LABORATORY TESTS OF AN INSULATION MONITORING DEVICE

Radi Tenev

Kardzhali Branch of the University of Mining and Geology “St. Ivan Rilski” - Sofia, 6600 Kardzhali; raditenev@abv.bg

ABSTRACT. The IT system is safe only in the presence of an insulation monitoring device which monitors the level of insulation resistance and turns off the voltage, if it is lowered below a pre-set value. The Insulation Monitoring Device ensures the safety of a person in contact with a live conductive part only, if it is triggered at the moment and switches off the voltage. That is why, time response is an important parameter of the device.
This article examines the response time of an apparatus in laboratory conditions. The operation of the device in a three-phase network is presented. Statistically, the most common electrical injury from is the when is a person is in contact with a live conductive part. The resulting single-phase leakage is described for the three possible cases: with a small network length or negligible capacity, with a large network length or high capacity and operating the device together with a compensator, that reduces the capacitive leakage current.
The experiments were carried out with an insulation monitoring device, which was made on universal board with electronic components

Keywords: IT system, Insulation Monitoring Device, Insulation resistance.

ЛАБОРАТОРНИ ИЗСЛЕДВАНИЯ НА АПАРАТ ЗА КОНТРОЛ НА ИЗОЛАЦИЯТА

Ради Тенев
Филиал Кърджали на Минно-геоложки университет ”Св. Иван Рилски” – София, 6600 Кърджали

РЕЗЮМЕ. Мрежата с изолиран звезден център е безопасна само при наличието на апарат за контрол на изолацията, който следи нивото на изолационното съпротивление и изключва напрежението, ако то се понижи под предварително зададена стойност. Апаратът за контрол на изолацията осигурява безопасност на човек допрял се до тоководеща част единствено, ако се задейства на момента и изключи напрежението. Ето защо времето за което сработи апарата е основен параметър.
Статията разглежда определянето на бързодействието на апарата в лабораторни условия. Показана е работата на устройството в трифазна мрежа. Статистически най-често срещаното поражение от електрически ток е допир на човек до тоководеща част. Получената еднофазна утечка е експериментирана при трите възможни случая: при малка дължина на мрежата или незначителен капацитет, при голяма дължина на мрежата или наличие на голям капацитет и работа на устройството съвместно с компенсатор, който намаля капацитивния ток на утечка.
Експериментите са проведени с апарат за контрол на изолацията, който е събран на универсални платки и е изпълнен изцяло с електронни компоненти.

Ключови думи: мрежа с изолиран звезден център, апарат за контрол на изолацията, изолационно съпротивление

Introduction

The task of an insulation monitoring device is to shut down the controlled network voltage when its insulation resistance drops below a pre-set value. The most common electrical injury is when a person is in contact with a live conductive part. This is single–phase leakage for the IT network, and the less time the current passes through the person, the smaller the risk of injury. It is assumed that the body resistance is about 1 kΩ and the response time of an insulation monitoring device is regulated according to BDS 10880-83 (Table 1).

Table 1. *Response time according to BDS*

Nominal network voltage [V]	Response time [s], not more than
To 1000	0.1

Exposition

The device is connected to a 220 V network. To determine the performance of the device the circuit shown in Fig. 1 is used. The timer uses a pulse counter МЭС-54. The device system is vibrational with a polarised relay acting as a drive unit. When the AC current flows through the polarised relay, the anchor of the electromagnet starts to vibrate between the poles of a permanent magnet at 50 Hz. The anchor of the electromagnet is connected to an axis that actuates the gearing drive mechanism. Before the measurement, the counter is reset. When the instrument is turned off, the arrows are read. The big arrow shows the tenths and hundredths of a second, the small arrow shows the seconds. If the measurement is carried out at a frequency other than 50 Hz, a correction should be made according to the formula:

$$t = \frac{t_1 50}{f} \tag{1}$$

where: t_1 - the indication of the instrument;

f - is the frequency of the network under which the measurement is performed.

