Leakage current clamp

A 1472, A1579

User manual

Version 1.2, Code no. 20 752 271

METREL®

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Version note
1.1: manual is valid also for A 1579

CE	Mark on your equipment certifies that this equipment meets the requirements of the EU (European Union) concerning safety and electromagnetic compatibility regulations.

1 Warnings

To ensure a high level of operator's safety during using of the leakage current clamp the following warnings have to be considered:

- **Do not use the current clamp if any damage is noticed!**
- **Do not leave open signal output terminals of the current clamp with current output (A 1472, A 1579) during measurement to avoid damage and electric shock on secondary side. Never enclose conductor in the jaw unless the clamp is connected to measuring instrument!**
- **Consider all generally known precautions in order to avoid risk of electric shock while dealing with electric installations and equipment!**
- **Do not extend hands over protection barrier during measurement to prevent of electric shock!**
- ⚠ **Symbol on the current clamp indicates possible hazardous live conditions if the required safety measures are ignored.**
- **Only a competent, authorized person is allowed to carry out service intervention!**
- **If the leakage current clamp is used in a manner not specified in this User manual, the provided protection can be impaired!**
- **The leakage current clamp may only be used within the operating ranges as specified in this User manual.**

2 Description of leakage current clamp

The A 1472 is a 1000/1 ratio leakage current clamp for measuring alternating currents in the range from 0.5 mA to 10 A.
The A1472 current clamp is specially designed to be used in combination with METREL DeltaPAT testers.
Refer to chapter *5. Technical specification* for list of all measuring instruments suitable to work with the A1472 current clamp.

Main clamp parts:

1. Current sensor
2. Protection barriers
3. Conductor opening
4. Signal output terminals

A 1472

2.1 Difference to A 1579

The leakage current clamps differs only in applied safety banana colours (4), those are red and black for the A 1579 instead green and brown for the A 1472.

A 1579

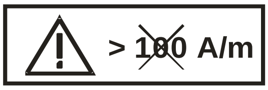
Warning:

- **Do not leave open signal output terminals of the current clamp during measurement to avoid damage and electric shock on secondary side, never enclose conductor in the jaw unless the clamp is connected to measuring instrument!**

2.3 Meaning of symbols

Symbol on the current clamp indicates that it is possible to use the current clamp on non-insulated conductors.

Symbol on the current clamp indicates possible hazardous live conditions if the required safety measures are ignored.



Symbol indicates that the current clamp can be applicable in presence of external magnetic fields of up to 100 A/m.

3 Maintenance

3.1 Inspection

To maintain operator safety and ensure reliability of the current clamp it is good practice to inspect it on a regular basis. Check that the enclosure and connections are undamaged.
The jaw surface must be clean. Pollution on jaw surfaces reduces the current clamp sensitivity.

3.2 Cleaning

Use a soft cloth moistened with soapy water or alcohol to clean non-metallic surface of the current clamps and leave them to dry totally before using it.
Notes!

- Do not use liquids based on petrol or hydrocarbons!
- Do not spill cleaning liquid over the current clamps!

To clean jaw cut surfaces use slightly oiled soft cloth.

3.3 Service and calibration

It is essential that your clamp is regularly calibrated in order to guarantee the technical specification listed in this User manual. We recommend 2-year calibration interval. Metrel encloses an original calibration certificate with every new instrument and current clamp.
For recalibration and repairs under or out of warranty time please contact your distributor for further information.

4 Leakage current clamp operation

4.1 Measuring of leakage currents

4.1.1 Origins of leakage currents

Leakage currents are currents driven by active conductors of a distribution system or electrical equipment to earth and/or protective conductors. Leakage currents flow wherever a conductive path (resistance and/or capacitance) is applied between active and earthed conductors/protected parts. Fig.1 shows leakage currents that usually flow in electrical installations in normal operation.

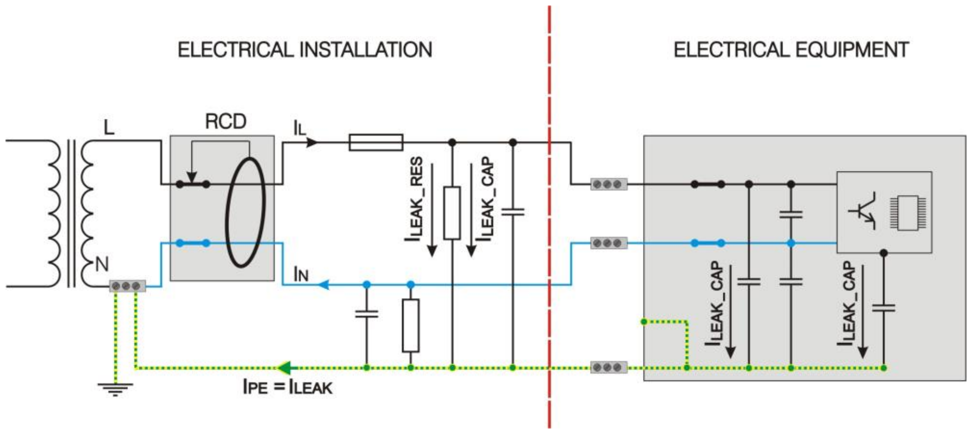


Fig. 1 Leakage currents in electrical installations in normal operation

The relation between leakage current and (insulation) resistance between line and earth is defined by the Ohm's law.

