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METHOD FOR DETERMINING A FULL CONDUCTIVITY OF INSULATION AND A SINGLE-PHASE EARTH-FAULT CURRENT IN VOLTAGE NETWORKS 6-10 KV BY THE METHOD OF LOGARITHMIC TRANSFORMATIONS

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To ensure the growth of the level of electrical safety and increase the reliability of the electrical safety system of power, industrial and mining enterprises, indirect methods for determining the insulation parameters and the current of a single-phase earth fault are developed.

Analysis of research methods for determining the insulation parameters and current single-phase earth fault has shown their considerable variety both in the execution of the circuit, and on the complexity of the use in electrical installations. This is due to the difference in mathematical formulas, by which the isolation and current parameters of a single-phase earth fault are determined.

At present, a method has been widely used to determine the single-phase ground fault current and the total conductivity of insulation in a network with an isolated neutral voltage higher than 1000 V [1 - 3].

The method is based on the measurement of the values of the line voltage modules – U_l, the phase voltage relative to the ground - $\mathbf{U_{ph0}}$, zero-phase-sequence voltage - $\mathbf{U_0}$, after connecting one of the phases of the electrical network and the ground of additional capacitive conductivity - b_0.

According to the measured values of the line voltage modules, phase voltage relative to the ground and zero-phase-sequence voltage after connecting between one of the phases of the electrical network and the ground of additional capacitive conductivity determine:

- full conductivity of network isolation

$$Y = \frac{U_{pho}}{U_o} b_o, \qquad \text{(I)}$$

- single-phase earth fault current

$$I_o = \frac{U_l \times U_{pho}}{U_o} b_o. (2)$$

The developed method for determining the full conductivity of a network and the current of a single-phase earth fault is explained by an electrical schematic diagram (Figure I) containing: a three-phase electrical network with phases A, B, and C; TV voltage transformer - (10); voltmeter, measuring the value of the line voltage – PV1; voltmeter, measuring the value of the phase voltage relative to the ground – PV2; voltmeter, measuring the value of the zero-phase-sequence voltage – PV3; load switch,additional capacitive conductivity between phase A of the electrical network and ground – QF; full conductivity of network isolation –Y; additional capacitive conductivity - b_0.

The method has significant drawbacks since the indirect definition itself implies visual removal of phase voltage values relative to the ground, line voltage, zero phase sequence voltage values, etc., as well as manual calculations, which leads to loss of efficiency in obtaining the necessary conclusions, to decrease in the reliability of the electrical safety detection system, to the costs of human resources, and hence to material costs.

On the basis of the foregoing, it is necessary to develop a microprocessor-based device for monitoring the insulation and current parameters of single-phase earth faults in networks above 1000 V.

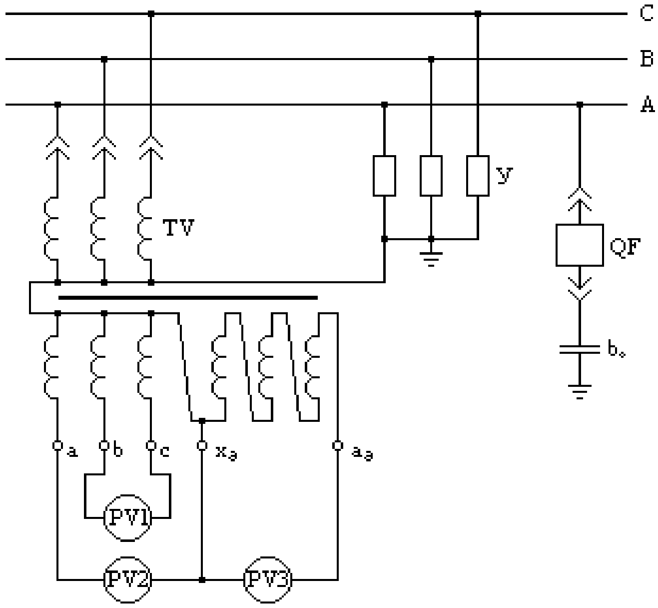

Figure 1 – Electrical scheme for the determination method of full network conductivity and single-phase earth fault current

