The method of determining the insulation parameters in three-phase electrical networks with isolated neutral with voltages up to and above 1000 V

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Abstract. In work the new method of definition of isolation's parameters in a three-phase symmetric electrical network with isolated neutral which is based on measurement of modules sizes of a linear voltage, voltages of phases C and A concerning to ground, after connection of active additional conductivity between phase A of electrical network and ground is shown and the analysis of a blunder of the developed method is made. The analysis of a blunder has shown, that the developed method provides satisfactory accuracy at definition of isolation's parameters, and also simplicity and the safety of operations in working electro installations of up to above 1000 V voltage.

1. Introduction

The implementation of modern technological processes in quarries, which are directly related to the growth of unit capacity of stripping and mining machines, are making increasingly stringent requirements to ensure the safety and security of the operation of electrical system [1, 2].

However, the increase in the length of electrical networks, which feed stripping and mining machines, increases the likelihood of single-phase ground fault, which, as a rule, are the main cause of the interruption of power supply. Relay protection and automation actions allow maintaining the continuity of power supply only if it is possible to control periodic insulation parameters mains phases with respect to ground.

Among the range of issues related to ensuring security of supply of electric power electrified mining equipment and the safety of its operation there is a development of methodology for determining the insulation parameters, which occupies a special place, as the results of the use of the method used are derived the main provisions of organizational and technical measures that promote a culture of service of the internal power supply of mining enterprises. The importance of developing the method to determine the insulation value is also determined by the fact that it can be used in other industries where there is three-phase electrical networks with isolated neutral with voltages up to and above 1000 V.

For experimental studies of the state of insulation of three-phase electrical networks with isolated neutral with voltages up to and above 1000, was proposed a number of methods [1, 2, 4 ÷ 5] with taking into account the specific characteristics of inherent in the internal power supply of open cast

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mining. For the insulation parameters measuring methods a number of requirements are presented, namely:

- Measurements should be carried out without interruption in the supply of electricity to consumers.
- The process of measurement should not cause damage to the insulation of electrical networks and electrical accidents.
- The measurements must be carried out using a small amount of electrical equipment and appliances.
- Execution of determining the insulation parameters should be safe both for researchers and for personnel servicing electrical systems.
- Measurements of baseline values should be sufficiently accurate and if possible have a short duration of works on measurement.
- Accuracy of the method must not exceed 10%.

Based on the analysis of existing methods [1, 2], considering the above requirements for experimental research of insulation parameters of three-phase electrical networks with isolated neutral was obtained the conclusion that the methods developed earlier is not fully meet the essential requirements. Therefore, at present in mines previously proposed methods were not used as a primary means of prevention, ensuring of uninterrupted power supply and operational safety of electrical installations.

In this regard, there are problems of further improvement of means of controlling insulation parameters of electrical networks in conjunction with the implementation of preventive measures and periodic measurements in different operating conditions. Method for determining the phase insulation parameters to earth of electrical networks must not affect the operation of the electricity system, and the calculation of insulation parameters must contain a minimum of computation.

In practice of operation of electrical networks with isolated neutral with voltage up to 1000 V and above it is necessary to know the value of the insulation parameters by which are developed the organizational and technical measures to ensure the safety and security of electricity supply of mining enterprises.

