Measurements on electric Installations in theory and practice Instruction manual

Code: 20 750 664

METREL®

1. Preface

1.1. Purpose of the manual “measurements on electric installations in theory and practice”

This manual is designed for electrical engineers who deal with measurements on new or modified low-voltage electrical installations in buildings or with the maintenance of these installations. In the manual the user can find an explanation for many practical problems whilst performing measurements and directions on how to solve the problems by using the measurement instruments produced by METREL d.d.

The main objectives of the manual are :

1. To present the new European standard EN 61557 in a manner which explains the safety of measurement instruments for performing measurements on low-voltage electrical installations. This standard is compulsory for member countries of the EU since 01.12.1997.

2. To describe the performance of individual measurements on an electrical installation. Compulsory and non-compulsory measurements are included which helps to eliminate errors, maintain the installation, and connect loads etc. For each specific type of measurement the measurement principle and practical performance of the measurement are demonstrated in various installation configurations. In addition, other parameters of measurement, various warnings and limit values of the measured parameters are included. All of the measurements are illustrated.

3. To describe the technological approach to the performance of the measurements at the circuit or device under test. We believe that the information offered will help the user(s) to shorten the time which is needed for the preparation and performance of the measurements themselves and recording of the measurement results.

4. To give advice to all potential buyers and users of measurement instruments in order to direct them towards the right choice of measurement equipment.

The full family of the latest measurement instruments produced by METREL d.d. for testing the safety of electrical installations is presented at the end of this manual.

1.2. Presentation of Metrel d. d. and its programme

METREL®

The factory has 42 years experience in the development and production of measuring and regulating equipment. The latest production program is for multitesters to test safety on low-voltage electrical installations, earthing systems and electrical appliances.

240 workers are employed, half of them on the measurement program. 17 engineers are employed in the R & D department.

One of the superior aspects of METREL is the speed at which it completes its development projects so that it takes at most 12 months from the idea to the production of the first series.
With regard to construction of the test equipment, METREL has linked up with The University in Ljubljana and the Ministry of Science and Technology. The results of our R & D activities are shown in numerous patents registered, both at home and in the countries of EU.
New products produced by METREL are launched in the market every year, in 1999 there will be 6 new measurement instruments from the production line. Our calibration laboratory checks each product after completing the production process and the relevant calibration certificates are enclosed.

METREL pays the greatest attention to the relationship with their partners and to the quality of its own products. Certification to ISO 9001 has also been achieved.
The distribution network has been developed in most countries worldwide.

This manual was written to enable better understanding of the problems associated with measurements on low-voltage electrical installations to the end users.
METREL has manufactured a demonstration board that simulates a practical electric installation. It is mainly designed for distributors of measurement instruments to demonstrate the performance of measurements on the installation to their potential buyers. METREL has also been using this board at seminars that are organized to educate/train the users.

2. European standards on measurement instruments

To ensure the conditions for safe usage of electrical energy, safety of electric installations, safety testing and maintenance, great effort was taken in the preparation of the appropriate standards.

The changes to the existing standards, which were well known to the producers and users of measurement equipment, were quite frequent during the preparation of the unified standard.
Although the general safety standard IEC 1010-1 and later harmonized European standard EN 61010 addressed the general safety of electrical measurement instruments, the safety viewpoint for the use of these instruments at low-voltage installations was missing. To ensure that unified principles for the use of measurement instruments taking measurements in electrical installations up to 1000 V a.c. and 1500 V d.c., IEC and CENELEC have prepared and issued the family of standards EN 61557 which to a great part follow the German family of standards DIN VDE 0413. EN 61557 has brought an important solution to this field of operation. For the national committees of individual countries of the European Union the new standards are expressed as follows:

- EN61557 will become the European standard and any national standard that does not comply, or is contradictory to EN61557 will be obsolete.

The introduction of the new standard signified various changes to the construction or the production of measurement instruments. In accordance with the agreement and because each change needs a definite time to come into operation, it was agreed to implement the changes from 1st December 1997.

METREL also took into consideration the demands of the new standard when developing the latest family of measurement instruments.

EN 61557 standard is divided into several parts; each part deals with the safety of the determined measurement at the electric installation as follows:

- EN 61557 Part 2 Insulation Resistance
- EN 61557 Part 3 Fault Loop Impedance
- EN 61557 Part 4 Continuity of Earth Connections and Equipotential Bonding
- EN 61557 Part 5 Earth Resistance
- EN 61557 Part 6 Residual Current Devices (RCD) in TT and TN earthing systems
- EN 61557 Part 7 Phase sequence
- EN 61557 Part 8 Insulation monitoring devices in IT earthing systems

Let’s see the main requirements of the separate parts of EN 61557 standard regarding the performance of measurements and the construction of measurement instrument.

EN 61557 Part 2 Insulation Resistance

- The maximum error should not exceed +/- 30 %.
- DC test voltage should be used.
- In case of 5 μF capacitor connected in parallel with measured resistance (Ri = Un · 1000 Ω/V), the test result should not differ from the one without a capacitor by more than 10 %.
- The test voltage shall not exceed the value of 1,5 · Un.
- The test current flowing to tested resistance of Un · 1000 Ω/V should be at least 1 mA.
- The test current shall not exceed the value of 15 mA_p while a.c. component shall not exceed 1,5 mA.
- External a.c. or d.c. voltage of up to 1,2 · Un connected to test equipment for 10s shall not damage the equipment.

EN 61557 Part 3 Fault Loop Impedance

- The maximum error should not exceed +/- 30 %.
- Test instrument shall give an indication if resistance of test leads is compensated.
- Contact voltage higher than 50 V should not appear during the measurement or the voltage must be terminated within 30 ms.
- An external voltage of up to 120 % of nominal mains voltage, connected to the test equipment, should not damage the equipment or cause any danger for the operator, also the fuse in the test equipment should not blow.
- An external voltage of up to 173 % of nominal mains voltage, connected to the test equipment for 1 min, should not damage the equipment or cause any danger for the operator, but the potential fuse in the test equipment may blow.

EN 61557 Part 4 Earth Connection or Equipotential bonding Resistance

- The maximum error should not exceed +/- 30 %.
- AC or DC test voltage within 4 up to 24 V may be used.
- The test equipment should enable reversing of test voltage polarity if a DC test voltage is used.
- The test current should be higher than 200 mA within the minimum measurement range.
- Minimum measurement range shall include the range 0,2 up to 2 Ω.
- Resolution of 0,01 Ω shall be assured on digital instruments while clear indication of which limit is exceeded shall be present on simple instruments.
- Any compensation of the test leads or additional external resistance must be indicated.

- External voltage of up to 120 % of the nominal mains voltage, connected to the test equipment, should not damage the equipment or cause any danger the for the operator, but the potential fuse in the test equipment may blow.

EN 61557 Part 5 Earth Resistance

- The maximum error should not exceed +/- 30 % under the following conditions:
    - Noise voltage of 3 V / 400 Hz, 60 Hz, 50 Hz, 16,66 Hz or d.c. is connected between E (ES) and S test terminals.
    - Resistance of auxiliary probes is 100 · R_E or 50 kΩ (whichever value is lower).
- AC test voltage should be used.
- The test voltage should be lower than 50 V_{eff} (70 V_p), or test current should be lower than 3,5 mA_{eff} (5 mA_p), or test signal should be present for less than 30ms.
- Test instrument must indicate exceeded resistance of auxiliary test probes.
- External voltage of up to 120 % of the nominal mains voltage, connected to the test equipment, should not damage the equipment or cause any danger for the operator, also the fuse in the test equipment should not blow.

EN 61557 Part 6 RCD test

- The test shall be carried out using AC sine test current.
- The test equipment should enable Contact voltage to be measured and displayed or at least give an indication of the exceeded limit value. The measurement may be carried out with or without an auxiliary test probe. When measuring the tripping current, the Contact voltage shall be scaled to the Tripping current and compared with the limit value.
- The error of Contact voltage measurement should be within 0 to +20 % of the limit value.
- Test equipment should enable Trip out time measurement and / or at least indication of the exceeded limit value.
- When a test is carried out at 0,5 · $I_{\Delta N}$, the test shall last at least 0,2 s, RCD should not trip during the test.
- Test instruments intended to test RCDs with a nominal differential current of 30 mA or less should also allow the tests to be performed at 5 · $I_{\Delta N}$ where the duration is limited to 40 ms. This limit is not relevant if the contact voltage is lower than the limit value (50 or 25V).
- The error of Trip out time measurement should not exceed +/-10 % of the limit value.
- Test equipment should enable Tripping current to be measured and displayed or at least indication of the exceeded limit value.
- The test current at Tripping current measurement should be within $I_{\Delta N}$ and 1,1· $I_{\Delta N}$.
- The test current when testing RCD with half the nominal differential current must be within 0,4 · $I_{\Delta N}$ to 0,5 · $I_{\Delta N}$.
- The error of Tripping current measurement should not exceed +/-10% of the nominal differential current.
- Declaration of errors is valid for normal conditions as follows:
    - There is no voltage at PE conductor.
    - Mains voltage is stable during the measurement.
    - There are no leakage currents on the installation under test.
    - Value of mains voltage during the measurement should be within

85 % to 110 % of nominal mains voltage.
  - Resistance of any auxiliary probe is within the range declared by the producer of test equipment.
- Contact voltage should not exceed 50 V_{eff} (70 V_p) during any test, or test current should not exceed 3,5 mA_{eff} (5 mA_p), or the voltage should last less than 30 ms.
- External voltage of up to 120 % of nominal mains voltage, connected to test equipment, should not damage the equipment or cause any danger for the operator, also the fuse in the test equipment should not blow.
- External voltage of up to 173 % of nominal mains voltage, connected to the test equipment for 1 min, should not damage the equipment or cause any danger for the operator, but the potential fuse in the test equipment may blow.

EN 61557 part 7, Phase sequence

- The test instrument should assure clear indication of phase sequence within the voltage range from 85 up to 110 % of the nominal mains voltage and within the frequency range from 95 up to 105 % of nominal frequency.
- The test instrument should enable either clear acoustic indication (even in presence of sound levels in excess of 75 dB) or clear visual indication (visible from the distance of 50 cm) even at external illumination levels of 30 to 1000 lx.
- Indication of phase sequence shall be continuous.
- The test instrument shall be portable even whilst the test is running. It should be produced in isolation materials of double insulation classification.
- If one or two of the test leads are connected to ground while the other test leads are connected to phase voltage the leakage current should be lower than 3,5 mA (at 110 % of the nominal mains voltage).
- External diameter of test leads shall be at least 3,5 mm, conductor section at least 0,75 mm^2 with diameter of separate wires max. 0,07 mm. Double insulation should be used at test leads.

As can be seen from the above the EN 61557 regulation offers exact requirements for the construction of measurement instruments. Some requirements are just adapted whilst others are completely new in comparison with previous regulations. That is why it is very important for all end users and distributors to verify that their test equipment conforms to the EN 61557 regulation.

3. European standards on electrical installations

This domain is covered on an international level by *the* IEC 60364-x regulation whilst on a European level *the* relevant regulation is issued in harmonized form as HD 384-x standard.
Individual countries have their own national regulations, some are listed below.

- Germany .... VDE 0100 - x (it is mostly identical with individual parts of European harmonized regulation HD 384 - x).
- England .... BS 7671: Requirements for Electric installations
  IEE Wiring Regulations
  16th edition
  interpretation brochures:
  HB 10011
  HB 10116 ÷ HB 10121
  HB 10123
- Austria .... ÖNORM B 5430 ÷ ÖNORM B 5435
- France .... NF C15 - 100
- Spain .... UNE 20 - 460 - x - x
- Italy........................ CEI 64 - 8
- Check Republic ..... ČSN 33 2130
  ČSN 2000 - x - x
- Finland .... SF S 5825
- Norway .... TH 30995

4. General comments on electrical installations

The figure below shows the installation to be discussed in detail. It shows the limit line between the electrical supply network and the electrical installation in the building.

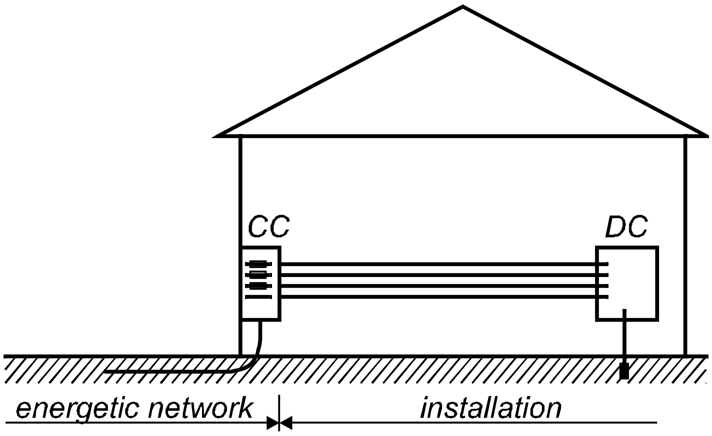


Fig. 1. Division between the electric installation and supply network

CC …………………. Connection cabinet
DC …………………. Distribution cabinet

Some measurements, which are carried out at the installation also, include a part of the supply network and source (e.g. Line and Fault Loop Impedance measurement, Earth Resistance measurement at the TN systems etc.)

The construction of an electrical installation is determined by standards. Generally the installations are divided into groups dependant upon the usage, the voltage shape, the type of earthing system etc.

With regard to the usage of installations, they are divided into:

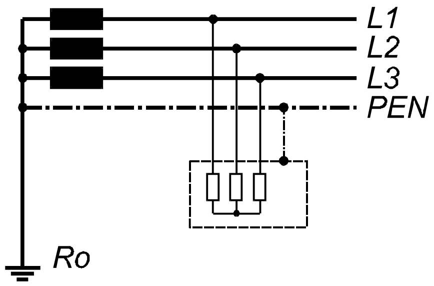
- **Low-voltage installations in buildings** for a.c. voltages up to 250 V with respect to earth (residential premises, business rooms, lodging houses, schools, public places, rural buildings etc.)
- **Low-voltage installations in industry** for a.c. voltages up to 600 V with respect to earth or d.c. voltages up to 900 V (electromotive drives, electromechanical processing machines, heating systems etc.)
- **Installations for safe voltages**, this is a voltage up to 50 V a.c. or up to 120 V d.c.(telephony, public address systems, aerial network, intelligent installations, safety systems, speech devices, local network etc.)

Concerning the voltage shape the installations can be as follows:

- **Installations for a.c. voltages**
- **Installations for d.c. voltages**

Concerning the relevant Earthing system (neutral point of the supply transformer and accessible conductive parts of loads and appliances), the installations can be divided as follows:

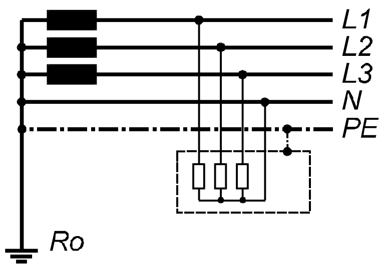
a) TN-C - system



- *Neutral point of energetic transformer is earthed*
- *Accessible conductive parts are connected to common PEN conductor*

Fig. 2. TN-C - system

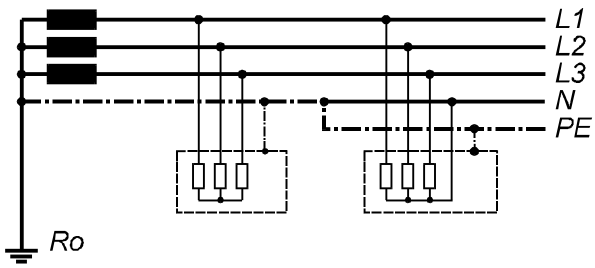
b) TN-S - system



- *Neutral point of energetic transformer is earthed*
- *Accessible conductive parts are connected to PE conductor*

Fig. 3. TN-S - system

c) TN-C-S - system

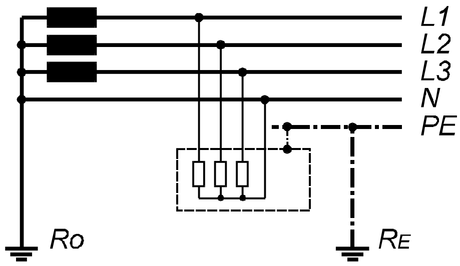


- *Neutral point of energetic transformer is earthed*
- *Accessible conductive parts are connected partially to common PEN conductor and partially to protection PE conductor*

Fig. 4. TN-C-S – system

When installing TN-C-S – system it is important to know that N and PE conductors should not be connected together again once *the* PEN conductor is separated from *the* N and PE.

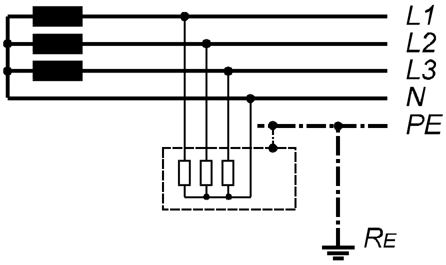
d) TT - system



- *Neutral point of energetic transformer is earthed*
- *Accessible conductive parts are connected dirrectly to autonomous earthing*

Fig. 5. TT - system

e) IT - system



- *Neutral point of energetic transformer is not earthed*
- *Accessible conductive parts are earthed*

Fig. 6. IT – system

Basic expressions which will often be used in electrical testing

- **Active accessible conductive part** is the conductive part of an electrical installation or appliance such as the housing, part of a housing etc. which can be touched by a human body. Such an accessible part is free of mains voltage except under fault conditions.
- **Passive accessible conductive part** is an accessible conductive part, which is not a part of an electrical installation or appliance (heating system pipes, water pipes, metal parts of air condition system, metal parts of building framework etc.).
- **Electric shock** is the pathophysic effect of an electric current flowing through a human or animal body.
- **Earthing electrode** is a conductive part, or a group of conductive parts, which are placed into earth and thus assure a good and permanent contact with ground.
- **Nominal voltage (Un)** is the voltage which electrical installations or components of electrical installations, such as appliances, loads etc. are rated at. Some installation characteristics also refer to nominal voltage (e.g. power).

- **Fault voltage (Uf)** is the voltage that appears between the active accessible conductive parts and the passive ones or ideal ground in the case of a fault on appliances connected to the mains installation (connected appliance). The figure below represents the Fault voltage (Uf) and division of the voltage into the Contact voltage (Uc) and voltage drop on floor/shoes resistance (Us).

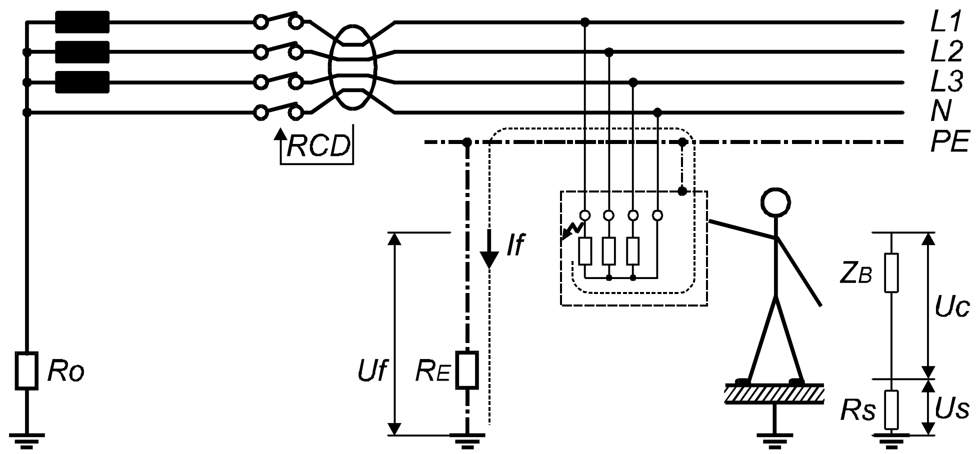


Fig. 7. Presentation of the voltages Uf, Uc and Us in case of a fault on an electric load

Z_B .... Impedance of human body.
Rs......... Floor and shoes resistance.
R_E......... Earth Resistance of active accessible conductive parts.
If .... Fault current.
Uc......... Contact voltage.
Us......... Voltage drop on floor/shoes resistance.
Uf.......... Fault voltage.

$Uf = Uc + Us = If \times R_E$ (floor material is placed to ideal ground)

- **Contact voltage (Uc)** is the voltage to which a human body is exposed when touching an active accessible conductive part. The body is standing on the floor or is in contact with passive accessible conductive part.
- **Limit Contact voltage (U_L)** is the maximum Contact voltage which may be continuously present under certain external conditions e.g. presence of water.
- **Nominal load current (In)** is the current that flows through the load under normal operating conditions and at nominal mains voltage.
- **Nominal installation current (In)** is the current that the installation draws under normal operating conditions.
- **Fault current (If)** is the current that flows to active accessible conductive parts and then to ground in case of a fault on a mains appliance.
- **Leakage current (I_L)** is the current that usually flows through isolation materials or capacitive elements to ground in normal conditions.
- **Short-circuit current (Isc)** is the current that flows in a short circuit between two points of different potential.

5. Measurements on electrical installations in buildings

In addition to conducting measurements it is also vital to ensure that various visual checks are undertaken (correct colour of insulation, conductor size, correct earth bonding and equalizing, quality of materials used etc.). Also, that functional tests such as direction of motor rotation, operation of lamps, heating systems etc., are carried out when taking over the responsibility of an electrical installation.
Only the theory and practice of measurements will be considered further in this manual.
All measured results must be correct regardless of the measurement instrument used and regardless of the measurement parameter (Insulation Resistance, Earth Resistance, Fault Loop Impedance etc.) before collating/comparing them with the allowed values.
Correction is needed because of measurement errors. The EN 61557 standard states the maximum allowed deviations for a separate parameter. The allowed deviation and therefore the required correction of measurement results are shown in the table below.

Parameter	Allowed deviation	Required correction of measurement result
Insulation Resistance	+/- 30 %	R × 0,7
Fault Loop Impedance	+/- 30 %	Z × 1,3
Resistance of protection conductors, conductors for main and additional equalizing and earthing conductors	+/- 30 %	R × 1,3
Earth Resistance	+/- 30 %	R × 1,3
Contact voltage	+20/-0 % of U_L	R + 5V (U_L= 25V) R + 10V (U_L= 50V)
RCD Trip out time	+/- 10 % of t_L	R + 0,1t_L (standard RCD) R + 0,1$t_{L\,max}$. (Sel. RCD) R – 0,1$t_{L\,min}$. (Sel. RCD)
RCD Tripping current	+/- 10 % of $I_{\Delta N}$	R + 0,1$I_{\Delta N}$ (upper limit) R – 0,1$I_{\Delta N}$ (lower limit)

Table 1. Correction of measurement results

where:
R....................Measurement result obtained by measurement instrument
U_L ....Limit contact voltage (25 or 50V)
t_L....................Limit value of RCD Trip out time
t_{Lmax} ....High limit value of RCD Trip out time
$t_{L\,min}$ ....Low limit value of RCD Trip out time
$I_{\Delta N}$..................Nominal differential current of RCD
The limits and values referred to in this table are the extreme limits, a skilled engineer with a thorough knowledge of his test equipment and its accuracy should be able to make measurement and corrections much closer to the ideal levels.

5.1. Insulation resistance EN 61557- 2

Appropriate Insulation Resistance between live parts and active accessible conductive parts is a basic safety parameter that protects against direct or indirect contact of the human body with mains voltage. Insulation Resistance between live parts, which prevents short circuits or leakage currents, is also important.

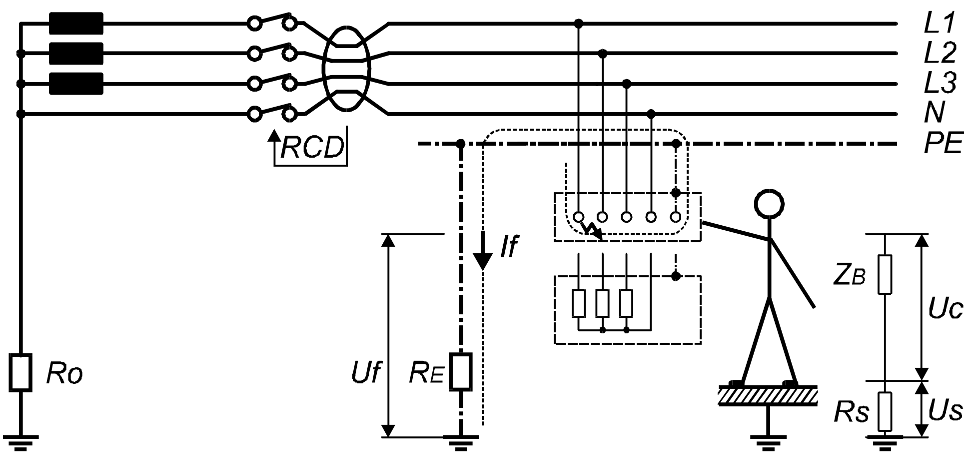


Fig. 8. An example of bad insulation in connection box for permanent connection of a load and resulting fault voltage Uf

If................ Fault current.
Uc .... Contact voltage.
Us .... Voltage drop on floor and shoes resistance.
ZB.............. Impedance of human body.
Rs .... Floor and shoes resistance.
RE .... Earth resistance of active accessible conductive parts.
Uf.............. Fault voltage.

$U_f = U_c + U_s = I_f \cdot R_E$

The upper figure represents a connection box with bad insulation material between phase conductor and the metal housing. Due to this situation, there is a fault current If flowing to *the* protection conductor via earth resistance to ground. Voltage drop on the earth resistance RE is called Fault voltage.

Different insulation materials are used in different cases such as cables, connection elements, insulation elements in distribution cabinets, switches, outlets, housings etc. Regardless of the material used, the Insulation Resistance should be at least as high as that required by *the* regulations, this is why it must be measured.

General comments on Insulation Resistance measurement
Measurements of Insulation Resistance are to be carried out before the first connection of mains voltage to the installation. All switches shall be closed and all

loads disconnected, enabling the whole installation to be tested and ensuring that the test results are not influenced by any load.

Measurement principle is presented in the figure below:

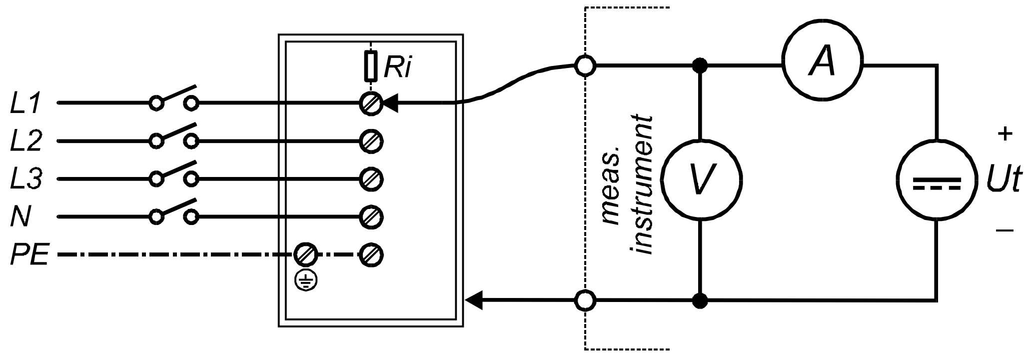


Fig. 9. Insulation Resistance measurement principle

U-I method is used.

Result = Ut / I = Ri

where:
Ut .... DC test voltage measured by the V-meter.
I................. Test current driven by a d.c. generator through insulation resistance Ri
(according to EN 61557 standard, the generator should drive a test current of at least 1 mA at the nominal test voltage). The current is measured by the A-meter.
Ri............... Insulation Resistance.

The value of test voltage depends on the nominal mains voltage of the installation under test. When using the Eurotest 61557, Instaltest 61557 or Earth – Insulation Tester test instrument, the test voltage can be as follows:

- 50 Vd.c.
- 100 Vd.c.
- 250 Vd.c.
- 500 Vd.c.
- 1000 Vd.c.

The Instaltest 61557 and Earth – Insulation Tester can, in addition to the voltages listed above, supply any test voltage within the range from 50, up to 1000 V in steps of 10 V.
Prescribed nominal test voltages, defined by nominal mains voltage, are listed in table 2.
All measurements must be brought into tolerance before a record is taken – see chapter 5.

5.1.1. Measurement of Insulation Resistance between conductors

The measurements are to be performed between all the conductors as follows:

- Separately, between each of the three phase conductors L1, L2 and L3 against neutral conductor N.
- Separately, between each of the three phase conductors L1, L2 and L3 against protection conductor PE.
- Phase conductor L1 separately against L2 and L3.
- Phase conductor L2 against L3.
- Neutral conductor against protection conductor PE.

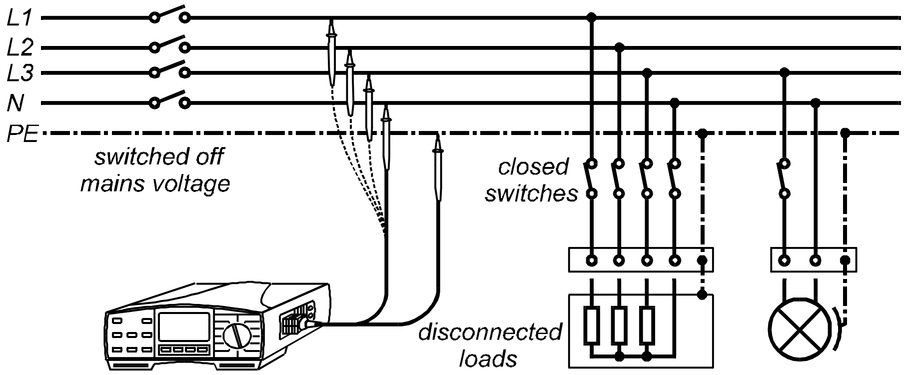


Fig. 10. An example of Insulation Resistance measurement between the PE and other conductors using the Eurotest 61557, Instaltest 61557 or Earth – Insulation Tester

Notes!

- Switch off mains voltage before starting the measurements!
- All switches should be closed during the test!
- All loads should be disconnected during the test!

The lowest values of insulation resistances are defined by regulations and are presented in the table below.

Nominal mains voltage	Nominal d.c. test voltage (V)	Lowest allowed Insulation Resistance (MW)
Safe low voltage	250	0,25
Voltage up to 500 V except safe low voltage	500	0,5
Over 500 V	1000	1,0

Table 2. The lowest allowed values of Insulation Resistance measured between mains conductors

5.1.2. Resistance measurement of non-conductive walls and floors

There are certain situations where it is desirable for a room to be totally isolated from the Protective Earth conductor (e.g. for conducting special tests in a laboratory etc.). These rooms are regarded as an electrically safe area and the walls and floor should be made of non-conductive materials. The arrangement of any electrical equipment in those rooms should be of such a manner that:

- It is not possible for two live conductors, with different potentials, to be touched simultaneously in the case of a basic insulation fault.
- It is not possible for any combination of active and passive accessible conductive parts to be touched simultaneously.

A protection conductor PE that could drive a dangerous fault voltage down to the ground potential is not allowed in non-conductive rooms. Non-conductive walls and floors protect the operator in case of a basic insulation fault.

The resistance of non-conductive walls and floors shall be measured with an Insulation Resistance tester using the procedure described below. Special measurement electrodes described below are to be used.

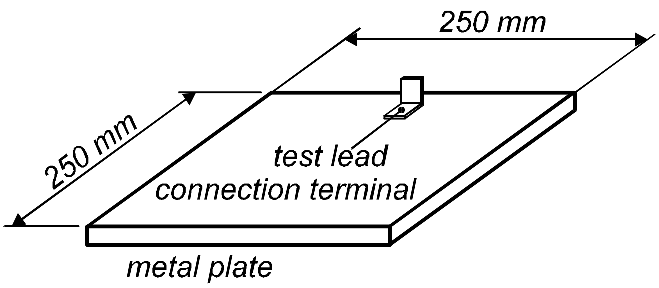


Fig. 11. Measurement electrode

The measurement is to be carried out between the measurement electrode and the protection conductor PE, which is only accessible outside of the tested non-conductive room.

To create a better electrical contact, a wet patch (270 mm × 270 mm) shall be placed between the measurement electrode and the surface under test. A force of 750N (floor measurement) or 250N (wall measurement) shall be applied to the electrode during the measurement.

The value of test voltage shall be:

- 500 V............. where the nominal mains voltage with respect to ground is lower than 500 V
- 1000 V........... where the nominal mains voltage with respect to ground is higher than 500 V

The value of the measured and corrected test result (see chapter 5.) must be higher than:

- 50 kΩ .... where the nominal mains voltage with respect to ground is lower than 500 V
- 100 kΩ........... where the nominal mains voltage with respect to ground is higher than 500 V

Notes!

- It is advisable that the measurement to be carried out using both polarities of test voltage (reversed test terminals) and the average of both results be taken.
- Wait until the test result is stabilized before taking the reading.

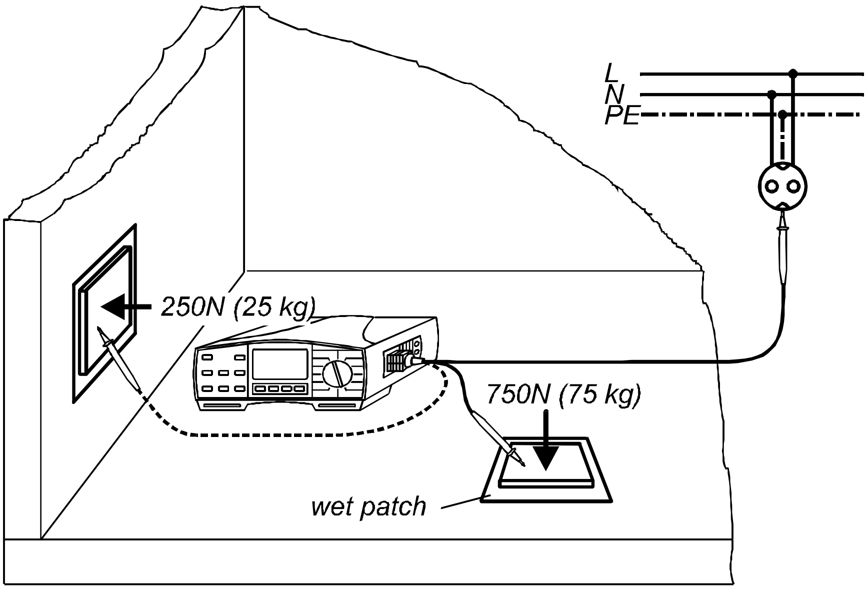


Fig. 12. Resistance of walls and floor measurement using Eurotest, Instaltest or Earth-Insulation tester.

5.1.3. Resistance measurement of semi-conductive floors

In some instances such as explosive-safe areas, inflammable material storehouses, lacquer rooms, sensitive electronic equipment production factories, fire endangered areas etc., a floor surface with a specific conductivity is required. In these cases the floor successfully prevents the build-up of static electricity and drives any low-energy potentials to ground.
In order to achieve the appropriate resistance of the floor, semi-conductive material should be used. The resistance should be tested using an Insulation Resistance tester with a test voltage within 100 up to 500 V.
A special test electrode defined by regulation is to be used, see the figure below.

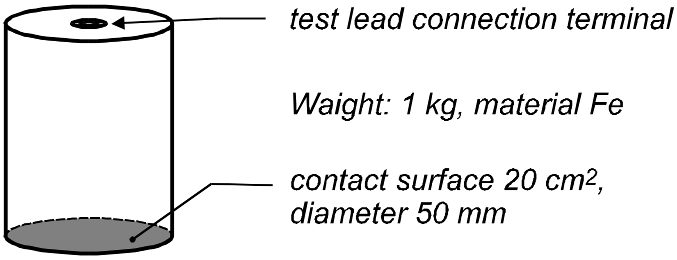


Fig. 13. Test electrode

Measurement procedure is presented on the figure below. The measurement should be repeated several times at different locations and an average of all *the* results taken.

