PROBLEMS OF POWER SUPPLY TO RESIDENTIAL AND PUBLIC CONSUMERS IN CITIES OF UZBEKISTAN

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Abstract. *The article discusses the main problems associated with improving the quality and reliability of power supply to public utility consumers in the cities of Uzbekistan. Five main problems of power supply of cities are presented: 1. In connection with the reconstruction and modernization of all power supply systems of cities, the possibility of building complex electrical networks in the republic. 2. Investigation of power consumption modes of public utility consumers for the purpose of energy saving. 3. Based on field measurements, patented methods have been developed for calculating electrical loads of the same type of household consumers and total electrical loads at transformer substations (TS), distribution points (DP), main regional substations (MRS) of power supply of cities. 4. The necessity of calculating and applying reactive power compensation in urban electric networks has been substantiated. 5. Recommended measures to reduce electricity losses in utility power networks.*

Thus, as a result of solving the tasks, based on the reconstruction and modernization of electrical networks in all cities of Uzbekistan. the quality of electricity and the reliability of electricity supply to urban consumers are increasing, and electricity losses are decreasing, which meets the energy saving policy in the republic.

Keywords: *closed networks, graphic design load, power quality, power reliability, power factor correction, the total electrical load, energy saving, reduction of energy losses.*

1. Introduction

At the present stage, the problems of quality and reliability of power supply to cities come to the fore. Due to the widespread use of new digital electronics in all industries and in the utilities of the residential and public sectors in cities, the problems of electricity quality and reliability of power supply are relevant and in demand.

The main directions for improving the quality of electricity and the reliability of electricity supply to consumers in the residential and public sectors are as follows:

1. On the basis of complex electrical networks, the construction of the most optimal power supply schemes for micro districts and improvement of the quality of voltage and electricity.

2. Development of methods for determining electrical loads and calculating urban networks according to the theory of probability.

3. Research and recommendations on the regime of electricity consumption in residential and public buildings.

4. Recommendations for the use of reactive power compensation in electrical networks of the residential and public sectors.

5. Measures to reduce electricity losses in electrical networks of residential and public sectors in micro districts.

1. On the basis of the new legislative framework, Presidential Decrees and normative materials, entire blocks of 5, 7, 9, 16-storey buildings in the Zangiotinsky and Sergeli districts of the city of Tashkent are being built in a short time, at the same time, all more than 340 objects of the residential and public sectors, as well as in the city of Andijan and other cities. After the commissioning of turnkey objects, there will be no new construction in this micro district. This requires an integrated approach to solving the problem of quality and reliability of power supply, using the latest innovative technologies, automated digital energy, the latest electrical equipment. As a result, in the future it will be possible to choose an optimal, complexly closed power supply scheme for these arrays. All these energy-saving measures help to improve the quality of electricity and the reliability of power supply to the neighborhoods.

In the practice of power supply to foreign cities, there is a significant spread of closed networks up to 1000 V, which have a number of indisputable advantages over other types of networks. Closed networks have high technical and economic indicators and proved to be the best in operation. The latter is confirmed by more than 30 years of experience in the operation of the closed-circuit network in New York and the widespread use of such networks in other cities in the United States. Currently 230 cities in the United States have closed circuit distribution networks. These networks have resulted in savings of $ 37.5 billion. The first closed networks in Europe appeared in the early 30s in Berlin, Malta. Currently closed networks up to 1000 V are used in the cities of Denmark, Switzerland, Germany. Norway. Despite the fact that the first experience of introducing closed networks in Moscow was not entirely successful, work in this direction continues to this day in a number of city networks and organizations. Thus, closed circuits were created in Moscow, St.Petersburg, Vyborg. Urban closed networks with voltage up to 1000 V provide almost uninterrupted power supply to consumers. In this case, the level of uninterruptible power supply is determined by the type of protection used in the network. Redundancy of individual network elements in case of their damage is carried out automatically through the network up to 1000 Volts through the use of appropriate protection and automation equipment. This provides for the parallel operation of transformers through a network up to 1000 V. The use of the principle of network closure up to 1000 V is the main difference between the considered type of urban networks, which determines the technical and economic indicators and operational characteristics of such networks. Closed networks differ in the number of distribution lines above 1000 V and according to the network execution scheme up to 1000 V. Depending on this, they are called cross-closed, three or four trunk and complex-closed. From the experience of using closed circuits, it was concluded that the widespread implementation of these circuits in the CIS is advisable, as they ensure economic and reliable operation and a good operating mode.[]