$$I_{leak\_res}(mA) = U_{nom} / R_{ins}(k\Omega) \qquad \text{Eq. 1}$$

I_{leak_res}.................resistive leakage current in mA
U_{nom}..................nominal line voltage, e.g. 230 V
R_{ins}....................resistance in kΩ

The relation between leakage current and capacitance between line and earth is shown in Equation 2.

$$I_{leak\_cap}(mA) = 6.28 \cdot 10^{-6} \cdot U_{nom} \cdot f \cdot C(nF) \qquad \text{Eq. 2}$$

I_{leak_cap}................capacitive leakage current in mA
U_{nom}..................nominal line voltage, e.g. 230 V
f.........................mains frequency
C(nF).................capacitance in nF

Capacitive and resistive leakage currents are forming the overall (total) leakage current. For continuous leakage currents of main frequency, Equation 3 can be used.

$$I_{leakage}(mA) = \sqrt{I^2_{leak\_res} + I^2_{leak\_cap}} \qquad \text{Eq. 3}$$

$I_{leakage}$................overall leakage current

Shapes of leakage currents are usually much more complicated. That will be described later in this article.

4.1.2 Leakage currents in normal operation

Typical leakage currents in normal operation are:

- Leakage currents caused by input filters in electrical equipment connected between live and earth (filters, monitors). The capacitors in input filters have a capacitance of ca. 10 nF to 100 nF (see Fig.1).
- Leakage currents caused by conductors' insulation resistance and their capacitances to earth. Long power cables have a lower insulation resistance and higher capacitances. The capacitance between a cable and earth is typically about 150 pF/m (sse Fig. 1).
- Leakage currents produced by frequency converters, switch mode power supplies, different rectifiers and similar equipment. The shape and frequency of this leakage currents can vary from pure d.c, pulsed d.c. components up to very high frequency.

In general, leakage currents in normal operation increase with the size of the electrical installation and the number of connected loads.

Table 1 shows the values of leakage currents for some typical capacitances and resistances.

Capacitance	Capacitive leakage current @ 230V/ 50Hz	Note
1 nF	0.072 mA	Typical values of capacitors in input cables
10nF	0.72 mA	
100nF	7.2 mA	
1uF	72 mA	Capacitance of long power cables
Resistance	**Resistive leakage current @ 230V/ 50Hz**	
10 kΩ	23 mA	
500 kΩ	0.46 mA	
1.00 MΩ	0.23 mA	Typical limits for insulation resistance
2.00 MΩ	0.115 mA	

Table 1: Leakage current / capacitance relations

In Table 2 typical values of leakage currents for different types of electrical equipment are shown.

Equipment	Leakage current
Stationary PC system	1 to 3
Photocopy machine	0.5 to 1.5
Floor heating	1mA / kW
Input EMC filter	1 mA
Printer/ fax	up to 1 mA
Photocopy machine	up tp 1.5 mA
Laundry machine, drying machine	up to 2 mA
Cookers, heaters	1mA / kW
Installed power cable 100 m	1 mA

4.1.3 Leakage currents in fault conditions

Faults in electrical installations and equipment can cause additional continuous or
short-lasting leakage currents. Typical faults that can cause increased leakage currents are:

- Deterioration of insulation (because of pollution, moisture, corrosion). This is causing a gradual increase of the resistive leakage current,
- Faults in electronic equipment.
- If the neutral and PE wiring are connected together anywhere in the installation this can result in an improper current distribution through the neutral and PE conductors.

Typical faults that usually results in a high fault current that will immediately trip the protective devices are:

- Misswiring like changing the N and PE conductors.
- Breakdown of insulation between active parts and earth anywhere in installation or equipment

Short-lasting leakage currents are often a result of:

- A sudden change in the voltage or current between active parts and PE. This can result in a short leakage currents from several us up to 100ms . Lightning and switching on/ off large loads can cause such changes.