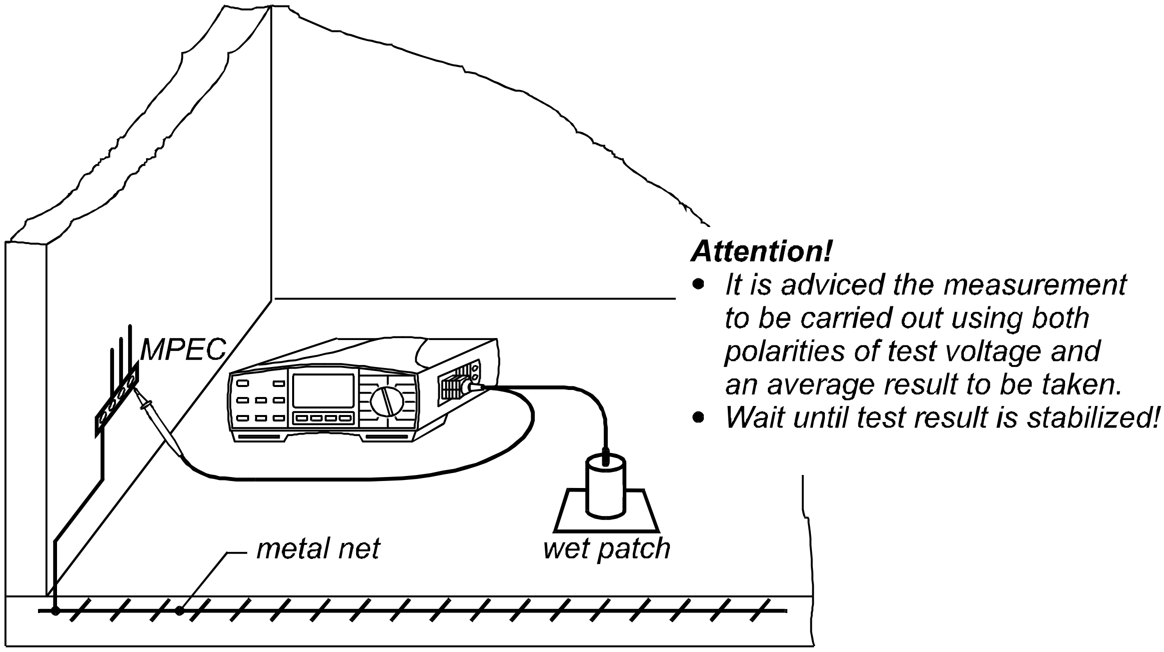


Fig. 14. Measurement of semi-conductive floor resistance

The measurement is to be carried out between the test electrode and metal network installed in the floor, which is usually connected to *the* protection conductor PE. Dimension of the area, where measurements are to be applied, should be at least 2 × 2m.

5.1.4. Insulation Resistance measurement on ground cables - 30 GW

The measurement is to be carried out the same way as between conductors on *the* installation, except that the test voltage shall be 1000 V because of the extreme conditions that such a cable should withstand. T*he* Insulation Resistance test shall be performed between all conductors at disconnected mains voltage.
Because of high Insulation Resistance values, the Earth – Insulation Tester is recommended to be used. The instrument allows measurements up to 30 GΩ.

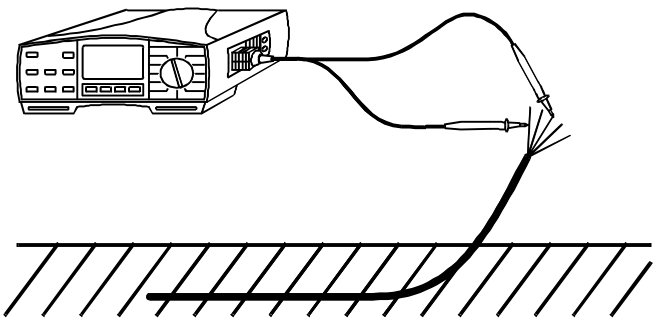


Fig. 15. Insulation Resistance on ground cable measurement using the Earth – Insulation Tester

5.2. Continuity of protection conductors, conductors for main and additional equalizing and earthing conductors <u>EN 61557- 4</u>

The above mentioned conductors are an important part of the protection system that prevents build-up of dangerous fault voltages (dangerous from the aspect of duration as well as absolute value). These conductors can only successfully serve their purpose if they are of the correct size and properly connected. This is why it is important to test the continuity and bond resistances.

General comments about the measurement

According to regulations, the measurement should be carried out using either an a.c. or d.c. test voltage with a value between 4 and 24 V. *The* test instruments produced by METREL use d.c. test voltage and U-I method. The principle of the measurement is presented on the figure below.

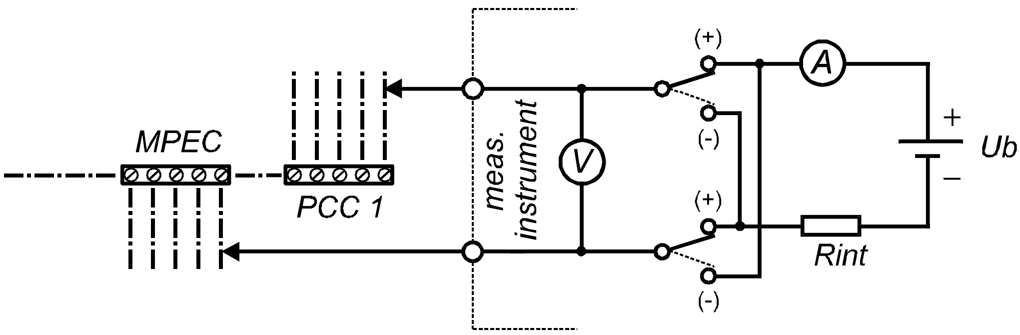


Fig. 16. Measurement principle

The battery voltage drives a test current into the tested loop via the A-meter and internal resistance Rint. The voltage drop is measured by the V-meter. Resistance Rx is calculated on the basis of the equation below:

Different junctions, usually rusty, may be involved in the tested loop. The problem with such junctions is that they may behave as a galvanic element, where resistance depends on the test voltage polarity (diode). That is why *the* regulations require test instruments to support the reversal of the test voltage. Up-to-date test instruments such as the Eurotest 61557, Instaltest 61557 or Earth – Insulation Tester will perform the measurement automatically with both polarities. Because of the two test voltage polarities, two subresults are available as follows:

Result (+) **= U / I = Rx** (+)..... switch is in full-line position (fig. 16)
Result (-) **= U / I = Rx** (-)....... switch is in interrupted-line position (fig. 16)

where:
U .... Voltage drop measured by the V-meter on the unknown resistance Rx.
I .... Test current driven by the battery Ub and measured by the A-meter.

Final result (highest value) is displayed.

If *the* test result is higher than *the* set limit value (the value is pre-settable), the instrument will give an acoustic warning signal. The purpose of the signal is so that measurer can be focused on his use of the test leads and not on the display.

In practice, different levels of inductance may be present on the protective conductors (motor windings, solenoids, transformers etc.) and may affect the tested loop. It is important that the test instrument is able to measure the resistance in these circumstances. The Eurotest 61557, Instaltest 61557 and Earth – Insulation Tester can all measure it.

Conductors that are too long, too small cross-sections, bad contacts, wrong connections etc, may cause unacceptably high resistance of protection conductors.

Bad contacts are the most common reason for high resistance, especially on old installations whilst the other reasons listed may cause problems on new installations.

As the measurements of protection conductors may be quite complex, three main groups of measurements are made:

- Measurements of protection conductors connected to Main Protective Earth Connector (MPEC).
- Measurements of protection conductors connected to Protection Conductor Connector (PCC) inside individual fuse cabinet.
- Measurements of protection conductors for additional and local earthing.

Presentation of practical measurement

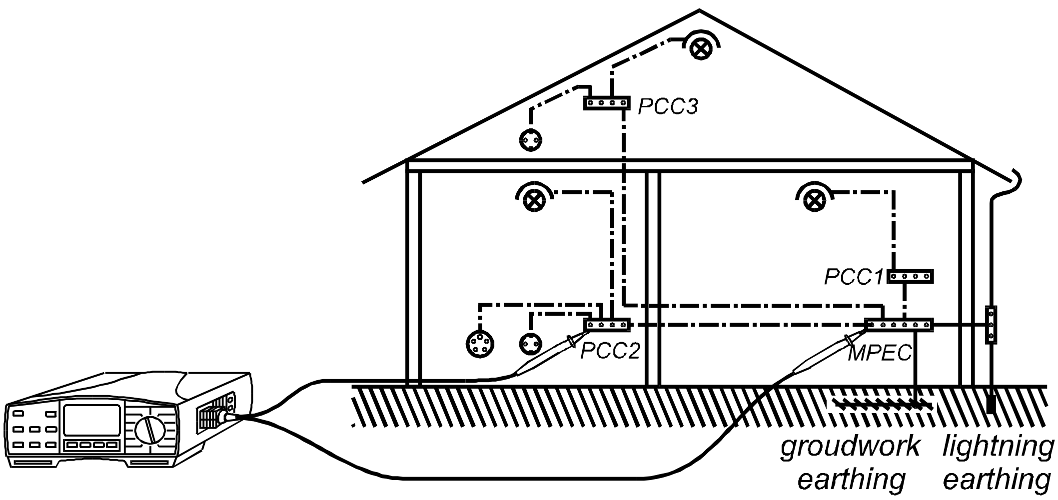


Fig. 17. Continuity measurement between MPEC and PCC

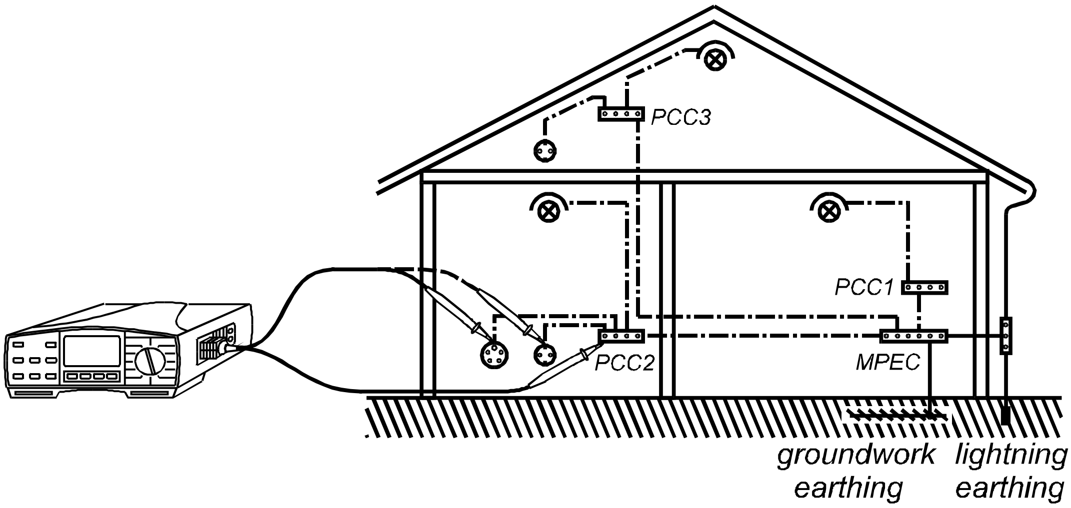


Fig. 18. Continuity measurement inside individual fuse cabinet (each current loop should be measured)

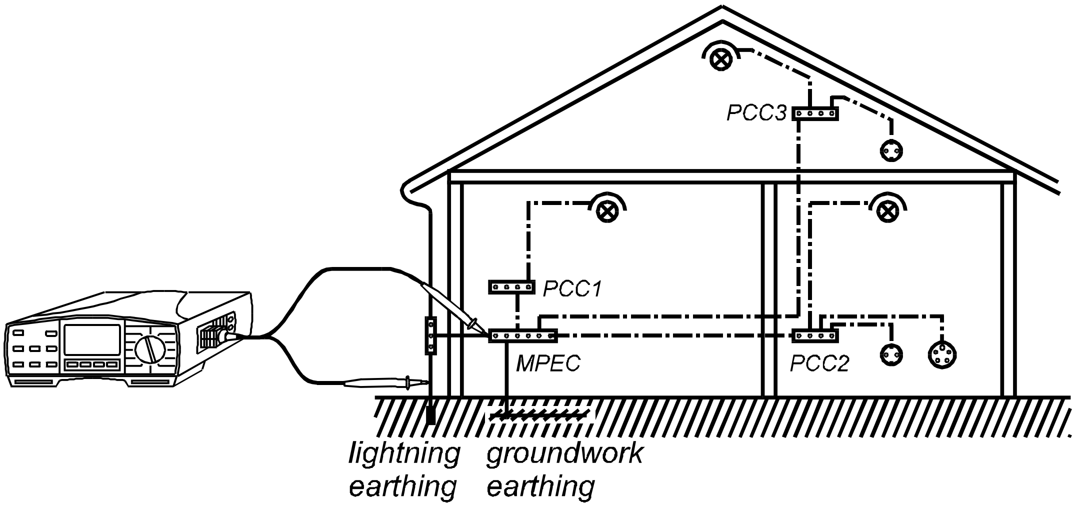


Fig . 19. Continuity measurement between MPEC and lightning conductor

Result of the measurement should correspond to the following condition:

$R_{PE} \leq U_L / I_a$

where:
R_{PE} .... Measured resistance of protection conductor.
U_L .... Limit contact voltage (usually 50 V).
I_a.................... Current which assures operation of installed protection device.

- $I_a = I_{\Delta n}$ Differential current protection - RCD
- $I_a = I_a$ (5s) Over-current protection

Because the conductors under test may be of considerable length, it may be necessary for the test leads also to be quite long and therefore have a high resistance, so it is important to ensure that the leads are compensated for prior to the measurement being carried out. If compensation is not carried out, the resistance should be taken into account in the final results.

5.3. Additional earth bonding EN 61557- 4

Where the main earthing is insufficient to prevent dangerous fault voltages from arising, additional earth bonding is to be applied. An example of main and additional earth bonding is shown below.

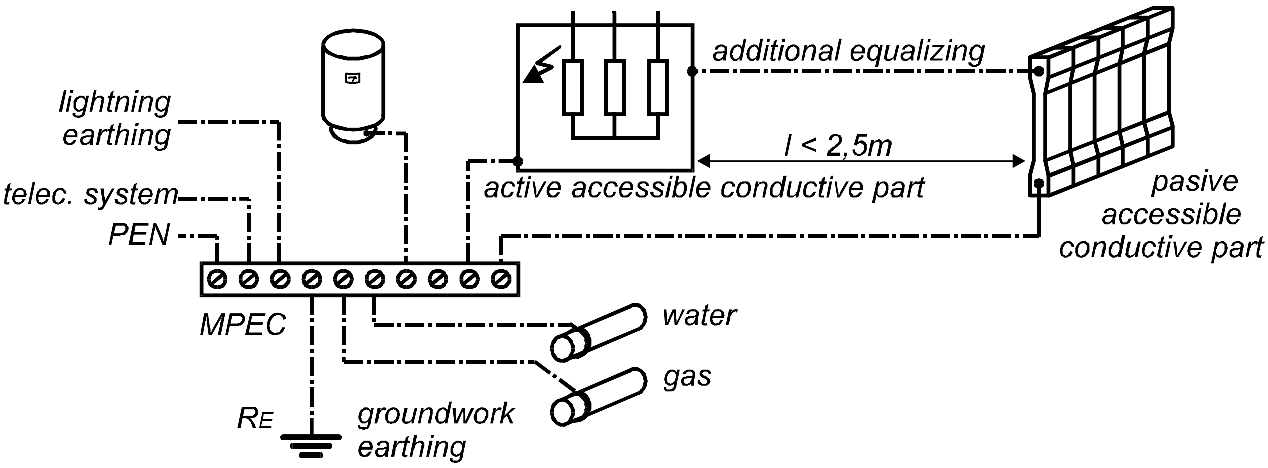


Fig. 20. Main and additional earth bonding

Main earthing consists of protection conductors connected directly to:

- Main MPEC or
- Protection Conductor Collector PCC

Protection conductors for additional equalizing connect *the* passive accessible conductive parts:

- directly with *the* active accessible conductive parts or
- with Connectors for Additional Earthing (CAE)

If a fault (short circuit) is present on any load e.g. *the* three-phase motor presented on the figure above, *the* short-circuit current Isc could flow to *the* protection conductor for main earthing. The current could cause a dangerous voltage drop Uc (against ground potential) due to too *the* high resistance of *the* protection conductor R_{PE}. As nearby passive accessible conductive parts (e.g. radiator) are still connected to ground potential, the voltage Uc will be present between the passive and active accessible conductive parts. If *the* distance between the parts is lower than 2,5 m, then there is a hazardous sitution (simultaneous touching of both accessible parts).

In order to avoid such a situation, additional earthing is required, which means that an additional connection between the active and passive accessible conductive parts is required.

How to ascertain the need for additional earthing

In order to ascertain the need for additional earthing, the resistance of the protection conductor from active accessible conductive part to the MPEC (PCC) should be measured, see the figure below.

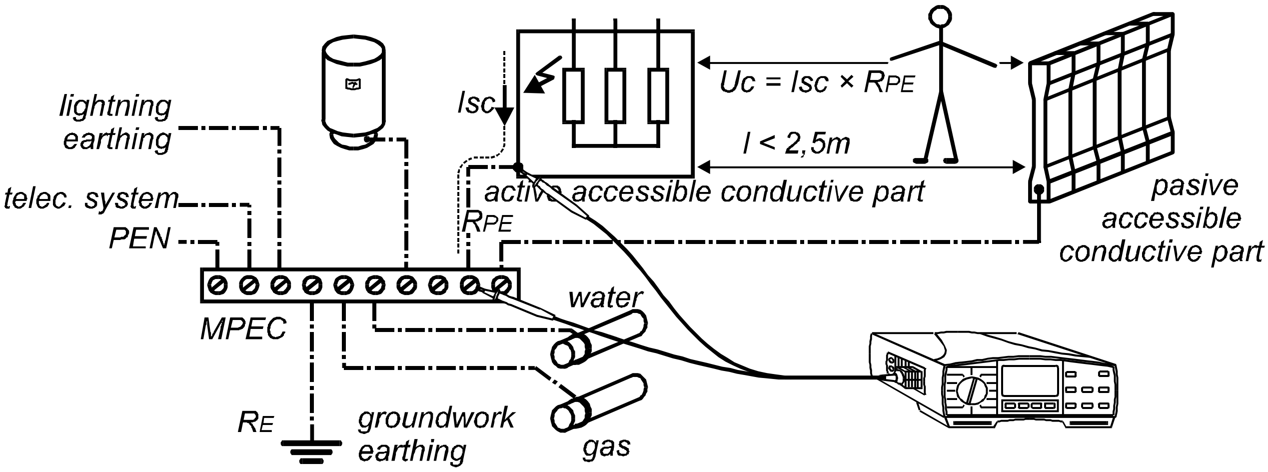


Fig. 21. Protection conductor measurement in order to ascertain the need for additional equalizing

If *the* test result is not in accordance with that required by the equation on page 26, additional earthing should be applied.

Once additional earthing is applied, the efficiency of that earthing should be tested. The test will be done by measuring *the* resistance between the active and passive accessible conductive parts again, see the figure below. The result must correspond to the same condition as in *the* basic measurement namely:
R £ U_L / I_a (see the description on page 26)

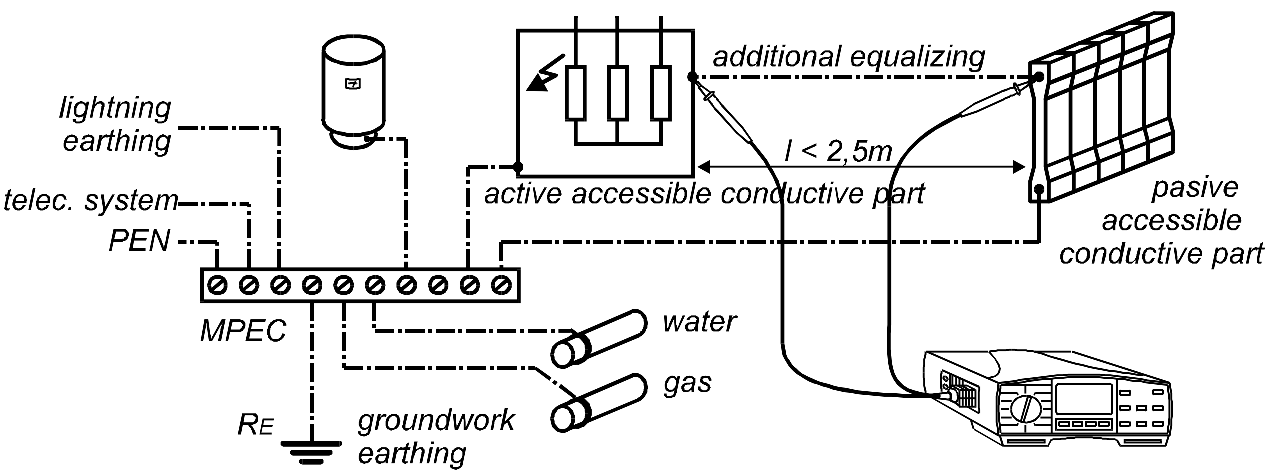


Fig. 22. Checking of efficiency of additional earthing

In practice the resistance level of *the* main earthing may easily be exceeded, especially in case of over-current protection. In that case only low resistances are allowed due to possible high fault (short-circuit) currents.

Test instrument Eurotest 61557 can also perform direct measurement of Contact voltage at Short-circuit current against passive accessible conductive parts. The connection of *the* test instrument and *the* measurement principle is detailed below.

Measurement of the Contact voltage at Short-circuit current against passive accessible conductive parts

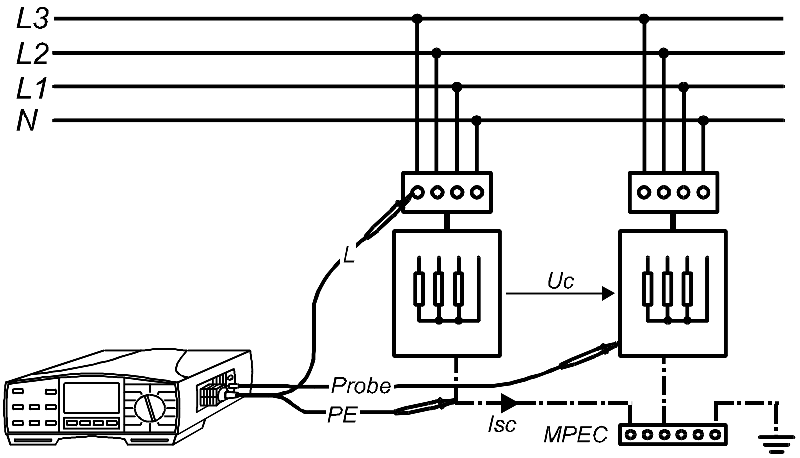


Fig. 23. Measurement of Contact voltage at Short-circuit current against passive accessible conductive parts using the Eurotest 61557 test instrument

The instrument will heavily load the mains voltage between the phase L and protection PE test terminals for a short period (test current of up to 23 A may flow). The test current will cause a specific voltage drop on the protection conductor connected between the tested load and the MPEC (PCC). The voltage drop is measured directly against another active or passive accessible conductive part, between the PE and Probe test terminals. The measured result is scaled to short-circuit fault current calculated by the test instrument.

On basis of the result the need for additional earthing may be established.

A good feature of the measurement is the high accuracy of test result due to the high test current, but the operator must be aware that the measurement can be done only if there is no RCD involved in the tested loop which would certainly trip during the measurement. RCD must be shorted in that case.

5.4. Low resistances

This function is useful when maintaining electrical installations and appliances, checking fuse condition, searching for different connections etc. The advantage of the function against the one for testing of protection conductors according to EN 61557 (described in *the* previous chapter) is that the function is continuous (low test current and no reversing of test voltage polarity) and is intended for quick tests. Test instruments Eurotest 61557, Instaltest 61557 and Earth -– Insulation Tester all offer this function.

The measurement principle is presented on the figure below.

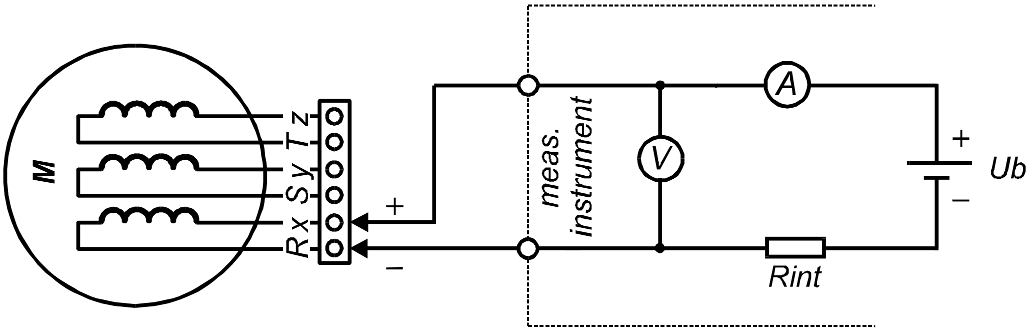


Fig. 24. Measurement principle

The battery imposes a test current on the tested loop via internal resistance Ri and
A-meter. Voltage drop caused on tested resistance is measured by the V-meter. Instrument calculates tested resistance on basis of the following equation:

Rx = U / I

where:
U............... Voltage measured by the V-meter.
I................. Test current measured by the A-meter.

The instrument’s internal resistance is higher in comparison with that from *the* previous function (EN 61557) this is why *the* test current is much lower (lower than 7 mA).

Measurement procedure and connection of test leads is exactly the same as in previous function.

If the measured resistance is lower than 20 Ω, the instrument will give an acoustic signal enabling the measurer to focus on the measurement itself and not on the display.

5.5. Earthing resistance EN 61557-5

Earthing is one of the most important considerations in the protection of humans, animals and in the installation of connected loads against the influences of electric current. The reason for earthing of active and passive accessible conductive parts of electrical loads is to conduct the possible electrical potential, which may appear during any fault on the electrical loads, to the earth level.
The earthing can be executed in various ways. Normally it is done by metal rods, bands, metal plates etc.

The complexity of earthing depends on the ground, the object which has to be earthed and by the maximum earthing resistance which is allowed in any particular case.

What is Earth Resistance?

This is the electrical resistance of the earthing electrode which the electric current feels whilst running through the earthing part to ground. It is influenced by the surface of the earthing electrode (oxides on the metal surface) and by the resistance of the ground mainly near to the surface of the earthing electrode.

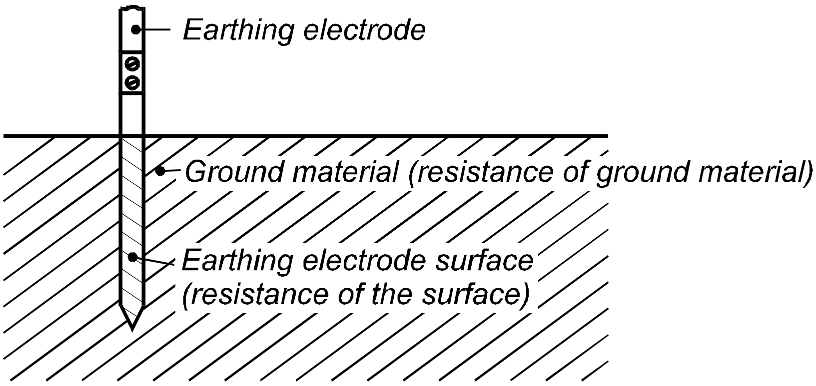


Fig. 25. Earthing electrode

If there is an existing fault on an installation or connected load, the current, which runs through the earth electrode, causes a voltage drop at the earthing resistance. A portion of this voltage is called ‘the voltage funnel’ and proves that the majority of the earth resistance is concentrated on the surface of the earth electrode (see figure below).

Step and Contact voltages arising as a result of current flowing through the earthing resistance are also shown.

Step voltage
Is measured throughout the critical area around the earthing electrode. The measurement is done between two metal measurement electrodes of 25 kg each and an appropriate surface of 200 cm_2 each. The two electrodes are placed 1 m away from each other.

Contact voltage
Is measured between the earthing electrode and two measurement electrodes (similar to the ones at Step voltage measurement) connected together and placed 1m away from tested earthing electrode.

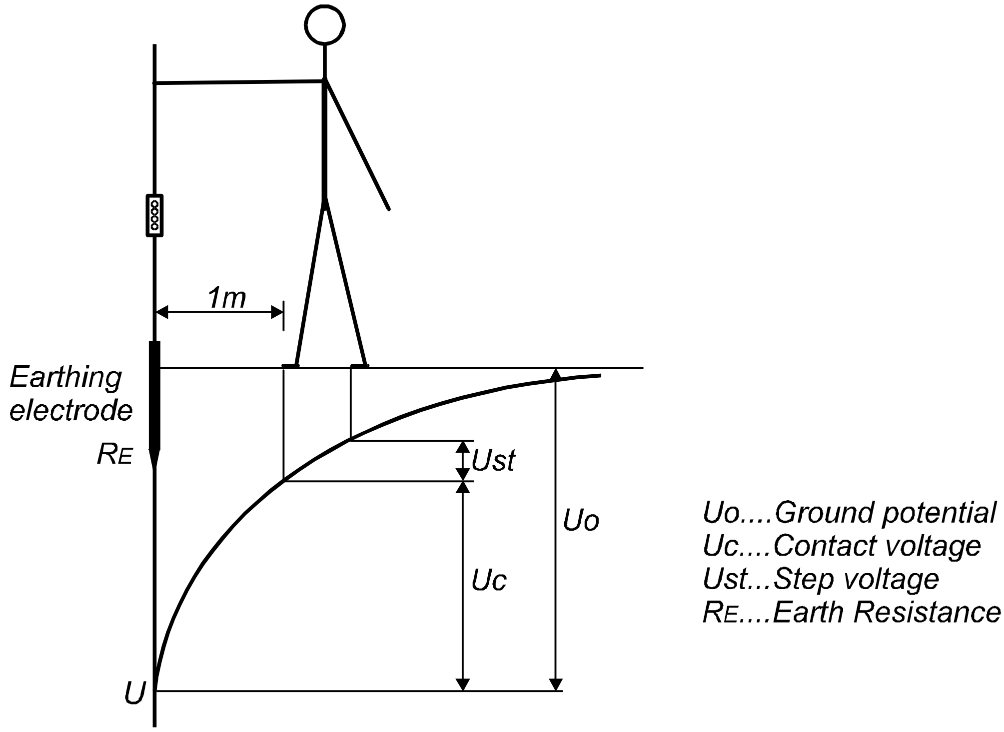


Fig.26. Voltage apportion across the Earth Resistance - voltage funnel

General considerations on Earth Resistance measurement

There are various earthing systems frequently met by the user, and different measurement principles with their own advantages and limits.
The measurement instruments Eurotest 61557, Instaltest 61557 and Earth – Insulation Tester produced by METREL use several principles (not all the principles are used by all test instruments) eg.:

- **Principle with internal generator (sine wave) and two measurement probes.**

  The use of a sinewave measurement signal presents a distinct advantage compared with the use of a squarewave. This is of particular use when measuring earth systems that have an inductive component in addition to the resistive. This is quite common where the earth connection is made by the use of metal bands that are wrapped around an object. This is the preferred principle provided that the physical conditions allow it.

This principle is used by Eurotest 61557 and Earth – Insulation Tester.

- **Principle using an external measurement voltage without the auxiliary measurement probe.**
  This principle is usually used when measuring Earth Resistance in TT systems where the value of the Earth Resistance is much higher than the resistance of other parts in the fault loop when measured between the phase and protective terminals. The advantage of this principle is that it does not need the use of auxiliary measurement probes which is appreciated in an urban environment where there is no ground area for test probes.

  Both the Eurotest 61557 and Instaltest 61557 use this principle.

- **Principle using an external measurement voltage and auxiliary measurement probe**
  The advantage of this principle is that an exact result can be given on TN systems, where the fault loop resistances between the phase and protective conductors are fairly low.

  Eurotest 61557 uses this principle.

- **Principle using an internal generator, two measurement probes and one measurement clamp**
  With this principle there is no need to mechanically disconnect any earth electrode which may be connected in parallel with the test electrode.

  Eurotest 61557 and Earth – Insulation Tester, both use this principle.

- **Rodless principle using two measurement clamps**
  In cases where a complex earthing system is to be measured (with numerous parallel earthing electrodes) or where a secondary earthing system with a low earthing resistance is present, this principle enables you to perform rodless measurements. The advantage of the principle is that there is no need to drive measurement probes and to separate the measured electrodes.

  Both the Eurotest 61557 and Earth – Insulation Tester, use this principle.

Attention!

- It is necessary to be aware that high-level disturbance signals are often present on the earthing systems to be measured. This is of particular concern on earthing systems in industry and power transformers etc. where large draining currents can run to ground. High creepage currents are often present in the area around the earthing electrodes especially near high-voltage distribution lines, railways etc. The quality of the measuring instrument is proven by its performance in such demanding environments. The Eurotest 61557, Instaltest 61557 and Earth – Insulation Tester use patented measurement principles which assure that exact results are given even where competitive instruments fail to perform.
- For successful measurement of the Earth Resistance using test probes it is important that the resistance of the measurement probes (current and voltage) is not too high. For that reason the aforementioned instruments, produced by

METREL, test both probes before performing the measurement. Therefore there is no need to reverse the current (C2) and voltage (P2) test leads by hand and then repeat the measurement. Where the test instrument tests only one probe resistance, each measurement is to be repeated at reversed auxiliary test probes P2 and C2.

The maximum allowed value of the Earth Resistance R_E differs from case to case. Fundamentally, the earthing systems, in combination with other safety elements (e.g. RCD protection devices, over-current protection devices etc.) must prevent dangerous contact voltages from arising.
The basic measurement of Earth Resistance uses the principle of an internal generator and two measurement probes (voltage and current). The measurement is based on the so-called method of 62%.
For this measurement it is important that the measured earthing electrode is separated from other parallel earths such as metal constructions etc. It must be considered that if a fault or leakage current is running to earth when the conductor is separated from the earthing electrode a dangerous situation could arise.

Measurement principle using classic four-terminal, two-probe method

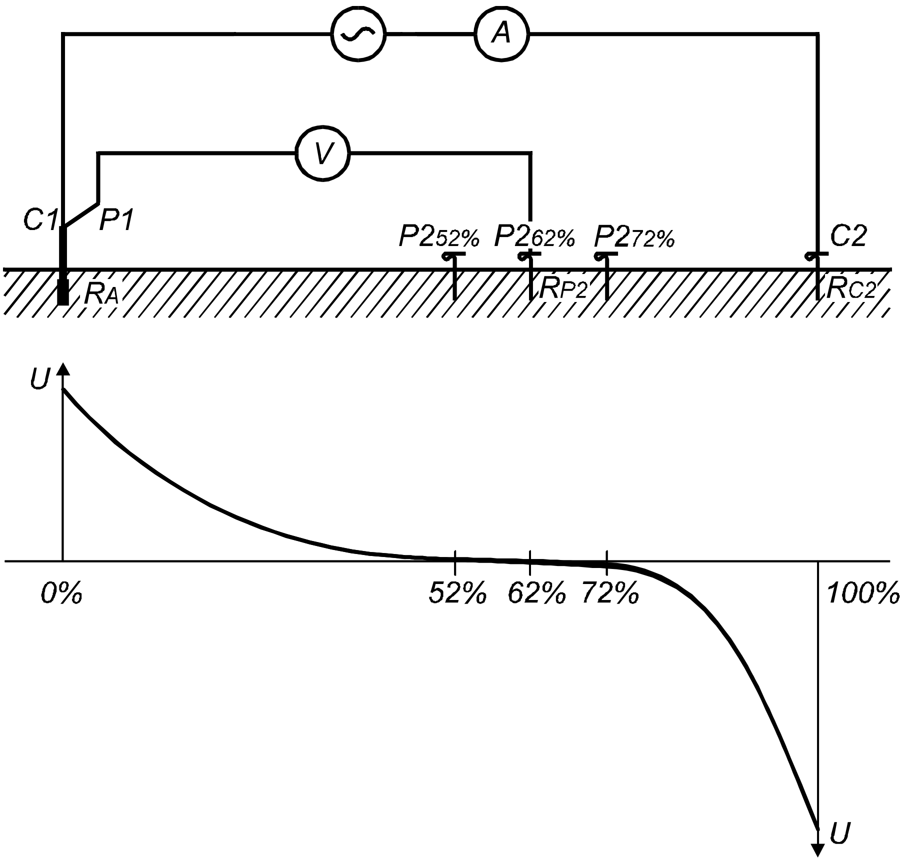


Fig. 27. Measurement principle and apportion of test voltage

Calculation of required distance between tested earthing system (simple rod or simple band electrode):

Basis for the calculation is *the* depth of simple rod electrode or *the* diagonal dimension of band earthing system.

