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EXPERIMENTAL STUDIES OF A DEVELOPED METHOD FOR DETERMINING THE INSULATION PARAMETERS IN A NETWORK WITH ISOLATED NEUTRAL VOLTAGE UP TO 1000 V

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Annotation

The article conducted experimental studies of the developed method for determining insulation parameters in an asymmetric network with a voltage of up to 1000 V for mining enterprises, based on measuring the magnitudes of the linear voltage modules, the phase angle between the phase voltage vector relative to earth and the phase phase linear vector larger than the measured phase voltage relative to earth, as well as the voltage of the phase relative to earth, which has a minimum value before and after connecting the capacitive additional conductivity between the electrical phases network and earth. Experimental studies have shown that the developed method for determining insulation parameters has a satisfactory accuracy, simplicity and safety of work in electrical installations during operation of electrical installations with voltage up to 1000 V.

Key words: current, voltage, neutral, insulation, network.

Introduction

One of the main factors reducing the efficiency of mining machines and complexes is damage to the insulation of the phase relative to the ground. Since the reliability of network operation and electrical equipment is associated with insulation damage in electrical installations with a voltage of up to 1000 V, therefore, the issues of personnel electrical safety are also open. It should be particularly noted that when operating personnel on mining machines and complexes there is a lethal electric shock. [1 – 8].

In three-phase electrical networks with voltage up to 1000 V, there is a lack of phase voltage symmetry. Asymmetry in low voltage networks is formed by two factors: asymmetric load on the phases of the electrical network; if the insulation is damaged, any phase relative to the ground.

The insulation condition is characterized by its active conductivity reducing the level of insulation in the network, as well as capacitive, full and active component of the insulation conductivities in an asymmetric electrical network with an insulated neutral voltage of up to 1000 V.

It should be noted that the active conductivity reducing the level of insulation in a network with an insulated neutral voltage of up to 1000 V of mining enterprises characterizes the magnitude of the leakage current to earth, as well as the magnitude of the touch voltage when the insulation is damaged. Therefore, in the practice of electrical installations, it is necessary to know the amount of active conductivity that reduces the level of insulation in one of the phases of the electrical network relative to the ground. Where by the magnitude of the active conductivity reducing the isolation level of one of the phases in the network relative to the earth, the development of organizational and technical measures to improve electrical safety in networks with voltage up to 1000 V of mining enterprises is being made [1].

Capacitive conductivity characterizes the network capacity, that is, the number of connected electrical receivers, and the length of air and cable lines. Therefore, in the practice of operating electrical installations, it is necessary to know the capacitive conductivity of the insulation of the phases of the electrical network relative to the ground.

Full conductivity reduces the level of insulation in a network with an insulated neutral voltage of up to 1000 V of mining enterprises, which characterizes the magnitude of the leakage current to earth, as well as the magnitude of the touch voltage when the insulation is damaged. Therefore, in the practice of operating electrical installations, it is necessary to know the value of the total conductivity reducing the level of insulation in one of the phases of the electrical network relative to the ground.

The active conductivity of the electrical network insulation characterizes the insulating properties of the dielectric. Therefore, in the practice of electrical installations, it is necessary to know the active conductivity of the insulation of the phases of the electrical network relative to the ground.

To ensure the growth of electrical safety, it is necessary to know the state of insulation of electrical installations under operating voltage. To do this need to develop methods for determining the active conductivity that reduces the level of insulation in the network, as well as the capacitive, full and active component of the insulation in a three-phase asymmetrical electrical network with an insulated neutral voltage of up to 1000 V. will allow to choose the right strategy for the development of organizational and technical measures to improve electrical safety in networks apryazheniem to 1000 mining enterprises.

In the practice of operating mining machines and complexes, there are no effective ways to monitor the insulation condition, protect a person from electric shock in a network with voltage up to 1000 V. Consequently, develop methods for monitoring insulation condition, protect from a person electric shock in a network with voltage up to 1000 V for mining machines and complexes is relevant.

Based of the obtained results of determining the insulation parameters of the electrical network phases relative to the earth, organizational and technical measures are being developed that increase the reliability of the internal power supply system of enterprises and ensure the growth of electrical safety during operation of electrical installations with voltage up to and above 1000 V.

