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FORECASTING ELECTRICITY CONSUMPTION USING NEURAL NETWORKS

Abstract. The problem of early and accurate forecasting of electricity consumption is acute for the unified energy system of Ukraine. With successful forecasting of consumption, which is based on many aspects, it is possible to buy electricity/losses in different market segments much more profitably, saving large amounts of money, which can then be directed to the development and modernization of electricity networks. This has always been an urgent issue, but today, when a large part of Ukraine's energy equipment has been destroyed by Russian missiles, it has become even more painful. The use of the method of artificial neural networks (ANN) for short-term forecasting of electricity consumption is considered. It was established that ANN can be used to make a forecast of electricity consumption a day ahead with an error of 4.86% compared to the actual amount of electricity consumption. Performing a comparison of forecast values with actual values allows us to talk about the adequacy of the selected forecasting model and its application in practice for the successful operation of energy supply companies in the electricity market.

Keywords: forecasting, artificial neural network, neural network architecture, Neural Network Toolbox module, hourly consumption database, Levenberg-Marquardt gradient algorithm, inverse error propagation algorithm.

Introduction

Forecasting is a very popular topic, given the large impact on business profitability, by minimizing costs. For the energy sector, consumption forecasts are the basic source information for decision-making in the process of planning optimal modes of operation and development of the power system. As the main tasks solved on the basis of the received forecasts of consumption of the electric power, it is possible to allocate the following:

1) planning of development of generating capacities and electric networks of electric power system;

2) tariff planning;

3) planning the loading of power plants for the next day, energy and power generation, fuel needs;

4) planning of repair works of the main equipment of power plants and networks.

Traditional statistical models (regression and time series models) and models based on expert systems and neural networks can be used to solve the problem of forecasting electricity consumption [1]. The most commonly used models are neural networks. This is due to the fact that it is not necessary to build a model of the object, does not lose performance with incomplete input information. Neural networks are resistant to interference, have high speed. Predicting electricity consumption using artificial neural networks is one of the most actively developed in the energy sector. This is due to the fact that this structure is a universal approximator and is able to build complex nonlinear dependencies, which allows you to successfully predict. he difficulty of creating a neural network is the unavailability of data for its training [2, 3].

In [4–7] the issue of forecasting the electrical load using neural networks was considered. Namely, neural network learning algorithms, neural network architecture and forecasting for different terms for different conditions. For our purposes on the basis of works the training of a neural network by a method of back propagation was chosen. The advantages of this method are the simplicity and speed of its application. The solution of [7] is suitable, as the paper performs short-term forecasting of electricity consumption, which depends on changes in air temperature. Based on this work, a neural network was created and training was conducted on our own data sample.

The main part of the article

1. Analysis of the time series of electricity consumption and the impact of weather factors on it. Knowledge of the characteristics of daily charts P(t) system helps to design adequate forecasting models that work effectively in different situations. Various factors that affect the change in the load of the power system can be divided into the following main categories: meteorological, seasonal (cyclical), economic, random disturbances. Ambient temperature is the factor that has the greatest impact on electricity consumption. This is due to the fact that maximum human productivity is achieved only when comfortable living conditions are created. The most comfortable for humans is the temperature range from 18 to 25 ° C.

2. Neural network model. The multilayer perceptron of an artificial neural network (ANN) is today one of the most common neural network models due to its ability to display complex nonlinear relationships between input and output parameters. The network consists of several layers of neurons and weights that reflect the relationships between them. The transfer of information is based on the method of direct dissemination. Presented in Fig. 1 model consists of one input layer, one hidden and one output layer as the ANN of this type allows to solve practically any problems with nonlinear relations [8, 9].

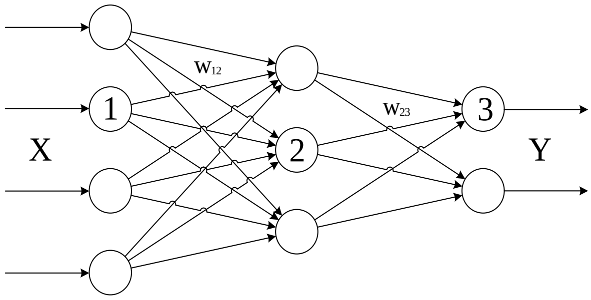

Fig. 1. Neural network of a multilayer perceptron

In Fig. 1: "X" - input vector; "W12" - vector of scales between the input and hidden layers; "W23" - vector of scales between the hidden and output layers; "Y" is the output vector (end result).

