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Improving Energy Efficiency by Household Consumers in the Republic of Tajikistan Based on the Developed Forecasting Method

Saidjon Sheralievich Tavarov*, Aleksandr Ivanovich Sidorov

South Ural State University, Lenin prospect 76, Chelyabinsk 454080, Russian Federation

Corresponding Author Email: tabarovsaid@mail.ru

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ABSTRACT

The work is devoted to the assessment of energy efficiency in electricity consumption by household consumers in the city of the Republic of Tajikistan. Methods of forecasting taking into account factor dependencies are proposed. According to the data obtained from the readings of electricity metering devices for groups of household consumers with different climates, meteorological conditions of the area and geographic area, comparisons of the actual power consumption with standard values were made. A non-standard excess of the actual specific loads in winter about the standard values was established, leading to a violation of the operating mode. The applied methods for calculating the proposed average monthly loads of all consumers and the average values of the electrical loads of the cities under consideration. It is substantiated that the proposed method makes it possible to increase the energy efficiency of urban electrical networks of 10 / 0.4 kV without violating the standard values.

1. INTRODUCTION

Over the past 10 years, the Republic of Tajikistan has seen a sharp increase in electricity consumption by household consumers. This was influenced by various factors, such as:

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

The developed norms of specific loads for residential consumers with standard designs do not fully correspond to the current conditions. This is primarily because these standards do not take into account electrical loads generated by air conditioners and electric water heaters.

However, because the main source of electricity in the Republic of Tajikistan is hydraulic power stations and the generation of electricity in them is dependent on the inflow of water, and the inflow of water comes from the mountains when glaciers melt on winter days due to frosts, a sharp decrease in water inflow is observed, thereby power shortage.

At the same time, it is necessary to take into account the specific feature of the location of cities in the Republic of Tajikistan. According to the climatic and meteorological conditions of the terrain and the geographical location of the city, they are located at different heights about a point above sea level with different ambient temperatures.

For example, in terms of territorial location, the ambient temperature in Dushanbe in winter does not drop below -5℃, and in the Gorno-Badakhshan Autonomous Region with the centre of Khorog, the ambient temperature in winter can reach -30℃, therefore, electricity consumption by household consumers in Khorog will be higher than in Khorog. Dushanbe. However, this prominence does not take into account the influence of the geographical location of residential consumers about a point above sea level. According to our assumption, this factor may be an additional factor leading to uneven power consumption, the detection of which will allow increasing the energy efficiency of urban electric networks.

The efficiency of the power supply system depends on the correct forecast of power consumption. The concept of efficiency is understood as the reliability of the power supply. In turn, reliability includes [1-15]:

- electricity quality;
- service life of electrical equipment;
- under-discharge of electricity.

Of the Republic of Tajikistan (RT) from geographical location has its characteristics.

Features include:

1. Large elevation differences with the location of cities;
2. Different climatic and meteorological conditions of the area.

Therefore, it is necessary to forecast power consumption by these consumers, since the absence of a forecast will lead to a decrease in the reliability of power supply and everything related to reliability. This is because the main source of electricity in the Republic of Tajikistan is hydraulic power generation stations, which depend on the inflow of water by melting glaciers.

2. RESEARCH METHOD

The proposed methods of forecasting power consumption in the works of many authors [14, 15] are not fully applicable in the conditions of the RT terrain.

Therefore, in this paper, the task is to offer a method that allows you to predict power consumption by household consumers, taking into account the above features and factors.

To offer a method that allows predicting power consumption by household consumers of the Republic of

Tajikistan, it is necessary to assess the dynamics of power consumption in previous years.

This dynamic of power consumption can be built on the data of the readings of electricity metering devices installed in household consumers.

To assess the specific electricity consumption, taking into account the above, according to the monthly readings of electricity metering from consumers of the household sector, received from OJSC "City Electric Networks" and OJSC "Pamir Energy", electricity consumption charts were built by months for 2017 climatic factors and territorial location, as well as the provision of consumers in the household sector with heat supply, temporary norms of specific power consumption were identified.

For comparison, the most typical consumers of the household sector in Dushanbe, receiving power from the Aviator substations, and the cities of the Gorno-Badakhshan Autonomous Region of Khorog and Rushon, were taken, which made it possible to establish the compliance of the monthly electricity consumption with the norms of specific power consumption or exceeding them.

