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A METHODOLOGY FOR MODELING POWER SUPPLY SYSTEMS

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The article is devoted to the development and testing of a methodology for analytical modeling of power supply systems that include multiple sources and multiple consumers of electricity, located at a distance from each other and connected by power transmission lines. The developed methodology will help designers assess the possibilities of distributing electricity among consumers while calculating the optimal voltages that need to be maintained at the nodes of the power sources, thereby achieving minimal voltage differences between the load nodes. The methodology is tested using a 10-node power supply system, in which the number of energy source nodes and load nodes is equal to 5.

The modeling methodology is based on calculating the parameters of the power supply system using the node potential method, along with Ohm's and Kirchhoff's laws. The calculations utilize the method of complex amplitudes and are carried out according to a proposed iterative algorithm, the flowchart of which is presented in the article. The calculations are performed in the MathCAD environment using the mathematical framework of matrix computations. For this purpose, a conductance matrix and a node current matrix are constructed, and the node potential matrix is calculated in MathCAD. The paper demonstrates how to transit from a three-phase system to a single-phase system, with all calculations performed on a single-phase scheme. To obtain accurate results, formulas are derived for converting the parameters of the three-phase system into single-phase parameters, including the conversion of consumed load powers into complex impedances. The results of the modeling are presented in tabular form and as directed graphs, indicating the potentials of the nodes and the directions of active power flows. The results of modeling two variants of power supply systems are provided. The proposed methodology is recommended for assessing the parameters of power supply systems that include multiple sources of electricity and several load nodes.

Keywords: power supply system, mathematical modeling, calculation methodology, node potentials, complex amplitudes.

Introduction. The task of continuously supplying quality electricity to consumers has always been and remains relevant. To achieve this, individual power plants (PP) in the country are interconnected into electrical networks, ensuring the possibility of supplying electricity to consumers from multiple power plants. It is advisable to assess the potential for balanced operation of power supply systems (PSS) when designing new power plants and modernizing the existing ones through

mathematical modeling. When modeling PSS with multiple power plants, the complexities lie in evaluating and regulating power flows between the power plants, ensuring that the voltages at the nodes of the PSS do not significantly deviate from the nominal values.

The goal of the work is to develop a methodology for modeling power supply systems that allows for the assessment of the possibility of uninterrupted electricity supply to consumers with minimal deviations of the voltages of the power sources from their nominal values.

Description of the research object. A 10-node power supply system (PSS) operating at a voltage class of 220 kV is studied. Five nodes of the PSS are sources of electricity (power plants), while the other five nodes represent loads. The nodes are connected by power transmission lines, forming an electrical network in which each node is connected to several neighboring nodes, ensuring the reliability of uninterrupted electricity supply to consumers.

One of the parameters of electricity is maintaining the voltage within specified limits. For a voltage of 220 kV, according to [1], the maximum system voltage is 245 kV. The minimum voltage, in this case, is not regulated. In normal operation, electricity with nominal voltage from the nearest power plant is supplied to the consumer. As it travels through the power transmission lines, some energy is lost, and the voltage drops. If the power of the power plant is insufficient, the voltage decreases to unacceptable levels. To prevent this, the missing electricity is sourced from other power plants, which increases their voltage. The higher the voltage at the power plant, the greater the power it can deliver to the consumer, thereby relieving the neighboring power plants.

Research methods. The research was conducted using analytical methods for calculating electrical circuits based on Kirchhoff's and Ohm's laws. The node potential method is chosen as the basic method, in which a system of equations is formulated that links the parameters of the PSS (resistances of the power transmission lines, generator voltages) with the potentials of the load nodes. The method of complex amplitudes was used to solve the system of equations, allowing for the consideration of phase shifts between currents and voltages in the elements of the PSS, thereby separately accounting for active and reactive power. Since the number of equations turned out to be quite large, the unknown node potentials were calculated using the matrix method in the MathCAD environment. The correctness of the calculations is verified by finding the power balance and using Kirchhoff's laws. An iterative algorithm is employed in the modeling, the flowchart of which is shown.

Initial data. In Table 1, the total powers of the electricity sources and loads

across the three phases are presented. Without the application of ЭС0, there is a deficit of active power throughout the system. This can be eliminated by supplying electricity from ЭС0.

