International Scientific Colloquium
Modelling for Material Processing
Riga, June 8-9, 2006

1000 volts Asymmetrical Network with Insulated Neutral Isolation Parameters Automatic Estimation Method

B. Utegulov, A. Utegulov, Z. Tursynbayeva, N. Meged, B. Begentayev

Abstract

The present work contains the development of the method of automatic estimation of the isolation parameters of a 1000 volts asymmetrical network with an insulated neutral. The method consists in reading from relative-to-earth phase voltage measuring unit, line voltage measuring unit, phase-sensitive device unit in which the data is mapped into digital code and is saved in memory. Then automatic connection with time delay equal to the preset period of isolation parameters estimation is performed. The isolation parameter values are estimated on the basis of the measurements taken before and after connecting complementary conductance; the isolation parameter values are estimated, saved in data memory, and then the complementary conductance is disconnected from the circuit.

The operating regime of an electric network isolated from earth is commonly used in electrical units which demand power-supply advanced reliability and are especially dangerous according to the electrical injury conditions.

In electrical networks and electrical units isolated from earth the conditions of electrical safety and power-supply reliability are substantially determined by the state of isolation, its resistance and relative-to-earth capacity.

The functions of an isolation control device lie in measuring the network's isolation resistance under operating voltage and by current collectors on, in estimating the measurement results by comparing with the predetermined level, which is specified, as a rule, according to the electrical safety conditions, and, in case of need, in turning on the warning or affecting the breaking unit.

Thus the isolation control device realizes "the protection of a man with electrical unit circuits' isolation" by carrying out the persistent measurement of the isolation resistance with the purpose of maintaining its level securing the electrical safety conditions.

As evidenced by the foregoing, the isolation control device is a necessary but not a sufficient condition of electrical safety conditions securing.

The state of electrical unit isolation is one of the decisive factors determining the safety of electro-technical equipment exploitation at delfts. The ground leakage currents of the electrical units with voltage up to 1000 volts conditioning various kinds of danger are finally determined by the electrical network isolation resistance values and their separate elements.

By now, a sufficient number of electrical unit isolation parameters estimation methods that underlie the configuration of control devices have been developed. These devices are commonly spread in various spheres of power engineering and, particularly, in the sphere of delft electrical equipment. The basic method used for examining the condition of the electrical network isolation at delfts is the ammeter-voltmeter method, the method based on the two-terminal network principle, and the phase-sensitive method.

At present isolation control devices different in the operation principle, the structural solution, the field of application and the operation safety are produced in Russia and abroad.

The leading position in the field of the isolation control devices developing and producing is occupied by the German firm “Walter Bender GmbH” which has affiliated branches and fellow subsidiaries in many countries of the world including the USA, Brazil, France, etc.

The manufacture programme of this firm includes the isolation control devices for alternating current networks with voltage up to 690 volts, direct current networks with voltage up to 500 volts, compound networks (alternating and direct current), open networks (activated periodically), the damaged connection search devices for multibranch alternating current networks with voltage up to 10 kilovolts and direct current networks.

The Russian enterprise ГП ОПЗ МЭИ has mastered producing the automatic isolation control device “АСТРО-ИЗО-470” under “W. Bender GmbH”’s license.

АСТРО-ИЗО-470 is designed for the continuous control (monitoring) of the earth isolation resistance of monophase and three-phase electrical units with IT ground system (insulated neutral regime); the device has high engineering data.

АСТРО-ИЗО-470 performs the following functions:

- the application to an operative current controllable network;
- continuous measurement of the current value of the operative current;
- processing the measurement results with an electronic device based on a microprocessor and comparing the results with the given setting;
- indicating the ground isolation resistance value of the controllable unit;
- activating the alarm signal in case of the isolation resistance decrease lower than the predetermined level (the setting).

The “АСТРО-ИЗО-470” automatic isolation control device is designed only for isolation parameters estimation in 1000 volts symmetrical networks with an isolated neutral at delfts.