Figures 1, 2 show the dependences of the average monthly electricity consumption for groups of household consumers with standard projects for the cities of Dushanbe and Khorog of the Republic of Tajikistan for 2017.

From the obtained annual power consumption graphs for household consumers, Figure 1, 2 for 2 cities of the Republic of Tajikistan, it can be seen that the electricity consumption by household consumers is different for each city. Electricity consumption is influenced by both their territorial location and landscaping. Thus, to establish the dependence of power consumption on climatic-meteorological and recommendation of power consumption norms, it is necessary to build a mathematical model taking into account the terrain conditions of the Republic of Tajikistan. This model should allow the establishment of electricity consumption standards that do not go beyond the permitted power output by city and district power grids.

Based on the data from electricity metering devices for the considered household consumers (see Figures 1, 2), the dependences of the total average monthly power consumption of all household consumers are plotted, which receives power from the Aviator 110/10 kV substation in Dushanbe and for one of the substations in Khorog with different climates - meteorological conditions of the terrain and the geographical location of the object of the Republic of Tajikistan Figures 3, 4.

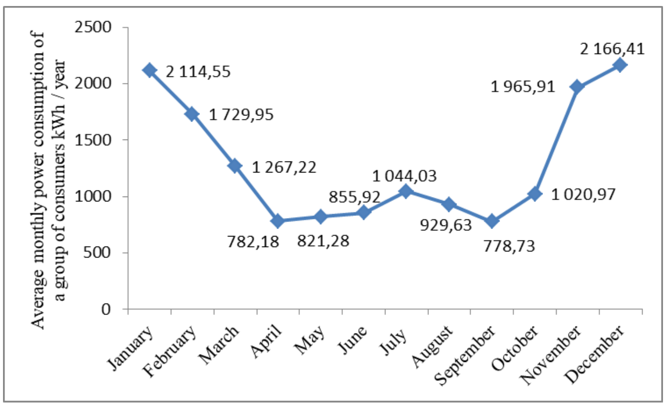

Figure 1. Average monthly electricity consumption by residential consumers with a typical design receiving power from the Aviator substation in Dushanbe (RT) for 2017

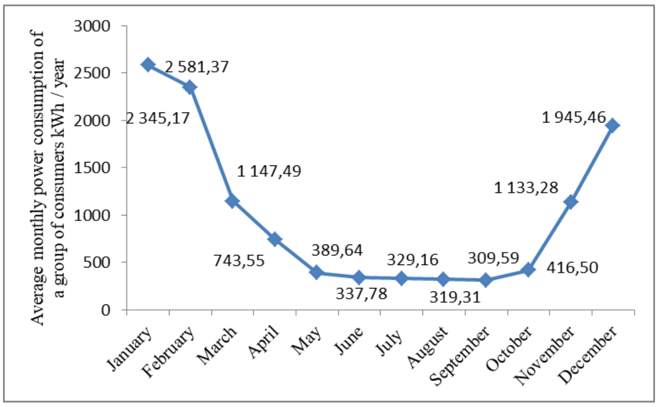

Figure 2. Average monthly electricity consumption by household consumers with a typical project in Khorog (RT) for 2017

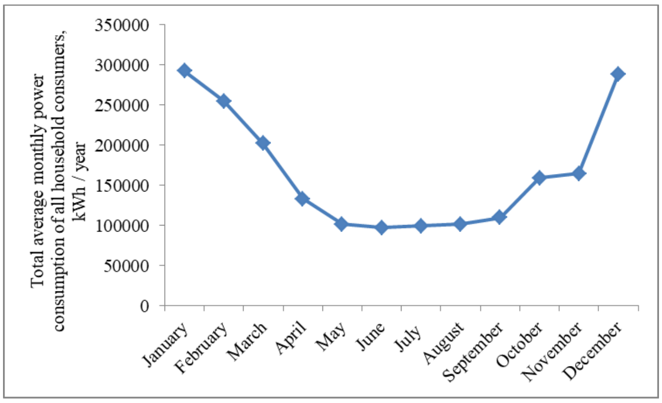

Figure 3. The total average monthly power consumption of all household consumers for one of the substations in Khorog