The developed method for determining the insulation parameters and the conductivity value, which reduces the isolation level of any phase relative to the ground, should be necessarily investigated for validity. The developed method for determining insulation parameters in three-phase asymmetrical networks with voltage up to 1000 V is based on measuring the magnitudes of the modules of linear voltage, phase voltage relative to earth, and phase angle between line voltage vectors and phase voltage relative to earth, before and after connecting additional active conductivity between one of the phases of electrical and ground.

Based on measured values of linear voltage modules – $U_л$, voltage phase to earth – $U_ф$ and $U_{ф1}$, and phase angle between line voltage and phase voltage vectors relative to earth – α and α_1, before and after connecting capacitive extra conductivity b_o between the phases of the electrical installation and the ground, as well as taking into account the magnitude of the capacitive additional conductivity, the active conductivity is determined g_o, reducing the level of isolation between one of the phases of the electrical network and the ground, capacitive, full and active conductance of isolation of the network relative to the earth according to mathematical dependencies:

- active conductivity, reducing the level of insulation between one of the phases of the electrical network and the ground

$$g_o = \frac{(U_л^2 - 3U_{фо}^2 - 3,46U_л U_{фо}\sin\alpha)(U_л^2 - 3U_{фо1}^2 - 3,46U_л U_{фо1}\sin\alpha_1)}{U_л\left[\begin{array}{l}(U_л^2 - 3U_{фо}^2 - 3,46U_л U_{фо}\sin\alpha)(U_л - 1,73U_{фо1}\sin\alpha_1) - \\ -(U_л^2 - 3U_{фо1}^2 - 3,46U_л U_{фо1}\sin\alpha_1)(U_л - 1,73U_{фо}\sin\alpha)\end{array}\right]} b_o, \qquad (1)$$

- total network insulation

$$y = \frac{U_{фо}\left[\begin{array}{l}(U_л^2 - 3U_{фо}^2 - 3,46U_л U_{фо}\sin\alpha)^{0,5} \times \\ \times (U_л^2 - 3U_{фо1}^2 - 3,46U_л U_{фо1}\sin\alpha_1)\end{array}\right]}{U_л\left[\begin{array}{l}(U_л^2 - 3U_{фо}^2 - 3,46U_л U_{фо}\sin\alpha)(U_л - 1,73U_{фо1}\sin\alpha_1) - \\ -(U_л^2 - 3U_{фо1}^2 - 3,46U_л U_{фо1}\sin\alpha_1)(U_л - 1,73U_{фо}\sin\alpha)\end{array}\right]} b_o, \qquad (2)$$

- capacitive conductance insulation network

$$b=\frac{(U_{л}^{2}-3U_{фо1}^{2}-3{,}46U_{л}U_{фо1}\sin\alpha_{1})(U_{л}-1{,}73U_{фо}\sin\alpha)}{(U_{л}^{2}-3U_{фо}^{2}-3{,}46U_{л}U_{фо}\sin\alpha)(U_{л}-1{,}73U_{фо1}\sin\alpha_{1})-(U_{л}^{2}-3U_{фо1}^{2}-3{,}46U_{л}U_{фо1}\sin\alpha_{1})(U_{л}-1{,}73U_{фо}\sin\alpha)}b_{o},\qquad(3)$$

- active conduction insulation network

$$g=\frac{1{,}73U_{л}U_{фо}\sin\alpha(U_{л}^{2}-3U_{фо1}^{2}-3{,}46U_{л}U_{фо1}\sin\alpha_{1})}{U_{л}\left[(U_{л}^{2}-3U_{фо}^{2}-3{,}46U_{л}U_{фо}\sin\alpha)(U_{л}-1{,}73U_{фо1}\sin\alpha_{1})-(U_{л}^{2}-3U_{фо1}^{2}-3{,}46U_{л}U_{фо1}\sin\alpha_{1})(U_{л}-1{,}73U_{фо}\sin\alpha)\right]}b_{o}.\qquad(4)$$

For practical purposes, it is necessary to take into account the error analysis, where limits are set for changing the ratio of voltages from the value of capacitive additional conductivity, to conduct experimental studies of the developed method for comparison with the classical ammeter-voltmeter method, developed in detail by Professor L.V. Gladilin.

