

# Increasing the Accuracy of Measuring the Resistance of the Grounding System with an Electrodeless Method

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## Abstract

Recently, electrodeless methods of measuring the resistance of grounding devices have appeared, with the help of special clamps. But a large methodological error limits the possibility of their use, especially when rationing low resistances. The article shows the possibility to improve the accuracy of electrodeless measurement methods using commercially available measuring instruments.

In electrical installations of telecommunication networks of buildings, structures and industrial enterprises, the form of the AC voltage signal of the industrial supply network (~220V, 50/60Hz) can differ greatly from the sinusoidal for short periods of time. The causes of distortions are usually associated with a sudden change in the network load [1], for example, when you turn on a powerful electric motor, furnace, welding machine, etc.

The occurrence of impulse overvoltages and interference caused by electromagnetic effects (lightning, switching, radio frequency and others) on low-voltage networks, not only leads to failure of electrical installations, cables, switchboards, but also to damage the terminal equipment and malfunction. This is due, primarily, to the saturation of modern buildings and structures with information, telecommunications and other digital equipment, which has a very low level of protection against impulse overvoltages and interference. All this makes it necessary to carry out appropriate protective measures. To reduce interference, it is necessary to perform a separate (working) ground loop, the resistance of which must be measured and periodically monitored.

There are devices that allow an electrodeless method to monitor and evaluate the resistance of the ground loop. But these devices have a greater measurement error than devices that measure the resistance of the earth electrode method.

The article deals with existing instruments (CA6410, MZC-303E) which can evaluate the resistance of the earth electrode and the possibility of increasing the accuracy of the measurement with the help of special current clamps is shown. Using a predetermined value of neutral impedance, the measurement error of the calculated resistance of the earthing switch can be determined with great accuracy.

**Keywords:** measurement accuracy, earthing/grounding, resistance, electrodeless method.

## 1. Introduction

The main parameters of electrical safety include: insulation resistance, resistance of grounding devices (GD), and contour resistance "phase-zero" [2]. Periodic monitoring and measurement of electrical safety parameters is a mandatory requirement of safety regulations and rules ([3], [4], [5], [6]) for the technical operation of electrical installations ([7], [8], [9]).

For these purposes, the world market offers a large selection of devices that guarantee the necessary accuracy of measurements, provided that the user meets certain operating conditions. Unfortunately, these conditions are not always feasible.

In particular, instruments for measuring the resistance of the grounding device, in addition to the performance of the climatic conditions of operation, require the specific placement of current and potential electrodes (metal pins jammed into the ground) relative to

the investigated ground contour (depending on the geometric dimensions of the circuit) and set the maximum permissible earth resistance of the electrodes themselves (depending on the resistivity of the soil in which they are placed).

In the central part of any city, where the saturation of buildings and underground utilities is high, solid asphalt or concrete, the application of these devices becomes impossible.

## 2. Main text

### 2.1. Problem Definition

In such cases, reckoning methods are used to determine the resistance of the GD, given the known geometric dimensions of the

ground contour under investigation and the known resistivity of the ground.

These initial parameters are practically unknown, and therefore other methods and means of measuring the resistance of the memory are needed, independent of the geometric dimensions of the grounding loop and the resistivity of the ground - electrodeless / unpinned methods.

This method excludes the placement of auxiliary electrodes in the ground, greatly shortens the measurement time and is often the only possible one. Electrodeless / unpinned methods consists in measuring the resistance of a closed electrical circuit, which must necessarily include the measured grounding electrode. This method is realized by means of two current clamps, or by current mites, in which two transformers are combined. One of which creates an EMF in a closed loop, and the other measures the current in the circuit.

Devices for measuring the resistance of the earth electrode by a electrodeless / unpinned method in their documents guarantee the obtaining of the necessary results, even when measuring small resistances. So, for example, the manufacturer of the device C.A.6410 (France) [10], guarantees the accuracy of measuring the resistance of the earth electrode of about 1.5% (Fig. 1).