A drawback of the network diagram thus realized is a certain increase in the measurement error at the expense of the inertia of the transformer, which is an inductive element of the circuit.

Technical characteristics of the МЭС-54 counter:

- reading error, not more than 0.1% of the reading;
- coil resistance of the МЭС-54 2200 plus minus 220 Ω counter;
- electric insulation strength 500 V;
- insulation resistance of not less than 20 MΩ;
- pulse count МЭС-54 starts counting the pulses at power +6 V.

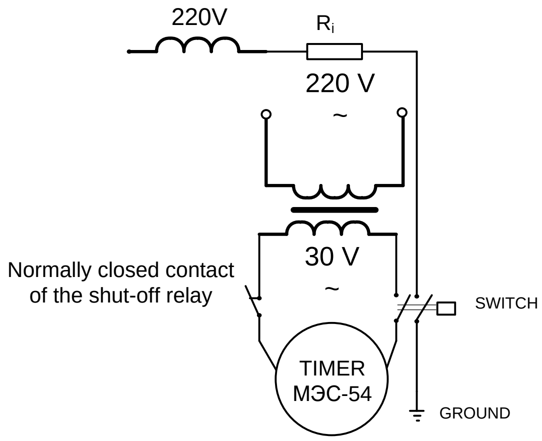

Fig. 1. Connection scheme of the МЭС-54 counter to measure performance

The counter is powered by an AC voltage of 30 V, which is produced by a transformer. The normally closed contact of the relay and the double switch are connected to the counter. One contact of the open switch is connected to the voltage source, in this case the transformer and the counter, respectively. The second contact is connected to the network that is being controlled and ground. When the circuits is closed, a low insulation resistance is simulated and the counter begins counting from that moment, the isolation monitoring device is triggered, the relay switches on, and the normally closed contact interrupts the operation of the counter. Time is reported. The following data were obtained from the experiment (Table 2).

Table 2. *Response time of the apparatus*

Insulation resistance, R_F	Response time [ms]
40 kΩ	200
30 kΩ	140
20 kΩ	120
10 kΩ	90

Operating the device in a three-phase network. Laboratory tests

The device is plugged into a three-phase network to test its functional capabilities. A dangerous event exemplifying the touching of a person to a live conductive part is simulated with a resistor with a value of 1000 Ω. Statistically, this is the most common case of injury and represents a one-phase leak to ground.

The current flowing through the human body can be considered as being composed of two components: I_a - active current determined by the insulating resistance of the phases of the network and the capacitive component I_c. Capacitive leakage current develops because any two conductors separated in space have a certain amount of capacitance between them. The electrical capacity of the network depends linearly on its length or on an average of 1 km of network, the capacity of each phase on earth is approximately 1 μF. According to the BDS, the insulation control devices operating in a three-phase IT network must be equipped with a compensating device. The principle of compensation is illustrated in Fig. 2. A choke coil is used whose inductance is sized relative to the network to which the apparatus is connected.

It is assumed $r1 = r2 = r3 = \infty$. If a person touches one of the phases of the network, the current that passes through his body is determined by the total capacity of the network C and the inductance L of the compensating choke coil which is connected to the neutral point of the secondary winding of the power transformer T. The total current passing through the man is the geometric sum of the capacitance current and the inductive current.

$$\dot{I}_h = \dot{I}_c + \dot{I}_L \quad (2)$$

To fully compensate the capacitive current it is necessary:

$$\dot{I}_C + \dot{I}_L = 0 \quad (3)$$

A condition for this is the current resonance:

$$\omega C = \frac{1}{\omega L} \quad (4)$$

In this case, the currents have a phase difference of 180 degrees and as a result the current through the human body is I_h=0. The condition I_h=0 is purely theoretical. Due to losses in the coils there is always some capacitive current that is not compensated (Fig. 2c). In practice, the total current passing through a person in contact with a live conductive part, is a geometric sum of the active, capacitive and inductive currents.