Table 1

Initial Powers

| Nodes | P, MW | Q, MVar | Nodes | P, MW | Q, MVar |
|-------|-------|---------|------------|-------|---------|
| ЭС-0 | | | ЭН-6 | 110 | 55 |
| ЭС-1 | 110 | 100 | ЭС-7 | 60 | 136,7 |
| ЭН-2 | 100 | 50 | ЭС-8 | 94 | 45 |
| ЭН-3 | 60 | 30 | ЭН-9 | 96 | 48 |
| ЭС-4 | 70 | 51 | Source | 334 | 332,7 |
| ЭН-5 | 80 | 40 | Load | 446 | 223 |
| | | | Not enough | 112 | -109,7 |

The calculation scheme. In the node potential method, the resistances of the loads are required, while the consumed powers are given as input data. To obtain an expression that relates the resistances of the consumers to the load power, we will use the following approaches.

The real scheme (Fig. 1) represents a three-phase power source (transformer) with power S_H , whose windings are connected in a "star" configuration, through three wires with a resistance of Z_n for the power transmission line connected to a load consisting of three complex resistances Z_A, Z_B, Z_C also connected in a star configuration. The input data specifies the total powers S_H , consumed by these resistances.

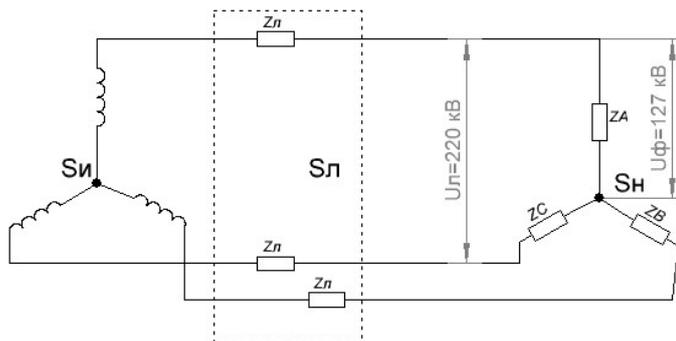


Fig. 1. A three-phase scheme

Fig. 1 shows a three-phase, three-wire symmetrical system. In this case, for the sake of simplifying calculations, one can transit from the three-phase system to the calculation of the electrical mode of a single phase, representing the three-phase

system as three identical single-phase circuits, as shown in Fig. 2.

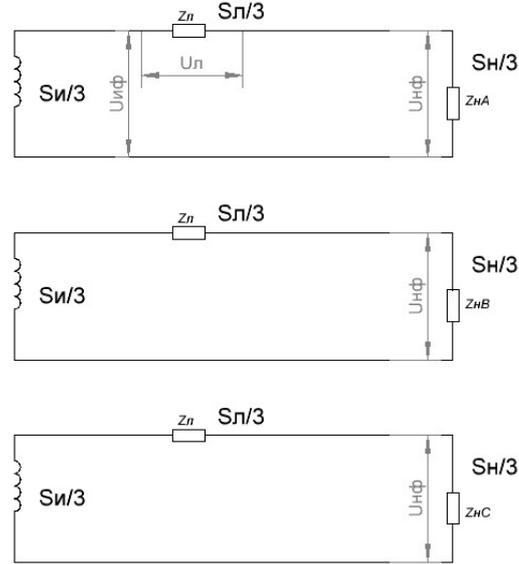


Fig. 2. Three equivalent single-phase circuits

In each phase, the consumer of the single-phase circuit will consume one-third of the total power $S_{H\phi} = \frac{S_H}{3}$.

The current in the load of one phase is found using the formula:

$$I_{H\phi} = \frac{U_{H\phi}}{Z_{H\phi}} = \frac{U_{HЛ}}{\sqrt{3} \cdot Z_{H\phi}}. \quad (1)$$

Considering that the phase complex conjugate the total power of the load given by the expression $S_{H\phi}^* = \underline{U}_{H\phi} \cdot \underline{I}_{H\phi} = \frac{U_{H\phi}^2}{Z_{H\phi}^*}$, we express the load resistance for each phase:

$$\underline{Z}_A = \underline{Z}_B = \underline{Z}_C = \underline{Z}_{H\phi} = \frac{U_{H\phi}^2}{S_{H\phi}^*} = \frac{U_{HЛ}^2/3}{S_H^*/3} = \frac{U_{HЛ}^2}{S_H^*}. \quad (2)$$

In the formulas, complex quantities are underlined, and complex conjugate quantities are indicated by an asterisk.