- Distance from tested earthing electrode to current measurement probe C2 = depth (rod electrode) or diagonal (band electrode) × 5
- Distance to voltage measurement probe P2 (62%) = Distance C2 × 0,62
- Distance to voltage measurement probe P2 (52%) = Distance C2 × 0,52
- Distance to voltage measurement probe P2 (72%) = Distance C2 × 0,72

Example: Band type earthing system, diagonal = 4 m.
C2 = 4 m × 5 = 20 m
P2 (62%) = 20 m × 0,62 = 12,4 m
P2 (52%) = 20 m × 0,52 = 10,4 m
P2 (72%) = 20 m × 0,72 = 14,4 m

The calculation is of course just theoretical. In order to make sure that *the* calculated distances correspond to *the* actual ground situation, the following measurement procedure shall be applied.

The first measurement is to be done at *the* potential probe driven into the ground at a distance of 0,62 × C2. The measurement shall be repeated at the distances of 0,52 × C2 and 0,72 × C2. If *the* results of *the* repeated measurements do not differ from the first one more than 10% of the first measurement (0,62 × C2), then the first result may be considered as correct. If a difference in excess of 10% occurs, both distances (C2 and P2) should be proportionally increased and all measurements repeated.

It is advisable for the measurement to be repeated at different arrangements of test rods namely, the test rods shall be driven in the opposite direction from tested electrode (180° or at least 90°). *The* final result is an average of two or more partial results.

Because of the fact that earthing systems can be quite complex, that many systems can be connected together either under or above ground level, that the system can be physically extremely large, that the integrity of the system cannot usually be visually checked etc., measurement of the Earth Resistance may be one of the most demanding measurements. That is why the selection of an appropriate test instrument is very important.

Identify the type of earthing system before starting the measurement itself. On *the* basis of the type, appropriate measurement method shall be selected.

Regardless of *the* selected method, the test result should be corrected before comparing it with the allowed value, see chapter 5.

The following are examples of practical measurements for various types of earthing systems.

5.5.1. Measurement of simple rod earthing electrode

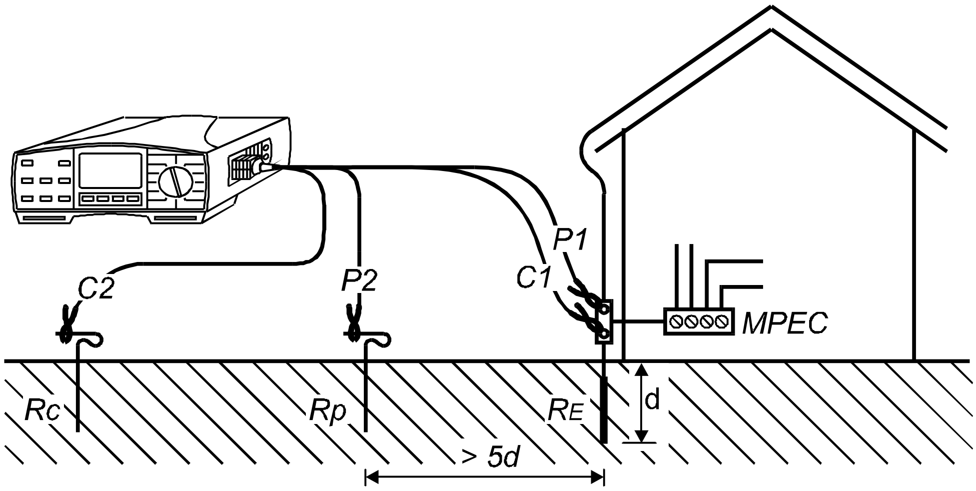


Fig. 28. Earth Resistance measurement of simple rod earthing electrode

Result = U/I = R_E

where:
U.................... Voltage measured by internal V-meter between P1 and P2 test terminals.
I...................... Test current driven to tested loop between C1 and C2 test terminals.

The measurement is fairly simple due to the fact that the earthing electrode can be considered as a single point electrode and it is connected to no other electrode. The distances between the tested electrode and test probes (current and potential) depend on the depth of the tested electrode.

Using the 4-lead connection, as supported by METREL test instruments, is much better than 3-lead method as there are no problems concerning contact resistance between the test clips and the usually rusty surface of the electrode under test.

Measurement probes are usually driven to ground in line with the electrode under test or in an equilateral triangle.

5.5.2. Measurement of simple band earthing electrode

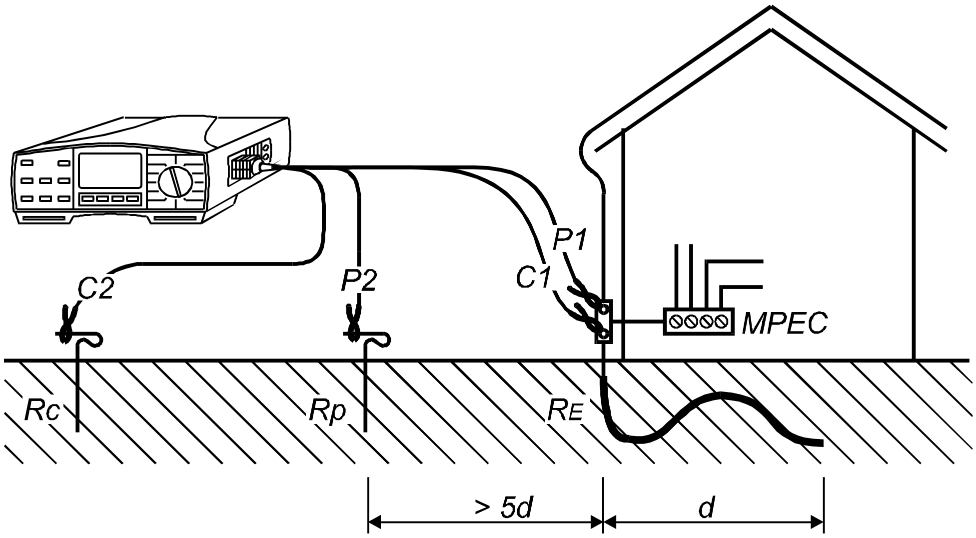


Fig. 29. Earth Resistance measurement of simple band electrode

Result = U / I = R_E

where:

U.................... Voltage measured by internal V-meter between P1 and P2 test terminals.

I...................... Test current between C1 and C2 test terminals.

The measurement is quite similar to the previous one, except that the electrode cannot be considered as a single point electrode, but the length of the band used must be taken into consideration. On basis of the length, the appropriate distance from *the* electrode under test to both of the test probes must be calculated and used, see the figure above.
Measurement probes are usually driven to ground in line with the electrode under test or in an equilateral triangle.

5.5.3. Measurement of complex earthing systems with several parallel electrodes

Two important aspects should be considered in such systems:

- The common resistance of an earthing system R_{Etot} is equal to the parallel connection of the individual earthing electrodes. Sufficient common low Earth Resistance meets the requirements for successful protection against electrical shock in for a load fault, but it may not offer successful protection for atmospheric discharging through the lightning conductor.

- Resistance of the individual earthing electrode R_{E1}…R_{EN}.

Individual earthing resistances must be of a sufficiently low value when the earthing system is intended for protection against atmospheric discharging. The atmospheric discharges are very rapid which is why discharge currents contain high-frequency components. For these components any inductance within the earthing system presents a high resistance and therefore disables a successful discharge. This may have catastrophic consequences.

The opposite effect than that required might occur when the lightning conductor has several separate earth paths, especially where the Earth Resistance is too high. The lightning system attracts the lightning because of its geometric shape and appropriate physical location (sharp edges/points and usually the highest places). Extremely high strength of electric field and subsequent air ionization may appear near the lightning system.

Measurement of total Earth Resistance

a) Classic four-lead, two-probe method

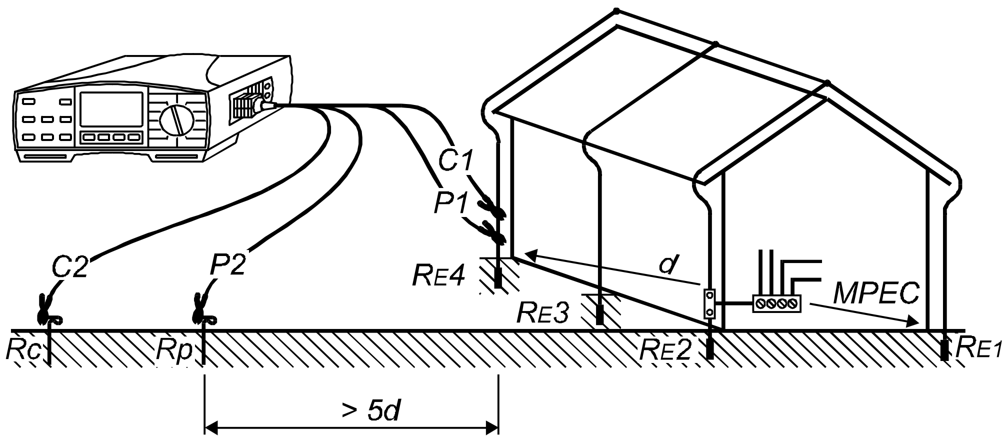


Fig. 30. Measurement of total Earth Resistance of a complex earthing system using the classic four-lead, two-probe method

The voltage and current measurement probes are driven into the ground far enough away from the measured system so that it can be considered as a point system. The required distance from the current probe must be at least 5-times longer than the longest distance between the individual earthing electrodes. The distance to the voltage probe is in accordance with the chapter: Calculation of required distance between tested earthing system (simple rod or simple band electrode) on page 35.

The advantage of this method is that it assures exact and reliable test results whilst the disadvantage is that it requires relatively large distances to set-up the measurement probes which may cause problems (especially in an urban environment).

Result = U/I = R_{E1}//R_{E2}//R_{E3}//R_{E4} = R_{Etot}

where:

U .... Voltage measured by an instrument between the test probes P1 and P2.
I .... Current driven by an instrument into the test loop between the test probes C1 and C2.
RE1 to RE4 .... Earth Resistance of individual earthing electrode.
REtot .... Total Earth Resistance of tested earthing system.

b) Rodless method using two test clamps

The Earth Resistance measurement can be simplified and performed without the use of earth spikes when an additional earthing electrode or a system of earthing electrodes with low total Earth Resistance is available. The measurement can be performed with the use of two test clamps if a measurement instrument such as the Eurotest 61557 or Earth – Insulation Tester is available.
Such instances are usually met in built up areas where other earthing systems with low Earth Resistances are also present (e.g. metal band installed along ground mains cable).

Below is a model of such an earthing system and connection of the test instrument.

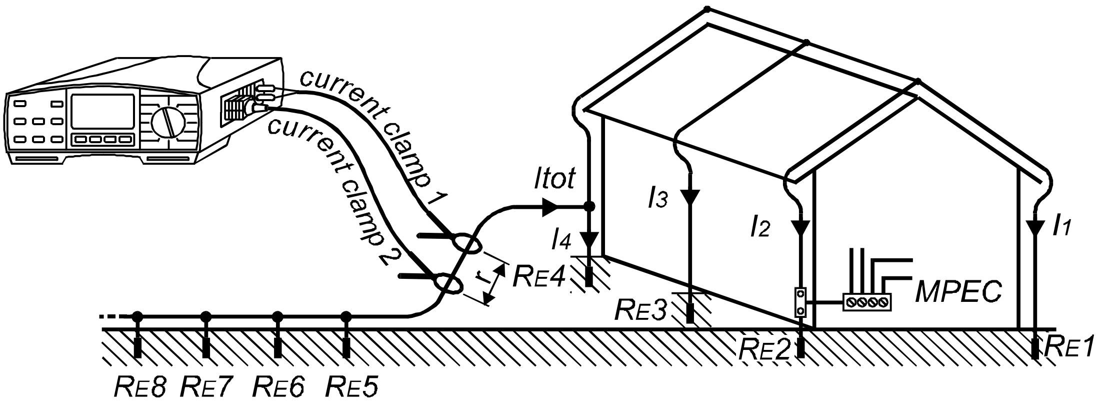


Fig. 31. Measurement of total Earth Resistance by using two test clamps

RE1 to RE4 ...... Individual Earth Resistances of earthing system under test.
RE5 to REN...... Individual Earth Resistances of auxiliary earthing system with low total Earth Resistance.
r .... Distance between the measurement clamps which has to be at least 30 cm, otherwise generator clamp may have an influence on the measuring clamp.

The figure below gives a better understanding of the previous example.

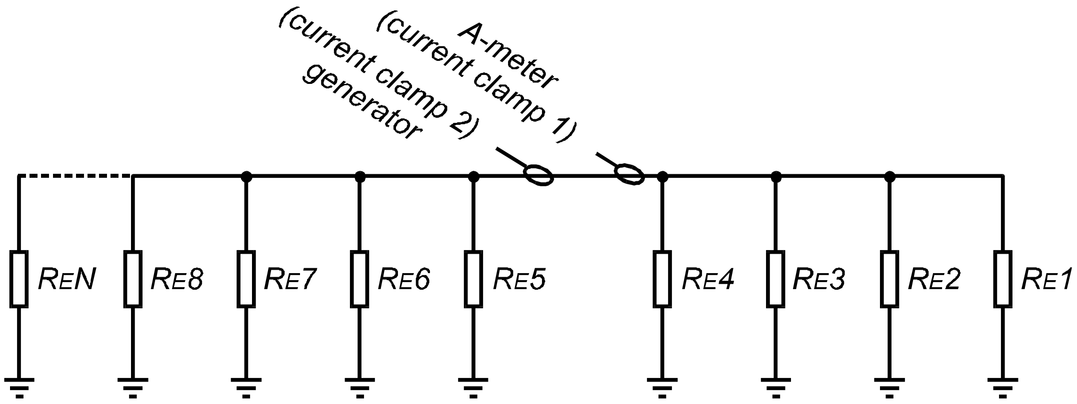


Fig. 32. Substitute electrical circuit diagram of the previous example

Result = (total resistance of earthing electrodes RE1 to RE4) +
+ (total resistance of auxiliary earthing electrodes RE5 to REN)

If it can be assumed, that total resistance of the auxiliary electrodes RE5 to REN is much lower than the total resistance of the measured electrodes RE1 to RE4, then the following can be written down:

Result » **(total resistance of measured earthing electrodes RE1 to RE4)**

If the result is lower than allowed value, then the exact value is on *the* safe side namely, it is even lower than *the* displayed one.

Particular Earth Resistance measurement

There are several methods to measure the Earth Resistance of a particular earthing electrode. The method which best fits to the actual earthing system, and is of course supported by the available test instrument, should be used.

a) Measurement with mechanical disconnection of the tested earthing electrode using the classic 4-lead 2-probe test method

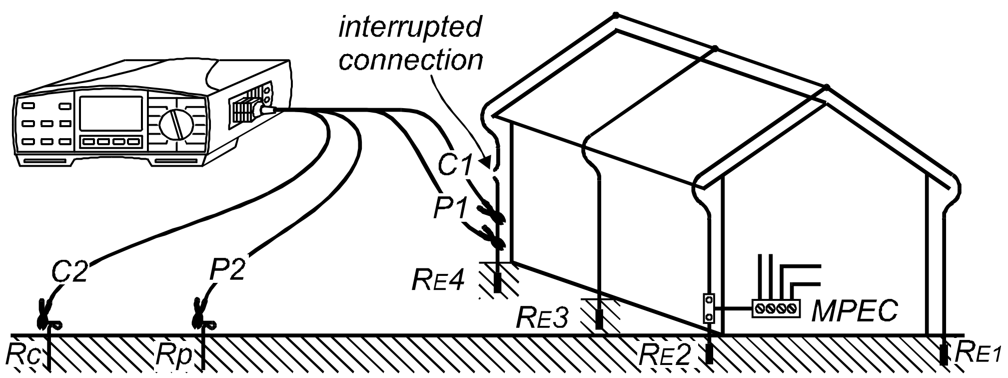


Fig. 33. Earth Resistance measurement of a specific earthing electrode

Result = U / I = RE4

where:

U.................... Voltage measured by internal V-meter between P1 and P2 test terminals.

I...................... Test current driven through tested loop between C1 and C2 test terminals.

The required **distance between *the* tested electrode and both of the test probes is the same as the one for simple rod electrode or simple band electrode dependant on *the* type of electrode used.**

The disadvantage of this method is that mechanical disconnection must be done before ***the*** measurement is applied. The disconnection may be problematical due to possible rusty junctions. the advantage of the method is high accuracy and reliability of ***the*** test result.

b) Measurement with mechanical disconnection of the tested earthing electrode using the classic 4-lead 2-point test method

If the number of total earthing electrodes is high enough, then a simplified, probeless method can be used, see the figure below.
The electrode under test should be mechanically disconnected and all the other electrodes will be used as auxiliary ones. **The** total Earth Resistance of ***the*** auxiliary electrodes is much lower than the one under test.

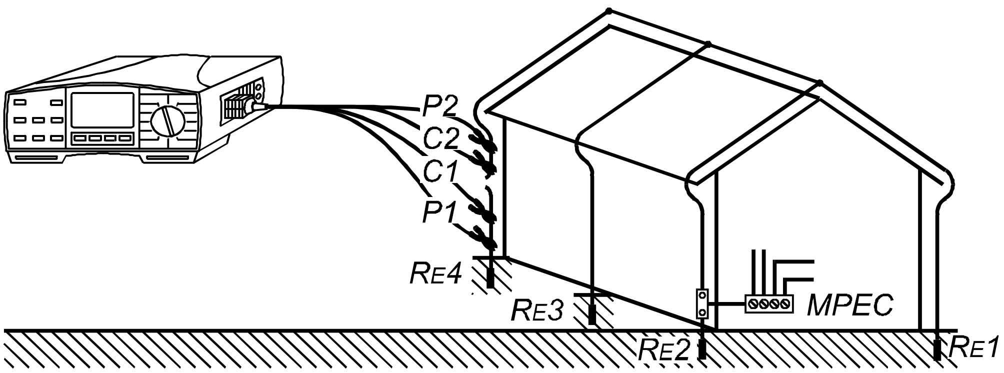


Fig. 34. Simlified probeless measurement

Result = $R_{E}4$ + ($R_{E}1$ // $R_{E}2$ // $R_{E}3$)

If ($R_{E}1$ // $R_{E}2$ // $R_{E}3$) is much lower than tested $R_{E}4$, the following can be noted**:**

Result » **$R_{E}4$**

c) Measurement using classic 4-terminal 2-probe test method in combinaton with test clamp

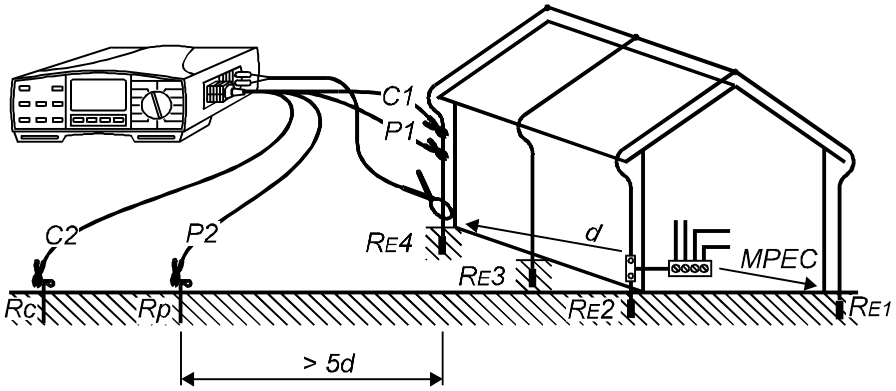


Fig. 35. Earth Resistance measurement using one test clamp

Substituted electrical circuit diagram of the above example is presented on the figure below.

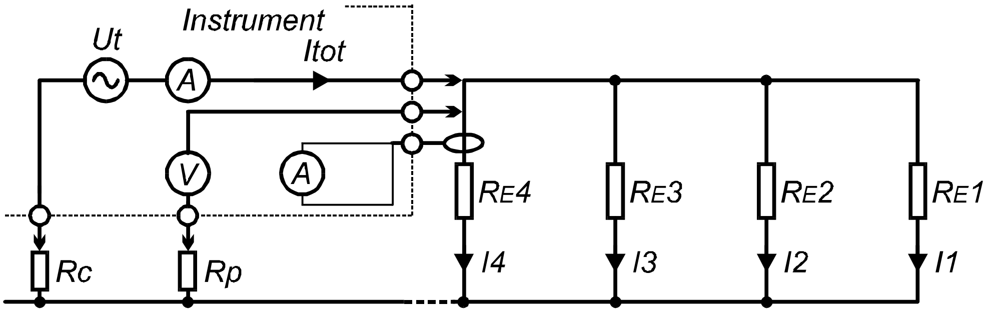


Fig. 36. Substituted electrical circuit diagram of the previous practical example

Ut.............. Test voltage.
Rc .... Resistance of current test probe.
Rp............. Resistance of potential test probe.
Itot............. Total current generated by the test voltage Ut and measured by A-meter connected in series with generator.
I1 to I4....... Separate test currents.

I1 + I2 + I3 + I4 = Itot

Result 1 = RE4 (the current measured by test clamp is considered)
Result 2 = Rtot (total current measured by A-meter is considered)

The advantage of this method is that there is no need to mechanically disconnect the electrode under test.

Moving the test clamp from electrode to electrode will measure only the current flowing in the earthing electrode under test. On the basis of this current the total current measured by the internal A-meter and the voltage measured by the internal V-meter, is used to calculate the specific Earth Resistance.

To ensure an accurate voltage measurement the distance from the tested electrode to the current probe must be at least 5 times further than the furthest distance between particular electrodes in the tested system.

Notes!

- Because of the large distances between particular electrodes, it is often not possible to move the test clamp from electrode to electrode! The instrument with its test wiring must be moved.
- If there is a large number of electrodes in the earthing system under test, it may be that the current measured by the test clamp in the electrode is too low. In this case the test instrument will advise of the unfavourable situation.

d) Probeless measurement using two test clamps

Complex earthing systems with numerous electrodes connected in parallel (see the figure below) or systems interconnected to other earthing systems (see the figure 39) are often met whilst testing. Also, in built up areas it may prove difficult or impossible to drive test probes to ground. In these cases the probeless method (if test instrument supports it) is recommended.

Both the Eurotest 61557 and the Earth – Insulation Tester can carry out the measurement even if high noise signals are present, because they both use a special **patented** technical solution.

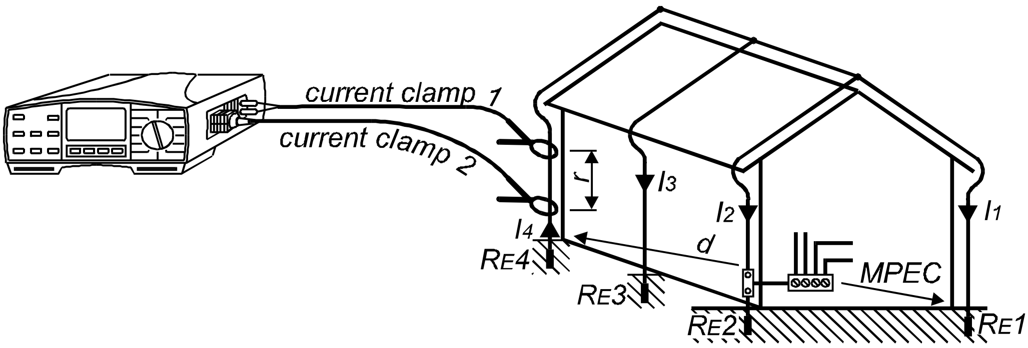


Fig. 37. Earth Resistance measurement using *the* probeless two-clamp method

Note!

- It is important to ensure that the minimum distance between the two test clamps is at least 30cm otherwise the two clamps will interact with each other and distort the readings.

Below is a substitute electrical circuit diagram of the example above.

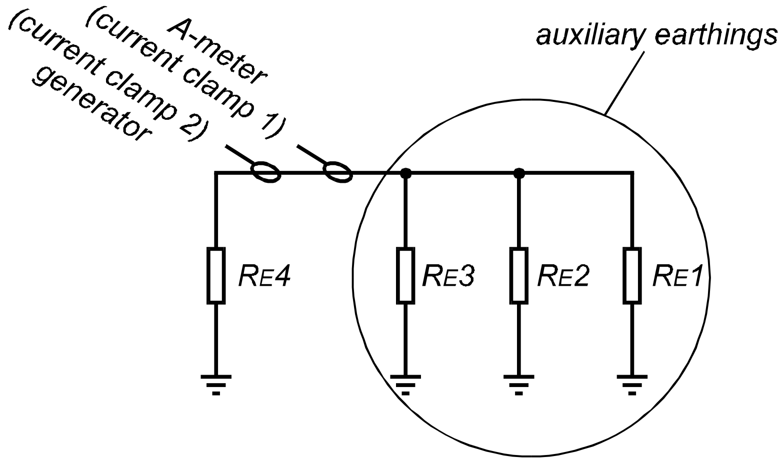


Fig. 38. Substitute electrical circuit diagram of *the* previous practical example

Result = RE4 + (RE3 // RE2 // RE1)

If the total Earth Resistance of the parallel connected electrodes RE3, RE2 and RE1 is much lower than the resistance of tested electrode RE4, the following decision can be made:

Result » **RE4**

If the result is lower than the allowed value, then the exact value is definitely on safe side ie. it is even lower than displayed one.

Other specific resistances can be measured by moving the test clamps to other electrodes.

If there is a practical example as presented in figure 31., then the test clamps may be connected as shown on the figure below. Required conditions for acceptable test results is that *the* total Earth Resistance of *the* earthing electrodes RE5 to REN is negligible in comparison with the total resistance of *the* tested object RE1 to RE4.

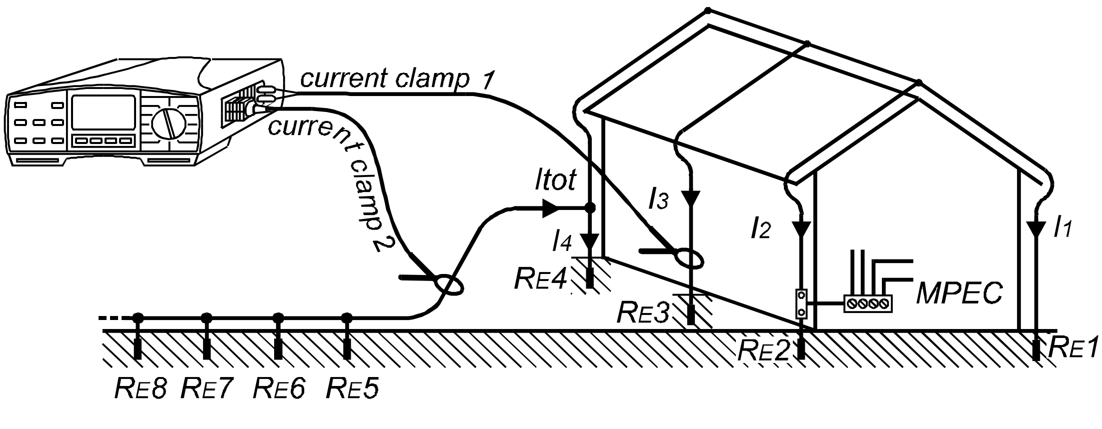


Fig. 39. Probeless Earth Resistance measurement using two test clamps

Connection is similar to the one in figure 31. Except that the current measurement test clamp is connected to a specific earthing elecrtrode and therefore the Earth Resistance of the electrode is measured.

Substitute electrical circuit diagram of the above example is presented on the figure below.

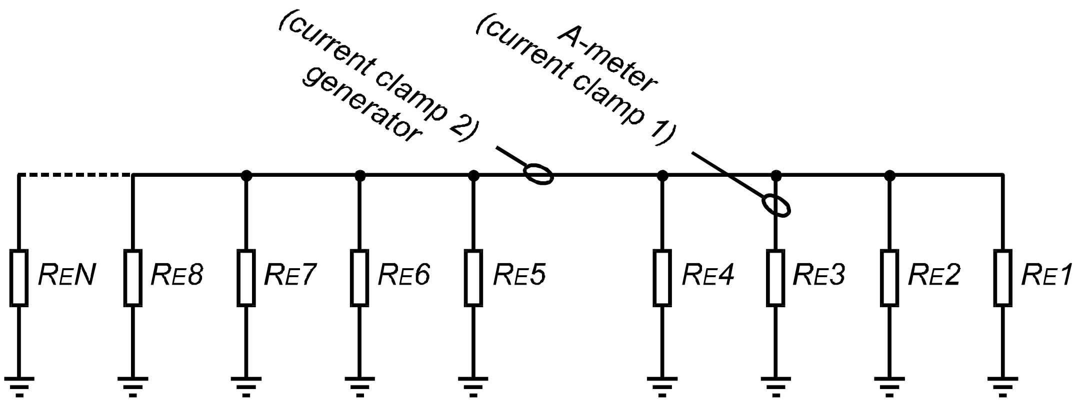


Fig. 40. Substitute electrical circuit diagram of the previous practical example

Where the total resistance of the auxiliary earths R_E5 to R_EN is much lower than the total resistance of electrodes R_E1 to R_E4, the following can be noted:

Result ≈ R_E3

Measurement of other earthing electrodes can be performed by moving the test clamp 1 (current measurement clamp) to the other electrodes.

Notes!

- This method can be used if individual earthing electrodes are close enough to each other to be reached with the test clamp 1. The Generator clamp should stay at the same place regardless of the electrode measured.
- If there is a large number of electrodes in the tested earthing system, it may be that the current measured by the test clamp in the tested electrode is too low. In this case the test instrument will advise of the unfavourable situation.

Earth Resistance measurement methods using external test voltage are described in chapter 3.8.4., under ‘RCD protection devices’.

5.6. Specific earth resistance (resistivity) EN 61557- 5

What is Specific Earth Resistance?

It is the resistance of ground material shaped as a cube 1 × 1 × 1 m, where *the* measurement electrodes are placed at the opposite sides of the cube, see the figure below.

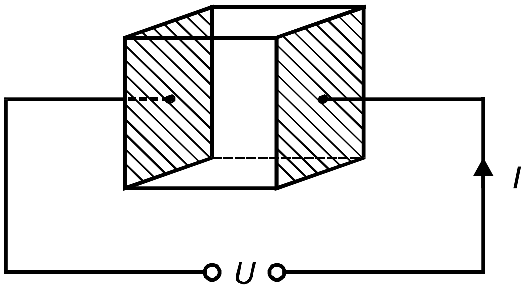


Fig. 41. Presentation of Specific Earth Resistance

Measurement of Specific Earth Resistance

The measurement is carried out in order to assure more accurate calculation of earthing systems e.g. for high-voltage distribution columns, large industrial plants, lightning systems etc.

AC test voltage should be used because of possible electro-chemical processes in *the* measured ground material if a DC test voltage is used.

Specific Earth Resistance value is expressed in Ωm, its absolute value depends on structure of the ground material

Measurement principle is presented on the figure below.

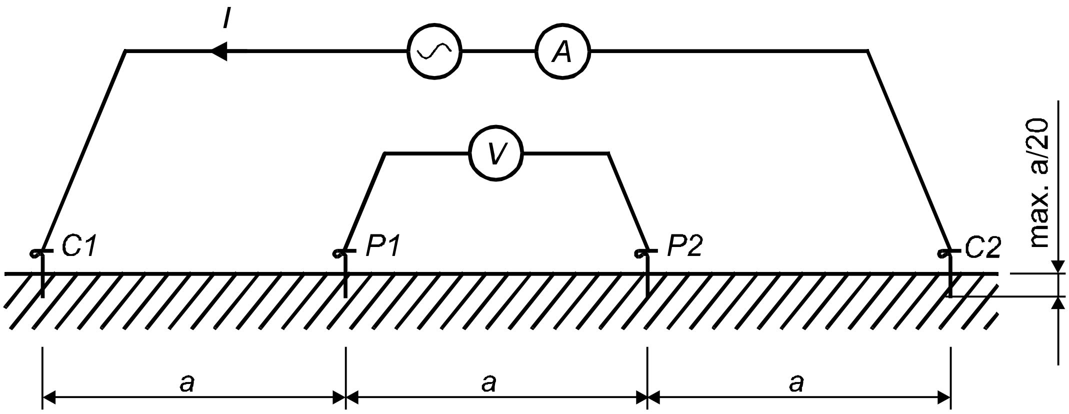


Fig. 42. Measurement principle

Result = 2 p **a U / I =** r

where:
a .... Distance between test probes.
U............... Voltage between test probes P1 and P2, measured by the V-meter.
I................ Test current, driven by an a.c. generator and measured by the A-meter.
ρ................ Specific Earth Resistance.

The above equation is valid if *the* test probes are driven to ground at maximum a/20.

In order to reach more objective results it is advisable that the measurement be repeated in different directions (e.g. 90° with regard to the first measurement) and an average value taken.

Using different distances between the test probes means that the material at different depths is measured. Because the bigger the distance is, then the deeper level of ground material is measured.

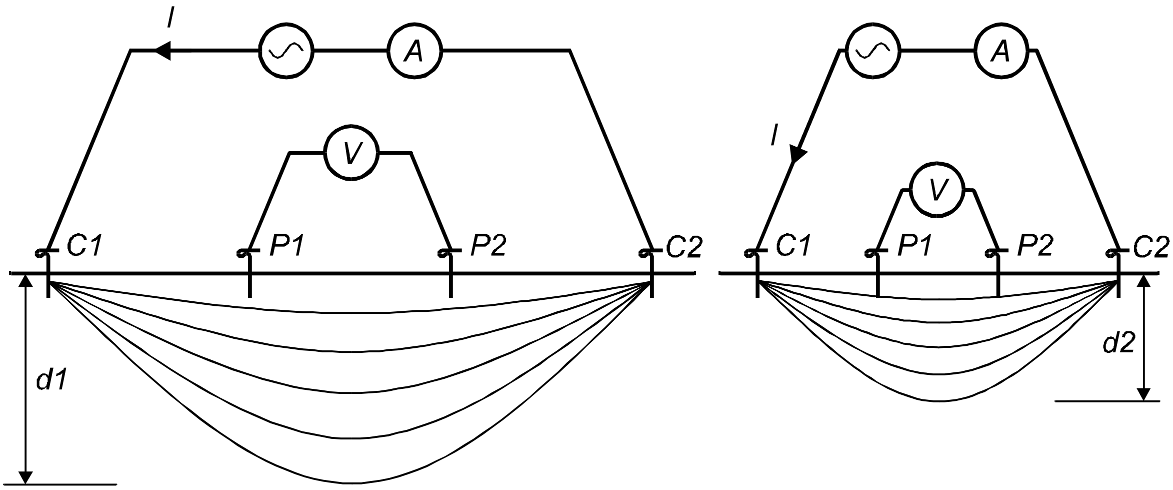


Fig. 43. Influence of the distance **a** to measured depth

d1.............. Depth involved at larger distance **a** between test probes.
d2.............. Depth involved at smaller distance **a** between test probes.

The earthing electrode should be sited at a place and depth where the lowest Earth Resistance will be reached (or at least a reasonable compromise shall be achieved), this is why test results obtained at different depths are to be taken.

Also a structure of the ground material can be roughly defined by measuring the Specific Earth Resistance.

The table below is representative of the orientational values of Specific Earth Resistances for a few typical ground materials.

Type of ground material	Specific Earth

	Resistance in Ωm
sea water	0,5
lake or river water	10 – 100
ploughed earth	90 – 150
concrete	150 – 500
wet gravel	200 – 400
fine dry sand	500
lime	500 – 1000
dry gravel	1000 – 2000
stony ground	100 – 3000

Table 3. Orientational values of Specific Earth Resistances for a few typical ground materials

Practical measurement using test instrument Eurotest 61557 or Earth – Insulation Tester is shown on the figure below.

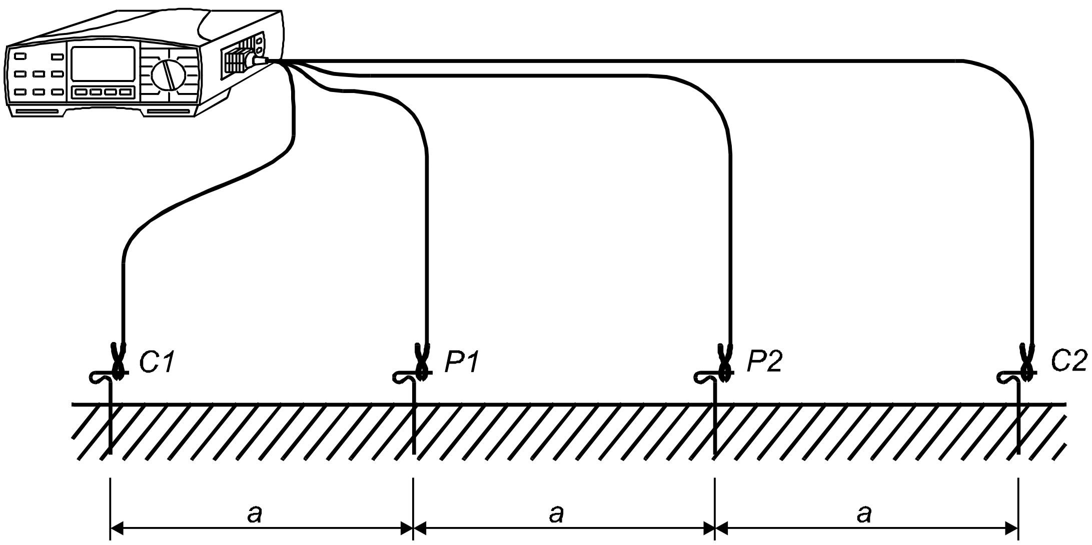


Fig. 44. Practical measurement of Specific Earth Resistance

5.7. Connection of protection conductor ‘pe’ at mains plug

At new installations as well as at adapted ones it may occur that the PE conductor is crossed with the phase conductor, this is a very dangerous situation! This is why it is important to test for the presence of phase voltage at *the* PE terminal. The test should be carried out before any other tests which requires the presence of mains voltage is conducted or before the installation is used.

