Building Facilities

Application catalogue

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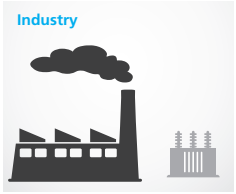
METREL®

Introduction of covered fields

Building Facilities

Any multi-dwelling, business or industrial building needs professional care to keep serving its residents. Building management includes everything from janitor services to installing fire extinguishers. Electrical safety is amongst the more notable duties. Standard family IEC/EN 60364 Electrical Installations for Buildings covers every possible aspect of it.



Electrical installation safety covers electrical measurements and visual inspections. Occasionally a functional inspection is necessary as well. The necessary measurements, limits on them and their frequency are covered by local regulations that are based on the IEC/EN 60364. Some local regulation may cover for historical specifics of the area. Part 4 of the standard covers protection for safety: protection from electric shock, from thermal effects, overcurrent and electromagnetic disturbances. Part 6 covers verification of the installation and therefore the required measurements. They generally, regardless of the locale, include line and loop impedances, earth resistance, lightning protection and insulation resistance. Measurements must be performed by qualified professionals. Parts of electrical installation that need testing are any supply (generator, photovoltaic panels), switchboards and divisions in installation, overvoltage protection devices, lightning protection system, grounding system, lighting system, and sockets. Where buildings are close together, their mutual impact should be considered, particularly in terms of grounding and lightning protection.

High complexity installations include any electrical system in the following non-residential spaces:

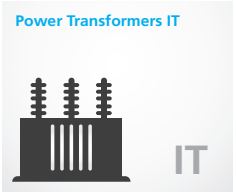
- With explosive atmosphere,
- With own electrical supply or transforming (photovoltaics, generator, transformer),
- With DC installations,
- EVSE,
- Battery banks,
- Supplied by uninterruptible power supply of apparent power that can affect a safety and health of a larger number of people,
- Protected by lightning protection level I or II:
- Higher than usual grid density,
- Overvoltage protection in level or zone application.

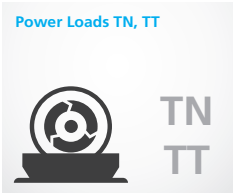
Low-complexity installations are the ones not included in high-complexity ones. Mainly, they are residential buildings, or smaller businesses. Regular maintenance is main facility management priority. When trouble in either electrical or other installations starts, it is imperative to discover the source and fix it as soon as possible. A thermal camera can be a great help with troubleshooting. It can 'see' some distance through the walls if the temperature difference is high enough for it to resolve it. This feature can be used to discover a number of problems, from leaking water piping to failing contacts in a switchboard. The camera is particularly valuable if solar power is used. Weak contacts and busted diodes that show on thermal image can be near impossible to find with electrical measurements alone.

Lightning protection covers all the safety issues in one. Without it, the buildings and everyone in them are exposed to electric shock, thermal effects and fire, overcurrent and extreme electromagnetic disturbances. Protection is combined from multiple parts: heavy conductors from the antennae to the ground, surge protection devices in the switchboards and elsewhere, equipotential bonding that prevents dangerous voltage differences, and a well-executed earthing system. Lightning protection in terms of design and building installation is covered in two standard families, IEC/EN 62305 and IEC/EN 62561. Effectiveness of lightning protection is highly dependent on well-executed earthing system. It needs to have a low enough resistance to successfully divert the high current.

Switchboards

Once low voltage power supply is connected to a building, it has to be distributed around it. The exception are locations with their own transformer and switchyard, which are usually housed in a separate building. Distribution board is the entrance to the consumer location. It also houses overvoltage protection, surge protection devices, and protection from residual currents (RCDs). Safety tests have to be performed there: protective bonding from sockets or fixed installed devices to the main earth bond, line and loop impedance, continuity of contacts and busbars, protective device functionality, isolation between phases, and others. Their construction, installation and safety are covered in standard IEC 60364-5, while protective device have their own standard, IEC 61643-11. It covers both requirements and testing methods.

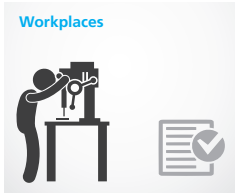




Power quality

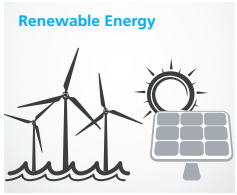
Switchboard is also the main location for power quality measurement in low voltage installations. It is not a periodic measurement for most installations. It lasts a long time and is expensive, so most managers only opt for it before the first use of the facility and when any important changes are made. In industry, this would be adding or removing large loads; in public and residential buildings, that would be changes of the supply connection. In some special installations and locations, UPS system makes an important difference for power quality. Measurement of power quality is a long duration monitoring of voltage and current at the measuring point. The current clamps and the clips for voltage are usually connected at the supply connection, at any large load, or at UPS bank, on all three phases and the neutral wire. Some measuring instruments have a separate connection for the PE wire as well. Measured values are interpreted into power parameters (apparent, active and reactive power, power factor, phi, and unbalance), harmonics and inter-harmonics, any unexpected events like voltage dips, swells or interruptions, flickers, transients and inrush current. Once power quality is established, some steps can be taken to improve it. Power factor can be improved by balancing inductive or capacitive character of prevailing loads. Power peaks can be time distributed to avoid addition between them. Improving

power quality usually means lower electricity bill and less stress on the infrastructure. There are multiple similar standards covering its properties and measurements: EN 50160, IEEE 1459, IEEE 1448, IEC 61000 family and IEEE 519. Power quality importantly affects quality of living. It makes a difference in light and noise in living space along with allowing general comfort of using electrical equipment with no disruptions.



Workplace and electrical equipment safety
Electrical equipment in the workplace is used often and intensively. The employer is responsible for health of their workers. These factors lead to frequent tests of the equipment used in a workplace. Electric appliances are possibly a larger hazard to users than installation, since they interact with them more. Testing is more frequent, usually at least once per year. Depending on the local legislation, the devices can sometimes be tested by laymen using certified testing equipment that supports the relevant international standards or has been programmed in advance. Testing includes PE wire continuity, insulation and leakage current. Test of fixed-installed equipment and devices is often performed separately, as frequency of inspections is different. Industrial environment has more difficult needs than residential or office. Electrical safety of machines is probably the most complex safety test, including measurements usually found in both installation and appliance testing. The instruments used are accordingly feature-rich, supporting even more than 40 different functions, some of which include high voltage or high currents that can be dangerous to the unqualified. There is a defined frequency for each test in local regulation or sometimes company internal acts. It depends on the location, from lowest in apartment buildings to highest in spaces with potentially explosive atmosphere. It can also vary with visual inspection results – if there are signs of wear and tear on the installation or appliance, or the intensity of use changes, more frequent check-ups are advised.

Special installations and locations
Some installations have a different construction that serves a specific need. They have to be tested accordingly. They are defined as special in the standard IEC/EN 60364-7, and requirements in it overrule the general standard.



There are 21 different special locations:
- Containing a bath or a shower.
- Swimming pools and fountains.
- Locations with sauna heaters.
- Construction and demolition sites.
- Agricultural and horticultural premises.
- Conducting locations with restricted movement.
- Caravan and camping parks.
- Marinas.
- Medical locations.
- Exhibitions, shows and stands.
- Solar photovoltaic supply systems.
- Furniture.
- External lightning.
- Mobile and transportable units.
- Communal facilities and workplaces.
- Caravans.
- Supply for electrical vehicles.
- Operating maintenance gangways.
- Temporary installations for fairgrounds.
- Heating cables and embedded heating systems.

Requirements for them include, for example, additional equipotential bonding, zones where no appliances are allowed, where only special appliances are allowed, mandatory protection by RCDs, isolation from earth, etc. Each has also special requirements for signalling, signs and warnings.
Measuring methods and appropriate instruments differ along with the requirements of the standard and the environment. For example, in construction sites, they should be dust-proof and the screens have to be easily readable in the sun.

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Building Facilities

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ELECTRICAL QUALITY AND SAFETY BUNDLES

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- Appliance and machine safety
- Low voltage power quality
- Special locations

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INSTRUMENTS FOR APPLICATION IN BUILDING FACILITIES
- MI 3155 EurotestXD
- MI 3360 OmegaGT XA
- MI 3309 BT DeltaPAT
- MI 3325 MultiServicerXD
- A 1422 Active 3-phase Adapter
- MI 3144 Euro Z 800 V
- MI 3108 EurotestPV
- MD 9930 IR thermal camera
- MD 9272 TRMS Leakage clamp meter with power functions
- MD 9070 TRMS isolation and continuity multimeter
- MI 2892 Power Master

FEATURED ACCESSORIES

LITERATURE AND EDUCATION

DEMONSTRATION EQUIPMENT

Electrical Quality and Safety Bundles

Solutions@Metrel®

INNOVATIVE APPROACH

Application bundles are combinations of tools in a set for each application, location or measurement regimen. They can be customised to match our customer's needs or pre-selected by Metrel. Licenses for the instrument, PC and Android software, customisation and appropriate accessories are included. Each solution also includes literature and posters, both printed and electronic, as well as training for the users to maximise the benefit to them. While the standard sets cover the anticipated installations, special locations and methodologies they can be further customised on request. Please use the selection guides on pages 5, 50, 52 and 54 to help you find the perfect match to your specific requirements.

AUTOSEQUENCE®

Autosequence®s are testing procedures prepared in advance for a specific application. They consist of a pre-programmed sequence of single tests with limits and parameters. In context of the Solutions@Metrel, testing procedures can be designed on-demand as part of the set. The operator can follow local regulations easily and safely, always achieving the objective.

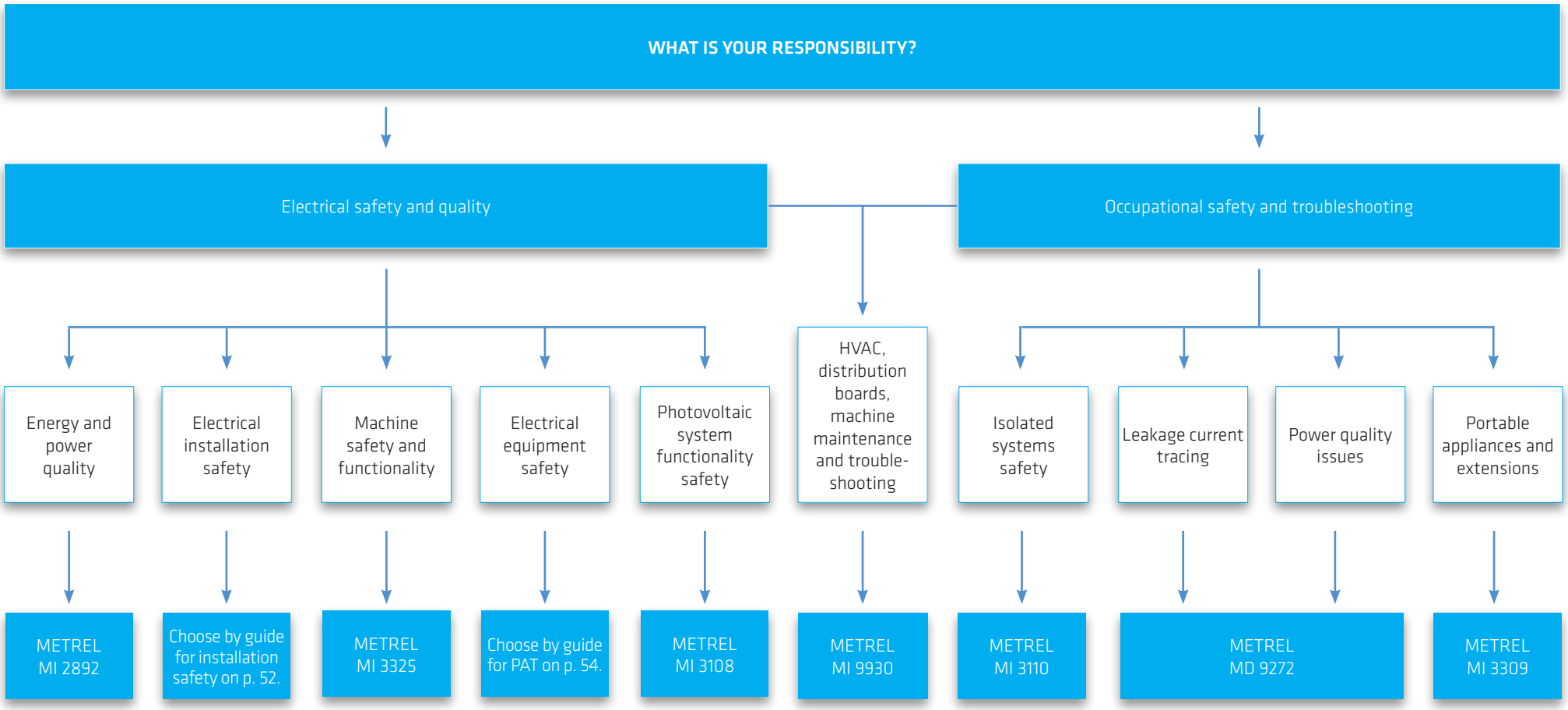
THE CASE

The sets are packed and delivered in waterproof case that facilitates transport, protects the equipment and prolongs its life. Cases are customized with foam forms, shelves and pockets to fit both the instruments and accessories. The case itself is made from tough plastic with strong locks, wheels and multiple handles for comfortable carrying. The hinges in the lid are designed to take not only the weight of the lid but also the weight of the accessories stored in it. Some of the instruments can be used still in the case, while others are hand-held and need to be removed while in use.

Selection guide by your job role

Selection guide

Metrel offers some pre-selected combinations of instruments in sets for certain installation types or locations. These in no way cover the full extent of our range. There are a multitude instruments with different features and price options available. Choices can be made using a number of variables: there are instruments that require little knowledge of electrical installations, instruments that will support the measurement methodology with which you are familiar giving you the results you require, instruments with really intuitive user interfaces, and small handheld units designed for field use. To minimise human error some instruments support AUTOSEQUENCE®. The guide below can help you refine and customise your solution.



Low voltage electrical installation safety

Solutions by the field of use

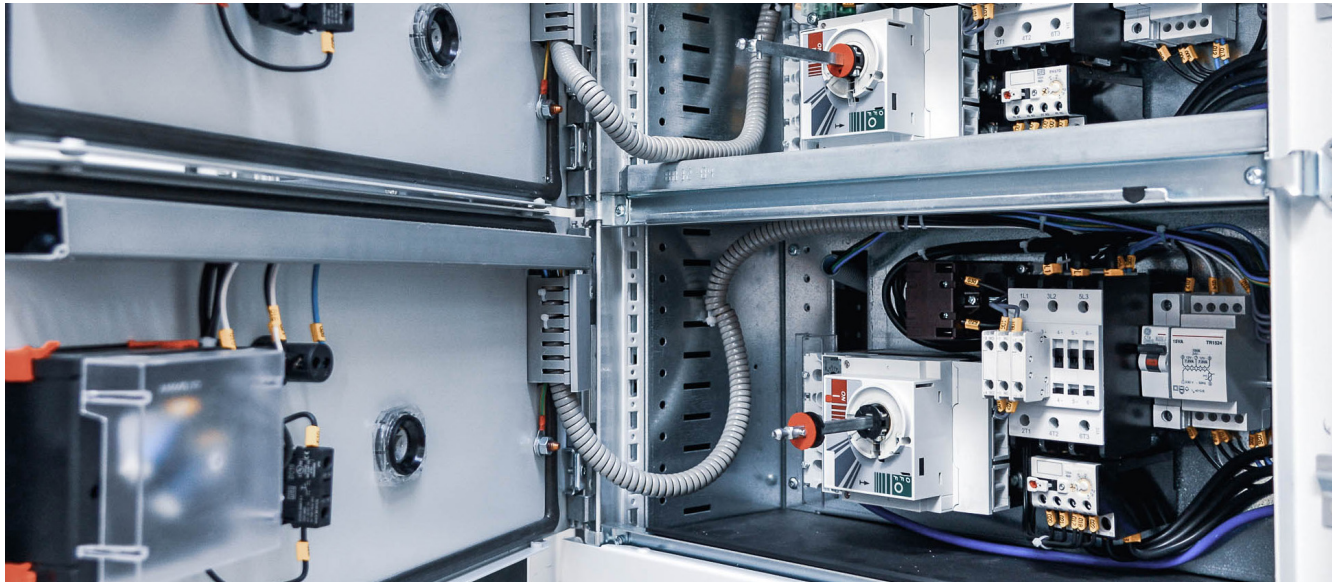
Generally, any residential space with an electrical installation has to conform to safety standards. Depending on the local regulator, they may be written with protection of life or protection of property as first priority.

Public places have to conform to the standards for low voltage installations and have a responsible authority confirm their safety before they opened to the public. Reconfirming compliance is performed periodically during the lifetime of the building and installation. Following the safety standards means ensuring protection from electric shock, electrical fire and explosion.

Public places and workplaces are similar in general: they are both filled with people who are not, themselves, responsible for the state of installations they use other than avoiding damage. Workplaces usually contain some electrical appliances or machines that need special care, and the employees are instructed in their use. Safety of the installation is however established with the same set of measurements as for public space, as required by the standard families IEC 60364 and IEC 61439. Measuring equipment used is covered by IEC 61557.