2. A fundamental step in the design, planning and operation of a rational city power supply system is to determine the calculated electrical loads. The procedure for calculating electrical loads of the proposed integrated method based on a complete set of typical (standard) daily graphs of electrical loads of consumers in the residential and public sectors and the theory of probability is as follows:

- first, on the basis of numerous experimental studies of urban electric consumers, using the mathematical apparatus of the theory of probability, typical (standard) daily graphs of electrical loads (almost a complete set) of the same type of urban electric consumers were constructed.

- further, on the basis of these characteristic daily graphs, the equations of the curve of the function of changing the modes of the typical (standard) daily consumption of electricity with a 30-minute maximum (interval) of each individual type of electrical consumer are determined.

The daily graph of the electrical load shows the change in the mode of electricity consumption at a given object during the day and can be represented as a function curve on the plane, where the load is given - along the ordinate, and the time of changing the operating mode - along the abscissa. This means that this curve can be expressed for each consumer in the form of an equation, a formula, on the load plane.

The essence of the proposed patented method is that, considering the calculated load as the maximum load in the time interval of half an hour, it is necessary to determine the equation of the function of the curve of the daily schedule of the same type of consumer and, knowing the installed (nominal) power, with a probability of 0.7 - 0.9 we determine the half-hour the maximum of the equation of the curve of the daily schedule of this consumer, which will be the calculated power of this consumer. It follows from this that the main task is to correctly and accurately determine the analytical formula expressing in the form of a curve the function of the daily schedule of each type of electrical consumers, based on the typical (standard) daily graphs of electrical loads.

Thus, a formula is determined that describes the curve of the daily load schedule, which closely coincides with the typical (standard) schedule. For each type of consumer, its own curve equation and its own calculation formula are used.

In connection with the above, various methods of determining the function of the curve of the daily schedule of these consumers are considered, which most closely coincide with the typical (standard) schedule. Accordingly, the methods of Lagrange, Newton, Chebyshev, Bessel, Stirling, the interval method, spline functions of 2, 3, 4 orders were considered to find the equation (calculation formula) of the function of the curve of the daily load schedule.

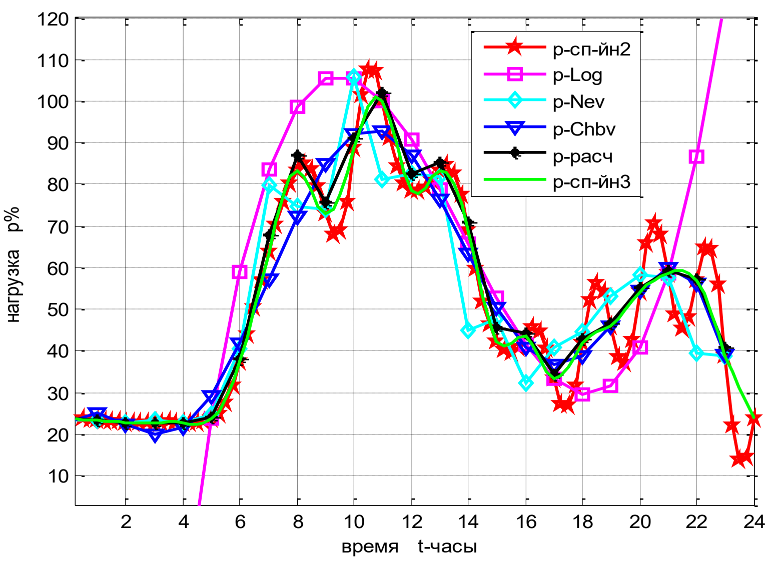

Fig. 1. Daily graphs of the hospital electrical loads, calculated by the interpolation formulas of Lagrange, Newton, Chebyshev, by the interpolation formula of the 2nd order spline function, 3 orders, and typical (standard) daily schedule

Figure 1 presents daily graphs of electrical loads calculated by the interpolation method of Lagrange (equation of 3 degrees) - orange line, by Newton method (equation of 5 degrees) - blue line, by the method of Chebyshev (equation of 8 degrees) - blue line, by the interpolation formula of spline function 2 order - red line, according to the interpolation formula of the spline function, 3rd order - green line and typical (standard) daily graph - black line.