ANN training is performed to approximate the nonlinear function to the predicted) and input variables.

The MATLAB software product was selected to create a forecasting model based on ANN. This choice is due to the experience of MATLAB, as well as the module Neural Network Toolbox for the creation and training of ANN. When creating the ANN model, a database of hourly electricity consumption from 2016 to 2018 inclusive was available. This amount of data is sufficient for training and network operation on test data samples.

A network of direct data dissemination and reverse error propagation was used to forecast electricity consumption. Fig. 2 shows a diagram of this network. The algorithm of the Levenberg-Markwardt gradient method was chosen for the study of ANN.

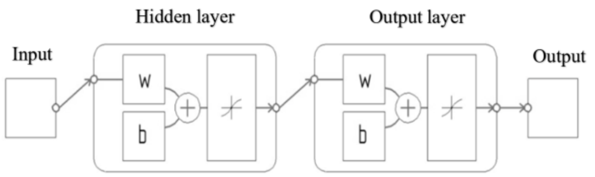

Fig. 2. ANN diagram of direct data dissemination and reverse error propagation

With this network architecture for learning, you need to set time series targets, which are the benchmark when creating a forecast, and the input data to be processed.

3. Generalization of the network training algorithm. In the first step, the scales are initiated by small random variables. After passing the signal from input to output, the value *d*, is entered and calculated, which is equal to the difference between the required or target output *T* i and the actual output *Y*:

$$d = (T - Y). \tag{1}$$

In the case when $d = 0$ in the network nothing changes, it means that the weight coefficients are chosen correctly. At $d \neq 0$ the correction of the value of the weight of each connection between the layers of the neural network in the direction from output to input is calculated.

$$D_i = hdx_i, \tag{2}$$

$$w_i(n+1) = w_i(n) + D_i, \tag{3}$$

where D_i – is the correction associated with the *i*-th input; $w_i(n+1)$ – weight value i after correction; $w_i(n)$ – weight value *i* before correction; x_i – the magnitude of the *i*-th output; *h* – coefficient of learning speed, which allows you to control the average amount of weight change. The process is repeated until the stop condition is fulfilled.

Weight coefficients are selected during training according to the training sample, that is in different places - in electric networks different volume of consumption at the same air temperature, accordingly selected weight coefficients for one network, will not be actual for any other.

The ANN model has the following parameters:
- number of layers - 2 (hidden, output);
- the number of neurons in the hidden layer – 24;
- the number of neurons in the output layer – 24;
- the function of activation of the hidden layer is sigmoid;
- learning algorithm - reverse propagation of error;
- speed of learning – 0,3;
- impulse coefficient – 0,3;
- number of learning epochs – 1000.

The forecast of electricity consumption in the network is considered in Fig. 3. It should be noted that ANN correctly recognized the regularity of the graph and the result was the construction of a similar graph with an accuracy of 4.86% deviations modulo the total volume per day, which in quantitative terms amounted to 1,081,367 kWh.

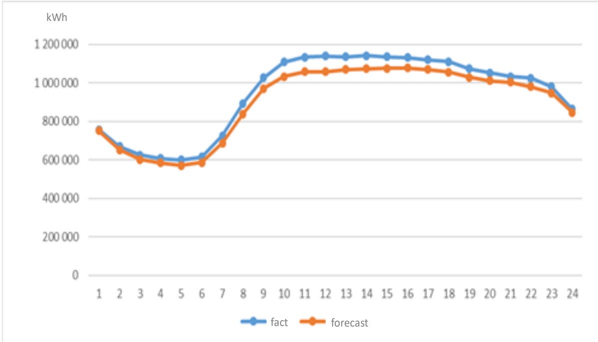

Fig. 3. The result of forecasting electricity consumption on July 17, 2019 (Wednesday) in Kyiv Electric Networks

A forecast for the holiday was also made to check the operation of the network during accidents and disturbances. The results of forecasting on the holiday are shown in Fig. 4.