Measurements have to be performed by an authorised inspector or engineer. Commissioning and periodic tests are generally similar. However commissioning tests usually have additional visual tests before the installation is covered by décor, furniture or appliances.

A large majority of public places and workplaces has TT or TN grounding system, which means a low or very low PE resistance. The working voltage is measured between phase and neutral conductors. Measurements include earth resistance, lightning protection, surge protection and equipotential bonding (see other notes in this catalogue), insulation resistance, leakage currents, earth loop impedances and short-circuit currents, and RCD functionality.



The main way of determining safety, even with these electrical test available, is still visual inspection. Every accessible part of the installation has to be visually checked for adequacy and signs of degradation or corrosion. A great majority of problems is discovered visually. The inspection contains everything from checking compliance to wire colours and warning inscription regulations to fire prevention measures.

LIST OF PRODUCTS IN THE PROPOSED CUSTOMISABLE BUNDLE:

- MI 3155 EurotestXD Multi-functional installation tester
- MI 3144 Euro Z 800 V High current network and loop tester
- MD 9272 TRMS Leakage clamp meter with power functions
- Metrel ES Manager Basic or Pro Licence
- Android Metrel ES Manager
- Custom case

Substation electrical safety

Low voltage electrical installation safety

Local substation
Large facilities, from factories to hospitals, often have their own substation. It can be more effective for large consumers to maintain the transformer, that reduces distribution voltage to local voltage, in house. The substation houses the step-down transformer, primary switching panels and primary overvoltage/ overcurrent protection. Its design is dependent on the power requirements and the location on the campus. They tend to be in the proximity of buildings they service.

Design
The utility company will specify to the substation owner the particular types of transformers to use in order to protect the network from distortion and imbalance.
With the exception of some applications (e.g. welding), the transformers should have a delta-wye configuration and use oil for cooling. Agreement has to be reached on acceptable power in respect to the power of the local distribution network. The customer has to decide on the number of transformers and their configuration regarding the power needs, required reliability and cost. Above the power of 1000 kVA, provision of two transformers is necessary. Some typical configurations include a single transformer, two with one spare, two in parallel, two simultaneously working but separate transformers, etc.

Earthing
Local substation has an electrode type earthing system installed directly beneath its footprint, regardless of its location.
Possible designs include electrode mat directly under the floor slab (in within the foundation of the building), pocket design, or a copper strap. The electrodes must be 3 or less meters apart and connected in a cable type grid.

The substation earthing system must be independent and separated from earthing systems of other parts of the building and from any lightning protection systems.

Switching and protection
Protective devices depend on power of the transformers and its coolant. A dry type has to be more carefully protected from overstress and overheating, but it presents a smaller fire hazard. Shunt trips are used close to dry type transformer to shut them off in case of dangerously high temperatures. Protection is partly integrated in standard ring main substations that house both switchgears and circuit breakers or fuses. Combined devices that can isolate the transformer and protect it from unexpected events can be used.

Environment
The indoor substations with power in excess of 1500 kVA or higher have to be mechanically ventilated. Natural ventilation is insufficient. The transformers have to be safely distanced from walls and other equipment, the distance depending on their power. The specified operating temperature of the equipment has to be maintained. Large transformers are designed for slightly higher operating temperatures. Illumination has to be adequate for any workers to do their job safely. There are strict regulations on distancing from bare live cables and the use of safety barriers to keep workers as safe as possible.

MI 3155 and MI 3144 are a powerful combination for measuring large earthing systems.

MEASUREMENTS

MI 3155, combined with MI 3144, can perform all the necessary tests for confirming safety and functionality of a substation. MI 3144 provides high test currents necessary for thorough testing of bonding continuity, trip-out protection and earthing tests with clamps, while MI 3155 by itself supports voltages up to 2500 V for insulation tests. Overcurrent and overvoltage protection can be tested as line and loop impedance tests, where MI 3144 provides test current up to 300 A. MI 3155 supports 4-wire impedance testing on live transformers, making the test less costly to execute. Its 4-wire continuity testing allows for very accurate results, particularly in combination with higher currents that the impedance adapter provides, and its automatic polarity reversal during measurement. Illumination of the workspace can be measured using the Luxmeter accessory A 1172 for MI 3155.

Mains bonding and touch voltages during fault

Low voltage electrical installation safety

Equipotential bonding is a system that lowers potential differences in an installation by bonding the conductive parts together and to protective earth. It is possibly the most important safety measure in an installation. The earthing system shortens the duration of the hazardous voltages, while equipotential bonding lowers the voltage differential between points of contact during a fault. Any conductive surface or item should be considered for bonding, regardless of its connections to electrical installation. Parts of electrical installation are called 'exposed metalwork' while other conductive parts are called 'peripheral' or 'extraneous'. Examples of the latter include water, gas and heating pipes, metal window and door frames.

The importance of bonding cannot be overstated in risky environments. Non-distilled water is good conductor and can carry stray voltage or current to unexpected spots.
A potential difference between metal parts of a building incorporating a bathing pool and a swimmer could occur and rise to dangerous levels. The swimmer's wet skin has a lowered resistance making them even more susceptible to dangerous leakage currents. No exceptions are permitted for bonding in wet locations, every single conductive surface must be connected.

Equipotential bonding at installation level is generally not considered separately from the rest of the safety measures. Tests that cover it include loop testing, continuity and touch voltage measurement, and testing with the Metrel Human resistance probe A 1597. Loop impedance measurement, also called earth fault loop impedance tester just loop test, passes current in a loop between line and PE wires to measure its impedance and calculate the potential short- circuit current. It is most commonly performed at the switchboard, where line, neutral and protective earth are accessible. Potential short-circuit current is calculated to assist selection of correct overcurrent protection. There are multiple guidelines for protection sizing, but to conform to equipotential bonding requirements, it has to disconnect at 50

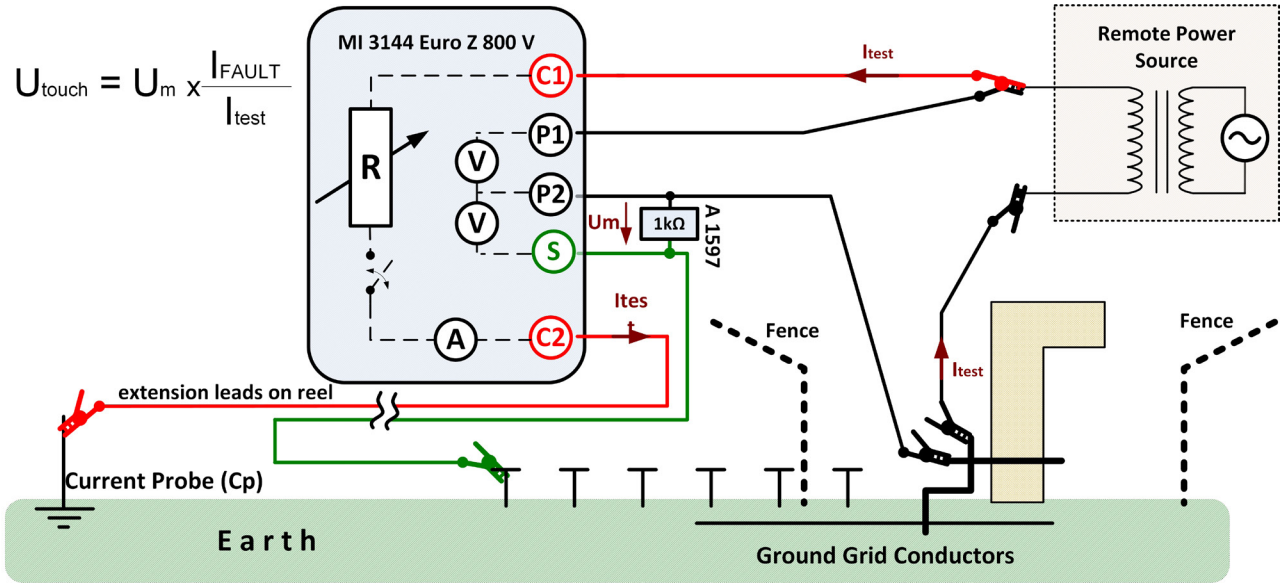
times smaller current than short circuit within 5 s. In context of equipotential bonding, a similar test is performed: a current is passed via the bond, through the protective devices like fuses and RCDs, and the earthing system to which it is connected. The measured impedance must be low enough to conform to equation: R ≤ (50V)/Ia, where Ia is the current that ensures the operation of the protective device within 5s. The measurement is usually performed along with earthing system tests, between earth bonds or electrodes and the measured item.

Human resistance probe A 1597 can be used to measure touch voltage, which is closely connected to bonding resistance. Touch voltage is the voltage between the item and the earth when considering the resistance of the human body in parallel to it. Measuring it gives a direct estimate of danger to life at the location.

MEASUREMENTS

It is important that in selecting an overcurrent or other protective device it has sufficient power breaking capacity.

Metrel's flagship MI 3155 only uses 200 mA for continuity measurement, which is sufficient for most indoor applications. R Loop function is a high current loop test injecting about 6 A and can be used for Larger distances. It is always better to use the 4-wire method for measuring low impedances.



Measuring touch voltage with MI 3144 and A 1597. MI 3155 can be used in the same way, but can only utilise a fraction of MI 3144's test current.

MI 3155 has pre-programmed tests with automatic disconnection of protective devices. The measurement is 4-wire: two probes connect to the measured surface and two to protective earth in the closest switchboard. This method enables high accuracy even at low current and automatically compensates for test leads resistance. It also automatically reverses polarity to compensate for any material asymmetry and electromechanical effects. To achieve higher accuracy or measure longer cables, the MI 3242 is a good choice. It uses 4-wire method with a 2 A test current, supports automatic switch of polarity and other methods to improve result. It however doesn't cover automatic disconnection.

Switchboards and automatic trip-out protection

Low voltage electrical installation safety

A switchboard or a distribution board is the part of installation where the single main supply in-comer is divided into sub-circuits distribution of power around the building. It incorporates protective measures such as surge protection, circuit breakers and RCDs.

It is the place to conduct a number of tests that would be difficult or impossible in other locations. In particular leakage current measurement and automatic circuit breaking tests are performed here.

The automatic trip out protection ability test is done to confirm the protection is adequate. It is performed during the initial inspection, periodic predictive maintenance and first response troubleshooting. The use of the MI 3144 is recommended where energetic loads and sources of protection exceed 200 A, like transformers, generators, turbines, contactors, distribution boards and switchyards. It provides high precision methods with high current, temperature management and 4-wire connection.

Methods for partial voltage and current drops enable measurement without disconnecting any wire or removing cable screens. ELR electrical leakage relays are an industrial type of protection in case of high leakage current. They can be properly tested only from switchboard side with fault current injection and trip-out time measurement. Testing relays to proper reaction to faults or leakages, high neutral current, missing phase situations or asymmetry will protect people and livestock as well as electrical loads and supply.

Leakage current measurement is not normally part of periodic inspection, but it is a great troubleshooting tool. Leakage current is both a part of normal operation of installations and devices, usually in the order of mA, and an indication of fault if too high. It is a consequence of imperfect insulation, capacitive coupling, and other parasitic effects. It can be also caused by electro-magnetic

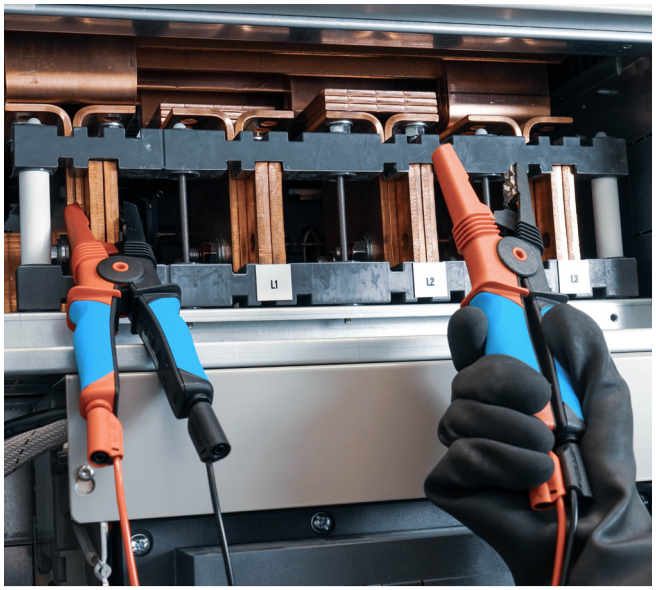
disturbances or non-linear filters. This common occurrence can cause a number of problems, most obvious of them being unnecessary RCD tripping and possibility of dangerous touch voltages. RCD tripping can be prevented by using careful design, dividing the circuits between users and switches so that expected maximum leakage for each of the circuits never reaches 20% of RCD rating.

Leakage current manifests as current flowing through the PE conductor, or any unbalance in currents between phase and neutral wires. This gives the key principles of the measuring method. Direct method uses current clamps around the PE cable, but this ignores the potential of parallel earth paths, while differential method clamps phase and neutral cables to measure any unbalance between them. In differential method, direction of each current is important. Ideally, both methods are used and the worse result considered.

Higher than normal leakage can be a symptom of a weakened insulation or a failing device somewhere in the building. After tracing the circuit showing high leakage current, first through the sub-distribution boards, and then by turning the devices on and off sequentially, the source can be located relatively simply. Leakage current measurement can be an alternative to insulation resistance measurement when looking for failures where high-voltage testing is not possible. That is mainly in presence of sensitive equipment that cannot easily be taken offline e.g. communication or medical devices. Leakage and insulation measurements however are not directly comparable. It depends on the ratio of capacitive and resistive properties of the insulation material. Insulation is measured at high DC voltage and considers only resistive component, while leakage is AC and contains both capacitive and resistive elements.

Contact voltages in surroundings of switchboard can be measured during simulated fault to ground. With insulated voltmeter and parallel 1 kΩ resistor connected to simulate body resistance, realistic touch and step voltages can be scaled to faults like phase to ground or even a lightning strike.

Leakage measurement is an important troubleshooting technique.



Measuring busbar continuity with large Kelvin clamps A 1593.

Other measurements done in the switchboards are continuity of protective bonding, optionally RCD or ELR tests, voltage properties tests, and power quality logging. See other application notes in this publication for more details.

MEASUREMENTS

Leakage current is a measurement of a low current in presence of much higher currents in close proximity, which cause significant electromagnetic fields that would result in high errors. Earth leakage clamps should be high quality, with good magnetic shielding and magnetic concentrator in the core that provides a good immunity to external electric fields or capacitive connections, as required by standard IEC/ EN 61557-13. Metrel recommends MD 9272 for work in small enclosures and rapid troubleshooting, MI 3155 with A 1019 for most locations, or MI 3144 for high energy locations that require particularly high precision.

Public places electrical safety

Low voltage electrical installation safety

MEASUREMENTS

After the installation passes visual inspection, electrical measurements are necessary to ensure operational safety.

Earth resistance

Earth resistance is measured at the main earth electrode. If there is space available and ground allows electrode placement, the 3-spike method is used. It involves driving two probes into the ground at a considerable distance (the further (C) at 5 times radius of the building complex and the closer (P) at 62% of this distance) from the electrode under test and using them to inject current and measure voltage. In urban areas, more often than not this isn't possible. In many such sites, 2-clamp method should be used instead. It is also useful for testing lightning protection. It injects current into earthing system of the building, as close to the ground as possible. It calculates resistance of the whole installation – the more parallel earths are available, the closer the result is to resistance of a single rod. Both methods are described in more detail in their own notes.

Continuity of PE wire and equipotential bonding

Continuity has to be tested with a 200 mA current and voltage between 4 and 24 V to conform to the standard. This measurement is usually done between the point under test and the nearest distribution board, and on the higher level between distribution boards and the point of supply, and eventually the substation to conform to the standard. Every contact and switch in the distribution board should be tested. The measurement method is chosen according to situation and grounding system to achieve the required accuracy. Accessible metal surfaces have the bonding checked periodically, while those concealed during construction are tested during initial inspection and when there is a fault.

In dry areas only the items that are large enough to be gripped or that can contact a significant part of the body surface are

considered. Smaller items are less dangerous even if they become live. Touching them will cause the muscle to contract away from them breaking the contact.
It is important that within a single building there is no potential difference between any of the protective earths

For example it is possible to build a communication or computer system entirely separately, but it must still be connected to the protective earth system to ensure a common potential.

Insulation resistance and leakage current
Insulation prevents unwanted electrical contact and corrosion of the wire. Insulation resistance and leakage current are alternative ways to determine its quality. Insulation resistance is a test using high DC voltages, depending on the installation can be 250 V – 2.5 kV. This gives a pure resistive result with no capacitive effects outside the initial charge. On the other hand, leakage current is measured in AC conditions. It takes account of the capacitive elements of the insulation. The results are therefore not immediately comparable.

RCD testing
RCDs are automatic switches that turn the supply off if they sense a current in PE (or alternately a difference between currents in phase and neutral). This way, they provide protection from electric shock. There should be multiple, protecting different parts of the installation, and a hierarchy should exist between them. Some offer overcurrent protection as well, but mostly, overcurrent devices are separate. RCDs have to be tested for contact voltage, trip-out time, and trip-out current. Testing procedure consists of measuring trip-out time at different factors of the rated current. Contact voltage is the voltage between accessible grounded metal part and the PE contact on the RCD.

