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Satbayev University

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ИЗВЕСТИЯ

НАЦИОНАЛЬНОЙ АКАДЕМИИ
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КАЗАХСТАН
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SYSTEM OF SHORT-TERM FORECASTING OF WIND TURBINE OUTPUT POWER CONSUMPTION

Abstract. When solving the problems of increasing the efficiency, reliability and optimization of the operation of wind turbines, it is necessary to consider the problems of forecasting and calculating electricity consumption. The stage of forecasting the consumption of electrical energy will increase the efficiency of the wind turbine by adjusting the process of automating the storage, load, accumulation and analysis of data necessary for building and training a system for predicting the consumption of electrical energy based on artificial intelligence. This article considers a system for predicting the consumption of the output power of a wind turbine, taking into account various parameters. In order to increase the speed of forecasting the consumption of output power, the method of artificial neural networks was applied. To develop a high-quality forecast database, a static base of output power consumption of the past period was created. This will allow you to find coefficients that characterize the change in power consumption depending on various conditions (seasonal changes, weekends and holidays, time of day, etc.). Thus, in this work, not only weather conditions, time of year, but also day parameters are taken into account (working, weekend, first day of the week, last, etc.).

Key words: short-term forecasting, neural network, power consumption, power output, wind turbine.

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ЖЕЛ ГЕНЕРАТОРЫНЫҢ ШЫҒЫС ҚУАТЫН ТҰТЫНУЫН ҚЫСҚА МЕРЗІМДІ БОЛЖАУ ЖҮЙЕСІ

Аннотация. Жел генераторларының тиімділігін, сенімділігін және жұмысын оңтайландыру мәселелерін шешу кезінде электр энергиясын тұтынуды болжау және есептеу мәселелерін қарастыру қажет. Электр энергиясын тұтынуды болжау кезеңі жасанды интеллект негізінде электр энергиясын тұтынуды болжау жүйесін құру және оқыту кезінде қажетті деректерді сақтауды, жүктемені жинақтауды және талдауды автоматтандыру процесін реттеу есебінен жел генераторы жұмысының пайдалы әсер коэффициентін ұлғайтуға мүмкіндік береді. Бұл мақалада әртүрлі параметрлерді ескере отырып, жел генераторының шығыс қуатын тұтынуды болжау жүйесі қарастырылған. Шығу қуатын тұтынуды болжаудың жылдамдығын арттыру үшін жасанды нейрондық желілер әдісі қолданылды. Болжамның сапалы дерекқорын әзірлеу үшін өткен кезеңнің шығыс қуатын тұтынудың статикалық базасы құрылды. Бұл әртүрлі жағдайларға (маусымдық өзгерістер, демалыс және мереке күндері, күн уақыты және т.б.) байланысты қуатты тұтынудың өзгеруін сипаттайтын коэффициенттерді табуға мүмкіндік береді.Осылайша, бұл жұмыс тек ауа-райын, жыл мезгілін ғана емес, сонымен қатар күннің параметрлерін де ескереді (жұмыс, демалыс, аптаның бірінші күні, соңғы және т.б.).

Түйін сөздер: қысқа мерзімді болжау, нейрондық желі, энергияны тұтыну, шығу қуаты, жел генераторы.

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СИСТЕМА КРАТКОВРЕМЕННОГО ПРОГНОЗИРОВАНИЯ ПОТРЕБЛЕНИЯ ВЫХОДНОЙ МОЩНОСТИ ВЕТРОГЕНЕРАТОРА

Аннотация. При решении проблем повышения эффективности, надежности и оптимизации работы ветрогенераторов необходимо рассматривать проблемы прогноза и расчета потребления электроэнергии. Этап прогнозирования потребления электрической энергии позволит увеличить коэффициент полезного действия работы ветрогенератора за счет наладки процесса автоматизации хранения, нагрузки, накопления и анализа данных, необходимых при построении и обучении системы прогнозирования потребления электрической энергии на базе искусственного интеллекта. В данной статье рассмотрена система прогнозирования потребления выходной мощности ветрогенератора с учетом различных параметров. С целью повышения быстродействия прогноза потребления выходной мощности, применен метод искусственных нейронных сетей. Для разработки качественной базы данных прогноза создана статическая база потребления выходной мощности прошедшего периода. Это позволит найти коэффициенты, характеризующие изменение потребления мощности в зависимости от различных условий (сезонные изменения, выходные и праздничные дни, времени дня и т.д.). Таким образом, в данной работе учтены не только метеоусловия, время года, но и параметры дня (рабочий, выходной, первый день недели, последний и тд).