The Eurotest 61557 will do this test whenever the operators finger touches PE test probes adjacent to the START key.

Let’s see the test principle.

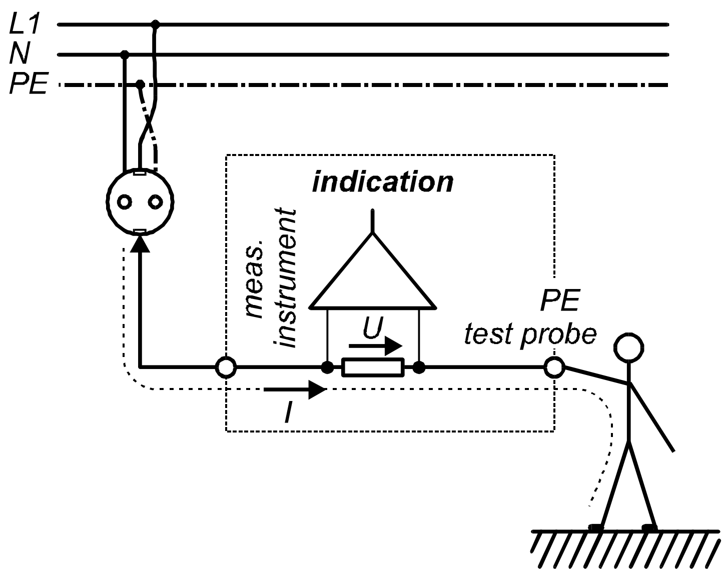


Fig. 45. Test principle

If phase voltage is present at *the* PE terminal, then a certain current flows from the terminal via the internal resistance of the test instrument and the operator’s body to ground as soon as the operator’s finger touches the PE test probe. The current causes a specific voltage drop across the internal resistance of the test instrument, which is detected by the instrument’s electronic circuitry.

Attention!

- If presence of phase voltage is detected, stop all further activities immediately and ensure that the situation is made safe before proceeding further.
- The user should stand on a conductive floor during the test.

5.8. Rcd protection devices <u>EN 61557- 6</u>

A RCD device is a protection element intended to protect humans and animals from electric shock. It works on the basis of a difference between *the* phase currents flowing to different loads and the returning current flowing through the neutral conductor. If the difference is higher than the tripping current of the installed RCD protection device, the device will trip and thereby switch off the mains voltage. The aforementioned current difference must flow to ground as a leakage current (via insulation or capacitive coupling) or as a fault current (via faulty insulation or partial/total short circuit between live parts and accessible conductive parts).

Such a protection is effective only if the RCD device is installed correctly, if the installation is correctly specified and if the Earth Resistance value is under the allowed limit value for an installed RCD device.

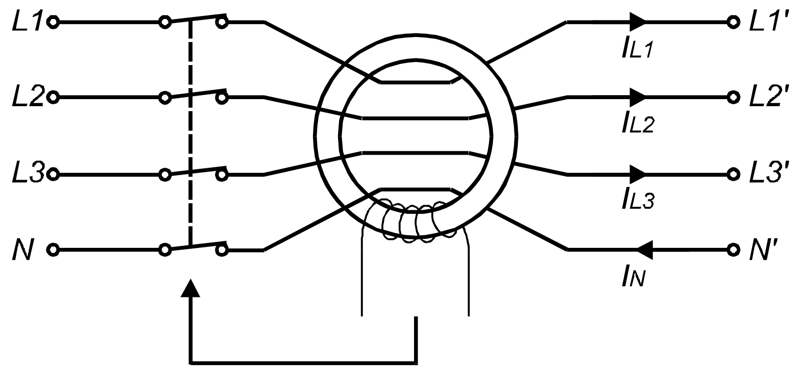


Fig. 46. Schematic representation of the RCD protection device

L1, L2, L3, N .... Input terminals for connection of electrical supply network.
L1', L2', L3', N'........... Output terminals for connection to installation in building.

$\mathbf{I_D = I_{L1} + I_{L2} + I_{L3} - I_N}$

The formula above is valid regardless of *the* type of connected load (single-phase, three-phase three-cable, three-phase four-cable, symmetrical, non-symmetrical).

Condition for RCD trip out is as follows:

$\mathbf{I}_D$ ³ **trip**

where:
I_Δ.................... Differential current which is equal to the sum of fault and leakage current.
I_Δ trip.............. Tripping current of installed RCD device.

To ensure correct operation on any shape of current waveform there are three basic types of RCDs are available namely:

- **AC type**, sensitive to alternating differential current. This is the most frequently used type due to the fact that most installations supply loads with alternating current.

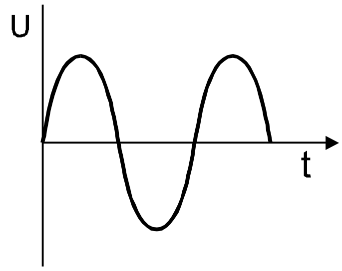


Fig. 47. Shape of differential current, AC type of RCD is sensitive to

- **A type**, in addition to alternating current they are also sensitive to half or full-wave rectified a.c. current. These units are rarely used in practice as there are not a many installations that supply their connected loads with such a current (e.g. d.c. motors, galvanization plants etc.)

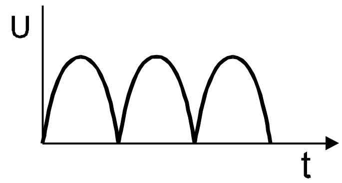


Fig. 48. Shape of differential current to which ‘A’ type of RCDs are also sensitive.

- **B type**, in addition to alternating and half or full-wave rectified a.c. current, these types are also sensitive to pure or nearly pure d.c. current. It is rarely used in practice as there are not many installations that supply their connected loads with a pure d.c. current (e.g. full-wave rectified three-phase voltage etc.)

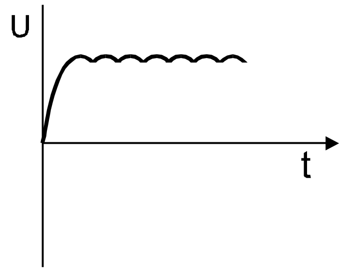


Fig. 49. Shape of differential current to which ‘B’ type of RCDs are also sensitive.

Regarding required trip out time of RCD protection devices, two types are available namely:

- Standard type (instantaneous trip out)
- Selective type (delayed trip out)

To assure successful protection using RCD protection devices, the following parameters are to be tested:

- Contact voltage Uc
- Trip out time t_Δ
- Tripping current I_Δ
- Earth Resistance R_E

All measurements of the above mentioned parameters should ideally be carried out in dry, preferably summer conditions when *the* Earth Resistance reaches its highest value. Otherwise the measurements should be carried out periodically e.g. once per month or:

- after each trip out or
- after each short circuit on installation or
- after considerable atmospheric discharges or
- after performing modifications on the protection system or
- after changing *the* earthing conditions (digging around *the* earthing system, drying-up the area around earthing system etc.)

5.8.1. Contact voltage

What is contact voltage?

Contact voltage is the voltage which can arise under fault conditions on any conductive accessible parts which can come into contact with the human body.

Due to a faulty load, fault current If may flow to ground via the protection conductor. The fault current causes a certain voltage drop across the Earth Resistance R_E
(TT – system), called Fault voltage. A part of the Fault voltage may be accessible to *the* human body and is therefore called Contact voltage. See schematic presentation of Contact voltage on figure 7.

Value of maximum allowed Contact voltage is called Limit voltage (marked as UL) and is usually 50 V, although in some cases (rural environment, hospitals, computer rooms etc.) it is just 25 V.

Measurement of Contact voltage Uc

For reasons of safety the Continuity of protection conductors and the Insulation Resistance should be measured before any circuit is connected to RCD operation.

Measurement of Contact voltage is usually carried out using a test current of $I_{\Delta n}/2$ or $I_{\Delta n}/3$, which is why the RCD device will not trip during the measurement (if RCD device, installation and connected loads are in good working condition).

The Eurotest 61557 offers two methods of carrying out the measurement namely:

- Without using auxiliary test probe
- Using auxiliary test probe

a) Measurement of Contact voltage without using auxiliary test probe

Principle of the measurement is presented on the two figures below.

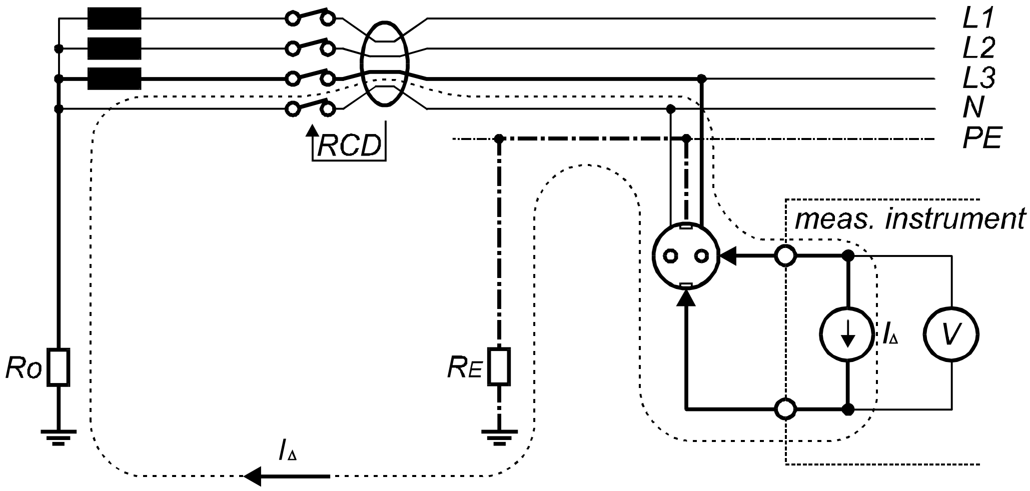


Fig. 50. Principle of Contact voltage measurement in TT- system without using auxiliary test probe

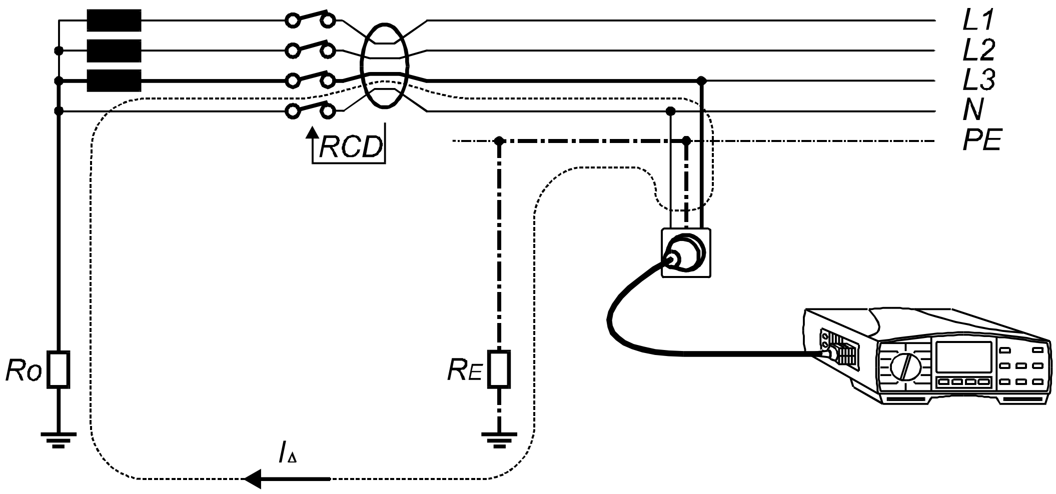


Fig. 51. Practical connection of test instrument Eurotest 61557 or Instaltest 61557

The test instrument simulates a fault on the connected load, driving a fault current from the phase conductor to *the* protection conductor and then to ground. The test current flows through the following loop: Protection conductor from test instrument to earthing electrode, ground from earthing electrode to power transformer, secondary of power transformer, phase conductor from power transformer to test instrument. It can be assumed that the earth resistance of *the* unit under test is much higher than the sum of all other resistances in the tested loop, so most of the fault voltage is concentrated at the earth resistance. The voltage at the earth resistance is referred to as the Contact voltage and is measured by the test instrument, using the phase terminal as a reference point.

The described method (without using auxiliary test probe) gives quite exact results especially in TT – systems and is very convenient as there is no need to drive auxiliary test probes. For absolutely exact results of Contact voltage and especially for exact calculation of Earth Resistance R_E, test method using auxiliary test probe is recommended.

b) Measurement of Contact voltage using auxiliary test probe

Principle of the measurement is presented on the two figures below.

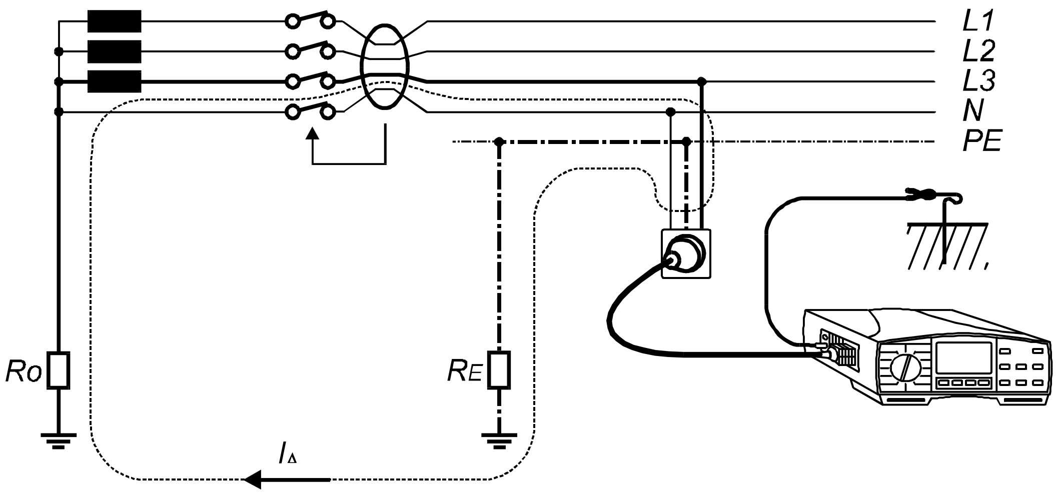


Fig. 52. Principle of Contact voltage measurement in TT- system using auxiliary test probe

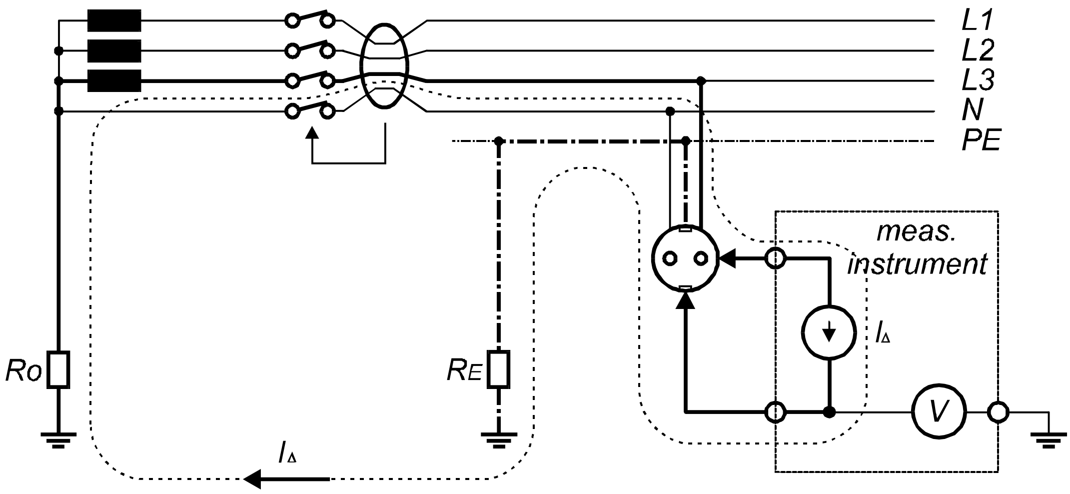


Fig. 53. Practical connection of test instrument Eurotest 61557

Notes!

- If the Contact voltage is above the allowed level then the Earth Resistance should be checked.
- If the RCD trips during Contact voltage measurement, there is a strong possibility that a leakage or fault current is already flowing to ground. The load, which causes such a current, should be disconnected during the measurement.

5.8.2. Trip out time

What is Trip out time?

Trip out time tΔ is the time taken by the RCD to trip at *the* nominal differential current IΔN.

Maximum allowed values of Trip out time are defined by EN 61009 standard and are listed in the table below:

Type of RCD	IΔn	2IΔn	5IΔn*	Remark
Standard	0,3 s	0,15 s	0,04 s	max. allowed value
Selective	0,5 s	0,2 s	0,15 s	max. allowed value
	0,13 s	0,06 s	0,05 s	min. allowed value

* Test current of 0,25A shall be used instead of 5IΔn where the nominal differential current IΔn ≤ 30 mA.

Table 4. Max. allowed Trip out times according to EN 61009 standard

Measurement of Trip out time tΔ

Measurement circuit diagram is the same as that for Contact voltage measurement (see figures 50., 51., 52. and 53.) but the test current is either 0,5 IΔn, IΔn, 2 IΔn or 5 IΔn. For safety reasons the test instrument measures Contact voltage every time before Trip out time.

If the measured Trip out time is out of the allowed limits, then the RCD device should be changed as Trip out time value mostly depends on the installed RCD device.

5.8.3. Tripping current

What is Tripping current?

This is the lowest differential current I∆ that can still cause tripping out of the RCD.

The allowed range of Tripping current value is prescribed by IEC 61009 standard and depends on the type of RCD (AC, A or B) as follows:

I∆ = (0,5 up to 1) × I∆n .... AC type
I∆ = (0,35 up to 1,4) × I∆n .... A type
I∆ = (0,5 up to 2) × I∆n .... B type

Measurement of tripping out current

Measurement circuit diagram is the same as that for Contact voltage measurement (see the figures 50., 51., 52. and 53.). The test instrument starts to drive a test current of 0,5 I∆n or lower and then increases it until the RCD trips or up to 1,1 I∆n.
If the tripping current is out of the prescribed range, then the tested RCD as well as installation circuits and the condition of the connected loads should be checked. If the test result is too low then there is a high possibility that a leakage or fault current is already flowing to ground.

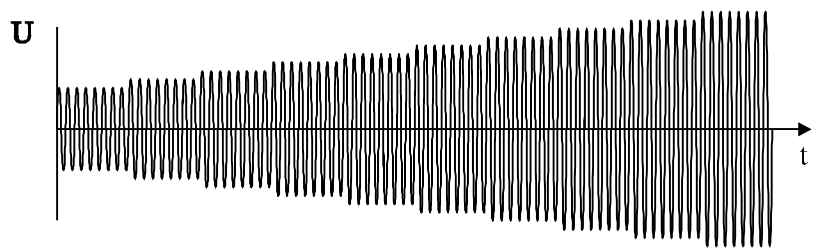


Fig. 54. Shape of test current applied when testing the Tripping current of AC type

The shape of the test current may differ slightly from producer to producer of test equipment, also the total number of steps may be different (even a smoothly rising shape can be found), but the basic principle is always the same.

5.8.4. Earth Resistance (external source of test voltage)

Appropriate Earth Resistance is of vital importance when RCD protection is used against electric shock. If the Earth Resistance is too high then an unacceptably high Contact voltage may appear on accessible conductive parts under faulty conditions. The voltage represents a potential risk of electric shock.

With regard to the aforementioned, Earth Resistance is to be tested in all cases where the Contact voltage is too high.

Up-to-date test instruments display both results (Earth Resistance and Contact voltage) simultaneously as the measurement principle is absolutely the same.

The test instruments Eurotest 61557 and Instaltest 61557 support the measurement of all four parameters (Contact voltage, Earth Resistance, Trip out time and Tripping current) which is important for successful protection against electric shock. The Eurotest 61557 can measure the Earth Resistance either with or without the auxiliary test probe whilst the Instaltest 61557 can only perform the test without the auxiliary test probe. It is important to know that real Earth Resistance is measured using auxiliary test probe only. If the measurement is performed without using the auxiliary test probe, the whole resistance in the tested loop (fault loop) is measured, which is quite similar to the Earth Resistance in TT – system.

a) Fault loop Resistance measurement without using auxiliary test probe

The method is used mainly in TT – systems. The measurement circuit diagram as well as the connection of test instrument is the same as for Contact voltage measurement (see the figures 50. and 51.). The final result is expressed mathematically as follows:

$$\mathbf{Result} = \Delta U / I_t = (U_O - U_L) / I_t = R_{sec} + R_L + R_{PE} + R_E + R_G + R_O$$

where:

I_t .... Test current (in most cases the value is half or third of nominal current which still does not cause trip out of RCD device).

U_O .... Mains voltage measured during the first step of the measurement i.e. mains voltage unloaded.

U_L .... Mains voltage measured during the second step of the measurement i.e. mains voltage loaded with test current.

$R_{sec.}$ .... Resistance of transformer's secondary.

R_L ....Phase conductor resistance from power transformer to tested outlet.

R_{PE} .... Protection conductor resistance from tested outlet to protection earthing electrode.

R_E .... Earth Resistance of protection earthing electrode.

R_G .... Ground resistance from protection earthing electrode to power transformer.

R_O .... Earth Resistance of power transformer's earthing electrode.

Maximum allowed Earth Resistance of earthing electrode if a RCD protection device is used, is clearly defined if the following two parameters are known:

- Nominal differential current $I_{\Delta n}$ of installed RCD (it can be read at the device). Standard values of $I_{\Delta n}$ are as follows: 0,01A, 0,03A, 0,1A, 0,3A, 0,5A and 1A.

- Maximum allowed Contact voltage U_L.
  Usually the voltage is 50 V, in some cases it can be 25 V only.

Max. allowed Earth Resistance can be calculated as follows:

R_E max. = U_L / $I_{\Delta n}$

where:
UL.................. Limit Contact voltage (25 or 50 V).
I∆n.................. Nominal differential current of installed RCD protection device.

The following table presents the calculated maximum allowed values of Earth Resistance.

Nominal differential current I∆n (A)	0,01	0,03	0,1	0,3	0,5	1
Max. allowed Earth Resistance value at U_L = 50 V (Ω)	5000	1666	500	166	100	50
Max. allowed Earth Resistance value at U_L = 25 V (Ω)	2500	833	250	83	50	25

Table 5. Max. allowed values of Earth Resistance.

The described measurement of Earth Resistance value differs from the measurement described in the chapter entitled “Fault loop impedance and Prospective Short-circuit current” in that it does not cause the trip out of the RCD due to the low test current
(<0,5 I∆n).

If it can be assumed that the Earth Resistance R_E is much higher than the sum of all the other resistances in the tested loop (which is true in the case of TT – systems), then the following can be noted:

Result » **R_E**

b) Earth Resistance measurement using auxiliary test probe

The method is appropriate for both TT and TN – systems.
The measurement circuit diagram and the connection of test instrument is the same as that for Contact voltage measurement (see figures 52. and 53.).

Final result is again result of mathematical equation as follows:

Result = Uc / I = R_E

where:

U_c .... Contact voltage measured by the V-meter against auxiliary test probe. It is equal to the voltage across the Earth Resistance of the protection earthing electrode.

I...................... Test current driven through the Earth Resistance, measured by the A-meter.

R_E .... Earth Resistance of protection earthing electrode.

Max. allowed Earth Resistance R_E is equal to the one presented in table 4.

5.9. Fault loop impedance and Ipsc EN 61557- 3

If current loops (fuse loops) are protected by over-current protection devices (fuses), then Fault loop impedance **Zs** should be measured. The Fault loop impedance should be low enough for the potential fault current **If** to interrupt the installed protection device within the prescribed time interval in case of a faulty load.

Fault loop impedance in TN- system consists of the following partial impedances:

- Impedance of power transformer's secondary
- Phase conductor resistance from the power transformer to the fault location
- Protection conductor resistance from the fault location back to the power transformer

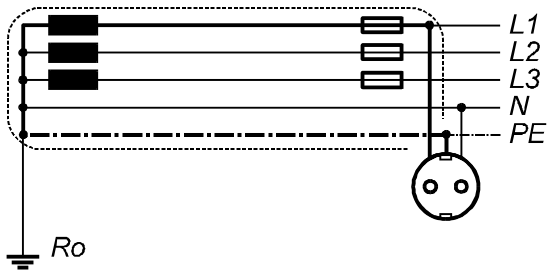


Fig. 55. Presentation of Fault loop in TN- system

Fault loop impedance in TT- system consists of the following partial impedances

- Impedance of power transformer's secondary
- Phase conductor resistance from power transformer to fault location
- Protection conductor resistance from fault location to earthing electrode
- Earth Resistance R_E
- Ground resistance from earthing electrode R_E to power transformer
- Resistance of power transformer's earthing system Ro

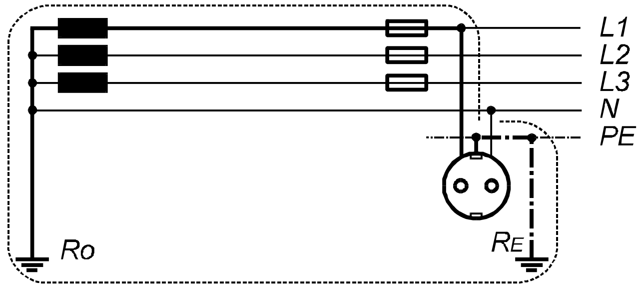


Fig. 56. Presentation of Fault loop in TT- system

Max. allowed Fault loop impedances where melting fuses type gG are used in installations with nominal mains voltage U_{L-N} = 220 V are presented in the next table.

Nominal current of over-current protection device (A)	**gG 0,4 s**		**gG 5s**	
	Ia (A)	**Zs (W)**	**Ia (A)**	**Zs (W)**
2	16	13,7	9,2	23,9
4	32	6,8	18,5	11,8
6	47	4,6	28,0	7,8
10	82	2,6	46,5	4,7
16	110	2,0	65	3,3
20	147	1,4	85	2,5
25	183	1,2	110	2,0
32	275	0,8	150	1,2
40	320	0,6	190	1,1
50	470	0,4	250	0,8
63	550	0,4	320	0,6
80	840	0,2	425	0,5
100	1020	0,2	580	0,3
125	1450	0,1	715	0,3

Table 6. Max. allowed Fault loop impedances for circuits using gG melting fuses

Ia............... Fault loop current which already assure tripping of protection device.

In some countries, gL type of over-current protection devices is used instead of the gG (one). Below is the corresponding table for the gL protection devices constructed according to VDE 0636 and used in installations with U_{L-N} = 220 V.

Nominal current of over-current protection device (A)	**gL 0,2 s**		**gL 5s**	
	Ia (A)	**Zs (W)**	**Ia (A)**	**Zs (W)**
2	20	11,0	9,21	23,9
4	40	5,5	19,2	11,5
6	60	3,7	28,0	7,9
10	100	2,2	47	4,7
16	148	1,5	72	3,1
20	191	1,2	88	2,5
25	270	0,8	120	1,8
32	332	0,7	156	1,4
35	367	0,6	173	1,3
40	410	0,5	200	1,1
50	578	0,4	260	0,8
63	750	0,3	351	0,6
80	—	—	452	0,5
100	—	—	573	0,4
125	—	—	751	0,3
160	—	—	995	0,2

Table 7. Max. allowed Fault loop impedances for circuits using gL melting fuses

Max. allowed Fault loop impedances for circuits using automatic fuses type B, C and K in installations with nominal mains voltage U_{LN} = 220 V are presented in the table below.

Nominal current of over-current protection device (A)	Type of automatic fuse B		Type of automatic fuse C		Type of automatic fuse K	
	Ia=5·In (A)	Zs (W) (0,2s)	Ia=10·In (A)	Zs (W) (0,2s)	Ia=15·In (A)	Zs (W) (0,2s)
2	10	22	20	11	30	7,3
4	20	11	40	5,5	60	3,7
6	30	7,3	60	3,65	90	2,4
10	50	4,4	100	2,2	150	1,5
16	80	2,8	160	1,4	240	0,9
20	100	2,2	200	1,1	300	0,7
25	125	1,8	250	0,9	375	0,6
32	160	1,4	320	0,7	480	0,5
35	175	1,3	350	0,65	525	0,4
40	200	1,1	400	0,55	600	0,37
50	250	0,9	500	0,45	750	0,29
63	315	0,7	630	0,35	945	0,23

Table 8. Max. allowed Fault loop impedances for circuits using automatic fuses type B, C and K

Fault loop impedance measurement

The two figures below illustrate the measurement principal and the practical connection of the test instrument.

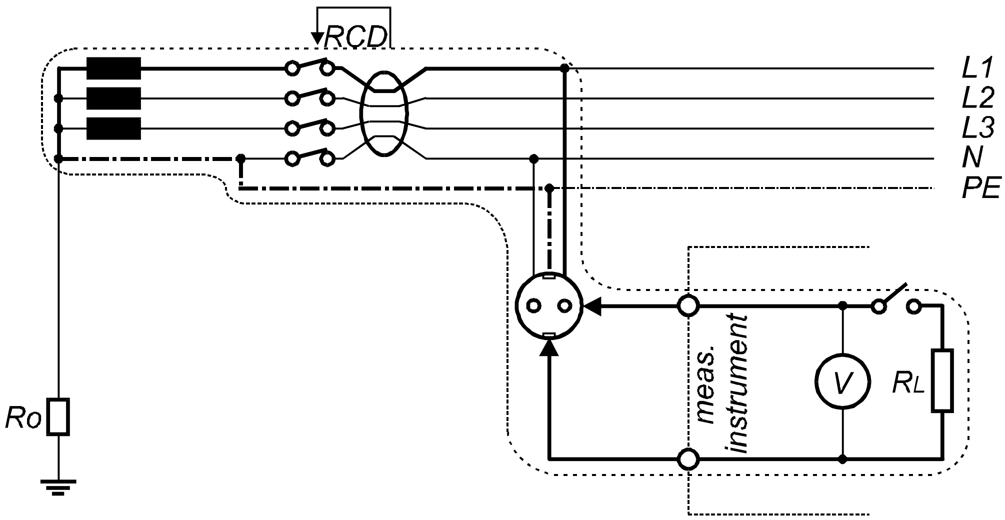


Fig. 57. Measurement principle

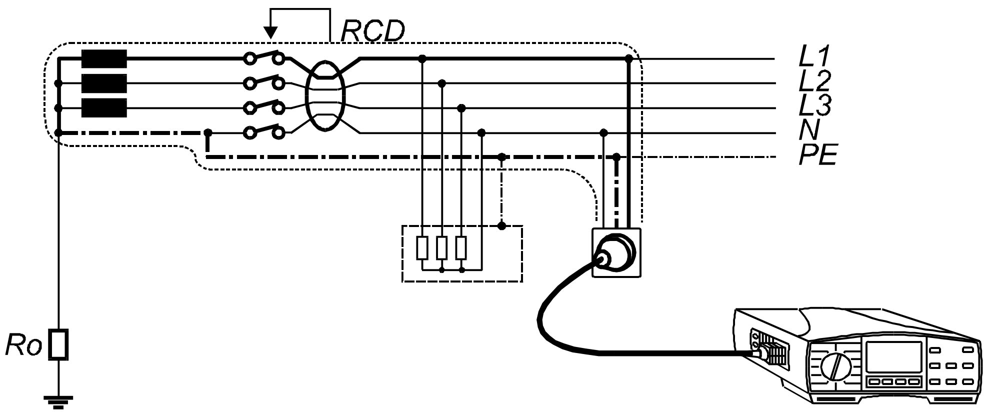


Fig. 58. Practical connection of test instrument Eurotest 61557 or Instaltest 61557

Result = Zsec + R_{L1} + R_{PE} = Zs

where:
Zsec.............. Impedance of transformer's secondary.
R_{L1}................ Phase conductor resistance from power transformer to tested outlet.
R_{PE} .... Protection conductor resistance from test outlet to power transformer.

The test instrument is connected across the mains voltage (between phase and protection conductors) and provides an appropriate load resistance thereby strongly loading the mains voltage over a short period of time. Test current flows in the loop marked with interrupted line (see the figures 57. and 58.). The voltage drop caused by the test current is measured by V-meter. The phase delay between the test current and mains voltage is also measured. On the basis of the measured parameters the test instrument will calculate the Fault loop impedance Z_{LOOP}.

Up-to-date test instruments display Fault loop impedance simultaneously with the Prospective Short-circuit current **Ipsc** calculated as follows:

Ipsc = Un x 1,06 / Z_{LOOP}

where:
Ipsc................ Fault loop Prospective Short-circuit current.
Un.................. Nominal mains voltage between the phase and protection conductors (220 V or 230 V).
Z_{LOOP}............. Fault loop impedance.

5.10. Line impedance and Prospective Short-circuit current

Line Impedance is the impedance measured between phase L and neutral N terminals on a single-phase system or between two phase terminals on a three-phase system. The Line Impedance should be measured when checking the ability of an installation to supply for example high power loads when verifying installed over-current breakers etc. The Impedance consists of the following partial impedances:

- Impedance of power transformer secondary
- Resistance of the phase conductor from the power transformer to the test point
- Resistance of the neutral conductor from the power transformer to the test point

General comments about Line Impedance measurement.
The measurement principle is exactly the same as at Fault Loop Impedance measurement (see the description in chapter 5.9.) but the measurement is carried out between L and N terminals.

5.10.1. Line Impedance between the phase and neutral terminals

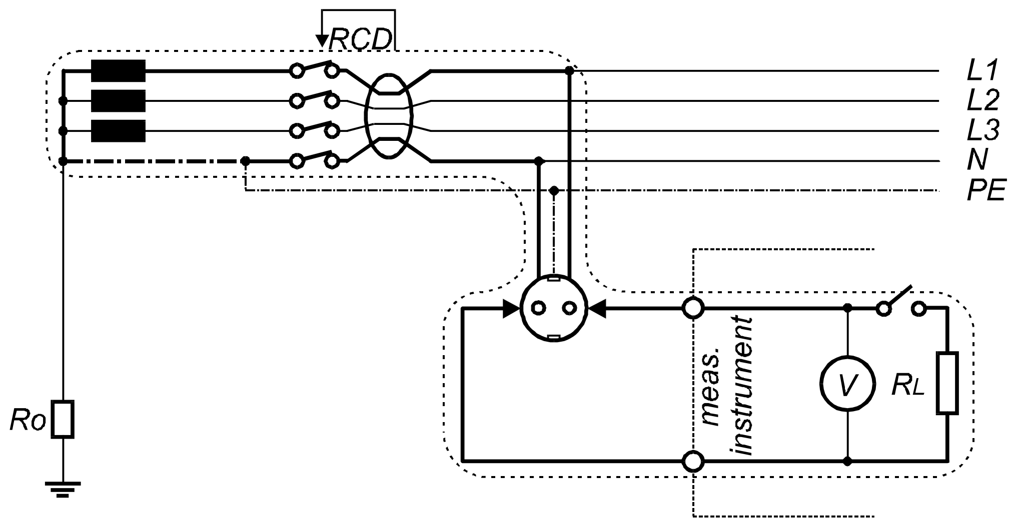


Fig. 59. Measurement principle of Line Impedance measurement between the phase L1 and neutral N terminals

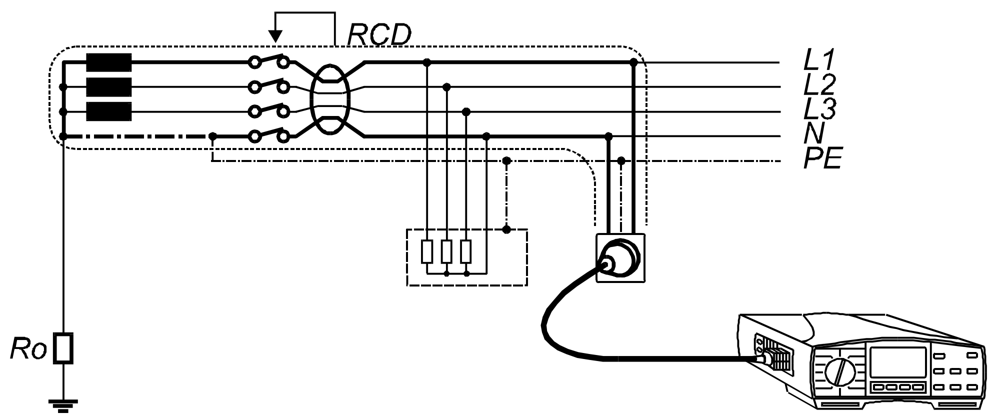


Fig. 60. Practical connection of test instrument

Result = Zsec + R_{L1} + R_N = Z_{LINE}

where
Zsec...... Impedance of power transformer secondary.
R_{L1}........ Resistance of phase conductor from power transformer to tested point.
R_N .... Resistance of neutral conductor from power transformer to tested point.
Z_{LINE}..... Line Impedance.