The existing methods of isolation parameters estimation are subdivided according to the application to symmetrical and asymmetrical networks.

The isolation parameters of the symmetrical networks are conditioned by such conditions that the conductance and the capacitive susceptance of the relative-to-earth phases are equal, i.e. [1].

$$g_A = g_B = g_C = g, \tag{1}$$

$$b_A = b_B = b_C = b. \tag{2}$$

The isolation parameters in asymmetrical networks are conditioned by the fact that one of the relative-to-earth phases of the electrical units has a leak due to complementary conductance g_o, i.e.

$$g_A + g_O \neq g_B = g_C \neq g, \tag{3}$$

The methods of isolation parameters estimation in asymmetrical networks have the complex mathematical dependence of basic values.

Therefore it is necessary to develop the asymmetrical networks isolation parameters estimation method that will make the measurement scheme performance more convenient and mathematical dependence of desired quantities determination easier.

The phase-sensitive method of isolation parameters estimation in operative units has been developed to increase the fail-safety of delft internal power supply systems and to provide the increase of electrical safety by exploiting 1000 volts three-phase electrical networks with an isolated neutral [2,3].

The developed phase-sensitive method of isolation parameters estimation in the 1000 volts three-phase asymmetrical network with an insulated neutral is based on measuring line voltage value modules, the phase voltage relative-to-earth, the phase-shift angle between the vectors of the voltage relative-to-earth and the line voltage before and after connecting complementary conductance between one of the electrical unit's phases and earth.

According to the measured line voltage module values, the phase voltage relative-to-earth, the phase-shift angle between the vectors of the voltage relative-to-earth and the line voltage before and after connecting complementary conductance between one of the electrical unit's phases and the ground, and granting the complementary conductance value we determine the conductance decreasing the rate of isolation between one of the network's phases and the ground, the capacitive susceptance and the conductance of the network's isolation relative-to-earth by mathematical dependences (4), (5), (6):

- the conductivity decreasing the isolation rate between one of the network's phases and the ground

$$g_o = \frac{U_{ф1} Cos\alpha g_1 \left(U_л^2 + 3U_ф^2 - 3{,}46 U_л U_ф Sin\alpha\right)}{U_ф Cos\alpha \left(U_л^2 + 3U_{ф1}^2 - 3{,}46 U_л U_{ф1} Sin\alpha_1\right) - U_{ф1} Cos\alpha_1 \left(U_л^2 + 3U_ф^2 - 3{,}46 U_л U_ф Sin\alpha\right)}, \quad (4)$$

- the capacitive conductance of the network's isolation

$$b = \frac{1{,}73 U_л U_{ф1} Cos\alpha_1 g_1 (U_л - U_ф Sin\alpha)}{U_ф Cos\alpha (U_л^2 + 3U_{ф1}^2 - 3{,}46 U_л U_{ф1} Sin\alpha_1) - U_{ф1} Cos\alpha_1 (U_л^2 + 3U_ф^2 - 3{,}46 U_л U_ф Sin\alpha}, \quad (5)$$

- the conductance of the network's isolation

$$g = \frac{1{,}73 U_л U_ф U_{ф1} g_1 Cos\alpha Cos\alpha_1}{U_ф Cos\alpha (U_л^2 + 3U_{ф1}^2 - 3{,}46 U_л U_{ф1} Sin\alpha_1) - U_{ф1} Cos\alpha_1 \left(U_л^2 + 3U_ф^2 - 3{,}46 U_л U_ф Sin\alpha\right)}, \quad (6)$$

- the complex conductance of the network's isolation

$$y = \sqrt{g^2 + b^2}. \quad (7)$$

The phase-sensitive method of isolation parameters estimation in the 1000 volts three-phase asymmetrical network with an insulated neutral is realized in the electrical schematic circuit (see figure 1).

