A short-term load forecasting method using artificial neural networks and wavelet analysis

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Abstract: - Load forecasting is an issue of great importance for the reliable operation of the electric power system grids. Various forecasting methodologies have been proposed in the international research bibliography, following different models and mathematical approaches. A precise electric load forecasting results in cost saving and secure operational conditions. Moreover, it can also be helpful in power supply strategy, market research and financing planning. In the current work a methodology based on artificial neural networks methods reinforced by an appropriate wavelet denoising algorithm is implemented, in order to obtain short-term load forecasting. Real recoded data obtained from the Bulgarian power system grid was used in the analysis. The extracted outcomes indicate the effectiveness of the proposed method, reducing the relative error between real and theoretical data.

Key-Words: - Artificial neural networks; Back-propagation algorithm; Denoising algorithm; Short-term load forecasting; Wavelet analysis.

1 Introduction

Electric power system contains two parts: electric power grid and electric power users. Electric power system provides reliable and stable electric power to different kinds of consumers economically. The electric power's generation, transmission, distribution and consumption happen synchronously, meanwhile electric power is difficult to store, so it requests the electric power, which is generated from power grid, and the load to keep dynamic balance. Otherwise, the quality of electric power will be affected, endangering the safety and stability of electric power grid. Therefore, electric load forecasting is necessary in power system operation.

Electric load forecasting is to predict the electric load of a certain time in the future using historical data with consideration of the characters of power system and natural conditions. Electric load forecasting is the foundation and premise of power system's control, planning, design, and research. A precise electric load forecasting results in cost saving and secure operational conditions. Moreover, it can also be helpful in power supply strategy, market research and financing planning. Therefore, the electric load forecasting has gained extensive attention. Various degrees of sophistication exist in the available methods of forecasting, ranging from linear regression [1] and complex econometric models [2] to complex fuzzy models [3], data mining procedures [4] and autoregressive integrated moving average (ARIMA) models [5]. Significant was also the use of artificial neural networks (ANN) in the electricity demand load forecasting where several studies were published referring to the short-term load forecasting [6], the mid-term load forecasting [7] and the long-term load forecasting [8], exploiting ANNs computational speed, ability to handle complex non-linear functions, robustness and great efficiency even in cases where full information for the studied problem is absent.

Load forecasting becomes a significant data source of electric power trade and it is also the foundation of planning generation, generator maintenance, making price and power grid planning. The precision of electric load forecasting has a higher standard than before. Electric power researchers have to face the challenges from the requirements of load forecasting.

Considering the traditional forecasting methods and the advantages of artificial neural networks in the analysis of nonlinear problems, a load forecasting model based on an advanced BP neural network is proposed in this paper. The problems of BP algorithm in the electric load forecasting are analysed, and some improvements are put forward. A load forecasting model based on neural networks is designed and implemented in this work. A wavelet denoising algorithm has been also introduced in order to solve the problems of actual power load signal. Real recorded data obtained from the Bulgarian power system grid was used.

2 Load Forecasting

Load forecasting is a mathematical method using historical load data to predict the demand of electric power in the future with sufficient consideration of system characteristic, capacity decision, natural conditions and social influence. The methods of load forecasting have developed from simple to complex, from single to multiple models combination, from only considering historical load to considering various factors that influence the load changes, from traditional statistic methods to modern intelligent methods. Prediction accuracy has been improved significantly. In general, there is no fixed method which could be used in all types of load forecasting. In practice, trial comparing method can be used to analyze actual load change rules and influenced factors, and use historical data of a power grid to determine the most effective algorithms. Electric load forecasting can be classified by time [9]:

- **Ultra short-term load forecasting:** very short-term forecasting up to a few minutes ahead.
- **Short-term load forecasting:** forecasting with a lead time of up to a few days ahead.
- **Medium-term load forecasting:** forecasting energy requirement over a six month.
- **Long-term load forecasting:** forecasting of the power system peak load up to 10 years ahead.

The results of long-term load forecasting and medium-term load forecasting are beneficial for deciding the time and place of the new installed capacity. The increase on capacity of power grid and reconstructing power grid also needs the results of long-term and medium-term load forecasting. Short-term load forecasting predicts electric load for a period of hours, days or weeks. It is an important research area of electric power system operation. The purposes of short-term load forecasting are:

- For the small independent power grid, short load forecasting is necessary in order to predict the output capacity of the running units.
- For a large power grid, starting up and shutting down of power plants must be organized reasonably and economically to make power system stay in a safe situation and to decrease consumption of spinning reserve according to the results of short load forecasting.
- When controlling power grid using computers online, the data form of short-term load forecasting should be used to realize the reasonable management of power grid and satisfy the requirements of power grid running. At the same time, the costs of generation could be decreased [10, 11].
- Accurate short-term load forecasting is to ensure a necessary condition for business operation of transmission and distribution companies, and is the precondition for the power grid to generate economic benefits.