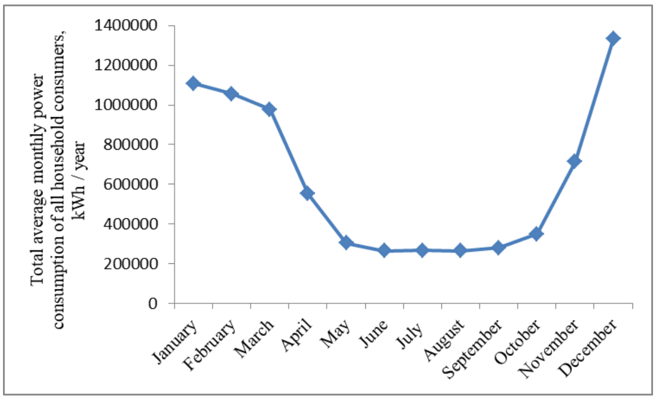

Figure 4. The total average monthly power consumption of all household consumers, powered by the 110/10 kV Aviator substation in Dushanbe

To establish the influence of peculiarities of the terrain conditions of the RT on energy consumption, annual schedules of electricity consumption by household consumers was built for two characteristic conditions of the area of the cities of the RT, namely in the city of Khorog with the location at an altitude of 2123 m. above sea level and Dushanbe at an altitude of 706 m. above sea level (see Figures 3, 4).

When developing methods for predicting power consumption by household consumers, taking into account the climate-meteorological features of the terrain conditions and the geographical location of the consumers in question, the results of comparison with the results shown in Figures 3, 4.

For another proof, the fact that the real data of power consumption, depending on the specific electrical load, does not correspond to the real conditions developed in Soviet times and factors influencing these conditions [16-18].

Based on the results shown in Figures 1-4, we present the results of comparing the standard values of the specific load [19, 20] corresponding to the number of household consumers. These dependencies, presented in the form of histograms (Figures 5, 6), allow showing a real picture of the compliance of regulatory data with the measurement results, which, in turn, will allow us to assess the degree of energy efficiency of the considered household consumers and assume their influence on the operating parameters of urban electrical networks 10 / 0.4 kV.

From the results of the comparison of Figures 5, 6 it can be seen that due to the increased energy consumption of the considered consumers in Dushanbe during the evening winter maximum load, the exceeded value of the exceeded standardized value, and in summer there is no excess. For the city of Khorog during the hours of winter evening maximum loads, the measured values are 2 times higher than the normalized value, and in summer there is no excess.

Based on a comparison of the results obtained in Figures 5, 6 of the results of tests carried out to improve the energy efficiency of urban networks of the considered urban networks, it is necessary to propose a new method of comparison without violating the normative values of load balancing due to optimization of power consumption. At the same time, electrical networks consume all external energy consumption [16-18].

The proposed following method for increasing the energy efficiency of the considered electrical networks, taking into account all the stated factors.

$$W_{power\ consumption\ forecasting} = W_{temp.\ pow.\ consum.\ stand.} \cdot (1 - \alpha_{terrain\ conditions}) \quad (1)$$

where, $W_{temporary\ power\ consumption\ standards} = P_{allowed.} \cdot t_{time\ of\ the\ month}$, kW / h., $P_{allowed.} \cdot t_{time\ of\ the\ month}$ - installed permitted capacity of Barki Tajik, 4-5 kW, $t_{time\ of\ the\ month}$ - time in a month, h.

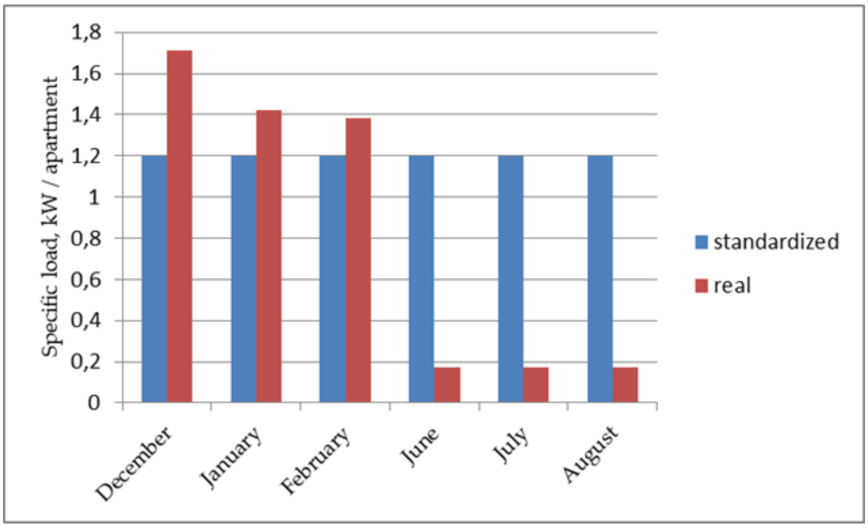

Figure 5. Comparison of the measurement results with the normative considered types of high-quality household consumers in Dushanbe