Determination of insulation parameters by the ammeter-voltmeter method consists in measuring the magnitude of the voltage module of the phase relative to the earth before and after connecting active additional conductivity and measuring the magnitude of the total fault current to earth by directly connecting the electrical installation phase to earth.

Based on measurements of the magnitude of the modulus of the phase voltage relative to earth $U_{ф}$ and $U_{фо}$ before and after connecting the active additional conductivity and measuring the magnitude of the modulus of the single-phase earth-fault current – I_{o}, and also taking into account the magnitude of the active additional conductivity g_{o}, insulation parameters are determined by the formulas:

- total network insulation

$$y=I_{o}U_{ф}^{-1},\qquad(5)$$

- total network insulation conductance

$$y_{\Sigma}=I_{o}U_{фо}^{-1},\qquad(6)$$

- active conduction of network insulation

$$g=0{,}5(y_{\Sigma}^{2}-y^{2}-g_{1}^{2})2g_{o}^{-1},\qquad(7)$$

– - capacitive conductivity of network insulation

$$b=(y^{2}-g^{2})^{0{,}5}.\qquad(8)$$

–Experimental studies were carried out in laboratory conditions of a distribution network with voltage up to 1000 V according to the circuit diagram Figure 1.

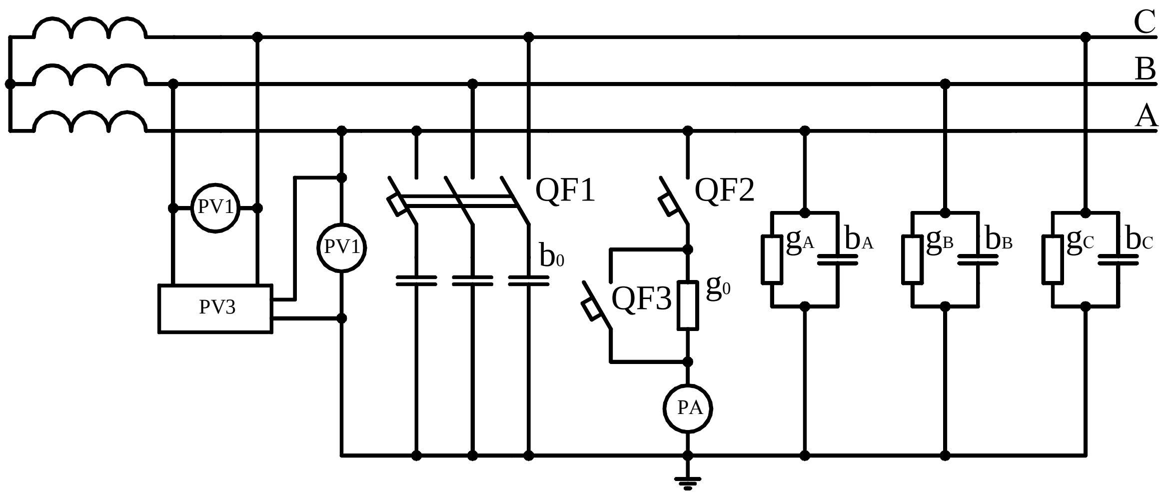

Figure 1 – Electrical schematic study of the developed method for determining insulation parameters in a network with insulated neutral voltage up to 1000 V with damaged insulation between one of the network phases and ground

The electrical schematic study of the developed method for determining insulation parameters in a network with insulated neutral voltage up to 1000 V with damaged insulation between one of the network phases and the ground, shown in Figure 15, contains:

- investigated three-phase electric network with insulated neutral, with phases A, B and C;
- PV1 voltmeter, measuring the magnitude of the linear voltage modulus;
- PV2 voltmeter, which measures the magnitude of the voltage module of the phase A relative to the ground, provided that during the phase A of the electrical network there is a damage to the insulation between it and the ground;
- measuring device PV3, measuring the phase angle between the voltage vector of phase A relative to the earth and the vector of linear voltage;
- capacitive conductance insulation network b_A, b_B, b_C;
- active conductance isolation network g_A, g_B, g_C;
- QF1 – a switch disconnecting the capacitive additional conductivity between the phases of the electrical network and the ground;
- QF2 – a switch disconnecting the conduction, reducing the level of insulation between the phase A of the electrical network and the ground;
- QF3 – a disconnect switch that shunts the conductivity and reduces the level of insulation between the phase A of the electrical network and the ground;
- g_o– active additional conductivity, reducing the level of insulation between phase A of the network and the ground;
- b_o– capacitive additional conductivity connected between the phases of the electrical network and the ground;
- PA – Ammeter

measuring: leakage current flowing through active additional conductivity, reducing the insulation level of phase A relative to the ground when it is switched by the QF2 switch disconnector, the value of the current of the RPA when shunting active additional conductivity, reducing the insulation level of phase A relative to the ground.

For measuring the values of current and voltage modules, devices of type Э-515 with an accuracy class of 0,5 and with current measurement limits I = 0 ¸ 5 A, voltages U = 0 ¸ 500 V are used.

Resistance type PE-200 with nominal value R_o = 1000 Om was used as an active additional conduction. Capacitors of the KBGS-MP type with a capacitance of 0.5 μF, were used as capacitive additional conductivity, $U_н = 1000\,B$.

The study of the developed method for validity in comparison with the method of ammeter-voltmeter is carried out according to the following program.

1. 3 load switches QF1, QF2 and QF3 are selected.
2. Testing is performed on the working capacity of the selected load switches.
3. After checking them for operability of the load switches QF1, QF2 and QF3, work is being done to prepare additional capacitive connection circuits – b_o and active – g_o conductivities.
4. A load switch QF1 is connected to phases A, B and C of the electrical network and additional capacitive conductivity is connected for switching between the outgoing contacts of the load switch and ground b_o.
5. Active additional conduction is connected to the phases A of the load break switch QF2, which reduces the insulation resistance between this phase and the ground – g_o which is shunted by a QF3 load switch and between capacitive extra conductivity – b_o and the earth is connected to the ammeter PA.
6. After connecting the breakers QF1, QF2 and QF3 to the electrical network and, accordingly, connecting them to additional capacitive – b_o and active – g_o conductors with an ammeter in series connection of active additional conductivity of the circuit, connect measuring instruments PV1, PV2 and PV3, measuring the magnitudes of the modules of linear voltage, phase voltage relative to earth, and the phase angle between phase voltage vector relative to earth and line voltage vector.
7. After work on points 6, the values of measuring instruments are connected, which are connected for experimental research.
8. After the work on paragraph 7, the QF2 switch disconnects the active additional conductivity, which reduces the isolation level between the phase A of the network and the ground, and the current flowing through this conductivity is recorded, the ammeter PA, voltmeters PV1 and PV2 measure the values of the linear voltage modules voltage phase relative to the earth, and the measuring device PV3 recorded the phase angle between the phase voltage vectors relative to the earth and the line voltage.

9. After carrying out the work on paragraph 8, the active additional conductivity g_o is shunting between the mains phase and the ground with the QF3 load switch. The current measured without active additional conductivity is registered by the ammeter RA, and the work on measuring according to item 8 is carried out.

10.After making the work under paragraph 9, the QF3 load switch is disconnected and thus the active additional conductivity g_o is connected between the mains phase and the ground. A measurement is made of the amount of current flowing through the active additional conductivity with an RA ammeter, and also the work is carried out to carry out the measurements in accordance with clause 8.

11.After the work made under paragraph 10, the QF1 load switch is connected between the mains phases and the ground of the additional conductivity vessel. A measurement is made of the amount of current flowing through the active additional conductivity with an RA ammeter, and also the work is carried out to carry out the measurements in accordance with clause 8.

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12. After work under paragraph 11, the load break switches QF1 and QF2 are disconnected.

With a time interval of 0.5 hours, work on items 8 ¸ 12is alternately made. After work with a time interval of 0.5 hours and the number of measurements n = 8, the production scheme of the research of the developed method for determining insulation parameters in an asymmetric network with an insulated neutral voltage of up to 1000 V is dismantled at the OEB1-C-R26.08.2005 laboratory complex “Electrical Safety Basics”.

