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THE UNBALANCED REGIMES IN SYSTEMS OF HOUSEHOLD ELECTRIC POWER CONSUMERS

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Abstract: The modeling of the operation modes of the 0.4 / 0.23 kV power supply systems by the Monte Carlo method using computer program is considered. The statistical processing of simulation results and testing of the Pearson distribution law hypothesis using the Mathcad program are carried out. An analysis of the existing power supply system is fulfilled and an alternative, economically feasible version of the power supply system is proposed.

1. INTRODUCTION

The improvement of the electric energy quality is an actual problem in rural electrical networks with a voltage of 0.4 / 0.23 kV and it is inextricably linked with the reduction of additional electric power loss, which are caused by an asymmetric phase load. It is also important when choosing installation locations for the distributed generation sources.

Analysis of operating modes of rural networks with a voltage of 0.4 / 0.23 kV [1,2] shows that the unbalance of the currents is caused to the communal-household load mainly. The most of this load are distributed unevenly on the phases of single-phase electric receivers that have a random electricity consumption usually. The knowledge of currents asymmetry in the network makes it possible to clarify the level of energy loss and may be used measures to reduce them [3] if possible. Modern computer software allows modeling unbalanced network mode and calculating additional power loss, which are the result of asymmetry. The purpose of this study is to develop the recommendations of improving the scheme of energy distribution in power supply systems and to investigate the possibility of changing power supply system from 0.4 kV to 10 kV in order to reduce power loss and improve the electricity quality. The study results show the need for reconstruction and modernization of power supply systems. Basing on the researches, we can recommend that when the existing transmission lines are completely rebuilt or new transmission lines are constructed to switch to the proposed power supply system, which allows to significantly reduce the power loss in the network, providing higher energy quality indicators.

2. THE INFLUENCE OF HOUSEHOLD ELECTRIC POWER CONSUMERS

2.1. The object of study

The change in the load of single-phase household consumers of electric energy is of a random nature and it is very difficult to determine accurately its value at any time. It is possible only with a certain probability to establish some limits for which electricity consumption does not come out at a given moment in time.

Even if single-phase consumers with equal power and daily total electricity consumption are distributed evenly, then due to the probabilistic nature of power consumption for any time in a three-phase supply network, one should expect the asymmetry of the phase currents, and, as a consequence, the asymmetry of the voltages.

In the asymmetric mode, the technical and economic performance of the network deteriorates sharply: energy loss increase, voltage deviates from the nominal. The current flows in the zero conductor and it causes the appearance of significant potentials on the electrical equipment that connected to the zero wire, which leads to the danger of electric shock. In addition, the service life of the asynchronous electric motors connected to the network is dramatically reduced. So a number of negative electromagnetic phenomena are observed both in the network and in the load. The loss of active energy which resulting from the uneven load of phases in 0.4 / 0.23 kV lines and consumer transformers of 10 / 0.4 kV increase by more than a third comparing with loss that would occur under uniform load [1].

2.2. Background information

We have considered a section of a three-phase four-wire overhead line of 0.38 / 0.22 kV with a length of 210 m (six supports), one single-phase consumer is connected to each of the three phases at each support. A transformer, the secondary windings of which are connected in the «star with zero» scheme, powers the network. The network circuit is modeled in the Electronics Workbench program and it represents three single-phase voltage sources connected in the "star with zero" scheme. The initial phases of the sinusoid are equal to 0, 120, 240 degrees correspondingly.

The resistance of the aluminum wires of sections of the overhead line between the points of connection of consumers (for overhead lines it is the distance between supports) are represented by a row of series-connected active resistances (R = 0.012 Ohm, X = 0.011 Ohm for AC-35 wire).

The consumers are connected to the phase and zero wires, the load resistance of the consumers have the following values alternating in phases in different sequences on different supports: 20 Ohm, 30 Ohm, 40 Ohm. The consumers are connected to the line in such a way that at substation buses 10 / 0.4 kV the line 0.38 / 0.22 kV represents a symmetrical load.

Because the change in the load of domestic consumers is random, subject to the normal distribution of random variables, we will perform a statistical simulation of the network cross section using the Monte Carlo method. On Fig. 1 shows one of the version for the simulating scheme. The results (values of currents, A) are given in table1.

Basing on the tests, we performed statistical processing of modeling results and verification of hypothesis of the distribution law according to the Pearson criterion. We used the system Mathcad to do this.