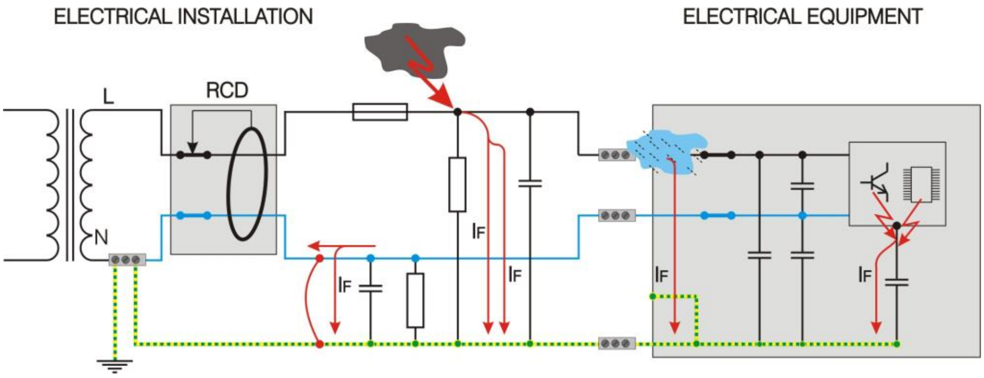


Fig.2: Fault leakage currents in electrical installations

4.1.4 Problems caused by leakage currents

Too high leakage currents can cause very critical problems in electrical installations. The most often problems are nuisance tripping of protective devices and safety problems due to increased fault, earth and touch voltages.

Nuisance tripping of protective devices
Nuisance tripping occurs if the sum of leakage currents exceeds the tripping level of the residual current protective device.
In circuits with a lot of installed equipment the sum of leakage currents in normal operation can be close to the trip out limit. In this case even a small added leakage current (caused by switching on/off loads or connection of a new equipment) can trigger the nuisance tripping.
It must be considered that leakage currents can vary in time and the tripping could be only occasional.
A solution is to add RCD(s) and divide the circuits in a way that the leakage currents in normal operation stay below 20% of the nominal value of each RCD. For further information refer to *METREL handbook Guide for testing and verification of low voltage installations*.

Problems because of non- typical shape of leakage current
Leakage currents can have different non-sinusoidal shapes. They are caused by nonlinearity of loads, nonlinearity of insulation materials and presence of harmonic voltages and currents in the power systems:

- high frequency leakage current
- d.c. pulsed and smooth d.c. leakage current
- arcing leakage current
- harmonic leakage currents
- transient and other leakage currents of short duration

The amount of the mentioned leakage currents in power systems is increasing because more and more electronic controlled devices are connected to the power system.
It must be considered that standard protection devices and measuring equipment is not suited for monitoring and measuring of the mentioned currents.

Impact on protection devices
Atypical shapes of leakage current can blind standard RCDs. For instance general type RCD’s are not sensitive to leakage currents with pulsed DC components or smooth DC current. High frequency leakage currents caused are not dangerous for human safety but can result in wrong operation of the RCD. It could happen that a dangerous fault leakage occur at the same time and is not detected by the RCD.

Impact on measuring equipment
It is preferred to use at least TRMS measuring equipment for measuring leakage currents. For more demanding applications instruments that include harmonic analysis, time diagrams and DC sensitive measuring equipment must be used.

On Fig.3 two non-sinusoidal leakage currents are shown.

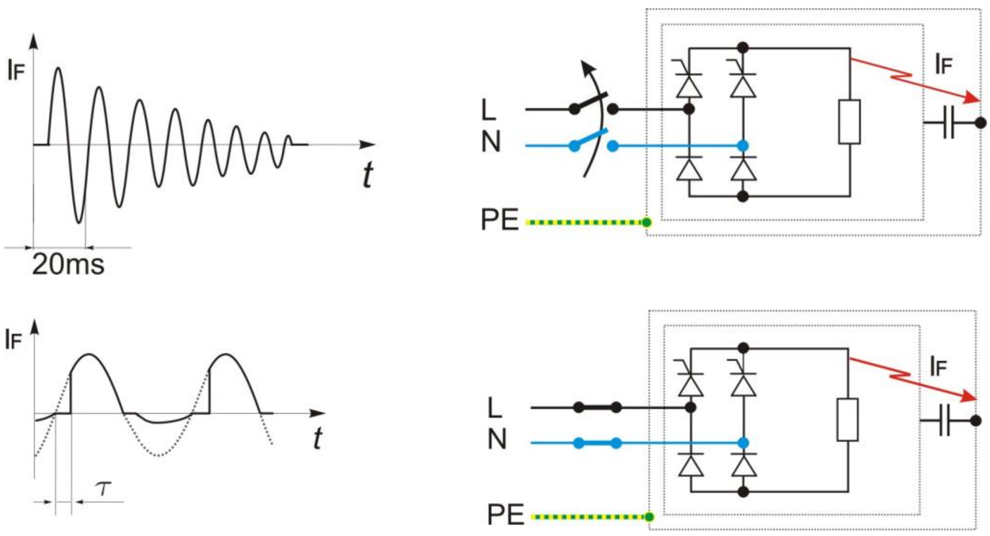


Fig.3: Examples of atypical leakage current

Impaired safety due to fault, earth, touch voltages

Leakage currents that are flowing into earth and PE conductors cause a voltage drop on exposed conductive parts. In case of inadequate protective measures this voltage can increase above a safe level and presents a danger for the people if it would be touched.