If the contact voltage is significant it usually means the PE is broken, this should also trip the RCD.

Using MI 3155 and one of the Autotests is a fast way to check the installation.

Line and loop impedances
Line and loop testing creates a short circuit between phases and measures the series impedance from the transformer leg to the measuring point. Line is the line-to-neutral impedance, and loop in the line-to-PE. The measurement is meant to test overcurrent devices and supply line impedance. Similarly, loop impedance tests overcurrent devices in the fault loop, residual current devices and PE impedance. In both measurement, the prospective fault current is calculated. It has to be high enough to operate overcurrent devices.

Electrical installation is not a simple system. The measurements can be an indication of its safety. Warning labels, symbols and inscriptions are part of the safety system as much as the electrical features, so the users are able to keep themselves safe. Once electrical safety of the installation is established, the wise manager will move to testing the appliances, and to functional testing.

Low voltage earthing and lightning protection

Solutions by the field of use

Many building complexes grow organically, essentially not planned for final size when the building began. Constructing, maintaining and testing the resulting earthing system can be a serious challenge.

Large building complexes, such as hospitals, large shopping malls or factories can become a major part of common power earthing system. They can have an internal substation with earthing for the whole complex constructed with a particularly low impedance, and its underground distribution has to be taken into account for the wider surroundings.

Courtyards and other open spaces within the complex have to be kept at an equalised potential to prevent any hazard in case of a lightning strike or a phase-to-ground fault. Step or touch voltages in case of a steep voltage funnel close to the electrode can otherwise become significant. Earth electrodes should be a widely spread underground device like a loop, mesh or a plane with multiple parallel connections to it. There should be a lattice of conductors throughout the foundations with their own path to earth, keeping the base potential of each building constant. The ground electrode is usually a loop or a mesh and covers most of the area under the building.

Lightning protection design depends on the roof of the buildings and grounds shape. Sensitive equipment, for example communication or medical, needs special protective measures inside the building. Separate buildings, and sometimes rooms or parts of the installation within the complex also need their own connections to earth to lower any interference from other parts of the installation through earth. Further protective options are an isolated system, or even a Faraday cage. The protective measures extend to devices used. They have to be connected to the protective earth system and any accessible surfaces bonded to keep voltage differences to a minimum. The first fault to be considered when designing the grounding system is phase to ground fault. It can cause dangerously high voltages on enclosures or any grounded conductive surfaces. Grounding system must have a low enough resistance to pull the voltage down to safe levels. Since it is a type of fault that lasts until fixed, permissible touch voltages in Table 1 are much lower than for instantaneous events. The voltage is defined in regard to its danger to life.

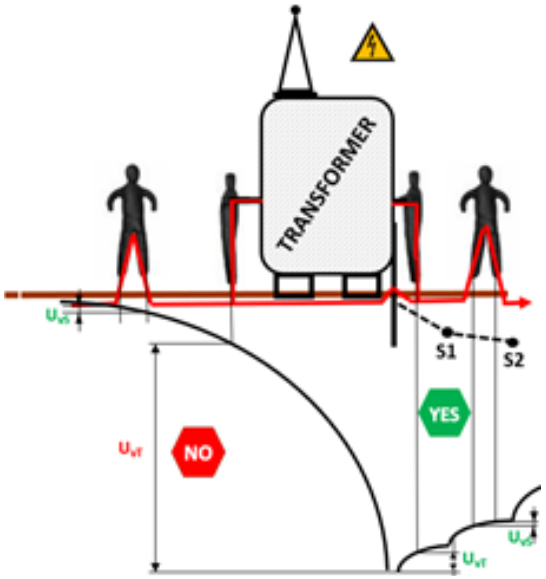
A lightning surge is usually fast and extremely high-powered, reaching into hundreds of kilovolts and kiloamperes. However, since it passes so quickly, permissible voltage on accessible conductive parts of the equipment can be quite high without posing danger to life. Protection of equipment is a secondary consideration.

Fault duration (s)	Permissible body current IB (mA)	Permissible touch voltage UTp (V)
0,05	900	716
0,10	750	654
0,20	600	537
0,50	200	220
1,00	80	117
2,00	60	96
5,00	51	86
10,00	50	85

Table 1

Some values with regard to fault duration are collected in the table above. Lightning strike lasts 0.2 s on average, usually made up from a number of shorter flashes of 60 – 70 µs. Danger to life is usually described with two terms: contact/touch voltage and step voltage.

Some sources also separate contact and touch voltage as different measurement methods with slightly different results. Contact voltage is a voltage between point of contact, usually a grounded conductive surface, and the ground potential, usually under the toucher's feet, measured with a high-resistance voltmeter. Standard touch voltage measurement is made with 1 kΩ Human resistance probe like A 1597. Step voltage is the voltage over the distance between the feet when walking. In standards, 1m is considered. The voltage depends on the shape and slope of the potential funnel around the earth electrodes.



Us - step voltage; Uc - contact voltage; Uf - fault voltage+

Testing the protection requires very high currents to make it represent real occurrences and avoid spurious currents. MI 3144 can provide up to 300 A, which is enough for almost all system.

LIST OF PRODUCTS IN THE PROPOSED CUSTOMISABLE BUNDLE:

- MI 3155 EurotestXD Multi-functional installation tester
- MI 3144 Euro Z 800 V High current network and loop tester
- MD 116 Non contact voltage detector
- Metrel ES Manager Basic or Pro Licence
- Android Metrel ES Manager
- Custom case

Earthing measurement with fall of potential method

Low voltage earthing and lightning protection

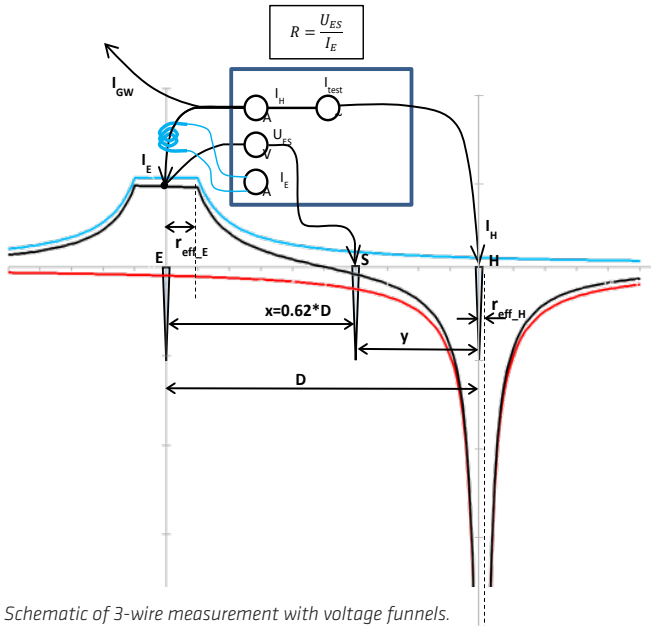
Measuring earthing resistance can be both difficult and tedious. It requires special equipment and multiple repetition of measurements, particularly on large systems with multiple earthing points.

The fall of potential method, also called the 3-wire or 3-spike method, is a common way of measurement and the first recommendation by standard IEEE 80. It is particularly useful for earths in remote locations. The three measurement spikes are the earth electrode under test and two extra, often labelled P (for potential) and C (for current). Metrel instruments however use notation S for potential and H for current. The measurement principle is very simple. The H electrode injects current into the system that comes out via the electrode under test, and potential difference between S spike and the electrode under test (denoted E) is taken. Resistance is calculated using Ohm's law. The PE (or PEN) of a TN system should be disconnected. If a single earth electrode is to be measured, it should be disconnected from the rest of the system.

However, we have described the idealised case. Every electrode has an area (or effective radius) of distributed resistance in the earth. To achieve accurate measurement, the electrodes must be far enough from each other that the areas of effective resistance do not overlap. If the electrode S is too close to E, the result will be too low, as only part of the measurement funnel will interact. If the electrodes S and H are too close together, the H electrode funnel will impact the result.

Other important source of inaccuracy is presence of conductive materials underground like pipes or fences.

The distances depend on the size of the longest diagonal or diameter of the protected object. Distance, D, between E and H should be at least 5 times its greatest dimension. The electrode S is placed at 62% of distance, D, from E. There are some variants of this method with different electrode positioning. If



Schematic of 3-wire measurement with voltage funnels.

E – measured electrode
S – voltage electrode
H – current electrode
D – 'long' distance from E
x – optimal distance for S
reff_E – effective radius of E
reff_H – effective radius of H
IH – current in H
Itest – generated current
IGW – leakage current
IE – current to E
UES – voltage between E and S
R – what the instrument displays

Red line: voltage funnel of current electrode
Blue line: voltage funnel of measured electrode
Black line: combined voltage funnel
S (voltage) electrode should be situated where both current and measured electrode's funnels are at zero.

there is particularly large space available, the 5 times distance can be extended and the S electrode put at halfway. This allows measurement without a measuring tape.

The electrodes can also be placed as vertices of the equidistant triangle. Measurement result at any electrode positioning should be checked by repetition at different distances. S electrode is moved about 10% closer to, then further from the E in regard to original position. Standard IEC 60364 -6 advises moving it by 6m each time. The reading shouldn't change more than 10%. Otherwise, the probes should be moved further away from the measured electrode. If there are suspect object underground, perhaps moving them to a different position would help.
It is good practice to repeat the measurement with different electrode positioning. At least they should be put to the other side of the object under test, at 180 degrees from the first measurement.

Distances can be impractically large even for medium-sized objects. The method can rarely be used in urban areas, where access to earth is also a problem. It however works well in remote areas, and it is the only method that can be used when there is only a single connection to earth in the system.

MEASUREMENTS

MI 3155 is a multifunctional installation tester that can cover every aspect of the installation from its establishment to years of regular maintenance. Amongst its many features are also three methods for measuring earth resistance. It comes equipped with a number of different probes and test leads for easy testing.
The instrument is equipped with 20 m long cables and rods for earth resistance measurements as standard. Optional extensions are available. Software on-board and in the office gives the option to set a maximum resistance limit and gives a pass/fail signal. The test is run automatically once initiated. The result can be saved. Exporting the results to PC allows further processing. The instrument also displays resistances of each measurement electrode for reference.

Larger earthing systems can be more easily measured using MI 3144 adapter. It offers higher test current and more measurement options. For more information, please refer to its datasheet and other publications.

The procedure starts by examining any documentation on the earthing system. The electrical centre of building has to be determined. Rods are set to the required distances and connected with cables to the instrument. Socket designations are H for current electrode, S for voltage electrode and E/ES for the measured earthing probe.

2-clamps method for measuring lightning and earth protection

Low voltage earthing and lightning protection

Particularly in urban areas, the classic earthing measurement with rod electrodes isn't possible. There is neither space to put them at a distance from the object to be measured nor access to actual earth to drive in the rod. One has deal with the situation. One alternative is a measurement using two clamps. It is useful for distributed earthing system with a lot of electrodes or for lightning conductors, and quicker and easier to perform than the rod measurements It requires 2 clamps, one a generator for inducing a known voltage to the system and the other for measuring current flowing in the earth electrode under test. The clamps must be as close as possible to the earth electrode, and certainly before any connections to other parts of the earthing system. In a TN system, measurement is performed on incoming PEN/PE bond. No bond needs to be disconnected. Current is injected into the earthing leg as close to the electrode as possible.

A voltage-inducing clamp can be used, or any kind of connector that can be applied to the earth without disconnection. The induced voltage causes current in the whole earthing system. The measurement taken is a loop measurement. In the case of a large system with an internal substation, like a hospital, it goes from the measured point all the way to transformer secondary and back underground through the earthing system. The more parallel earthing rods there are in the system, the closer to resistance of the single rod will the measured value be (example with equal resistances of 10 Ω in Equation 1). It is a quite straight-forward consequence of essentially measuring a single leg in series with a- parallel network in a building.

If the tested electrode has high resistance, that will be immediately obvious. However, if one of the electrodes somewhere in the system is defective, or if there is another error in the loop, the change in measured value might not stand out.

It can often only be noticed if there are previous measurements which show a trend. The whole resistance of the system is still low enough, and one failed connection somewhere might not make a difference.

$$R_{loop} = R_m + \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \frac{1}{R_4} + \frac{1}{R_5} + \frac{1}{R_5}}$$

$$= 10\ \Omega + \frac{1}{\frac{1}{10} + \frac{1}{10} + \frac{1}{10} + \frac{1}{10} + \frac{1}{10} + \frac{1}{10}}$$

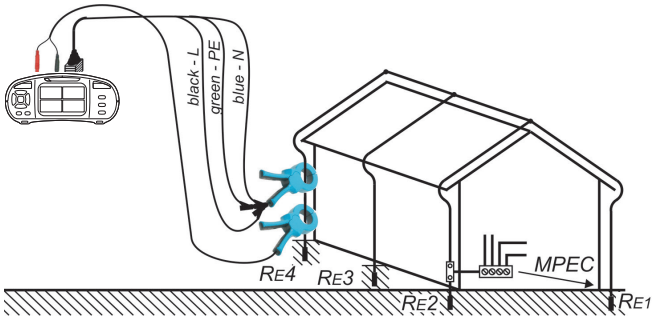
$$= 10\ \Omega + \frac{1}{\frac{6}{10}}\ \Omega = 10\ \Omega + \frac{10}{6}\ \Omega = 11.67\ \Omega$$

Equation 1: Example of calculation for 6 earthing electrodes with 10Ω resistance each. Rm is the measured leg.

The method lacks a way of proving the result similar to changing the positioning of electrodes in the 3-wire method. The results have to be taken in good faith. It is very important to check for any other low-impedance path that excludes the soil, e.g. antenna in cell tower. Method will not work in that case.
Another consideration is the possibility of connection between the earthing electrodes underground. The injected current will then travel by this connection instead of into the ground, and the result will be falsely low.

MEASUREMENTS

A pair of clamps is part of the standard set for MI 3155. Though their connectors differ: A 1018 has integrated test wire for connection to the instrument, and A 1019 has connectors for standard 3 wire test leads. The only settable parameter is maximum acceptable resistance for pass/fail indication. The measurement is entirely automatic, and it is unimportant which clamp is top or bottom. Use the three-wire test lead and insert it into the test connector on the top of the instrument.
Connect the banana connectors one on top of the other and insert into the clamp. Use the current clamp connectors (black and red) to connect the other clamp. Push the button to measure, and save the result as desired.



Circuit for 2-clamp measurement

Surge protection devices

Low voltage earthing and lightning protection

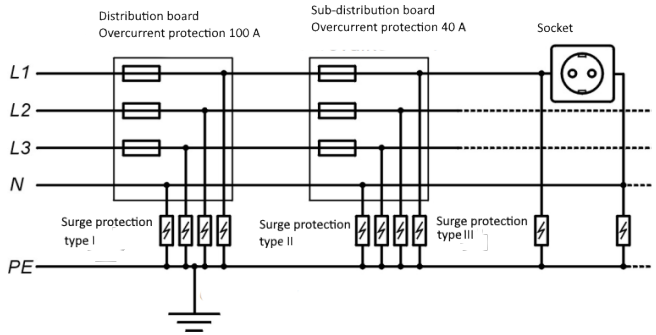
Surge protection devices are an important part of lightning protection system. They however can do precious little on their own without a properly designed lightning system behind them.

A surge protection device is designed to redirect current to the ground once the limit voltage is exceeded, and do it very quickly. Some are only conductive when the limit is exceeded, while others switch to a different path, depending on the construction. Reaction times generally stay below 100 ns. They are used at every level of electrical network, from the largest installations to the most sensitive devices, protecting from everything from voltage transients on the network to actual lightning strikes in the close vicinity. They can be grouped by the position in the installation, construction, reaction time, rated voltage, maximum safely diverted current, rise and fall time of the surge they safely divert, and other properties. General guidelines for installation are covered in the standard EN 62305 Lightning protection standard, while the devices usually conform to IEC 61643 Low-voltage surge protection devices.

The surge protection system from top (at supply to the building) to bottom (at the asset or appliance) needs to be coordinated so that they open in right order to an incoming surge. Each level has to be chosen so that it protects equipment behind it, but doesn't age prematurely due to conducting unreasonably often.

Type I protects the installation. A number of these are installed in the main distribution board where the supply enters the building. Exact number, construction type and positioning depend on the grounding system and installation's power. Ahead of them sometimes a thermal fuse is installed, depending on the installation and the SPD manufacturer's instructions.

Type II protects non-sensitive appliances and devices, like large machines. The SPDs are found in the sub-distribution boards between the phase and ground wires.



Connecting surge devices into the installation.

Type III and IV protect more sensitive devices and are not covered in the scope of this note.

Protection devices have to be installed in a hierarchy of rated voltages, or they might not do their job. A transient of just the right size might burn out a too-small type III device, but fail to trip the type II phase.

