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doi:10.15199/48.2023.03.28

Modeling household power consumption by residents of the Republic of Tajikistan

***Abstract**. The paper proposes modeling power consumption, taking into account factors and identifying the dependence of the geographical location above sea level and meteorological conditions of the location of residential consumers of the Republic of Tajikistan on power consumption. A mathematical and computer model has been proposed, which makes it possible to take into account the influence of changes in geographic locations above sea level and meteorological conditions in the area where household consumers are located on power consumption. To compare the results obtained in the models, the results were compared with the results of experimental values; for the experimental data, the readings of the electricity metering devices were taken, which showed high convergence.*

***Streszczenie.** W pracy zaproponowano modelowanie zużycia energii elektrycznej z uwzględnieniem czynników oraz określenie zależności położenia geograficznego nad poziomem morza oraz warunków meteorologicznych lokalizacji odbiorców mieszkaniowych Republiki Tadżykistanu od zużycia energii elektrycznej. Zaproponowano model matematyczno-komputerowy, który umożliwia uwzględnienie wpływu zmian położenia geograficznego nad poziomem morza oraz warunków meteorologicznych na obszarze, na którym znajdują się gospodarstwa domowe, na zużycie energii. W celu porównania wyników uzyskanych w modelach wyniki porównano z wynikami wartości eksperymentalnych; dla danych eksperymentalnych pobrano odczyty urządzeń pomiarowych energii elektrycznej, które wykazały dużą zbieżność. (**Modelowanie zużycia energii elektrycznej w gospodarstwach domowych przez mieszkańców Republiki Tadżykistanu**)*

Keywords: power consumption, mathematical and computer model, ambient temperature
Słowa kluczowe: pobór mocy, model matematyczny i komputerowy, temperatura otoczenia

Introduction

In the last decade, there has been a sharp increase in electricity consumption by household consumers in the cities of the Republic of Tajikistan. This was influenced by many factors, such as:

- a sharp decrease in the production capacity of large enterprises;
- disconnecting consumers from gas supply and heat and hot water supply;
- the use of non-energy efficient electrical receivers.

The distribution of electricity consumption for 2011-2019 can be conditionally divided into 4 groups:

Group 1 - industrial, non-industrial, agricultural and equated consumers;

Group 2 - consumers of the public sector, utilities and electrified transport;

Group 3 - pumping stations for pumping irrigation systems, borehole and reclamation pumping stations;

Group 4 - population, settlements and hostels.

In Fig. 1 shows the structure of electricity consumption by the indicated groups in 2011-2019.

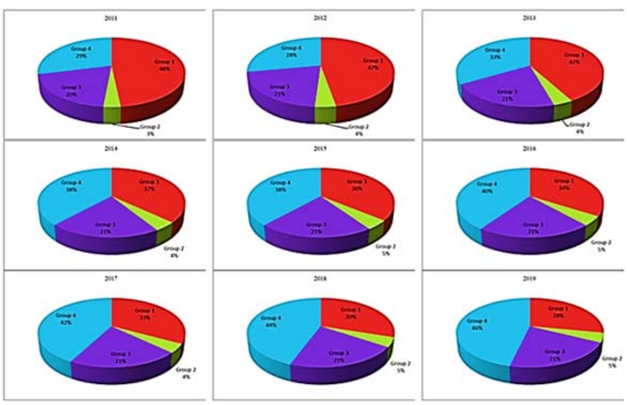

Fig. 1. The structure of electricity consumption by the indicated groups in 2011-2019

Fig. 1 show that the power consumption of the 4th group related to household consumers is increasing annually, which is mainly due to the disconnection of these consumers from gas supply and heat and hot water supply, as well as the use of ineffective electrical consumers. In turn, the factor of disconnecting consumers from gas supply and heat and hot water supply significantly influenced the increase in power consumption. This is explained by the fact that on winter days, due to a decrease in the ambient temperature, the indicated shutdown leads to an increase in the electrical load, thereby increasing power consumption, in particular, during peak load hours.

Consequently, forecasting electricity consumption in everyday life for the energy supplying organization of the Republic of Tajikistan is becoming an urgent and unsolved task at the moment.

On the issue of forecasting power consumption, a fairly large number of works, both foreign [1-13] and Russian, have been carried out, taking into account various factors [14-25]. The results of these studies are described in the form of various mathematical equations, models, etc. etc. However, these works do not take into account the geographical location of objects above sea level, which, in addition to the meteorological dependence, makes its own changes. In addition, the normative document for houses according to standard projects necessarily provides for the availability of gas supply and heating and hot water supply for household consumers.

Research method

The study of temporary changes in power consumption, average electrical load, load at peak hours is advisable to carry out either using mathematical or computer models.

In this case, it becomes possible to take into account the geographic location of the electricity consumer and the temperature of the surrounding air. The corrective indicator in our case is the lack of gas supply and heat and hot water supply.

Mathematical model

For the mathematical description of power consumption depending on the geographical and meteorological conditions of the area of the Republic of Tajikistan, the following expression is proposed.

