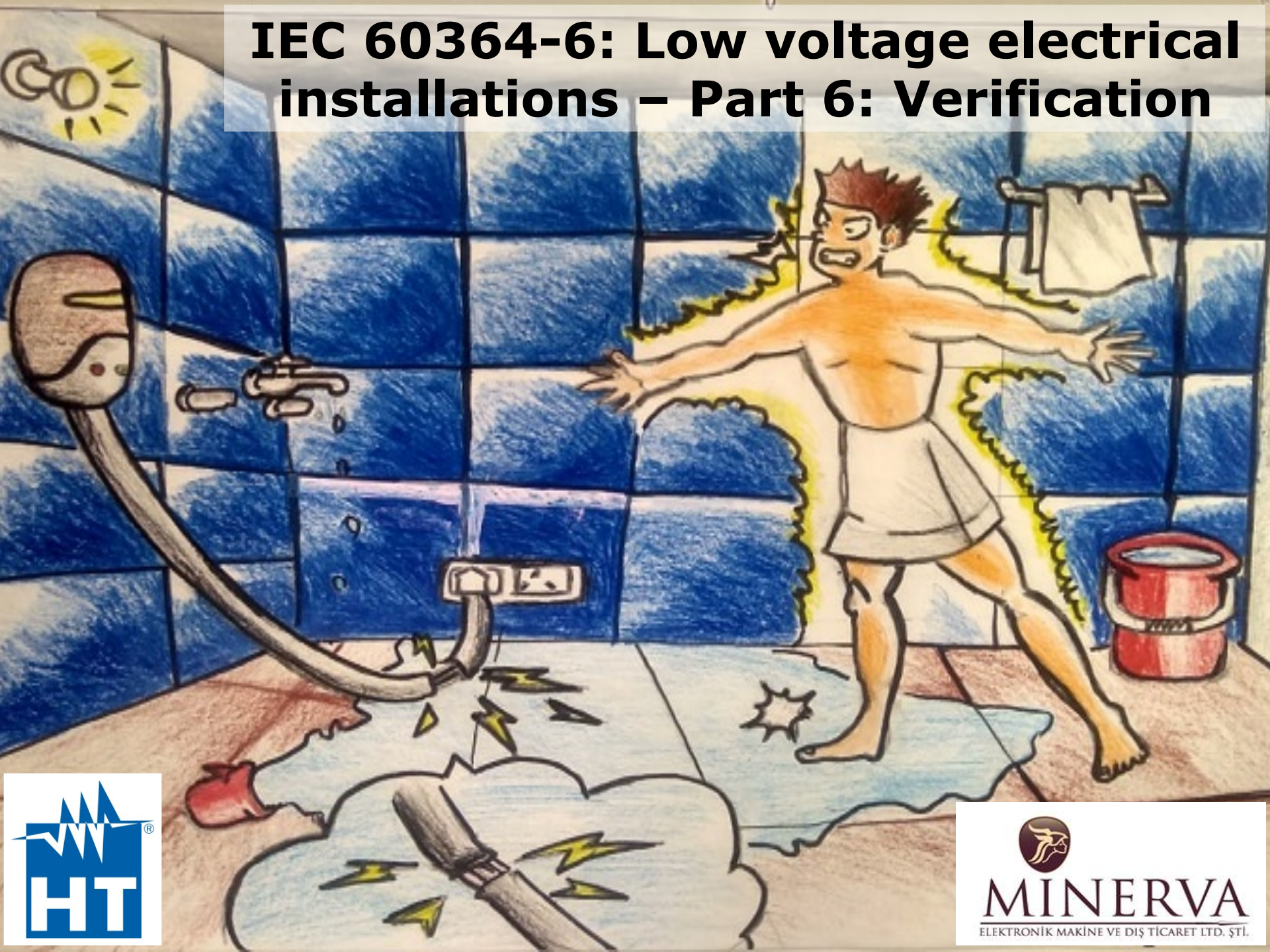


# IEC 60364-6: Low voltage electrical installations – Part 6: Verification





# Electric installation safety

## Measurements and tests



### Electrical installation safety

The risks linked to incorrect use of electricity may include:

- life-threatening danger for people,
- threat of damage to electrical installations and property,
- harmful effects on systems operation and equipment life spans.

So the purpose of electrical installation testing is primarily to ensure that people and goods are kept safe and are protected in the event of a fault. It also facilitates preventive maintenance of installations, preventing serious faults which might prove expensive. To guarantee people's safety with regard to these installations and the electrical equipment connected to them, standards have naturally been developed and updated to take changes into account. The IEC 60364 standard and its various national equivalents specify the requirements concerning electrical installations in buildings. Chapter 6 describes the requirements for testing the compliance of an installation.

The effectiveness of the safety measures implemented can only be guaranteed if regular tests prove they are operating correctly. This is why the standards cover not only the initial verifications when installations are commissioned, but also periodic testing.





# Electric installation safety

## Measurements and tests



### Electrical installation safety

Every installation shall be verified during erection, as far as reasonably practicable, and on completion, before being put into service. Precautions shall be taken to ensure that the verification shall not cause danger to persons or livestock and shall not cause damage to property and equipment even if the circuit is defective.

It shall be verified that an extension, addition or alteration to an existing installation complies with the IEC 60364 series and does not impair the safety of that installation, and that the safety of the new installation is not impaired by the existing installation.

The electrical testing is divided into 2 parts:

**1. Visual inspection** to guarantee that the installation complies with the safety requirements (presence of an earth electrode, protective devices, color of the cables, etc.) and does not show any visible evidence of damage.

#### **2. Measurements**

Measuring instruments and monitoring equipment and methods shall be chosen in accordance with the relevant parts of the IEC 61557 series. If other measuring equipment is used, it shall provide no less a degree of performance and safety.



# Electric installation safety

## Measurements and tests



### Installation safety tests

The following tests shall be carried out where relevant and should preferably be made in the following sequence:

- a) continuity of conductors;
- b) insulation resistance;
- c) insulation resistance testing to confirm the effectiveness of protection by SELV, PELV or electrical separation;
- d) insulation resistance testing to confirm the effectiveness of floor and wall resistance/impedance;
- e) polarity test;
- f) testing to confirm effectiveness of automatic disconnection of supply;
- g) testing to confirm the effectiveness of additional protection;
- h) test of phase sequence;
- i) functional tests;
- j) voltage drop.