Ключевые слова: краткосрочное прогнозирование, нейронная сеть, энергопотребление, выходная мощность, ветрогенератор.

Introduction. The forecast of electrical energy consumption today remains a topical issue in the use and development of wind turbines. So, at the stage of development of wind turbines, this will allow designing the energy complex for the needs of the consumer as accurately as possible, and at the stage of operation, this will allow us to evaluate the capabilities of the wind generator and optimize its operation (Ahmad, 2017). The system for forecasting the consumption of the output power of a wind generator will be relevant for any type of wind generators (Alina Fazylova, 2020). By solving the problem of forecasting, the problem of setting the level of consumption and distribution of electrical energy between wind generators in a single network is solved. Also, forecasting can solve the problems of scheduling repair work and the problem of calculating the operating modes of wind turbines (A.L. Yang, 2020). The first step is to maintain monthly statistics on the volume of electricity consumption and the planned level of consumption in the future for each wind turbine or wind turbine substation. It is also necessary to have a system for collecting and analyzing data for a single control room. One of the most important indicators of the forecast of electrical energy consumption is its quality, which affects the reliability of wind turbines, and also determines the power level of the network and affects the process of transmission and redistribution of electricity between wind turbines (Singh, P., 2017). The novelty of this work is the development of a method for predicting the consumption of output power for various weather conditions, seasonal changes, time intervals (days of the week, working and weekend days, etc.). The forecasting method under study is reliable only for a short-term forecast, since a long-term forecast carries an additional error associated with a sharp and unplanned change in climatic conditions. While the short-term forecast of climatic conditions is more reliable. The purpose of this work is a short-term forecast of the consumption of generated power, based on data from previous periods of time and an analysis of various factors that affect the change in the level of consumption of electrical energy. Checking the correct operation of the intelligent neural network, taking into account the listed parameters, will show the response of the artificial neural network when various parameters are changed. As an example, an object with an electrical energy consumption of up to 9000 kWh per day was chosen. To develop a mathematical model for predicting the consumption of output power in the climatic conditions of the city of Almaty based on artificial neural networks, the MATLAB Neural Network Toolbox software was used.

Research materials and methods. To develop a model for predicting the level of consumption of the output power of wind turbines, the first step is to determine the software where the artificial neural network is built. To do this, it is necessary to study the existing structures, as well as to determine the static and dynamic parameters that affect the consumption forecast. To date, a large number of software is known that allows modeling and developing artificial neural networks. One of the popular programs is the software product Statistica Automated Neural Networks (Nikolenko S., 2016). This software is able to automatically determine the optimal network parameters and is able to create applications for predicting power consumption (Basilio de Braganca Pereira, 2016). However, this software requires extensive user training to operate it.

Therefore, the Mathlab software product was chosen with the Neural Network Toolbox (Y. Zhang, 2017), which includes packages for training and creating artificial neural networks (C.U. Yeom, 2017). The main advantage of this software product is that it contains network templates, which allows you to interpret existing models for your tasks (Taylor J.W, 2012). Also, this software is affordable and does not require deep knowledge in programming.