$$\dot{I}_h = \dot{I}_a + \dot{I}_c + \dot{I}_L \quad (5)$$

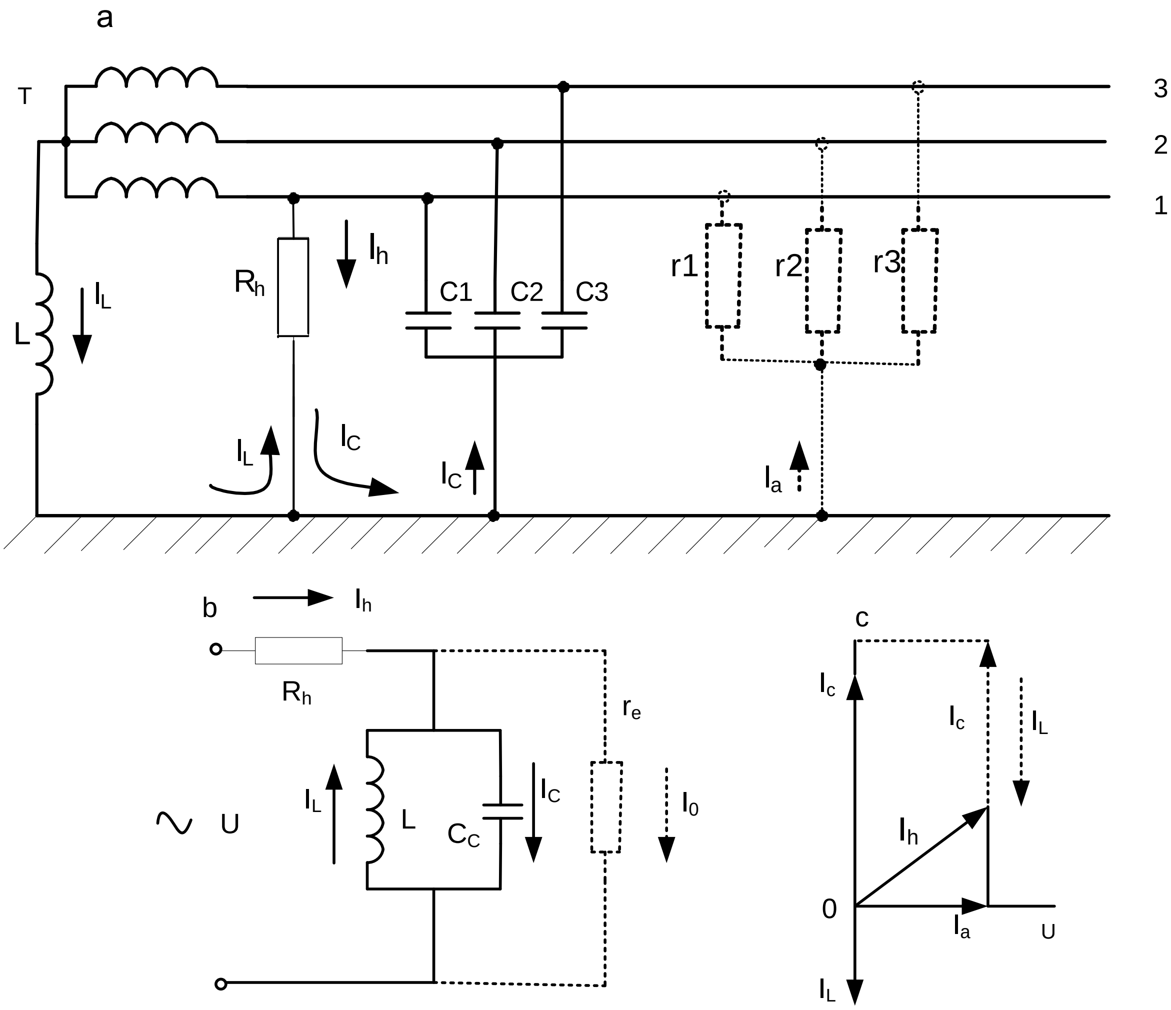

Fig. 2. Capacity compensation principle: (a) network scheme: (b) substitution scheme (c) vector flow diagram

To limit the capacitive current when changing the network capacity, it is necessary to change the inductance of the choke so that the residual current is minimal.