In the event of any test indicating failure to comply, that test and any preceding test, the results of which may have been influenced by the fault indicated, shall be repeated after the fault has been rectified.



# Electric installation safety

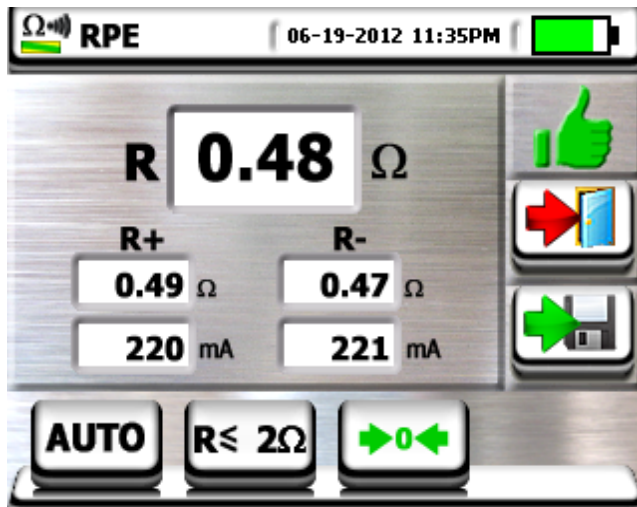
## Measurements and tests



### a) Continuity of conductors

The continuity of conductors and connection to exposed-conductive-parts, if any, shall be verified by a measurement of resistance on protective conductors, including protective bonding conductors, exposed-conductive-parts, and in the case of ring final circuits, live conductors. The continuity shall be measured:

- a) between the earth electrode and the earth collector,
- b) between the earth collectors (if there are more than one),
- c) between the exposed-conductive-parts and the earth collector(s),
- d) between the exposed-conductive-parts (if there are more than one).



When carried out by generating AC current, it is advisable to use a multimeter capable to avoid variations of their impedance that would affect the measurement performed.

When carried out by generating DC current, it is advisable to use an ohmmeter with the polarity and carry out two tests, providing both



# Electric installation safety

## Measurements and tests



### b) Insulation resistance

Good insulation is essential to prevent electric shocks. The insulation resistance shall be measured between live conductors, and live conductors and the protective conductor connected to the earthing arrangement.

The power must be switched off and the installation must be disconnected before performing this test to ensure that the test voltage will not be applied to other equipment electrically connected to the circuit to be tested.

To measure the insulation resistance the test voltage is applied between conductors. The stray capacitance between active conductors and ground slows the voltage rise.



The test voltage is applied for a sufficient time for the transients to die away and the steady state value is reached.



# Electric installation safety

## Measurements and tests



### c) Insulation resistance testing to confirm the effectiveness of protection by SELV, PELV or electrical separation

The separation of live parts from those of other circuits (protection by PELV) and from earth (protection by SELV or electrical separation) shall be confirmed by a measurement of the insulation resistance.

The resistance value obtained shall be at least that of the circuit with the highest voltage present in accordance with the following table.

Nominal circuit voltage	DC test voltage [V]	Insulation resistance [M $\Omega$ ]
SELV and PELV	250	$\geq 0,5$
Up to and including 500 V, including FELV	500	$\geq 1,0$
Above 500 V	1.000	$\geq 1,0$





# Electric installation safety

## Measurements and tests



### d) Insulation resistance/impedance of floors and walls

When it is necessary to comply with the requirements of IEC 60364-4-41:2005, Clause C.1, at least three measurements shall be made in the same location, one of these measurements being approximately 1 meter from any accessible extraneous-conductive-part in the location. The other two measurements shall be made at greater distances. The measurement of resistance/impedance of insulating floors and walls is carried out with the system voltage to earth at nominal frequency.

The above series of measurements shall be repeated for each relevant surface of the location.

Current  $I$  is fed through an ammeter to the test electrode from the output of the voltage source or from the phase conductor  $L$ . The voltage  $U$  at the electrode is measured by means of a voltmeter with internal resistance of at least  $1 \text{ M}\Omega$  towards PE. The impedance of the floor insulation will then be  $Z_x = U_x / I$

The measurement for ascertaining the impedance shall be carried out at as many points as deemed necessary, selected at random, with a minimum of three.





# Electric installation safety

## Measurements and tests



### e) Polarity

Where relevant, the polarity of the supply at the origin of the installation shall be verified before the installation is energized.

Where single pole switching devices are not permitted in the neutral conductor, a test shall be made to verify that all such devices are connected in the line conductor(s) only.

During the polarity test, it should be verified that:

- a) every fuse and single-pole control and protective device is connected in the line conductor only, and
- b) except for E14 and E27 lamp-holders according to IEC 60238, in circuits having an earthed neutral conductor center contact bayonet and Edison screw lamp-holders, the outer or screwed contacts are connected to the neutral conductor, and
- c) wiring has been correctly connected to socket-outlets and similar accessories.