2. Method for determining the insulation parameters in an electrical network with insulated neutral

One of the factors of electric shock is the weakening of insulation condition of a three-phase electrical network with insulated neutral voltages up to and above 1000 V. In order to ensure the increase of efficiency of power supply system is necessary to develop a method of determining the parameters of isolation under operating voltage. Under the effectiveness we accept the ensuring of growth of electrical safety and reliability in the operation of electrical installations with voltage up to and above 1000 V. The known [1] method of determining the parameters of isolation, "Ammeter-voltmeter" is a classical method, as it provides a satisfactory accuracy of the unknown quantities, but it does not ensure work safety in electrical installations production works and reduces the reliability of power supply of industrial machinery and equipment. Reduction of electrical installations work reliability and level of electrical safety in the operation of three-phase power networks up to and above 1000 determined that by using the method "Ammeter-voltmeter" it is necessary to make the metal circuit of a mains phase to earth and measuring the total current single-phase fault ground. Since during a metal closure of any phase to earth phase voltage of the two other phases of the mains with respect to ground reaches linear values and can thus lead to a short circuit in a multi-phase mains operated, which determines the reliability of power decrease production machinery. A reduction in electrical safety determined by that in the metal closure of any phase of electrical network and ground, contact voltage and step voltage will have the maximum value, and thereby provides maximum increase the probability electric shock to persons.

The presented in work [3] method of determining the insulation parameters in three-phase electrical network with insulated neutral voltages above 1000 V, based on the measurement values of the modules of the line voltage, zero-sequence voltage and phase voltage with respect to ground when connected known active extra conduction between electrical network of the measured phase and ground, has a significant error. A significant error determined by that in determining the insulation parameters using the value of zero sequence voltage module, and thus it is necessary to use a voltage transformer windings, allowing to allocate the residual voltage

On the basis of the foregoing methods for determining the insulation parameters in three-phase mains with insulated neutral voltages up to and above 1000 V, which provides a satisfactory accuracy of the unknown quantities by eliminating the measurement of the modulus of the residual voltage, the operational safety of electrical installations and the reliability of the electricity system, in connection excluding the measurements of the total current of the module for single-phase earth fault between a mains phase with respect to ground.

A method for determining the insulation parameters in three-phase balanced networks with voltage up to and above 1000 V, based on the measurement values of the modules of the line voltage, the phase voltages A and C relative to the ground after connecting additional active conductivity between the phase A and the mains ground was developed.

As a result of the measurement values of the modules of the line voltage and phase voltage C and A with respect to the ground, taking into account the magnitude of the additional active conductivity by mathematical formulas are defined:

– the total conductance of network insulation

$$y = \frac{1.73 U_1 U_A}{U_C^2 - U_A^2} g_o, \tag{1}$$

– the active conductance of network insulation

$$g = \left(\frac{3U_l^2 (U_1^2 - 3U_A^2)}{(U_C^2 - U_A^2)^2} - 1 \right) 0.5 g_o, \tag{2}$$

– capacitive conductance of network insulation

$$b = \sqrt{y^2 - g^2}, \tag{3}$$

where U_l – line voltage; U_A – A phase voltage with respect to the ground; U_C – C phase voltage with respect to the ground; g_o – additional active conductance.

The method developed in the implementation does not require the creation of a special measuring device, since the measuring devices, i.e. voltmeters, available in the service manual. The PE-200 resistance is used as an active additional conductivity with R = 1000 ohms, where by means of parallel and serial connection provides the required power dissipation. To switch the active standby is used more conductivity cell load switch.

The developed method provides satisfactory accuracy, simple and safe in its implementation in the three-phase electrical networks with isolated neutral voltages up to and above 1000 V.

3. Analysis of error of method determining the insulation parameters in an electrical network with isolated neutral

The obtained mathematical dependences for determining the total and active conductances of electrical network insulation provide easy and safe work of electrical installations with voltage up to and above 1000 V.

Perform error analysis of the developed method of determining the insulation parameters in symmetrical three-phase electrical networks with isolated neutral which is based on measurement of unit line voltage, phase voltage C and A relative to the earth, after the active connection of additional conduction between phase And the electric network and earth.

To improve the efficiency of the developed method for determining the parameters of isolation in a symmetrical three-phase network with isolated neutral, based on error analysis for each specific network is selected additional active conductivity, in order to ensure satisfactory accuracy of required quantities.

Random relative error in determining the total conductivity of insulation and its components in three-phase balanced networks with voltage up to and beyond 1000, based on the measurement values of the modules of the line voltage, phase voltage C and A with respect to ground, after connecting the active additional conduction between the phase and the electric network and earth, determined according to equation (1), (2) and (3).