When checking the power balance in one phase, we will use the expression:

$$|I_{H\phi}|^2 \cdot Z_{H\phi} + |I_{Л\phi}|^2 \cdot Z_{Л} = I_{H\phi}^2 \cdot U_{H\phi}. \quad (3)$$

The powers of the electricity sources and the electricity receivers are found as three times the values of the phase powers. To calculate the potentials of the nodes for each phase, we construct a conductance matrix for the load nodes. In this matrix, the main diagonal contains the self-conductances of the nodes, taken as positive, while the other elements of the matrix represent the inter-node conductances, which

are always negative. The self-conductances of the nodes are found as the sum of the conductances of the branches entering the node. The inter-node conductances are the conductances of the branches connecting the two corresponding nodes.

The matrix form of the equation will look like:

$$\|G\| \cdot \|\varphi\| = \|J\|, \quad (4)$$

where $\|G\|$ - square matrix of conductivities, C_M ; $\|\varphi\|$ - column matrix of nodal potentials, B ; $\|J\|$ - column matrix of nodal currents, A .

Using MathCAD, we find the matrix of potentials of load nodes of a separate phase $\|\varphi\|$. We define the branch currents as the ratio of the potential difference of adjacent nodes connected by a branch to the resistance of the branch.

Simulation results. The values of deficit/excess of power of power plants in the initial system at ES voltages equal to 220 kV are given in Table 2. At the 1st and 4th power plants, there is a deficit (minus sign) of power.

Table 2

| Power deficit in the original system | | |
|--------------------------------------|----------------------|--------------------------|
| Power plant | Active power (P), MW | Reactive power (Q), MVar |
| ЭC1 | -34,96 | 53,06 |
| ЭC4 | -124,64 | -67,26 |
| ЭC7 | 19,92 | 106,86 |
| ЭC8 | 63,78 | 35,30 |

Analyzing the numbers given in the table, it is easy to notice that the first and fourth power plants do not have enough active capacity, in addition, the fourth power plant also has a shortage of reactive power. The seventh and eighth power plants operate with a reserve of generated capacity.

Phase currents in power transmission lines. Currents in the conductors of a power transmission line are calculated using the potential difference of adjacent nodes and internodal conductivity using the formula:

$$I_{ij} = (\varphi_i - \varphi_j) \cdot G_{ij}.$$

The current is considered positive if it is directed from the node corresponding to the first index to the node corresponding to the second index. The minus sign indicates that the direction will be opposite. For example, $I_{03}=68.98-i48,84$, where i is an imaginary unit. This means that active power is directed from node 0 (first index) to node 3 (second index), since the active current is positive, and reactive power is the opposite: from node 3 to node 0, since the reactive current is negative.

The values of currents in the transmission line are summarized in Table 3.

Table 3

Currents in the power lines of the original system

| Current in power transmission lines | Active current, A | Reactive current, A | Current module, A |
|-------------------------------------|-------------------|---------------------|-------------------|
| I_{01} | 0 | 0 | 0 |
| I_{03} | 64,98 | -48,84 | 81,29 |
| I_{12} | 160,58 | -85,44 | 181,89 |
| I_{16} | 219,86 | -37,74 | 223,07 |
| I_{23} | -80,84 | 59,89 | 100,61 |
| I_{25} | -11,85 | -13,38 | 17,87 |
| I_{34} | -170,00 | 90,27 | 192,49 |
| I_{45} | 138,18 | -63,51 | 152,08 |
| I_{46} | 99,87 | -83,11 | 129,93 |
| I_{49} | 102,73 | -73,48 | 126,30 |
| I_{56} | -76,10 | 27,92 | 81,06 |
| I_{67} | -40,54 | 50,36 | 64,65 |
| I_{78} | 0 | 0 | 0 |
| I_{79} | 64,63 | -27,95 | 70,41 |
| I_{89} | 79,32 | -25,45 | 83,30 |

In all transmission lines, except the transmission line between nodes 2 and 5, active and reactive movements move in different directions. In transmission lines 01 and 78, power is not transmitted. Information from one or another node to which active flows are transmitted is shown as a directed graph (Fig. 3). This graph also shows the line voltages of the electricity consumers. Of particular interest is the 25 power transmission line, which has a very high inductance and low active resistance. In it, the active energy goes from a lower potential to a higher one.