# Electric installation safety

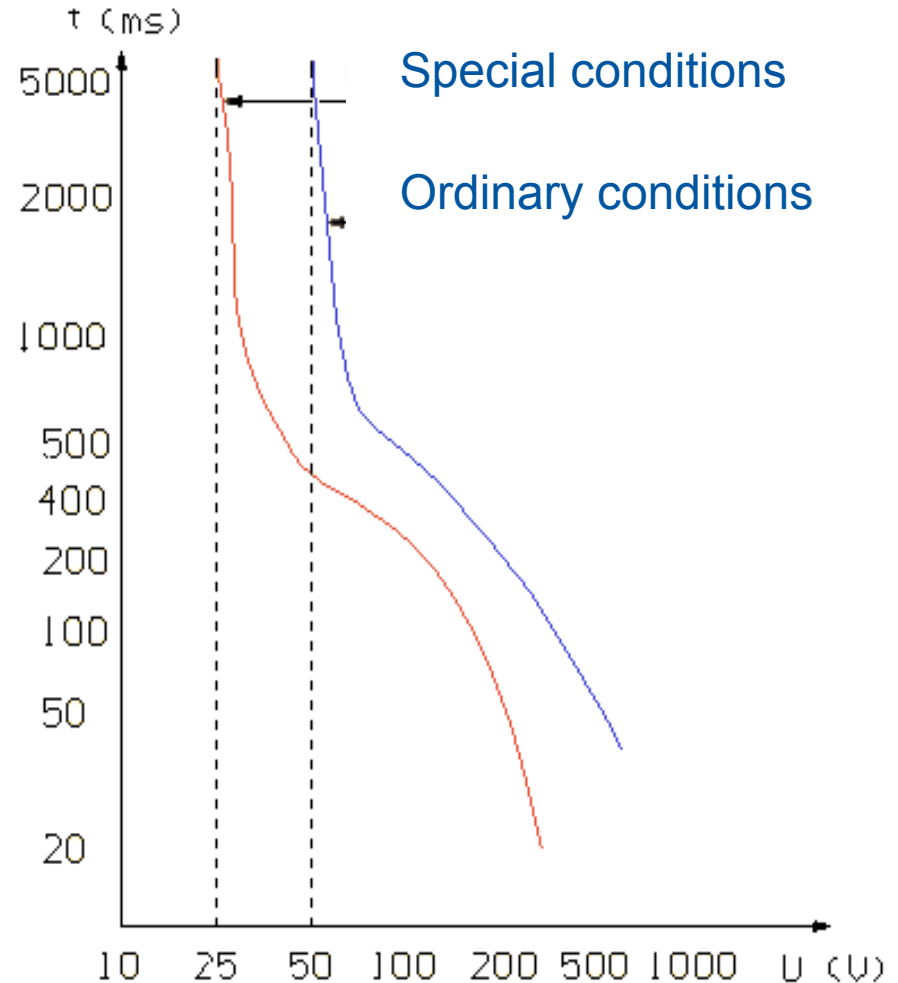
## Measurements and tests



### f) Protection by automatic disconnection of supply

In the protection against indirect contacts by automatic interruption of the power supply, the protection device (RCD / MCB / FI / fuse) must trip in case of ground fault so that a contact voltage higher than the limit indicated by the regulation can not persist for a dangerous time for people.

For the purpose of coordinating protection against indirect contacts, the structures of the plants and the distribution systems have to be considered. Tests depend on the composition of the fault circuit.





# Electric installation safety

## Measurements and tests



### Automatic disconnection of supply – TN

For a **TN system** the following tests shall be performed:

1. Measurement of the earth fault loop impedance.
2. Verification of the characteristics and/or the effectiveness of the associated protective device. This verification shall be made:
  - for overcurrent protective devices, by visual inspection or other appropriate methods (i.e. short time or instantaneous tripping setting for circuit-breakers, current rating and type for fuses);
  - for RCDs, by visual inspection and testing.

The effectiveness of automatic disconnection by RCDs shall be verified using suitable test equipment according to IEC 61557-6 confirming that the relevant requirements in IEC 60364-4-41 are met taking into account the operating characteristic of the device. The effectiveness of the protective measure is verified if disconnection occurs with a fault current lower than or equal to the rated residual operating current  $I_{\Delta n}$ .

It is recommended that the disconnection times required by IEC 60364-4-41 be verified.



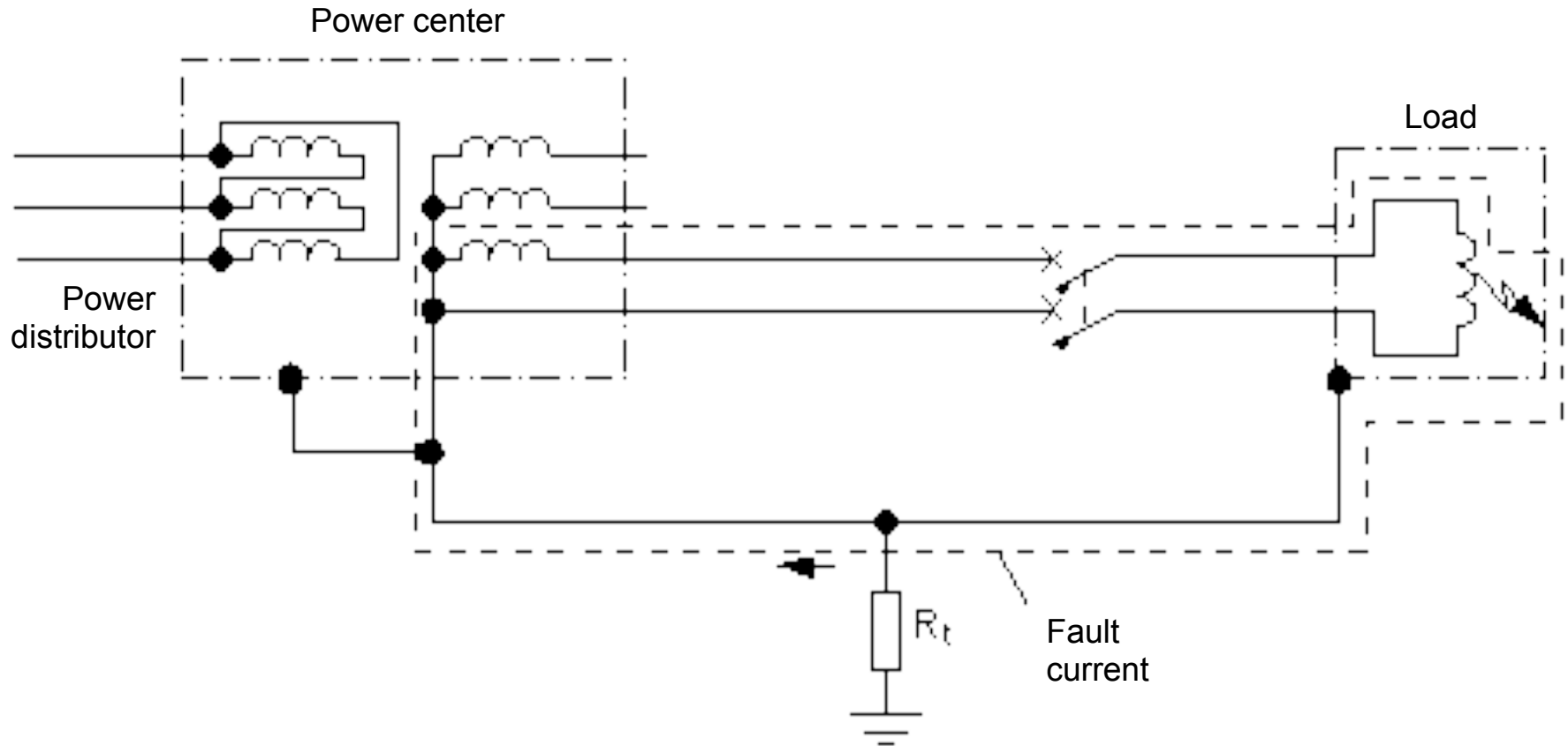
# Electric installation safety

## Measurements and tests



### Automatic disconnection of supply – TN

The fault circuit always involves the protective conductor, while it does not involve the earthing electrodes.