Random relative error in determining the total conductance of mains phase insulation relative to the ground is determined from the formula (1):

$$y = \frac{1.73 U_l U_A}{U_C^2 - U_A^2} g_o,$$

where U_l, U_A, U_C, g_o – values that define the total conductance of network insulation and obtained by direct measurement. The relative mean square error in determining the total conductance of mains phase insulation relative to the ground is determined from the expression [3]:

$$\Delta y = \frac{1}{y}\left[\left(\frac{\partial y}{\partial U_A}\Delta U_A\right)^2 + \left(\frac{\partial y}{\partial U_C}\Delta U_C\right)^2 + \left(\frac{\partial y}{\partial U_l}\Delta U_l\right)^2 + \left(\frac{\partial y}{\partial g_o}\Delta g_o\right)^2\right]^{1/2}, \quad (4)$$

where $\frac{\partial y}{\partial U_A}$, $\frac{\partial y}{\partial U_C}$, $\frac{\partial y}{\partial U_l}$, $\frac{\partial y}{\partial g_o}$ – partial derivatives $y = f\,(U_l, U_A, U_C, g_o)$.

Here ΔU_l, ΔU_A, ΔU_C, Δg_o – absolute errors of direct measurement values U_l, U_A, U_C, g_o which are defined by the following expressions:

$$\begin{aligned} \Delta U_l &= U_l \cdot \Delta U_{l*}; \\ \Delta U_C &= U_C \cdot \Delta U_{C*}; \\ \Delta U_A &= U_A \cdot \Delta U_{A*}; \\ \Delta g_o &= g_o \cdot \Delta g_{o*}. \end{aligned} \quad (5)$$

To determine the errors of measuring devices accept that $\Delta U_{l*} = \Delta U_{A*} = \Delta U_{C*} = \Delta U_*$, where: ΔU_* - the relative error of voltage measurement circuits; $\Delta g_{o*} = \Delta R_*$ - the relative error of the measuring instrument, which measures the resistance which is connected between the phase A electrical and ground. Determine the partial derivative functions $y = f\,(U_1, U_A, U_C, g_o)$ by the variables U_1, U_A, U_C, g_o:

$$\begin{aligned} \frac{\partial y}{\partial U_1} &= \frac{1.73 U_A}{U_C^2 - U_A^2} g_o; \\ \frac{\partial y}{\partial U_A} &= \frac{1.73 U_1 (U_C^2 + U_A^2)}{(U_C^2 - U_A^2)^2} g_o; \\ \frac{\partial y}{\partial U_C} &= -\frac{3.46 U_1 U_A U_C}{(U_C^2 - U_A^2)^2} g_o; \\ \frac{\partial y}{\partial g_o} &= \frac{1.73 U_1 U_A}{U_C^2 - U_A^2}. \end{aligned} \quad (6)$$

Solving the equation (4), substituting the values of the partial derivatives of equation (6) and private values of absolute errors (5), at the same time, assuming that $\Delta U_* = \Delta R_* = \Delta$, we obtain:

$$\varepsilon_y = \frac{\Delta y}{\Delta} = \frac{1.73 U_l U_A g_o}{U_C^2 - U_A^2} \left(2 + \frac{4U_C^4 + (U_C^2 + U_A^2)^2}{(U_C^2 - U_A^2)^2} \right)^{1/2} . \quad (7)$$

The obtained equation (7) is divided into the equation (1):

$$\varepsilon_y = \frac{\Delta y}{\Delta} = \left(2 + \frac{4U_C^4 + (U_C^2 + U_A^2)^2}{(U_C^2 - U_A^2)^2} \right)^{1/2} . \quad (8)$$

The obtained equation (8) we express in relative units, and after the conversion obtain:

$$\varepsilon_y = \frac{\Delta y}{\Delta} = \left(2 + \frac{4 + (1 + U_*^2)^2}{(1 - U_*^2)^2} \right)^{1/2} , \quad (9)$$

where $U_* = \dfrac{U_A}{U_C}$.