Therefore, precise short-term load forecasting is the guarantee of economic and secure operation of power system. A reliable short-term forecasting can reduce the cost of power generation and improve the economic and social benefits. Accurate short-term load forecasting has already become one of the important content of the modernization of power system management. With the revolution in the power system, high quality short-term load forecasting becomes more and more necessary and urgent.

A number of random factors, like population, social change, electricity price and holiday periods, can affect the electricity consumption in a region [9]. Generally speaking, the impact factors of electric load also include time, weather and random factor. In order to acquire higher accuracy of load forecasting, random factors, especially some special events, need to be human intervened.

Prior the short-term load forecasting, historical data should be analyzed firstly. Based on typical electricity load graphs can be concluded, that the closer the sampling times between the power loads is taken, the greater the similarity will be presented. When the forecasting time is far away from the historical data, the error is relatively large. Then, historical data needs to be disposed, such as denoising, weakening its fluctuations and so on. The processed data is put into the load forecasting model which has already been established to get the results. At last, the error should be analyzed and further improvement would be made. Fig.1 depicts a flow chart of short-term load forecasting.

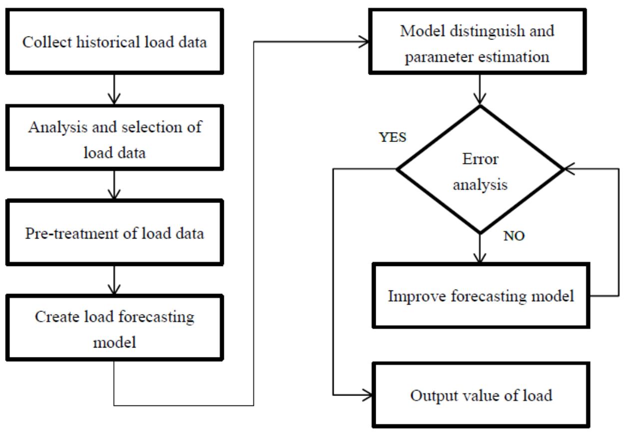

Fig. 1 Short-term load forecasting flow chart.

3 Analysis of the implemented methodologies

Scope of the current paper is to propose a load forecasting model based on the combination of artificial neural networks methods and wavelet analysis (denoising algorithms), in an effort to improve the quality of input signal.

3.1 Artificial neural networks (ANN)

Artificial neural networks (ANN) represent a parallel multilayer information processing structure. The characteristic feature of these networks is that they consider the accumulated knowledge acquired during training and respond to new events in the most appropriate manner, given the experience gained during the training process. An ANN called feed-forward has been decided to be used in the current work. The name feed-forward implies that the flow is one way and there are not feedback paths. A typical two layer feed-forward ANN is presented in Fig. 2. In its basic form, a feed-forward ANN consists of an input layer, an output layer and one or more hidden layers. Each layer consists of a set of neurons or nodes that are fully connected to the neurons in the next layer. The connections have multiplying weights associated with them. The neuron receives its input either from other neurons or from the outside world. The sum of all weighted inputs represents the neuron transfer function. The number of neurons and hidden layers to be used depends on the problem studied. The process of determining the weights is called the training process. In the training process, sets of input and output data are associated by proper adjustment of the weights in the network such that a sum of squared error function is minimised. This is achieved using a specified learning rule. Thus each ANN model is determined according to its architecture, the transfer function and the learning rule.

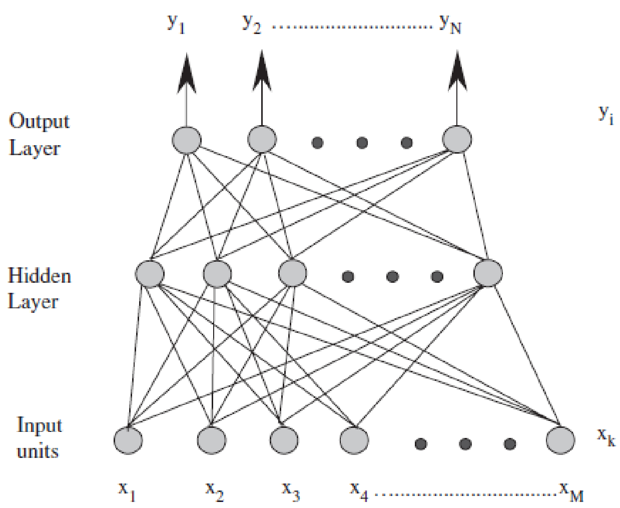

Fig. 2 A typical two layer feed-forward artificial neural network.