Results and discussion. The next step is to choose an artificial neural network training algorithm and its architecture to predict the wind turbine output power consumption (C.C. Aggarwal, 2018). The most popular method is the Levenberg-Marquardt algorithm, this method is based on minimizing the mean square error. The essence of this method is that the learning process continues until the error reaches the minimum value. This method was tested in (Nikolenko S., 2018) and this model showed a large error compared to other models for building a system for predicting output power consumption. In this regard, this model had to be abandoned. A prediction algorithm based on the Bayesian model is also known. This model differs from the Levenberg-Marquardt algorithm, first of all, by a large network training time. In (Ribeiro T.H., 2016), a study of this algorithm was carried out, where it was found that the error has a smaller value with a larger value of the elapsed time (Serban I.V., 2016). Thus, it is necessary to form an artificial neural network capable of selecting weight coefficients so that the standard deviation error is minimal. The selected artificial neural network model was built in the Mathlab software environment in the Neural Network Toolbox application (Figure 1). Based on the artificial neural network shown in Figure 1, an artificial neural network will be developed to predict the consumption of the output power of the wind turbine (P. Suksawang, 2018). To improve the accuracy of the artificial neural network, it is necessary to modernize the circuit shown in Figure 1, so that the input data is processed by the network, taking into account weight coefficients, then the feedback network returns to the input, this will change the backpropagation error. The modified scheme of the artificial neural network is shown in Figure 2.

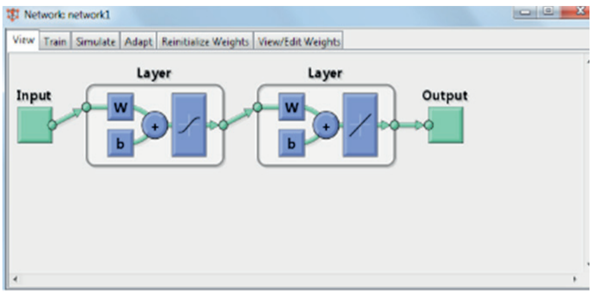

Figure 1 - General scheme of the artificial neural network of data forward propagation and error back propagation

Main results and analysis. Data on the actual consumption of electricity were taken at the Almaty plant of rubber shoes "ARGO" and entered in Table 1. When testing the network shown in Figure 2, the parameters of weather conditions, the time of year and the nature of the day (working / day off, first working day and day off) were taken into account. When testing an artificial neural network, taking into account the maximum covered parameters, it is possible to clearly prove the correctness and ability of the network to rebuild when the nature of the data changes. The network settings window is shown in Figure 3.