Random error in determining the active conductance of mains phase insulation relative to the ground is determined from the formula (2):

$$g = \left(\frac{3U_l^2 (U_1^2 - 3U_A^2)}{(U_C^2 - U_A^2)^2} - 1 \right) 0.5 g_o ,$$

where U_1, U_A, U_C, g_o – values that define the active conductance of network isolation and obtained by direct measurement.

Relative mean square error of the method when determining the active conductivity of phase insulation of electrical network relative to the ground is determined from the expression:

$$\Delta g = \frac{1}{g} \left[\left(\frac{\partial g}{\partial U_A} \Delta U_A \right)^2 + \left(\frac{\partial g}{\partial U_C} \Delta U_C \right)^2 + \left(\frac{\partial g}{\partial U_1} \Delta U_l \right)^2 + \left(\frac{\partial g}{\partial g_0} \Delta g_o \right)^2 \right]^{1/2} , \quad (10)$$

where $\dfrac{\partial g}{\partial U_A}$, $\dfrac{\partial g}{\partial U_C}$, $\dfrac{\partial g}{\partial U_1}$, $\dfrac{\partial g}{\partial g_o}$ – partial derivatives, $g = f\ (U_1, U_A, U_C, g_o)$.

Here ΔU_1, ΔU_A, ΔU_C, Δg_o – absolute errors of direct measurement values U_1, U_A, U_C, g_o which are defined by the following expressions:

$$\begin{aligned} \Delta U_1 &= U_1 \cdot \Delta U_{1*} ; \\ \Delta U_C &= U_C \cdot \Delta U_{C*} ; \\ \Delta U_A &= U_A \cdot \Delta U_{A*} ; \\ \Delta g_o &= g_o \cdot \Delta g_{o*} . \end{aligned} \quad (11)$$

To determine the accuracy of measuring devices accept that $\Delta U_{1*} = \Delta U_{A*} = \Delta U_{C*} = \Delta U_*$, where: ΔU_* - the relative error of voltage measurement circuits; $\Delta g_{o*} = \Delta R_*$ - the relative error of a measuring instrument that measures resistance which is connected between the phase A electrical and the ground.

Determine the partial derivatives $g = f\ (U_1, U_A, U_C, g_o)$ by the variables U_1, U_A, U_C, g_o:

$$\frac{\partial g}{\partial U_l} = \frac{3U_l(2U_l^2 - 3U_A^2)}{2(U_C^2 - U_A^2)^2} g_o;$$
$$\frac{\partial g}{\partial U_A} = -\frac{3U_l^2 U_A(3U_C^2 + 3U_A^2 - 2U_l^2)}{(U_C^2 - U_A^2)^3} g_o;$$
$$\frac{\partial g}{\partial U_C} = -\frac{6U_l^2 U_C(U_l^2 - 3U_A^2)}{(U_C^2 - U_A^2)^3} g_o; \tag{12}$$
$$\frac{\partial g}{\partial g_o} = \frac{3U_l^2(U_l^2 - 3U_A^2)}{2(U_C^2 - U_A^2)} - 0.5 .$$

Solve equation (10), substituting the values of the partial derivatives of equation (12) and the values of the partial absolute errors (11), at the same time, assuming that $\Delta U_* = \Delta R_* = \Delta$, we obtain:

$$\frac{\Delta g}{\Delta} = \frac{3g_o}{(U_C^2 - U_A^2)^3}\begin{pmatrix}(U_C^2 - U_A^2)^2[2U_l^4(U_l^2 - 3U_A^2)^2 - (U_C^2 - U_A^2)^4] + \\ + U_l^4\{U_A^4[3(U_C^2 - U_A^2) - 2U_l^2]^2 + U_C^4(U_l^2 - 3U_A^2)^2\}\end{pmatrix}^{1/2}. \tag{13}$$

