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ACCURACY ANALYSIS IN DETERMINING THE CONDUCTANCE OF PHASES INSULATION OF ELECTRICAL NETWORK WITH RESPECT TO GROUND WITHIN THE FRAMEWORK OF DEVELOPED METHOD FOR MONITORING THE INSULATION PARAMETERS IN NETWORKS OF 6 KV

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Abstract

In this work study of accuracy analysis in determining the conductance of phases insulation of electrical network with respect to ground within the framework of developed method for monitoring the insulation parameters in networks of 6 kV at auxiliaries of the power station were conducted. The developed method is based on connecting the additional conductance between phase of electrical network and ground; measuring the phase voltage module value with respect to ground before connecting the additional conductance; measuring the zero sequence voltage module values; measuring the phase voltage value with respect to ground during connecting the additional conductance between this phase and ground. The study has shown that determining the conductance of network isolation with respect to ground within the framework of developed method provides satisfactory accuracy, as well as ease and safety of works in operating electrical installations by voltage 6 kV of auxiliaries of the power station.

Key words: voltage, insulation, network, conductance, accuracy.

Introduction

Errors analysis is made with using main provisions of the calculus, the theory of errors, the theoretical foundations of electrical engineering [1, 2 – 4].

Let required value is determined by expression:

$$Y = f(X_1, X_2, X_3), \tag{1}$$

where X_1, X_2, X_3 – are values determining Y and subjected to direct measurement.

Herewith mean square error of indirect measurement will be determined according to expression in a general form [2]:

$$\Delta Y = \frac{1}{Y}\sqrt{\left(\frac{\partial Y}{\partial X_1}\Delta X_1\right)^2 + \left(\frac{\partial Y}{\partial X_2}\Delta X_2\right)^2 + \left(\frac{\partial Y}{\partial X_3}\Delta X_3\right)^2}, \tag{2}$$

where $\frac{\partial Y}{\partial X_1}$; $\frac{\partial Y}{\partial X_2}$; $\frac{\partial Y}{\partial X_3}$ – partial derivative of function $y = f(X_1, X_2, X_3)$;

ΔX_1, ΔX_2, ΔX_3 – absolute errors of direct measurements of values X_1, X_2, X_3.

Relative mean square error is determined by the formula:

$$\Delta Y_* = \frac{\Delta Y}{Y}. \quad (3)$$

By formulae (1), (2), (3) determine relative and absolute errors of the developed method, which are possible during determining the active conductance of electrical network's insulation with isolated neutral by voltage 6 kV.

Theoretical studies

One of the priorities of developed indirect methods for determining insulation parameters in the network of 6 kV is the accuracy of finding of the required values. For indirect determining the insulation parameters in the network with isolated neutral are set stringent requirements concerning ensuring the veracity of the required values.

Accuracy analysis of the conductance of network insulation within the framework of developed method for determining the parameters of insulation in the network by voltage 6 kV is produced. The developed method is based on measuring the phase voltage module value with respect to ground before and during connecting additional conductance. Where the value of the conductance of network insulation within the framework of developed method for determining insulation parameters in the network of 6 kV is determined by following mathematical formula:

$$g = \left(\frac{U_{ph}}{\sqrt{U_{phz}^2 + U_z^2}} - 1 \right) g_z. \quad (4)$$

It should be noted when determining the conductance of insulation in the network with isolated neutral, on results of measuring the phase voltage module value with respect to ground before and during connecting additional conductance between this phase and ground, in view of the additional conductance value, becomes necessary to establish methodical error of obtained mathematical relationship.

Based on the accuracy analysis are developed practical recommendations, which provide:

- the normal operation of electroreceivers during the production of measurements;
- satisfactory accuracy of developed method for determining the conductance

of insulation in the network by voltage 6 kV;

- achieving the safety at work in electrical installations, as well as providing simplicity and ease of measurements.

