

ANNOTATION

dissertation work of Kalantaevskaya Natalia Igorevna "Short-term forecasting of energy consumption volumes using machine learning technologies" is submitted for the degree of Doctor of Philosophy (PhD) in the specialty 8D07103 - "Power Engineering"

The relevance of the work. On the rise of the energy sector of Kazakhstan, when the volume of production reaches stable high rates, capacities are regulated practically according to demand in industry and consumption of consumers in the energy sector, the issue of the quality of the energy supply of the system as a whole becomes relevant.

The main feature of the characteristics of electricity consumption is the constant generation, as well as the process of simultaneous consumption and energy consumption. Optimal energy consumption among the representatives of the energy market is associated with the emergence of the need for energy consumption. So a sharp change in the amount of energy consumption can lead to overload and exit from the design of the equipment, as well as to a change in the functionality of the power supply system as such. The load on equipment and power lines directly depends on energy consumption. The information about the amount of consumption in the next hour and the next day becomes restored. Drawing up a correct forecast of energy consumption to create an operational dispatch control system that allows you to change the topology of the heating network in advance and avoid emergency situations.

In addition, since 2008, work has begun on the territory of Kazakhstan to balance the oil market. Thus, energy production can not only supply energy to the region in which it is produced, but also by increased energy consumption in other regions and countries, or vice versa, purchase energy.

A feature of this work is the choice of the market for the acquisition, as well as the sale of alternative resources, lining up on free trade conditions, on conditions that make up the market, buying exclusive differences between the actually used trade and the one that was previously required. Therefore, the greater the difference between consumption costs and the accumulation of resources, the greater the material costs of an organization operating in a balancing market. The rules of operation describe market conditions, prerequisites and conditions when it is beneficial for organizations participating in the auction to build the most accurate forecasts that allow consumption to be used.

Various methods and load prediction. The most common cases of application in practice are various statistical methods. Not in all cases this method gives a good result. Various objects that have a specific characteristic nature of energy consumption, as well as factors characterizing the volume of energy consumption at technical or other objects. Among the features of energy consumption, one can single out features depending on the dependencies of factors influencing energy consumption and actual power consumption, as well as changes in the level of impact on the impact of factors.

The works of the following scientists are devoted to solving various problems in energy consumption forecasting: Berdin A.S., Benn, Vasilyeva E.E., Vagin V.A., Voropai N.I., Gotman N.E., Kudrin B.I., Makoklyuev B.I., Melamed A.M., Nadtoka I.I., Sedov A.V., Shumilova G.P. etc.

In connection with the changing conditions of work in the balancing electricity market, changes and complication of power supply systems, the requirements for the quality and accuracy of forecasting are changing. The problem of load forecasting remains relevant and its study is actively developing. The degree of modern development of intelligent data analysis methods allows improving forecasting systems.

A forecasting method that allows you to get a reliable result with uncertain or incomplete input parameters is the use of machine learning tools, namely artificial neural networks.

Purpose and tasks of the work. The aim of the work is to develop methods, models and algorithms for predicting the volume of energy consumption using machine learning tools, namely artificial neural networks, for further use in a system to support operational dispatching decisions.

To achieve the goals set in the dissertation work, the following tasks were identified and solved:

1. A task book has been created for training a neural network, containing the values of the volumes of consumed load for the day preceding the day of forecasting, retrospective information about the volumes of consumed load on the same day of the previous year, data on the type of day of the week, as well as information on the numerical value of air temperature on the day of forecasting ;

2. An analysis was made of the degree of influence of various databases on the accuracy of forecasting;

3. A neural network learning algorithm has been developed, including a neural network architecture, a learning process suitable for time series forecasting;

4. A methodology has been developed to support the adoption of dispatcher decisions based on the forecasting of energy consumption;

5. A database of recommendations has been created for warning about a possible state of the power system, for changing the topology of the power system for more efficient operation.

Object of study: daily schedules of energy consumption in the city of Petropavlovsk, North Kazakhstan region, Republic of Kazakhstan.

Subject of study: methods and processes for forecasting energy consumption.

Scientific novelty lies in the following provisions and results:

- An intellectual model of short-term forecasting of energy consumption based on an artificial neural network has been developed;

- Identified the basic composition of factors, the introduction of which into the neural network improves the accuracy of forecasting;

- A technique has been developed for using forecast data to support dispatcher decision-making.

practical value.

1. An algorithm has been developed to support the adoption of dispatching decisions based on predicting the consumption of electricity by electric power systems using artificial neural networks.

2. The software implementation of forecasting the volume of electricity consumption in the MATLAB environment has been implemented.

The provisions of the dissertation submitted for defense:

- model of an artificial neural network with a data set of a training task book for short-term forecasting of energy consumption for the day ahead;

- algorithm for setting the data of the training problem book and training the neural network;

- structure of the methodology for supporting the adoption of operational dispatching decisions;

- algorithm of functioning of the decision support unit;

- schematic diagram of the functional architecture of the decision-making system.