Obtained equation (13) divide by the equation (2):

$$\varepsilon_g = \frac{\Delta g}{\Delta} = \begin{pmatrix}\frac{2U_l^4(U_l^2 - 3U_A^2)^2 - (U_C^2 - U_A^2)^4}{[3U_l^2(U_l^2 - 3U_A^2) - (U_C^2 - U_A^2)^2]^2} + \\ + \frac{U_l^4\{U_A^4[3(U_C^2 - U_A^2) - 2U_l^2]^2 + U_C^4(U_l^2 - 3U_A^2)^2\}}{(U_C^2 - U_A^2)^2[3U_l^2(U_l^2 - 3U_A^2) - (U_C^2 - U_A^2)^2]^2}\end{pmatrix}^{1/2}. \tag{14}$$

The resulting equation (14) the value of the line voltage is expressed in terms of the phase voltages in accordance with the fact that $U_1 = \sqrt{3}U_{\phi}$:

$$\varepsilon_g = \frac{\Delta g}{\Delta} = 3\begin{pmatrix}\frac{18U_{ph}^4(U_{ph}^2 - U_A^2)^2 - (U_C^2 - U_A^2)^4}{[27U_{ph}^2(U_{ph}^2 - U_A^2) - (U_C^2 - U_A^2)^2]^2} + \\ + \frac{3U_{ph}^4 U_A^4(U_C^2 - U_A^2 - 2U_{ph}^2)^2 + U_C^4(U_{ph}^2 - U_A^2)^2}{(U_C^2 - U_A^2)^2[27U_{ph}^2(U_{ph}^2 - U_A^2) - (U_C^2 - U_A^2)^2]^2}\end{pmatrix}^{1/2}. \tag{15}$$

Simplifying the formula (15) we obtain the equation (16):

$$\varepsilon_g = \frac{3}{27U_{ph}^2(U_{ph}^2 - U_A^2) - (U_C^2 - U_A^2)^2}\begin{pmatrix}18U_{ph}^4(U_{ph}^2 - U_A^2)^2 - (U_C^2 - U_A^2)^4 + \\ + \frac{3U_{ph}^4 U_A^4(U_C^2 - U_A^2 - 2U_{ph}^2)^2}{(U_C^2 - U_A^2)^2} + \\ + \frac{U_C^4(U_{ph}^2 - U_A^2)^2}{(U_C^2 - U_A^2)^2}\end{pmatrix}^{1/2}. \tag{16}$$

Obtained equation (16) express in relative units, and after the conversion obtain:

$$\varepsilon_g = \frac{\Delta g}{\Delta} = \frac{3}{27(1-U_{A*}^2)-(U_{C*}^2-U_{A*}^2)^2}\left(\begin{array}{l} 18(1-U_{A*}^2)^2-(U_{C*}^2-U_{A*}^2)^4+ \\ +\dfrac{3U_{A*}^4(U_{C*}^2-U_{A*}^2-2)^2}{(U_{C*}^2-U_{A*}^2)^2}+ \\ +\dfrac{U_{C*}^4(1-U_{A*}^2)^2}{(U_C^2-U_A^2)^2}\end{array}\right)^{1/2}, \quad (17)$$

where $U_{A*}=\dfrac{U_A}{U_{ph}}$, $U_{C*}=\dfrac{U_C}{U_{ph}}$.