(1) $$F(x,y) = y\cdot(1-x),$$

Where: x - temperature coefficient; y - power consumption, kWh.

In turn, the temperature coefficient is determined as follows:
at ambient temperatures from and above.

(2) $$x = \frac{|x_1| + |x_2|}{x_3},$$

where: x_1 - ambient air temperature at the location of the consumer, C_1, x_2;, - additional temperature, C taking into account the difference in temperature from the outside of the house and the temperature inside the room);; x_3 - ambient air temperature at sea level,. C

at an ambient temperature of $-4^\circ C$ до $-6^\circ C$

(3) $$x = \frac{|x_1|}{x_3},$$

and at an ambient temperature below $-7^\circ C$

(4) $$x = \frac{|x_1| - |x_2|}{x_3}.$$

As can be seen from expression (3) at an ambient temperature from $-4^\circ C$ before $-6^\circ C$ if the construction of a residential building is made of reinforced concrete, the additional temperature is not taken into account. This is explained by the fact that at a given ambient temperature, the design of a residential building does not affect the rise in temperature inside the room. If other heat-insulating materials are used, the dependence of the temperature coefficient on the ambient temperature must be determined either by expression (2) or by (4).

Attitude x_1/x_3 shows the influence of the consumer's geographic location above sea level.

The dependence of power consumption on the temperature coefficient is determined by the expression.

(5) $$y = P_{\text{load}}\cdot t_{\text{month}}\cdot(1-x),$$

where: P_{load} - load, kW; t_{month} - month or time of maximum loads, h.

Computer model

To describe the physical process of the influence of the geographical location of the consumer above sea level and meteorological conditions on the predicted power consumption, a computer model was built in the Matlab Simulink software environment.

The purpose of constructing this model is to represent changes in power consumption at a known load and a change in the geographical location of the consumer above sea level, the ambient temperature at the location of consumers, as well as to identify the average load during the month and during the hours of maximum loads according to the previously proposed maximum load factor for cities Republic of Tajikistan [26 - 29].

The computer model is attached in the form of control units (see Fig. 2).

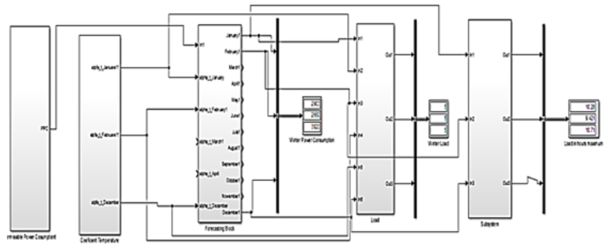

Fig. 2. Computer model with control units

The offered model consists of 5 control units:
1. Block of simulation of the input load;
2. Block for modeling the temperature coefficient;
3. Block for modeling the forecasting of electricity consumption by household consumers;
4. Block for modeling the average load during the month;
5. Block for simulating the load at peak hours.

The control unit simulation of the input load is shown in Fig. 3.

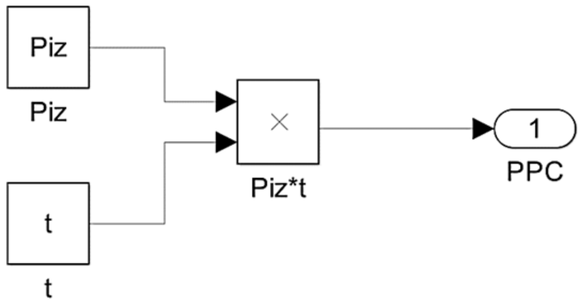

Fig. 3. Input load simulation control unit

The block for modeling the temperature coefficient is shown in Fig. 4, 5.

The block for modeling the forecasting of electricity consumption by household needs is shown in Fig. 6.

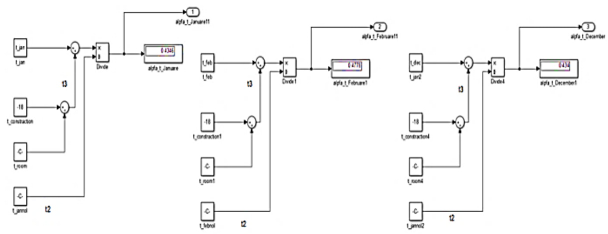

Fig. 4. Block for simulating the temperature coefficient at an ambient temperature above 0°

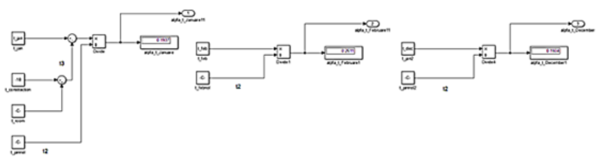

Fig. 5. Block for simulating the temperature coefficient at an ambient temperature from $-4^\circ C$ before $-6^\circ C$