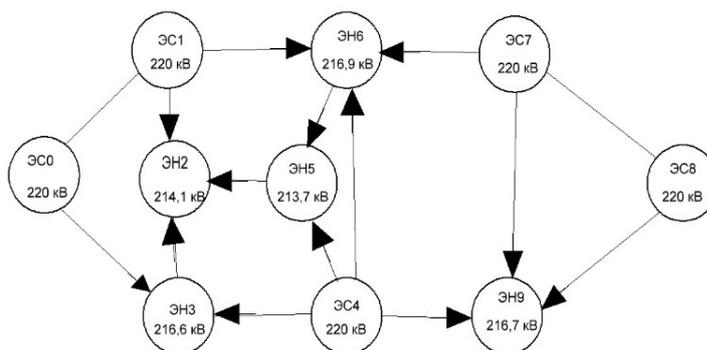


Fig. 3. Active power flows and potentials of nodes in the original system

Table 4

Phase currents of power sources

| Power plants | Active current, A | Reactive current, A |
|--------------|-------------------|---------------------|
| 0 | 64,98 | -48,84 |
| 1 | 380,43 | -123,19 |
| 4 | 510,79 | -310,36 |
| 7 | 105,17 | -78,31 |
| 8 | 79,32 | -25,45 |

Table 5

Power generated by power plants

| Power plants | Active power, MW | Reactive power, MVar |
|--------------|------------------|----------------------|
| 0 | 8,25 | 6,2 |
| 1 | 48,32 | 15,65 |
| 4 | 64,88 | 39,42 |
| 7 | 13,36 | 9,94 |
| 8 | 10,07 | 3,23 |

From the analysis of the numbers in Table 5, it is easy to see that the zero power plant, which has unlimited capacity, supplies the smallest amount of electricity to the SES under consideration, which is illogical. It is necessary to ensure such an operating mode of the SES that the supply of electricity from ES0 increases, and from ES1 and ES4 (deficit ES) decreases. To do this, we redistribute the power of power plants by changing the voltage in the corresponding nodes according to the proposed algorithm, the diagram of which is shown in Fig. 4.

The algorithm shown in Fig. 4 works as follows. First, the initial active and reactive powers of the loads and power plants, as well as the complex resistances of the transmission lines, are entered. The voltages of all power plants are equated to the nominal line voltage, which is 220 kV. Next, using formula (2), the complex load resistances for each phase are calculated, the conductivity matrices and nodal currents are compiled, and the nodal potentials, active and reactive powers consumed by the load, powers dissipated in the transmission lines, and deficits/excesses of power plant capacities are calculated. The deficit/excess of power is calculated as the difference between the nominal power and the required power for the operation of the solar power plant. In this case, if the power plant cannot provide the required power, we get a negative number (power deficit), and if the power plant operates with a power reserve, we get a positive number. Next, we go through the power plants and adjust their voltages by adding a value proportional to the power deficit/excess to the initial voltage. In this case, if there is a power deficit, the power

plant voltage decreases, and if there is a power surplus equal to or greater than 10% (the value specified in the upper logical block), the power plant voltage increases. This process is iterative and ends when, after another iteration of all power plants, the voltage is not adjusted on any of them (the Kor flag in the lower logical block remains equal to 0).

By applying the algorithm described above, we obtain a variant in which all power plants operate in a deficit-free mode. In this case, the linear voltages at power plants must be maintained at the levels:

$$\varphi_0=238 \text{ кВ}; \varphi_1=218 \text{ кВ}; \varphi_4=212 \text{ кВ}; \varphi_7=220 \text{ кВ}; \varphi_8=220 \text{ кВ}; \varphi_{10}=0 \text{ кВ}.$$