The electrical schematic circuit realizing the phase-sensitive method of isolation parameters estimation in the1000 volts three-phase asymmetrical network with insulated neutral includes the 1000 volts three-phase asymmetrical network with an insulated neutral, phases A, B and C; PV1 voltmeter measuring the A phase voltage module value relative-to-earth by connecting complementary conductance between the A phase and the ground; PV2 voltmeter measuring the line voltage module value; the PV3 measuring device measuring the α phase-shift angle between the vectors of the phase voltage relative-to-earth and the line voltage; the QF interconnecting device connecting the known complementary conductance between the A phase of the network and earth; the complementary conductance g_1; the conductance decreasing the isolation rate between the A phase of the network and earth g_o; the capacitive susceptances b_A, b_B, b_C; the conductances of the network's isolation g_A, g_B, g_C.

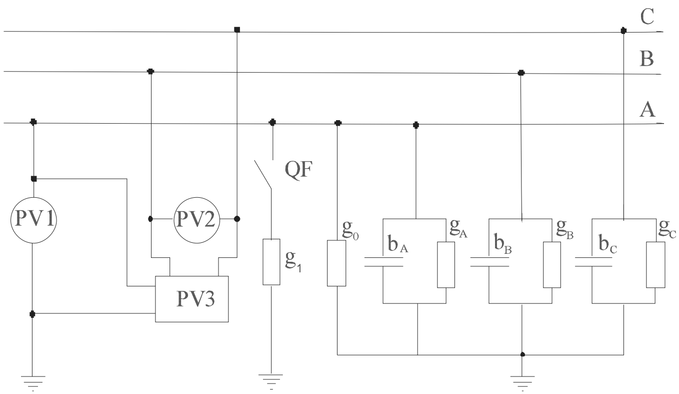

Fig. 1. The electrical schematic circuit of the phase-sensitive method of isolation parameters estimation in the 1000 volts three-phase asymmetrical network with an insulated neutral

To determine the conductivity decreasing the isolation rate between one of the network's phases and earth and also the conductance, the capacitive susceptance and the complex admittance of the isolation in the 1000 volts three-phase asymmetrical network with an insulated neutral, which is under operating tension and supplies power to collectors, the QF interconnecting device connects the known complementary conductance g_1 between the network's A phase and earth. During this connection the A phase voltage module value is measured by the PV1 voltmeter, the module value of the line voltage between phases B and C is measured by the PV2 voltmeter, the phase-shift angle between the vectors of the relative-to-earth phase voltage and the line voltage is measured by the PV3 measuring device. After registering the module value U_{ph0} (the A phase voltage relative-to-earth), the module value U_L (the line voltage between the network's phases B and C) and α value (the phase-shift angle between the vectors of the phase voltage relative-to-earth and the line voltage) the QF interconnecting device disconnects the complementary conductance g_1.

The phase-sensitive method provides the exact and easy estimation of the isolation parameters in the 1000 volts three-phase asymmetrical network with an insulated neutral by excluding the voltage source of zero string. Due to the reliable isolation parameters estimation organizational and technical measures are taken to increase the electrical safety rate in exploiting the internal power-supply system at delfts.

The phase-sensitive method suffers from a considerable disadvantage when used as an isolation state control device. The disadvantage lies in the indirect determination of the sought quantities using individual mathematical apparatus for isolation parameters calculation.

Thus it is necessary to develop the device for the isolation state automatic control by determining the conductance, the capacitive susceptance and the complex admittance of the isolation and earth short circuit current in 1000 volts operative electrical units for delfts.

The method of the isolation parameters automatic estimation in the asymmetrical electrical network with insulated neutral with voltage up to 1000 volts has been developed. It consists in reading from the relative-to-earth phase voltage measurement unit, the line voltage measurement unit, the phase-sensitive device unit measuring the α value phase-shift angle; the data is mapped into digital code and is saved in memory. Then automatic connection is performed with time delay equal to the preset period of the estimation of isolation parameters, complementary conductance between one of the network's phases and earth and of the reading from the relative-to-earth phase voltage measuring unit, the line voltage measuring unit, the unit of the phase-sensitive device measuring the phase-shift angle between the vectors of the phase voltage relative-to-earth and the line voltage, the line voltage value and the phase voltage relative-to-earth value. The values are mapped into digital codes; the isolation parameter values are estimated on the basis of the measurements made before and after the connection of the complementary conductance. The parameters are saved in data memory, and then the complementary conductance is disconnected from the network.