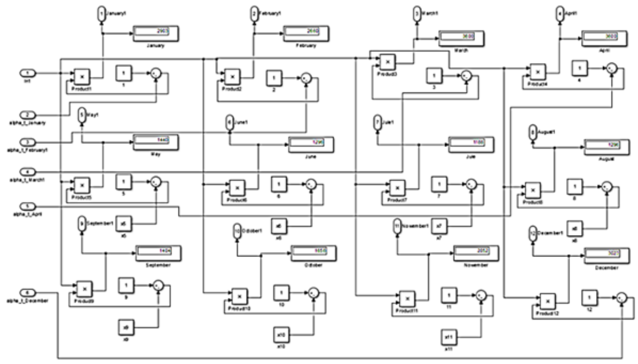

Fig. 6. Block of modeling of forecasting of electricity consumption by household needs

Modeling the average load during the month is carried out by the block shown in Fig. 7.

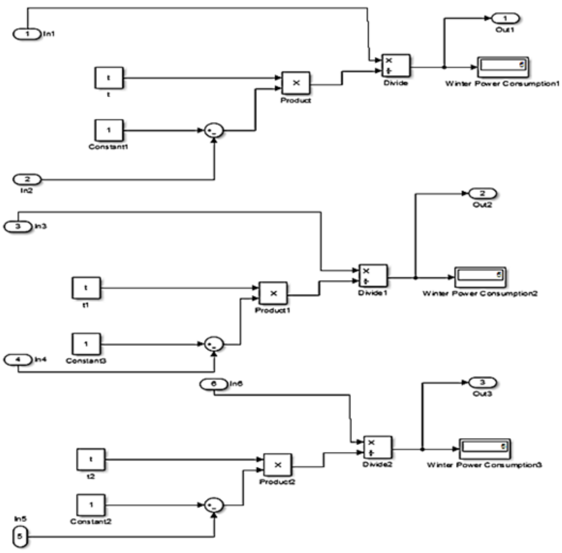

Fig. 7. Block for modeling the average load for a month

The block for simulating the load during peak hours is shown in Fig. 8.

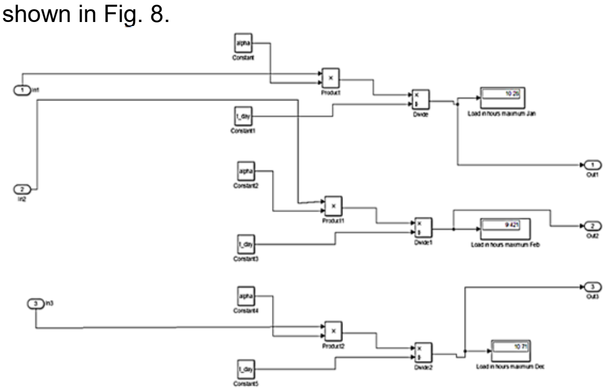

Fig. 8. Block for simulating load during peak hours

The resulting computer model (Figure 2) with simulation blocks (Figure 3-8) shows that with changes in the geographical position above sea level and meteorological conditions, power consumption increases.

It should be noted that the average load during the month does not exceed the established standard values given in [30, 31]. However, during peak load hours, a 25% excess is observed.

Practical part and discussion

To check the adequacy of the proposed models, the results obtained were compared with the experimental data. For experimental data, readings of electricity metering devices for groups of household consumers were taken. The comparison results are presented in the form of a histogram for the winter periods of time (Fig. 9).

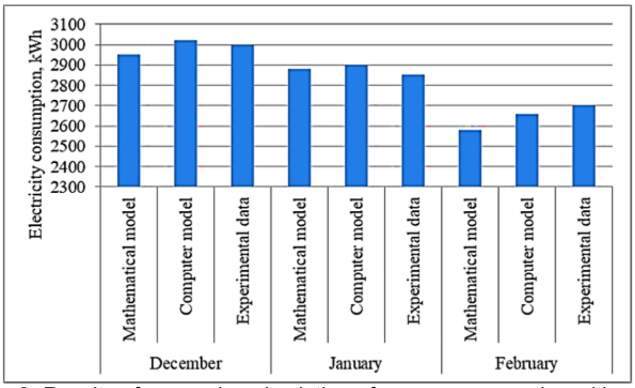

Fig. 9. Results of comparing simulation of power consumption with experimental data

Comparison of the obtained results with experimental data show that for the mathematical model the discrepancy for the winter periods is not more than 2.2%, and for the computer model - 1.3%.

Conclusions

1. Proposed mathematical and computer models that allow predicting household power consumption. The simulation results obtained are compared with experimental data, the discrepancy with which for the winter months does not exceed 2%.

2. These models take into account the geographical position above sea level and meteorological conditions at the location of consumers.

3. Blocks for simulating the load at maximum hours allows you to determine the electrical loads at the maximum hours, ie, to identify consumers that affect the modes of operation of the electrical network. This will allow by organizational measures to increase the reliability of the electrical distribution networks of the Republic of Tajikistan.

Conflict of Interest

The authors declare no conflict of interest.

Acknowledgment

This research received no external funding.

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