See description of the measurement in the next chapter!

5.10.2. Line Impedance measurement between two phase conductors

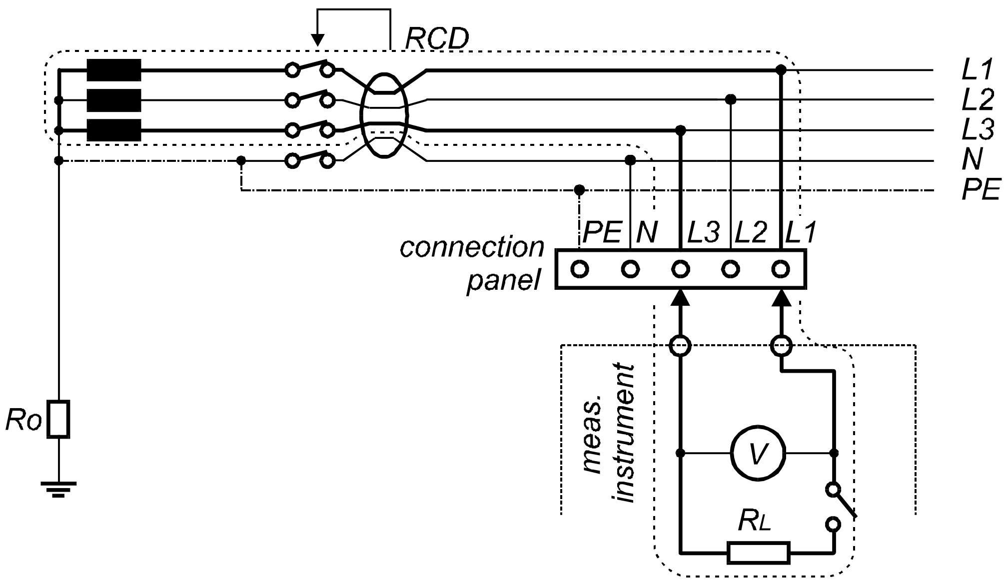


Fig. 61. Measurement principle of Line Impedance measurement between two phase terminals (L1 and L3)

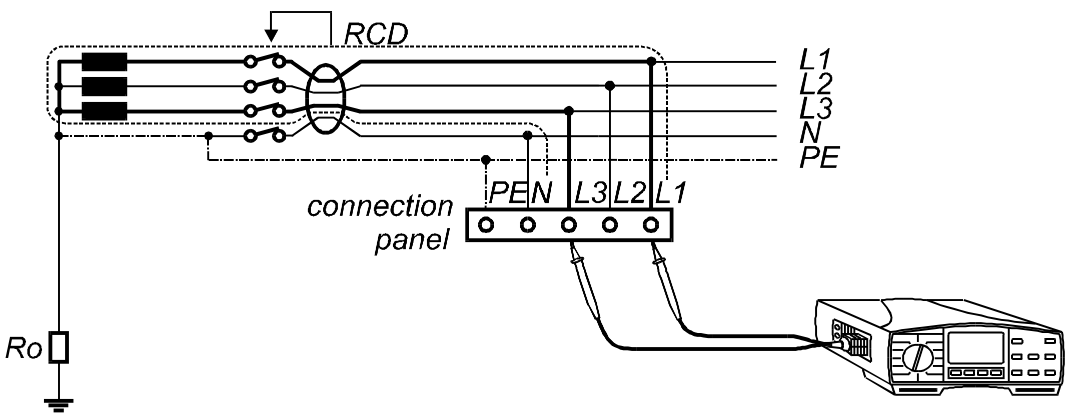


Fig. 62. Practical connection of test instrument
Result = Zsec + R_{L1} + R_{L3} = Z_{LINE}

The measurement is carried out in two steps. The voltage of the unloaded system is measured in the first step then a high power load is switched on to the tested terminals for a short period. The test current flows in the loop marked with interrupted line **(**see figures 59, 60, 61, and 62**)**. On basis of voltage difference (loaded and unloaded system) and phase shift between voltage and current, the test instrument calculates the Line Impedance Z_{LINE}.

Prospective short-circuit current Ipsc is calculated according to the following formula:

$I_{psc} = U_n \times 1{,}06 / Z_{LINE}$

where:
Ipsc........... Prospective Short-circuit current.
Un............. Nominal mains voltage between the phase and neutral conductors, or between two phase conductors (115 / 230 / 400 V).
Z_{LINE}......... Line Impedance.

The breaking current capacity of any installed over-current protection device should be higher than the calculated Prospective Short-circuit current, otherwise it is necessary to change the type of over-current protection device used.

5.11. N–PE Loop resistance

Up-to-date test instruments, with built in modern electronics, can measure resistance even between the neutral N and protection PE conductors in spite of possible high currents in the neutral conductor. The current, which is driven by phase voltages through different linear and non linear loads, causes voltage drops of extremely irregular (non sine wave) shape. The voltage drops interfere with the test voltage and thereby disturb the measurement. Internal test voltage (approx. 40V, a.c., <15 mA) is used, as there is no mains voltage between neutral and protection conductors.

Important advantage of this measurement against Fault Loop test (L – PE) is, that the RCD does definitly not trip during the measurement, this is due to the low test current (<15 mA).

Test instrument Eurotest 61557 uses special (**patented**) measurement principle to filter the test signal and therefore assures correct measurement results.

What can we deduce from the measurement?

The following conclusions can be reached on the basis of the measurement result:

- Type of used protection conductor connection (TN, TT or IT- system)
- Earth Resistance value for TT- system
- In case of TT or TN- system, the result is quite similar to the Fault Loop Resistance value, this is why the test instrument can also calculate the Fault Loop Prospective Short-circuit current.

Generally about the measurement principle

As there is no mains voltage between the N and PE terminals which could be used as a test voltage the instrument must generate an internal one. This voltage may be either d.c. or a.c. Instrument Eurotest 61557 uses a.c. test voltage, measurement is done following the U-I method according to the figure below.

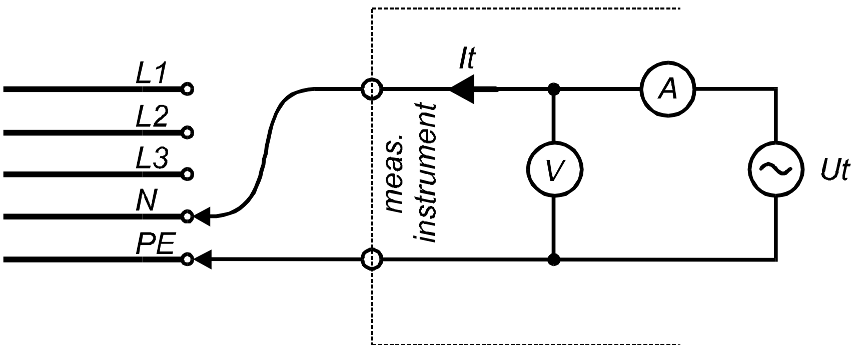


Fig. 63. Measurement principle

Result = Ut / It = R$_{N\text{-}PE}$

where:
Ut.................. Test voltage measured by the V-meter.
It.................... Test current measured by the A-meter.
R_{N-PE}............. Resistance of N-PE loop.

5.11.1. Measurement of N–PE loop resistance in TN- system

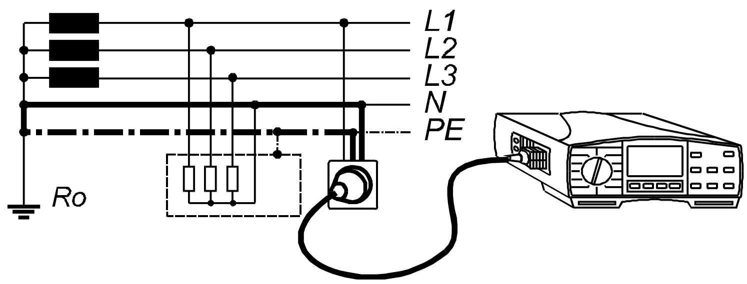


Fig. 64. Resistance measurement between neutral and protection conductor in TN- system

The test instrument measures the resistance of the neutral and the protection conductors from the power transformer to the measurement site (the loop is marked with a bold line on upper figure). The test result in this case is quite low (maximum a couple of ohms), showing that a TN- system is involved.

Result 1 = $R_N + R_{PE}$
Result 2 = Ipsc = 230V x 1,06 / ($R_N + R_{PE}$)

where
R_N .... Resistance of neutral conductor (marked with bold line).
R_{PE} .... Resistance of protection conductor (marked with bold dotted line).
Ipsc .... Prospective short-circuit current of fault loop.

5.11.2. Measurement of N–PE loop resistance in TT- system

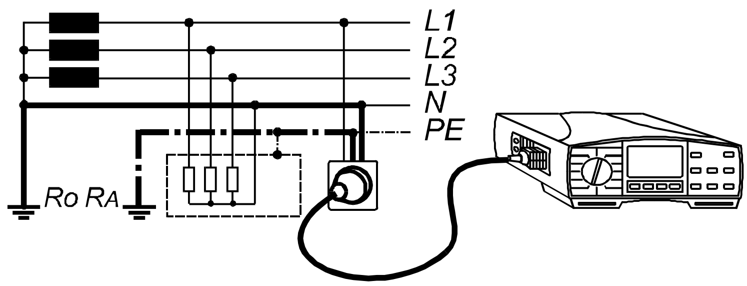


Fig. 65. Resistance measurement between the neutral and the protection conductor in a TT- system

The test instrument measures the resistance in the following loop: Neutral conductor from power transformer to measurement site (mains outlet), protection conductor from the mains outlet to earth electrode and then back to the power transformer via soil and the transformer's earthing system (the loop is marked with a bold line on the figure above). The test result in this case is quite high (in excess of ten ohms), showing that a TT- system is involved.

Result 1 = $R_N + R_{PE} + R_E + R_O$
Result 2 = Ipsc = $230V \times 1{,}06 / (R_N + R_{PE} + R_E + R_O)$

As it could be presumed, that resistance R_E is much higher than the sum of all other resistances, the following can be noted:

Result 1 $\approx R_E$
Result 2 = Ipsc $\approx 230V \times 1{,}06 / R_E$

where
R_N .... Resistance of neutral conductor from power transformer to measurement site (mains outlet).
R_{PE} .... Resistance of protection conductor from the mains outlet to earthing electrode.
R_E .... Earth resistance of protection earth electrode.
R_O .... Earth resistance of transformer's earthing system.
Ipsc .... Prospective short-circuit fault loop current.

5.11.3. Measurement of N–PE loop resistance in IT- system

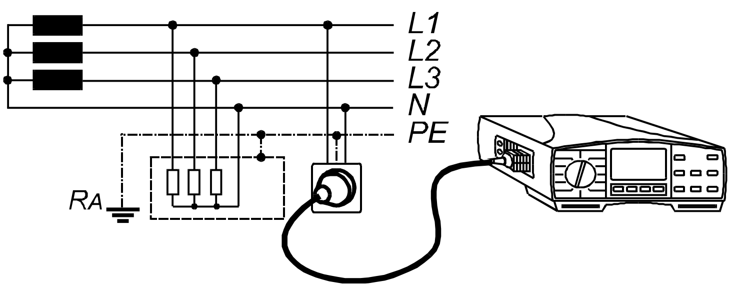


Fig. 66. Resistance measurement between neutral and protection conductor in IT- system

As can be seen from the figure above, there is no hard wired connection between the neutral and protection conductor in an IT- system. The test result is therefore very high (it can even be out of display range), Showing that an IT- system is involved.

Attention!
A high test result in itself is not sufficient evidence that an IT- system is involved (it could be just an interrupted protection conductor in a TN or TT- system).

5.12. Phase rotation EN 61557- 7

In practice, we are often faced with the connection of three-phase loads (motors and other electro-mechanical machines) to a three-phase mains installation. Some loads (ventilators, conveyors, motors, electro-mechanical machines etc.) require a specific phase rotation and some may even be damaged if the rotation was reversed. This is why it is advisable to test phase rotation before connection is made.

The test can be done comparatively with respect to a reference mains outlet.

How to measure the phase rotation

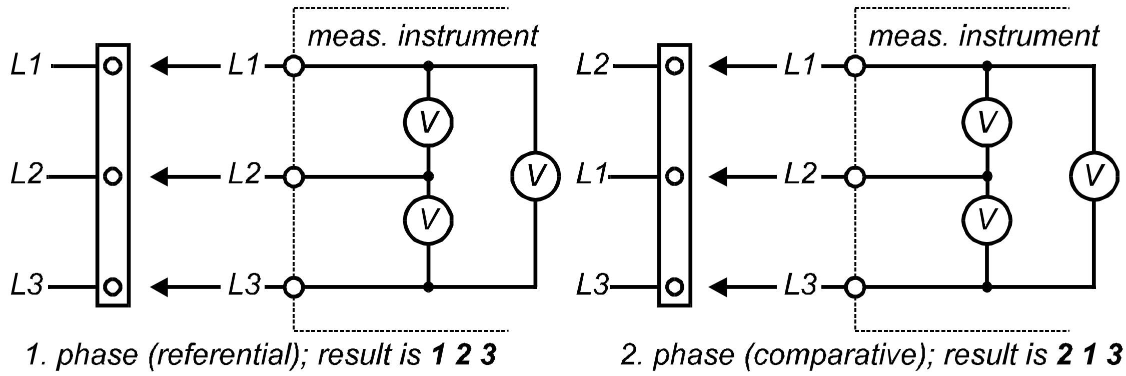


Fig. 67. Measurement principle

The test instrument compares all three phase to phase voltages concerning phase delay and on that basis determines the phase rotation.

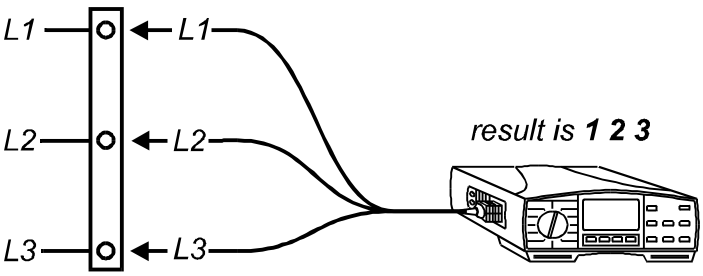


Fig. 68. Measurement of phase rotation

Procedure:

- First, we need to measure phase rotation on the reference mains outlet, where behavior of a specific machine (e.g. direction of phase rotation) is known. The direction should be noted.
- Measurement should to be repeated on an unknown mains outlet and both results compared.
- If necessary, two phase conductors must be exchanged between each other in order to reverse the phase rotation.

5.13. Measurement of voltage, frequency and current

5.13.1. Voltage and frequency measurement

Voltage measurement should be carried out often while dealing with electric installations (carrying out different measurements and tests, looking for fault locations etc.). Frequency is to be measured for example when establishing the source of mains voltage (power transformer or individual generator).

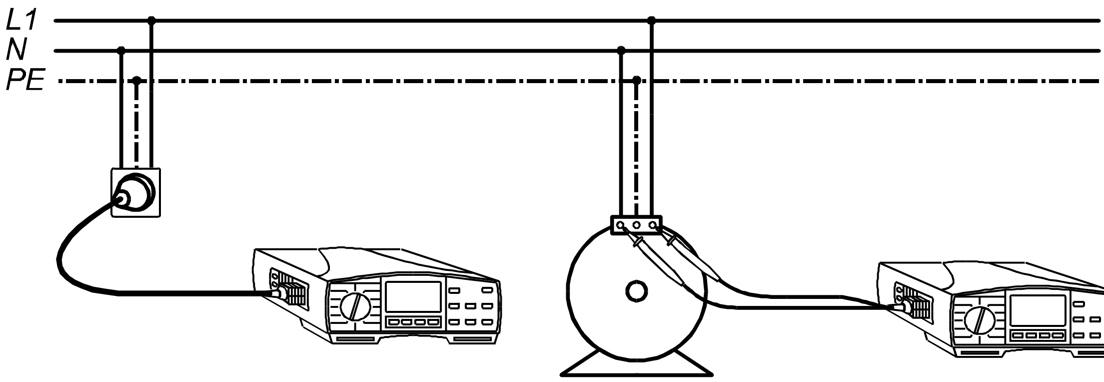


Fig. 69. Voltage/frequency measurement on mains outlet via 13amp Plug and on motor's connection terminals via Universal test cable

5.13.2. Current measurement

The Eurotest 61557 and Earth – Insulation Tester measure current via current test clamp, which is a welcome feature as there is no need to interrupt the measured current loop. Thanks to a wide measurement range, the two test instruments can measure currents from 0,5 mA up to 200 A.

The figure below presents low current measurement using current clamp while figure 72. Represents the simultaneous measurement of load current in phase L2 and phase to phase voltage $U_{L2\text{-}L1}$.

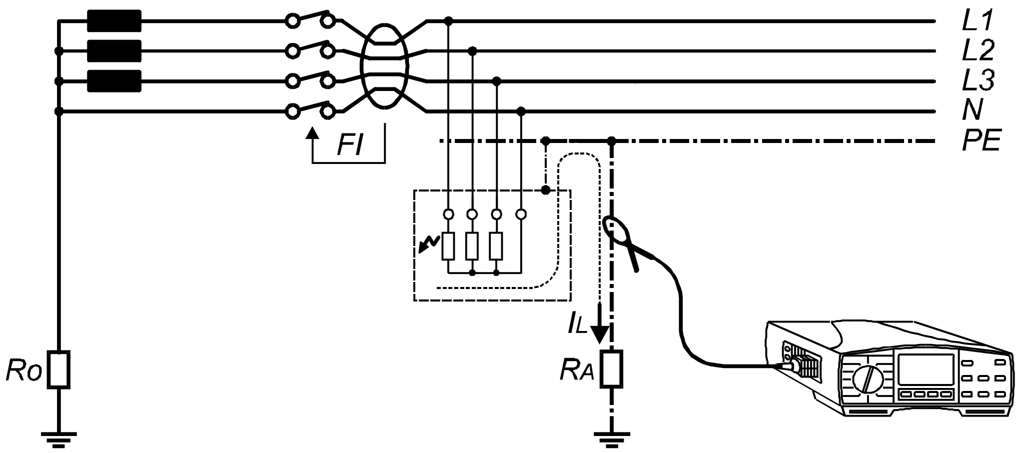


Fig. 70. Low current measurement

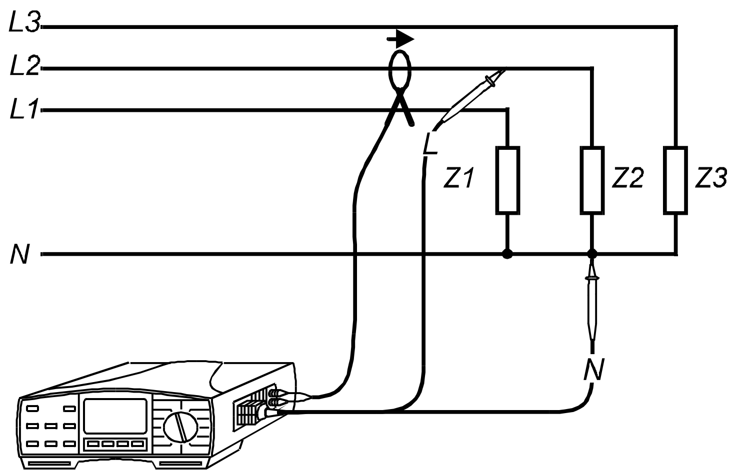


Fig. 71. Load current and phase to phase voltage measurement

The shape of the measured current is usually a non-sinusoidal wave. The shape is distorted by various non-linear loads connected to mains installation. That is why it is important, that the test instrument (such as Eurotest 61557 or Earth -Insulation Tester) measures the true RMS value of the current, otherwise the result can be misleading.

5.14. Varistor overvoltage protection devices

Varistor over-voltage protection devices are usually used to protect highly sensitive electronic equipment against lightning effects. The protection is most needed in areas where atmospheric discharges are often present. Examples of actual loads to be protected are PC computers, printers, telephone exchanges etc. The protection devices are either permanently installed in an electrical installation or inserted into a mains installation adjacent to the protected equipment (a part of the mains plug, extension etc.).

To ensure the most effective protection the devices are usually installed in several stages namely:

- In connection cabinets at the input of the mains voltage (the devices prevents the spread of supply overvoltages)
- In distribution cabinets of individual installation units.
- Adjacent to connected electrical loads (equipment).

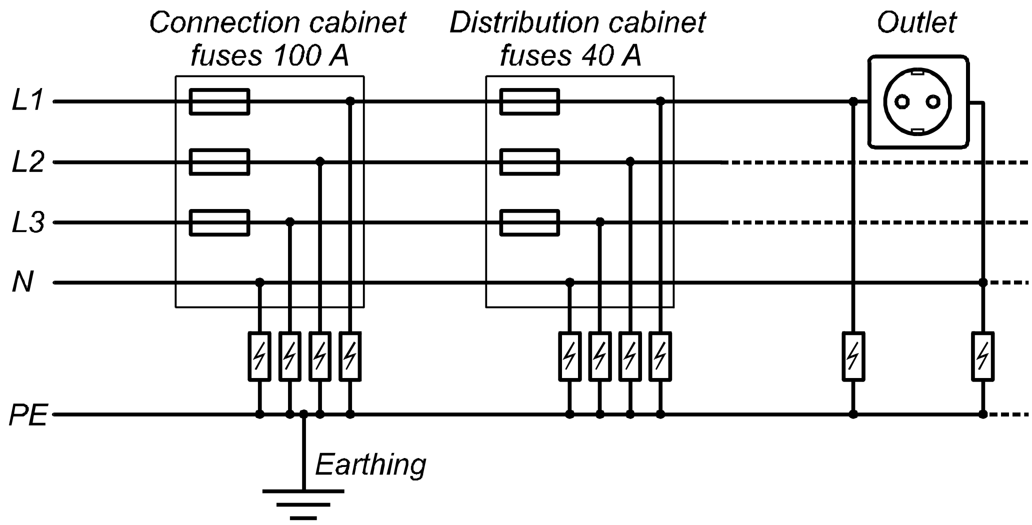


Fig. 72. Connection of multi-stage protection

The construction of protection devices is very diverse. They may consist of varistors only, gas arresters, fast diodes, solenoids, capacitors or a combination of these and other different protection elements etc.

The devices may, due to the absorption of high-voltage pulses, change their characteristics in two ways:

- Breakdown voltage may drop. Because of that reason they may be destroyed by the mains voltage itself.
- They may break totally. Therefore the protection function is lost completely.

Test instruments such as Eurotest 61557, Eurotest 61557 or Earth – Insulation Tester can do nondestructive tests of varistor overvoltage protection devices using test voltage of 50 up to 1000 V.

Measurement principle is represented in the figure below.

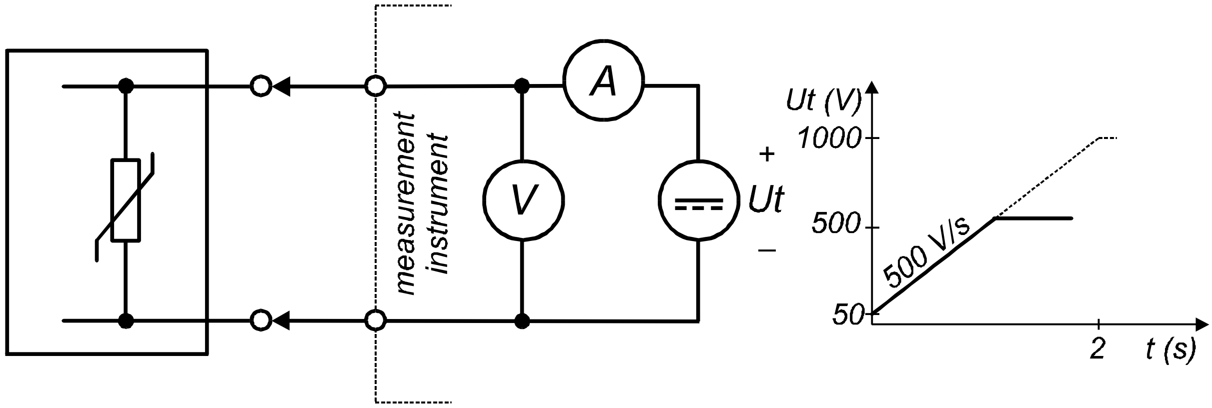


Fig. 73. Measurement principle

A DC generator increases the test voltage with the slope of 500 V/s while A-meter measures forward current. As soon as the current reaches the value of 1 mA (the threshold current), the generator stops to generate the test voltage and the last voltage is displayed (breakdown voltage).

The user should compare the displayed test voltage with the nominal one noted at the device's enclosure and change the device if needed.

The protection device is considered to be defective in the following circumstances:

- If it is open circuit (displayed result >1000 V). There is no protection function left.
- If the displayed breakdown voltage is too high (displayed value is, for example, double the nominal value). The protection is partially corrupted and it may allow too high overvoltages.
- If the displayed breakdown voltage is too low (displayed value is close to the nominal mains voltage). Total destruction of the device may be caused by the mains voltage in the near future.

Attention!

- The test is to be done at voltage-free protection device.
- Tested device should be removed from the installation before testing it in order that other loads connected to the installation do not influence the test.

5.15. Tracing of electrical installation

When dealing with electrical installations such as installing new installations, maintaining existing ones, eliminating installation faults, drawing installation plans on the basis of existing installations, carrying out measurements etc., the engineer is often faced with the problem of how to trace certain parts of the electrical installation. Typical practical problems faced are as follows:

- Recognition of protective element (fuse) responsible for a certain current loop.
- Location of short circuit.
- Location of conductor interruption.
- Tracing of a specific conductor under live conditions.
- Tracing of a specific voltage-free conductor (not connected to mains voltage).

Measurement instrument Eurotest 61557 or Eurotest 61557 in combination with hand-held detector, can solve all the problems listed above.
The operator can select either capacitive or inductive mode of receiving test signal on hend-held indicator. The mode shall be selected in accordance with instrument's mode namely:

- Inductive mode — Instrument operates on installation under live conditions (it loads mains voltage)
- Capacitive mode — Instrument operates on voltage-free installation (it imposes its own signal)

The test instrument selects the appropriate mode automatically dependant on whether or not the mains voltage is present.

Below is the principle of tracing electrical installations and the operation of test instrument.

a) Recognition of protective element in installation with mains voltage present.

Set detector to inductive mode of receiving.

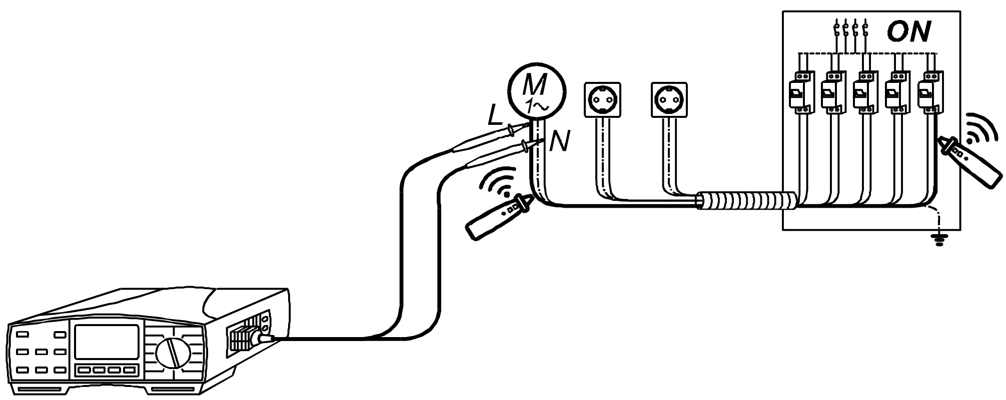


Fig. 74. Connection of test instrument to phase and neutral conductors of electric appliance

The test instrument imposes a load on the mains supply i.e. it generates current test pulses of a specific frequency from phase terminal to neutral terminal. The current creates an electro-magnetic field around the connected conductors which can be detected by the hand-held detector. In this way the detector identifies the fuse associated with that circuit.

If the fuse feeding a specific mains socket is to be identified then the test instrument should be connected directly to the socket according to the figure below.

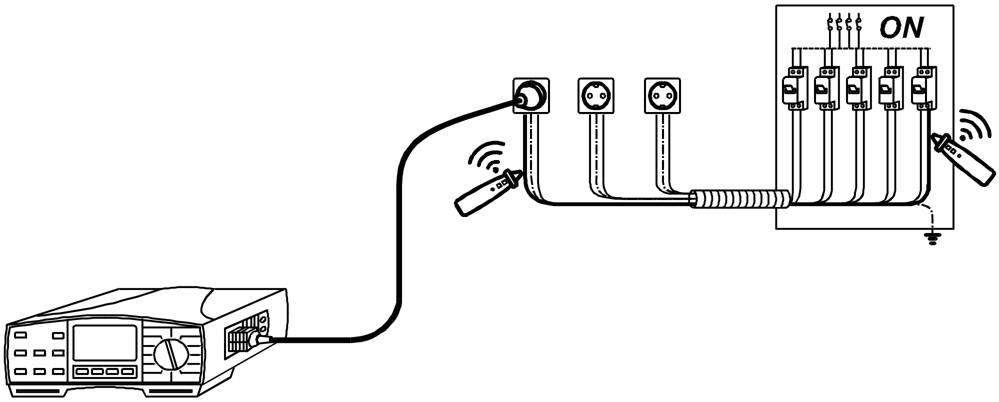


Fig. 75. Connection of test instrument directly to mains socket

The working principle of the test instument is in both cases (test instrument connected directly to mains socket – fig. 76. or to electric appliance – fig. 75.) exactly the same i.e. the test instrument loads the mains voltage, generating current test pulses from phase to neutral terminal.

b) Recognition of protective element in voltage-free installation

Set detector to capacitive mode of receiving.

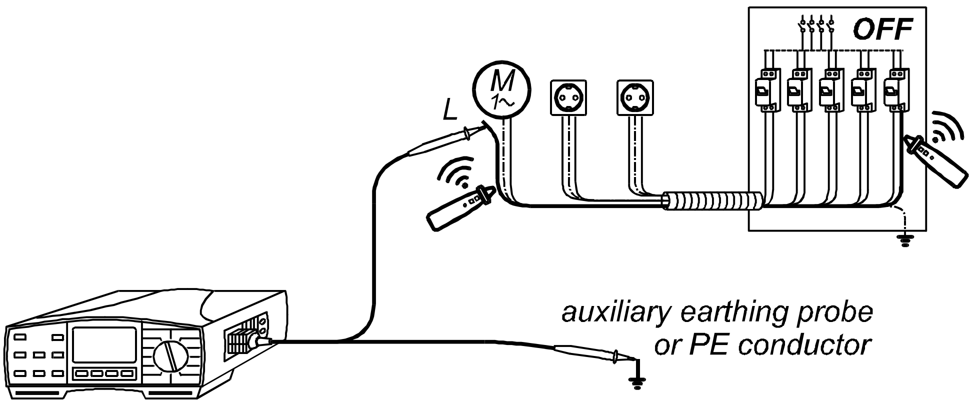


Fig. 76. Recognition of protection element at voltage-free (auxiliary earth probe or PE terminal is used as referential terminal)

The test instrument imposes a test signal of audible frequency between the reference point and the tested conductor. The conductor radiates the imposed signal (intensity of the signal decreases with increased distance from the conductor) which can be detected by the hand-held indicator. In this way the detector identifies the protection element (fuse) involved.

Before starting the measurement, it is necessary to disconnect the phase conductor from the appliance. If this was not done then the imposed signal would be transferred via the internal resistance of the connected appliance to the neutral conductor which is generally at ground potential. This would mean that the imposed signal would be shorted and therefore the measurement unsuccessful.
The same measurement can be done if the test instrument is connected directly to a mains socket in accordance with the figure below.

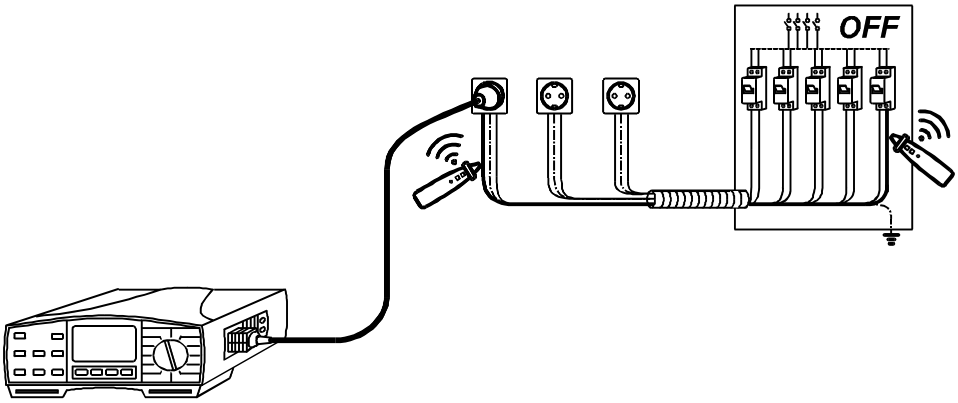


Fig. 77. Recognition of protection element at voltage-free installation (neutral terminal of mains socket serves as reference point)

Both of the above examples (fig. 77. and fig. 78.) are the same except that the reference point is different (PE terminal/auxiliary probe - fig. 77. and neutral conductor – fig. 78.)

c) Location of short circuit between phase and neutral conductor

Set detector to inductive mode of receiving.

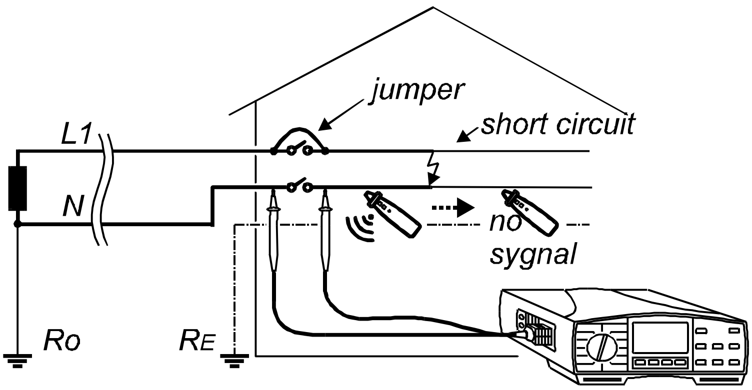


Fig. 78. Connection of test instrument in order to locate short circuit between the phase and neutral conductor

Before starting the measurement, it is necessary to short one pole of the two-pole switch (neutral or phase conductor), thereby enabling the test instrument to load the mains voltage.

The following current loop is established: Transformer, phase conductor from transformer via inserted bridge to short circuit, neutral conductor from short circuit to test instrument and neutral conductor from test instrument to power transformer. The generated current causes an appropriate electromagnetic field which can be detected by the hand-held indicator.

d) Location of short circuit between phase and protection conductor

Set detector to inductive mode of receiving.