In accuracy analysis of the developed method is determined the ratio between a relative methodical error and error of measuring devices that measure the phase voltage module value with respect to ground and the resistance value that is used as additional value.

Accuracy analysis of the developed method for determining the conductance of insulation in the network by voltage 6 kV is produced with the use of main provisions of the theory of errors and the theoretical foundations of electrical engineering.

Relative mean square error for the conductance of insulation in the network with isolated neutral by voltage above 1000 V is determined from mathematical relationship (4):

$$g = \left(\frac{U_{ph}}{\sqrt{U_{phz}^2 + U_z^2}} - 1 \right) g_z .$$

where U_{ph}, U_{phz}, U_z, g_z – quantities that determine the conductance of insulation in the symmetric network, which obtained by direct measurement.

Relative mean square error of method for determining the conductance of insulation in the symmetrical network with isolated neutral by voltage above 1000 V is determined from expression:

$$\varepsilon_g = \frac{1}{g} \sqrt{ \begin{gathered} \left(\frac{\partial g}{\partial U_{ph}} \right)^2 (\Delta U_{ph})^2 + \left(\frac{\partial g}{\partial U_{phz}} \right)^2 (\Delta U_{phz})^2 + \\ + \left(\frac{\partial g}{\partial U_z} \right)^2 (\Delta U_z)^2 + \left(\frac{\partial g}{\partial g_z} \right)^2 (\Delta g_z)^2 \end{gathered} } , \qquad (5)$$

where $\frac{\partial g}{\partial U_{ph}}$; $\frac{\partial g}{\partial U_{phz}}$; $\frac{\partial g}{\partial U_z}$; $\frac{\partial g}{\partial g_z}$; – partial derivative of function $g = f(U_{ph};$ $U_{phz};$ $U_z;\ g_z)$.

Determine the partial derivatives of function $g = f(U_{ph};\ U_{phz};\ U_z;\ g_z)$ with respect to arguments U_{ph}, U_{phz}, U_z, g_z:

$$\frac{\partial g}{\partial U_{ph}} = \frac{g_z}{\sqrt{U_{phz}^2 + U_z^2}};$$
$$\frac{\partial g}{\partial U_{phz}} = - \frac{U_{ph} U_{phz} g_z}{\sqrt{(U_{phz}^2 + U_z^2)^3}};$$
$$\frac{\partial g}{\partial U_z} = - \frac{U_{ph} U_z g_z}{\sqrt{(U_{phz}^2 + U_z^2)^3}}; \qquad (6)$$
$$\frac{\partial g}{\partial g_z} = \frac{U_{ph} - \sqrt{U_{phz}^2 + U_z^2}}{\sqrt{U_{phz}^2 + U_z^2}}.$$

There ΔU_{ph}; ΔU_{phz}; ΔU_z; Δg_z – absolute errors of direct measurements of values
U_{ph}, U_{phz}, U_z, g_z, which are determined by the following expressions:

$$\Delta U_{ph} = U_{ph} \Delta U_{ph} \;;$$
$$\Delta U_{phz} = U_{phz} \Delta U_{phz} \;;$$
$$\Delta U_z = U_z \Delta U_z \;; \qquad (7)$$
$$\Delta g_z = g_z \Delta g_z \;.$$

To determine the errors of measuring devices accept that $\Delta U_{ph} = \Delta U_{phz} = \Delta U_z$
$= \Delta g_z = D$,
wher e ΔU_{ph}; ΔU_{phz}; ΔU_z – a relative error of measuring circuits of voltage;
Δg_z – the relative error of measuring device that measure the value of additional conductance connected between one phase of electrical installation and ground.