Relative mean square error method for determining the conductivity of the capacitive isolation mains phases relative to the ground is determined by the expression (3):

$$\Delta b = \frac{1}{b}\left[\left(\frac{\partial b}{\partial y}\Delta y\right)^2+\left(\frac{\partial b}{\partial g}\Delta g\right)^2\right]^{1/2}, \quad (18)$$

or

$$\varepsilon_b = \frac{\Delta b}{\Delta} = \frac{\left[(1-\tan^2\delta)^2\left(\dfrac{\Delta y}{\Delta}\right)^2+\left(\dfrac{\Delta g}{\Delta}\right)^2\right]^{1/2}}{\tan^2\delta}. \quad (19)$$

Solving the equation (19) substituting the values of mathematical descriptions of the relative rms dependences of total (8) and active (16) conductivities of electrical installations phase insulation relative to the ground phase we get the following equation:

$$\varepsilon_b = \frac{\Delta b}{\Delta} = \frac{\left(\begin{array}{l} (1-\tan^2\delta)^2\left[2+\dfrac{4U_C^4+(U_C^2+U_A^2)^2}{(U_C^2-U_A^2)^2}\right]+ \\ +\dfrac{9}{[27U_{ph}^2(U_{\mathrm{ph}}^2-U_A^2)-(U_C^2-U_A^2)^2]^2}\times \\ \times\left[\begin{array}{l} 18U_{ph}^2(U_{\mathrm{ph}}^2-U_A^2)^2-(U_C^2-U_A^2)^4+ \\ +\dfrac{3U_{ph}^4U_A^4(U_C^2-U_A^2-2U_{ph}^2)^2+U_C^4(U_{\mathrm{ph}}^2-U_A^2)^2}{(U_C^2-U_A^2)^2}\end{array}\right]\end{array}\right)^{1/2}}{\tan^2\delta}. \quad (20)$$

Obtained equation (21) express in relative units, and after the conversion obtain:

$$\varepsilon_b = \frac{\Delta b}{\Delta} = \frac{\left(\begin{array}{l} (1-\tan^2\delta)^2\left[2 + \dfrac{4U_{C*}^4 + (U_{C*}^2 + U_{A*}^2)^2}{(U_{C*}^2 - U_{A*}^2)^2}\right] + \\ + \dfrac{9}{[27(1-U_{A*}^2) - (U_{C*}^2 - U_{A*}^2)^2]^2} \times \\ \times \left[\begin{array}{l} 18(1-U_{A*}^2)^2 - (U_{C*}^2 - U_{A*}^2)^4 + \\ + \dfrac{3U_{A*}^4 (U_{C*}^2 - U_{A*}^2 - 2)^2 + U_{C*}^4 (1-U_{A*}^2)^2}{(U_{C*}^2 - U_{A*}^2)^2} \end{array} \right] \end{array} \right)^{1/2}}{\tan^2\delta} . \quad (21)$$

Based on the results of random relative mean square errors in determining the active, capacitive and total conductivities of mains phase isolation relative to the ground, build the dependence:

$$\varepsilon_y = \frac{\Delta y_*}{\Delta} = f(U_*)\,;$$

$$\varepsilon_g = \frac{\Delta g_*}{\Delta} = f(U_{A*}, U_{C*})\,;$$

$$\varepsilon_b = \frac{\Delta b_*}{\Delta} = f(U_{A*},\ U_{C*},\ \tan\delta)\,,$$

shown in figure 1, figure 2, figure 3. Mathematical dependence of the relative mean square errors of the total – ε_y, active – ε_g and capacitive – ε_b conductivities of phase insulation of electrical network with insulated neutral on graphic illustrations (figure 1, figure 2, figure 3) characterize the change in error depending on the amount of additional active conduction g_o, which is inserted between the A-phase of electrical network and earth.