The results of experimental studies to compare the developed method with the classical method of ammeter-voltmeter are recorded in Tables 1 and 2.

To prove the reliability, according to the estimation of the errors stated in [9-11], it is necessary to make at least four measurements. In this case, we take eight measurements with an interval between measurements of 0.5 hours

Table 1 - The results of determining the insulation parameters according to the method of ammeter-voltmeter

Insulation parameters	Number of measurements							
	1	2	3	4	5	6	7	8
Total network insulation y x 10^{-3}, S.	0,80	0,75	0,75	0,72	0,75	0,68	0,71	0,86
Capacitive conductivity of network insulation b x10^{-3}, S.	0,68	0,77	0,83	0,48	0,69	0,58	0,75	0,62

Active conduction of network insulation g x 10^{-3}, S.	0,32	0,21	0,34	0,32	0,37	0,28	0,49	0,27

Table 2 - The results of determining the insulation parameters of the developed method

Insulation parameters	Number of measurements							
	1	2	3	4	5	6	7	8
Total network insulation y x 10^{-3}, S.	0,84	0,69	0,75	0,71	0,85	0,88	0,83	0,75
Capacitive conductivity of network insulation b x10^{-3}, S.	0,68	0,77	0,71	0,65	0,87	0,73	0,91	0,65
Active conduction of network insulation g x 10^{-3}, S.	0,25	0,32	0,32	0,35	0,25	0,37	0,36	0,35

To compare the results of the developed method and the ammeter-voltmeter method, the error is estimated using the following calculation algorithm [9 – 11]:

1. The average values of the studied parameters are determined.

$$\overline{X} = \sum_{i=1}^{n} X_i n^{-1} . \quad (9)$$

2. According to the mathematical dependence, the standard deviations of a single result are determined for n = 8 dimensions of the parameter under study.

$$\sigma = \left(\sum_{i=1}^{n} X_i n^{-1} - \overline{X}_i^2 \right)^{0,5} . \quad (10)$$

3. Determine the rms error of a single result of the parameter under study.

$$S_n = \left\{ \left[(\overline{X} - X_1)^2 + (\overline{X} - X_2)^2 + (\overline{X} - X_3)^2 + ... + (\overline{X} - X_n)^2 \right] (n-1)^{-1} \right\}^{0,5} . \quad (11)$$

Based on theoretical studies of the error analysis of the developed method, we determine the values of α, the confidence probability for the confidence interval, expressed in fractions of the root-mean-square error ε.

According to the relative mean square error of the developed method for determining the unknown quantities, random relative errors do not exceed 10% when using measuring devices with cl. accuracy 1.0, when using measuring devices with cl. accuracy 0.5 errors of the required values do not exceed 5%.

Since the confidence probability should be equal to $\alpha = 0.9 \div 0.95$ according to the recommendation set out in [9 - 11], for our case with the value of $\varepsilon = 5\%$ we take $\alpha = 0.95$, which confirms the accuracy of the error estimate analysis developed method

4. The absolute error in determining the desired quantity is expressed by the mathematical dependence:

$$\Delta X = t_{\alpha n} S_n n^{-0,5}, \qquad (12)$$

where for the value of $\alpha = 0.95$ with $n = 8$ we take the Student coefficient $t_{\alpha n}$ (according to table 2 [9 - 11]), which is equal to 2.4.

5. The relative error of the compared methods for determining the insulation parameters of the phases of the electrical network relative to the earth is calculated by the formula:

$$\Delta X_* = \Delta X \cdot \overline{X}^{-1} \cdot 100\,\% . \qquad (13)$$

The results of the experimental studies presented in Tables 1 and 2 were processed by the above algorithm and made it possible to obtain probabilistic statistical characteristics for estimating the error of the developed method in comparison with the method of an ammeter-voltmeter. The results are summarized in Table 3.

As a result of visual comparison of the characteristics of the electrical network insulation parameters, summarized in the table, it can be said that the developed method for determining insulation parameters and conductivity values, reducing the isolation level of any phase relative to the earth, has satisfactory accuracy, since the rms errors of single measurements and relative rms errors of determining the insulation parameters of electrical networks developed method and the method of ammeter-voltmeter practic cally not different.