Solving the equation (5) by substituting in it values of the partial derivatives (6) and the values of the partial absolute errors (7), while believing that $\Delta U_* = \Delta R_*^{-1} = \Delta$, we obtain the mathematical relationship of determining a random relative mean square error for the conductance of insulation in the network by voltage up to 1000 V:

$$\varepsilon_g = \frac{\Delta U_{ph}}{U_{ph} \sqrt{U_{phz}^2 + U_z^2}} \sqrt{2 + \frac{U_{phz}^4 + U_z^4}{\left(U_{phz}^2 + U_z^2\right)^2} \quad \frac{2\sqrt{U_{phz}^2 + U_z^2}}{U_{ph}} + \frac{U_{phz}^2 + U_z^2}{U_{ph}^2}}. \qquad (8)$$

Obtained equation (8) express in relative units and perform research in Mathcad:

$$\varepsilon_g = \frac{\Delta U_{ph}}{1 \quad \sqrt{U_{phz}^2 + U_z^2}} \sqrt{2 + \frac{U_{phz}^4 + U_z^4}{\left(U_{phz}^2 + U_z^2\right)^2} \quad 2\sqrt{U_{phz}^2 + U_z^2} + U_{phz}^2 + U_z^2}\ , \qquad (9)$$

where $U_{phz} = \dfrac{U_{phz}}{U_{ph}}$, $U_z = \dfrac{U_z}{U_{ph}}$.

Based on obtained results of random relative mean square errors when defining the conductance of insulation in the symmetric network with isolated neutral by voltage above 1000 V, under the operation voltage, we plot the following dependence:

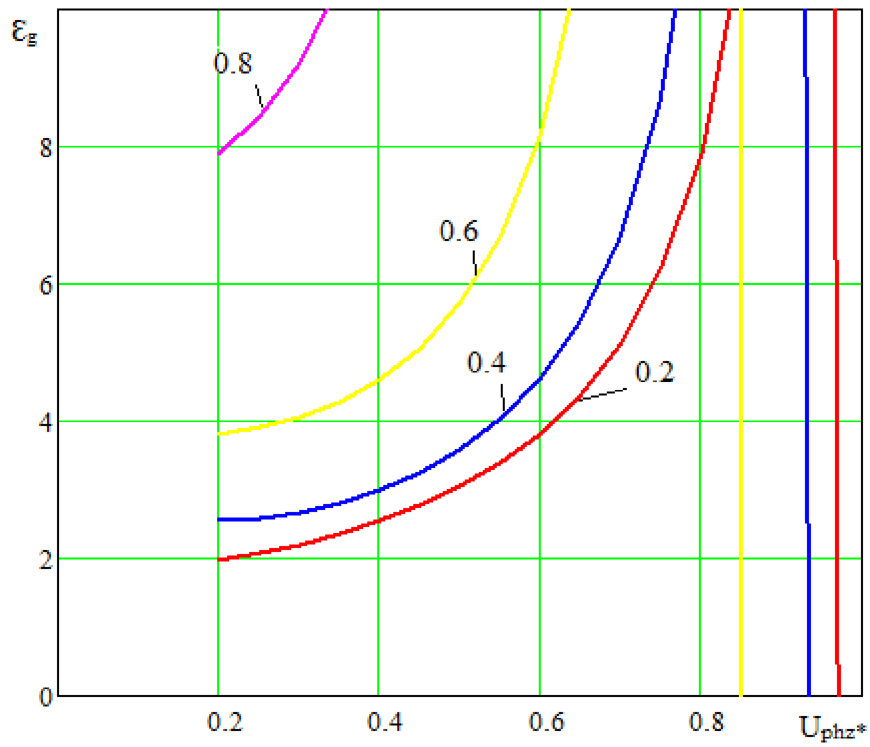
$$\varepsilon_g = \frac{\Delta g}{\Delta} = f\,(U_{phz}\ ;\ U_z\ )\,,$$

shown in picture 1.

Obtained mathematical relationship of the relative mean square errors for conductance – e_g of phases insulation of electrical network with respect to ground, which presented in graphic performance and reflected on picture 1, shows that additional conductance value g_o, which is introduced between phase of electrical network and ground, affects on error change in dependence of veracity of required values.

Analysis of errors indicates that in order to ensure the required accuracy for each specific network is selected the additional conductance value.