The problem is that the values of the signals U_{fo} and U_o of the incoming formulas for determining the total conductivity (1) and the single-phase ground fault current (2) vary over a wide range: from 0 to 100 V. This creates certain difficulties in circuit projecting, since the dynamic range of the circuit depends on the range of each circuit element. Performing the arithmetic operations of multiplication and division with parameters varying in the range from 0 to 100 V, is also an obstacle in the schematic implementation.Many of these problems can be avoided and minimized by using logarithmic converters, which tend to compress the dynamic range of the signal, process it in a compressed form, and then, if necessary, stretch it by inverse transformations.By using logarithmic schemes, arithmetic operations are performed using the following identities:

$$X \times Y = e^{(\ln x + \ln y)}; (3)$$

$$\frac{X}{Y} = e^{(\ln x - \ln y)}. \quad (4)$$

Equations (I) and (2) are transformed in accordance with the mathematical relationships (3) and (4):

$$\ln Y = \ln U_{\text{фо}} - \ln U_o + \ln b_o ; (5)$$

$$\ln I_o = (\ln U_{\text{л}} + \ln U_{\text{фо}} - \ln U_o) + \ln b_o . (6)$$

The obtained equations (5) and (6) make it possible to simplify considerably the circuit solutions in the development of a microprocessor device for determining the total conductivity of the insulation and the current of single-phase earth faults in 6-10 kV networks.The simplification of the device is that the circuit uses devices performing mathematical operations of addition and subtraction.

The logarithmic converter (Figure 2) consists of:

- Three logarithmic amplifier - U_1, U_2, U_3;
- Adder –S_1;
- Subtractor- S_2;
- Antilogarithmic amplifier - $U_{4.}$

All three values of the voltage U_l, U_{pho}, $U_o$are fed to the logarithmic amplifiers U_1, U_2, U_3, respectively. From the output of the signal amplifiers, the values of $\ln U_l$, $\ln U_{ph0}$ go to the adder S_1.From the output of the adder S_1 and from the output of the amplifier U_3, the signals with the values $\ln U_l + \ln U_{pho}$ and $\ln U_o$ respectively enter the subtractor S_2. From the output of the subtracter S_2, the signal with the value $\ln U_l + \ln U_{ph0} – \ln U_o$ goes to the antilogarithmic amplifier U_4. And finally, from the output of the anti-logarithmic amplifier U_4, we get the value I_o.

This scheme is valid both for formula (5) and for formula (6). Only in the second case, the signal to the amplifier U_1 is not fed and the signal Y - of the total conductivity of the network is removed.Therefore, in what follows we shall consider all the transformations for formula (6). The value of b_o is proportional to the gain of the antilogarithmic amplifier U_4

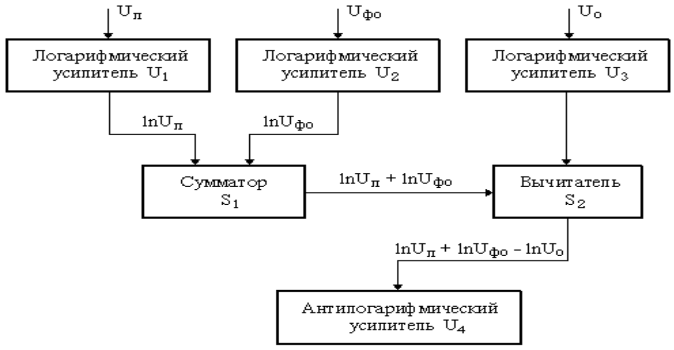

Figure 2 – Structural scheme

The device for determining the values of the single-phase ground fault current and the total conductivity of the insulation in a network with an isolated neutral voltage higher than 1000 V consists of integrated circuits that are operational amplifiers in various switching modes.From here follows the minimal volume and weight of the structure, the minimum costs of installation and installation of the device, the high reliability and immunity of the device, as well as the relative inexpensiveness of the device.The structure of the device assumes universality of application for both formula (5) and for formula (6).

Conclusions

On the basis of the foregoing, the following conclusions are formulated:

- a mathematical model is developed by logarithmic mathematical dependencestransformation of the total conductivity determination of insulation and the current of a single-phase earth fault in 6 to 10 kV networks;

- to improve the accuracy of determining the insulation and single-phase ground fault current, and to automate the monitoring of insulation conditions, to protect electrical installations from single-phase earth faults, it is necessary to create an architecture for a microprocessor-based insulation and current monitoring device for single-phase earth faults in networks above 1000 V .

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