Furthermore if the protection devices are not respond in due time the released energies on faulty spots can result in mechanical damage, overheating or even fire.

For more information regarding safety aspects of fault currents refer to METRELs handbook *Guide for testing and verification of low voltage installations*.

4.2 Measuring leakage currents with current clamps

The simplest way of measuring leakage current is the measurement with leakage current clamps. The measuring principle is shown on Figure 4 and in Equations 3,4.

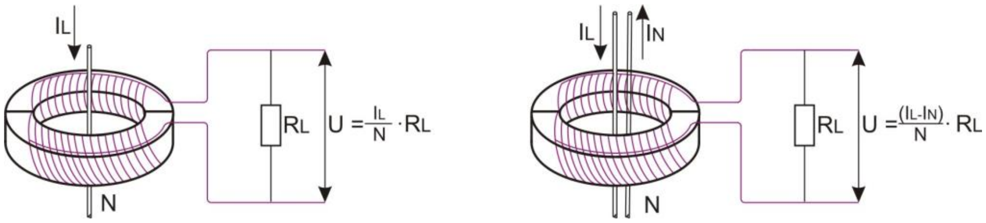


Fig.4: Measuring principle of current clamp – direct and differential method

$$U_{out} = I_{PE} \cdot \frac{1}{N} \cdot R_L$$ *Eq.3*

$$U_{out} = (I_L - I_N) \cdot \frac{1}{N} \cdot R_L$$ *Eq.4*

U_{out}......................output voltage of current sensor
I_{PE}, I_L, I_N..............measured currents
R_B........................load (burden) resistor
N.........................number of turns of current clamp

The main advantage of the measurement with current clamp is that disconnection of conductors is not needed – it is a non-contact measuring method.
In general two methods are used for the leakage currents measurement.

4.2.1 Direct method

The current through one (embraced) conductor is measured in the direct method.

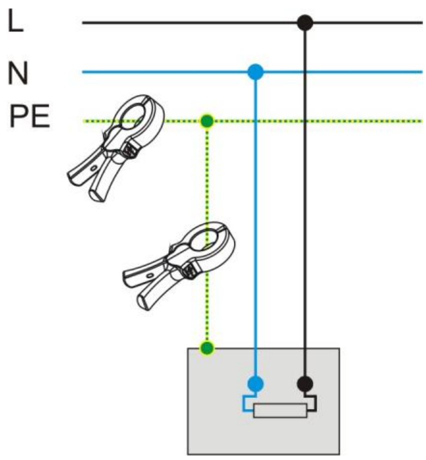


Fig.5: Leakage current measurement – direct method

4.2.2 Differential method

The sum of currents through two or more active (embraced) conductors is measured in the differential method. If no current is leaking into PE conductors/ earth the sum of currents through active conductors must be exactly zero regardless of the load currents. If a leakage current flows it is of the same size as the measured sum between active conductors measured with the clamp.

Note
Note that the direction of currents in the conductors must be considered if the differential method is used.

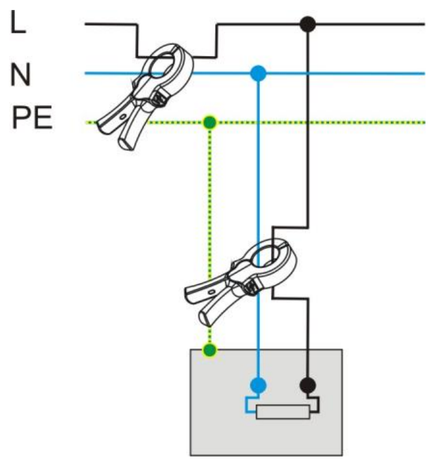


Fig.6: Leakage current measurement – differential method

4.3 Testing procedures

4.3.1 Finding sources of excessive leakage current

The described testing procedure in this chapter is applicable for troubleshooting in the installation and electrical equipment in case of nuisance tripping of protective devices.

1. Embrace all active conductors (L and N, L1 and L2 and L3, L1 and L2 and L3 and N) at the origin of installation.
   The advantage of using the differential method is that all leakage currents downstream the point of measurement will be captured. The same leakage as “seen” by the RCD is measured.