# Electric installation safety

## Measurements and tests

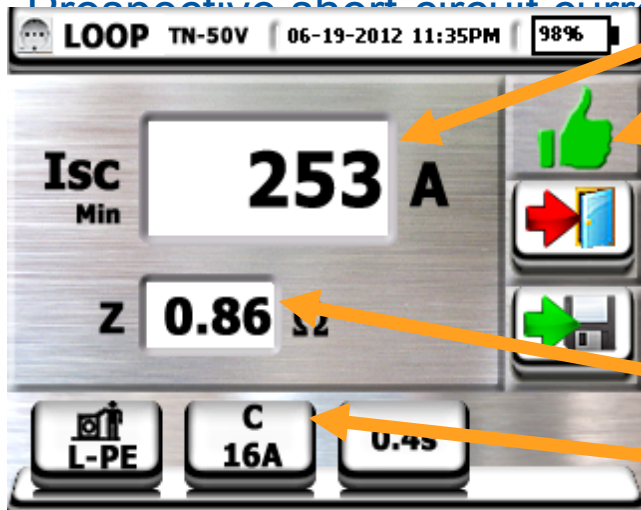


### Automatic disconnection of supply – TN

The fault loop impedance value shall be coordinated to the rated current/curve and the short circuit breaking capacity of the protection device. To check the specifics of the protective devices such as fuses or MCBs, a fault loop impedance measurement is carried out to calculate the corresponding short-circuit/fault current.

The condition  $I_{SC} > I_a$  shall be fulfilled in any part of the circuit. The prospective short circuit current  $I_{SC}$  is given by  $U_o / Z_s$  where  $U_o$  is the nominal voltage and  $Z_s$  is the fault loop impedance.  $I_a$  is the current triggering the active protections within 0.4 s.

Prospective short circuit current





# Electric installation safety

## Measurements and tests



### Automatic disconnection of supply – TT

For a **TT system** the following tests shall be performed:

- 1) Measurement of the resistance  $R_A$  of the earth electrode for exposed-conductive-parts of the installation.
- 2) Verification of the characteristics and/or the effectiveness of the associated protective device. This verification shall be made:
  - for overcurrent protective devices, by visual inspection or other appropriate methods (i.e. short time or instantaneous tripping setting for circuit-breakers, current rating and type for fuses);
  - for RCDs, by visual inspection and testing.

The effectiveness of automatic disconnection by RCDs shall be verified using suitable test equipment according to IEC 61557-6 confirming that the relevant requirements in IEC 60364-4-41 are met taking into account the operating characteristic of the device. The effectiveness of the protective measure is verified if disconnection occurs with a fault current lower or equal to the rated residual operating current  $I_{\Delta n}$ .

It is recommended that the disconnection times required by IEC 60364-4-41 be verified.



# Electric installation safety

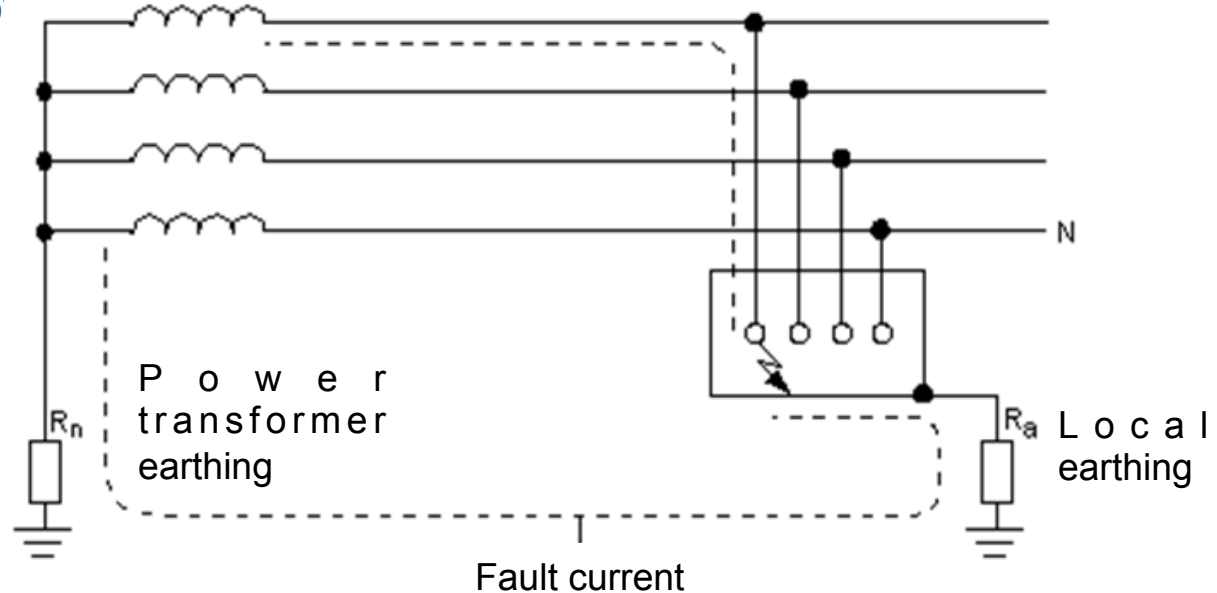
## Measurements and tests



### Automatic disconnection of supply – TT

The fault circuit always involves the ground between the user earth electrode and the center of the secondary winding of the power transformer. The current closes through the ground to the generator by the grounded center of the secondary winding.