Constructions can be a combination of different elements, but the most common are varistor and gas discharge tube. Varistor is a semiconductor device whose resistance varies with the applied voltage. At low voltage, the resistance is high, but at the rated voltage, it drops sharply. Exact characteristic depends on materials used. Most common is zinc oxide grains, which offer a sharp knee at rated voltage. Varistors have a life expectancy limited by amount of energy they conducted. They may fail catastrophically with a very high power surge or a lightning strike that exceeds their rated current by multiple orders of magnitude. They can remain in conductive state then, or they can open permanently. On the other hand, they can fail with multiple surges over time, and appear undamaged on visual inspection. They generally remain open if they failed over time.
Gas discharge tube is a sealed glass vial, filled with a gas, and with a pair of electrodes inserted. Once the voltage is high enough, the gas ionizes and an arc forms between the electrodes. It is slower than a varistor, by the order of 100 ns. It can conduct higher current per size than any other protection device. The arc can be sustained at voltages lower than the inital one – this is called follow-up current, and it can damage or destroy the device if left unchecked. Similarly to the varistors, they have a finite life expectancy in terms of translated energy over time. They can be designed to short in case of failure, but most commonly they will fail by becoming ineffective. It may need additional protective devices due to its relative slowness and the sustained arc. Their capacitance is exceptionally low, which makes them a good match for higher frequency applications.

MEASUREMENTS

MI 3155 has an automatic test for varistors. Before using it to electrically test them, they have to be thoroughly visually inspected for following points:

- check the building guidelines
- check SPD presence
- check for any obvious signs of failure (breaking, overheating)
- contacts have to be clear and firm (use a thermal camera like MD 9930 if available)
- each units is firmly attached
- equipotential leads are appropriately sized
- type and location of installed protection are appropriate to earthing system used
- check coordination of SPDs
- check distance from SPDs to their protected location

The voltage will ramp up from 50 V to the set upper limit (1000 V or 2500 V) with slope of 100 V/s (for 1000 V range) or 350V/s (for 2500 V range). The test ends when measured current through the device exceeds 1mA or the voltage reaches top of the range. Limit should be set to get a pass/fail evaluation.

Appliance and machine safety

Solutions by the field of use

Electrical devices are the fabric of everyday life, being used practically every waking second of our lives. In everyday use, we trust their manufacturer that they are safe, or in later years, visual inspections. Accidents still happen, but with necessary education and visual inspections, they are rare. In public place or a workplace however, the appliances get used much more intensely, and the responsibility for their continued safety lies with the owner or employer. Cost of regular testing is much lower than the cost of injuries or fire damage. In some countries, it is prescribed by national legislation, in others it is required by insurers. Where it is not mandatory, it is strongly advisable.

Standards divide electrical equipment to groups in regards to their use and properties. There are multiple subgroups. Standards relevant for periodic testing include:

- Portable electrical appliances (German VDE 0702 is the most widely used),
- Medical electrical devices (standard groups IEC/EN 60601 and IEC/EN 62353),
- Electrical machines (standard group IEC/EN 60204),
- Electrical switchgears (standard group IEC/EN 61439).

In facility management, testing is limited to periodic tests. Type-testing and end of line testing are left to manufacturer. Safety certification can be done by the manufacturer themselves before applying for CE mark, but independent laboratories are more reputable.

Retest periods depend on the asset's location, use, type of equipment, protection class, and local regulations. It is typically quite short, anywhere between 3 and 24 months. This makes test optimization necessary. An important eliment is communication between the testing provider, the owner of the asset and the users. The users should be well aware of electrical safety and care of the appliances. Another is the execution of the tests. Modern tester improve the flow of work by automating the procedures, saving the results, keep them for future reference and certification, and simplify device recognition by using barcodes or other tags. The intuitive user interface expedites the process.

Testing continuity of protective wires on a hospital bed.

Larger machines must be tested using a different set of electric tests, but the concept is roughly similar. They have to be compliant to their technical documentation, visually inspected, electrically and functionally tested. General extent of testing is covered with particular standards for the machine type, but technical documentation for a specific device is the definitive source.

The volume of test results can become a problem to save, manage and monitor. It is the most important to keep them consistent and transparent, though systems may differ. Usually, devices to be tested are marked with an inventory number on a barcode. The Metrel system encourages organising the devices by their location in the facility. Results are saved in the instrument's memory structure. Apart from the number, much additional information can be saved on the tested asset itself using a QR code, RFID chip or a NFC sticker. Common accessories for the testers are a printer or NFC/RFID writing device to save new data.

A particular case of appliance and machine safety testing is care for safety in the workplace. The employer is responsible for safety of work equipment and installation and for educating the worker.

LIST OF PRODUCTS IN THE PROPOSED CUSTOMISABLE BUNDLE:

- MI 3360 OmegaGT XA
- MI 3325 MultiServicerXD
- A 1422 Active 3 phase Adapter
- MD 9272 TRMS Leakage clamp meter with power functions
- Metrel ES Manager Basic or Pro Licence
- Android Metrel ES Manager
- Custom case

PAT measurements and management

Appliance and machine safety

Once passing the visual inspection, portable appliances have to be tested electrically as well. Depending on the local legislation, this can be done by professionals or by laymen. The latter are rather dependant on automation in the instruments that they use, but education is always the preferable way.

In essence, there are three electrical tests to be performed on each appliance: continuity of protective earth, insulation resistance and leakage current. Functional test can also include measurement of power parameters. The tests actually performed depend on type of device, its protection class and state of repair.

Protection classes include:

- **Class I**: connected to PE in the installation with three-pole supply cord, basic insulation (double in case of unearthed accessible parts)
- **Class II**: not connected to PE, double insulation, two-pole supply wire
- **Class III**: not connected to mains (battery operated, or through a safety low voltage supply), basic insulation.

MEASUREMENTS

Earth bond (continuity of protective conductor) test

It determines that PE contacts in the supply cord and grounded metal parts are strong. PE wire prevent dangerous voltages on the accessible parts and conducts any leakage current from the device.

It can use currents of 100 mA and higher, depending on the local legislation, device and intention. Most commonly used value is 200 mA. Using higher current can provide better accuracy, and it can also break weakened contacts that would soon fail. Usually, instruments support test currents of 10 A and 25 A. The latter is also prescribed for testing in some special cases in the standards, and for all medical equipment. Test signal is applied between PE pin of the supply cord and accessible earthed part under test. A flexible supply cord has to be folded during test to check contact under every angle. There has to be good contact between the probe and the measured surface – the expected measured values are very low (a couple hundred mΩ) and contact resistance can be considerable.

Insulation
Insulation test determines resistance between live conductors and accessible metal parts of the asset. It is performed with high DC voltage, so it only takes resistance into account, not capacitive or other effects (with exception of brief loading at the start of the test). Resistance depends on the state of the material, which can deteriorate due to a number of external issues. Moisture and pollution are the most common. Weakened insulation can result in dangerous voltage on accessible surfaces, high leakage, RCD trips and overheating. To measure the insulation, the voltage is applied between PE and live pins of the supply cord for Class I protected devices, or between accessible metal part and live pins in Class II protected device. Class III is tested in a similar way to Class II, but the limits are different. If there are no accessible metal parts, the test is not applicable. Voltage used depends on the local legislation and device type. Common values are 250 V or 500 V. After the insulation test, subleakage test is recommended.

Leakage current
There is a number of variants on this test. It is generally performed between accessible metal parts and live while the device is in different working states – the device is turned on. It considers the stray currents at mains voltage and frequency – in AC conditions, which makes it different from an insulation test. It includes capacitive elements and can also be a symptom of a fault in mains circuit or the device. Too high leakage causes high voltages on accessible partsof the device, RCDs tripping, and overheating. Particularly dangerous is a double fault, where protective earth is a not connected. If line and neutral wire positions are not predefined, both options have to be measured and the higher value considered.

PE conductor (direct) leakage
In a class I device, measurement is made on the PE conductor with the device turned on. The floor under the device has to be isolating, or part of the leakage is going to escape through it – this is the main weakness compared to the differential test. If the leakage differs with different working modes of the device, all of them should be checked.

MI 3360 M can be used for troubleshooting devices during service.

Differential leakage
Both neutral and line wires are passed through the current clamp to measure the difference between them. Current clamp however must be exceptionally well designed to be able to discriminate between the low leakage current from the much higher working current.

Touch leakage
Leakage current measured between line wire and accessible isolated metal parts on both Class I and Class II devices. Device is powered up through the measurement instrument and probe is used on the surface under test. The probe is a human body simulator with resistance of 1 kΩ. Each accessible part of the asset has to be tested separately.

Medical leakage tests
Medical equipment has to be more thoroughly tested for leakage, since it can be applying voltage directly to patients, who are often in a compromised state. There is a further number of leakage tests to be performed, particularly on the patient-applied parts.

Functional testing
Essence of functional test is to ensure correct operation of the device. In its scope testing the power and leakage combination test can be performed. Usually, current clamps are used for it, and therefore, it is more suited to fixed appliances with higher power. The test can be used to discover problems like stuck motors in danger of overheating, or whether appliances with high nominal currents are causing problems to the installation. Changed power factor can point to problems in supply handing in the appliance.

Machines and fixed connected loads safety

Appliance and machine safety

Electrical machines are quite different from appliances. They are comparatively large, their supply can be high-voltage, they are fixed installation, their safety depends on state of the installation and they are tested as an assembly. The first test is visual inspection of the machine, any existing technical documentation, and any previous test reports.

This determines assembly state of the machine (fully assembled or dismantled), length of supply wires, and its electrical status.

Each measurement must be performed on a large number of locations on the machine: motors, control circuits, any sensitive equipment that has to be tested separately, supply circuit, input filters, any built-in protective devices, accessible conductive surfaces, etc. A measurment instrument should be equipped with a memory system and enough probes to allow doing a number of locations at once and change them without losing track.

Protection from indirect contact by automatic disconnection
First electrical safety consideration to be tested is protection from indirect contact by automatic disconnection. The exact mechanism and test depend on the grounding system:

- In TN, it is an overcurrent devices (covered in standard IEC/EN 60204-1-5),
- In TT, it is a RCDs (standard IEC/EN 60364-6),
- In IT, it is an IMD or RCM (standard IEC/EN 60364-6).

The extent of testing is determined by a decision model or flowchart, based on the information collected. The most extensive variant includes full testing of continuity for all relevant accessible surfaces and cables, and full loop impedance.

Test current for continuity of cables is between 200 mA and 10 A, higher currents are preferred, especially for lower resistances. Supplementary protective bonding are grounding connections for any grounded accessible surfaces. Impedance on
them has to be low enough to assure contact voltage less than 50 V between any two grounded surfaces.

Fault loop and prospective short-circuit current are measured between L and PE conductors at connection points to the machine's load, and result compared to relevant protective devices (fuses or breakers). In three-phase machines, all three phases have to be considered.

RCDs on a machine are tested for the same results as the installation: trip-out time at nominal current, touch voltage and trip-out current. Supply is on during the measurement.

Limits for some of the tested value results are defined by physical properties or technical documentation where available. Acceptable continuity impedance values are calculated from conductor properties: length, cross-section, and material.
Disconnection time depends on length of cables and acceptable touch voltage, or can be taken as fixed and used to calculate fault loop impedance. Prospective fault current must consider fuse type and size, nominal voltage, and changes due to temperature. Tables of values are available in standards and supporting literature.

Insulation resistance
As in PAT testing, it is measured between live pins and PE terminal at each eligible machine component. Lower voltage is used on the sensitive components or where built-in protective devices could be operated. On a standard machine and where surge protection can be disabled, the voltage is 500 V and resistance limit is 1 MΩ. On some special parts of the machine, e.g. busbars, conductor bars or slip-ring assemblies, values down to 50 kΩ are allowed. Testing is performed in the same manner as on a portable device – between any insulated part and line wire, and between line and PE wires.

High voltage/withstanding test
Test is usually performed on parts of the machine or installation between power circuit and the protective bonding circuit. Test voltage is twice the nominal voltage of the machine, and tested part should survive 1 s with no insulation breakdown. Any part of the machine not rated to withstand the voltage or that has been previously tested to their standards should be disconnected.

Protection from residual voltage
Residual voltage on live parts is a consequence of material capacitance. The limit for it is 60 V, or the surface has to be discharged to 60 V within 5 s after end of operation. Plugs and similar devices have to be discharged to 60 V in 1 s. If this cannot be achieved, firstly there has to be better IP protection, and secondly extra switching devices and visual warnings shall be applied. Measurement is performed on relevant live parts, most commonly at the supply to the machine, after the device is turned off.

Functional test
Test of machine operating correctly. It can however include other tests that are sometimes also used in troubleshooting: power characteristics, leakage current, or others.

Workplace safety
Main workplace safety features are connected to safety of devices used daily. Particularly manufacturing workplaces can be hazardous if proper precautions are not observed. Compared to an office or other environment, the production line requires more safety knowledge and action, but also more safety devices and measures.

Hazards and avoiding them
Protection from shock is extended to accidental contacting a live conductor, most common at overhead power wires, but can happen with underground lines or at a substation. Any metallic object can make an accidental contact: a crane, a ladder, metallic construction material, etc.

Particularly in construction sites or other incomplete areas, bits of electrical safety measures may be missing. Protective earth or RCD protection may not be in place yet. Such an installation shouldn't be live. The installation must be tested regularly for safety features like continuity of wires and safety devices working properly.

A common hazard is using the equipment in a way not prescribed by the manufacturer. The built in safety may fail to protect the user in such a case. Examples include problems from using obviously damaged equipment, removing its safety features to making extension leads from unsuitable materials.
Equipment has to be tested for safety features regularly – frequency of testing depends on working conditions. Non-tested equipment can be considered hazardous.

MEASUREMENTS

Machines can break in any number of ways. They tend to be complex, with a lot of moving parts and a combination of mechanical and electrical parts. Safety tests can be useful for troubleshooting as well: for example, higher leakage current can be indicative of a problem. If the clamps like A 1472 are used, it can be sometimes determined which part of the machine is causing the higher leakage. Continuity and insulation tests can point to broken wires or failed insulation. A very powerful tool for troubleshooting is a thermal camera like MD 9930. It can identify pressure or friction points that causes parts to wear out prematurely. An overstressed motor's heat signature is going to be immediately obvious. Regular imaging can help identify devices or components that are more likely to fail as their temperature rises with age. Measuring the temperature remotely can be a powerful maintenance tool.

Metrel collection for industrial settings includes MI 3394, MI 3325 and MI 3155. MI 3394 is the most complex Metrel instrument that covers more than 40 safety and functionality measurements. MI 3325 is meant for CE testing of products in the line and less for machinery, but also covers some measurements that MI 3394 doesn't, like DC voltage. MD 3155 is the flagship of installation testers with some machine testing capabilities.

Low voltage power quality

Solutions by the field of use

The power delivered from a supply is specified as pure sine at country-specific RMS voltage and frequency. It shouldn't deviate from this ideal. But does it? There is a number of effects that can distort voltage or current from the perfect sine. Some disturbances can have a source inside the system and can be fixed, while others are caused by far distant phenomena on the network or simple carelessness on supply side. Measurement, monitoring and detection of these phenomena is covered by standards IEEE 1448, EN 50160, IEEE 1459 and IEEE 519. They cover different aspects of power quality and reporting, from voltage characteristics to energy consumption.

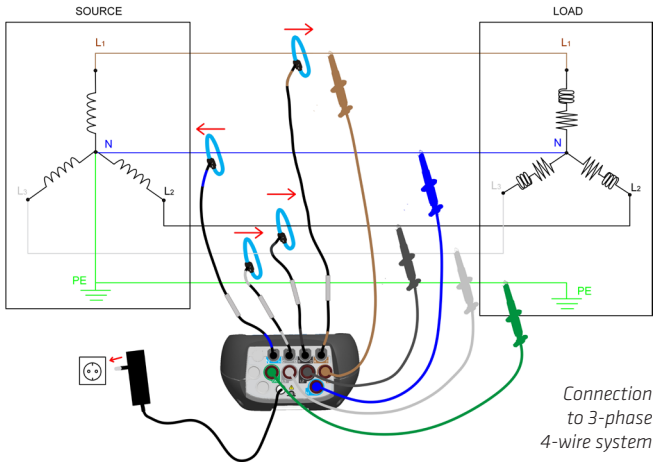
Variables that are considered a part of power quality according to European standard EN 50160:

- Voltage balance. Phase difference and voltage megnitude between phases should be equal.
- Phase current, its magnitude, shape and trends.
- Frequency. The standard permits no more than 2 Hz deviation.
- Active, reactive and apparent power. They mean how much power is carried towards the energy consumer and how much away from it. It depends on the consumer more than the source.
- Power factor or cos fi is the ratio of active to apparent power. It
- should be as high as possible.
- Harmonic components. Harmonic distortion means change of the signal shape to less than a perfect sine. It is described in terms of frequency components in the signal.
- THD is ratio of harmonic content vs. the base component.
- Special events. They are consequences of some extreme event in the network, e.g. a lightning strike, or adding a particularly large consumer. They manifest as transients or in-rush current.
- Flicker. A flicker is a change in brightness of an ordinary light-bulb as consequence of voltage fluctuation. It is no longer as much of an issue, since control of the network has improved over the years, and there are many fewer incandescent light-bulbs in use. It is however still part of the standard.