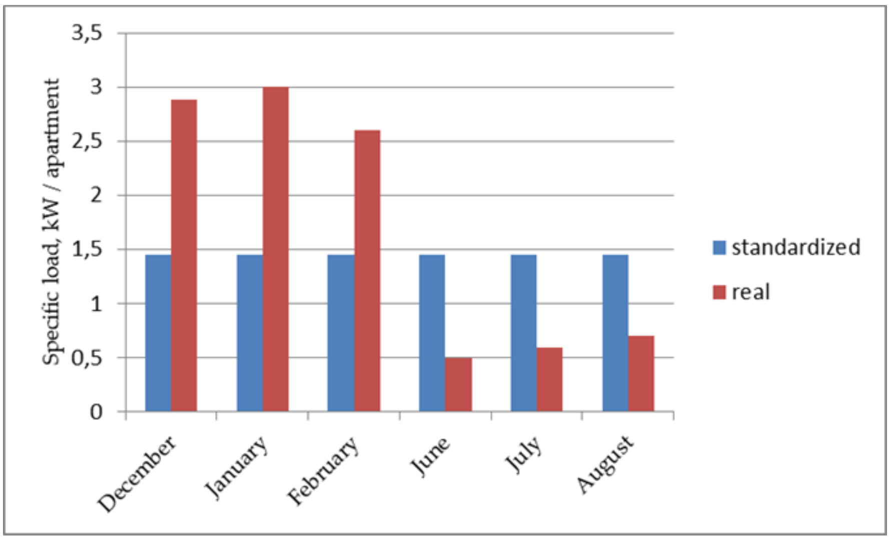

Figure 6. Comparison of measurement results with standard data corresponding to the considered number of household consumers in Khorog

The coefficient that characterizes the terrain conditions ($\alpha_{terrain\ conditions}$) is determined by the expression:

$$\alpha_{terrain\ conditions} = \frac{(t_{av.\ mon.\ am.\ tem.} + t_{tem.diff.})}{(t_{av.\ mon.\ am.\ tem.} + t_{av.mon.\ add.\ tem.})}, \quad (2)$$

From expressions (2) $t_{av.mon.\ add.\ tem.}$ is determined by the following method:

$$t_{average\ incremental.} = t_{av.\ mon.\ am.\ tem.} \pm t_{int.\ sur.\ temp.} \pm t_{ind.\ temp.} \quad (3)$$

where, $t_{av.\ mon.\ am.\ tem.}$ – average monthly ambient temperature, ℃. This value corresponds to the data obtained from the hydrometeorological station for the forecast year and the territorial locations of the considered cities of the Republic of Tajikistan above sea level;

$t_{tem.diff.}$ – temperature changes in different points of the location of the cities under consideration for which it is planned to predict monthly power consumption, ℃;

$t_{av.\ mon.\ am.\ tem.}$ – data on changes in the average monthly temperature at 0 points above sea level in relation to the forecast point of power consumption of the corresponding month, ℃;

$t_{av.mon.\ add.\ tem.}$- average monthly temperature difference inside and outside the room, ℃. (This temperature indicator allows you to estimate the inside room temperature by changing the outside temperature for the months in question).

$t_{int.\ sur.\ temp.}$ - the temperature of the inner surfaces of the walls of the construction of houses [21], ℃;

$t_{ind.\ temp.}$- the temperature inside the room (apartment), ℃, a plus $t_{ind.\ temp.}$ at minus the average monthly ambient temperature, that is, in order to achieve the optimum room temperature +22℃ [21], it is necessary to increase the power of the electric heater taking into account the factor in our in the case of lack of heating, minus $t_{ind.\ temp.}$at a positive average monthly ambient temperature in order to achieve the optimum room temperature of +22℃, it is necessary to cool the premises using an air conditioner.