The earth resistance value shall be coordinated to the rated differential current of the active protection device. The earth resistance value of the typical TT system (low voltage consumer) should not exceed the product of 50 V / I<sub>a</sub>.





# Electric installation safety

## Measurements and tests



### Automatic disconnection of supply – TT

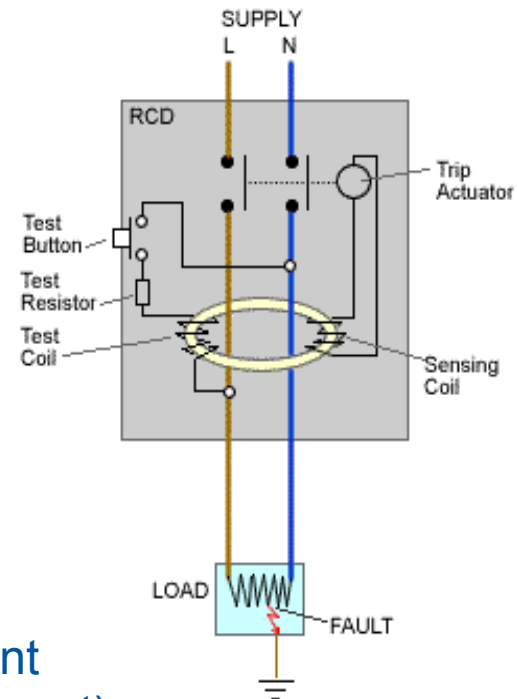
The RCD is a device designed to quickly and automatically disconnect a circuit whenever the current is not balanced between the supply and return conductors (indicating leakage current), which presents a shock hazard.

IEC 60755 defines three types of RCD depending on the waveforms and frequency of the fault current:

- type **AC** RCD that trips on sinusoidal residual currents,
- type **A** RCD also responding to pulsating or continuous direct currents of either polarity,
- type **B** RCD also responding to higher frequency currents or for combinations of alternating and direct currents.

There are three groups of devices according to the trip time:

- G** general RCDs (must not trip at  $\frac{1}{2}$  of the nominal current rating, maximum trip time 300 ms for rated current),
- S** selective RCDs (must not trip at  $\frac{1}{2}$  of the nominal current rating, providing a delay of tripping at rated current),
- R** time-delayed RCDs (must not trip at  $\frac{1}{2}$  of the nominal current rating, providing a user-selectable delay of tripping at rated current)







# Electric installation safety

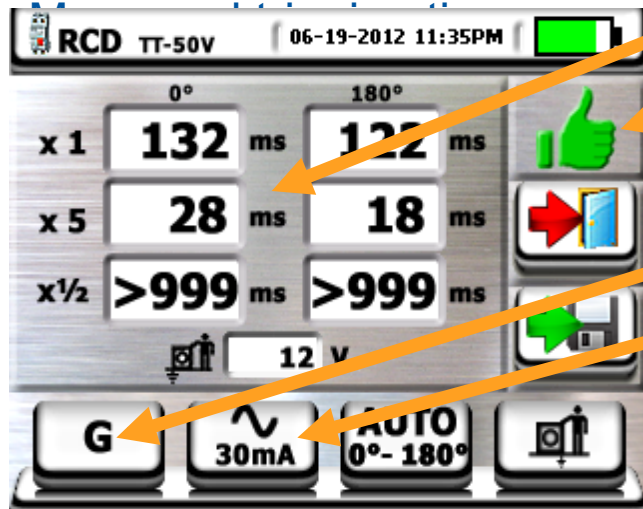
## Measurements and tests



### Automatic disconnection of supply – TT

The RCD tripping time test shall be performed on a live installation. Where the circuit includes equipment that is likely to influence the results, such equipment shall be disconnected.

The suitable test equipment shall operate according to IEC 61557-6 confirming that the relevant requirements in IEC 60364-4-41 are met.



According to the IEC 60364-4-41



# Electric installation safety

## Measurements and tests



### Automatic disconnection of supply – IT

For a **IT system** compliance with the rules shall be verified by calculation or measurement of the current  $I_d$  in case of a first fault of a live conductor. Precautions are to be taken while making the measurement in order to avoid the danger due to a double fault.

In the case of a double earth fault, the fault loop impedance shall be verified by calculations or by measurements. Where the condition is similar to that of a TT-system, verification shall be made as for a TT system. Where conditions are similar to that of a TN-system, verification by measurement shall be made as for TN systems.