Most of these values have to be monitored over an extended amount period, from a few days to a few weeks. The instrument records values at defined intervals. It will save any unusual events. Depending on the settings, it can also save the oscilloscope image.

There are two typical locations for power quality measurement. One is at the main supply connection, where every disruption from the network will be visible, but internal influences will not yet be pronounced. The other is wherever a sensitive device will be installed, and it has to be confirmed that it will be able to work with the available power. At the first point, the main issues are reactive power or power factor and events on the network. At the second point, there will be more trouble with harmonic content.

A specific location for power measurement is a UPS battery stack. The on-line system with large rectifiers that do not include extensive filtering can be a source of serious disturbances. Filtering systems generally comes included, but its functionality has to be checked periodically.



Connection to 3-phase 4-wire system

The power quality measurement has to be set up with great care. Nobody will want to take time to do it again should an error occurs.

The instrument is set up with measurement of voltage and current in all the phases at the required location, then programmed. Monitoring can run for the whole planned period, or it can be interrupted in case of a pre-defined event. Data can be sent to be saved in a cloud service, or kept in the instrument. Poor power quality can manifest in a number of ways. The most obvious are higher energy consumption and power stress on the cables. There can also be noticeable interferences between parts of the network. There are measures in place to prevent too high reactive power and power at higher frequencies. Main ones are notch filters that only allow desired frequency to pass, and capacitive banks to correct power factor. Isolated system or even faraday cage isolation can be necessary to keep the interferences at bay.

Isolated areas are very specific in terms of power quality. They can be prone to disturbances that can't be removed via the earth bonding, but on the other hand, they are more isolated from the interference from earth.

LIST OF PRODUCTS IN THE PROPOSED CUSTOMISABLE BUNDLE:

- MI 2893 Power Master XT
- MD 9272 TRMS Leakage clamp meter with power functions
- A 1565 Waterproof case
- Metrel PowerView 3

Uninterruptible power supply

Low voltage power quality

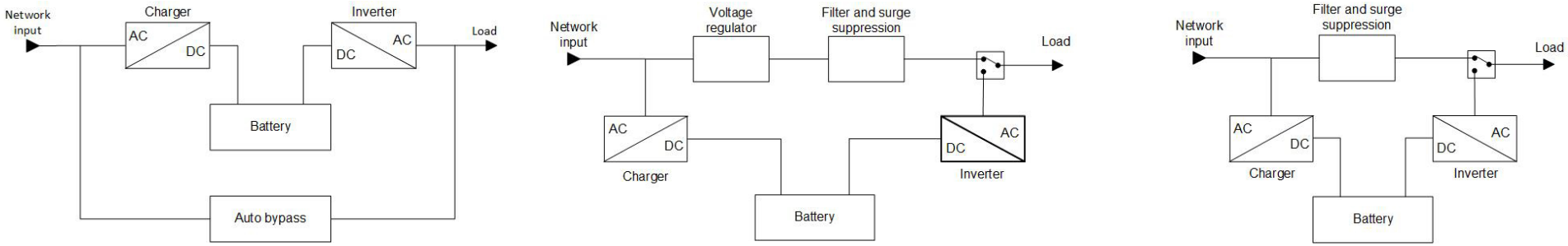
A number of processes cannot be interrupted by a power outage. Most have backup generators or alternative power source available, but they can take a while to start. The UPS system is there to bridge the gap between outage and backup source coming online.

UPS is a battery or a battery system connected to the installation, intended to start powering the protected circuits immediately if the main power fails. They can also provide protection from power quality issues on the network. There are three essential methods for its installation into the system: online, offline (standby) and line-interactive.

Offline system is the simplest and the cheapest, commercially offering up to 20 min working time and surge protection. Devices connected to it are working directly on the power supply. If the voltage falls below the predefined limit or rises above it, it switches to battery power and its DC/AC output. Response time is some milliseconds.

Line-interactive system is similar, but contains an auto-transformer or a transformer with adjustable input and output. It can tolerate prolonged lowered voltage (a brownout) by increasing used current.

Online or double-conversion system is always connected to a rectifier and an inverter. If the power fails, the rectifier drops from the line and the batteries are nearly immediately online. When it returns, the rectifier starts charging the batteries. It provides very good protection from events on the network with double conversion acting as a buffer. It has higher initial cost, mainly due to the necessary strength of the rectifier. The rectifier can however cause a certain amount of current harmonics, since the current it draws is not sinusoidal. Most double conversion models come with some kind of filtering built-in, the most effective are active filters in integrated form.



Schematic of three ways to connect the UPS into the installation: online, line interactive, offline.

UPSs have to report their status to other devices. They can support any type of serial ports, an internet connection, or proprietary protocol. They also perform and report regular self-checks. Batteries are subject to a number of chemical effects and problems that can in some cases make self-checks insufficient. Deep discharge tests should be run periodically, but not too often, as they damage the battery to a small degree. Li-ion batteries are less sensitive both to chemical events and discharge damage.

MEASUREMENTS

Measurements on the UPSs are made with power quality analyser like Metrel MI 2892 or MI 2893. One has to check any possible state and transition in the system and check the state of the batteries. Tests are divided to pre-installation and combined.
Pre-installation is the more thorough set of test to be performed before connecting a new, sensitive load. It involves checking functionality, specifications, functionality under symmetric or asymmetric load, run test for 8 or 24 hours, transients when changing loads, turning it on or off under load, function during transition to battery operation and back, discharge test, function when hot-swapping batteries if available, and functionality of external bypass if available.
Combined tests are run when UPS unit is in operation. They are the similar to the pre-installation, but have to be performed at zero and at full load.

Power quality reports

Low voltage power quality

It may be desirable to formalise the reporting of the quality of the power supply and energy rating of a building, but the first priority is: do the instruments perform the required measurements? The initial report follows the standard EN 50160. It mainly covers general voltage characteristics over time. The general recorder is set to periods of 10 minutes over at least 7 days. This measurement ought be performed after installing any new large loads to test for any energy pollution they might cause on the grid. The general recorder saves about 4000 parameters and values of the electrical network, processed from voltage and current measurements. They are then interpreted into easily understandable power quality properties of the supply. Values are sampled and averaged over a pre-defined integration period to calculate RMS, minimum and maximum. The instrument can present the results in a number of graphical representations. For EN 50160 report, the 3D histograms and trend graphs are commonly used for evaluation of voltage changes over time. It can also include reports from other recorders, e.g. transient.

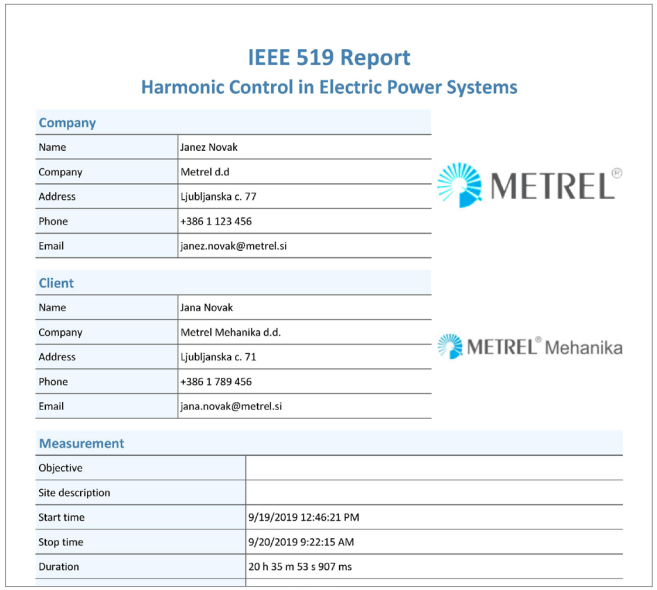
Power properties are calculated and presented in great detail. Active power is aggregated into two quantities: import or consumed power, designated a plus sign, and export or generated power, designated a minus sign. Non-active power is aggregated into four parts: positive inductive, positive capacitive, negative inductive and negative capacitive. This is also true for power factor. Energy is closely connected to power and expressed in a similar manner. If necessary, a graphical presentation can be generated.

IEEE 519-2014 is another measuring and reporting standard, more closely directed to harmonic content. It recommends limits on harmonics and interharmonics. A general recorder is used with monitoring window of 7 days, with 3-second interval every 10 minutes. Voltage and current harmonics can be saved. Interharmonics are becoming a bigger problem with time, as more equipment that both generates them and is sensitive to them is added to the system. Interharmonics are any frequency

components that are not an integer multiple of base frequency. They can be caused by any amplitude modulation of voltage or current, by non-periodic changes, e.g. a load in transient state, a device switching asynchronously to mains, saturation in inductive devices, capacitive oscillations, or other phenomena. Like other non-functional signals in the system, they can cause problems with heating, shortened life expectancy and higer maintenance cost. Higher harmonic content also increases the risk of resonance.

Energy and energy demand reports are produced with data from the general recorder with registration period of 15min and monitoring window of at least 7 days. It includes energy use profiling by hour, day and week, evaluation of use in different tariff, and cost evaluation. For optimization of energy use, a consumption profile can be created. It is the most graphical of reports, with the intention of helping with planning energy use by time of day. This can lower the maximum demand. It can also help with optimization of power factor if it changes during the day. It can be beneficial to check the efficiency view during recording. It contains a balance overview between phases, one of the easiest changes that help with efficient energy use and improves power quality in general.

Power quality instruments can be used for troubleshooting. The integration period has to be shortened to give detailed data. Waveform and transient recorders can also be used. Waveform recording is a function in the instruments that captures actual waveform, similar to an oscilloscope. The trigger for capture has to be set with specific network or problem to solve in mind; it can be set to voltage/current level or to voltage events. An alarm can be set along with the trigger. Waveform and general recorders can run simultaneously. Transient recorder monitors voltage or current spikes that can be caused by transient effects in the grid or by errors in generation. It offers a very high sampling rate to capture the brief transient as faithfully as possible.



IEEE 519 Report

Harmonic Control in Electric Power Systems

Company

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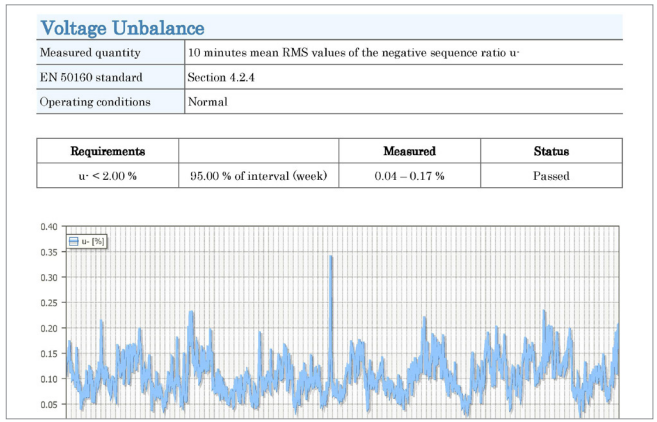
Measurement

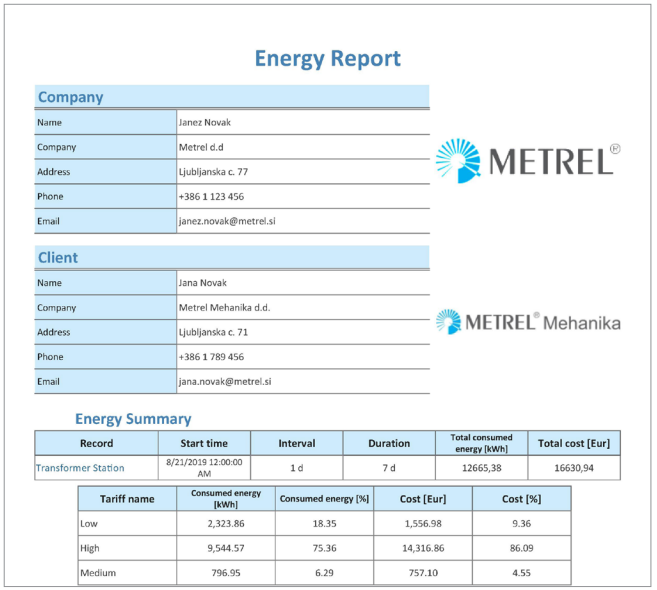
Objective	
Site description	
Start time	9/19/2019 12:46:21 PM
Stop time	9/20/2019 9:22:15 AM
Duration	20 h 35 m 53 s 907 ms



Voltage Unbalance

Measured quantity	10 minutes mean RMS values of the negative sequence ratio u-
EN 50160 standard	Section 4.2.4
Operating conditions	Normal

Requirements		Measured	Status
u- < 2.00 %	95.00 % of interval (week)	0.04 – 0.17 %	Passed



Energy Report

Company

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Energy Summary

Record	Start time	Interval	Duration	Total consumed energy [kWh]	Total cost [Eur]
Transformer Station	8/21/2019 12:00:00 AM	1 d	7 d	12665,38	16630,94

Tariff name	Consumed energy [kWh]	Consumed energy [%]	Cost [Eur]	Cost [%]
Low	2,323.86	18.35	1,556.98	9.36
High	9,544.57	75.36	14,316.86	86.09
Medium	796.95	6.29	757.10	4.55

The third recorder and an application in itself is the inrush current recorder. It is specifically developed to monitor the current at a motor start-up.

MEASUREMENTS

All mentioned reports are generated with Metrel PowerView 3 PC software. It can process the data in a number of ways and create graphical representations before generating a report to the chosen standard.

Effects of power quality issues on living and working environment

Low voltage power quality

Power quality has an easily noticeable affect all the elements living and working environments. Issues with PQ can affect with all the elements that affect human comfort: temperature, light and noise.

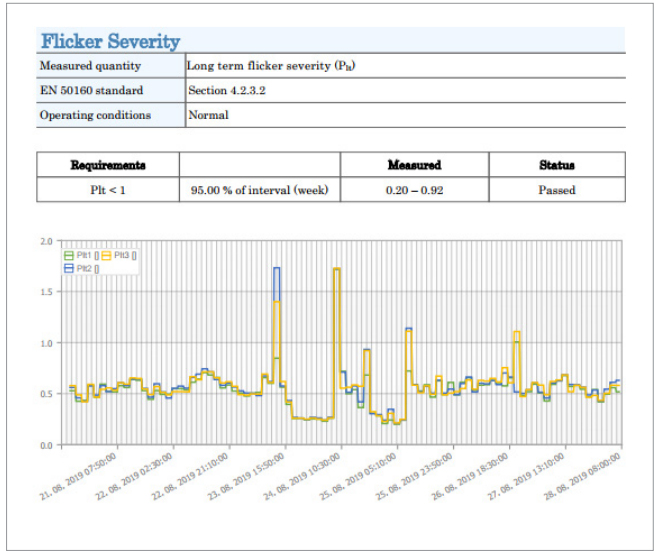
Interruptions of power have the most obvious effect on work and living: there is little human activity that doesn't depend on electrical power being available. Work has to very nearly stop for the duration of the interruption, at least until the secondary power sources come online. Quality of life drops dramatically: there is no lighting available, few people have gas cooking equipment, no consumer electronics, few public services remain, and life very nearly comes to a standstill. Sudden interruptions can damage some more sensitive equipment, particularly electronics, making even return to normal difficult.

A voltage dip is not as dramatic, but can still cause trouble to both businesses and homes. Some devices can handle lowered voltage, by using some or other type of voltage regulation, or simply by being insensitive. Lights, particularly LEDs however, often won't work.

Large machines or other production equipment will not work, in particular some feedback loop circuits tend to fail.

Voltage swell rarely causes severe problems in the short term. It is possible to overstress sensitive components or insulation, lose data due to switching errors, etc., but these are all more in the domain of transients. Devices might heat more and in the long term, their life expectancy will be shorter. Effect on immediate living comfort is usually very small. Few machines will change the ambient temperature to any notable degree due to higher operating voltage.

Flicker is among the most serious power quality issues in terms of its effect on everyday life. It manifests as flickering of light that causes medical issues like headaches, migraines and even



Flicker Severity

Measured quantity	Long term flicker severity (P_{lt})
EN 50160 standard	Section 4.2.3.2
Operating conditions	Normal

Requirements		Measured	Status
Plt < 1	95.00 % of interval (week)	0.20 – 0.92	Passed

Example of report on flickers.

epilepsy. From a safety perspective, flickering lights distort the view of rotating items and things on conveyor belts, making them appear slower or even still. In the workplace, it lowers productivity and makes some light-dependent jobs, like photography, almost impossible.

Distortion or harmonic content is less of an issue in terms of quality of life. Most everyday appliances handle them with no noticeable change. Some may become louder or cause unexpected sounds. Rectifiers can give high-pitched squeal. Transformers may become louder and vibrate more. The effect of harmonics is hidden, but quite serious – deformation of mains voltage can overstress the neutral wire in three phase system, disturb signal systems or electronic regulators, lif the operating temperature, llower efficiency and cause resonance. Depending on the location and ventilation, the heat can become considerable.

Power factor means essentially having more energy in transmission than the load is using. It causes extra stress, heating and aging, while the system has to be slightly oversized to accommodate the power. In extreme cases, the heat can be considerable and affect human productivity, but this is a rare.