Table 1.

Relative error in calculating daily graphs of electrical loads (in percent) by various methods

Time	Typical	Lagrange	Newton	Chebyshev	Spline 2	Spline 3
0.00-1.00	23.9800	106.519	1.7827	4.1477	11.7827	1.7827
1.00-2.00	23.9800	109.131	0.6413	6.9465	10.3859	0.3859
2.00-3.00	22.7700	113.976	0.9647	2.6956	10.1319	0.1319
3.00-4.00	22.7700	126.463	2.8322	14.9726	10.1319	0.1319
4.00-5.00	22.7700	193.513	0.9780	4.8789	10.1319	0.1319
5.00-6.00	24.1000	2.2920	1.9720	17.6099	32.2920	2.2920
6.00-7.00	38.1900	35.3657	5.9033	8.5481	32.3312	2.3312
7.00-8.00	67.9500	18.7494	14.8898	18.9761	36.4380	4.4380
8.00-9.00	87.0100	11.7479	16.3898	20.1164	34.3536	4.3536
9.00-10.00	75.8200	28.0470	2.3727	10.6330	24.0340	4.0340
10.00-11.00	91.2300	13.4247	13.7488	0.8698	22.9452	2.9452
11.00-12.00	101.950	1.9500	25.3803	9.8856	21.9500	1.9500
12.00-13.00	82.6500	8.8208	0.0433	5.1709	25.3940	4.3940
13.00-14.00	85.3000	8.3662	4.3238	11.4608	12.3027	2.3027
14.00-15.00	71.0600	8.3108	58.2433	12.2649	23.2699	3.2699
15.00-16.00	45.6300	13.4573	3.8932	9.5213	27.9489	4.9489
16.00-17.00	44.1300	6.4161	36.1976	8.0262	41.5884	1.5884
17.00-18.00	34.3800	3.4296	15.8806	6.3574	33.4296	3.4296
18.00-19.00	42.9400	45.8634	3.4896	10.8078	22.2868	2.2868
19.00-20.00	46.4900	47.7481	12.5094	1.5798	20.8460	0.8460
20.00-21.00	55.3400	35.8951	4.8644	1.6105	32.0468	2.0468
21.00-22.00	59.3900	1.3308	3.0173	0.6750	21.3308	1.3308
22.00-23.00	57.3600	33.7100	44.9742	2.3374	20.8971	0.8971
23.00-24.00	40.7900	67.5962	5.1831	4.7950	15.1831	3.1831

Table 1 shows the relative errors in calculating the daily graphs of the hospital electrical loads (in percent) by various methods. Calculation of daily graphs of electrical loads for all consumers of the same type in the residential and public sectors using the method of Lagrange, Newton, Chebyshev, Spline function of the 2nd order when visualizing daily graphs using these methods, the sharp peaks of the extreme points of the daily graph curve are cut off. As a result, the calculated curve differs from the typical (standard) one and has maximum relative errors according to the Lagrange method - an error of more than 100%, according to Newton method - an error of 58.2%, according to the Chebyshev method - an error of 20.1%., According to the spline function method. 2nd order - 41.5%, etc., except for the spline function method of 3rd order, where the maximum relative calculation error is an error of up to 5%. Thus, a third-order spline function formula is adopted, which almost completely coincides with the typical (standard) daily schedule of electrical loads.

The third-order spline function method uses piecewise approximation of the daily schedule at half-hour intervals, as a result, a high accuracy of the calculated function of the daily schedule curve was obtained, which almost closely coincides with the typical (standard) daily schedule of the same type of residential and public sector consumers. [6.p.16, 8 p. 831].