The principle of operation of the developed method is explained by the functional scheme of the isolation parameters estimation device for 1000 volts asymmetrical networks at delfts (figure 2). The functional scheme includes a three-phase electrical network with phases A, B and C; an automatic circuit-breaker QF; MU1 – a relative-to-earth phase voltage measuring unit, U_{ph0}; MU2 – a line voltage measuring device, U_L; PDU - the unit of a phase-sensitive device measuring the phase-shift angle α between the vectors of phase voltage relative-to-earth and the line voltage vector; network isolation capacitive susceptances b_A, b_B, b_C; network isolation conductances g_A, g_B, g_C; the conductivity decreasing the isolation rate between the A phase of the electrical network and earth g_o, complementary conductance – g_1; a display unit D; an amplifier unit AU; an effector E; the central processor CP; an input port IP; output ports OP1 and OP2; read-only memory ROM; random access memory RAM; an analog-to-digital converter ADC; a real-time timer RTT; a commutator device CD; a data internal bus IB.

The developed method of isolation parameters estimation in the 1000 volts asymmetrical electrical network with the insulated neutral is realized in the following way. The following items are connected to the network:

- MU1 – the relative-to-earth phase voltage U_{ph0} measuring unit;
- MU2 – the line voltage U_L measuring unit;
- PDU - the unit of a phase-sensitive device measuring the phase-shift angle α between the vectors of phase voltage relative-to-earth and the line voltage vector;
- complementary conductance g_1 through the automatic circuit-breaker QF and the commutator device CD.

The consecution of the developed method realization is as follows: the signals of the relative-to-earth phase voltage value, the line voltage value and the signal for measuring the phase-shift angle α between the vectors of phase voltage relative-to-earth and the line voltage vector before and after complementary conductance connection are taken from the MU1 (the relative-to-earth phase voltage U_{ph0} measuring unit), the MU2 (the line voltage U_L measuring unit), the PDU. Then the signals proceed to the input port IP, then to the analogue-to-digital converter ADC. The analogue-to-digital converter ADC, the output ports OP1 and OP2, the read-only memory ROM, the random access memory RAM and the real-time timer RTT are connected to the central processor CP through the internal bus IB. The output port OP1 is connected to the display unit. The output port OP2 is connected to the effector through the amplifier unit.

The central processor CP fulfils the data processing programme logged in the read-only memory ROM which performs the function of programme memory; the central processor CP sends the complementary conductance g_1 connection signal to the output port OP2, the signal amplified by the amplifier unit AU proceeds to the effector E of the commutator device CD. The complementary conductance g_1 is connected to the A phase of the network.