Experiment Description

In the experiments three identical divided coils were used. The following scheme (Fig. 3) is applied to measure their inductance.

The active resistance of the windings is measured by an ohmmeter. The network voltage measured by a voltmeter showed 225 V. The data are given in Table 3.

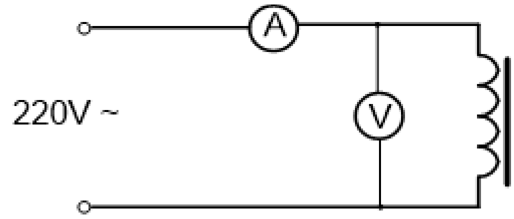

Fig. 3. Determination of coil inductance by ammeter and voltmeter method

Table 3. *Choke coil parameters and the corresponding capacity that compensates*

R [Ω]	I [mA]	$Z = \frac{U}{I}$ [Ω]	$X_L = \sqrt{Z^2 - R^2}$ [Ω]	L [H]	C [μF]
441	40	5625	5608	18	0.567
345	65	3460	3443	11	0.925
260	115	1956	1939	6	1.64
225	150	1500	1483	5	2.15

To measure the current passing through a person in contact with a live conductive part, the circuit shown in Fig. 4 is used. The insulation monitoring device is connected to a three phase network through a 200 kΩ limiting resistor. The body resistance is simulated with R_h. In series with R_h an ammeter is connected to measure the current.

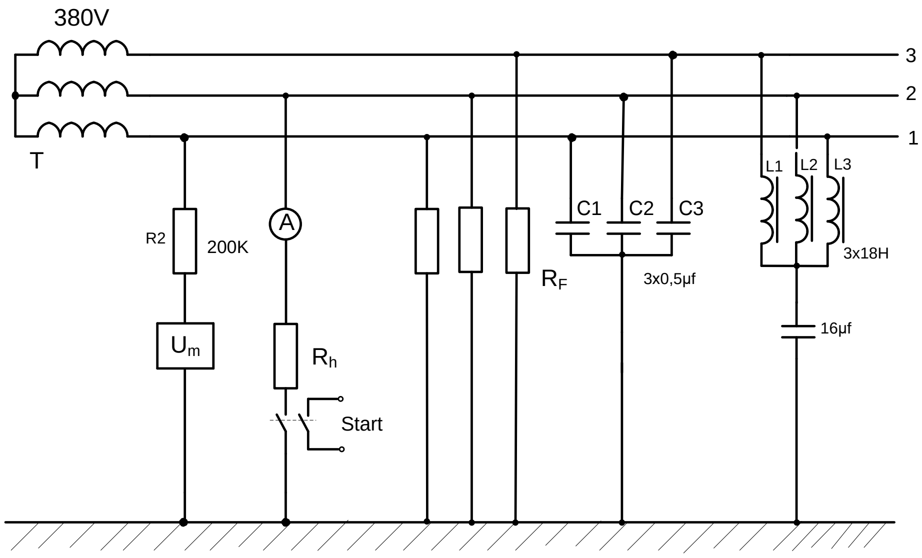

Fig. 4. A scheme that determines the current through the person

When the IT network is of a small length, the capacity of the network may be disregarded. The current passing through a person in contact with a live conductive part is determined only by the active resistance of the network. The value of R_h = 1000 Ω, in this case simulates the body resistance. In this measurement, the components C1, C2, C3 as well as L1, L2, L3 are not included in the network.

The second measurement was carried out with three connected capacitors, one for each phase with a capacity of 0,5 μF. In this case capacitors carry capacitive conductivity and the scheme simulates a network with a long length (a network of significant capacity).