Approbation of work. The main provisions and results of the dissertation research were reported and discussed at: III International Scientific and Technical Conference (Omsk, 2019); International scientific and practical conference "Problems of development of technical potential and directions for its increase" (Ufa, 2019); as well as the International Scientific and Practical Conference "Kozybaev Readings-2018: Eurasian Potential and New Development Opportunities in the Context of Global Challenges" (Petropavlovsk, 2018).

Publications. The results of the dissertation research were published in 8 printed scientific papers, namely, in 4 articles published in publications recommended by the Committee for Quality Assurance in Education and Science of the Ministry of Education and Science of the Republic of Kazakhstan, in 1 article in an international scientific journal with a non-zero impact factor (indexed in the Web of Science and Scopus database), in 4 papers reflected in the proceedings of international scientific conferences, including 3 in foreign and 1 in republican ones, as well as in 1 patent.

Personal contribution of the author.

The author of the dissertation owns the main results of theoretical and experimental research. The participation of the author in joint publications with co-authors consists in setting tasks and conducting experimental studies, developing methods and algorithms, calculations and generalizing the results obtained.

Dissertation structure. The dissertation has a classical structure: introduction, main part (five chapters, including conclusions for each chapter), conclusion, list of references. The work is presented on 102 pages of computer text, includes 45 figures, 7 tables and 105 bibliographic sources, 2 appendices.

The introduction describes the relevance of the topic of the dissertation research, goals. The description of the subject and object of research is given. The provisions submitted for defense are indicated. A brief description of each chapter of the study is given.

The first chapter describes the energy market of the North Kazakhstan region. The main problems existing in the energy industry of Kazakhstan are

considered. The digitalization of the energy sector is considered as one of the most effective and relevant ways to improve the quality of the functioning of the energy system.

The second chapter analyzes the existing methods for forecasting energy consumption. The most common forecasting methods are described and their main advantages and disadvantages are indicated. The use of machine learning tools, namely artificial neural networks, is considered as the most effective way to predict the volume of energy consumption. A description is given and the main varieties and methods of operation of artificial neural networks are indicated.

The third chapter describes the main steps and algorithms for training an artificial neural network. The analysis of the initial actual data for forecasting is carried out, the optimal composition of the training sample is supported.

The fourth chapter describes a methodology for supporting the adoption of operational dispatching decisions based on short-term forecasting of energy consumption volumes. The algorithm of operation and description of the main blocks of the dispatcher decision support system are given.

In the fifth chapter, experimental studies of the energy consumption forecasting system for decision support are carried out. An experimental study of the accuracy of the forecast from the composition of the initial data is carried out.

In conclusion, the conducted research is summarized and conclusions are drawn based on the results obtained.

Works published on the topic of the dissertation

1. Kalantaevskaya N.I., Koshekov K.T., Latypov S.I. On the question of how to predict the consumption of electric power // Materials of the MNPK "Kozybaev Readings-2018: Eurasian Potential and New Development Opportunities in the Context of Global Challenges", Vol.2. - Petropavlovsk: NKGU im. M. Kozybaeva, 2018. p. 259-262

2. Kalantaevskaya N.I., Koshekov K.T., Latypov S.I. Forecasting the energy consumption of railway infrastructure by means of artificial neural networks in the North Kazakhstan region // Collection of articles on the results of the International scientific and practical conference "Problems of development of technical potential and directions for its increase." Agency for International Studies. 2019. P.42-46.

3. Kalantaevskaya N.I., Koshekov K.T., Latypov S.I. Neural network technologies in the energy sector // Bulletin of Pavlodar State University. Energy Series, No. 1(2019), 2019, pp. 237-243

4. Kalantaevskaya N.I., Koshekov K.T., Savostin A.A. Latypov S.I. Forecasting the energy consumption of Northern Kazakhstan based on deep learning technology // Problemy mashinovedeniya. Proceedings of the III International Scientific and Technical Conference. Publisher: Omsk State Technical University (Omsk), 2019

5. Kalantaevskaya N.I., Koshekov K.T., Latypov S.I. Balancing energy consumption using machine learning technologies // Collection of articles based on the results of the International scientific and practical conference "Science-intensive technologies and intelligent systems". Agency for International Studies. 2019. P.19-22

6. Kalantaevskaya N.I., Koshekov K.T., Latypov S.I. Model of data organization and learning process of a neural network when constructing load graphs for the day ahead // Bulletin of the Almaty University of Energy and Communications. - Almaty, 2019. No. 3 (46) - S. 11-16

7. Kalantaevskaya N.I., Koshekov K.T., Latypov S.I. Studies of the influence of the method of organizing a training sample on the accuracy of predicting the electrical load. Bulletin of Pavlodar State University. Energy Series, No. 3(2019), 2019, pp. 250-256

8. Kalantaevskaya N.I., Koshekov K.T., Latypov S.I. Investigation of the effectiveness of data normalization in the construction of load graphs for the day ahead using machine learning techniques. Bulletin of Pavlodar State University. Energy Series, No. 3(2019), 2019, pp. 257-264

9. Kalantayevskaya NI, Koshekov KT, Latypov SI, Savostin AA, Kunelbaev M M. Design of decision-making support system in power grid dispatch control based on the forecasting of energy consumption // Cogent Engineering (2022), 9: 2026554 DOI: 10.1080/23311916.2022.2026554