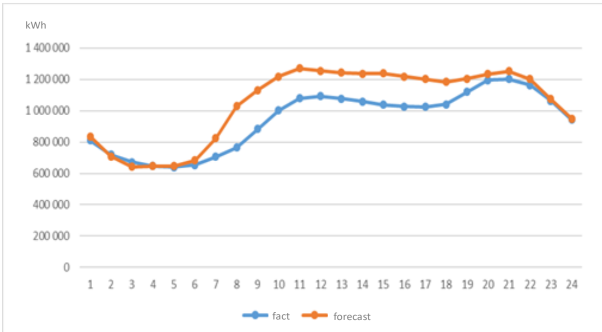

Fig. 4. Result of forecasting electricity consumption on October 14, 2019 (Monday, public holiday) in Kyiv Electric Networks

The graph of imbalance between the actual and projected volume of electricity consumption is given in Fig. 5 and 6 in absolute units and percentages, respectively, to compare the results.

As the experiment showed, the network is not adapted to forecasting on holidays. To do this, you need to enter another factor that will affect the forecast - it's a holiday/weekend or weekday.

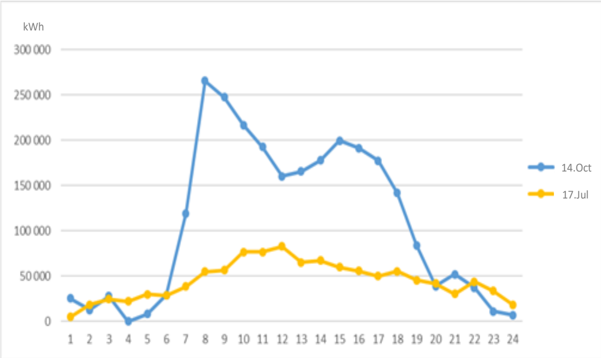

Fig. 5. Graphs of imbalances between actual and projected volume in absolute units

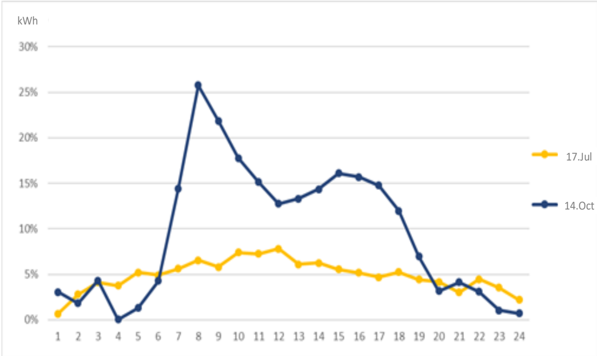

Fig. 6. Graphs of imbalances between actual and projected volume in percent

Conclusions

The influence of air temperature on electricity consumption is analyzed and the features that need to be taken into account when building a forecast consumption model using ANN are identified.

On the basis of the built model of ANN the forecast of consumption of the electric power for 2 days (weekday and holiday) of the Kiev electric networks is created. A significant increase in the error of forecasting electricity consumption on the holiday was revealed. Therefore, you need to introduce an additional factor for forecasting - a holiday/weekend or weekday.

Therefore, it can be concluded that the introduction of another such factor can significantly improve the quality of the ANN forecast.

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Прогнозування споживання електричної енергії за допомогою нейронних мереж

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Анотація. Проблема завчасного та точного прогнозування споживання електричної енергії гостро стоїть для об'єднаної енергетичної системи України. При вдалому прогнозуванні споживання, яке базується на багатьох аспектах, можна значно вигідніше купляти електроенергію/втрати на різних сегментах ринку, заощаджуючи великі кошти, які потім можна направити на розвиток та модернізацію електричних мереж. Це завжди було актуальним питанням, але сьогодні, коли значна частина енергетичного обладнання України знищена російськими ракетами, воно стало ще більш болючим. Розглянуто використання методу штучних нейронних мереж (ШНМ) для короткострокового прогнозування електроспоживання. Встановлено, що ШНМ може бути використана для складання прогнозу споживання електричної енергії на добу наперед із похибкою 4,86% порівняно з фактичним обсягом споживання електроенергії. Виконання порівняння прогнозних значень із фактичними дозволяє говорити про адекватність обраної моделі прогнозування та її застосування на практиці для успішної роботи енергопостачальних компаній на ринку електроенергії.

Ключові слова: прогнозування, штучна нейронна мережа, архітектура нейронної мережі, модуль Neural Network Toolbox, база даних погодинного споживання, алгоритм градієнтного методу Левенберга-Марквардта, алгоритм зворотного поширення помилки.