During determining the conductance of phases insulation of electrical network with respect to ground is selected a such additional conductance g_z, so that U_{phz*} = 0,2 – 0,7 for values U_z =
= 0,2; 0,4; 0,6 , then error does not exceed 10 % when measuring devices accuracy class is 1.0 , and up to 5 % when measuring devices accuracy class is 0.5 , and when measuring devices accuracy class is 0.2 – error is no more than 2 %.



U_z =0,2; 0,4; 0,6; 0,8

Picture 1 – The relative mean square errors of determining the conductance of insulation in the network with isolated neutral by voltage above 1000 V.

Conclusions

Research of accuracy analysis in determining the conductance of network insulation with respect to ground within the framework of developed method for monitoring the insulation parameters in a symmetric networks by voltage 6 kV of auxiliaries of the power station were conducted. The developed method is based on connecting the additional conductance between phase of electrical network and ground; measuring the phase voltage module value with respect to ground before connecting the additional conductance; measuring the zero sequence voltage module values; measuring the phase voltage value with respect to ground during connecting the additional conductance between this phase and ground.

Research have shown, that determining the conductance of network insulation with respect to ground within the framework of developed method provides satisfactory accuracy, as well as ease and safety of works in operating electrical installations by voltage 6 kV of auxiliaries of the power station.

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Түйін

Жұмыста кемшілікті талдау белсенді өткізгіштігі оқшаулады айқындау желі жерге қатысты, дайындалған тәсілмен электр станцияларының 6 кВ меншікті қажеттілік кернеуі. Осы әдіс электр желілері мен өлшеген шаманың арасындағы жер мен кернеу қосылған белсенді модуль белсенді фазасының сатысы жерге қатысты қосымша қосылым дейін қосымша өткізгіштігі мен өлшемдер мен жердің арасындағы кернеудің фазасын кернеу қосылған кезде осы жерге қатысты қосымша өткізгіштігі белсенді және реттілігінің модульдерді өткізгіштік шама нөлдік сатысы негізделген. Зерттеулер көрсетті: талдау белсенді өткізгіштігі оқшаулады айқындау желі жерге қатысты дайындалған тәсілімен қанағаттанарлық дәлдік, сондай-ақ қарапайымдылығын және өндірістік қауіпсіздік жұмысын қолданыстағы электр қондырғыстарында жылу электр станцияларының 6 кВ меншікті қажеттілік кернеуінде қамтамасыз етеді.

Резюме

В работе проведены исследования анализа погрешности определения активной проводимости изоляции сети относительно земли, по разработанному способу определения параметров изоляции в симметричной сети напряжением 6 кВ собственных нужд электростанций, основанный на подключении активной дополнительной проводимости между фазой электрической сети и землей и измерении величины модуля напряжения фазы относительно земли, до подключения активной дополнительной проводимости и измерении величин модулей напряжения нулевой последовательности и напряжения фазы относительно земли при подключенной активной дополнительной проводимости между этой фазой и землей. Исследования показали, что определения активной проводимости изоляции сети относительно земли, по разработанному способу обеспечивает удовлетворительную точность, а также простоту и безопасность производства работ в действующих электроустановках напряжением 6 кВ собственных нужд тепловых электростанций.

Summary

In this work study of accuracy analysis in determining the conductance of phases insulation of electrical network with respect to ground within the framework of developed method for monitoring the insulation parameters in networks of 6 kV at auxiliaries of the power station were conducted. The developed method is based on connecting the additional conductance between phase of electrical network and ground; measuring the phase voltage module value with respect to ground before connecting the additional conductance; measuring the zero sequence voltage module values; measuring the phase voltage value with respect to ground during connecting the additional conductance between this phase and ground. The study has shown that determining the conductance of network isolation with respect to ground within the framework of developed method provides satisfactory accuracy, as well as ease and safety of works in operating electrical installations by voltage 6 kV of auxiliaries of the power station