   Alternatively, if the main protective conductor at the origin of installation.is accessible the direct measurement can be used.
   If measuring currents through PE conductors it is possible that a part of the leakage currents will not be measured as they are flowing through different parallel paths. Refer to METRELs handbook *Guide for testing and verification of low voltage installations* for more information about parallel paths.

2. All suspicious loads should be connected. If the leakage current lies inside expected limits try to run the suspicious loads in different operation modes and find out if any of them is problematic. Use MAX, PEAK, LOGGING functions on the measuring equipment if available.
3. If the leakage current is too high try to isolate the fault downstream of the installation. This can be done by disconnection of individual parts of the installation as shown on Fig. 7 - sub distribution boards, fuses, switches, appliances etc. When the faulty part is disconnected the leakage current value will drop or fall to zero.
4. Sometimes it is not allowed to disconnect the mains voltage. In this case additional measurements (direct or differential) should be carried out downstream of the installation’s input as shown on Fig. 8. By doing this the measured leakage currents will be limited to a smaller part of the installation.

By using any of the procedures described above the faulty point can be determined very precisely.

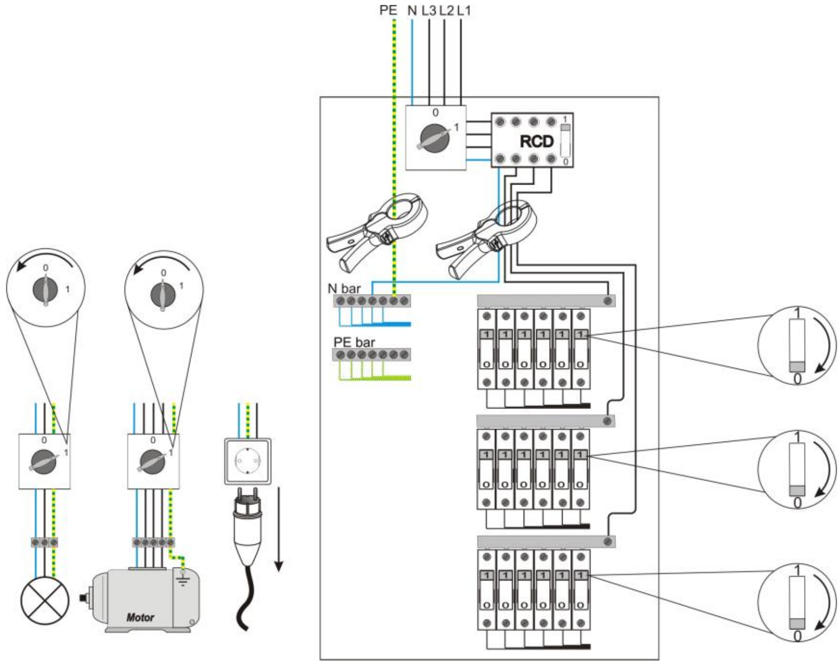


Fig. 7: Finding source of excessive leakage current – by disconnection

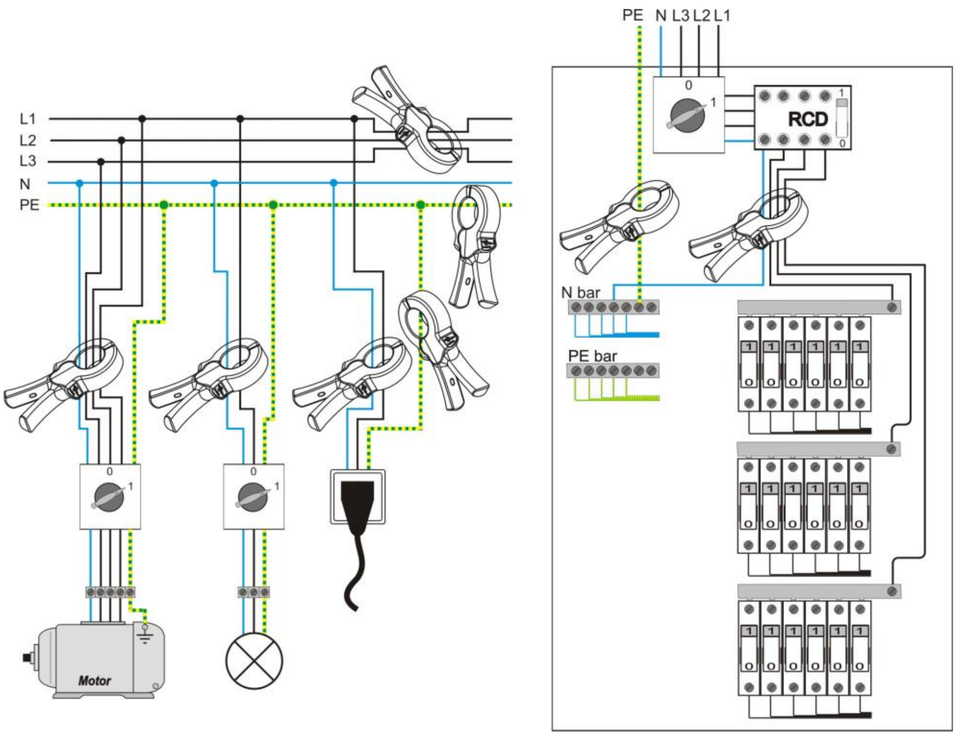


Fig. 8: Finding source of excessive leakage current – measuring downstream the installation

4.3.2 Insulation resistance testing

The standard high voltage insulation resistance test can sometimes not be carried out – if the installation is not allowed to be disconnect for a longer time or sensitive equipment is connected.
In this case the leakage current measurement can conditionally be used as an alternative to the insulation resistance test.
However the results cannot be directly compared because the leakage currents are flowing through resistance and capacitances between line and earth. Degradation of isolation causes only a drop of the resistance and not of the capacitance.

The applicability of leakage current measurement as an alternative to the insulation resistance test depends on following factors:

- The ratio between capacitive and resistive leakage currents in the installation should be known. If the resistive part is completely blinded by the capacitive leakage currents, the measurement will give no indication about the insulation. If both portions are comparable and the number of loads connected to the mains is not changing in time at least trends can be determined.
- Old measuring results should be available. This will enable observing the trends.
- The capacitive and resistive currents are not simply summed therefore the interpretation of results should be made by a skilled person.

Note:
Before using this alternative test check if it is allowed in your country.

4.4 Influencing quantities

Unfortunately measurements with leakage current clamp are subjected to different influencing quantities that have a big impact on their performance. High uncertainty and non-repeatability of readings often lead to wrong interpretations. Three most important influencing quantities are described in this document.

4.4.1 Influence of nearby external magnetic field

Current carrying conductors, transformers and chokes in electrical equipment are producing magnetic fields that are coupling into the sensor and cables of the current clamp and are disturbing the results. The coupling should be as small as possible. It strongly depends on the current sensor quality. Protective measures are proper magnetic shielding, symmetry of the winding, twisting of all connection cables, high permeability of the sensor core etc.

4.4.2 Influence of load current in differential leakage current test

This influencing quantity is similar than the influence of nearby magnetic fields. During a differential leakage test the sum of currents flowing through the clamp is measured. Lets assume that the load current through the line conductor is 10 A and the returning current through the neutral conductor is 9.999 mA. This means that a leakage current of 1mA is obtained on base of the measured difference of: (10000 mA – 9999 mA).
Any small anomaly in the current sensor will result in an asymmetry and consequentially in a large measuring error. Protective measures are symmetry of the winding, high permeability of clamp core etc)

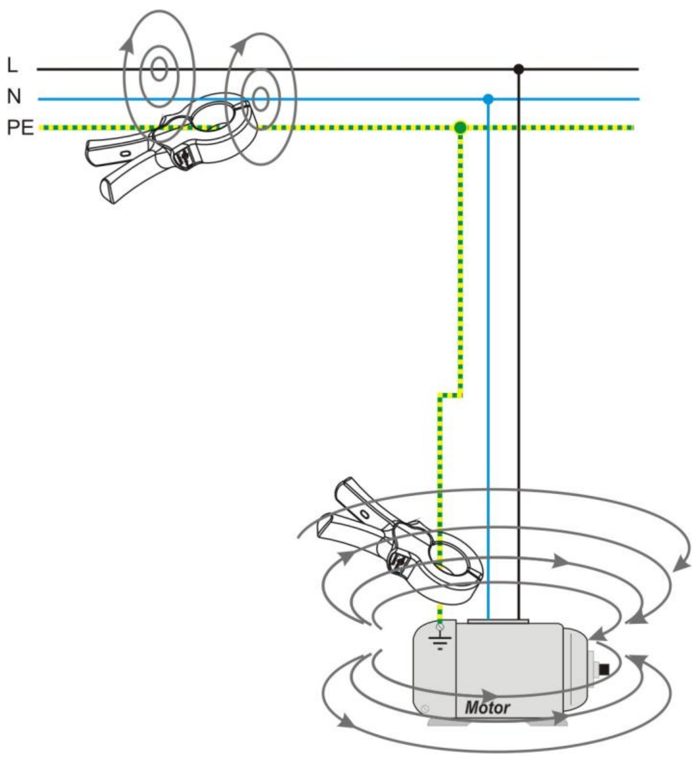


Fig. 9: Influence of external magnetic fields

4.4.3 Influence of external electric field

The electric field caused by voltage on measured conductors or any other conductors/ parts in vicinity can interact with the current clamp through capacitive coupling. This can happen through the sensor, housing, test cables, measuring instrument etc.. The capacitive coupling factor should be as small as possible and depends on electric shielding and common mode rejection of the measuring stage,