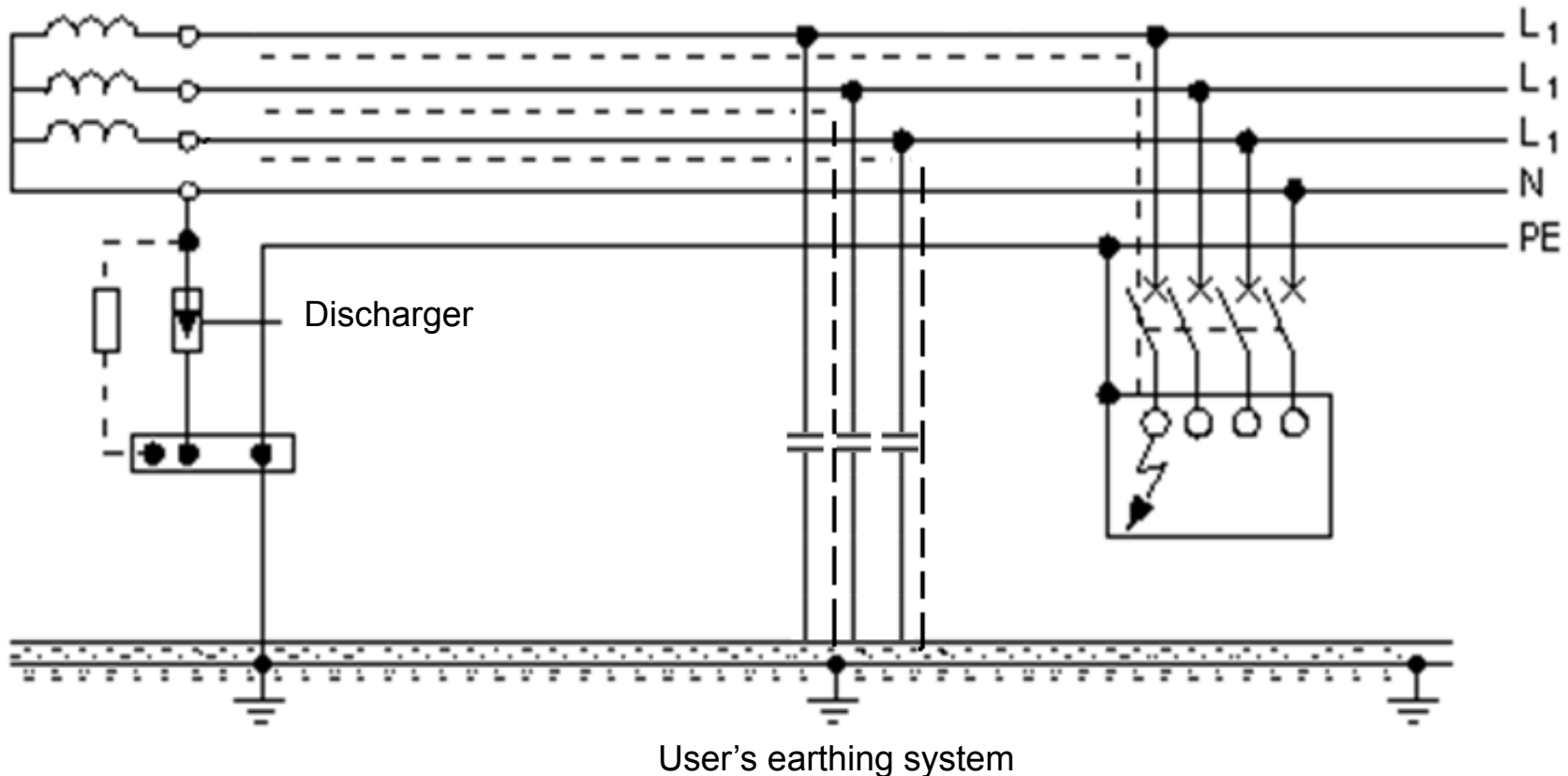
# Electric installation safety

## Measurements and tests



### Automatic disconnection of supply – IT systems

First fault circuit closes through the protective conductor and, through the ground and the parasitic capacitances on the two live cables not involved in the first fault.





# Electric installation safety

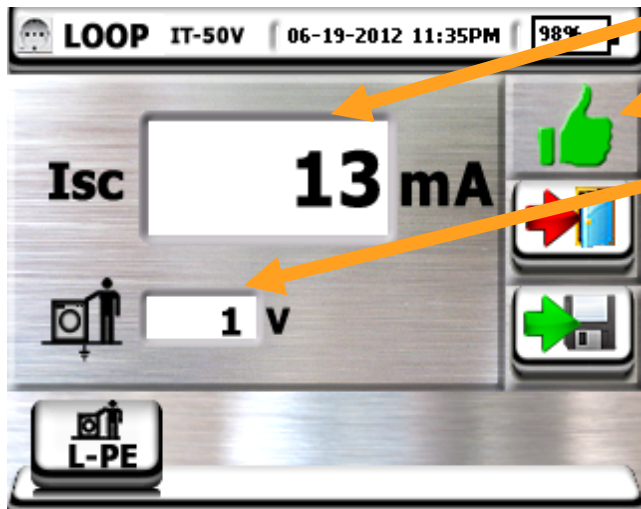
## Measurements and tests



### Automatic disconnection of supply – IT systems

First fault current shall be measured by taking precautions in order to avoid the danger due to a double fault. Earth resistance is measured

The condition  $R_a \times I_d < U_L$  shall be fulfilled, where  $R_a$  is the value of the earth resistance,  $I_d$  is the first fault current (to earth), and  $U_L$  is the maximum contact voltage allowed.



First fault current

Evaluation of the measure

Measured contact voltage





# Electric installation safety

## Measurements and tests



### Measurement of the resistance of the earth electrode

Measurement of the resistance of an earth electrode shall be made by an appropriate method.

Where the location of the installation (e.g. in towns) is such that it is not possible in practice to provide the two auxiliary earth electrodes, measurement of the earth fault loop impedance will give an acceptable approximate value

Three test procedures are possible:

- measurement of earth electrode resistance using an earth electrode test instrument,
- measurement of earth electrode resistance using a fault loop impedance test instrument,
- measurement of earth electrode resistance using current clamps (stakeless).



# Electric installation safety

## Measurements and tests



### Measurement of earth electrode resistance using an earth electrode test instrument

The following procedure may be adopted when measurement of the earth resistance is necessary.

An alternating current of a steady value is passed between the earth electrode, and a temporary auxiliary earth electrode, placed far enough that the resistance areas of the two electrodes do not overlap.

A second temporary probe electrode is then inserted half-way between the two, and the voltage drop is measured. Was a network of earth electrodes to be under test, the distance between the farthest earth electrodes is the dimension to consider. The auxiliary electrodes may be arranged in a linear formation.

The resistance of the earth electrode is then the voltage measured divided by the current flowing, provided there is no overlap of the resistance areas. The 4-wire measuring technique keeps voltage and current circuits separated, avoiding cables and contact resistances. Extensions can be used without compensation.

To check that the resistance of the earth electrode is a true value, two further readings are taken with the second electrode moved from the original position.