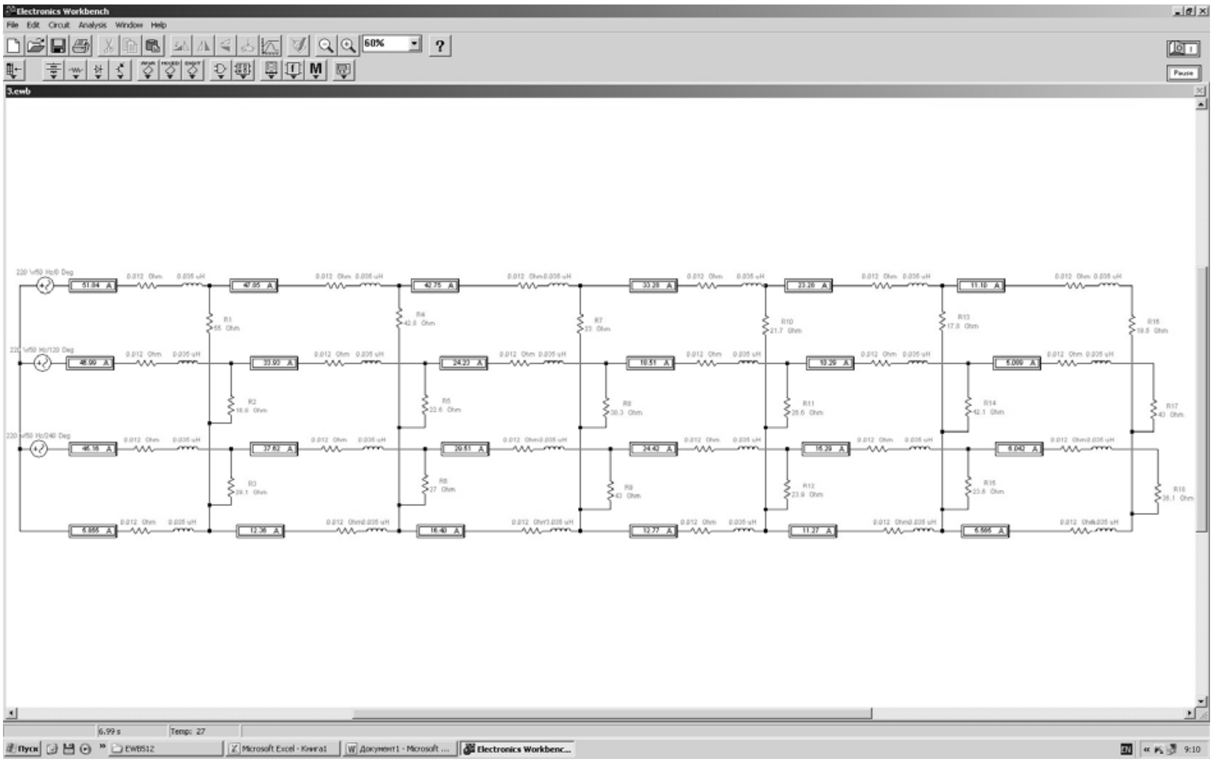

Fig.1 Some version of simulating system

Table 1. The results of simulation

Phases	Segments					
	1	2	3	4	5	6
A	51,84	47,85	42,75	33,28	23,28	11,1
B	46,99	33,93	24,23	18,51	10,29	5,09
C	45,16	37,62	29,51	24,42	15,29	6,04
N	5,86	12,36	16,4	12,77	11,27	5,57

Because of the statistical processing of the data, we obtained the following values of the mathematical expectation M and the current dispersion s and the power loss for the line sections of the 0.4 / 0.23 kV (Table 2).

Since the found value of the criterion $\chi^2 = 0.804$ is less than the critical value 3.8, the hypothesis H_0 is adopted.

Thus, the performed studies show that the change in the load currents on the network segments and the electric energy loss in an asymmetrically loaded network of 0.4 / 0.23 kV are subject to the normal distribution law.

With increasing numbers of consumers, the length of the line and the magnitude of the currents flowing along the line increases, which leads to increasing in electric power loss. Therefore, there is a necessary to apply appropriate measures to reduce energy loss. Today, there are many devices for balancing the network, but all of them, because of their high cost and low reliability and inefficiency for long lines feeding the communal-household load, have not been widely used in 0.4 / 0.23 kV networks. Therefore, with the complete reconstruction of existing transmission lines or during constructing new transmission lines, it is necessary to shift to other power supply systems.