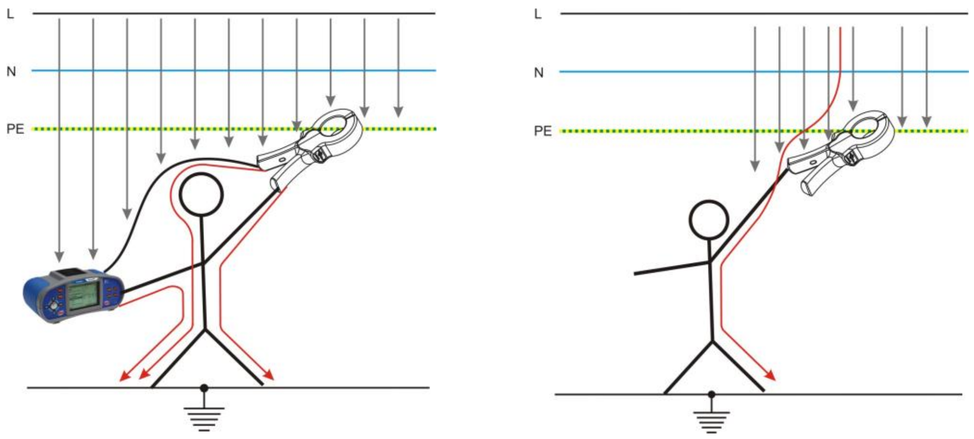


Fig. 10: Influence of external electric fields

4.4.4 How to recognize accuracy problems ?

If following problems are noted then it is likely that external fields are influencing the results:

- The size of load currents is higher than several Amperes (especially critical for the differential measurement).
- The result depends on the position of the clamps (in regard to the measured conductor(s), measured electrical equipment, nearby current carrying conductors, switchboards etc). If the results strongly fluctuate in regard to the current clamp position it is unlikely to get an usable result.
- The reading is not zero although no current is flowing through the clamp.

4.4.5 How to minimize the influencing quantities

- Do not use current clamp without information about immunity against external fields.
- The line and neutral conductors should be placed as close as possible and in the middle of the clamps. If possible they should be twisted to increase the symmetry (for differential measuring method) – see Fig. 11.
- The protective conductor should be placed in the middle of the clamps (for the direct measurement).
- Avoid placing the current clamp near to other line conductors and/ or current carrying conductors. If using a clamp sensor connected to a measuring instrument the placement of the cable is important too.
- Placing the current clamp/ cables close to grounded surfaces usually lowers the coupling and improves the immunity.
- The current clamp / test cables should be placed as far as possible from the tested object – see Fig.12.