Taking into account the proposed method for increasing energy efficiency and the coefficient characterizing the conditions of the area, the equations for determining the average electrical load are proposed:

$$P_{Average\ electrical\ load} = \frac{W_{power\ consumption\ forecasting}}{t_{maximum\ load\ time}} \cdot \alpha_{terrain\ conditions}, \quad (4)$$

3. RESEARCH RESULTS AND DISCUSSION

To check the adequacy of the proposed method for predicting power consumption by household consumers, taking into account the specific terrain conditions of the cities in question, the Tajik hydro-meteorological Station for the period 2017 obtained data on changes in the average monthly temperature of the environment for the months of 2017, the results are shown in Table 3.

Consider the example of Khorog and Dushanbe for January, we take the data from the Table 1.

- Khorog city

$$t_{aver.\ increm.} = -7{,}4 - 18 + 22 = -3{,}4\ ℃$$

- Dushanbe city

$$t_{aver.\ increm.} = 4{,}3 + 18 - 22 = 0{,}3\ ℃$$

To compare the results obtained by calculating Eq. (1) with experimental data (readings of electric power accounting tools), it is necessary to determine the values of the coefficient that characterizes the terrain conditions using the expression (2) for the period under consideration. The results are shown in the form of a Table 2.

Based on the obtained values of the coefficients characterizing the conditions of the terrain and geographical location of the considered household consumers with standard designs using Eq. 4, the average values of electrical loads were calculated. The calculation results are presented in Tables 3, 4.

Table 1. The average temperature in 2017

The presence of cities	January	February	March	April	May	June	July	August	September	October	November	December
Khorog $t_{av.\ mon.\ am.\ tem.}$, ℃	-7.4	-5.3	0.2	6.7	12.6	16.1	20.1	19.1	15.4	6.8	0.5	-4.7
Dushanbe, $t_{av.\ mon.\ am.\ tem.}$, ℃	4.3	5.7	11.2	15.8	20.8	25.3	29.7	26.5	22.1	15.7	8.3	5.2

Table 2. Coefficients describing the terrain conditions

The presence of cities	January	February	March	April	May	June	July	August	September	October	November	December
Khorog,$\alpha_{terrain\ conditions}$	0.254	0.353	0.604	0.704	0.755	0.773	0.803	0.794	0.773	0.704	0.614	0.384
Dushanbe,$\alpha_{terrain\ conditions}$	0.344	0.373	0.483	0.542	0.602	0.641	0.671	0.642	0.614	0.543	0.433	0.362

Table 3. The total average monthly power consumption of all household consumers, powered by the 110/10 kV Aviator substation and the calculated value of the average electrical loads in Dushanbe

Month	December	January	February	June	July	August
The total average monthly electricity consumption of all household consumers, kWh / month	1332566	1108729	1055659	265341.5	266781.5	266058
Average electrical loads, kW	1165.99	970.14	923.70	121.62	122.275	121.94

Table 4. The total average monthly power consumption of all household consumers for one of the substations and the calculated value of the average electrical loads in Khorog

Month	December	January	February	June	July	August
The total average monthly electricity consumption of all household consumers, kWh / month	288153.9	292767	255138.2	97365	99768	101603
Average electrical loads, kW	420.22	426.95	372.08	85.19	87.30	88.90

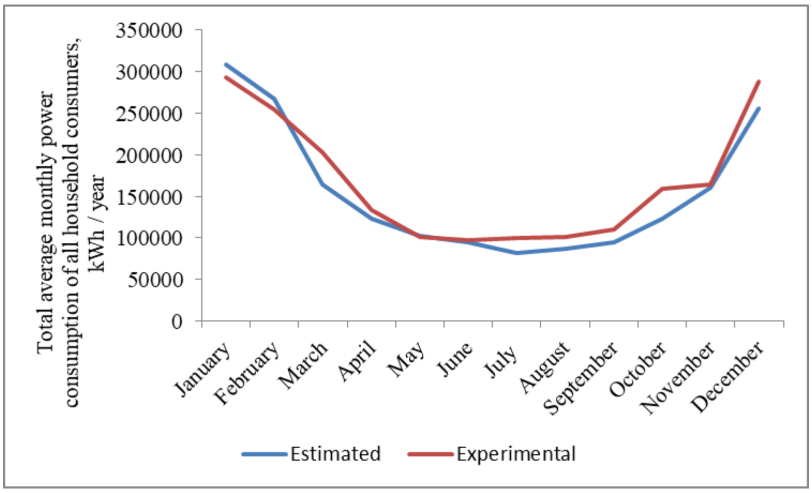

Figure 7. Comparison of the results of the total averaged monthly power consumption of all household consumers for one of the substations in Khorog obtained by calculation and experiment