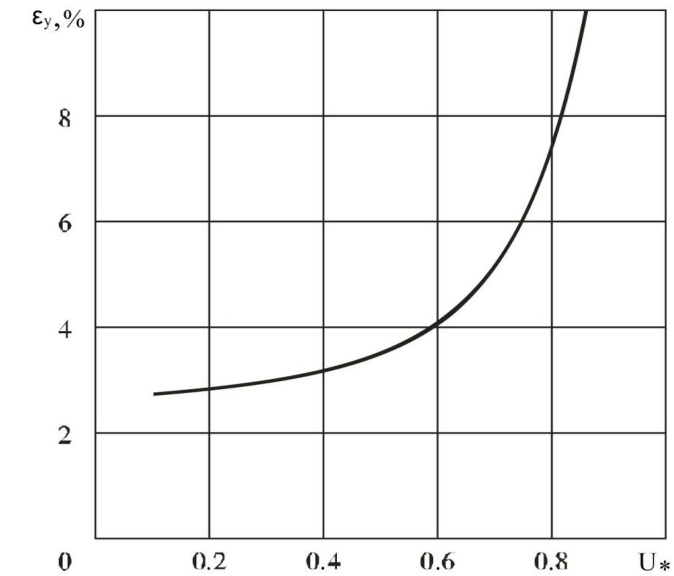
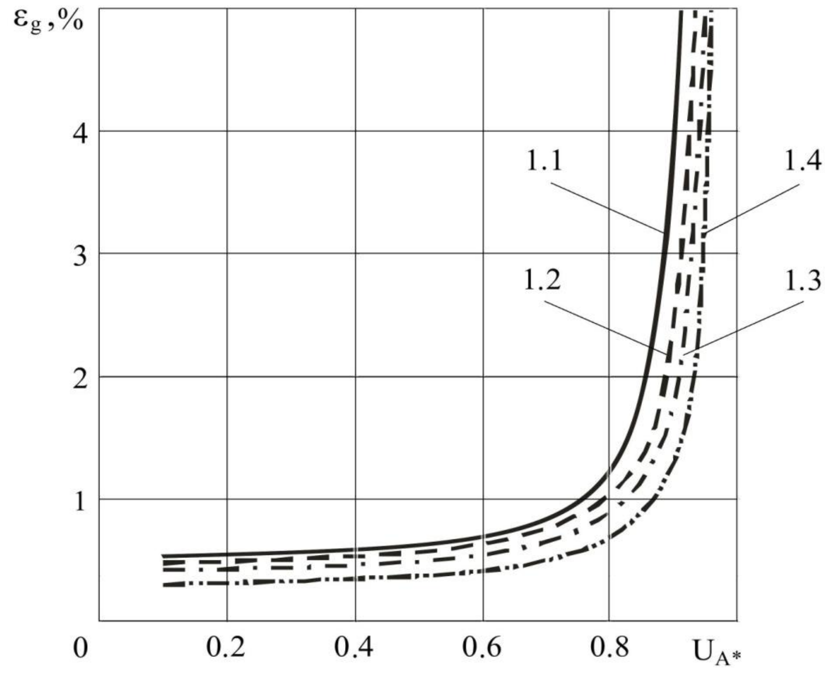
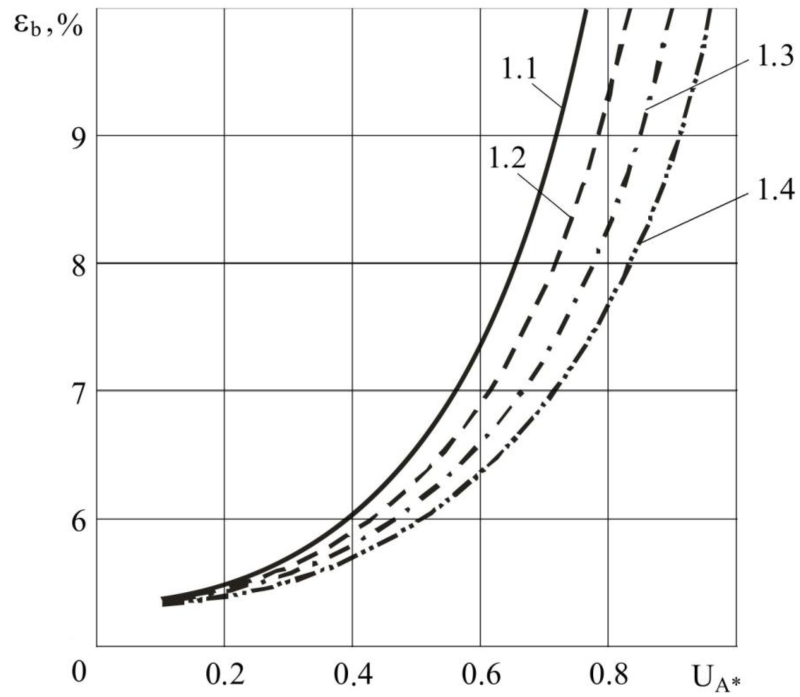


Figure 1. Analysis of the error in determining the total conductance of the network insulation.