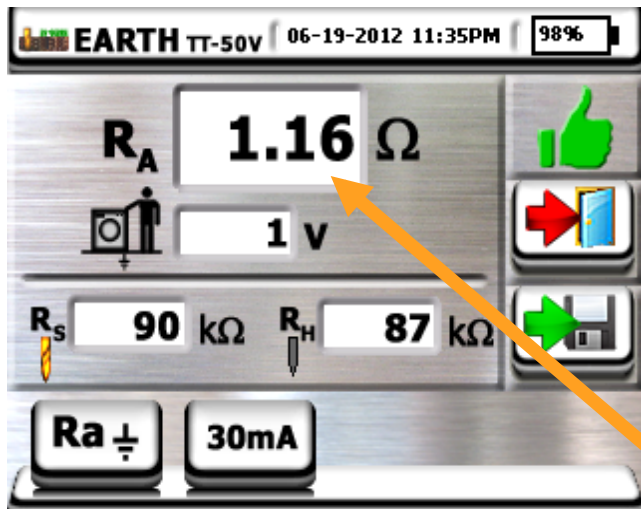
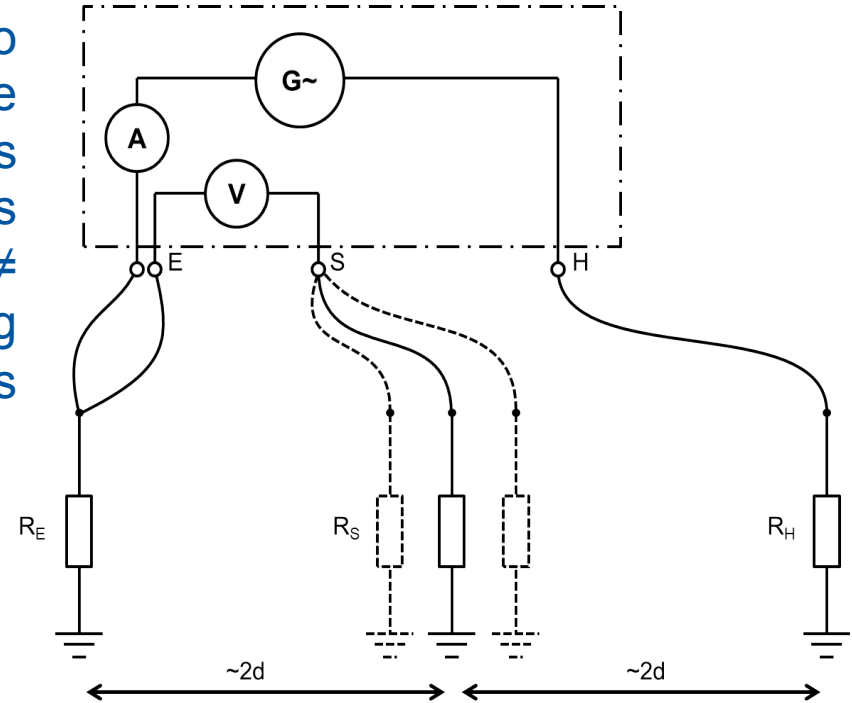
# Electric installation safety

## Measurements and tests



### Measurement of earth electrode resistance using an earth electrode test instrument

To increase the test current it is possible to pour some water into the ground near the auxiliary electrodes. Some guidelines recommend a test frequency  $<150\text{Hz}$ . It is convenient to inject a signal at a frequency  $\neq 50\text{Hz}$  to avoid noise. The 4-wire measuring technique keeps voltage and current circuits separated.



Measured earth resistance



# Electric installation safety

## Measurements and tests



### Measurement of earth electrode resistance using a fault loop impedance test instrument

Measurement of the earth fault loop impedance at the origin of the electrical installation may be carried against the measurement of earth electrode.

The test should be performed on the main switch with the supply to the installation switched ON. The test instrument should be connected to L and PE.

The instrument introduces a load between L and PE generating a voltage drop. Le fault impedance is given by the product of  $(V_{oc} - V_L) / I_L$  where  $V_{oc}$  is the open circuit voltage (no load connected),  $V_L$  is the voltage at the load and  $I_L$  the current flowing through it.

The test result should not exceed the product of  $50 \text{ V} / I\Delta n$ .

It should be noted that the values of resistance obtained using this method will typically be slightly higher (so safer) than those obtained using temporary auxiliary earth electrodes because of the earth loop measurement.



# Electric installation safety

## Measurements and tests

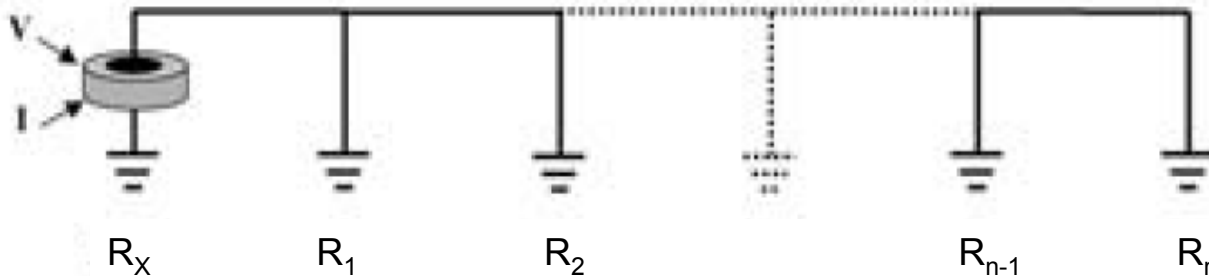


### Earth electrode resistance stakeless measurement

With reference to next figure the first clamp induces a measuring voltage  $U$  into the loop, the second clamp measures the current  $I$  within the loop. The loop resistance is calculated by dividing the voltage  $U$  by the current  $I$ . As the resulting value of parallel resistances  $R_1 \dots R_n$  is normally negligible, the unknown resistance is equal to, or slightly lower than, the measured loop resistance.

The voltage and current coils may be in a single combined clamp or in individual clamps separately connected to an instrument. In this case, while taking the measurement distance between them has to be enough to avoid mutual influence.

This method is directly applicable to TN systems and within meshed earthing of TT systems.







# Electric installation safety

## Measurements and tests



### g) Additional protection

The verification of the effectiveness of the measures applied for additional protection is fulfilled by visual inspection and test.

Where an RCD is required for additional protection, the effectiveness of automatic disconnection of supply by RCD shall be verified using suitable test equipment according to IEC 61557-6.

Where additional protection is provided by supplementary protective bonding, the effectiveness of that bonding shall be checked according to IEC 60364-4-41:2005, 415.2.2.



# Electric installation safety

## Measurements and tests



### h) Phase sequence

In the case of multiphase circuits, it shall be verified that the phase sequence is maintained.



# Electric installation safety

## Measurements and tests



### i) Functional testing

Equipment shall be subjected to functional testing to verify that it is properly mounted, adjusted and installed in accordance with the relevant requirements of the IEC 60364 series.

Examples of such equipment are:

- switchgear and controlgear assemblies, drives, controls and interlocks,
- systems for emergency switching off and emergency stopping,
- insulation monitoring,
- etc.