Table 2. The results of statistical processing

Mathematical expectation and dispersion of current (A)							
Phases	Segments						
	Mathematical expectation and dispersion	1	2	3	4	5	6
A	*M*	51,603	45,163	37,972	26,543	20,389	11,666
	s	9,949	9,021	8,84	6,612	5,706	4,099
B	*M*	53,184	40,636	34,285	26,216	13,565	7,334
	s	9,894	7,766	7,01	5,638	3,539	2,702
C	*M*	52,485	44,765	33,887	27,415	18,393	5,558
	s	10,691	9,478	8,911	8,648	6	1,263
N	*M*	17,323	13,207	12,519	10,546	9,096	6,225
	s	11,934	9,063	9,11	7,389	6,585	3,205
Mathematical expectation and dispersion of electric power loss (W)							
Phases	Segments						
	Mathematical expectation and dispersion	1	2	3	4	5	6
A	*M*	31,954	24,476	17,303	8,454	4,989	1,633
	s	1,1878	0,977	0,94	0,525	0,3907	0,202
B	*M*	33,943	19,815	14,106	8,247	2,208	0,645
	s	1,175	0,724	0,59	0,382	0,15	0,088
C	*M*	33,056	24,047	13,78	9,019	4,06	0,371
	s	1,372	1,078	0,953	0,898	0,432	0,019
N	*M*	3,601	2,093	1,881	1,335	0,993	0,465
	s	1,709	0,986	0,996	0,655	0,52	0,123

The schemes of electrical networks and systems of electricity supply were formed in the middle of the last century, taking into account the minimization of capital assets. Nevertheless, it has led to their physical and moral deterioration.

Most of the electrical networks today require a complete replacement, since they have lost reliability, are physically obsoleted and do not meet the requirements of energy saving and safety. Therefore, it becomes necessary to use the system of maximum decentralization during reconstructing the existing networks or building new networks, which will significantly reduce loss and investments.

Using the Electronics Workbench [4] software, we simulated the operation of the typical traditional power supply system. We have loaded network with users, the load resistance of which have the following values: 20 Ohm, 30 Ohm, 40 Ohm, the initial phases of sinusoid voltage are respectively equal to 0, 120, 240 degrees. The resistance of aluminum wires are presented as series-connected active and reactive resistances of segments of an overhead line (R = 0.012 Ohm, X = 0,011 Ohm for wire AC-35) between the points of consumers' connection (for overhead lines it is the distance between supports). Consumers are connected between one of the phase conductors and the neutral conductor (3 consumer at the point of attachment, with different loads in each of the phases). A full phase segment (Fig.2) of a 210 m long line is simulated (six supports, one-phase consumers are connected to each).