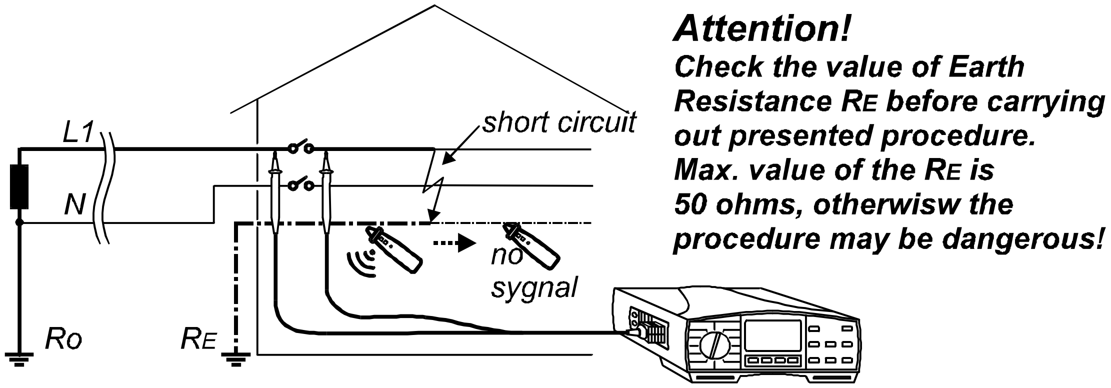


Fig. 79. Connection of test instrument to locate short circuits between phase and protection conductor

The test instrument loads the mains voltage. The following current loop is established: Transformer, phase conductor from transformer via test instrument to short circuit, protection conductor from short circuit to earthing system, and via soil back to transformer. The generated current causes an appropriate electromagnetic field which can be detected by the hand-held detector.
If there is a RCD protection device built in to the tested loop, it may cause the device to trip out. In order to avoid this situation, it is necessary to short the RCD device, otherwise it is not possible to carry out this test.

e) Location of current loop (conductor) interruption

Set detector to capacitive mode of receiving signal.

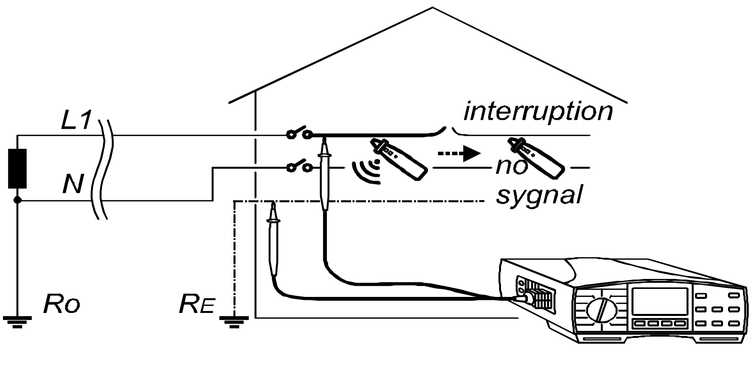


Fig. 80. Connection of test instrument in order to locate interruption of current loop

The measurement should be carried out on a voltage-free installation. The test instrument imposes a test signal of audible frequency between the reference point (protection earth conductor) and the conductor under test. The conductor radiates the imposed signal which can be detected by the hand-held indicator. If there is no PE conductor available, it may be replaced with an auxiliary earth probe driven to ground.

Note!

- When dealing with complex installations (long conductors with several current loops connected in parallel), it is advisable to disconnect the circuit under test from any elements which are not actual parts of the installation. If this is not done then the test signal be spread all over the installation and therefore the selective test will be unsuccessful.

5.16. Power

Electrical loads, connected to a mains installation, differ from each other with respect to their rated power, the character of the internal impedance, the number of phases etc.

As the installations are designed only to supply limited power, it is necessary to monitor the power consumed. If not then it may cause the installation to be overloaded or even damaged, it can also automatically trip out, some loads can suffer from low mains voltage due to overloaded system etc. It is also important to measure the character of the consumed power i.e. cos φ and compensate it if necessary.

The following figure presents power diagram in complex area.

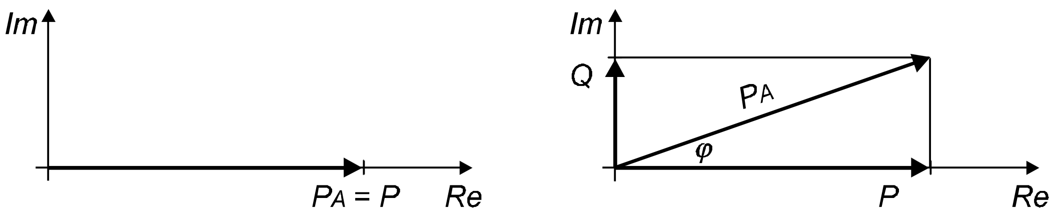


Fig. 81. Power diagram in complex area (cos φ = 1 on left diagram and cos φ ≠ 1 on right one)

where:
Im.................. Imaginary axes.
Re.................. Real axes.
P .... Active power.
Q................... Reactive power.
PA .... Apparent power.

5.16.1. Power measurement on single-phase system

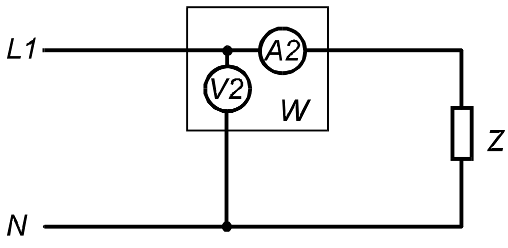


Fig. 82. Principle of power measurement on single-phase system

Measurement of all three powers (active, reactive and apparent) can be carried out indirectly measuring phase voltage U_{L-N}, phase current I_L and phase delay φ between the voltage and current. Angle φ is the result of an inductive or capacitive load, connected to the mains installation.

Using the test instrument Eurotest 61557 or a Power Meter, it is possible to measure all three types of power on a single-phase load (Eurotest 61557) – see connection of test instrument on the figure below or on three-phase load (Power Meter). Power levels are calculated by the test instrument in accordance with the equations below and can be read-out directly on the display.

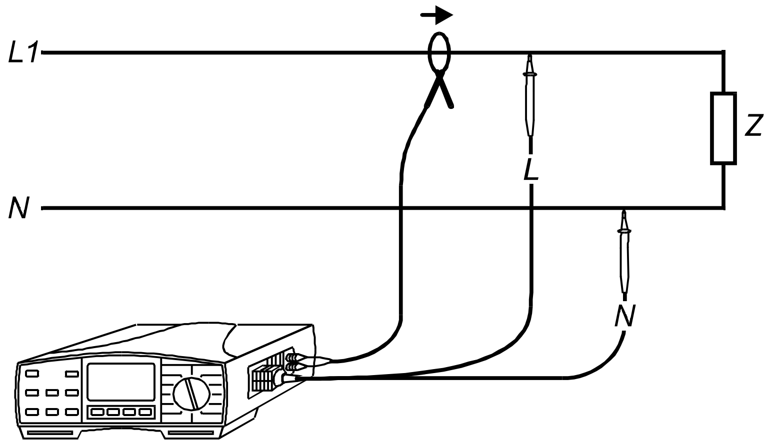


Fig. 83. Connection of test instrument for power measurement on single-phase system

$P = U \cdot I \cdot \cos\varphi$ .... (active power in W)

$Q = U \cdot I \cdot \sin\varphi$ .... (reactive power in VAr)

$P_A = U \cdot I$ .... (apparent power in VA)

where

U .... effective value of phase voltage

I .... effective value of phase current

φ .... angle between the phase voltage U and phase current I

5.16.2. Power measurement on three-phase system

Power measurement on a three-phase system is one of the following:

- **measurement on four-wire system**
- **measurement on three-wire system**

The three-wire system is mostly used when transporting energy at high voltages. It is also used at low voltages when there are powerful, symmetrical loads without a neutral conductor (motors, heating systems etc.) to be connected to the mains installation.

A four-wire system is suitable to supply unbalanced, three-phase loads or single-phase loads distributed on all three phases of a low voltage installation.

When measuring power on a three-phase system, it is necessary to take into consideration the fact that the three-phase power supply system might not be balanced (pointers of phase to phase voltages $U_{L1/L2}$, $U_{L2/L3}$ and $U_{L3/L1}$ taken in sequence do not form an equilateral triangle), due to powerful unbalanced three-phase loads connected to the mains installation.

Power measurement on four-wire system

a) Three-phase W-meter method

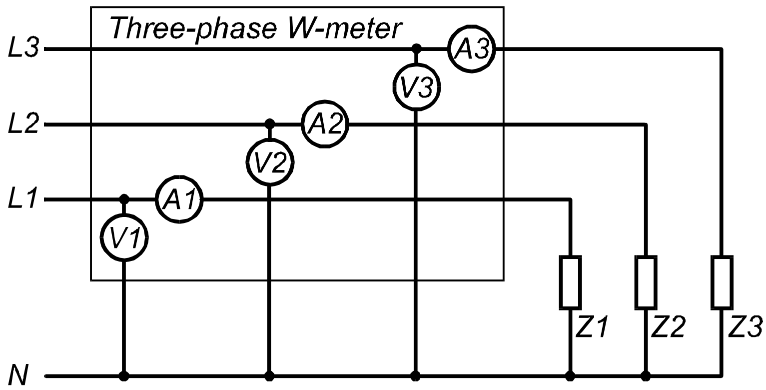


Fig. 84. Principle of power measurement on three-phase four-wire system using three-phase W-meter

Three-phase W-meter measures all three-phase voltages, phase currents and delays between the voltages and currents. On this basis it can calculate the three power levels separately for each phase, as well as the level of the total three-phase system.

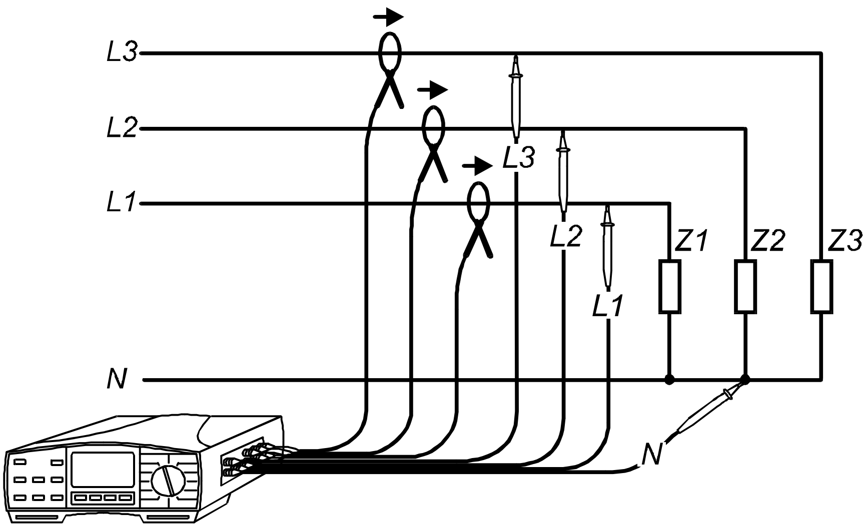


Fig. 85. Power measurement on three-phase four-wire system, using the Power Meter

All three power levels can be read out directly on the display. This method enables power measurement on all three phases simultaneously and is particularly suitable for unbalanced power. In the case of balanced power, one W-meter can be used and moved to all three phases in three steps. See presentation of the method in the following chapter.

b) Single-phase W-meter method

Where there are nonsymmetrical three-phase loads or single-phase loads usually connected to four-wire system, it is necessary to measure power on all three phases (it is not possible to measure one phase only and calculate the power of total three-phase system). Measurement, using the Eurotest 61557 runs in three steps, where each step is equal to the measurement on a single-phase system.

First step:

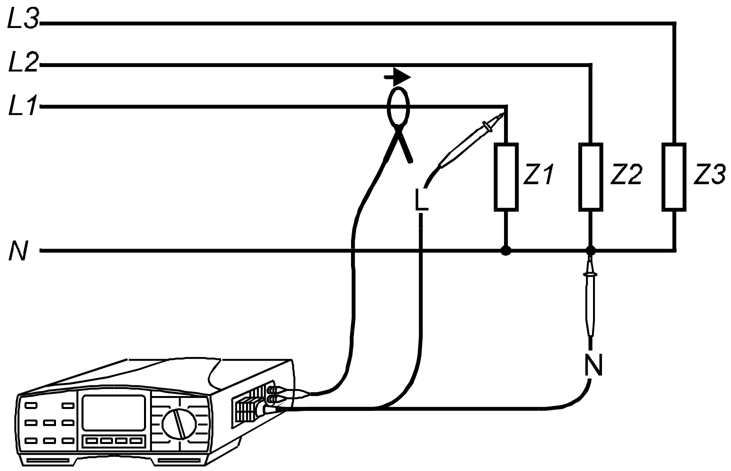


Fig. 86. Power measurement on three-phase system (first step)

Result 1 = P1 = U1 · I1 · cos φ1............... (active power)
Result 2 = Q1 = U1 · I1 · sin φ1 .... (reactive power)
Result 3 = PA1 = U1 · I1 .... (apparent power)

Second step:

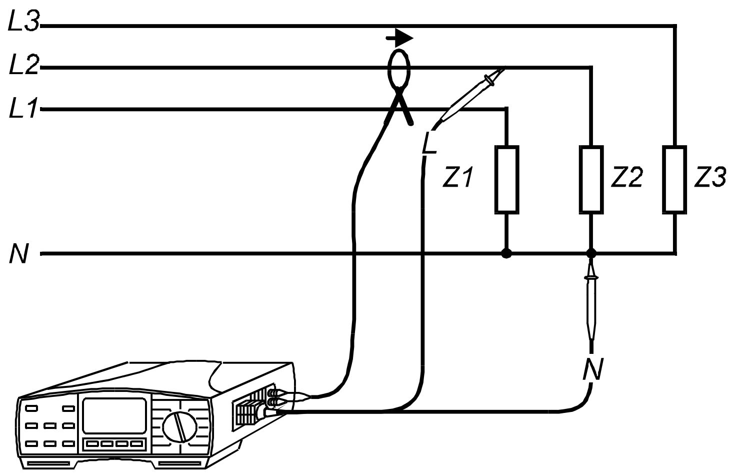


Fig. 87. Power measurement on three-phase system (second step)

Result 1 = P2 = U2 · I2 · cos φ2......... (active power)

Result 2 = Q2 = U2 · I2 · sin φ2 .... (reactive power)
Result 3 = PA2 = U2 · I2 .... (apparent power)

Third step:

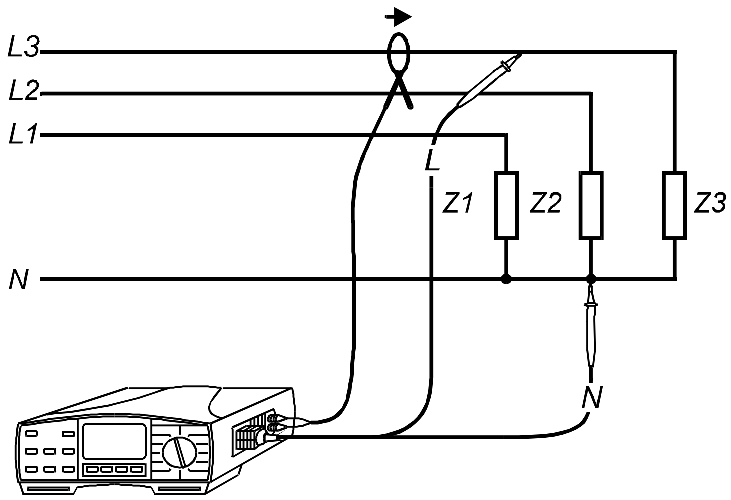


Fig. 88. Power measurement on three-phase system (third step)

Result 1 = P3 = U3 · I3 · cos φ3......... (active power)
Result 2 = Q3 = U3 I3 · sin φ3 .... (reactive power)
Result 3 = PA3 = U3 · I3 .... (apparent power)

In each step the instrument measures phase voltage, phase current and delay between the voltage and current. On the basis the of measured results for each phase, we can calculate all three total powers of three-phase system according to the following equations:

Ptot = P1 + P2 + P3 .... (total active power of three-phase system)
Qtot = Q1 + Q2 + Q3......................... (total reactive power of three-phase system)

$PAtot = \sqrt{Ptot^2 + Qtot^2}$ ……..……(total apparent power of three-phase system)

PFtot = Ptot / PA tot.......................... (power factor)

Power measurement on three-cable system

a) Method of two single-phase W-meters (Aron's connection)

If we are only interested in the total power of the three-phase system and not in the separate power of each phase, then the method of two W-meters in Aron's connection can be used. Connection of two W-meters is presented on the figure below. The method allows for the correct calculation of the total active power even with non symmetrical three-phase loads (the load's impedances per phase are not equal to each other), or with unbalanced voltages (pointers of phase to phase voltages $U_{L1/L2}$, $U_{L2/L3}$ and $U_{L3/L1}$ taken in sequence do not form an equilateral triangle).

Calculation of the total apparent power is correct only if the connected load is symmetrical and the phase to phase voltages are balanced i.e. if the power supply system is balanced.

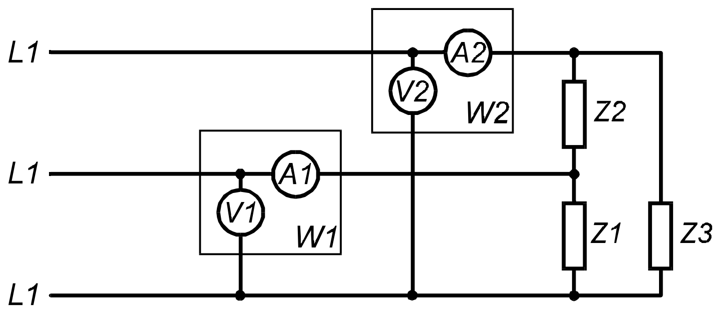


Fig. 89. Principle of power measurement on three-phase, three-wire system, using the two W-meter method

This method can also be used when measuring with the Eurotest 61557, but in this case it is necessary to carry out the measurement in two steps and afterwards calculate the total power. This procedure is explained below.

First step:

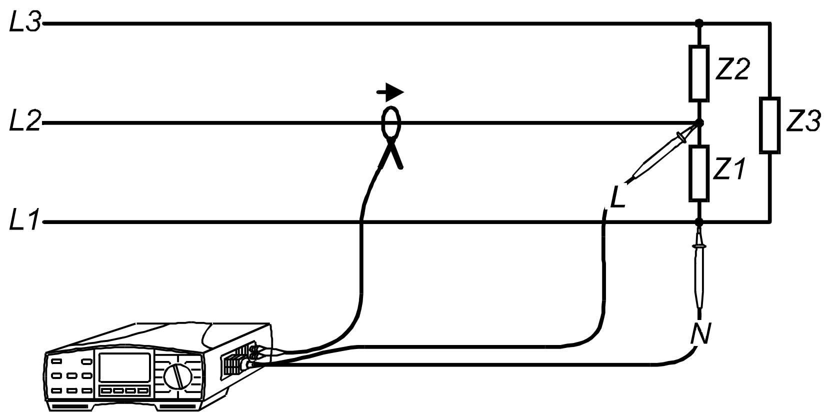


Fig. 90. Power measurement using the Eurotest 61557 (first step)

Result 1 = $U_{L2/L1} \cdot I_{L2} \cdot \cos\delta = P_{L2/L1}$
Result 2 = $U_{L1/L2} \cdot I_{L2} = P_{A\,L1/L2}$

where
δ................ delay between phase to phase voltage $U_{L2/L1}$ and current I_{L2}

Second step:

Current clamp and voltage test probe should be moved from L2 conductor to L3 and the measurement repeated.

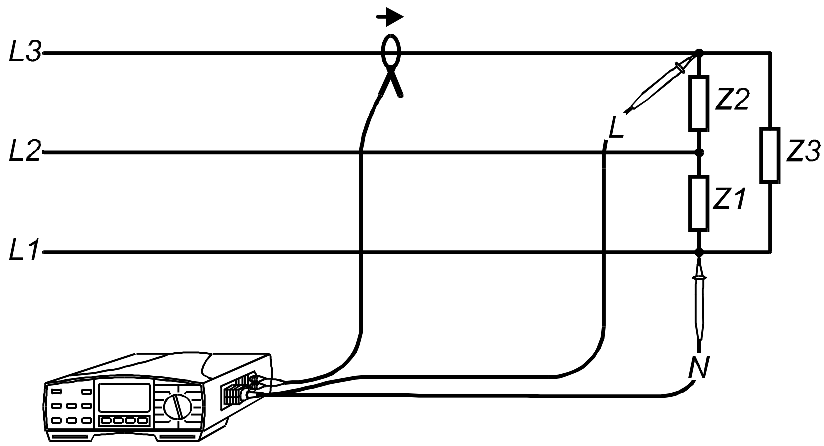


Fig. 91. Power measurement using the Eurotest 61557 (second step)

Result 1 = $U_{L3/L1} \cdot I_{L3} \cdot \cos\delta = P_{L3/L1}$

where
δ................ delay between phase to phase voltage $U_{L3/L1}$ and current I_{L3}

Total active power and apparent power can be calculated in accordance with the following equations:

$P_{tot} = P_{L2/L1} + P_{L3/L1}$................................ (total active power)
$P_{A\,tot} = P_{A\,L2/L1} \cdot 1{,}732$...................... (total apparent power)
$PF_{tot} = P_{tot} / P_{A\,tot}$........................... (power factor)

Attention!

- It is necessary to ensure the correct polarity of the voltage test probes as well as the current clamp (see markings on test leads and current clamp), otherwise calculated result may be incorrect.
- If the power measured is a negative value (possibly caused by a high delay or lag between phase voltage and phase current) then the minus sign should be used in the final calculation!
- It is necessary to be aware, that the measured results have no real meaning, but can only be used in final calculation of total power!

- The calculated total active power is correct irrelevant of the potential unbalanced power supply system (nonsymmetrical loads or unbalanced phase to phase voltages.)

The calculated total apparent power is correct only if the three-phase power supply system is balanced. The same is true for the calculation of power factor! The measured apparent powers in both steps are equal to each other if there is a balanced power supply system.

b) Method for balanced three-phase power systems

In cases of balanced three-phase power systems, and Y type of load connection with an accessible neutral point, the one W-meter method can be used. It is enough to measure power at one phase only and then calculate the total power. The method is usually used when measuring power on three-phase motors or similar symmetrical loads.
Below is the procedure, using the Eurotest 61557 or Power Meter.

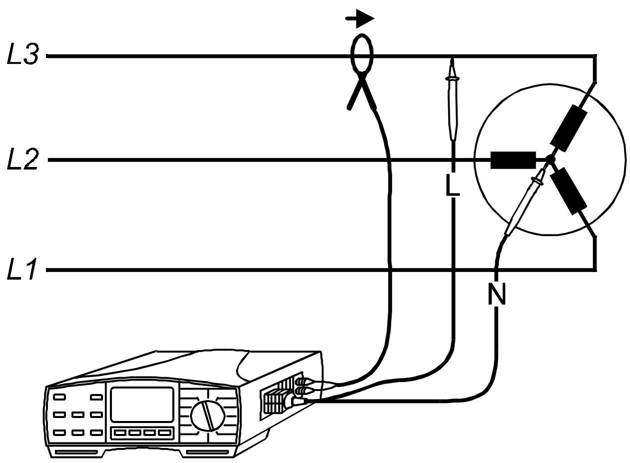


Fig. 92. Connection of test instrument

Result 1 = $U_{L3} \cdot I_{L3} \cdot \cos \varphi 1 = P1$........ (active power)
Result 2 = $U_{L3} \cdot I_{L3} \cdot \sin \varphi 1 = Q1$........ (reactive power)
Result 3 = $U_{L3} \cdot I_{L3} = P_{A1}$.................. (apparent power)
Result 4 = $P1 / P_{A1} = PF1$.................. (power factor)

Calculation of total power of three-phase system:

Ptot = 3 · P1...................................... (total active power of three-phase system)
Qtot = 3 · Q1..................................... (total reactive power of three-phase system)
PA tot = 3 · PA1................................. (total apparent power of three-phase system)
PFtot = Ptot / PA tot = PF1.............. (total power factor)

Attention!

- It is necessary to verify that the connected load is indeed symmetrical. This can be done by measuring all three-phase currents, which must be exactly equal to each other at the balanced phase to phase voltages!
- If the neutral point at the connected load is not accessible (because of mechanical protection, Δ connection etc.) it is possible to use the neutral point of the power supply generator (transformer), assuming of course that it is accessible. If the phase to phase voltages are balanced, it is also possible to simulate a neutral point using three resistors (see the figure below). When using a simulated neutral point, it is necessary to be aware that the internal resistance of the resistor voltage divider should be much lower than the internal impedance of test instrument at mains frequency.

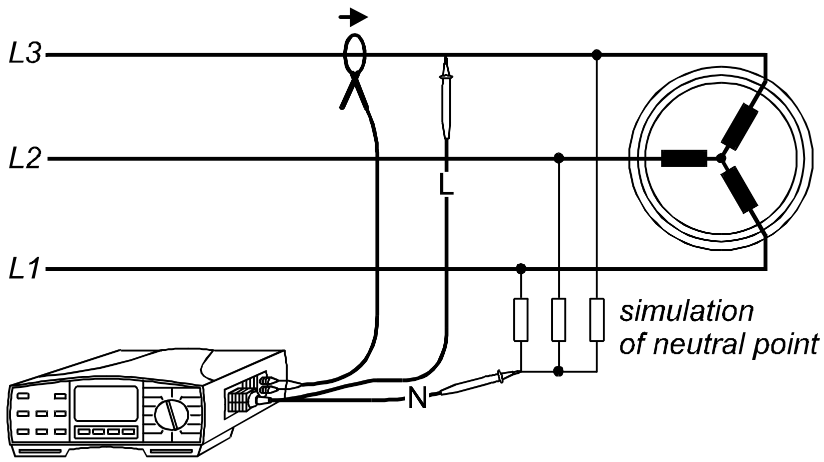


Fig. 93. Connection of test instrument to simulated neutral point

c) Method with one W-meter for nonsymmetrical loads

The measurement must be carried out in three steps (separately at each phase). Using the Eurotest 61557, the measurement can be done in exactly the same way as on a single-phase system except that the measurement neutral point must be referenced to the power supply or it must be simulated (absolutely not the neutral point of the nonsymmetrical load). Of course this is valid for balanced phase to phase voltages. The measurement must be done separately at each phase.

First step:

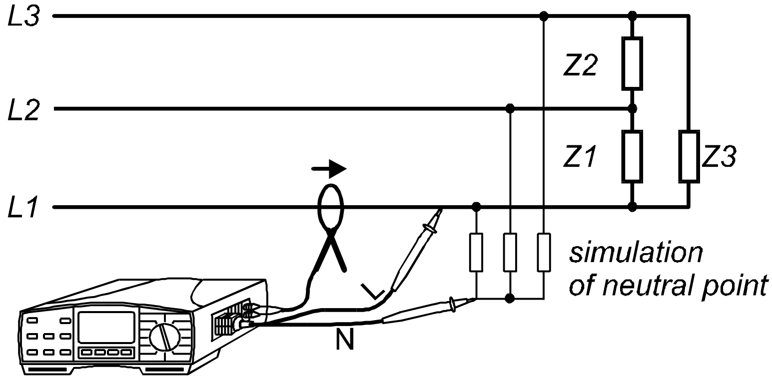


Fig. 94. Power measurement on a three-wire system with nonsymmetrical loads using the Eurotest 61557 (first step)

Result 1 = $U_{L1} \cdot I_{L1} \cdot \cos\varphi 1 = P1$ .... (active power)

Result 2 = $U_{L1} \cdot I_{L1} \cdot \sin\varphi 1 = Q1$ .... (reactive power)

Result 3 = $U_{L1} \cdot I_{L1} = P_{A1}$ .... (apparent power)

PF1 = $P1/ P_{A1}$ .... (power factor)

Second step:

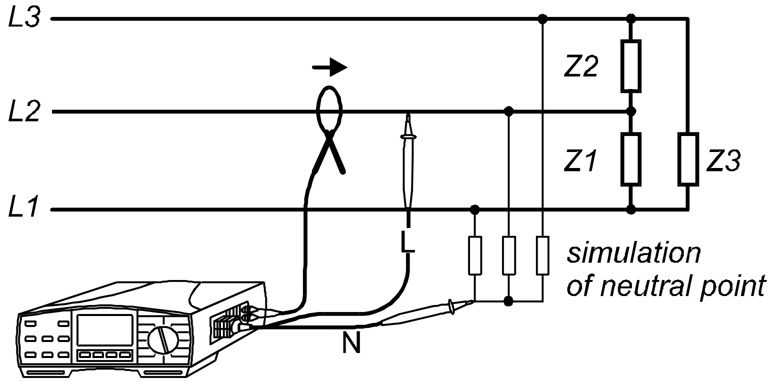


Fig. 95. Power measurement on a three-wire system with nonsymmetrical loads using the Eurotest 61557 (second step)

Result 1 = $U_{L2} \cdot I_{L2} \cdot \cos\varphi 2 = P2$ .... (active power)

Result 2 = $U_{L2} \cdot I_{L2} \cdot \sin\varphi 2 = Q2$ .... (reactive power)

Result 3 = $U_{L2} \cdot I_{L2} = P_{A2}$ .... (apparent power)

PF2 = $P2/ P_{A2}$ .... (power factor)

Third step:

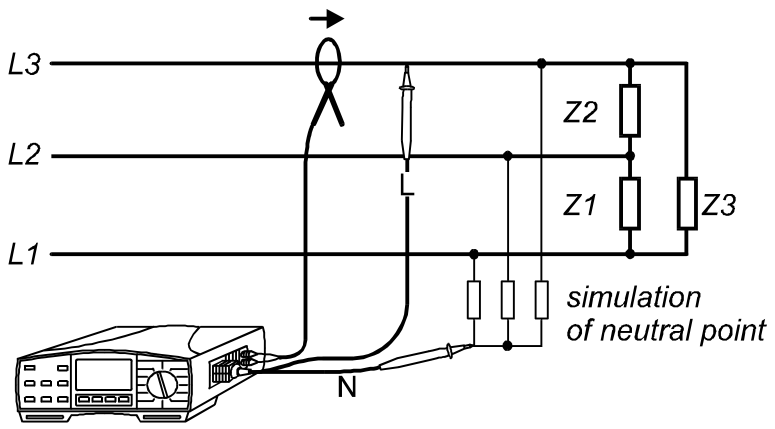


Fig. 96. Power measurement on a three-wire system using *the* Eurotest 61557 (third step)

Result 1 = $U_{L3} \cdot I_{L3} \cdot \cos\varphi 3 = P3$ .... (active power)

Result 2 = $U_{L3} \cdot I_{L3} \cdot \sin\varphi 3 = Q3$ .... (reactive power)

Result 3 = $U_{L3} \cdot I_{L3} = P_{A3}$ .... (apparent power)

PF3 = $P3/ P_{A3}$ .... (power factor)

On the basis of the above measurement results it is possible to calculate all three power levels of the three-phase system according to the following equations:

Ptot = P1 + P2 + P3 .... (total active power of three-phase system)
Qtot = Q1 + Q2 + Q3......................... (total reactive power of three-phase system)

$PAtot = \sqrt{Ptot^2 + Qtot^2}$ ……..…. (total apparent power of three-phase system)

PFtot = Ptot / PA tot.......................... (power factor)

5.17. Energy

Where there is a constant power consumption at a specific load then the consumed energy can be calculated on the basis of the load's power and the time over which it was consumed. When power is variable (regulated heaters, intermittently running motors etc.), the energy can not be calculated, but must be measured. It is also necessary to measure the energy (it cannot be calculated) if a load's power is not known. For this reason, *the* Eurotest 61557 test instrument can measure *the* consumed energy on single-phase mains loads. The following illustrates the connection of the test instrument.

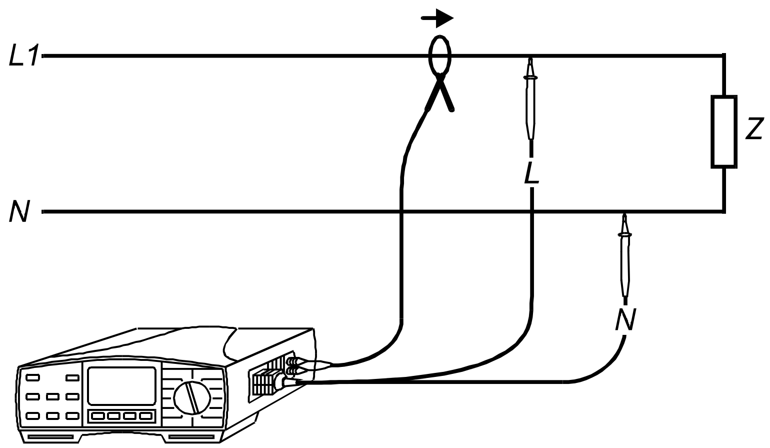


Fig. 97. Energy measurement on a single-phase system

The test instrument measures *the* phase voltage U, *the* phase current I (by means of a current clamp) and *the* delay φ between the voltage and current. On the basis of this data it calculates the consumed energy according to the following equations:

$$W = U \cdot I \cdot \cos\varphi \cdot t = P \cdot t$$

where
W .... Energy.
U .... Phase voltage.
I................. Phase current.
φ .... Delay between the voltage U and current I.
t................. Time of consumption.
P .... Active power.

Energy measurement using *the* Eurotest 61557 test instrument is limited to 25 hours.

5.18. Harmonic analysis

Dealing with harmonic components just a few years ago, was considered as highly academic and absolutely not practical, almost mystic. The problems caused by harmonics is now much much more relevant and can cause high priced damage to distribution systems and electric loads. This is why any electrician may meet a need to control harmonics in their every-day job. Thanks to highly-efficient, simple to use, hand-held instruments, the measurement is now quite simple.

Distortion of the mains voltage and current, and therefore the appearance of harmonic components is to be expected in an era of modern electronics with a wide range of different electronic equipment connected to the distribution system. In general the harmonics are a negative influence on electrical loads as well as to the power source and the electrical installation. The quality of the electrical energy is thus decreased.

How can the presence of harmonic components be detected?

- Connected loads (motors, transformers etc.) will start to overheat.
- Losses in the power distribution system will increase, requiring load shedding.
- Regulated motors will start to become unstable, due to incorrect triggering of electronic circuitry at voltage zero-crossing.
- High energy power supply transformers will start to overheat, requiring load shedding.
- Electronic fuses which detect peak value of the load current, will start to trip out.
- Stability of test results at some measurements on the electrical installation (line/loop impedance, power, voltage, current etc.) will be decreased, also due to incorrect triggering of electronic circuitry at voltage zero-crossing.

Why do harmonic components arise?

Various non-linear loads (particularly high-powered ones) such as a.c. to d.c. converters, motor regulators, personal computers, CNC machines in industry etc., may draw current in short pulses rather than in a smooth manner, as would be desired. Because of such current pulses, a voltage drop of the same shape is caused on the neutral and phase conductors, as well as on the power sources (transformers). The result of these voltage drops is a distortion of the mains voltage which may supply other, noncritical loads.

A second reason suspected for the appearance of harmonic components, is the unfavourable disposition of inductive and/or capacitive loads, which may cause oscillations on the electrical network and so the appearance of harmonics.
Below is an example of harmonic components caused by a simple a.c. to d.c. converter such as a powerful car-battery charger.