The generalized formula for the spline function of the curve of the 3rd order of the daily graph of electrical loads of electric consumers in the residential and public sectors is presented as follows:

$$S(x)=\frac{(x-x_2)\cdot(x-x_3)\cdot\dots\cdot(x-x_{24})}{(x_1-x_2)\cdot(x_1-x_3)\cdot\dots\cdot(x_1-x_{24})}\cdot S_1(x)+ \\ +\frac{(x-x_1)\cdot(x-x_3)\cdot\dots\cdot(x-x_{24})}{(x_2-x_1)\cdot(x_2-x_3)\cdot\dots\cdot(x_2-x_{24})}\cdot S_2(x)+ \\ +\dots\dots\dots\dots\dots\dots+ \\ \frac{(x-x_1)\cdot(x-x_2)\cdot\dots\cdot(x-x_{23})}{(x_{24}-x_1)\cdot(x_{24}-x_2)\cdot\dots\cdot(x_{48}-x_{47})}\cdot S_{48}(x) \quad (1)$$

In general terms, this expression looks like this:

$$S(x)=\bigcup_{i=1,..48}\cdot S_i(x). \quad (2)$$

Substituting the data from the daily schedule into these equations, the segments of the curve are obtained and, having laid all 48 segments, as a result, the curve of the daily schedule is obtained, which almost completely coincides with the typical (standard) daily schedule of electrical loads of consumers, this allows, based on the analytically found daily schedule, with 0.7-0.9 and the rated power of the object, determine the maximum (calculated) electrical load of this consumer, choosing a half-hour maximum load. Figure 2. the combined daily schedule of the hospital's electrical load is presented.

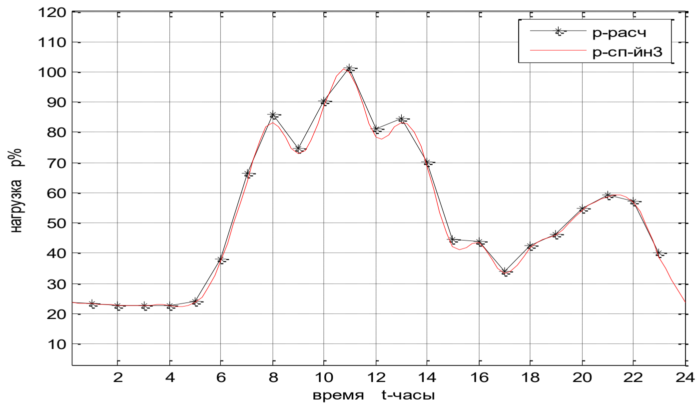

Fig. 2. Daily graphs of electrical loads calculated using the interpolation formula of the 3rd order spline function (red line) and a typical (standard) daily graph (black line) Accuracy + -5%.

Knowing the design load of each consumer outgoing from TS, DP, hydraulic fracturing (any number of consumers), on the basis of typical (standard) daily schedules, we add up the loads for each half hour of 48 options and the maximum amount of these 48 options will be the total calculated load of TS, DP. Hydraulic fracturing at any time interval of the daily schedule, without any coefficients, without errors. First, the calculation of loads, after which the calculation of the electrical network and electricity losses is carried out.

The calculated total load of consumers of residential and public buildings at a voltage of 0.38 kV is a single calculated load on a transformer substation or a substation at a voltage of 6-10 kV, and the calculated total load of urban networks of 6-10 kV is the initial design load for the city's power supply system with a voltage of 35 -110 kV. The addition of active powers must be carried out according to the probabilistic-statistical method for calculating electrical loads according to the formulas:

$$\overline{P}_{\Sigma i} = C_{i1}\overline{P}_1 + C_{i2}\overline{P}_2 + C_{i3}\overline{P}_3 + \cdots + C_{in}\overline{P}_n = \sum_{i=1}^{n} C_i\overline{P}_i \,, \qquad (3)$$

$$\sigma_{\overline{P}_i} = \sqrt{C_{i1}^2\sigma_{P1}^2 + C_{i2}^2\sigma_{P2}^2 + \cdots + C_{in}^2\sigma_{Pn}^2}$$

C_i – distribution coefficients of the schemes;

$\overline{P_i}$ – mathematical expectation of the load of the i-th consumer;

$\sigma_{\overline{P}_i}$ – standard deviation of the load of the i-th consumer.