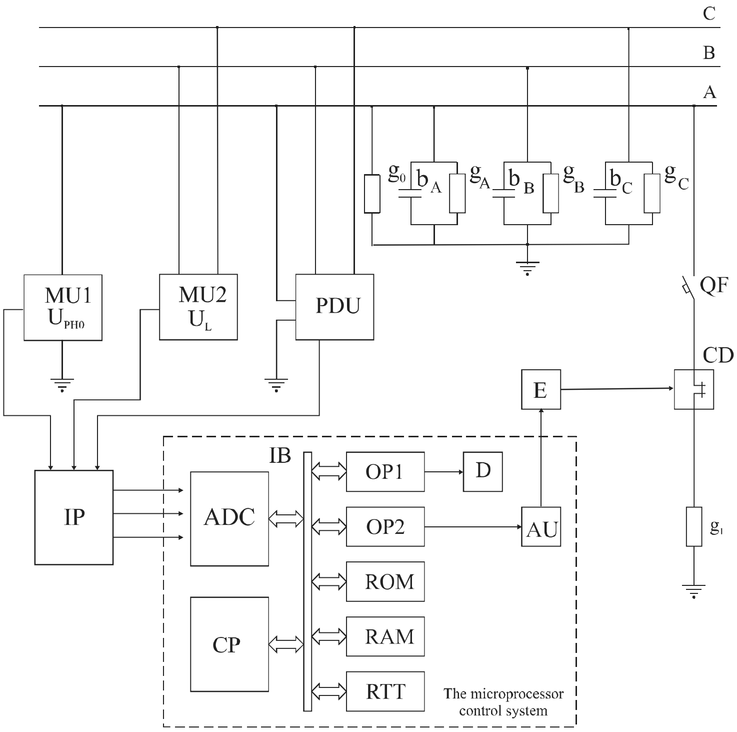

Fig. 2. The functional scheme of the isolation parameters estimation device for 1000 volts asymmetrical networks at delfts

The central processor CP starts the real-time timer RTT which specifies the time sufficient for connecting complementary conductance g_1. After the time delay the real-time timer RTT sends a signal to the central processor CP, after that the central processor CP sends the analogue-to-digital converter ADC the command to convert the modules of the voltages from the relative-to-earth phase voltage measuring unit, the line voltage measuring unit and the phase-sensitive device unit into digital codes. The analogue-to-digital converter ADC sends the conversion completion signal to the central processor CP, after that the central processor CP reads the digital codes of the voltage modules from the analogy-to-digital converter ADC and calculates the isolation parameter values according to the expressions (4 - 7).

The calculated isolation parameter values are logged by the central processor CP to the random access memory RAM, which fulfils the function of data memory, and sent to the output port OP1. From the output port OP1 the parameter values proceed to the display unit D. The central processor CP sends the commutator device CD breaking signal to the output port OP2, the signal is amplified by the amplifier unit AU and proceeds to the effector E of the commutator device. The complementary conductance is disconnected from the A phase of the three-phase network by the effector E of the commutator device CD through the automatic circuit-breaker QF. The central processor CP starts the real-time timer RTT which performs the time delay equal to the specified period of isolation parameters determination. After the time delay the real-time timer RTT sends a signal to the central processor which begins performing the data processing programme again.

As appears from the above, the organizational and technical measures in increasing the electrical units' operation safety and ensuring the increase of the electrical safety rate by exploiting the 1000 volts electrical units at delfts can be elaborated with the help of the automatic estimation of the isolation parameters in 1000 volts asymmetrical network with isolated neutral.

References

[1] Bessonov L. A. Theory of electrotechnology // - Moscow: Higher school, 1964, - 216 p.
[2] Utegulov B.B., Utegulov A.B., Kushchugulov B.A. The method of isolation parameters determination in a 1000 volts network with an isolated neutral // Patent №7940, Bulletin of inventions: "ONERKASIP MENSHIGI", №80271.1, Almaty, 1998, 4 p.
[3] Utegulov B.B., Utegulov A.B., Volgin M. E., Zhumadirova A. K., Tursynbayeva Z. D. The method of isolation parameters automatic determination in a 1000 volts symmetrical network with an isolated neutral. PSU Bulletin. The scientific magazine of Pavlodar State University after S. Toraygyrov. Pavlodar, 2005, № 2, 33 – 38 p.

Authors

Doctor of Technical Sciences, Professor Utegulov, Bolatbek
Candidate of Technical Sciences Utegulov, Arman
Tursynbaeva, Zaure
Meged, Natalya,
Begentayev, Bagustar
Power Industry Department, Energy Faculty
Pavlodar State University named after S. Toraygyrov
Lomov str. 64, Pavlodar, 140008, The Republic of Kazakhstan
e-mail: bolatu@mail.ru