U_{C*} = 1.1; 1.2; 1.3; 1.4

Figure 2. Analysis of the error in determining the active conductance of the network insulation.



U_{C*} = 1.1; 1.2; 1.3; 1.4

Figure 3. Analysis of the error in determining the capacitive conductance of the network insulation when $\tan\delta = 1.0$.

In determining the parameters of isolation in a symmetrical three-phase electrical network with isolated neutral on the basis of the method of analysis of error for each specific network select additional active conduction, so as to ensure satisfactory accuracy required.

In determining the total conductance of mains phases isolation relative to the ground is chosen such additional active conductivity, the values were within U_*= 0.2 ÷ 0.8, at the same time as shown in figure 1, the error does not exceed 5% when using measuring devices with accuracy class 1.0, and 2.5% when using measuring devices with accuracy class 0.5.

In determining the value of the active conductance in the three-phase electrical network with insulated neutral voltage up to 1000 V and above, select this additional g_o, so that U_{A*}= 0.2 ÷ 0.8, when U_{C*}= 1.1 ÷ 1.6, , then on the basis of graphic illustrations of figure 2 error does not exceed 3.5% when using measuring devices with accuracy class 1.0.

In determining the capacitive conductance mains phase isolation relative to the ground selection of additional active conductance g_o based on a graphic illustrations of figure 3 so that U_{A*}= 0.2 ÷ 0.8, when U_{C*}= 1.1 ÷ 1.6, when tan δ = 1.0, to provide error to 4 % when using measuring devices with accuracy class 1.0.

It should be noted that when using measuring instruments with an accuracy class of 0.5, errors of ε_y – total, ε_g – active, ε_b – capacitive admittances of isolation is reduced by half, to provide more reliable data when determining the insulation parameters developed method.

The developed method provides satisfactory accuracy when determining the parameters of isolation, as well as the ease and safety of production work in existing electrical installations voltages up to and above 1000 V.

4. Conclusion

In work was obtained the following results:

- A method for determining the parameters in three-phase networks with isolated neutral voltage up to 1000 V and above, is to measure the modulus of the line voltage, phase voltage with respect to ground and A, after you connect an additional active conductivity between the A-phase mains and earth was developed.
- Method for determining the parameters of isolation in three-phase electrical network with isolated neutral, through error analysis for each particular network is selected additional active conductance, so as to ensure satisfactory accuracy required when determining the:

The total conductance of mains phase insulation relative to the ground is chosen such additional active conductance, the values were within = 0.2 ÷ 0.8, with the error does not exceed 5% when using measuring devices with accuracy class 1.0, and 2.5% using measuring devices with accuracy class 0.5;

Active conductance in three-phase electrical network with isolated neutral voltages up to and above 1000 V select such active additional conductance g_o, so thatU_{A*}= 0.2 ÷ 0.8, when U_{C*}= 0.2 ÷ 0.8, then the error does not exceed 3.5 % when using the measuring devices with accuracy class 1.0;

Capacitive conductance of electrical network phase insulation relative to the ground select such additional active conductance g_o, so that U_*= 0.2 ÷ 0.8, with the change tan δ = 0.6 ÷ 1.6, then the error does not exceed 5 % when using the measuring devices with accuracy class 1.0, and 2.5 % when using the measuring devices with accuracy class 0.5.

- The developed methods provide satisfactory accuracy simplicity, and security in its implementation in the three-phase electrical networks with isolated neutral voltages up to and above 1000 V.

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