The numerical characteristics of the apparent power will be equal:

a) mathematical expectation

$$\overline{S} = \sqrt{\overline{P}^2 + \overline{Q}^2} \qquad (4)$$

b) standard deviation

$$\sigma_{\overline{S}} = \sqrt{\cos^2\overline{\varphi}\sigma_{\overline{P}}^2 + \sin^2\overline{\varphi}\sigma_{\overline{Q}}^2} \,.$$

When determining the total load of heterogeneous consumers, the following expressions are used for each calculated hour:

a) mathematical expectation

$$\overline{S_{\Sigma}} = \sqrt{\left(\sum_{i=1}^{n}\overline{P_i}\right)^2 + \left(\sum_{i=1}^{n}\overline{Q_i}\right)^2} \qquad (5)$$

b) standard deviation

$$\sigma_{\overline{S_{\Sigma}}} = \sqrt{\cos_{\Sigma}^2\overline{\varphi}\sum_{i=1}^{n}\sigma_{\overline{P_i}}^2 + \sin_{\Sigma}^2\overline{\varphi}\sum_{i=1}^{n}\sigma_{\overline{Q_i}}^2} \,. \qquad (6)$$

The advantage of the proposed method is that when determining the calculated loads, it more accurately and reliably reflects the actual total loads in electrical networks, since the calculation is carried out in 48 options (for half-hour intervals of the maximum electrical load) and takes into account the own maximum load of each individual consumer entering to this network with the help of the developed 3 computer software products and using the automatic system of commercial energy metering (AEM).

3. Research has shown that the load in any element of the urban network is a function of a large number of factors and their numerous random combinations and changes over time. Consequently, all quantities calculated on the basis of electrical loads will be probabilistic quantities - functions of random variable electrical loads.

This circumstance makes it expedient to calculate urban networks by a probabilistic method based on typical daily graphs of electrical loads of consumers, given by stochastic values, for each half hour of a day of one of 48 options. Such a calculation allows you to have a real picture of the electrical network mode for each half hour and to optimize the power supply system by level and by year, taking into account the development prospects, the probabilistic values of electrical loads can be considered as numerical characteristics of statistical distributions. The well-known formulas for calculating urban networks have been improved, by converting them into a probabilistic form, in the form of mathematical expectation and standard deviation, as a result, the calculation of the city electrical network is more accurate and reliable.

Below we consider the methods of determination necessary for network calculations of quantities in the probabilistic setting of consumer loads using the elements of analysis of multidimensional random functions.

Improving the methodology for calculating electrical loads, we will determine all the calculated electrical quantities in the form of mathematical expectation and standard deviation.

$$P_P = \overline{P_p} + t_\alpha \cdot \sigma_{\overline{P}} \quad . \qquad (7)$$

Using the expansion of the function of random arguments in a multidimensional Taylor series in accordance with the definition of its numerical characteristics for the function of independent random arguments, in the most general form, they have the form:

a) mathematical expectation

Taking into account the functional dependence of the total load S on active P and reactive Q, which makes up its first and second partial derivatives, are determined by the formulas:

$$\frac{\partial S}{\partial P} = \frac{P}{\sqrt{P^2 + Q^2}} = \cos\varphi; \qquad \frac{\partial S}{\partial Q} = \frac{Q}{\sqrt{P^2 + Q^2}} = \sin\varphi \qquad (8)$$

$$\frac{\partial^2 S}{\partial P^2} = \frac{Q^2}{\sqrt{(P^2 + Q^2)^3}} = \frac{\sin^2\varphi}{S}; \qquad \frac{\partial^2 S}{\partial Q^2} = \frac{P^2}{\sqrt{(P^2 + Q^2)^3}} = \frac{\cos^2\varphi}{S}. \qquad (9)$$