Distortion or harmonic content is less of an issue in terms of living quality. Most everyday appliances handle them with no noticeable change. Some may become louder or cause unexpected sounds. Rectifiers can give high-pitched squeal. Transformers may become louder and vibrate more. The effect of harmonics is hidden, but quite serious – deformation of mains voltage can overstress the neutral wire in three phase system, disturb the signal systems or electronic regulators, lifting the operating temperature, lowered efficiency, and resonance. Depending on the location and ventilation, the heat can become considerable.

MEASUREMENTS

Metrel instruments can assist at improving power quality and consequentially the environment. PQA instruments like MI 2892 and MD 2893 are designed for easy diagnosis and reporting of power quality issues. MD 9272 can quickly suggest a reason for losses or distortion in the system. Multimeters can easily measure a large spectrum of temperatures.

Working and living space comfort can be created using a number of measures. Power quality may not be the most prominent, but it can add the cherry on top to a comfortable location.

Special locations

Solutions by the field of use

Just as the installations in particular locations are specialised and vary, so are the measurement methods and instruments for use in them. One has to consider the working environment in terms of dust, moisture, temperature and ambient light, voltage, current and frequency ranges, accessibility of installation and other challenges that may present themselves in the field. Special requirements for installations can be roughly divided to groups.

Wet places
They include bathrooms, swimming pools, and marinas. Wet area is defined as any that has the potential to get in considerable contact with water. This ranges from areas of particularly high humidity and condensation to actually submerged areas. Outdoor installation usually have to conform to similar requirements. Typical extra requirements include mechanical compliance and limiting locations for appliances.

Local supply Installations
They include solar photovoltaics and fixed installed generators. Fixed installed generators are a source of backup power for emergencies, when main supply is cut off. They can be installed in homes, but most commonly can be found in public service facilities that can't be just shut down. The most obvious is a hospital. Patients cannot be just removed from life support due to an outage. Similarly, some systems in an airport have to keep working to get the incoming planes to land safely . A generator usually cannot start immediately, so to have a truly uninterrupted service, a UPS system has to be installed as well. The generator can be started automatically if the main supply fails, or started manually. In terms of electrical safety, it is preferable to start it manually after checking its status. Solar power has specific components, like inverter and charge controller for the batteries. Specific components take specific measurement methods and instruments. The system is expected to need little maintenance but regular checks.

Agricultural areas are electrically special locations due to high moisture content and specific equipment like electric fence.

Isolated locations
They include medical installations, transportable installations, installations in the mobile units and caravans. Isolated means an installation that has neutral and protective earth strictly separated, and only the latter is grounded. This arrangement makes for higher power quality. The first fault doesn't cause it to turn off, just sounds an alarm. The installation is still safe to use. For protection from the second fault, RCDs have to be installed, as it could cause very high fault currents. Main safety issue is insulation, and there is an insulation monitor installed to test it continuously and sound the alarm if it lowers too much. The main construction issue is finding the fault once present. This and the price are the reasons it is often used as a small island in more common grounding system.

Outdoor locations
They include construction sites, agricultural sites, camping parks and external lighting. Temporary installations like fairgrounds and festivals are only slightly different. Nearly always, there is a fixed part to them, or at least part connected to the local supply, where standards for supplies apply. The fixed and the temporary parts must be separable at a glance with different colour tape flags. A number of extra precautions for switchboards and cabling which have to be installed and tested, mostly to protect from mechanical stress and the elements. Dust and damp are present in all of them. Specifics for construction site are the expectation of high currents, up to 50 A on the main overcurrent device – it has to be chosen and sized appropriately, and placed in a secure location. Similar goes for main RCD. Testing frequency for most of the installation is every six month or less and has to be performed by a professional. RCDs have to be checked monthly, but can be done by a competent worker or site representative. In the agricultural environment, the specifics are cow trainers and electric fences. They should be separate from the rest of the installation, particular care must be taken about separating the grounding – they work with high voltage and can cause considerable disruptions to the rest of the installation. They have to be designed to provide just the right amount of power to scare the animal without harming it.

LIST OF PRODUCTS IN THE PROPOSED CUSTOMISABLE BUNDLE:

- MI 3155 EurotestXD Multi-functional installation tester
- A 1632 E-mobility analyser
- A 1532 EVSE adapter
- MI 3110 EurotestIM
- MI 3108 EurotestPV
- Metrel ES Manager
- Android Metrel ES Manager
- Custom case

Wet and outdoor locations

Special locations

Measurements in wet locations are not too different from general electrical safety tests. Mainly, one has to be familiar with extra requirements and test their conformity. Wet conditions can be found in a number of special locations: farming, horticulture and livestock breeding, public places like pools and spas, public gardens and parks with fountains, residential premises with bathroom and kitchen, restaurants, operating theatres in hospitals, etc. Essential requirements for all are the same.

Mechanical properties

The first line of safety is mechanical and chemical compliance of any equipment used and parts of the installation. Cables and devices should be coated in insulation certified for wet locations. Other types of insulation may degrade quickly. Moisture is one of the most common problems for insulation intended for dry places. Main reason to care about it in particular is the danger of leakage currents in combination with water and the possibly wet skin. With non- distilled water as general conductor in e.g. a pool, leakage can be dangerous to swimmers even meters away from the fault. Any equipment (lights, massagers, pumps, etc.) used in contact with water must have IPX7 or higher protection certification.

Cables need extra certification for mechanical stress resistance wherever they are exposed. Outdoor switchboards have to be considered an appliance in wet location and therefore IP certified.

Safety areas

Safety areas are defined by the distance from actual submersion in water, e.g. inside a bath or pool is zone 0. No electrical part should be installed there unless it has an IPX7 or above rating. Zone 1 is the immediate vicinity of the submerged area, like wall above the bath or pool. It gets splashed regularly, but is not submerged. Zone 2 is the extended vicinity, up to approximately 60cm from the wet edge. It can get splashed, but more rarely. Zones 1 and 2 can contain equipment with protection IPX4 (or IP X5 for any space with horizontal water jets). Extra

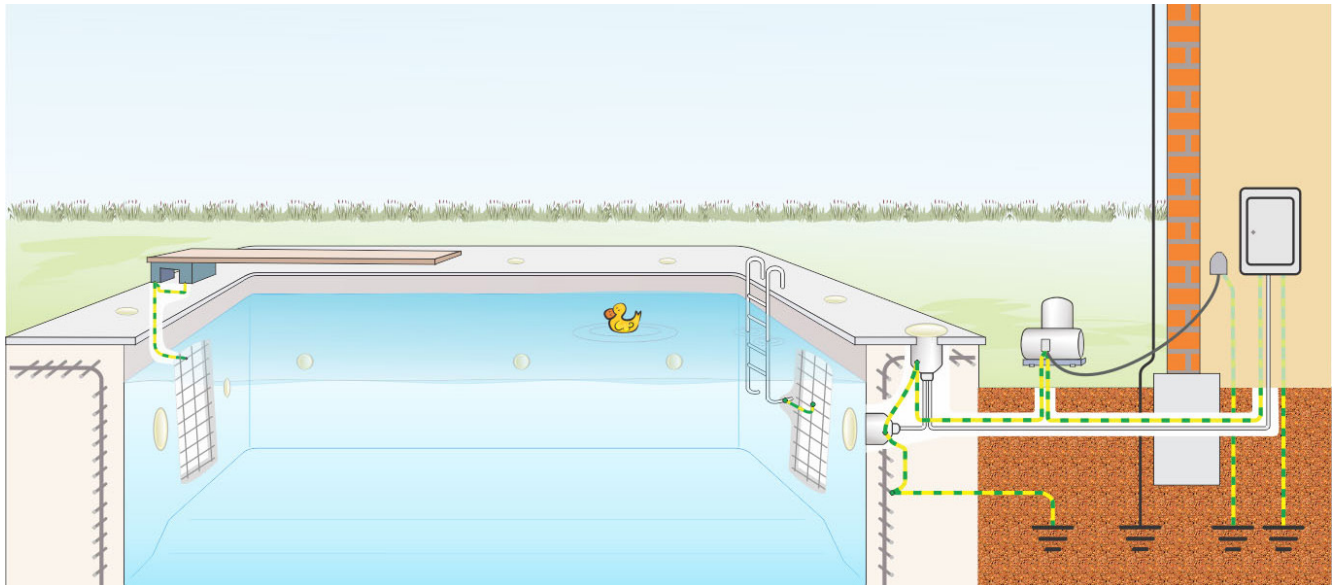
caution is still advised when working in these areas. Switches can be installed outside zone 2, but one can still reach them with wet hands. Exchanging them for cord-operated variants is the safest way. The maximum operation voltage of the devices that can be switched on from a wet space is 12V.

Electrical safety measures
Generally speaking, electrical safety is the same as for any public place, but it should be observed very rigorously. Any wet place should have the installations well-insulated, and leakage current should be carefully monitored. Protection by 30 mA RCDs is mandatory, as unexpected shocks are much more likely than in dry rooms. Equipotential bonding must reach any metal object. Exceptions that can be used for dry places do not apply. Maximum contact voltage is 30V.

For workers and visitors, it is most important that they take care of their own safety. Nobody should be operating electrical devices, particularly ones with no water proofing, with wet hands. Appliances that operate at higher voltages should be kept at a safe distance from water. Any bathroom or pool appliances should be installed high up on the walls and out of reach.

MEASUREMENTS

Metrel offers a choice of installation testers that can work in a wet or any other area as long as it is dried for the maintenance. MI 3155 is the first choice for any installation, with its long battery life and rich choice of functions. It is certified to IP 56, making it splash and dust resistant enough for most environments. In the specific case of a wet area, the defining feature is its ability to test the special types of insulation at voltage of 2,5 kV, determining the insulation's state with high accuracy. The high voltage is sufficent to test electric fences. It contains a number of pre-programmed tests for RCDs and fuses for any premises. Equipotential bonding is amongst the most important electrical safety aspects and has to be tested thoroughly. Even low potential differences can be hazardous to wet hands. MI 3155 is also enabled to measure leakage in installation.



Equipotential bonding of a pool area.

IT system

Special locations

Any installation that needs 100% power availability must be constructed with the neutral isolated from the local transformer's ground or earth. Such systems are critical parts of hospitals, communications transceivers, airports, and other. This type of construction has a number of advantages in terms of power quality and availability. First fault only generates an alarm, but the system remains functional and safe. The fault current is very low, the nominal voltage rises a little and leakage on the equipment rises very slightly. To conform to the standard IEC 61557-8, voltage between accessible surfaces cannot exceed 50 V. Construction of an IT grounded installation is generally more expensive than TT or TN, and the maintenance can become complex in the long run, particularly if it is large. Therefore, it is usually constructed as an island or islands in a TT or TN grounded building.

Isolating transformers

An isolating transformer is a transformer whose primary intent is galvanic separation of parts of installation or device. It works as an input to an IT island in the TN/TT installation. It is usually a transformer with a 1:1 ratio, with the galvanic separation between primary and secondary – not an autotransformer. It must conform to the standard IEC 60364-8 that requires a range of power 0.5 kVA to 10 kVA and maximum line-to-line voltage 250 V.

Isolation monitoring device

Monitoring device is installed between phase and protective earth. As the insulation degrades, the resistance between phase and PE reduces and a current starts flowing to ground. The IMD senses a voltage drop on the measuring resistance and alarms once the leakage current is significant. Exact measuring principle used depends on the system to be measured and can be proprietary. IMDs mostly include some form of interference suppression. Its own leakage or use of high voltages in the vicinity might otherwise influence the results. It must be able to measure both

symmetrical and asymmetrical insulation faults, as required by the standard IEC 61557-8. Symmetrical fault is one where insulation on all connected conductors fails in the same way. Asymmetrical is the degradation the insulation of a single wire, or connection to a faulty device. IMDs are mainly meant as an early warning and a call to maintenance. They can have a built-in self-test, or they can be tested by changing the resistance between phases with an instrument. Limit for bad insulation is most commonly 55 kOhm.

RCD protection

RCDs should not be activated at the first fault in an IT system. The leakage at first fault is barely measurable, so there is no reason for RCD to trip. It can sometimes happen due to combining higher leakage currents from large appliances. That should be taken into the account when designing and maintaining protection. At first fault, IT system should essentially start working as TN/TT system, and as such needs to be protected with RCDs. Second fault current can be exceedingly high, creating a fire hazard and severe danger to life.

Fault finding system

Locating the fault in an IT system is its main limitation. There is only one IMD (as opposed to a number of RCDs in other earthing systems), which can make looking for a fault a major operation. Fault locators are devices that help with that. They are systems of current transformers at different points in the installation. To find a fault, a brief simulation of a ground fault is induced with electronically controlled current magnitude. A circuit is formed from the live conductors via insulation fault through PE and back to the tester. CTs measure the current in any relevant point in the network. Fault can be located by comparing the measured values to expected ones, or by observing the current dividing between the branches. The system has to be built in along with the IMD, and is usually very expensive.

Testing protective RCDs in a mobile hospital. The whole such installation is isolated from ground.

MEASUREMENTS

There is a choice of multifunctional testers with support for measurements in IT grounding system in Metrel's portfolio, and one specialized tester that requires no electrical knowledge. They all work with the concept of Autosequence®s. There is nothing that can go wrong using them for testing. Tests collected into the Autosequence are insulation monitoring device test, mains voltage and frequency, first fault current measurement, voltage drop and line impedance test. Troubleshooting can be done with MI 3155 2-clamp method. It generates a signal into the network while the second clamp can be used to search for it. If there is an obvious drop in it, there must be an insulation break somewhere between source and measuring point. MI 9273 as an adapter can work this method wirelessly with its 128 Hz function.

Low voltage photovoltaic installations

Special locations

Installations at least partially powered by photovoltaic cells are ever more common, since they are considered environmentally low-impact. They can be used both in domestic and industrial settings. The installation, however, has cope with over and under production of energy.

Components

Photovoltaic system is composed of solar cell arrays and its supporting system commonly referred to as Balance of System, or BOS. It contains supportive structures, wiring, overvoltage protection, an inverter to convert the DC produced to AC voltage, and optionally a battery system, charge controller, a metering solution for returning power to the grid, maximum power point tracker, and other equipment for improving efficiency. All of these components need testing upon installation and then periodically. Generally, photovoltaic system needs little maintenance, but as with any electrical installation it is better to be on the safe. It is particularly hard to locate fault once they occur in large systems, so it is important to prevent them.

Construction

Each PV module produces insufficient voltage to be useful; therefore they are connected in series to form a string or array. Multiple strings are then connected in parallel to achieve desired power. A solar panel's power can be measured under STC (standard test conditions) or PTC (PVUSA test conditions). Panels are typically designed to output 100 – 400 W. Together with wiring between the modules and arrays, they are packed into protective housing against the weather while allowing for best possible cooling and easy handling. High temperature and mechanical stress importantly lower the panel's efficiency and longevity.

Efficiency

Efficiency of commercial solar panels by design was about 17% in

2019, and is expected to rise. There are however a large number of effects at work that can reduce it. The most obvious is shading. In the shaded cell, the electrons reverse direction through the p-n junction, while using the voltage from illuminated ones to break it down. This effect can suck up the energy from a number of neighbouring cells. Most panels are supplied with a diode to bypass the shaded current, cutting the losses to only the shaded portion. For tilted arrays, the rain is generally enough to keep them clean, but in dry and windy areas extra effort may be needed.

The absorption of energy is best when the panel is perpendicular to the sun rays. Tracking systems can be installed to boost it, but they add cost and require maintenance, and are therefore not common. Usually the fixed tilt is set for the rays to be perpendicular at noon. A number of other efficiency boosting techniques can be used, mainly connected to tracking system control and cooling. Part of successful energy transformation is also (usually software) management of surplus energy on sunny days.

Inverter

Inverter has to take the DC input from the solar panels and change it into sine, with frequency synchronized to grid frequency and amplitude limited to grid value. Disconnection from the grid in case of an outage to prevent islanding is also managed in the inverter. Grid-connected inverters will use a technique to extract maximum power from the cells, called maximum power point tracking (MPPT). It comprises of digital sampling of the solar output and applying optimal resistance to the output. The algorithm and exact execution are usually proprietary. Typically inverters achieve 98% power efficiency.

Solar panels in a private building can be used to directly power devices that already use DC.

MEASUREMENTS

MI 3108 is a combination tester for installations safety and photovoltaics. Installation part covers the requirements of standard IEC/EN 61557. The photovoltaic part covers requirements of the standard IEC/EN 62446 and extra – I-U characteristic, STC values as required by IEC 61829 and power measurements on AC and DC sides. These measurements give an indication of panel health, its efficiency at given conditions, and (depending on the connections) locate the fault. Use safety probe for testing the high-voltage parts. High-quality thermal camera is a must for regular maintenance of solar panels. MD 9930 is possibly still short in terms of resolution for any large-scale facility, but can work for smaller home panels and for close-up inspection. It can be used to locate power losses due to overheating, weakened contacts and hot spots due to parasitic currents, and other faults on wiring and supportive systems. The images can also point to a new cooling design and other improvements.