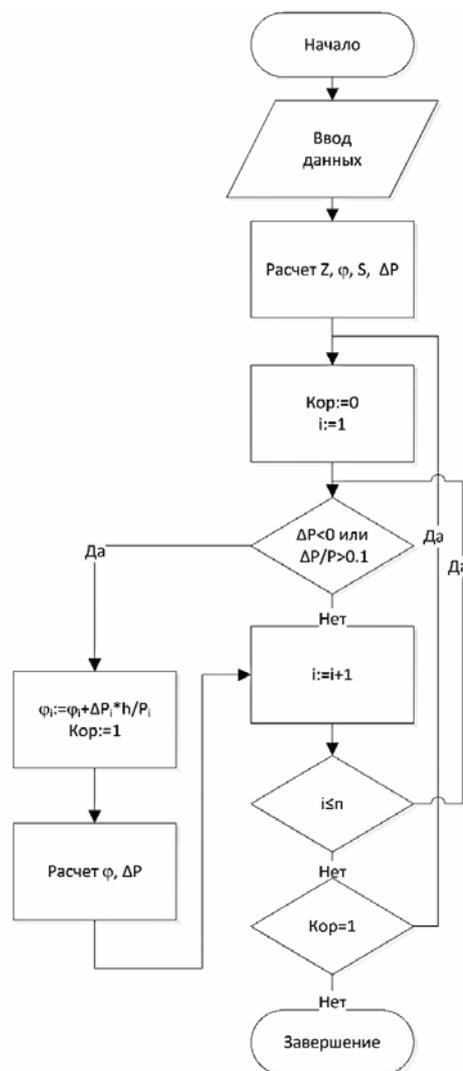


Fig. 4. The scheme of the algorithm for finding the voltages of power plants

All power plants have a small power reserve, which is indicated in Table 6.

Table 6

Power plant capacity reserves

| Power plant | Active power (P), MW | Reactive power (Q), MVar |
|-------------|----------------------|--------------------------|
| ЭС1 | 14,16 | 171,42 |
| ЭС4 | 5,27 | 164,05 |
| ЭС7 | 1,03 | 58,12 |
| ЭС8 | 51,44 | 10,90 |

The values of currents in power transmission lines are presented in Table 7.

Table 7

Currents in power transmission lines

| Current in power transmission lines | Active current, A | Reactive current, A | Current module, A |
|-------------------------------------|-------------------|---------------------|-------------------|
| I ₀₁ | 237,09 | -382,86 | 450,32 |
| I ₀₃ | 190.31 | -396.20 | 439.54 |
| I ₁₂ | 166.91 | -89.92 | 189.59 |
| I ₁₆ | 324.02 | -103.80 | 340.24 |
| I ₂₃ | -86.65 | 108.87 | 139.14 |
| I ₂₅ | 3.07 | -68.04 | 68.11 |
| I ₃₄ | -49.53 | -208.04 | 213.86 |
| I ₄₅ | 97.41 | -1.10 | 97.42 |
| I ₄₆ | -15.31 | 51.18 | 53.42 |
| I ₄₉ | 44.64 | 49.76 | 66.85 |
| I ₅₆ | -97.39 | 33.89 | 103.11 |
| I ₆₇ | -68.17 | 121.74 | 139.53 |
| I ₇₈ | 0 | 0 | 0 |
| I ₇₉ | 86.60 | -84.48 | 120.98 |
| I ₈₉ | 111.70 | -89.48 | 143,12 |

In lines 34 and 49 the real (active) and imaginary (reactive) parts of the current have the same sign. The directions of the active power flows and the values of the node potentials are shown in Fig. 5.

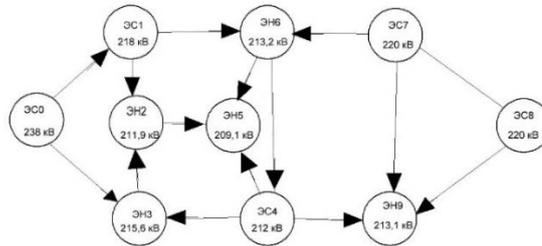


Fig. 5. Active power flows and node potentials in the system with voltage correction of power plants

After adjusting the voltage of the ES, currents 25 and 46 change their direction. Due to large flows of reactive power, the potential of ES4 is less than the potentials of the load nodes EN3 and EN9, to which the active current flows from ES4.

The consumer has the largest voltage deviations from the nominal at the 5th load node and amount to minus 5%, which is a good indicator. The generators has the largest voltages at the zero load node and amount to 8.2% more than the nominal, and the voltages at the power plants of the ES1 and ES4 nodes have to be reduced by 0.9% and 3.6%, respectively, relative to the nominal.

The phase currents of power plants after voltage correction are summarized in Table 8, and the power consumed from power plants is summarized in Table 9.