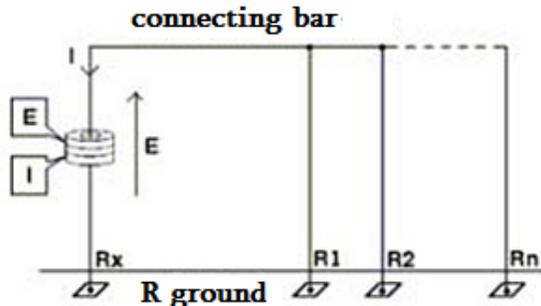


Fig.1. C.A 6410 – earthing/grounding resistance meter

To create a closed electrical circuit, the developers propose to use the neutral wire and neutral ground of the supply transformer (It is assumed to use a power supply system with a dead-grounded neutral, in which the resistance of the neutral wire and the ground contour of the transformer neutral can be neglected).

When the test voltage E by means of a special transformer is applied to the grounding rod (conductor with resistance Rx), the resultant current I begin to flow through the circuit. The resultant current I is increased by the receiving coil. The internal filter of the instrument (tuned to the frequency of the applied test voltage) cuts off all currents except the resultant current I [10], which is equal to:

$$I = E / R_{\text{contour}} \tag{1}$$

Knowing the value of E (given by the generator) and I (measured), you can calculate the R circuit (this value is displayed on the instrument screen).

$$R_{\text{contour}} = R_x + R_G + (R_1 // R_2 // \dots // R_n) + R_{\text{Connectors}} \tag{2}$$

$R_G$  - is the resistance of the earth, the value of which is usually much less than 1 Ohm;

$R_1 // R_2 // \dots // R_n$  - is a negligible value;

$R_{\text{connecting tire}}$  - value, usually much less than 1 Ohm.

Approximately:  $R_{\text{contour}} = R_x$  is the desired value.

This approximation is only permissible when measuring the resistance of the earthing switch above 10 Ohm, or more.

There is an MZC-303E device (Fig.2) that calculates the expected short-circuit current based on the impedance of the short circuit contour [2].

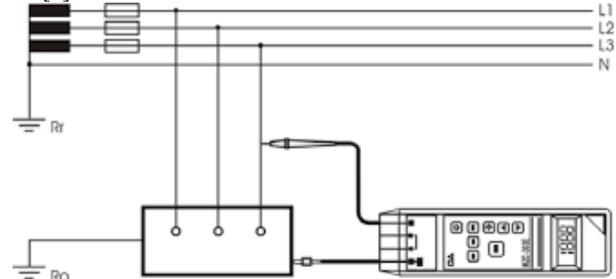


Fig.2. MZC-303E Measuring instrument for power supply circuits of buildings

The device is recommended for measurements in electrical installations, networks of buildings, structures and industrial enterprises in which the error caused by neglect of reactive resistance can be of significant significance. Based on the meter reading and measuring the expected short-circuit current, it is possible to select the required values of the residual current circuit-breakers for each power supply circuit. The device allows to monitor the integrity of the zero protective conductors, to carry out measurements without disconnecting the power supplies and protection and to evaluate the resistance of the grounding device. When assessing the resistance of the grounding device to the measurement result, instead of the resistance of the neutral wire, the resistance of the investigated circuit and the grounding contour of the substation feeder transformer will be included.

To increase the accuracy of measuring the resistance of the grounding contour in an electrodeless / unpinned manner and in the first and second cases, it is necessary to reduce the total resistance of the grounding contours in the neutral circuit of the substation transformer.

## 2.2. Proposed Method.

For example, perform a neutral ground loop of a substation transformer with a resistance of less than 0.5 ohms. True, this is a very time-consuming and expensive option.

There is an option and simpler, which consists in determining the resistance of all external ground loops connected to the neutral of the transformer, if you know the intrinsic resistance of the earthing contour of the substation transformer, when it is put into operation.

Then calculate the total earth resistance of the neutral and introduce it as an amendment to the result of the measurement of the ground loop being examined.

To implement such an option, it is proposed to measure directly on the substation the resistance of the closed electrical circuit formed between the internal ground of the substation transformer and all external earthing switches. For example, using test clamps, considering the connection of all external circuits by zero wire. The calculated value of the total resistance of the neutral for each transformer should be known and periodically fixed in the transformer's passport.