Error back-propagation algorithm (BP) is the most widely used neural network algorithm at present. It is composed of input layer, output layer and one or more hidden layers. BP algorithm is a kind of learning algorithm. The learning progress consists of two parts: positive signal propagation and error back propagation process. An input can be given by the input layer through the forward travel, and sent to the output layer after handling by the hidden layer. If there is a deviation between the output and the actual signal expectation, then the process will enter the back propagation. According to a certain algorithm, errors will be allocated to each unit to carry out weights and threshold adjustment, and after that, they will enter the forward propagation again. This learning process cycles until satisfactory results are obtained. The procedure to set up a BP network is [12]:

- Select input and define output variables
- Determine layers and the number of neurons in hidden layers
- Training
- Testing
- Recalling

However, BP algorithm presents disadvantages, considering slow convergence and low learning efficiency. In order to face these drawbacks, appropriate techniques are implemented such as: momentum method, adaptive learning rate adjustment method and momentum-adaptive learning rate adjustment combination method.

3.2 Wavelet denoising algorithm

As a time series, electric load data is often collected based on variable voltage, which might produce abnormal data and noise load signal that decrease the precision of forecasting. When the number of data is large, the workload is very huge and error-prone. As a kind of time-frequency analysis, wavelet analysis has a broad application prospect in signal analysis, pattern recognition, image processing, and earthquake prediction. Wavelet analysis can filter out noise and has good time-frequency localization properties. Based on this, the current work uses a wavelet denoising algorithm presented in [13]. This method uses wavelet to factorize historical load data into signals with different frequency which will be divided into different base bands. After that, wavelet will be reconstructed. The new reconstruction signal not only has the low pollute rate, but also keeps a good sequence of original data. Mathematically, wavelet transform is a kind of integral transform based on a series of parameters through wavelet base. How to select the wavelet base becomes the most important step. Wavelet base has some characteristics, such as regularity, symmetry, etc. Therefore, the specific situation should be considered when choosing the appropriate wavelet base function. Moreover, wavelet decomposition scale is also very important. If the decomposition is too small, the low frequency part of signal will be too similar with the load waveform itself, and high frequency part will not be able to go out. If the scale is too large, the difference between low frequency part and original signal will be big, so there will be no real response of load change trend.

4 Results

According to the methods presented in the previous section, three different forecasting models are examined (Table 1), considering real recorded data obtained from the Bulgarian power system grid [14].

Table 1. Implemented models.

Model	Input	Forecasting Model
1	original signal	conventional ANN BP
2	original signal	improved ANN BP
3	signal after denoising	improved ANN BP

Fig. 3 depicts the calculated relative error between the real data and the predicted value by using the presented methodologies. The obtained results indicate that model 3 definitely gives outcomes of higher accuracy.

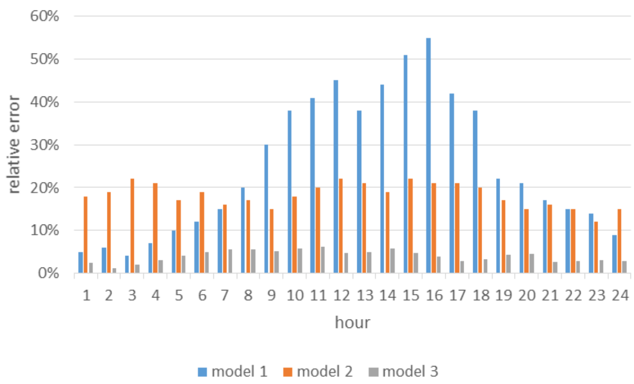

Fig. 3 Relative error between real data and predicted values.

Comparing the results of the three models, wavelet denosing algorithm provides good historical load signal for neural network training and greatly improve the load forecasting accuracy. Therefore, it is an effective way to predict short-term load. However, the proposed forecasting model in this paper has still a number of shortcomings. The model does not take into consideration the holiday factor and the economic development factor which are very important for load forecasting.

5 Conclusion

Short-term load forecasting is a significant basic work to guarantee the economic operation and security of power grid. A load forecasting model based on artificial neural networks and more specifically on a BP algorithm is proposed in this paper. The several problems that exist on the collection of the actual electrical load data, such as the strong interference, the wide spectrum range and the noise were dealt with the use of a wavelet denoising algorithm. Real recorded data obtained from the Bulgarian power system grid was used in the analysis and the obtained results have clearly shown that the wavelet denoising algorithm has effectively improved the load signal quality and provided good input samples for the load forecasting models.

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