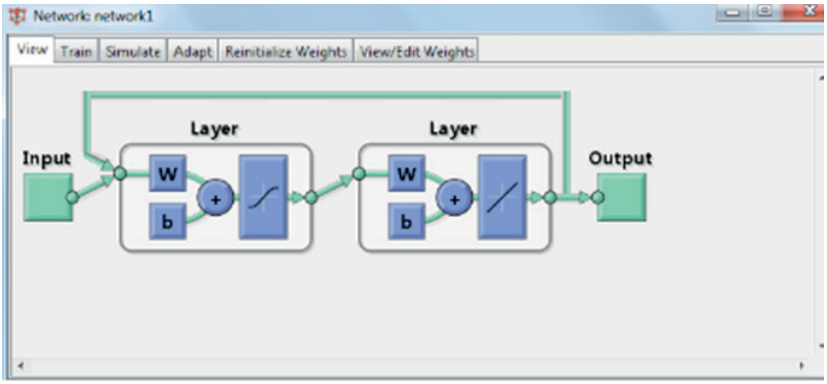

Figure 2 - Modified scheme of an artificial neural network with feedback

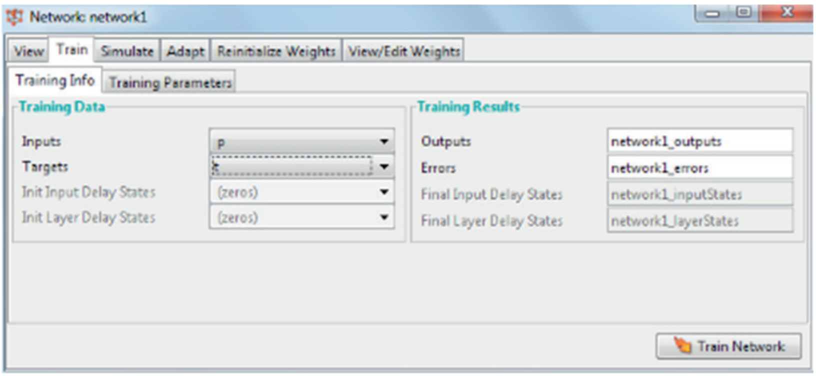

Figure 3 - Network settings window

For the first test, a day off on June 13, 2021 was chosen. This period is considered summer and electricity consumption in it is lower, as it is included in the unheated season. After training the artificial neural network in the first test, it was experimentally found that the prediction error per day is 2.3% (Figure 4). It is necessary to take into account the fact that at the stage of forecasting the consumption of the output power of a wind turbine, special attention is paid to the level of energy consumption during peak hours, where the maximum consumption of electrical energy occurs. During the summer, there is a significant consumption of electricity due to the increase in the use of climate control equipment for the production room. Upon completion of the training of the artificial neural network, as well as the formation of forecast and actual energy consumption graphs, it was found that on June 13, 2021, the maximum electricity consumption per day was 387 kWh, and according to the result of forecasting for this period, 357 kWh of energy, which corresponds to a prediction error of 2% and is acceptable for short-term forecasting (Goldberg Y.A., 2017) similar experiment was carried out in winter. A feature of the winter period is the increase in energy consumption due to the fact that during this period an additional burden of energy consumption is borne by pumps used in the central heating system. For the second test, the first working day was chosen on December 6, 2021 and the last working day on December 10, 2021 (Figure 5). It can be seen that in the first 10 days the error is greater than in the next, this is due to the peculiarity of the learning process of artificial neural networks. The average forecast error per day for the second experiment was 2.27%, and for the third experiment 2.3% (Figure 6), which corresponds to the forecast error for the summer period, despite the increase in the level of electricity consumption. This suggests that the developed neural network, according to the forecast of output power consumption, works equally effectively under various conditions. The forecast data are listed in Table 1.

Table 1 - Comparison of the predicted value with the actual

hours	Forecast for 13.06 kW	Forecast for 06.12 kW	Forecast for 10.12 kW	Actual at 13.06 kW	Actual at 06.12 kW	Actual at 10.12 kW	Error at 13.06 %	Error at 06.12 %	Error at 10.12 %
1	350	375	380	346	368	368	-1.1	-1.9	-3.2
2	360	381	389	348	372	378	-3.45	-2.4	-2.9
3	358	383	392	351	371	380	-1.99	-3.2	-3.1
4	361	379	373	355	368	361	-1.7	-1.1	-3.6
5	345	395	384	331	384	372	-4.2	-2.8	-3.2
6	370	393	390	360	380	381	-2.4	-3.4	-2.3
7	372	371	382	360	362	373	-3.3	-2.5	-2.4
8	368	364	397	361	355	388	-2.76	-2.5	-2.3
9	374	355	402	364	354	395	-2.74	-0.3	-1.8
10	375	386	393	369	369	381	-1.6	-4.6	-3.1
11	360	391	400	352	382	392	-2.27	-1.8	-2
12	357	395	395	351	385	386	-1.7	-2.6	-2.3
13	358	396	382	351	387	371	-2	-2.3	-2.96
14	368	383	386	361	375	385	-1.9	-2.1	-0.2

15	370	375	390	361	371	381	-2.5	-1.1	-2.36
16	350	376	385	342	367	377	-2.3	-2.4	-2.1
17	358	385	383	352	375	375	-1.7	-2.6	-2.1
18	364	390	405	354	383	389	-2.8	-1.8	-4.1
19	371	393	368	363	384	361	-2.2	-2.3	-1.9
20	358	379	379	351	370	370	-2	-2.4	-2.4
21	358	375	375	351	370	372	-2	-1.3	-0.8
22	350	380	360	342	373	353	-2.4	-1.9	-1.98
23	370	376	365	365	363	359	-1.37	-3.6	-1.7
24	365	373	360	361	367	358	-1.1	-1.6	-0.5
Sum	8690	9149	9215	8502	8935	9006			
Mean	362	381	384	354	372	375	-2.3	-2.27	-2.3