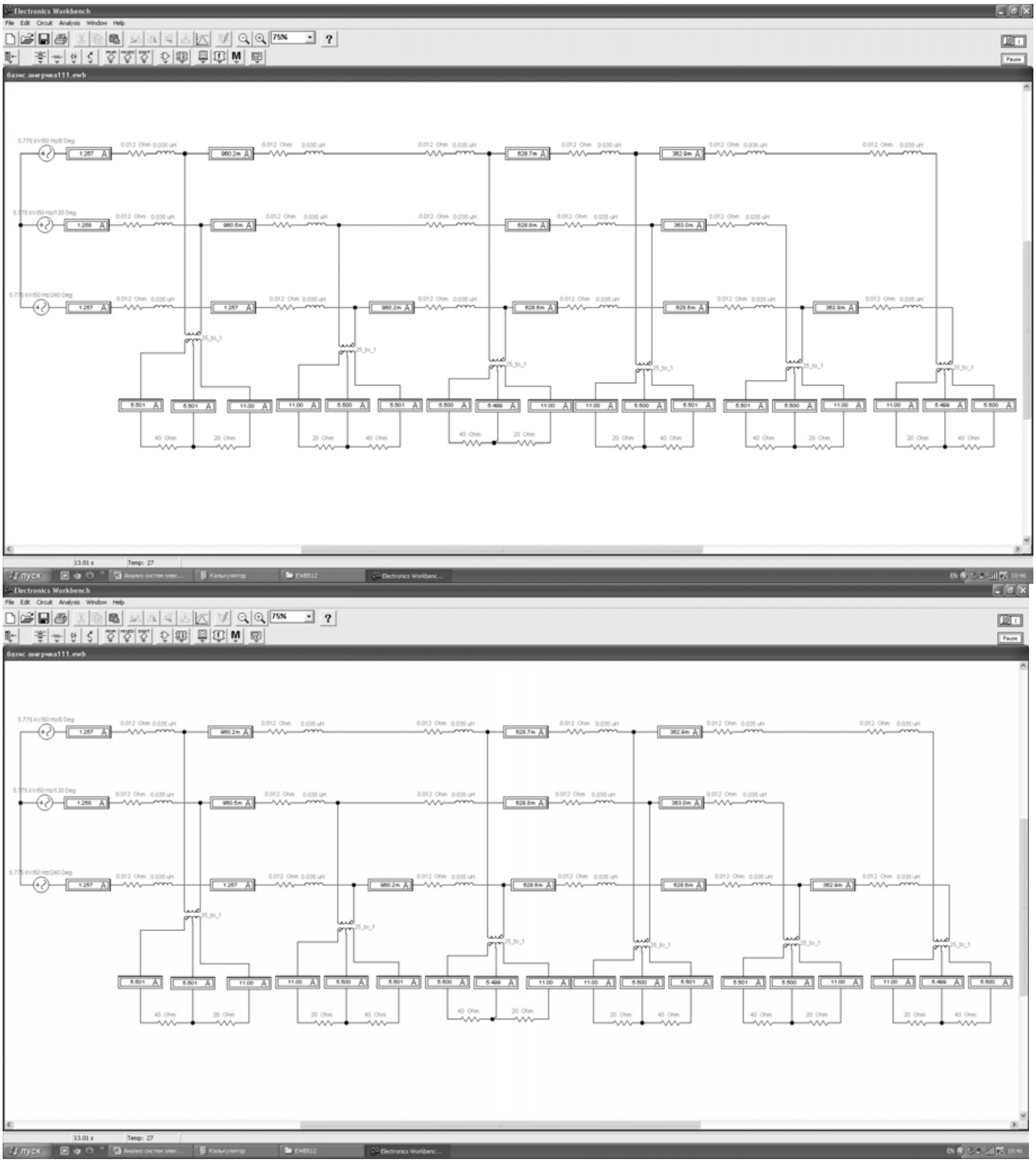

Fig.2 Segment of network

The loss in each segment in the phase and zero wires are shown in Table 3. Total loss in the network will be 105W. Now let us consider a network with the same loads, but with a voltage of 10 kV, in which the 10 / 0.4 kV transformers are located directly on the supports [4] (Fig. 2). There is a scheme in Fig. 2, which also shows modeled a full-phase segment of the 210 m length line (six supports, one-phase consumers are connected to each). Table 3 shows the loss in each section of the network. Total loss in the network is 0.15013 W.

Table 3 The each segment loss in the phase and zero wires

Losses distribution in wires by segments at traditional power supply system						
The wire	Segment 0-1	Segment 1-2	Segment 2-3	Segment 3-4	Segment 4-5	Segment 5-6
Phase A	12,91 W	8,95 W	8,95 W	3,22 W	1,43 W	1,43 W
Phase B	12,98 W	5,76 W	3,24 W	3,24 W	0,36 W	–
Phase C	12,9 W	12,9 W	5,72 W	3,22 W	3,22 W	0,36 W
Zero wire	–	1,05 W	1,055 W	–	1,06 W	1,066 W
Losses distribution in wires by segments at proposed power supply system						
The wire	Segment 0-1	Segment 1-2	Segment 2-3	Segment 3-4	Segment 4-5	Segment 5-6
Phase A	0,01896 W	0,01106 W	0,01106 W	0,00474 W	0,00158 W	0,00158 W
Phase B	0,01899 W	0,01106 W	0,00474 W	0,00474 W	0,00158 W	–
Phase C	0,01896 W	0,01896 W	0,01106 W	0,00474 W	0,00474 W	0,00158 W
Zero wire	–	–	–	–	–	–

Comparison of loss shows that in the proposed network loss are much lower than in the traditional power supply system. Also in the proposed power supply system, the amount of nonferrous metals decreases by a quarter, since three wires are needed instead of four.

Statistical studies show that it is possible to adopt a network with one 10 / 0.4 kV transformer and an outgoing cable that has a household loading with length of 700 m as mathematical expectation. A comparative analysis of power supply systems shows that consumers who feed on the proposed power supply system (from power transformers of small power, which was installed on transmission towers) have power quality parameters that fully satisfy standard, also.

3. CONCLUSION

1. The studies, which have been performed, showed that the variation of the load currents in the segments and the loss of electric energy in an asymmetrically loaded network of 0.4 / 0.23 kV are subject to the normal law. With increasing the number of consumers, the length of the line and the magnitude of the currents, which flowing along the line, are increased and the power loss are increased too . Therefore, there is a need to apply appropriate measures to reduce energy loss.

2 The studies have shown that the consumers who feed on the traditional power supply system have unsatisfactory quality of electrical energy (several times exceeding the standard coefficients of non-sinusoidal, zero and negative phase-sequence), high level of voltage loss (as result unacceptable voltage deviations in remote consumers). That is inadmissible by standard. In addition, in the proposed power supply system, the energy loss in the wires are

much lower than in the traditional power supply system. Investments in both projects are equivalent.

3. Basing on the researches that were fulfilled, we can recommend the using of modern improved structure for the new power supply systems. The reconstruct most of the existing transmission lines are needed together with the building new transmission lines in the old power supply systems. That such switching to the proposed power supply system allows to significantly reducing the power loss in the network and improving energy quality. And taking into account the growing of the household loads power and the non-symmetry of currents, the increasing of the lines length and the number of consumers at the single transmission line, it becomes necessary to replace the system of nominal voltage 0.4 / 0.23 kV to higher values.

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