DC installations

Special locations

DC powered installations
DC power is again, after more than a hundred years, becoming a major player in both distribution and consumer sides of the electrical network. It has always been used in some ways, examples being HVDC, or more lately UHVDC energy transfer over long distances and between incompatible AC grids, and also very low power battery-powered devices. It is now gaining acceptance again with advent of distributed power generation. Solar and fuel cells generate DC power directly, while microturbines, small hydro generators and wind turbines generate AC at a different frequency from standard mains. The easiest way to change frequencies and stabilise the grid is to convert it to DC first. In both cases, conversion from DC to AC can be avoided to boost efficiency. A home with its own power generation can have almost all everyday devices powered directly by DC, plus some newer increasingly popular ones like a vehicle charging station and energy storage.

LVDC home installation
Low voltage for a home is usually under 50 VDC. The value is chosen for safety reasons – there is little or no risk of electric shock at this low voltage, making the system intrinsically safe. At the same time, the voltage must not be too low, as losses in wires can become considerable even at such small distances. A lot of small devices also runs at voltages like 12V or 24V, making these values worth considering.

The the major advantage of a DC installation in a home with local power generation is efficiency. Local generator for DC can be:
- Solar power, which already produces DC voltage,
- Wind power, which for small turbines produces a high frequency AC that is more efficiently transformed to DC than mains frequency AC,
- Fuel cells.

There is a number of savings compared to using AC: no conversions for most the commonly used devices (saving

materials and energy), better use of conductor cross-section with no skin effect and reactive power, a genuinely uninterrupted service (AC can blink for some milliseconds to resync), and ability to charge local energy storage directly. Local storage for the amount of energy that DC devices need is much more affordable than powering the whole system. There may be need for changes in DC level, but when well-executed this is a highly effective transformation. The main problem with DC in a home is that it (currently) cannot power every home appliance. Most typical that require AC are washing machine, fridge and stove.

EVSE DC charging
With current technologies DC charging stations are the fastest way to fill a car battery. It connects directly to the car battery, bypassing internal converter. In other words, the conversion is made outside the car. This removes problems with internal components that couldn't handle high currents. DC stations in 2019 can provide up to 120 kW, with solutions for up to 350 kW under development. Most cars however can only handle 50 kW. DC and fast charging are possible using specially installed systems, such as CHAdeMO, a proprietary Tesla supercharger, or an adapted (but compatible) IEC type 2 connector. Generally, DC charging is designed to be the fast option.

There are currently laboratory experiments on charging cars directly with DC from solar panels. Photovoltaics are not a stable source, so both the voltage and current on the output have to be regulated. An example is a system developed by TU Delft, which is small (about 30% of regular AC charging station) and 96% effective. The DC/DC regulator works using silicon-carbide field-effect transistors and a quasi-resonant converter. It uses both solar DC and grid AC power and can provide 10 kW power. It allows for stacking the systems together for up to 150 kW systems suitable for business parks or large highway service stations. There is an option to charge an extra battery with solar power. A system to do fast battery to battery charging exists, but it is designed for large-scale and very fast charging.

MEASUREMENTS

MI 3155 is the trusty companion for measurements on a DC system. Voltages used in domestic and EVSE installations are generally below 500 V DC, which is still comfortably within its safety certification. Measurements are similar to any TT, TN or IT grounded installation: earth resistance, insulation between phase and neutral with appropriate DC test voltage, equipotential bonding and tests of protective devices, MRCDs or Modular Residual Current Devices are necessary during the line and loop impedances. There are some exceptions to testing in particularly low-voltage installation, e.g. there is less need for bonding where voltages don't reach 50 VDC. Tables for touch voltage and shut down time are different. Both switches and isolating devices need to conform to special requirements against arcing. Arcs are common even at low voltages (typical welding rig works at 24 V).

MI 3108 may be necessary for a more thorough test of the photovoltaic panels, as it supports their specific needs.

EVSE construction and testing

Special locations

Electric mobility has become a powerful trend in recent years. The network is expanding rapidly, the cars are being developed at break-neck speed, and the standardisation organisations are struggling to keep up.

Electric Vehicle Supply Equipment (EVSE) stations are the face of the network, the part that the customer comes into contact It means the system of supply from the network and the hardware that enables plugging into the car. For most customers, it is the most powerful electric device or piece of installation they regularly see. In 2019, fast chargers can deliver up to 120 kW, with 350 kW stations planned. It can be considered either a fixed-installed device or a part of the installation.

Historically, one could plug the car into just about any outlet of an installation to charge it. Some owners carried a range of converters, and manually adjusted the chargers in the cars to draw just as much current as the installation would allow. This limited the charging speed prohibitively, and it depended entirely on the protection measures within the installation.
The charging station can be installed making higher power available, it provides a much faster charge and is equipped with extra safety devices. Functional features and testing are covered in the standard group IEC/EN 61851.

There are 3 possible setups for car charging:

- **Case A**: cable integrated into the car (not available in practice),
- **Case B**: cable detachable at both ends,
- **Case C**: cable integrated into the charging station.

There are currently 4 levels of charging ability and safety features:

- **Mode 1**: charging in case B directly from domestic outlet to the car with a normal cable. 1 phase could provide up to 240 V/16 A, 3 phase allowed up to 480 V/16A. Not allowed in most EU countries.

- **Mode 2**: charging in case B from domestic outlet using a cable with extra protective devices. 1 phase could provide up to 240 V/16 A, 3 phase allowed up to 480 V/16A.
- **Mode 3**: charging from an EVSE configured as in case B or C. 1 phase could provide up to 250 V/70 A, 3 phase allowed up to 480 V/63A.
- **Mode 4**: fast charge with specialized EVSE, configured as case C. DC charging with 300-500 V and up to 350 A allowed in standard, currently up to 125 A in practice.

The Standard for connectors in the EU is the CCS (Combined Charging System) Type 2, also called mennenkes or Type 2 combo. Present are also others like: Tesla superchargers, Type 1, Type 1 combo, CHAdeMO, etc.

The charger and the car communicate using a simple protocol called Control Pilot. Different voltage levels on pulsed signal define 5 states of charging: State A: not connected, State B: connected and locked – not charging, State C: connected and charging, State D: connected and charging on a station with or without ventilation, State E: error. Apart from charging state, the car and station also communicate the highest current that can pass between them over a separate port named Proximity Pilot. The value is read from pulses' duty cycle, and is currently only defined for up to 50 A.

Cars in 2019 have up to 100 kWh battery storage. Charging them at 63 A takes about 2h to 100%.

Recommended inspection intervals are half a year for cables and a year for a whole system in public use. tests include visual and functional inspections, continuity measurement, insulation measurement, RCD test, impedance tests, and optionally leakage current. MI 3155 in combination with A 1532 or A 1632 can thoroughly test the station using the EVSE Autosequence. Refreshed standard IEC/EN 61815 requires testing for protection from 6 mA DC current – the RCD or similar protection has to trip when such current is detected. This is included in the MI 3155's EVSE Autosequence.

View to testing a home charging station with MI 3155 and A 1632.

MEASUREMENTS

A 1532 EVSE adapter is the basic accessory for testing the charging stations. It simulates the car to test the function of Control Pilot and Proximity Pilot. It performs electrical tests on its output socket. It is supported by Autosequence®s in MI 3155 and MI 3152.

A 1632 is a different kind of the instrument. It is designed to thoroughly test the charging station on both the installation and the output sides. It can test Mode 2 and Mode 3 cables and monitor communication between station and car. Rather than for periodic testing, it is meant for installation tests and equipment producers. Professional reports for both station and cable status can be created in Metrel electrical safety management software (MESM).

Selection guide by application

Selection guide

LOCATION	Application	Electrical Installation Safety	Power Quality Analysis	Appliance / Machine / Switchboard Safety		
		MI 3155 EurotestXD	MI 2892 Power Master	MI 3309 BT DeltaPAT	MI 3360 M OmegaPAT XA	MI 3325 MultiServicer XD
						
RESIDENTIAL BUILDINGS, PUBLIC PLACES, WORKPLACES WITH NETWORK POWER SUPPLY	Basic electrical safety	•				
	Safety of electrical appliances			•	•	
	Safety of 3-phase appliances				•	
	Lightning protection	•				
	Troubleshooting and maintenance	•		•	•	
	Irradiance	•				
	Basic power quality	•	•			
RESIDENCE, PUBLIC PLACE OR WORKPLACE WITH OWN POWER SUPPLY	Advanced electrical safety	•				
	Photovoltaic installation					
	Safety of generators	•				•
	Safety of electrical appliances			•	•	
	Safety of 3-phase appliances				•	
	Lightning protection	•				
	Troubleshooting and maintenance	•		•	•	
	Irradiance	•				
	Basic power quality	•	•			
	Advanced power quality		•			
INDUSTRIAL FACILITIES	Advanced electrical safety	•				
	Safety of electrical appliances				•	
	Safety of 3-phase appliances				•	•
	Machine safety					•
	Lightning protection	•				
	Grounding system design and maintenance	•				
	Troubleshooting and maintenance	•			•	•
	Irradiance	•				
	Power quality	•	•			
SPECIAL LOCATIONS	Electrical safety of IT grounding system	•				
	Safety of electrical appliances		•		•	
	Safety of 3-phase appliances			•	•	•
	Photovoltaic installations					
	Lightning protection	•				
	Troubleshooting and maintenance	•		•	•	
	Irradiance	•				
	Power quality	•	•			

Adapters		Photovoltaic testers	Multimeters and IR cameras		
MI 3144 Euro Z 800 V	A 1422 Active 3-phase Adapter Plus	MI 3108 EurotestPV	MI 9930 IR thermal camera	MD 9272 TRMS multimeter	MD 9070 Digital multimeter
					
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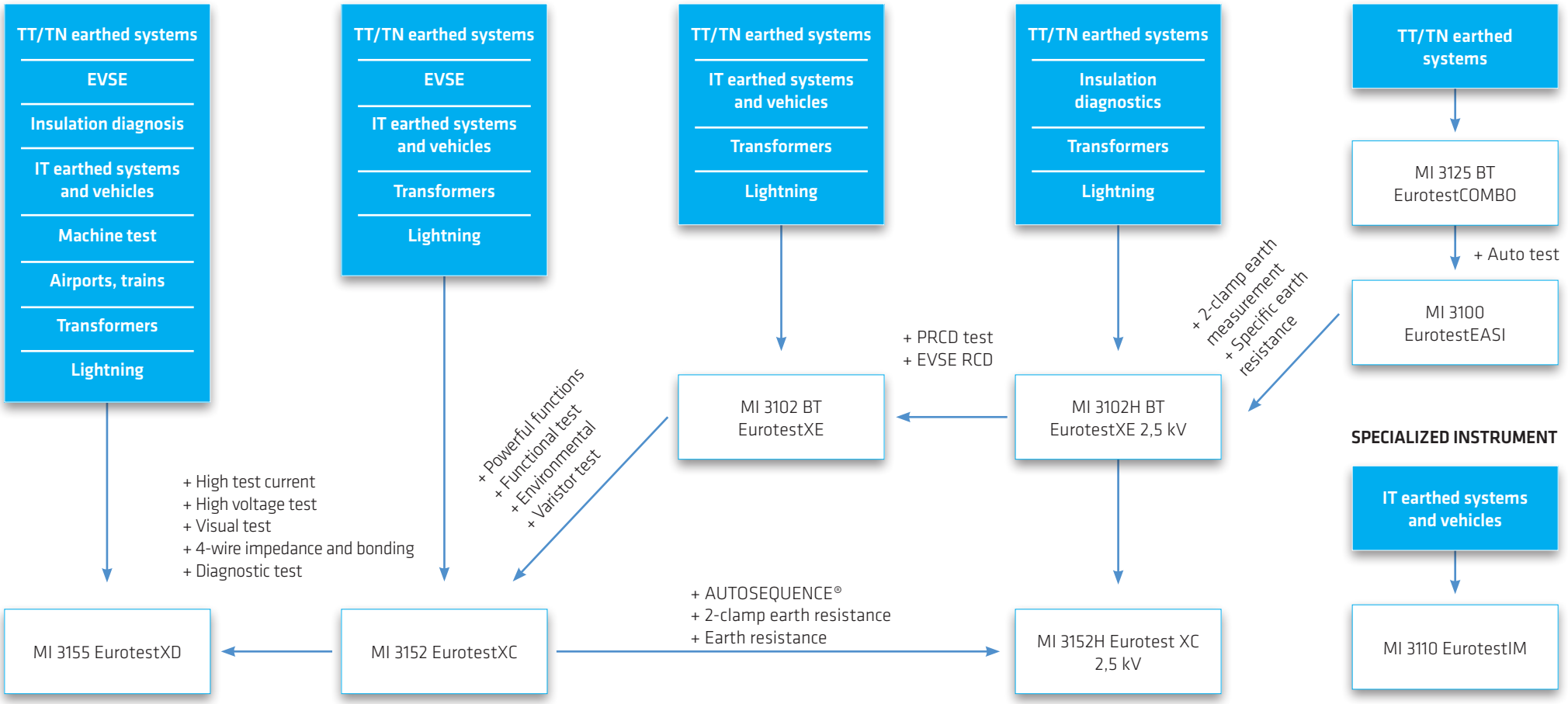
Selection guide for Installation testers

Selection guide

The mentioned are part of the installation safety line. They can all guarantee the basic safety. The flagship testers, however, cover much more than the essentials. Choice depends on required features and desired comfort of the built-in platform. For more information refer to the Metrel website, www.metrel.si.



MI 3155 EurotestXD

Electrical Installation Safety

HIGHEST LEVEL INSTALLATION SAFETY

MI 3155 EurotestXD is the flagship of Metrel portfolio. It is a most versatile installation tester for any type of earthing system, offering every test from basic insulation, line/loop impedance and continuity to multiple options for earth analysis and various additional measurements. In special locations, insulation monitoring devices test and first fault leakage current are often invaluable. It offers advanced software features, from predefined AUTOSEQUENCES®, custom AUTOSEQUENCES®, multilevel programmable location structure and complementary firmware.

MEASURING FUNCTIONS

- Live Transformer's Impedance Measurement with Four Wire Test;
- Hi-precision Short Circuit Current evaluation with Calculated Hot factor;
- 3-wire test of PE (RPE function) without extension lead conductor;
- Autotest insulation function between L-N, N-PE and L-PE (R ISO ALL function);
- 4-wire continuity test;
- Insulation resistance with DC voltage from 50 V to 2500 V and PI, DAR calculation;
- Varistor test;
- Continuity of PE conductors with 200 mA DC test current with polarity change;
- Continuity of PE conductors with 7 mA test current without RCD tripping;
- 2-wire and 3-wire loop impedance (L-PE) measurement with Trip Lock RCD function;
- Touch voltage / Contact voltage measurement with external P/S probe.
- 2-wire and 3-wire line impedance (L-L, L-N) measurement;
- 1-phase / 3-phase TRMS voltage and frequency measurements;
- Line, loop and RCD measurements at frequency range 16 ... 400 Hz;
- Phase sequence;
- Power and THD measurement (up to the 12th harmonic);
- RCD testing (general and selective, type AC, A, F, B, B+, MI RCD, EV RCD, PRCD, PRCD-K, PRCD-S);
- Earth resistance (3-wire and 2-clamps method);
- Specific earth resistance with Ro-adapter (option);
- TRMS leakage and load currents (option);
- First fault leakage current (ISFL);
- Testing of Insulation Monitoring Devices (IMDs);
- Machine mode support with time discharge;
- Illumination (option);
- High resolution Loop impedance (mΩ) (option);
- EVSE (Electrical Vehicle Supply Equipment) support (option);
- Determining location of cables (option);
- QR and/or barcode scanner support (option).