When determining the total load of consumers, they are found as the first and second partial derivatives of this function and have the form:

$$\frac{\partial S_\Sigma}{\partial P_i} = \frac{\sum_{i=1}^{n} P_i}{\sqrt{\left(\sum_{i=1}^{n} P_i\right)^2 + \left(\sum_{i=1}^{n} Q_i\right)^2}} = \cos_\Sigma \varphi; \qquad (10)$$

$$\frac{\partial S_\Sigma}{\partial Q_i} = \frac{\sum_{i=1}^{n} Q_i}{\sqrt{\left(\sum_{i=1}^{n} P_i\right)^2 + \left(\sum_{i=1}^{n} Q_i\right)^2}} = \sin_\Sigma \varphi:$$

$$\frac{\partial^2 S}{\partial P_i^2} = \frac{\sum_{i=1}^{n} P_i}{\sqrt{\left(\left(\sum_{i=1}^{n} P_i\right)^2 + \left(\sum_{i=1}^{n} Q_i\right)^2\right)^3}} = \frac{\cos^2{}_\Sigma \varphi}{S}; \qquad (11)$$

$$\frac{\partial^2 S_\Sigma}{\partial Q_i} = \frac{\sum_{i=1}^{n} Q_i}{\sqrt{\left(\left(\sum_{i=1}^{n} P_i\right)^2 + \left(\sum_{i=1}^{n} Q_i\right)^2\right)^3}} = \frac{\sin^2{}_\Sigma \varphi}{S}.$$

Hence, the numerical characteristics of the total total load of consumers are equal:

a) mathematical expectation

$$S_{\Sigma} = \sqrt{(\sum_{i=1}^{n} P_i)^2 + (\sum_{i=1}^{n} Q_i)^2} \qquad (12)$$

b) standard deviation

$$\sigma_{S_{\Sigma}} = \sqrt{\cos_{\Sigma}^2 \varphi \sum_{i=1}^{n} \sigma_{P_i} + \sin_{\Sigma}^2 \varphi \sum_{i=1}^{n} \sigma_{Q_i}}^{\,2} \qquad (13)$$

According to the conservative position of P.L. Chebyshev for any distribution law at least (1-1 / t2) 100 are distributed in the interval X + tα σ. At tα = 3, this is 95%, which fully satisfies the required accuracy of engineering calculations. The practical use of the obtained calculation formulas requires a preliminary determination of the mathematical expectations and standard deviations of consumer loads.

The application of the above method for calculating electrical quantities for stochastic assignment of loads significantly increases the complexity of the calculations, however, this circumstance in the presence of a computer is not an insurmountable obstacle.

For an example, the calculation of power supply for a residential area of the city of Tashkent is considered. As the initial data, we used experimental measurements carried out over the past three years on objects of public and residential buildings in cities of Uzbekistan, including this microdistrict. Based on the results of experimental measurements, computer programs were developed for calculating characteristic daily schedules and power supply networks of urban consumers and implemented on a computer in the MATLAV programming language

4. Recommendations for the use of reactive power compensation in electrical networks of the residential and public sectors. As the measurements carried out in urban networks have shown, due to the widespread use of small motor loads (motors of refrigerators, washing machines, fans, vacuum cleaners, lighting from LED lamps) in residential and public buildings, the active power factor became equal to Cosφ = 0.78-0, 89. Therefore, the task is to apply reactive power compensation in urban electrical networks. To do this, it is necessary to pre-inspect each transformer substation and calculate the required amount of reactive power and select standard capacitor banks.

5. Optimization of installation devices of electrical networks in terms of reactive power, optimal power and stimulation of the installation of compensating devices at consumers, optimization of operating voltages. in power centers and radial power grids, equalization of phase loads in 0.38 kV power grids, installation and commissioning of reactive power compensation devices in urban networks, replacement of wires on overloaded lines, replacement of underloaded power transformers, transfer of power grids to a higher voltage Unom, elimination of underload and overload in secondary current and voltage circuits, etc.

Conclusions:

1. On the basis of the reconstruction and modernization of all city power supply systems, it is possible to build complex electrical networks that are more economical and reliable.

2. A new way of determining the calculated loads of municipal consumers, more accurate and economical.

3. The electrical load of the power supply systems of cities changes every minute, therefore, the calculation of the electrical network must be carried out by a probabilistic-statistical method.

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