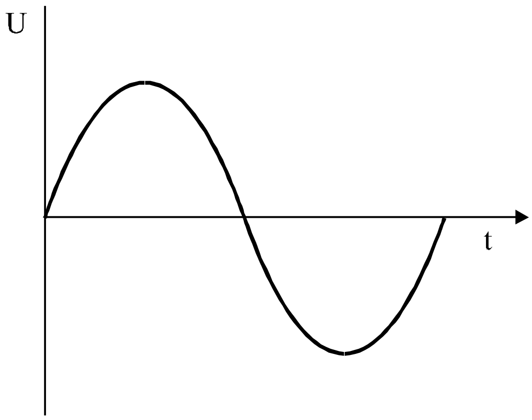


Fig. 98. Shape of pure (not distorted) sine wave voltage which supplys a.c. to d.c. converter

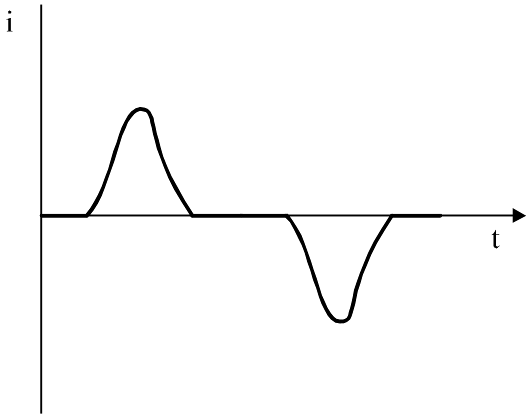


Fig. 99. Shape of distorted current, drawn by a.c. to d.c. converter

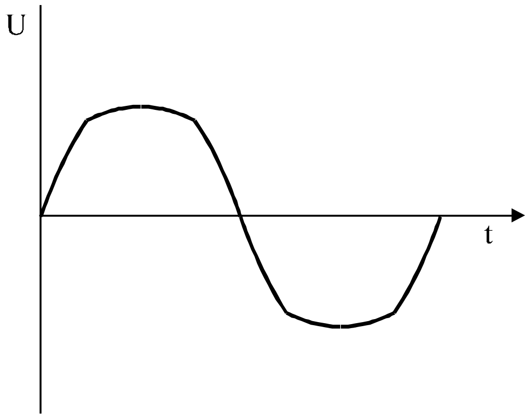


Fig. 100. Shape of the mains voltage, distorted due to voltage drops on conductors and the internal impedance of the power supply

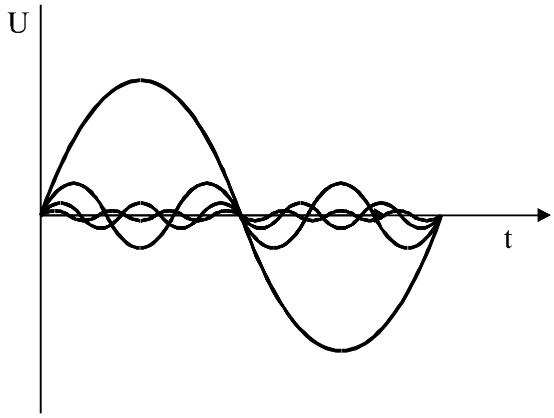


Fig. 101. Presentation of distorted voltage (see fig. 101), analized according to Fourier transformation method into the fundamental frequency and harmonics. The presentation is in time domain.

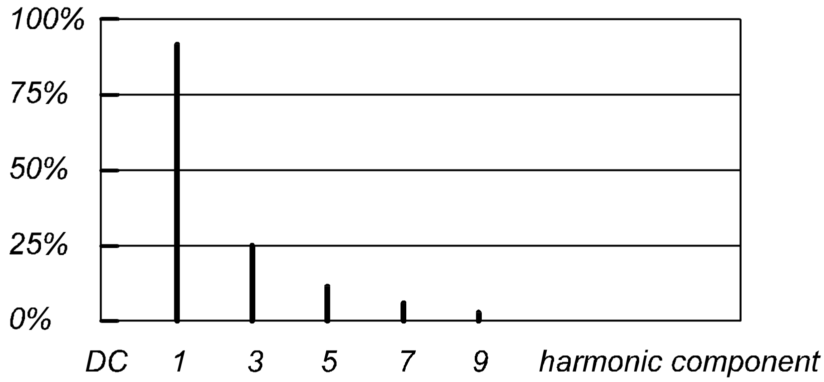


Fig. 102. Presentation of distorted voltage (see fig. 101), analized according to the Fourier transformation method into the fundamental frequency and harmonics. The presentation is in frequency domain.

Intensity of harmonic components can be presented directly in volts or in percentage with respect to the fundamental component.

Voltage harmonic measurement is usually carried out when checking the quality of the mains voltage in general. If we are looking for distortion makers (harmonic component generators), then it is advisable to measure current harmonics.

The Eurotest 61557 test instrument can carry out indicative measurements of odd voltage and current harmonics up to the 21st component. The purpose of the measurement is to estimate the intensity of the harmonics present. In a critical situation, it is necessary to use a professional test instrument such as the Power Meter, produced by METREL.

The analyser is a professional test instrument which enables analysis up to 50-th component. Otherwise it can carry out analysis of voltage and current harmonics in real time on three-phase system including recording test results. It can also perform power measurements of all three types (active, reactive and apparent), simultaneously on all three phases.

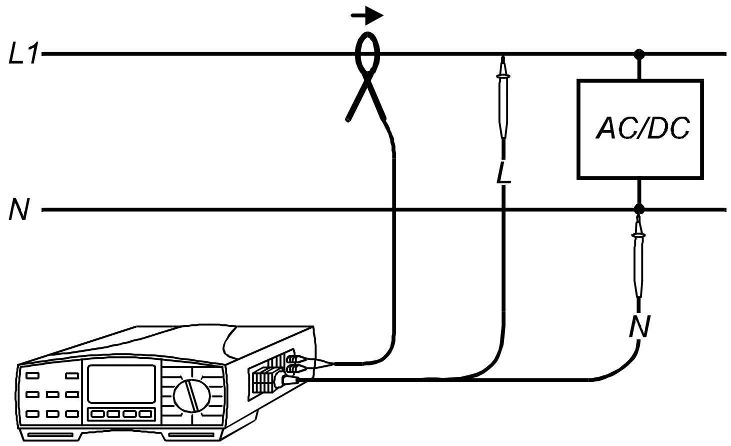


Fig. 103. Measurement of voltage and current harmonics on a single-phase system, using the Eurotest 61557 test instrument or Power Meter

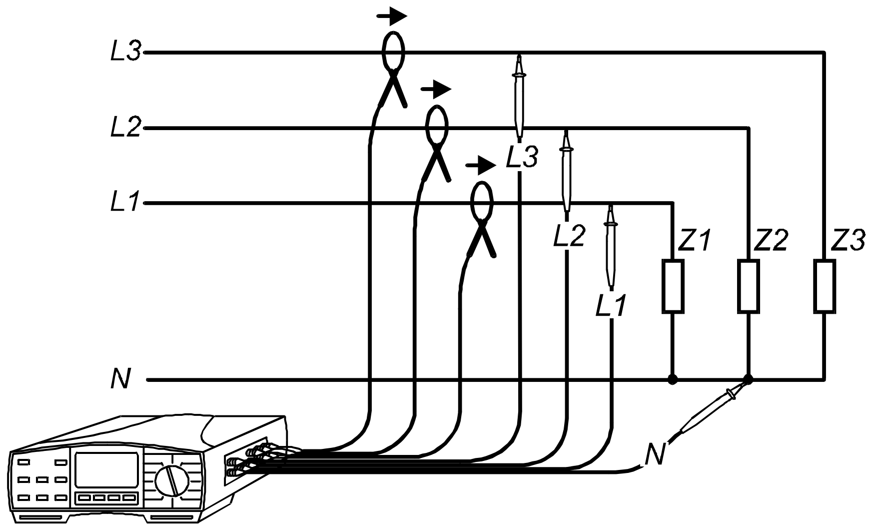


Fig. 104. Measurement of voltage and current harmonics on a three-phase system, using the professional test instrument Power Meter

Useful equations:

If harmonic components are present on a distribution system then all simple power calculations fail. Below are some useful basic equations which are valid for distorted voltages and currents.

Effective value of voltage

$$Ui = \frac{1}{\sqrt{2}}\sqrt{\sum_{n} U^{2}_{n,i}}$$

where
i...................... phase index
n..................... harmonic component index
Ui .... effective value of voltage at phase i
Un,i .... amplitude of n-th voltage harmonic component at phase i

Effective value of current

$$Ii = \frac{1}{\sqrt{2}}\sqrt{\sum_{n} I^{2}_{n,i}}$$

where
i...................... phase index
n..................... harmonic component index
Ii..................... effective value of current at phase i
In,i.................. amplitude of n-th current harmonic component at phase i

Phase active power

$$Pi = \frac{1}{2}\sum_{n} U_{n,i} \bullet I_{n,i} \bullet \cos\varphi_{n,i}$$

where
i...................... phase index
n..................... harmonic component index
Pi .... active power of all harmonic components at phase i
Un,i .... amplitude of n-th voltage harmonic component at phase i
In,i.................. amplitude of n-th current harmonic component at phase i
φn,i................. delay between n-th voltage harmonic component and n-th current harmonic component at phase i

Total active power

$$Ptot = \sum_{i} Pi$$

where
i...................... phase index
Ptot .... total active powert of all harmonic components at all phases
Pi .... active power of all harmonic components at phase i

Phase apparent power

$$P_{A}i = Ui \bullet Ii = \frac{1}{2}\sqrt{\sum_{n} U^{2}n,i} \bullet \sqrt{\sum_{n} I^{2}n,i}$$

where
i...................... phase index
n..................... harmonic component index
PAi .... apparent power of all harmonic components at phase i
Ui .... effective value of voltage at phase i
Ii..................... effective value of current at phase i
Un,i .... amplitude of n-th voltage harmonic component at phase i
In,i.................. amplitude of n-th current harmonic component at phase i

Total apparent power

$$P_{A}tot = \sum_{i} P_{A}i$$

where
i...................... phase index
PA tot .... total apparent power of all harmonic components at all phases
PAi .... apparent power of all harmonic components at phase i

Power factor PF

$$PFi = \frac{Pi}{P_{A}i}$$

where
i...................... phase index
PFi .... power factor at phase i
Pi .... active power of all harmonmic components at phase i
PAi .... apparent power of all harmonic components at phase i

Average power factor PFavr

$$PFavr = \frac{\sum_{i} P\,i}{\sum_{i} PAi}$$

where
i...................... phase index
PFavr............. average power factor of all phases
Pi .... active power of all harmonic components at phase i
PAi .... apparent power of all harmonic components at phase i

As well as the intensity of the separate harmonic components, it is also important to find out what the total voltage or current harmonic distortion (THD) is at a specific phase. It can be calculated according to the following equation:

For voltage

$$\boldsymbol{THDi} = \frac{\sqrt{\sum_{n,n\neq 1} \boldsymbol{U}^2_{n,i}}}{\boldsymbol{U}_{1,I}}$$

where
THDi .... total harmonic distortion of voltage at phase i
Un,i .... amplitude of n-th voltage harmonic component at phase i
U1,i .... amplitude of fundamental voltage component at phase i

For current

$$\boldsymbol{THDi} = \frac{\sqrt{\sum_{n,n\neq 1} \boldsymbol{I}^2_{n,i}}}{\boldsymbol{I}_{1,i}}$$

where
THDi .... total harmonic distortion of current at phase i
In,i.................. amplitude of n-th current harmonic component at phase i
I1,i.................. amplitude of fundamental current component at phase i

6. Technology of carrying out measurements, using test equipment produced by Metrel d.d.

In analyzing the wide range of electrical test equipment currently available on the market a number of shortfalls become apparent. These shortfalls are of such a nature as to involve the operator in increased activities (such as producing work schedules, completing inspection reports and filling in and copying test results), this takes up valuable time which could be spent in more profitable areas.

This is what prompted METREL to focus its energy on overcoming these shortfalls in developing its latest family of multi-function testers. Its basic target was to construct easy to use instruments which can support the user through his wide range of testing activities.

Wide range of activities means the whole procedure, starting at the operator's initial preparation, continuing with the visual inspection of the installation, measurements, functional testing of the electric equipment and finishing at the final protocol printout. Let's examine the process in the following pages and try to understand the roots of the procedure.

In order to achieve the aforementioned target, the whole procedure must be considered and incorporated into the test equipment (test instrument plus PC software). We refer to this procedure as the technology of carrying out measurements. It's purpose is to help the operators to make their job as simple as possible and increase speed, thereby reducing costs and increasing productivity.

To improve understanding the whole procedure can be split into three main parts:

PREPARATION

- *Visual inspectin of tested object.*
- *Preparation of installation plans.*
- *Insertion of installation structure to PC and then to Eurotest 61557.*

▼

CARRYING OUT MEASUREMENTS

- *Realization of the measurements and storing of test results to prepared structure.*
- *Functional test of connected equipment (loads).*

▼

FORMING OF FINAL PROTOCOL

- *Transfer of stored results to PC.*
- *Insertion of basic data on subscriber and tested installation to PC.*
- *Print-out of final protocol including test results.*

-

Visual inspection of equipment under test

If the measurements have already been taken in accordance with this technology at a particular site (regular inspection), then the purpose of the inspection is only to verify any potential deviations of the installation when compared to the last inspection.
If the measurements are to be carried out in accordance with this technology for the first time, then the installation is not really known to the operator, so the inspection must be undertaken in order for the operator to discover and record some of the basic characteristics of the installation such as:

- Address of tested site, type of distribution transformer, distributor of electric energy etc.
- Type of installation with respect to its earthing system (TN-C, TN-S, TN-C-S, TT
or IT) – see this booklet on page 14 and 15.
- Number of distribution boards (fuse cabinets) involved and their markings.
- Number and type of current loops (fuse loops) at each distribution board.
- Type of protection system used against electric shock for indirect contact (RCD protection device, automatic over-current fuses – type?, melting over-current

fuses – type?, non-conductive rooms, isolated power supply, safety voltage etc.)
- Type of earthing system (rod type, band type, panel type, chemically-active type, etc.).
- Design of earthing system (one earthing electrode, many earthing electrodes, overhead connection between the columns, underground connection between the columns, connection of lightning conductor to tested earthing system, connection of distribution earthing to tested earthing system etc.).
- Presence of over-voltage protection devices.
- Sections of protection conductors.
- Inspection of protection conductors connection to main potential equalizing collector (MPEC).
- Inspection of protection conductors connection to protection conductor collector (PCC) in each distribution cabinet.
- Inspection of main equalizing.
- Inspection of additional equalizing.
- Marking of individual installation parts (distribution boards, fuses, switches etc.) and correspondance to regulations.
- Conductor colours.
- Connection of tested installation to distribution system (underground, overhead).
- etc.

When carrying out the above listed activities, an operator can use the test instrument Eurotest 61557 which in addition to the measurements required by regulations, also offers a wide range of auxiliary tests and measurements such as: Tracing installation conductors, tracing over-current protection devices, fault locating, power measurement, energy measurement, current measurement, PE terminal test (presence of phase voltage), over-voltage devices tests etc.

Above mentioned characteristics, are to be manually added to the blank form of final protocol and later transferred to PC. They will automatically be included in final protocol when printing it out.

Preparation of installation plans

To ensure that the operator is aware of his actions and to follow the measurements in a sensible way, it is necessary to prepare an updated plan in accordance with the actual installation. If the plan already exists, then the operator only needs to check (or insert) the appropriate markings of installation parts, such as distribution boards, current loops, lightning systems, individual earth columns of lightning system, connections between earth columns, main potential equalizing collectors (MPEC), connections to MPEC, earthing systems connected to MPEC etc. If the plan does not exist (old or adapted installation), then it is advisable to draw one up, to ensure that any further activities are carried out in a fast and efficient manner. It is also advisable to insert all of the above mentioned markings of the installation parts.

Insertion of intallation structure on PC and then to Eurotest 61557

The structure of electric installation is a plan of the electrical installation, transferred in a form acceptable for installing on to a PC and then to the test instrument Eurotest 61557. The structure also includes all of the attendant markings of installation parts. The structure, when installed on to the test instrument offers simple and transparent memorizing of test results to prepared and marked memory locations. It is also possible to attribute certain measurements (parameters to be measured) to a certain measurement location (current loop, MPEC etc.) in advance, by means of PC. In this way the operator can verify at any time which measurements are still to be done and where. While carrying out the measurements and memorizing the test results, the operator is led by the Eurotest 61557 which displays the actual names of the measured location.

To ensure that the procedure of setting up the structure is both simple and repeatable, regardless of the equipment under test, the appropriate software has a pre-prepared model of the structure.

The PC software is designed to interactively lead the operator through installing the procedure, as well as other activities which the operator is dealing with on the PC. The model of the structure offers general names of installation parts such as:

measurement object 1
- block 1
- block 2
- block 3
  - fuse 1
  - fuse 2
  - fuse 3

The general names listed above may be exchanged with real ones when inserting the structure to PC. See some examples of real names below:

measurement object = Alphatek factory
- block = Main offices
- block = Development department
- block = Industrial plant
  - fuse = Lighting system
  - fuse = Single-phase outlets
  - fuse = CNC machine

The following is a typical plan of an electrical installation commonly found when testing in buildings. The plan will serve afterwards, to form the general model of the structure.

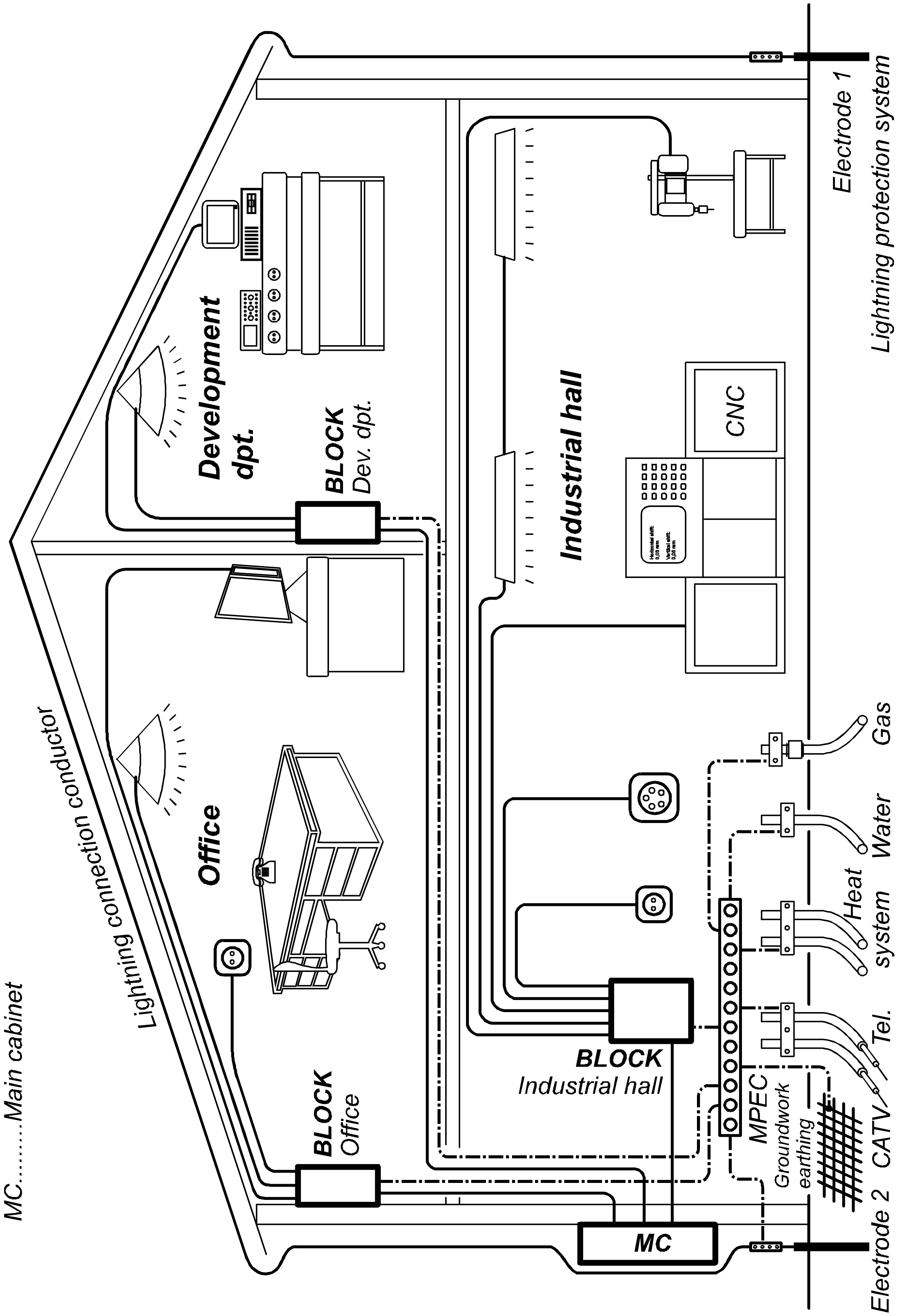


Fig. 105. Diagram of general electric installation

A general model of the electrical installation structure (see the figure below) can be created on the basis of the general installation presented above. The model can be used when inserting the structure of the electrical installation to the PC and to the Eurotest 61557, regardless of any potential deviations at the actual real installation. The deviations are to be incorporated in this model.

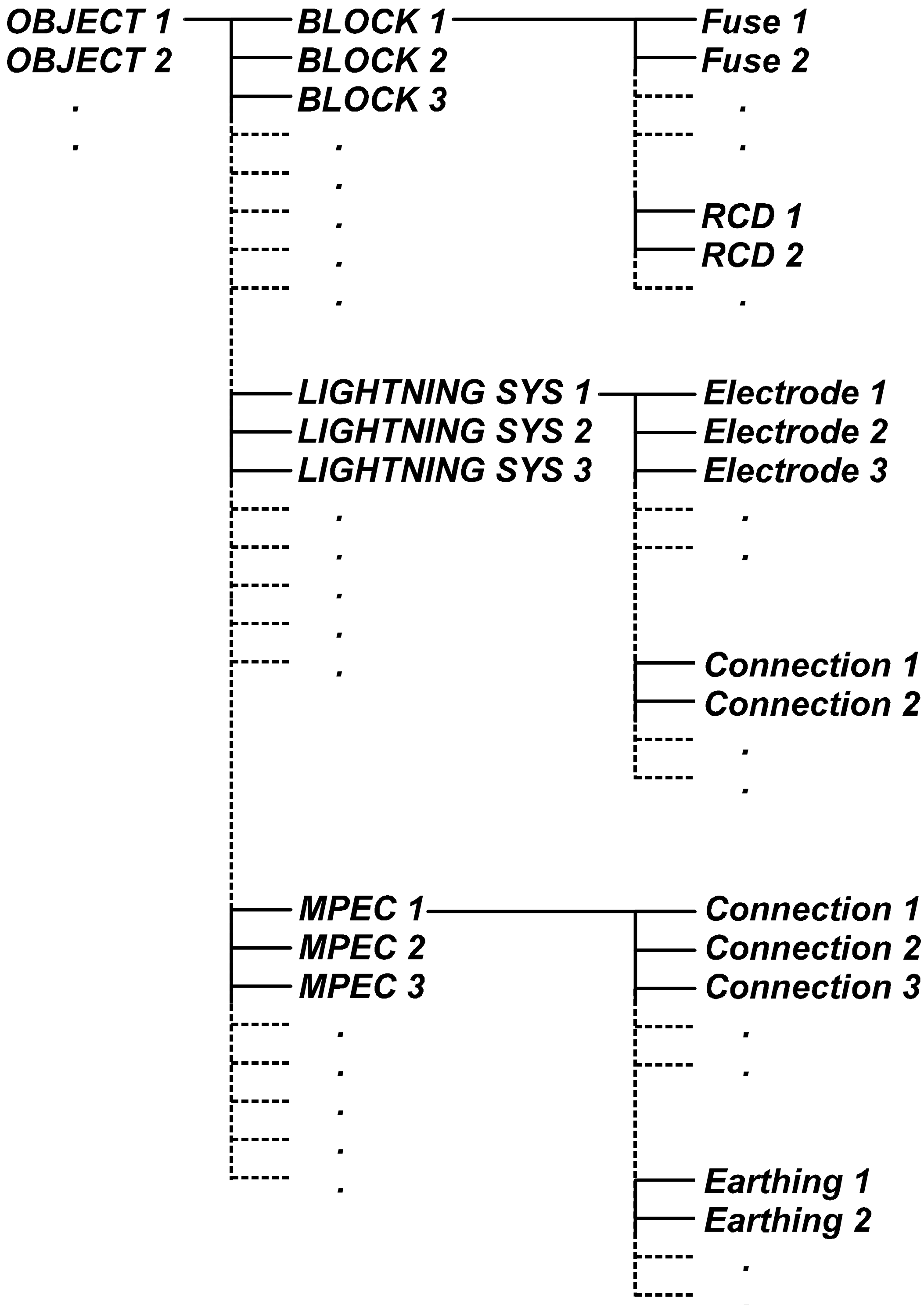


Fig. 106. General model of electric installation structure, suitable for inserting the structure to PC and to Eurotest 61557

Description of above presented model:

- **First level.**
  Object is the main location where all the measurements will be carried out.
  Example: Alphatek factory

- **Second level.**
  The whole object is devided to **Blocks**, **Lightning systems** and **Main Potential Equalizing Collectors**(MPE).
  Example: »Block« Main offices,
  »Block« Industrial plant,
  »Block« Development department,
  »Lightning system« Main building,
  »MPE« Main building etc.

- **Third level.**
  Block is devided to various **Fuses** and **RCDs***.*
  Example: »Fuse« Lighting net,
  »Fuse« CNC machine,
  »Fuse« Single-phase outlets etc.
  »RCD« Switch board 1

  Lightning system is devided to individual **Electrodes** and **Connections** to the lightning system.
  Example: »Electrode« Electrode 1,
  »Electrode«Electrode 2,
  »Connection« Gas installation,
  »Connection« MPE etc.

  Main potential equalizing collector (MPE) is devided to **Connections** with the MPE and earthings connected to the MPE.
  Example: »Connection« Water installation,
  »Connection« Central heating installation,
  »Connection« Gas installation,
  »Connection« Protection conductor collector (PCC) Industrial plant,
  »Connection« Protection conductor collector (PCC) Dpt. department,
  »Earthing« Earthing Groundwork,
  »Earthing« Protection system etc.

After inserting the structure onto the PC, it is to be transfered to Eurotest 61557.

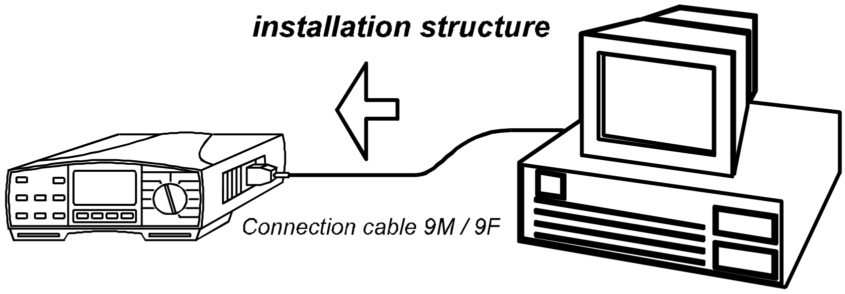


Fig. 107. Transfer of structure from PC to Eurotest 61557

Measuring and storing of test results to prepared structure

Measurements are to be carried out in turn from main distribution cabinet (input of mains system) in direction to connected electric loads, namely:

- Earthing systems (earth resistance of individual earth column, connections between columns, connections of passive accessible conductive parts with the earthing system).
- Main potential equalizing collectors (MPEC) (connections to MPEC, earth resistance of earthing system connected to MPEC).
- Distribution cabinets (continuity of main potential equalizing protection conductors at all current loops, efficiency of additional equalizing protection conductors, insulation resistance between conductors at all current loops, fault loop impedance and prospective short-circuit current at all current loops, test of RCD protection devices at all current loops, phase sequence etc.).

The test results obtained whilst carrying out the above listed measurements, are to be stored to the prepared (inserted with structure) memory locations. The Eurotest 61557 will lead the operator while storing the test results, displaying real names of test locations (fuses, blocks etc.)

The important advantage of the Eurotest 61557 is that the operator can verify at any time which measurements have not been completed and stored. Please find detailed instructions, about how to store test results, in Instruction manual Eurotest 61557.

Functional test of connected equipment (loads)

After completing the measurements, it is also required to carry out functional tests on certain eqipment connected to the installation under test. Some examples of the equipment: Motors (rotation direction), ventilators, control and protection devices, heating systems, lighting systems etc. Results of the test (OK or not OK) are to be inserted manually into blank form of final protocol, and later transferred to PC. They will automatically be included in final protocol when printing it out.

Transfer of stored results to PC

The transfer is completed automatically by placing a simple command to the PC

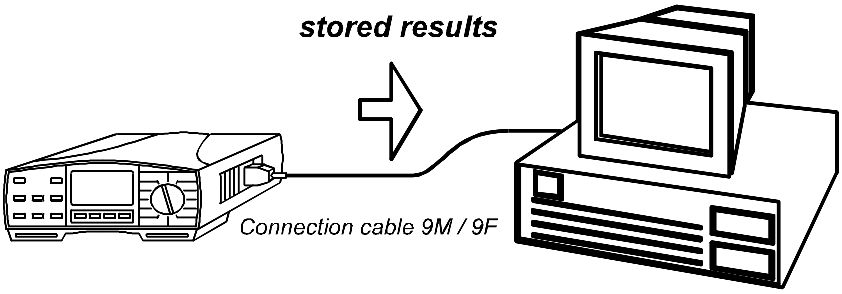


Fig. 108. Transfer of stored results from test instrument to the PC

Insertion of basic data on subscriber and tested installation to PC

The final protocol offered by the PC software requires the insertion of various data obtained while performing a visual inspection of the equipment under test. The data is described under paragraph »**Visual inspection of the equipment under test**« and will be automatically included in the final protocol when printing it out.

Print-out of final protocol including test results

After transferring all of the data (visual inspection of tested object, test results and functional tests) to the PC, the final protocol can be created on the PC and printed out by the printer. There are several forms of final protocol, see Instruction manual Eurotest 61557.

There is only one action left to be performed by the operator namely the test results and the installation structure of the site under test are to be stored to the operator's archives. The data will be used again when carrying out the next periodic inspection of the same site.

Thus the whole procedure is completed!

Let's sumarise again all the advantages, offered by the technology described in this chapter using the latest test instrument Eurotest 61557 in combination with PC software, all produced by METREL.

- **The structure of a specific installation, prepared just once, can be used to repeat the same measurements on the same equipment. It is only to be transferred from the archives to the Eurotest 61557. The instrument is then ready to store new test results to the same memory locations.**

- **The structure of a specific installation, sent to the Eurotest 61557 can be freely adapted whenever required. This feature offers complete flexibility in the field.**

  The adaptations can be done regardless of how the structure has been entered on the test instrument (by PC software or manually).

- **When storing test results,** the **actual markings of** the **distributionboards, current loops (circuits), earthing systems etc. are displayed. Additional manual noting is not needed.**

- **The operator can verify anytime which measurements have not yet been done and where.**

- **Creating of final protocol is automatic and fast, thanks to** the **appropriate PC software. Printed out document is ready to be handed over to client.**

- **All the data (structure and test results) can be stored to the operators archives at PC or to disk. Whenever the same equipment is to be tested the operator need only transfer the stored structure back to the test instrument.**

If an operator does not set up the structure via the PC for any reason (no plan of electric installation available, etc.), the same technology can still be used. In this case the test instrument will offer general markings of the installation components when storing the test results, see page 105. After transferring the results to the PC the general names can still be exchanged with real ones which will be used in final protocol.

7. Presentation of test instruments produced by Metrel d.d.

There are various instruments available for the complete testing of electrical installations. The main difference between the instruments is in the list of main and auxiliary parameters (those not required by EN 61557 standard), that a specific instrument can support. Below are the main characteristics of each instrument.

1. Highly professional multitester for the ultimate testing of electrical installations **Eurotest 61557**.
   It is intended for professional engineers who are dealing with installing, maintaining, servicing and approving electrical installations at the highest level (they possess wide knowledge about the installations). The advantage of the instrument is that in addition to all of the main parameters required by the EN 61557 standard, it can also measure a wide range of auxiliary parameters such as Harmonics up to 21st component, Power, Energy, Current, Installation tracing, Continuity using low test current, Varistor protection device test etc.

2. Highly professional multitester for the complete testing of electrical installations **Instaltest 61557**.
   It is intended for all electricians, who are dealing with installing, maintaining, servicing and approving electrical installations. It offers measurements of all parameters required by the EN 61557 standard as well as some auxiliary ones such as Installation tracing, Continuity using low test current, Varistor protection device test etc.

3. Highly professional multitester for the complete testing of Earth Resistances and
   Insulation Resistances
   Earth Insulation Tester.
   It is intended for engineers and electricians who are dealing with the *installing, maintaining, servicing and approving of earthing systems and insulation on electrical installations. It measures a wide range of auxiliary measurements such as Current, Continuity of protection devices, Continuity using low-test current, Varistor protection device test etc.*

4. High professional portable three-phase **Harmonic - Power analyzer**.
   It is intended for high demanding measurers, who are dealing with inspection of electrical energy quality. The advantage of the instrument is that it can monitor all three phase currents and voltages on a three-phase system simultaneously. All the measurements run in real time (any period is controlled), results are recorded and can be used later for further analysis. The instrument operates autonomously (independent of the *connected mains voltage) thanks to internal battery power supply.*

7.1. Technical specifications Eurotest 61557

Functions

Insulation resistance

Meas. range Riso (Un ≥ 250V)... (0,008 ÷ 1000)MΩ

Display range Riso (MΩ) Un ≥ 250V	Resolution (MΩ)	Accuracy*
0,000 ÷ 1,999	0,001	±(2% of r. + 2D)
2,00 ÷ 19,99	0,01	
20,0 ÷ 199,9	0,1	
200 ÷ 1000	1	±(10% of r.)

Meas. range Riso (Un < 250V).. (0,012 ÷ 199,9)MΩ

Display range Riso (MΩ) Un < 250V	Resolution (MΩ)	Accuracy*
0,000 ÷ 1,999	0,001	±(5% of r. + 3D)
2,00 ÷ 19,99	0,01	
20,0 ÷ 199,9	0,1	

*Specified accuracy is valid if **Universal test cable** is used while it is valid up to 20 MΩ if **Tip Commander** is used.

Display range Test voltage (V)	Resolution (V)	Accuracy
0 ÷ 1200	1	±(2% of r. + 3D)

Nom. test voltage.......50, 100, 250, 500, 1000Vd.c.
Current capability of test generator
(at Utest. > U_N) ....>1mA
Short-circuit test current...............................<3 mA
Automatic discharge of tested object.................yes

Continuity of Protection Conductors

Meas. range R.............................(0,08 ÷ 1999)MΩ

Display range R (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	±(2% of r. + 2D)
20,0 ÷ 199,9	0,1	±(3% of r.)
200 ÷ 1999	1	

Open-terminal test voltage..................... 4 - 7 Vd.c.
Short-circuit test current.......................... > 200 mA
Compensation of test leads (up to 5 Ω).............yes
Sound signal..yes
Automatic polarity exchange.............................yes
Measurement mode................single measurement

Continuity

Display range R (Ω)	Resolution (Ω)	Accuracy
0,0 ÷ 199,9	0,1	±(3% of r. + 3D)
200 ÷ 2000	1	

Open-terminal test voltage ....4 - 7 Vd.c.
Short-circuit test current .... < 7 mA
Sound signal .... yes
Measurement mode ....continuous measurement

Earth Resistance, four-lead method

Meas. range R_E...........................(0,11 ÷ 19,99k)Ω

Display range (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	±(2% of r. + 3D)
20,0 ÷ 199,9	0,1	
200 ÷ 1999	1	
2,00k ÷ 19,99k	10	±(5% of r.)

Additional spike resistance error
at Rc max. or Rp max.................... ±(3% of r. + 5D)
Rc max. ....(4kΩ + 100R_E) or 50kΩ (lower value)
Rc = Rc1 +Rc2 (Earth Resistivity)
Rp max. ....(4kΩ + 100R_E) or 50kΩ (lower value)
Rp = Rp1 +Rp2 (Earth Resistivity)
Additional error
at 20 V voltage noise (50 Hz) ....±(5% of r. +10D)
Open-terminal test voltage ....40 Va.c.
Test voltage shape................................ sine wave
Test voltage frequency ....125 Hz
Short-circuit test current ....< 20 mA
Automatic test of current and
potential test probe resistance.......................... yes
Automatic test of voltage noise .... yes

Earth Resistance using one clamp in combination with four-lead method

All technical data listed under four-lead method are valid, additional ones are listed below:

Additional error at 3A noise current generated
by mains voltage (50 Hz)............. ±(5% of r. + 10D)
Additional error
of resistance ratio.....................Rpartial/Rtotal · 1%
Rpartial = resistance measured with clamp
Rtotal = resistance of total earthig system

Indication in case of low clamp current .... < 0,5 mA
Automatic test of noise current..........................yes
Additional clamp error is to be considered.

Earth Resistance using two clamps

Meas. range R_E ....(0,08 ÷ 100)Ω

Display range R_E (Ω)	Resolution (Ω)	Accuracy*
0,00 ÷ 19,99	0,01	±(10% of r. +2D)
20,0 ÷ 100,0	0,1	±(20% of r.)

* .... distance between test clamps >25 cm

Additional error at 3A noise current generated by mains voltage (50 Hz) ....±(10% of r. + 10D)
Automatic test of noise current..........................yes
Additional clamp error is to be considered.

Specific Earth Resistance (resistivity)

All technical data listed under four-lead method are valid, except display range table, see below.