In the third measurement, three chokes with an inductance of 18 H, one for each phase, whose purpose is to compensate for the capacitive conductivity of the network, are added to this scheme. The data are tabulated in Table 4. An increase in current through the R_h resistance is seen when the capacitors that introduce capacitive conductivity are added to the circuit. In the presence of inductance coupled in parallel to the capacitors, the current through R_h decreases as the currents through the capacitor and the inductance are in antiphase. Full compensation of the capacitive component of the current is virtually impossible due to losses in the core and windings of the coils.

Table 4. *Current through a person*

Insulation resistance [kΩ]	40	30	20
Not count the capacitive current [mA]	26	35	49
Taking into account the capacitive current [mA]	154	165	150
With compensation [mA]	62	64	78

Determining response time

Fig. 5 is a schematic diagram for determining the performance of the apparatus when it is connected to a three-phase network. The reported data is shown in Table 5.

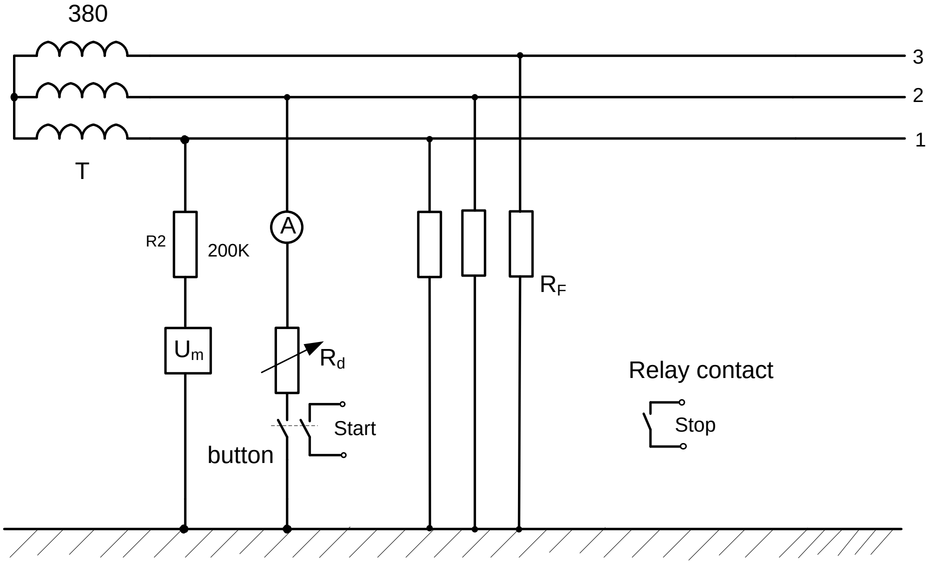

Fig. 5. Determining response time

Table 5. *Response time at different insulation resistance values*

Rd [kΩ]	40	30	20	10	1
ΔT [ms]	150	150	120	110	95

For the determination of the response time, an interval meter is used - L23. The change of R_d simulate a single-phase leakage at different values of the insulation resistance. The double button gives earth to one phase through the corresponding resistor (single-phase leakage) and simultaneously includes the interval meter.

The normally open contact of the relay closes the meter at intervals. The data obtained are shown in Table 5.

When changing the insulation resistance, with its decrease, the time for triggering the apparatus also decreases.

Conclusion

The experiments were carried out with an insulation monitoring device that was assembled on universal boards and made entirely of electronic components, which allows for a device with a small mass and gauge. With single-phase leakage of 1 kΩ (simulation of a person in contact with a live conductive part), the device fits into BDS 10880-83 regarding trigger time. When connected to a three-phase network, the device works successfully with a compensator.

Acknowledgements. The paper was implemented with the support of Research Project FK-018 / 11.03.2019 of UMG "St. Ivan Rilski" - Sofia.

References

BDS 10800-83. 1983. Suoruzeniya electricheski rudnichni. Aparati za zashtita ot tokove na utechka za mrezhi na naprezeniya do 1200 V s izoliran zvezden tsentur. Sofia, (in Bulgarian).

Kolosyuk, V. P. 1980. *Zashcitnoe otklyucheniye rudnichnykh elektroustanovok*. Nedra, Moscow (in Russian).