahead electricity price based on ELM information fusion

Our analysis focuses on one such program run by the PJM interconnection summer power market. The electricity price data form May to July is used as training data set to establish the electricity price prediction models [9, 10]. The inputs of neural network will be deal with before being used for information fusion[11]. The main method is reflecting the information to a common description space firstly. And then, the information registration and information fusion will be done. Finally, the different characters of inputs information will be described uniformly and the results of fusion will be obtained. Here the inputs data will be normalized into [-1, 1]. The neural network information fusion method based on ELM is showed in Figure 2.

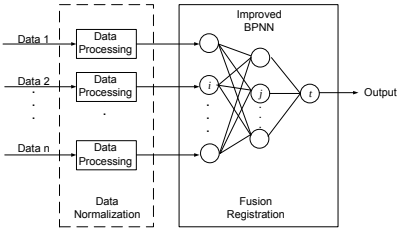

Fig. 1. Information Fusion Method Based on Improved BPNN

Experiments

In order to test the performance of novel prediction model based on ELM information fusion modeling method, the model based on BP neural network is used to predict the electricity price firstly. And then, the comparisons are done among the electricity price prediction models based on BP neural network and improved BPNN information fusion. The output of the model is predicting electricity price $p(d,t)$. The inputs of BP neural networks are 6. They are the history electricity prices and the system load. The history electricity prices are electricity prices before the predicting electricity prices a period time $p(d,t-1)$, a day $p(d-1,t)$ and a weak $p(d-7,t)$ are selected as the inputs. The system load data before the system load a period time $L(d,t-1)$, a day $L(d-1,t)$ and a weak $L(d-7,t)$ are also selected as the inputs of ELM and BP neural network. In the model based on BP neural network, the number of layers is 3. The number of the nodes in hidden layer is computed according to the empirical formula, and is 15. The results of comparison experiments are also showed in TABLE 1. The criterions of performance of different models are percentage error:

$$\text{MAPE} = \frac{\sum_{i=1}^{N}\left|\frac{\hat{y}_i - y_i}{y_i}\right|}{n} \times 100\% \tag{7}$$

and RMS error：

$$\text{RMSE} = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(\hat{y}_i - y_i)^2} \tag{8}$$

Where, y_i is real value, $\hat{y}_i$ is prediction value. The results of experiments demonstrate that the performance of electricity price prediction model based on improved BPNN information fusion is better than the one based on traditional BP neural network.

Table 1 Comparison of predicted day-ahead electricity by different prediction model

	RMSE	MAPE
BP neural network	1.2368	12.89
Improved BPNN information fusion	0.9425	10.35

Conclusion

In this paper, a novel information fusion method is proposed to establish the day-ahead electricity price prediction model. The suitable intelligent algorithm improved BPNN is selected for its better performance compared with the traditional neural networks. The information fusion method with improved BPNN is proposed. The electricity price model based on improved BPNN information fusion is established. This information fusion method can improve the performance and overcome the shortages of using sing neural network. The real data from PJM Interconnection of American are selected to test the performance of novel electricity price diction model based on improved BPNN information fusion. The prediction model based on BP neural network is also established to compare the performances of different models. The results of the comparison experiments demonstrate that the performance of the model using novel improved BPNN information fusion method is better than the one using traditional BP neural network. The accuracy of prediction by the improved BPNN information fusion is better than the electricity price prediction model respectively based on traditional BP neural network, and is satisfied for the needs of practical applications.

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