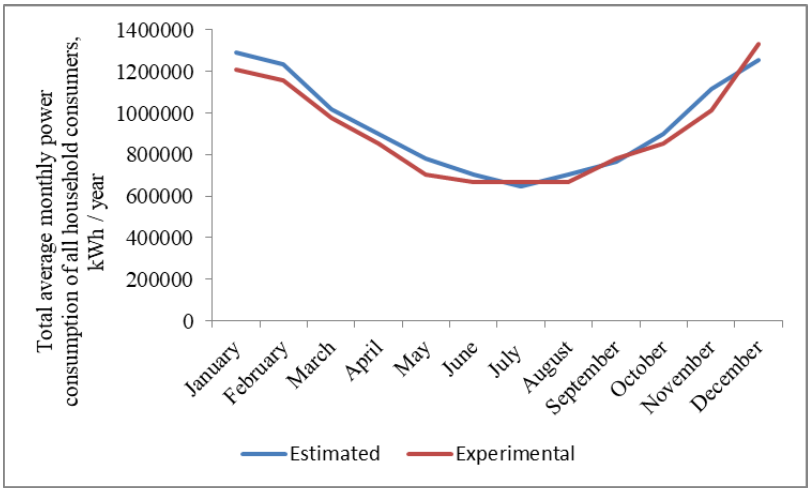

Figure 8. Comparison of the results of the total averaged monthly power consumption of all household consumers receiving power from the Aviator 110/10 kV substation in Dushanbe, obtained by calculation and experiment

The results of comparison of the predicted power consumption by household consumers obtained by Eq. (1) with experimental data (see Figures 3, 4) are presented as a dependence of the annual power consumption graphs for the period under consideration Figures 7, 8.

The comparison results are shown in Figures 7, 8 (calculated and experimental) for the period under review clearly show the adequacy of Eq. (1) and expression (2).

Thus, if the location of household consumers above sea level and all the above-mentioned ambient air temperatures are known, it is possible to predict power consumption by household consumers in RT using the above equations.

However, it should be noted that for a more accurate application of the obtained equations, it is necessary to develop and propose temporary norms of power consumption by household consumers, depending on the local conditions of the location of household consumers. I would like to note that the proposed Eq. (1) allows not only to determine and forecast power consumption for consumer groups, but also a single consumer [17].

Based on the results obtained, the following conclusions can be drawn.

4. CONCLUSIONS

1. According to the data of electricity metering facilities, the average monthly power consumption for groups of household consumers and the total average monthly power consumption of all household consumers, which receives power from the 110/10 kV Aviator substation in Dushanbe and for one of the substations in Khorog, were constructed to identify the compliance of the current power consumption with normative values.

2. A method has been developed for predicting electricity consumption by household consumers and determining the average electrical load, taking into account the proposed coefficient characterizing the conditions of the terrain and geographical location of the consumers in question.

3. Based on the developed method, the average electrical loads for winter and summer periods are proposed, which does not deviate from the actual data of compliance, which can improve energy efficiency.

REFERENCES

[1] Zakaria, Y., Anup, P. (2018). An optimal load schedule of household appliances with leveled load profile and consumer's preferences. International Conference on the Domestic Use of Energy (DUE), Cape Town, South Africa, pp. 1-7. http://dx.doi.org/10.23919/DUE.2018.8384382

[2] Zakaria, Y., Pule, K.H. (2018). A binary integer programming model for optimal load scheduling of household appliances with consumer's preferences. International Conference on the Domestic Use of Energy (DUE). Cape Town, South Africa, pp. 1-8. http://dx.doi.org/10.23919/DUE.2018.8384381

[3] Sidorov, A., Tavarov, S. (2021). Enhancing reliability of electricity supply of city electric networks cities of Dushanbe. Bulletin of Electrical Engineering and Informatics, 10(1): 46-54. https://doi.org/10.11591/eei.v10i1.2114