Table 8

Phase currents of power sources

| Power plants | Active power, MW | Reactive power, MVar |
|--------------|------------------|----------------------|
| 0 | 427.40 | -779.06 |
| 1 | 253.84 | 189.14 |
| 4 | 176.28 | 307.88 |
| 7 | 154.76 | -206.22 |
| 8 | 111.70 | -89.48 |

After adjusting the voltages, the power supplied to the solar power plant by the first and fourth power plants decrease, while that of the 0th, 7th and 8th power plants increase.

Table 9

Power generated by power plants

| Power plants | Active power, MW | Reactive power, MVar |
|--------------|------------------|----------------------|
| 0 | 58,73 | 107,05 |
| 1 | 31,95 | -23,81 |
| 4 | 21,58 | -37,68 |
| 7 | 19,66 | 26,19 |
| 8 | 14,19 | 11,37 |

Conclusions

Thus, the article proposes a method for mathematical modeling of the power supply system, which allows for balanced operation of power plants, in which the voltages of the power plant and consumers differ slightly from the nominal ones. The method has been tested on a 10-node SES. It is shown that in the analyzed SES, it is possible to ensure the balanced operation of power plants, in which the voltage at the load nodes will not fall below 5% of the nominal. In this case, the voltage at the zero power plant should be increased by 8.2%, and the voltage at the power plants of nodes No. 1 and No. 4 should be reduced by 0.9% and 3.6%, respectively, relative to the nominal. The proposed methodology is recommended for assessing the parameters of solar power plants that include several power sources and several load nodes.

References

1. **Demirchyan K.S., Neyman L.R., Korovkin N.V.** Theoretical foundations of electrical engineering: Textbook for Universities.- V.1.- Peter, 2009.- 512 p.
2. **Demirchyan K.S., Neyman L.R., Korovkin N.V.** Theoretical foundations of electrical engineering: Textbook for Universities.- V.2.- Peter, 2009.- 432 p.
3. **Andrianov D.P. and Badalyan N.P.** On the optimization of parameters of dynamic systems // Energy system: Proceedings of the II International Scientific and Technical Conference BSTU named after V.G. Shukhov, 23–24 November's 2017.- Belgorod (Belgorod: BSTU), 2017.-134-7.
4. **Badalyan N.P., Andrianov D.P.** Optimization of parameters of electric circuits described by differential equations // Bulletin of the Engineering Academy of Armenia: Collection of scientific and technical articles.- Yerevan, Armenia, 2018.- Vol. 15, N2.- P. 224-227.
5. **Badalyan N.P., Andrianov D.P., Kolesnik G.P.** Non-stationary modes of electric networks // IOP Conference Series: Materials Science and Engineering.- Vol. 1089; V International Scientific and Technical Conference "Energy Systems" (ICES - 2020), 19th – 20th November 2020.- Belgorod, Russia, 2020.

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ԷՆԵՐԳԱՄԱՏԱԿԱՐԱՐՄԱՆ ՀԱՄԱԿԱՐԳԵՐԻ ՄՈԴԵԼԱՎՈՐՄԱՆ ՄԵԹՈԴԱԲԱՆՈՒԹՅՈՒՆ

Ն.Պ. Բադալյան, Գ.Ֆ. Դոլգով

Հոդվածը նվիրված է էլեկտրամատակարարման համակարգերի վերլուծական մոդելավորման մեթոդաբանության մշակմանը և փորձարկմանը, որոնք ներառում են միմյանցից որոշակի հեռավորության վրա գտնվող և էլեկտրահաղորդման գծերով միացված բազմաթիվ աղբյուրներ և էլեկտրաէներգիայի սպառողներ ներառող

էլեկտրաէներգիայի համակարգերի վերլուծական մոդելավորման մեթոդաբանություն: Մշակված մեթոդաբանությունը կօգնի նախագծողներին՝ գնահատելու էլեկտրաէներգիան սպառողների միջև բաշխելու հնարավորությունները՝ միաժամանակ հաշվարկելով էլեկտրաէներգիայի աղբյուրների հանգույցներում պահպանվող օպտիմալ լարումները, այդպիսով հասնելով բեռնման հանգույցների միջև լարման նվազագույն տարբերությունների: Մեթոդաբանությունը փորձարկվում է 10 հանգույցից բաղկացած էլեկտրամատակարարման համակարգի միջոցով, որտեղ էներգիայի աղբյուրի հանգույցների և բեռնման հանգույցների քանակը հավասար է 5-ի:

Մոդելավորման մեթոդաբանությունը հիմնված է էլեկտրամատակարարման համակարգի պարամետրերի հաշվարկման վրա՝ օգտագործելով հանգույցի պոտենցիալի մեթոդը՝ Օհմի և Կիրխոֆի օրենքների հետ միասին: Հաշվարկներն օգտագործում են բարդ ամպլիտուդների մեթոդը և իրականացվում են առաջարկվող իտերատիվ ալգորիթմի համաձայն, որի հոսքագիծը ներկայացված է հոդվածում: Հաշվարկները կատարվում են MathCAD միջավայրում՝ օգտագործելով մատրիցային հաշվարկների մաթեմատիկական շրջանակը: Այդ նպատակով կառուցվում են հաղորդականության մատրից և հանգույցի հոսանքի մատրից, և հանգույցի պոտենցիալների մատրիցը հաշվարկվում է MathCAD-ում: Հոդվածում ցուցադրվում է, թե ինչպես անցնել եռաֆազ համակարգից միաֆազ համակարգի, որտեղ բոլոր հաշվարկները կատարվում են միաֆազ սխեմայի համաձայն: Ճշգրիտ արդյունքներ ստանալու համար մշակվել են բանաձևեր՝ եռաֆազ համակարգի պարամետրերը միաֆազ պարամետրերի փոխակերպելու համար, ներառյալ սպառված բեռի հզորությունների փոխակերպումը բարդ իմպեդանսների: Մոդելավորման արդյունքները ներկայացված են աղյուսակային տեսքով և ուղղորդված գրաֆիկներով, որոնք ցույց են տալիս հանգույցների պոտենցիալները և ակտիվ հզորությամբ հոսքերի ուղղությունները: Ներկայացվում են էլեկտրամատակարարման համակարգերի երկու տարբերակների մոդելավորման արդյունքները: Խորհուրդ է տրվում առաջարկվող մեթոդաբանությունը կիրառել էլեկտրաէներգիայի բազմաթիվ աղբյուրներ և մի քանի բեռի հանգույցներ ներառող էլեկտրամատակարարման համակարգերի պարամետրերը գնահատելու համար:

Առանցքային բաներ. էլեկտրամատակարարման համակարգ, մաթեմատիկական մոդելավորում, հաշվարկման մեթոդաբանություն, հանգույցի պոտենցիալներ, բարդ ամպլիտուդներ:

МЕТОДИКА МОДЕЛИРОВАНИЯ СИСТЕМ ЭЛЕКТРОСНАБЖЕНИЯ

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Статья посвящена разработке и апробации методики аналитического моделирования систем электроснабжения, включающих несколько источников и несколько потребителей электроэнергии, расположенных на большом расстоянии друг от друга и соединенных линиями электропередачи. Разработанная методика поможет проектировщикам оценить возможности распределения электроэнергии между потребителями и рассчитать оптимальные напряжения, которые необходимо

поддерживать в узлах источников питания, тем самым достигая минимальных разностей напряжений между узлами нагрузки. Методика апробирована на примере 10-узловой системы электроснабжения, в которой количество узлов источников энергии и узлов нагрузки равно 5.

Методика моделирования основана на расчете параметров системы электроснабжения методом узловых потенциалов с использованием законов Ома и Кирхгофа. Расчёты выполнены методом комплексных амплитуд по предлагаемому итеративному алгоритму, блок-схема которого представлена в статье. Расчёты выполнены в среде MathCAD с использованием математического аппарата матричных вычислений. Для этого построены матрица проводимости и матрица узловых токов, а также рассчитана матрица узловых потенциалов в MathCAD. В работе показан переход от трёхфазной системы к однофазной, при этом все расчёты выполнены для однофазной схемы. Для получения точных результатов выведены формулы преобразования параметров трёхфазной системы в однофазные, включая преобразование потребляемой мощности нагрузки в комплексные сопротивления. Результаты моделирования представлены в табличной форме и в виде ориентированных графов с указанием потенциалов узлов и направлений потоков активной мощности. Приведены результаты моделирования двух вариантов систем электроснабжения. Предложенная методика рекомендуется для оценки параметров систем электроснабжения, включающих несколько источников электроэнергии и несколько узлов нагрузки.

Ключевые слова: система электроснабжения, математическое моделирование, методика расчета, узловые потенциалы, комплексные амплитуды.