This is explained by the figure (Fig.3) where it is indicated:

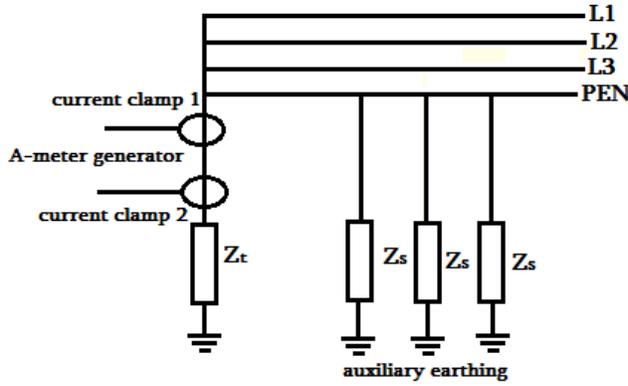


Fig. 3. Grounding resistance measuring circuit for current clamp

L1, L2, L3 - Winding of the transformer feeder of the substation, with a dead grounded neutral;  
 Zt - known, internal resistance of the earthing substation of the substation;  
 Zs- resistance of ground loops of electrical consumers connected by a neutral wire to the neutral of the supply transformer.  
 With the notations indicated in the figure 3, the result of the resistance measurement with the help of the clamp - Zx, will be:

$$Z_x = Z_t + \frac{Z_s}{3} \tag{3}$$

Considering that Zt is known (it is indicated in the passport when commissioning the substation), we can get the calculated value of the total resistance of auxiliary grounding included in the neutral -

$$Z_s/3 = Z_x - Z_t.$$

The circuit without measuring devices will have the form of parallel connected resistances (Fig. 4). The total resistance of the neutral Zr is given by:

$$Z_r = \frac{(Z_x - Z_t)Z_t}{Z_x - Z_t + Z_t} = Z_t \left(1 - \frac{Z_t}{Z_x}\right) \tag{4}$$

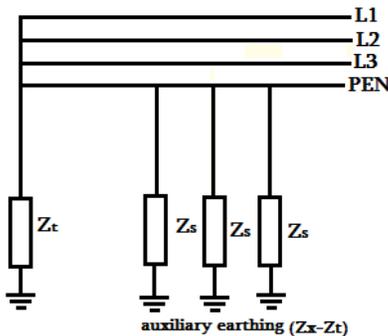


Fig. 4. Grounding resistance circuit without measuring devices

And in the future, to enter this calculated resistance value into the result of measuring the resistance of the ground loop under study, as an amendment.

As a result of the generalization of the above and similar electrodeless methods for measuring the resistance of earthing devices, we arrive at the following conclusions.

For example, by including a new consumer / equipment in the system that requires grounding of the neutral and observing the small values of the earthing resistance (Fig. 5), knowing the value of the neutral resistance Zr and measuring the resistance using the current clamp-Zx, it is possible to determine the resistance of the equipment ZG with high accuracy.

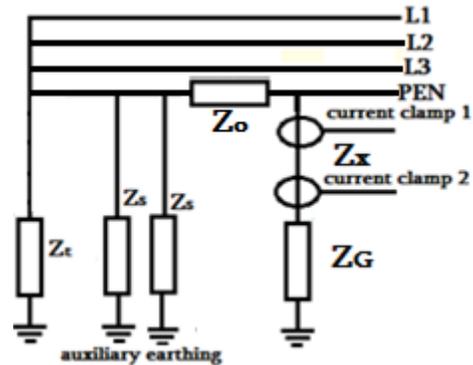


Fig. 5. Circuit for measuring the resistance of the equipment earthing switch with clamp

$$Z_G = Z_x - Z_r - Z_0 \tag{5}$$

$Z_0 = \rho \frac{l}{S}$  - resistance of the zero wire, which can be determined from geometric data.

### 3. Conclusions and Offers

As a result of generalization of the above and similar electrodeless methods of measuring the resistance of earthing switches, we arrive at the following conclusions:

1. The use of electrodeless / unpinned methods is justified for rough estimates and when the measurement results are less than or equal to the expected (necessary) values. It means that the results will always be greater than the actual values.
2. The large methodological error of electrodeless methods does not allow using the obtained measurement results for official presentation and recording of these results in the documentation.
3. With the help of a predetermined value of the neutral resistance, the error in measuring the design resistance of the earthing/grounding device can be determined with great accuracy.

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