[4] Gheorghe, G., Florina, S. (2015). Processing of smart meters data for peak load estimation of consumers. 9th International Symposium on Advanced Topics in Electrical Engineering (ATEE). Bucharest, Romania, pp. 864-867. http://dx.doi.org/10.1109/ATEE.2015.7133922

[5] Hussein, S., Boonruang, M. (2018). Intelligent algorithm for optimal load management in smart home appliance scheduling in distribution system. International Electrical Engineering Congress (iEECON), Krabi, Thailand, Thailand, pp. 1-4. http://dx.doi.org/10.1109/IEECON.2018.8712166

[6] Issi, F., Kaplan, O. (2018). The determination of load profiles and power consumptions of home appliances. Energies, 11(3): 607. https://doi.org/10.3390/en11030607

[7] Angrisani, L., Bonavolontà, F., Liccardo, A., Lo Moriello, R.S., Serino, F. (2018). Smart power meters in augmented reality environment for electricity consumption awareness. Energies, 11(9): 2303. https://doi.org/10.3390/en11092303

[8] Yan, K., Wang, X.D., Du, Y., Jin, N., Huang, H.C., Zhou, H.X. (2018). Multi-step short-term power consumption forecasting with a hybrid deep learning strategy. Energies, 11(11): 3089. https://doi.org/10.3390/en11113089

[9] Vojtovic, S., Stundziene, A., Kontautiene, R. (2018). The impact of socio-economic indicators on sustainable consumption of domestic electricity in Lithuania. Sustainability, 10(2): 162. https://doi.org/10.3390/su10020162

[10] Florian, Z. (2020). Load nowcasting: Predicting actuals with limited data. Energies, 13(6): 1443. https://doi.org/10.3390/en13061443

[11] Aqdas, N., Muhammad, U.J., Nadeem, J., Tanzila, S., Musaed, A., Khursheed, A. (2019). Short-term electric load and price forecasting using enhanced extreme learning machine optimization in smart grids. Energies, 12(5): 866. https://doi.org/10.3390/en12050866

[12] To, W.M., Lee, P.K.C., Lai, T.M. (2017). Modeling of monthly residential and commercial electricity consumption using nonlinear seasonal models-the case of Hong Kong. Energies, 10(7): 885. https://doi.org/10.3390/en10070885

[13] Seunghyoung, R., Jaekoo, N., Hongseok, K. (2017). Deep neural network based demand side short term load forecasting. Energies, 10(1): 3. https://doi.org/10.3390/en10010003

[14] Repkina, N.G. (2015). Research of factors affecting the accuracy prediction daily power consumption. Russian Electromechanics, 2: 41-43. http://dx.doi.org/10.17213/0136-3360-2015-2-41-43

[15] Valeev, G.S., Dzyuba, M.A., Valeev, R.G. (2016). Modeling of daily load schedules of 6-10 kV distribution network sections in cities and localities under conditions of limited initial information. Bulletin Of SUSU. A Series of "Energy", 16(2): 23-29. https://doi.org/10.14529/power160203

[16] SP 256. 1325800.2016. Electrical installations of residential and public buildings rules of design and installation [Electronic resource]. http://files.stroyinf.ru/Data2/1/4293751/4293751598.htm, accessed on November 07 2017.

[17] RM-2696-01. (2001). Temporary Instructions for Calculating Electrical Loads of Residential Buildings. Moscow. Publishing house GUP "NIAC", 22 p.

[18] GOST 30494-2011. Residential and public buildings. The Parameters of the Microclimate in the Premises.

[19] Sidorov, A.I., Tavarov, S.S. (2020). Method for forecasting electric consumption for household users in the conditions of the Republic of Tajikistan. International Journal of Sustainable Development and Planning, 15(4): 569-574. https://doi.org/10.18280/ijsdp.150417

[20] Sidorov, A.I., Khanzhina, O.A., Tavarov, S.S. (2019). Ensuring the efficiency of distribution networks C. dushanbe and Republic of Tajikistan. International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon), pp. 1-4. http://dx.doi.org/10.1109/FarEastCon.2019.8934377

[21] Gorshkov, A.S., Nemova, D.V., Vatin, N.I. (2013). The energy saving formula. Construction of Unique Buildings and Structures, 12(7): 49-63. https://doi.org/10.18720/CUBS.12.7