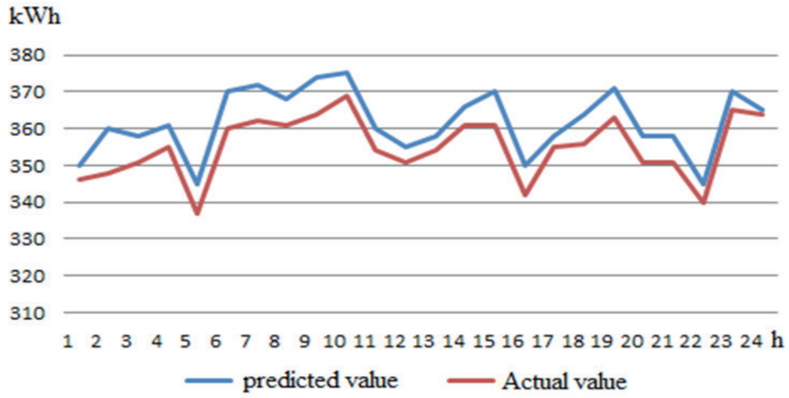

Figure 4 - Graph of the predicted and actual value of electricity consumption for 13.06.21

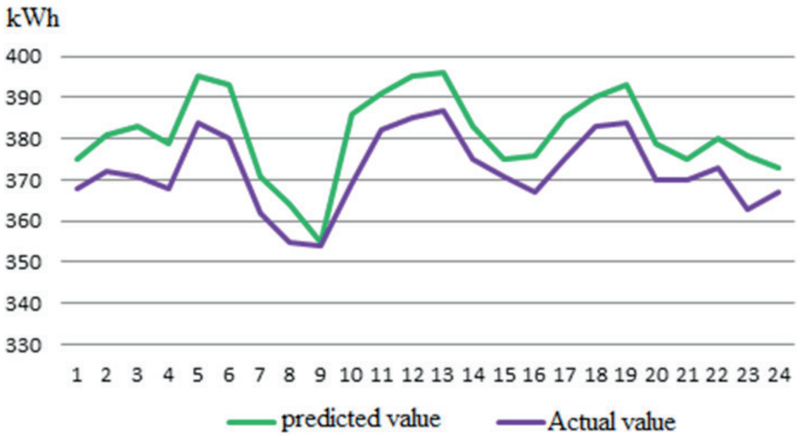

Figure 5 - Graph of the predicted and actual value of electricity consumption for 06.12.21

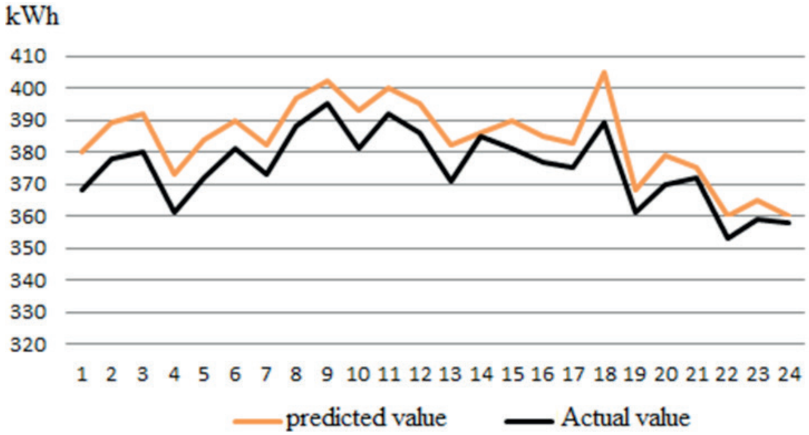

Figure 4 - Graph of the predicted and actual value of electricity consumption for 10.12.21

Conclusion. In the course of the work, a study was made of existing methods and algorithms for predicting the consumption of electrical energy, as well as methods for taking into account the influence of climatic conditions on energy consumption. Non-standard algorithms for predicting the consumption of the output power of a wind generator based on artificial neural networks are considered. In the Mathlab software environment in the Neural Network Toolbox application, an artificial neural network model was implemented and a database was formulated for predicting output power consumption using the example of the Almaty rubber shoe plant "ARGO", in view of the availability of data on actual energy consumption for various climatic conditions. Based on the research results, an average output power consumption prediction error of 2.3% was obtained for all three experimental studies, which proves the effectiveness of the developed artificial neural network under various climatic conditions and different levels of consumption.

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