Display range ρ (Ωm)	Resolution (Ωm)	Accuracy
0,00 ÷ 19,99	0,01	Consider accuracy of R_E Measurement $\rho = 2\pi a R_E$
20,0 ÷ 199,9	0,1	
200 ÷ 1999	1	
2,00k ÷ 19,99k	10	
20,0k ÷ 199,9k	0.1k	
200k ÷ 2000k	1k	

Distance between test rods.................1 up to 30 m

RCD – General data

Nominal differential currents .... 10, 30, 100, 300, 500, 1000 mA
Accuracy of actual differential currents:
-0 / +0,1·I_Δ; $I_\Delta = I_{\Delta N}$, 2·$I_{\Delta N}$, 5·$I_{\Delta N}$
-0,1·$I_{\Delta N}$ / +0; $I_\Delta = 0{,}5 \cdot I_{\Delta N}$
Test current shape..................................sine wave
Test current start at.................................0° or 180°
RCD type.............................Standard or Selective
Nominal input voltage .... 230/115V/ 45 - 65 Hz

RCD – Contact Voltage Uc

Meas. range Uc ....(10 ÷ 100)V

Display range Uc (V)	Resolution (V)	Accuracy*
0,00 ÷ 9,99	0,01	(-0 / + 10)% of r. ± 0,2V
10,0 ÷ 100,0	0,1	(-0 / + 10)% of r.

*The accuracy is valid if:
Mains voltage is stable during the meas.
PE terminal is free of interfering voltages

Measurement principle ... with or without aux. probe
Test current... < 0,5 $I_{\Delta N}$
Limit contact voltage...............................25 or 50 V
The Contact Voltage is calculated to $I_{\Delta N}$ (standard type) or to 2$I_{\Delta N}$ (selective type).

RCD – Earth (Fault Loop) Resistance R_E/R_L

Display range R_E (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	Consider acc. of Uc meas.
20,0 ÷ 199,9	0,1	
200 ÷ 1999	1	
2,00k ÷ 10,00k	0,01k	

Calculation .... R_E (R_L) = Uc / $I_{\Delta N}$
Measurement principle ..... with auxiliary probe (R_E)
without auxiliary probe (R_L)
Test current... < 0,5 $I_{\Delta N}$

RCD – Trip out time

Test current........................0,5 $I_{\Delta N}$, $I_{\Delta N}$, 2 $I_{\Delta N}$, 5 $I_{\Delta N}$
(multiplier 5 is not available if $I_{\Delta N}$ = 1000mA)

Meas. range t (G type) .... (0ms ÷ upper disp value)

Display range t t (ms) G type	Resolution (ms)	Accuracy
0 ÷ 300 (1/2$I_{\Delta N}$, $I_{\Delta N}$)	1	±3ms
0 ÷ 150 (2$I_{\Delta N}$)	1	
0 ÷ 40 (5$I_{\Delta N}$)	1	

Meas. range t (S type)..... (0ms ÷ upper disp value)

Display range t (ms) S type	Resolution (ms)	Accuracy
0 ÷ 500 (1/2$I_{\Delta N}$, $I_{\Delta N}$)	1	±3ms
0 ÷ 200 (2$I_{\Delta N}$)	1	
0 ÷ 150 (5$I_{\Delta N}$)	1	

RCD – Tripping current

Meas. range I_Δ .... (0,2 ÷ 1,1)$I_{\Delta N}$

Display range I_Δ	Resolution	Accuracy
0,2$I_{\Delta N}$ ÷ 1,1$I_{\Delta N}$	0,05$I_{\Delta N}$	±0,1$I_{\Delta N}$

Meas. range t_Δ....................................(0 ÷ 300)ms

Display range t_Δ (ms)	Resolution (ms)	Accuracy
0 ÷ 300	1	±3ms

Meas. range Uci ....(10 ÷ 100)V

Display range Uci (V)	Resolution (V)	Accuracy*
0,00 ÷ 9,99	0,01	(0 ÷ 10)% of r. ± 0,2V
10,0 ÷ 100,0	0,1	(0 ÷ 10)% of r.

*The accuracy is valid if:
Mains voltage is stable during the meas.
PE terminal is free of interfering voltages

Uci voltage is calculated to Tripping current I_Δ

Fault Loop Impedance and Prospective Short-circuit Current

Meas. range Z_{L-PE}, R, Xl.................(0,11 ÷ 1999)Ω

Display range Z_{L-PE}, R, Xl (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	±(2% of r. + 3D)
20,0 ÷ 199,9	0,1	
200 ÷ 2000	1	

Display range Ipsc (A)	Resolution (A)	Accuracy
0,06 ÷ 19,99	0,01	Consider Accuracy of Z_{L-PE}
20,0 ÷ 199,9	0,1	
200 ÷ 1999	1	
2,00k ÷ 19,99k	10	
20,0k ÷ 24,4k	100	

Ipsc calculation:....................Ipsc = $U_N \cdot 1{,}06 / Z_{L-PE}$
U_N = 115 V; (100 V ≤ U_{L-PE} < 160 V)
U_N = 230 V; (160 V ≤ U_{L-PE} ≤ 264 V)
Max. test current (at 230 V)................. 23 A (10ms)
Nominal input voltage .... 230/115V/ 45 - 65 Hz

Contact Voltage at Short-circuit Current

Display range Uc (V)	Resolution (V)	Accuracy
0,00 ÷ 9,99	0,01	±(3% of r. + 0,02Ω · Ipsc)
10,0 ÷ 99,9	0,1	
100 ÷ 264	1	

Max. test current (at 230 V)............................23 A
Nominal input voltage .... 230/115 V/ 45 - 65 Hz

Line Impedance and Prospective Short-circuit current

Meas. range Z_{L-N}, R, Xl.................. (0,11 ÷ 1999)Ω

Display range Z_{L-N}, R, Xl (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	±(2% of r. + 3D)
20,0 ÷ 199,9	0,1	
200 ÷ 2000	1	

Display range Ipsc (A)	Resolution (A)	Accuracy
0,06 ÷ 19,99	0,01	Consider acc. of Z_{L-N}
20,0 ÷ 199,9	0,1	
200 ÷ 1999	1	
2,00k ÷ 19,99k	10	
20,0k ÷ 42,4k	100	

Ipsc calculation:......................Ipsc = $U_N \cdot 1{,}06 / Z_{L-N}$
U_N = 115 V; (100 V ≤ U_{L-N} < 160 V)
U_N = 230 V; (160 V ≤ U_{L-N} ≤ 264 V)
U_N = 400 V; (264 V < U_{L-N} ≤ 440 V)
Max. test current (at 400 V) ....40 A (10ms)
Nominal input voltage... 400/230/115 V/ 45 – 65 Hz

Resistance of N-PE Loop and Prospective Short-circuit Current

Meas. range R_{N-PE}......................... (0,11 ÷ 1999)Ω

Display range R_{N-PE} (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	±(2% of r. + 3D)
20,0 ÷ 199,9	0,1	
200 ÷ 1999	1	

Display range Ipsc (A)	Resolution (A)	Accuracy
0,06 ÷ 19,99	0,01	Consider acc. of R_{L-PE}
20,0 ÷ 199,9	0,1	
200 ÷ 1999	1	
2,00k ÷ 19,99k	10	
20,0k ÷ 24,4k	100	

Ipsc calculation:.................... Ipsc = $U_N \cdot 1{,}06 / Z_{L-PE}$
U_N = 115 V; (100 V ≤ U_{L-PE} < 160 V)
U_N = 230 V; (160 V ≤ U_{L-PE} ≤ 264 V)
Technical data for generator see under **Earth Resistance, four-lead method.**

Phase rotation

Nominal mains voltage range ....100 ÷ 440V
Result displayed............................... 1.2.3 or 2.1.3

Voltage (except in harmonic function)

Display range U (V)	Resolution (V)	Accuracy
0 ÷ 440	1	±(2% of r. + 2D)

Nominal frequency range...................... 45 – 65 Hz

Current (True RMS)

Display range I (A)	Resolution (A)	Accuracy
0,0m ÷ 99,9m	0,1m	±(5% of r. + 3D)
100m ÷ 999m	1m	±(5% of r.)
1,00 ÷ 9,99	0,01	
10,0 ÷ 99,9	0,1	
100 ÷ 200	1	

Input resistance .... 10 Ω/1Wmax.
Measurement principle......... current clamp 1A/1mA
Nominal frequency.................................. 50/60 Hz
Additional clamp error is to be considered.

Peak Current

Display range I (A)	Resolution (A)	Accuracy
5 ÷ 280	1	±(5% of r.)

Sampling rate .... 2 measurements / ms
Measurement principle...................... current clamp
Nominal frequency.................................. 50/60 Hz
Additional clamp error is to be considered.

Varistor Overvoltage Protection Devices (Breakdown voltage)

Display range U (V)	Resolution (V)	Accuracy
0 ÷ 1000	1	±(5% of r. + 10V)

Measurement principle................. d.c.voltage ramp
Test voltage slope .... 500 V/s
Treshold current .... 1 mA

Fault/Fuse/Conductor locator

Principle ...... Line loading or Imposing of test signal

Loading (mains voltage range 30÷264V/45÷65Hz):
Is < 1A pulsed
fs = 3600 Hz
Imposing (voltage free installation):
Us < 7V pulsed
fs = 3600 Hz
Isc < 50mA pulsed

Power

Display range (W/VAr/VA)	Resolution (W/VAr/VA)	Accuracy*
0,00 ÷ 9,99	0,01	±(7% of r. + 1D)
10,0 ÷ 99,9	0,1	
100 ÷ 999	1	
1,00k ÷ 9,99k	0,01k	
10,0k ÷ 88,0k	0,1k	

*(U: 10 ÷ 440V, I: 10mA ÷ 200A)

Principle...................... single-phase, clamp current
Power type.. W, VAr, VA
Nominal input voltage..... 400/230/115 V / 50/60 Hz
Display range (cos φ) .... 0,00 – 1,00
Additional clamp error is to be considered.

Energy

Display range W (Wh)	Resolution (Wh)	Accuracy
0,000 ÷ 1,999	0,001	±(7% of r. + 1D)
2,00 ÷ 19,99	0,01	
20,0 ÷ 199,9	0,1	
200 ÷ 1999	1	
2,00k ÷ 19,99k	0,01k	
20,0k ÷ 199,9k	0,1k	
200k ÷ 1999k	1k	

Calculation.. $W = \sum P \cdot \Delta t$
Time interval .... presetable 1min up to 25 hr
Nominal input voltage...... 400/230/115V / 50/60 Hz

Harmonic Analysis (voltage and current)

Voltage measurement (True RMS):

Display range U (V)	Resolution (V)	Accuracy
10 ÷ 440	1	±(5% of r. + 3D)

Current measurement (True RMS):

Display range I (A)	Resolution (A)	Accuracy
10,0m ÷ 99,9m	0,1m	±(5% of r. + 3D)
100m ÷ 999m	1m	±(5% of r.)
1,00 ÷ 9,99	0,01	
10,0 ÷ 99,9	0,1	
100 ÷ 200	1	
Display range THD (%)	Resolution (%)	Accuracy
0,0 ÷ 100,0	0,1	±(5% of r. + 5D)

Display range Harmonics up to 21-th (%)	Resolution (%)	Accuracy
0,0 ÷ 100,0	0,1	±(5% of r. + 5D)

Display of result............in % of total effective value

Nominal frequency ....50/60 Hz
Clamp error is to be considered additionally.

General characteristics Eurotest 61557

Power supply... 6Vd.c. (4 × 1,5V battery IEC LR14)
Automatic comparison of test result with set high and low limit value.....................................yes
Visual and sound warnings ....yes
Dimensions (w × h × d)........... 26,5 × 11 × 18,5 cm
Weight (without accessories, with batteries)..2,1 kg
Display ... matrix LCD with backlight, 128 × 64 dots
Memories ....2000 measurements
Computer connection..................................RS 232

Protection classification ....double insulation
Overvoltage cat. .... CATIII/300V or CATII/600V
Pollution degree... 2
Degree of protection ....IP 44
Working temp. range ....0 ÷ 40 °C
Nominal (reference) temp. range............10 ÷ 30 °C
Max. humidity .... 85 % RH (0 ÷ 40°C)
Nominal (reference) hum. range....... 40 ÷ 60 % RH
Auto power off ....yes

7.2. Technical specifications Instaltest 61557

Functions

Insulation resistance

Meas. range Riso (Un ≥ 250V)... (0,008 ÷ 1000)MΩ ....

Display range Riso (MΩ) Un ≥ 250V	Resolution (MΩ)	Accuracy*
0,000 ÷ 1,999	0,001	±(2% of r. + 2D)
2,00 ÷ 19,99	0,01	
20,0 ÷ 199,9	0,1	
200 ÷ 1000	1	±(10% of r.)

Meas. range Riso (Un < 250V).. (0,012 ÷ 199,9)MΩ ....

Display range Riso (MΩ) Un < 250V	Resolution (MΩ)	Accuracy*
0,000 ÷ 1,999	0,001	±(5% of r. + 3D)
2,00 ÷ 19,99	0,01	
20,0 ÷ 199,9	0,1	

*Specified accuracy is valid if **Universal test cable** is used while it is valid up to 20 MΩ if **Tip Commander** is used.

Display range Test voltage (V)	Resolution (V)	Accuracy
0 ÷ 1200	1	±(2% of r. + 3D)

Nom. test voltage.... 50 ÷ 1000Vd.c. in steps of 10V
Current capability of test generator
(at Utest. > U_N) .... >1mA
Short-circuit test current............................... <3 mA
Automatic discharge of tested object................. yes

Continuity of protection conductors

Meas. range R................................ (0,08 ÷ 1999)Ω ....

Display range R (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	±(2% of r. + 2D)
20,0 ÷ 199,9	0,1	±(3% of r.)
200 ÷ 1999	1	

Open-terminal test voltage..................... 4 - 7 Vd.c.
Short-circuit test current.......................... > 200 mA
Compensation of test leads (up to 5 Ω)............. yes
Sound signal... yes
Automatic polarity exchange .... yes
Measurement mode................ single measurement

Continuity

Display range R (Ω)	Resolution (Ω)	Accuracy
0,0 ÷ 199,9	0,1	±(3% of r. + 3D)
200 ÷ 2000	1	

Open-terminal test voltage ....4 - 7 Vd.c.
Short-circuit test current .... < 7 mA
Sound signal .... yes
Measurement mode ....continuous measurement

RCD – general data

Nominal differential currents.................10, 30, 100, 300, 500, 1000 mA
Accuracy of actual differential currents:
-0 / +0,1·$I_Δ$; $I_Δ$ = $I_{ΔN}$, 2·$I_{ΔN}$, 5·$I_{ΔN}$
-0,1·$I_{ΔN}$ / +0; $I_Δ$ = 0,5·$I_{ΔN}$
Accuracy of actual diff. currents..........(-0 / +0,1)$I_{ΔN}$
Test current shape .... sine wave
Test current start at .... 0° or 180°
RCD type .... Standard or Selective

RCD – Contact Voltage Uc

Meas. range Uc.................................. (10 ÷ 100)V

Display range Uc (V)	Resolution (V)	Accuracy*
0,00 ÷ 9,99	0,01	(-0 / + 10)% of r. ± 0,2V
10,0 ÷ 100,0	0,1	(-0 / + 10)% of r.

*The accuracy is valid if:
Mains voltage is stable during the meas.
PE terminal is free of interfering voltage

Measurement principle .... without aux. probe
Test current... < 0,5 $I_{ΔN}$
Limit contact voltage...............................25 or 50 V
The Contact Voltage is calculated to $I_{ΔN}$ (standard type) or to 2$I_{ΔN}$ (selective type).

RCD – Fault Loop Resistance R_L

Display range R_L (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	Consider acc. of Uc and $I_{ΔN}$ R_L = Uc / $I_{Δn}$
20,0 ÷ 199,9	0,1	
200 ÷ 1999	1	
2,00k ÷ 10,00k	0,01k	

Calculation ....R_L = Uc / $I_{ΔN}$
Measurement principle .... without auxiliary probe
Test current... < 0,5 $I_{ΔN}$

RCD – Trip out time

Test current .... 0,5 $I_{\Delta N}$, $I_{\Delta N}$, 2 $I_{\Delta N}$, 5 $I_{\Delta N}$
(multiplier 5 is not available if $I_{\Delta N}$ = 1000mA)

Meas. range t (G type) .... (0ms ÷ upper disp. value)
....

Display range t (ms) G type	Resolution (ms)	Accuracy
0 ÷ 300 (1/2$I_{\Delta N}$, $I_{\Delta N}$)	1	
0 ÷ 150 (2$I_{\Delta N}$)	1	±3ms
0 ÷ 40 (5$I_{\Delta N}$)	1	

Meas. range t (S type) .... (0ms ÷ upper disp. value)
....

Display range t (ms) S type	Resolution (ms)	Accuracy
0 ÷ 500 (1/2$I_{\Delta N}$, $I_{\Delta N}$)	1	
0 ÷ 200 (2$I_{\Delta N}$)	1	±3ms
0 ÷ 150 (5$I_{\Delta N}$)	1	

RCD – Tripping current

Meas. range I_{Δ}.................................(0,2 ÷ 1,1) $I_{\Delta N}$

Display range I_{Δ}	Resolution	Accuracy
0,2$I_{\Delta N}$ ÷ 1,1$I_{\Delta N}$	0,05$I_{\Delta N}$	±0,1$I_{\Delta N}$

Meas. range t_{Δ}..................................(10 ÷ 300)ms

Display range t_{Δ} (ms)	Resolution (ms)	Accuracy
0 ÷ 300	1	±3ms

Meas. range Uci ....(10 ÷ 100)V

Display range Uci (V)	Resolution (V)	Accuracy*
0,00 ÷ 9,99	0,01	(-0/+10)% of r. ± 0,2V
10,0 ÷ 100,0	0,1	(-0/+10)% of r.

*The accuracy is valid if:
  Mains voltage is stable during the meas.
  PE terminal is free of interfering voltage

Uci voltage is calculated to Tripping current I_{Δ}.

Fault Loop Resistance and Prospective Short-circuit Current

Meas. range R_{L-PE}.........................(0,20 ÷ 1999)Ω

Display range R_{L-PE}, (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	
20,0 ÷ 199,9	0,1	±(5% of r. + 5D)
200 ÷ 1999	1	

Display range Ipsc (A)	Resolution (A)	Accuracy
0,06 ÷ 19,99	0,01	
20,0 ÷ 199,9	0,1	Consider accuracy of R_{L-PE}
200 ÷ 1999	1	
2,00k ÷ 19,99k	10	
20,0k ÷ 24,4k	100	

Ipsc calculation:....................Ipsc = U_N·1,06 / R_{L-PE}
U_N = 115 V; (100 V ≤ U_{L-PE} < 160 V)
U_N = 230 V; (160 V ≤ U_{L-PE} ≤ 264 V)
Max. test current (at 230 V) .... 2,5 A
Nominal voltage range .... 100 ÷264V / 45 - 65 Hz

Line Resistance and Prospective short-circuit current

Meas. range R_{L-N}.......................... (0,20 ÷ 1999)Ω

Display range R_{L-N}, (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	
20,0 ÷ 199,9	0,1	±(5% of r. + 5D)
200 ÷ 1999	1	

Display range Ipsc (A)	Resolution (A)	Accuracy
0,06 ÷ 19,99	0,01	
20,0 ÷ 199,9	0,1	Consider accuracy of R_{L-N}
200 ÷ 1999	1	
2,00k ÷ 19,99k	10	
20,0k ÷ 24,4k	100	

Ipsc calculation:.................... Ipsc = U_N·1,06 / R_{L-N}
U_N = 115 V; (100 V ≤ U_{L-N} < 160 V)
U_N = 230 V; (160 V ≤ U_{L-N} ≤ 264 V)
Max. test current (at 230 V) .... 2,5 A
Nominal voltage range .... 100 ÷264V / 45 - 65 Hz

Phase rotation

Nominal mains voltage range .... 100 ÷ 440V
Result displayed................................ 1.2.3 or 2.1.3

Voltage

Display range U (V)	Resolution (V)	Accuracy
0 ÷ 264	1	±(2% of r. + 2D)

Nominal frequency range ....45 – 65 Hz

Frequency

Display range f (Hz)	Resolution (Hz)	Accuracy
45,0 ÷ 65,0	0,1	±(0,1% of r. +1D)

Nominal voltage range ....10 ÷ 440V

Varistor Overvoltage Protection Devices (Breakdown voltage)

Display range U (V)	Resolution (V)	Accuracy
0 ÷ 1000	1	±(5% of r. + 10V)

Measurement principle................. d.c.voltage ramp
Test voltage slope .... 500 V/s
Threshold current .... 1 mA

Fault/Fuse/Conductor locator

Principle...... Line loading or Imposing of test signal

Loading (mains voltage range 30÷264V/45÷65Hz):
Is < 1A pulsed
fs = 3600 Hz

Imposing (voltage free installation):
Us < 7V pulsed
fs = 3600 Hz
Isc < 50mA pulsed

Voltage Logging

Final result .... UAVG, Umax/Nmax, Umin/Nmin
Input voltage range ....0 ÷440V
Sampling once per .... 1s÷99s in steps of 1s
Total number of samples .... 1 ÷1999

General characteristics Instaltest 61557

Power supply... 6Vd.c. (4 × 1,5V battery IEC LR14)
Automatic comparison of test result with set high and low limit value.....................................yes
Visual and sound warnings ....yes
Dimensions (w × h × d)........... 26,5 × 11 × 18,5 cm
Weight (without accessories, with batteries)..1,8 kg
Display .... LCD with backlight
Memories ....1000 measurements
Computer connection..................................RS 232

Protection classification .... double insulation
Overvoltage cat. .... CATIII/300V or CATII/600V
Pollution degree.. 2
Degree of protection ....IP 44
Working temp. range ....0 ÷ 40 °C
Nominal (reference) temp. range............10 ÷ 30 °C
Max. humidity .... 85 % RH (0 ÷ 40°C)
Nominal (reference) hum. range....... 40 ÷ 60 % RH
Auto power off ....yes

7.3. Technical specifications Earth Insulation Tester

Functions

Insulation Resistance

Meas. range Riso (Un ≥ 250V).. (0,008 ÷ 29,9k)MΩ

Display range Riso (Ω) Un ≥ 250V	Resolution (MΩ)	Accuracy*
0,000M ÷ 1,999M	0,001	±(2% of r. + 2D)
2,00M ÷ 19,99M	0,01	
20,0M ÷ 199,9M	0,1	
200M ÷ 1999M	1	±(10% of r.)
2,00G ÷ 19,99G	10	
20,0G ÷ 29,9G	100	

Meas. range Riso (Un < 250V).. (0,012 ÷ 199,9)MΩ

Display range Riso (Ω) Un < 250V	Resolution (MΩ)	Accuracy*
0,000M ÷ 1,999M	0,001	±(5% of r. + 3D)
2,00M ÷ 19,99M	0,01	
20,0M ÷ 199,9M	0,1	

*Specified accuracy is valid if **Universal test cable** is used while it is valid up to 20 MΩ if **Tip Commander** is used.

Display range Test voltage (V)	Resolution (V)	Accuracy
0 ÷ 1200	1	±(2% of r. + 3D)

Nom. test voltage...50 ÷ 1000Vd.c. in steps of 10 V
Current capability of test generator
(at Utest. > U_N) ....>1mA
Short-circuit test current...............................<3 mA
Automatic discharge of tested object.................yes

Continuity of protection conductors

Meas. range R................................(0,08 ÷ 1999)Ω

Display range R (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	±(2% of r. + 2D)
20,0 ÷ 199,9	0,1	±(3% of r.)
200 ÷ 1999	1	

Open-terminal test voltage..................... 4 - 7 Vd.c.
Short-circuit test current.......................... > 200 mA
Compensation of test leads (up to 5 Ω).............yes
Sound signal..yes
Automatic polarity exchange.............................yes
Measurement mode................single measurement

Continuity

Display range R (Ω)	Resolution (Ω)	Accuracy
0,0 ÷ 199,9	0,1	±(3% of r. + 3D)
200 ÷ 1999	1	

Open-terminal test voltage..................... 4 - 7 Vd.c.
Short-circuit test current..............................< 7 mA
Sound signal (R > 20Ω) ....yes
Measurement mode........ continuous measurement

Earth Resistance four – lead method

Meas. range R_E ....(0,11 ÷ 19,99k)Ω

Display range (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	±(2% of r. + 3D)
20,0 ÷ 199,9	0,1	
200 ÷ 999	1	
1,000 ÷ 1,999	1	
2,00k ÷ 19,99k	10	±(5% of r.)

Additional spike resistance error
at Rc max. or Rp max. .... ±(3% of r. + 5D)
Rc max. .... (4k Ω + 100R_E) or
50kΩ (whichever is lower)
Rp max. .... (4k Ω + 100R_E) or
50kΩ (whichever is lower)
Additional error
at 20 V voltage noise (50 Hz)........±(5% of r. +10D)
Open-terminal test voltage........................ 40 Va.c.
Test voltage shape ....sine wave
Test voltage frequency......................... 125/150 Hz
Short-circuit test current............................< 20 mA
Automatic test of current and
potential test probe resistance ....yes
Automatic test of voltage noise ....yes

Earth Resistance using one clamp in combination with four – lead method

All technical data listed under four-lead method are valid, except display and meas. ranges, see adapted ones below.

Meas. range R_E ....(0,11 ÷ 1,99k)Ω

Display range (Ω)	Resolution (Ω)	Accuracy
0,00 ÷ 19,99	0,01	

20,0 ÷ 199,9	0,1	±(2% of r. + 3D)
200 ÷ 999	1	
1,00k ÷ 1,99k	10	

Additional specification:

Additional error at 3A noise current generated
by mains voltage (50 Hz) ....±(5% of r. + 10D)
Noise current indication ....>2,4A
Additional error
of resistance ratio .... Rpartial/Rtotal · 1%
Rpartial = resistance measured with clamp
Rtotal = resistance of earthing system
Indication in case of low clamp current .... < 0,5 mA
Automatic test of noise current..........................yes
Additional clamp error is to be considered.

Earth Resistance using two clamps

Meas. range R_E ....(0,08 ÷ 100)Ω

Display range R_E (Ω)	Resolution (Ω)	Accuracy*
0,00 ÷ 19,99	0,01	±(10% of r. +2D)
20,0 ÷ 100,0	0,1	±(20% of r.)

*Distance between test clamps >30 cm

Additional error at 3A current noise generated
by mains voltage (50 Hz) ....±(10% of r. + 10D)
Automatic test of noise current..........................yes
Additional clamp error is to be considered.

Specific Earth Resistance (resistivity)

All technical data listed under four-lead method are valid, except display range table, see below.

Display range ρ (Ωm)	Resolution (Ωm)	Accuracy
0,00 ÷ 19,99	0,01	Consider accuracy of R_E measurement $\rho = 2\pi a R_E$
20,0 ÷ 199,9	0,1	
200 ÷ 1999	1	
2,00k ÷ 19,99k	10	
20,0k ÷ 199,9k	0.1k	
200k ÷ 999k (a < 8m) 200k ÷ 1999k (a ≥ 8m)	1k	

Display range ρ (Ωft)	Resolution (Ωft)	Accuracy
0,00 ÷ 19,99	0,01	
20,0 ÷ 199,9	0,1	
200 ÷ 1999	1	
2,00k ÷ 19,99k	10	
20,0k ÷ 199,9k	0.1k	
200k ÷ 999k (a < 8ft) 200k ÷ 1999k (a ≥ 8ft)	1k	

Distance between test rods.............1 up to 30 m or
1 up to 60 ft

Voltage a.c./d.c.

Display range U (V)	Resolution (V)	Accuracy
0 ÷ 600	1	±(2% of r. + 2D)

Nominal frequency range...............45 – 65 Hz, d.c.

Current (True RMS)

Display range I (A)	Resolution (A)	Accuracy
0,0m ÷ 99,9m	0,1m	±(5% of r. + 3D)
100m ÷ 999m	1m	±(5% of r.)
1,00 ÷ 9,99	0,01	
10,0 ÷ 99,9	0,1	
100 ÷ 200	1	

Input resistance 10 Ω/1W
Measurement principle.........current clamp 1A/1mA
Nominal frequency.................................. 50/60 Hz
Additional clamp error is to be considered.

Varistor overvoltage protection devices – Breakdown voltage

Display range U (V)	Resolution (V)	Accuracy
0 ÷ 1000	1	±(5% of r. + 10V)

Measurement principle................. d.c.voltage ramp
Test voltage slope..................................... 500 V/s
Threshold current.. 1 mA

General characteristics

Power supply.. 6 Vd.c. (4 × 1,5V battery IEC LR14)
Automatic comparison of test result with set
high and low limit value.....................................yes
Visual and sound warnings ....yes
Dimensions (w × h × d) .... 26,5 × 11 × 18,5 cm
Weight (without accessories, with batteries)...1,7kg
Display .... LCD with backlight
Memories ....1000 measurements
Computer connection..................................RS 232

Protection classification .... double insulation
Overvoltage cat. . ... CATIII/300V or CATII/600 V
Pollution degree.. 2
Degree of protection .... IP 44
Working temp. range ....0 ÷ 40 °C
Nominal (reference) temp. range ....10 ÷ 30 °C
Max. humidity .... 85 % RH (0 ÷ 40°C)
Nominal (reference) hum. range ....40 ÷ 60 % RH
Auto power off ....yes

Patents

METREL have registered and used the following patents when developing their latest family of test instruments:

- **Patent for measurement of earth resistance in presence of noise signals.**
- **Patent for measurement of contact voltage.**
- **Patent for generation of test current when testing FI protection devices.**
- **Patent on how to prevent double connection of test cables and communication cable.**
- **Patent for measurement of line and loop impedance and prospective short-circuit current.**

Cross-reference of important parameters on instruments produced by METREL

Parameter	**Eurotest 61557**	**Instaltest 61557**	**Earth – Insul. Tester**
Insulation resistance	**ü**	**ü**	**ü**
Display range	0,001 – 1000 MΩ	0,001 – 1000 MΩ	0,001M – 30GΩ
Test voltage 50 V	**ü**	**ü**	**ü**
Test voltage 100 V	**ü**	**ü**	**ü**
Test voltage 250 V	**ü**	**ü**	**ü**
Test voltage 500 V	**ü**	**ü**	**ü**
Test voltage 1000 V	**ü**	**ü**	**ü**
Optional test voltage (50 – 1000 V)	⁄	**ü**	**ü**
Test of varistor over-voltage protection devices	**ü**	**ü**	**ü**
Test range (continuously)	0 – 1000 V	0 – 1000 V	0 – 1000 V
Continuity of protection conductors	**ü**	**ü**	**ü**
Display range	0,01 – 2000 Ω	0,01 – 2000 Ω	0,01 – 2000 Ω
Automatic polarity exchange	**ü**	**ü**	**ü**
Compensation of test leads	**ü**	**ü**	**ü**
Possible test of inductive loads	**ü**	**ü**	**ü**
Acoustic sygnal	**ü**	**ü**	**ü**
Low resistances (continuous measurement)	**ü**	**ü**	**ü**
Display range	0,01 – 2000 Ω	0,01 – 2000 Ω	0,01 – 2000 Ω
Acoustic sygnal	**ü**	**ü**	**ü**
Earth resistance (internal source)	**ü**	▯	**ü**
Display range	0,01 Ω – 20 kΩ	⁄	0,01 Ω – 20 kΩ
Measurement principle	4 ter., 2 probes	⁄	4 ter., 2 probes
Shape of test voltage	sine wave	⁄	sine wave
Measurement using one test clamp	**ü**	⁄	**ü**
Measurement using two test clamps	**ü**	⁄	**ü**
Automatic test of Rc and Rp	**ü**	⁄	**ü**
High immunity against noise sygnal	**ü** (**patent**)	⁄	**ü** (**patent**)
Earth resistivity (specific earth resist.)	**ü**	▯	**ü**
Display range	0 – 2,5 MΩm	⁄	0 – 1999 kΩm
Measurement principle	4 ter., 4 probes	⁄	4 ter., 4 probes
Distance between test rods	1 – 30 m	⁄	1 – 30 m
RCD protection switches - General	**ü**	**ü**	▯
Nominal differential currents 0,01; 0,03; 0,1; 0,3; 0,5; 1A	**ü**	**ü**	⁄
Type of protection switches	AC	AC	⁄
Standard and selective switches	**ü**	**ü**	⁄
Autimatic evaluation of test result	**ü**	**ü**	⁄
Contact voltage (patent)	**ü**	**ü**	▯
Display range	0 – 100 V	0 – 100 V	⁄
Measurement current	< 0,5 IΔn	< 0,5 IΔn	⁄
Measurement without auxiliary test probe	**ü**	**ü**	⁄
Measurement with auxiliary test probe	**ü**	⁄	⁄
Automatic recognition of connected auxiliary test probe	**ü**	⁄	⁄
Limit contact voltage	25 or 50 V	25 or 50 V	⁄
Trip out time	**ü**	**ü**	▯
Display range	0 – 300 ms	0 – 300 ms	⁄

Test current	(1/2, 1, 2, 5) × IΔn	(1/2, 1, 2, 5) × IΔn	⁄
Tripping current	**ü**	**ü**	▯
Display range	0,2 IΔn – 1,1 IΔn	0,2 IΔn – 1,1 IΔn	⁄
Rising current	in steps of 0,05 IΔn	In steps of 0,05 IΔn	⁄
Earth resistance (external source)	**ü**	**ü**	▯
Display range	0,01 Ω – 2 kΩ	0,01 Ω – 2 kΩ	⁄
Measurement current	< 0,5 IΔn	< 0,5 IΔn	⁄
Measurement without auxiliary test probe	**ü**	**ü**	⁄
Measurement with auxiliary test probe	**ü**	⁄	⁄
Automatic recognition of connected uxiliary test probe	**ü**	⁄	⁄
Avtomatic test of RCD	**ü**	**ü**	▯
Fault loop impedance	**ü**	**(Resistance)**	▯
Display range	0,01 Ω – 2 kΩ	0,01 Ω – 2 kΩ	⁄
Test current	23 A; 2,3 A	2,5 A	⁄
Autimatic evaluation of test result	**ü**	**ü**	⁄
Measurement of contact voltage at prospective short-circuit current, using auxiliary test probe	**ü**	⁄	⁄
Prosp. short-circuit fault loop curr.	**ü**	**ü**	▯
Display range	0 – 23 kA	0 – 23 kA	⁄
Line Impedance	**ü**	**(Resistance)**	▯
Display range	0,01 Ω – 2 kΩ	0,01 Ω – 2 kΩ	
Z_{L-N} (230 V)	**ü**	**ü**	⁄
Z_{L-L} (400 V)	**ü**	**ü**	⁄
Prospect. short-circuit line current	**ü**	**ü**	▯
Display range	0 – 40 kA	0 – 40 kA	⁄
Resistance of N - PE loop (without trip out RCD protection switch)	**ü**	▯	▯
Display range	0,01 – 2000 Ω	⁄	⁄
Phase rotation	**ü**	**ü**	▯
Current (with clamp)	**ü**	▯	**ü**
Display range (two ranges)	1 mA – 200 A	⁄	1 mA – 200 A
Voltage	**ü**	**ü**	**ü**
Display range	1 V – 440 V	1 V – 440 V	1 V – 600 V
Voltage recording	⁄	**ü**	⁄
Frequency	⁄	**ü**	▯
Display range	⁄	45 – 65 Hz	⁄
Installation tracing	**ü**	**ü**	▯
Installation under voltage	**ü**	**ü**	⁄
Voltage-free installation	**ü**	**ü**	⁄
Active power	**ü**	▯	▯
Display range	0 – 88 kW	⁄	⁄
Reactive power	**ü**	▯	▯
Display range	0 – 88 kW	⁄	⁄
Apparent power	**ü**	▯	▯
Display range	0 – 88 kW	⁄	⁄
Energy	**ü**	▯	▯
Display range	0 – 1999 kWh	⁄	⁄
Harmonic analysis	**ü**	▯	▯
Display range	up to n = 21^{st}.	⁄	⁄

General			

RS 232 communication	**ü**	**ü**	**ü**
Memories	**ü**	**ü**	**ü**
Display	graphic LCD 75 × 42 mm	LCD 75 × 42 mm	LCD 75 × 42 mm
Display backlight	**ü**	**ü**	**ü**
Coustic warnings	**ü**	**ü**	**ü**
Automatic power OFF	**ü**	**ü**	**ü**
PE – test electrode	**ü**	/	/
Possible **SW upgrade** by means of **Internet**	**ü**	/	/
Windows compatible SW	**ü**	**ü**	**ü**

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Questions, advice, suggestions, remarks…. In connection with measurements on electrical installations and measurement equipment produced by

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