Table 3 - Probabilistic-statistical characteristics of the electrical network insulation parameters

Method of measurement	Parameters	$\overline{X}$, 10^{-3} S	S_n, 10^{-3} S	ΔX, 10^{-3} S	ΔX_*, %
According to the method of ammeter-voltmeter	y	0,743	0,042	0,040	2,2
	b	0,775	0,037	0,032	3,5
	g	0,300	0,010	0,079	2,4
According to the developed method	y	0,804	0,006	0,007	0,4
	b	0,745	0,005	0,005	0,3
	g	0,300	0,003	0,004	0,8

Analysis of the above measurement errors leads to the conclusion that the developed method for determining insulation parameters can be used along with the method of an ammeter-voltmeter. The proposed method with sufficient safety during operation can be recommended for implementation in production.

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Conclusions

In view of the above said that the comparative characteristics of the electrical network insulation parameters obtained as a result of the experiment showed that the developed method for determining the insulation parameters has a satisfactory accuracy, since the root-mean-square errors of single measurements and the relative root-mean-square errors of determining the insulation parameters of electric networks Voltmeter is almost the same.

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1000 В-ГЕ ДЕЙІНГІ ИЗОЛЯЦИЯЛАНБАҒАН БЕЙТАРАПТЫҚ КЕРНЕУІ БАР ЖЕЛІДЕГІ ИЗОЛЯЦИЯ ПАРАМЕТЕРЛЕРІН АНЫҚТАУҒА АРНАЛҒАН ДАМЫҒАН ӘДІСТІ ЭКСПЕРИМЕНТАЛДЫ ЗЕРТТЕУЛЕРІ

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Түйін

Тау-кен кәсіпорындарында кернеуі 1000 В дейінгі асимметриялық желілерде оқшаулау параметрлерін анықтау әдістемесін эксперименттік зерттеу жүргізілді, әдіс сызықтық кернеулі модульдердің шамаларын, фазалық кернеу арасындағы вектордың фазалық бұрышын және өлшенген кернеуден жоғары фазалық кернеу векторын өлшеуге негізделген жерге қатысты фазаға, сондай-ақ жерге қатысты кернеу фазасына, сыйымдылықты қосымша қосудың алдындағы және кейінгі ең аз мәні бар электр желісінің фазалардың және жерге арасындағы екінші өткізгіштік. Эксперименттік зерттеулер көрсеткендей, оқшаулау параметрлерін анықтау әдістемесі 1000 В дейінгі кернеумен электр қондырғыларын пайдалану кезінде электр қондырғыларында жұмыс істеудің қанағаттанарлық дәлдігі, қарапайымдылығы және қауіпсіздігі.

Түйінді сөздер: ток, кернеу, бейтарап, оқшаулау, желі.

ЭКСПЕРИМЕНТАЛЬНЫЕ ИССЛЕДОВАНИЯ РАЗРАБОТАННОГО МЕТОДА ОПРЕДЕЛЕНИЯ ПАРАМЕТРОВ ИЗОЛЯЦИИ В СЕТИ С ИЗОЛИРОВАННОЙ НЕЙТРАЛЬЮ НАПРЯЖЕНИЕМ ДО 1000 В

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Резюме

В работе проведены экспериментальные исследования разработанного метода определения параметров изоляции в несимметричной сети напряжением до 1000 В для горных предприятий, основанный на измерении величин модулей линейного напряжения, угла сдвига фаз между вектором напряжения фазы относительно земли и вектором линейного напряжения фазы, которая больше по величине измеряемого напряжения фазы относительно земли, а также напряжения фазы относительно земли которое имеет минимальное значение до и после подключения емкостной дополнительной проводимости между фазами электрической сети и землей. Экспериментальные исследования показало, что разработанный метод определения параметров изоляции обладает удовлетворительной точностью, простотой и безопасностью работ в электроустановках при эксплуатации электроустановок напряжением до 1000 В.

Ключевые слова: ток, напряжение, нейтраль, изоляция, сеть.