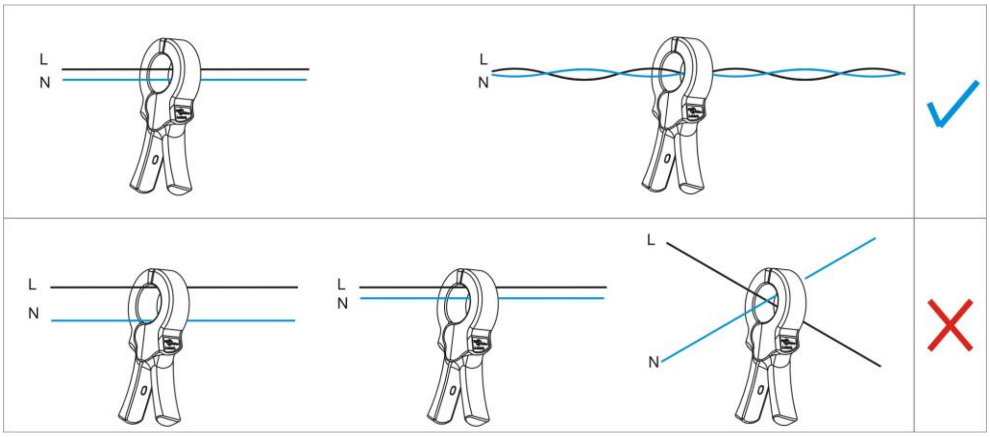


Fig. 11: Minimizing influencing quantities, correct placement of conductors

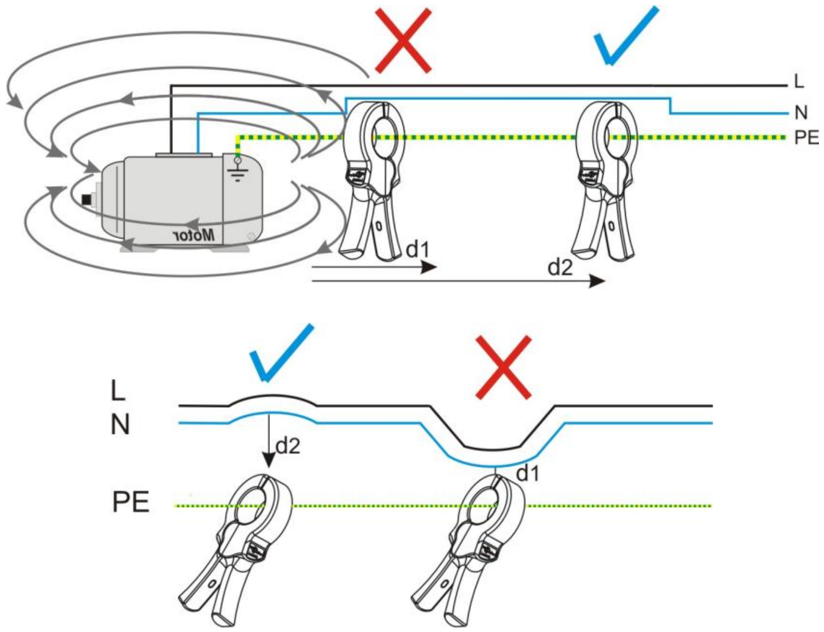


Fig. 12: Minimizing influencing quantities, avoiding external magnetic and electric fields

4.4.6 Consideration of influencing quantities

Only high quality current clamp can accurately measure in range of mA in presence of external fields and high load currents. The given resolution or basic accuracy are not telling a lot about the real quality of the current clamp. The immunity of the current clamp against influencing quantities is much more representative.
The IEC (International Electrotechnical Commission) is preparing a new international standard *IEC 61557-13 Hand-held and hand-manipulated current clamps and sensors for measurement of leakage currents in electrical distribution systems* that will cover the aspect of influencing quantities and will be launched in 2010. One of its main objectives is to define rules how to consider the immunity of influencing quantities in scope of the accuracy of leakage current clamps. This will enable the user to make a relevant comparison when deciding between different current clamp models.

4.5 Other important current clamp parameters

4.5.1 High measuring range

Leakage clamps with a high measuring range can be used for other applications too. A 20 A measuring range will cover most of application in standard residential electrical installations. A 200 A will cover industrial applications too.

4.5.2 Clamp diameter

In general a diameters of about 40mm is enough. For some applications a higher diameter would be useful. A slimmer design of the current sensor will be beneficial in most of applications.

4.5.3 Protection category

Overvoltage protection
Take care above the overvoltage category of the clamp. For use in offices, residential, industrial, domestic sites at least 300V CAT III is preferred.
For use in power utility sites 600V CAT III (300V/ CAT IV) is obligatory.

Use on uninsulated conductors
Current clamps marked with the  sign have additional protection and can be used for measuring on uninsulated conductors.

Current clamps without this sign or the sign can be used only on isolated conductors !

Note
The overvoltage category upstream the main fuses is usually CAT IV !
Refer to METRELs white paper *Electrical installation testers: CAT IV or CAT III?* for more information.

5 Technical specifications

List of instruments that support operation with A 1472
Current clamp is designed to be used in combination with following METREL testers:
PAT tester DeltaPAT BT MI 3309
PAT tester DeltaGT BT MI 3309
List of instruments that support operation with A 1579
PAT tester OmegaPAT MI 3360

Rated current: see the table bellow
Current ratio : 1000:1
Output:1 mA/A,
Output terminals: safety banana sockets Φ 4 mm, Guard terminal

Electrical characteristics
Measuring range: 0.5 mA ÷ 10 A
Accuracy: ≤ 5%
Frequency range: 40 Hz ÷ 5 kHz
Max. input current: 100 A

Safety specification
Type A (application around and removal form hazardous live conductors is permitted)
Over voltage category: 300 V CAT III/ 600V CAT II
Pollution degree: 2
Double insulation

Environment conditions
Working temperature: 0 °C ÷ 60 °C
Storage temperature: -20 °C ÷ 70 °C
Humidity: 0 % ÷ 85 %, linearly decreasing for T > 35 °C
Altitude: working 0 to 2000 m

Mechanical data
Jaw opening: 40 mm
Dimension: 177 mm x 53 mm x 23 mm
Weight: ~160 g

Applied standards
Safety: EN/IEC 61010-1
EN/IEC 61010-2-32