Protective devices shall be submitted to a test of their function, as necessary, to check that they are properly installed and adjusted. Where fault protection and/or additional protection is to be provided by an RCD, the effectiveness of any test facility incorporated in the device shall be verified.



# Electric installation safety

## Measurements and tests



### j) Voltage drop

Where required to verify compliance with IEC 60364-5-52: 2009, Clause 525, the voltage drop shall be evaluated by measurement or by calculation.

Measurement may be:

- comparison of the difference between the voltage with and without the design load connected, or
- comparison of the difference between the voltage with and without any known load connected and recalculated to the design load, or
- circuit impedance values.



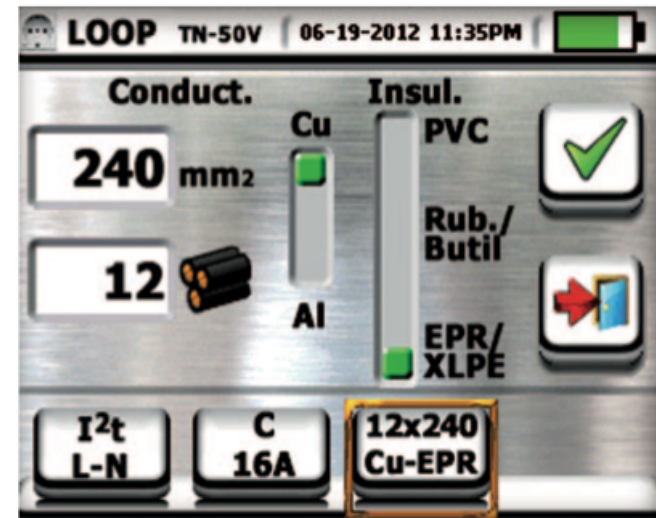
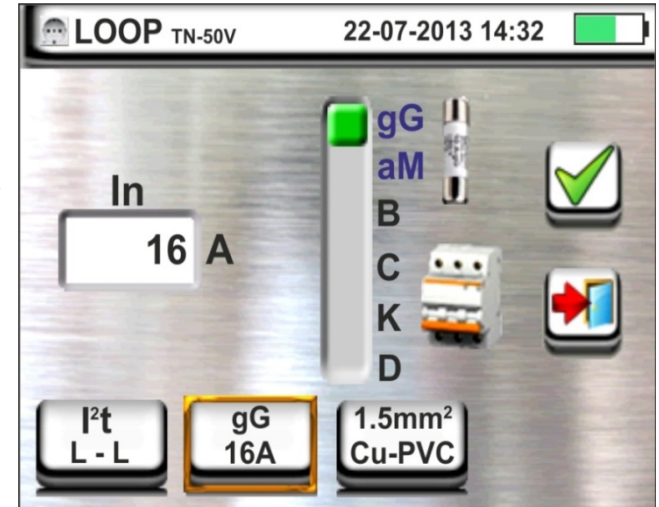
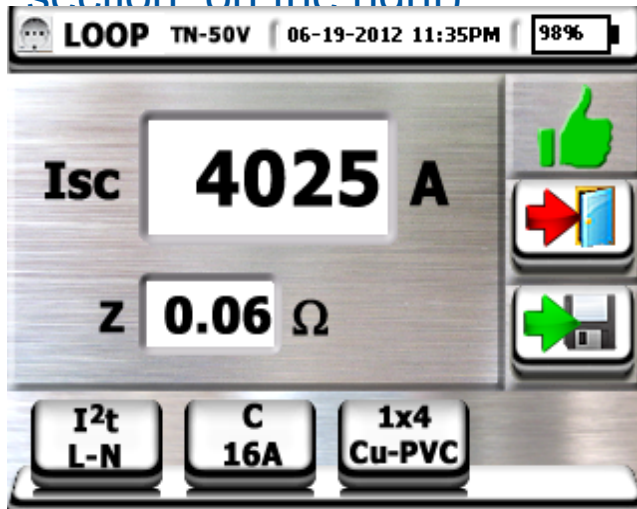
# Electric installation safety

## Measurements and tests



### Protection against short circuit thermal effect

Fuses and MCBs shall trip to protect the cables against fire and thermal effects. To verify the protection(s) and cables match properly, the line/fault impedance shall be measured. The condition  $I_{SC}^2 \times t \leq K^2 \times S^2$  shall be fulfilled, where  $I_{SC}$  is the maximum short-circuit current measured,  $K$  is given by the standards depending on conductive material and insulating sheath material, and  $S$  is the cable cross section (on the right)







# Electric installation safety

## Measurements and tests



### Macrotest series



Macrotest is the first series of combined safety tester with color touchscreen, iOS & Android compatibility, and real-time data upload to HTCLOUD for remote analysis.

MacrotestG3 checks all safety parameters and more, in half the time of a traditional instrument. With its large touch screen display, no time lost in surfing menus.

Beside the required measurements, MacrotestG3 verifies that the MV/HV protections, the system type, and the earth resistance match granting protection against direct contacts, returning the outcome OK/NO accordingly.

While measuring earth ground resistance by stakeless method, MacrotestG3 applies the innovative algorithm HTEarth storing all measures and automatically calculating the overall earth resistance value.

MacrotestG3 can save snapshots of main power quality parameters of single-phase installations.



# Electric installation safety

## Measurements and tests



### Macrotest series

Type A, AC, and B general, selective, and delayed RCDs up to 10A

Type RCD-EV for electric vehicle charging stations

Insulation resistance with 50, 100, 250, 500, 1000V DC

Continuity of protection conductors with 200mA

High resolution line/fault impedance and non-trip fault impedance

Line/fault impedance with short circuit current calculation

Curve B, C, D, and K MCBs and type gG and aM fuses

Selection of length, type, and insulation of cables under test

Selection of tripping time of protection devices under test

I<sup>2</sup>t test of MCB against short circuit thermal effect

Earth resistance and soil resistivity with auxiliary rods

Stakeless earth ground resistance measurement

Phase sequence indication - Leakage current

Power quality analysis, Environmental parameters

Percentage voltage drop

Wi-Fi interface to tablets and smartphones

TFT display with touch-screen

Help on-line - Rechargeable batteries







Thank you