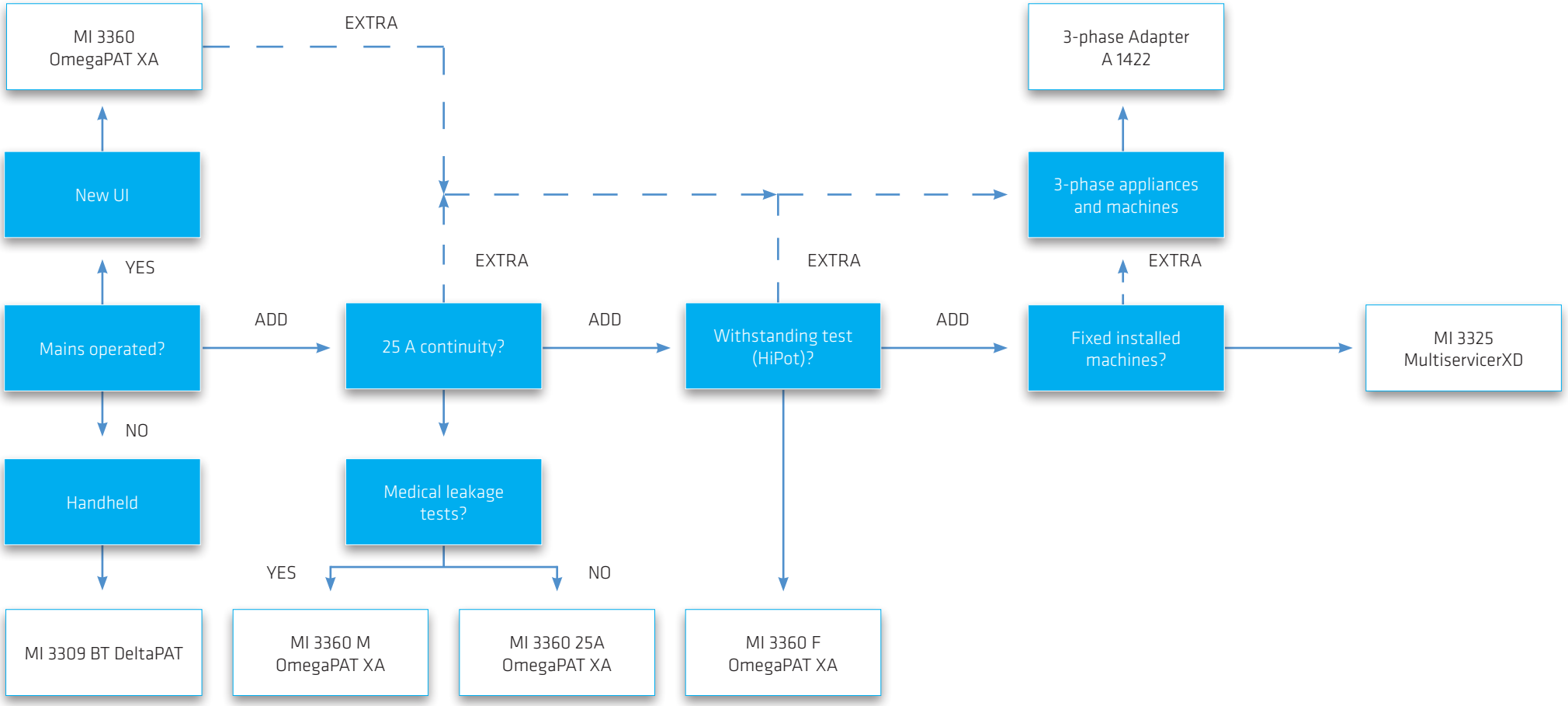
RECOMMENDED SET MI 3155 ST

- Instrument MI 3155 EurotestXD
- 8800 mAh battery pack
- Power supply adapter 12 V / 3 A
- Plug commander, 1.5 m
- Test lead, 4-wire, 1.5 m, 3-wire, 1.5 m, 2-wire, 2,5 kV, 1.5 m
- Test probe, 4 pcs (black, blue, green, red)
- Crocodile clip, 5 pcs (black 2 pcs, blue 1 piece, green 1 piece, red 2 pcs)
- Current clamp (A 1018 and A1019)
- Earth set 20 m
- USB cable
- Soft carrying bag
- Soft carrying neck belt
- Metrel ES Manager BASIC license
- Instruction manual on storage media
- Guide for testing and verification of Low voltage installations (CD)
- Calibration certificate
- Metrel ES Manager (program installation) A 1481 (CD)

Selection guide for PAT testers

Selection guide

The guide only takes the measuring capabilities into the account. For more information refer to the descriptions in previous chapter.



MI 3360 OmegaGT XA

Appliance / Machine / Switchboard Safety

PROFESSIONAL USE IN THE MOST DEMANDING SETTINGS

MI 3360 is a group of four instrument variants with different applications. The 25A variant supports the medical leakages only optionally. The F variant is mainly useful after a service, when high-voltage insulation test is necessary. Any of them can serve as a versatile general PAT tester, filled with advanced features for effortless periodic testing. They support both Metrel three-phase adapters, extending their application options. They come in a practical case for easy transport and offer a range of advanced features like AUTOSEQUENCES®, structured user interface, user accounts, automatic pass/fail evaluation, Bluetooth connection and optional label printing.

MEASURING FUNCTIONS

- Visual inspections;
- Fuse test;
- Continuity / Protective earth resistance 200 mA;
- Insulation Resistance (Riso, Riso-S);
- Sub-Leakage Current, Substitute Leakage Current - S;
- Differential Leakage current;
- PE leakage current;
- Touch leakage current;
- Insulation resistance (optional A 1422), IEC/EN 60974-4;
- Welding circuit leakage (optional A 1422), IEC/EN 60974-4;
- Primary leakage (optional A 1422), IEC/EN 60974-4;
- No-load voltage (optional A 1422), IEC/EN 60974-4;
- Power (P, S, Q, PF, THDu, THDi, CosØ, I, U,);
- PRCD test, (2-pole, 3-pole, K/Di (varistor), S (3-pole));
- PRCD PE probe test, PRCD open conductor test, PE conductor (PRCD) test;
- RCD test, (type A, AC, B, B+, F);
- Flash test, (1500 V, 3000 V);
- Polarity / Active polarity test;
- Clamp current (with optional A 1579);
- Continuity / Protective earth resistance 10 A, 25 A;
- Insulation resistance, IEC/EN 62353;
- Touch leakage current, IEC/EN 62353;
- Equipment leakage (direct, differential, alternative) IEC/EN 62353;
- Applied part leakage (direct, alternative), IEC/EN 62353.

RECOMMENDED SET MI 3360

- Instrument MI 3360 (25A, M, F) OmegaPAT XA
- Bag for accessories
- Smartball pen with touch screen function
- A 1556 Medical adapter
- A 1489 BT Bluetooth printer
- A 1653 QR/Barcode scanner
- Flash test probe (MI 3360 F only)
- Crocodile clip, red (MI 3360 F only)
- Crocodile clip, black
- IEC test cable, 2 m
- Test lead, black
- Test tip, black
- Mains cable
- USB cable
- Calibration Certificate
- Instruction manual on storage media
- PC SW Metrel ES Manager BASIC.

MI 3309 BT DeltaPAT

Appliance / Machine / Switchboard Safety

HANDHELD PAT WITH EARTH BOND, INSULATION AND LEAKAGE TESTS

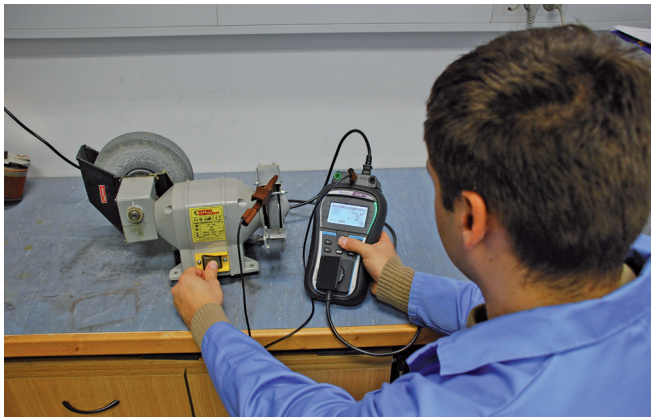
The **MI 3309 BT DeltaPAT** is both battery and mains powered, handheld, instrument intended to perform tests for electrical safety of the portable electrical equipment. Integrated unique PRCD testing technology prevents trip-out of mains RCD during measurement. Due to dual power capability MI 3309 enables differential leakage current test despite of its lightweight portable design.
A large graphical LCD with backlight, the PASS / FAIL LED indicators and HELP screens for each test make the use of the instrument clear and simple. Up to 1500 test results with parameters can be stored in the internal memory of the instrument and then downloaded to the PC for further data handling and creation of test report. Light, pre-programmed and custom test sequences, optional barcoding, and RFID systems make the MI 3309 an ideal instrument for high volume professional safety testing of portable appliances. Optional Android application offers use of QUERTY keyboard and camera for code scanning on the phone. Internal clock keeps time and notifies user when it is time to retest. The instrument found a use in special locations like devices in vehicles, where its portability is an important advantage.

MEASURING FUNCTIONS

- Functional and visual inspection;
- Earth bond resistance;
- Insulation resistance;
- Insulation resistance of isolated accessible conductive parts;
- Substitute leakage current;
- Substitute leakage current of isolated accessible conductive parts;
- Differential leakage current test;
- Touch leakage test;
- RCD and portable RCD testing, type (K, S);
- Power test;
- IEC cord polarity test;
- Leakage and load currents with current clamp;
- TRMS voltage meter;
- Enhanced TRMS test.

RECOMMENDED SET MI MI 3309

- Instrument MI 3309 BT DeltaGT
- Small soft carrying bag
- IEC cable, 2 m, 2 pcs
- A 1472 Leakage current clamp
- Test lead, black, green, brown, 1.5 m
- Crocodile clip, black, green, brown
- Test probe, black, green, brown
- PC software PATLink PRO
- RS232 cable
- USB cable
- NiMH rechargeable batteries, type AA, 6 pcs
- Instruction manual on storage media
- Short instruction manual
- Calibration certificate



MI 3325 MultiServicerXD

Appliance / Machine / Switchboard Safety

DIVERSE INDUSTRIAL APPLICATIONS

MI 3325 puts versatility as its main feature. It can be used for a large number of tests, from most basic portable appliance test to heavy-duty tests on production lines. The operating platform is modern, with a colour touchscreen and sophisticated user interface. It allows you to filter the tests by the field of use or by the relevant standard. It can be easily integrated with custom applications (or even a production line) through SDK, or it can be used alone. It can perform all the measurements found in PAT and machine testers, supporting any earthing system. The 3-phase adapter is an optional accessory for machine and switchboard testing. Furthermore, both impedance adapters are supported, extending the use to installation and grounding fields.

MEASURING FUNCTIONS

- Continuity (2-wire & 4-wire), 0.2 A, 4 A, 10 A, 25 A + voltage drop @ 10 A;
- HV AC, HV AC programmable 100 V - 5000 V;
- Insulation resistance (Riso, Riso-S) 50 V, 100 V, 250 V, 500 V, 1000 V DC;
- Sub-leakage current, (Isub, Isub-S) 110 V AC, 230 V AC;
- Z loop – fault loop impedance and prospective fault current (Ipsc, Ulpe, Uc(P));
- Zs rcd – fault loop impedance and prospective fault current in system with RCD (Ipsc, pe, Uc(P));
- Z line – line impedance and prospective short-circuit current (Ipsc, Uln);
- Functional test (power P/S/Q, voltage, current, cos φ, frequency, ThdU, ThdI, PF);
- Touch leakage current;
- RCD testing (RCD Uc, RCD t, RCD I);
- Differential leakage current;
- PE leakage current;
- Polarity;
- Clamp current;
- Voltage, Frequency, phase rotation;
- Varistor test;
- Voltage drop;
- Discharging time.

RECOMMENDED SET MI 3325

- Instrument MI 3325 MultiServicerXD
- HV test lead with test probe and HV test lead with crocodile
- Mains cable
- IEC test cable
- Residual voltage test cable
- Plug test cable
- 3-wire test lead, 3 m
- Continuity test lead, 2.5 m, 2 pcs
- Test lead, red, 1.5 m
- Test probe, 4 pcs (black, red, green, blue)
- Crocodile clip, green, blue
- Crocodile clip, red, black, 3 pcs
- Calibration certificate
- RS-232 cable
- USB cable
- Short instruction manual
- CD with instruction manual (full version)
- PC SW Metrel ES Manager BASIC
- Protective bag for accessories (mounted on the case)

A 1422 Active 3-phase Adapter

Adapters

A 1422 expands a test instrument's capabilities into new fields. The 3-phase adapter enables PAT and machine testers to work easily with 3-phase machinery and appliances up to 40 A of power. An important aspect is also testing of cables and leads. Test procedures on the instrument remain the same. Detection is automatic – just connect the cable. Built-in are CEE 3-phase/32 A 5-pin, CEE 3-phase/16 A 5-pin and CEE 1-phase/16 A 3-pin test sockets. The case is water- and dustproof.

RECOMMENDED SET A 1422

- A 1422 Active 3-phase Adapter
- Bag for accessories
- Measuring / Connection cable betwen Adapter and Instrument
- 3-phase mains cable 16 A male / 32 A female, 5-pin, 2 m
- RS232 cable
- Instruction manual, short instruction manual
- Calibration certificate

MI 3144 Euro Z 800 V

Adapters

MI 3144 Euro Z 800 V is an adapter for impedance measurement for installation and machine testers. It can also be used as an independent instrument, controlled by an Android app. It can supply up to 300 A test current. It is mainly applicable in industrial setting, close to the source of supply, where a particularly high accuracy of line or loop impedance measurements is necessary. Other notable features are ELR switch measurement, partial voltage drops and current path resistance measurement, ground fault analysis, floating voltmeter, and ground fault measurement with a clamp. It can also help analyse lightning protection system by measuring step, touch and contact voltages.

MEASURING FUNCTIONS

- High precision 4-wire 300 A Z Line and Z Loop Impedance Tester;
- High range impedance measurements in 800 V / 16 ... 420 Hz AC networks;
- DC source & line resistance measurements in 3 ... 260 V DC networks;
- High current dR 300 A 4-wire Partial Voltage drops and Current's Path Resistances;
- Earth Leakage Relay (ELR) trip-out testing time and current;
- ELR supported types AC, A, B;
- Ground fault analysis with Contact, Touch and Step voltage;
- Floating voltmeter for partial contact results;
- One-clamp high current grounding method with clamps (flex & iron);
- Selectable test load (16.6 % to 100 %);
- Improved thermal performance;
- Portable battery (Li-ion) or mains powered test instrument;
- IP protection: IP65 (case closed), IP54 (case opened);
- CAT IV 600 V (3000 m) safety category;
- Bluetooth communication;
- Black box design (remote-controlled via an Android device).

RECOMMENDED SET MI 3325

- Instrument MI 3144 Euro Z 800 V
- Mains cable
- RS232-PS/2 cable
- Test lead 5 m, black, 2 pcs
- Test lead 5 m, red, 1.5 mm2, 2 pcs
- Test lead 50 m, red, 1.5 mm2*
- Test lead 20 m, black
- Test lead 50 m, green*
- Large Kelvin test clip, 2 pcs
- Crocodile clip, black, 2 pcs
- Crocodile clip, red, 2 pcs
- Crocodile clip, green
- Test probe, black, 2 pcs
- Test probe, red , 2 pcs
- G clamp
- Human body resistance probe
- Test rod, 2 pcs
- Step voltage plates, 2 pcs
- Metrel ES Manager BASIC licenss
- Metrel aMESM Android app with P 1102 PRO license key
- Short instruction manual
- Calibration certificate
- Protective bag for accessories
- Soft carrying bag

MI 3108 EurotestPV

Photovoltaic testers

COMPLETE PHOTOVOLTAIC AND INSTALLATION TESTING

Combining photovoltaic and installations tester, the MI 3108 is an easy way to check the whole location with solar power. It supports installation measurements by standard IEC/EN 61557 and single-phase solar measurements by standard IEC/EN 62446. Apart from that, it also includes some extra abilities: graphical representations of I-U characteristic of the cells, calculation of STC values as required by IEC/EN 61829, and power measurement on both AC and DC sides of the inverter. Measurements can be done on installations with up to 1000 VDC and 15 ADC. Safety probe for work with these values and safe disconnection every time is a part of the standard set. Part of the power measurements is also calculation of efficiency and basic power quality analysis with harmonics and energy. Optional accessories permit use of a remote unit for measurement of irradiance and temperature of the modules. Advanced installation functions include loop measurement without RCD tripping or with a high current, B type RCD test, and current measurements. Some features are also applicable to both PV and installation parts of the instrument: it can show a scope view, save results and optionally connect to Bluetooth.

MEASURING FUNCTIONS

- Insulation resistance;
- Continuity of PE conductors;
- Uoc (Open Circuit Voltage) and Isc (Short Circuit Current);
- I - U curve of PV modules and strings;
- Voltage, current and power of strings and inverters;
- Irradiance;
- Module temperature;
- Voltage, current, power;
- Efficiency of PV module, inverter, PV system calculation;
- Insulation resistance;
- Continuity of PE conductors;
- Line impedance;
- Loop impedance without RCDs tripping or with a high current;
- RCD type A, B and AC test;
- Earth resistance;
- AC current (load and leakage);
- Power and energy;
- Harmonics.

RECOMMENDED SET MI 3360

- Instrument MI 3109 EurotestPV Lite
- EurotestPV Remote
- PV Safety Probe
- PV reference cell
- Temperature probe
- Soft carrying bag, 2 pcs
- Universal PV test lead, 3 x 1.5 m
- PV Continuity test lead, 2 x 1,5 m
- Test probe, 3 pcs (red, blue, green)
- Crocodile clip, 3 pcs (red, blue, green)
- PV MC3/4 male/female adapters
- AC/DC current clamp
- Power supply adapter + 6 NiMH batteries, type AA
- USB and RS232 - PS/2 cable
- PC SW EuroLink PRO
- Carrying strap
- Short instruction manual
- Instruction manual and handbook on CD
- Calibration certificate

MD 9930 IR thermal camera

Multimeters and IR cameras

SEE BEYOND VISIBLE LIGHT

MD 9930 IR thermal camera is the go-to imager for most applications. Extremely versatile, with a great thermal resolution of 120x150 pixels, it can view and check nearly any thermally stressed object. From electrical distribution boards, motors, bearings and friction, to hidden fault finding in the water or electrical systems in buildings. It can shoot both thermal, visible light and combined images to help orienting and locating the fault from the image. Thermal focus is can be set manually and there is 32x digital zoom available. Cursors and central thermometer make images easy to read while thermal videos with high frame rate can follow quick changes in temperature. Audio comments can be added to the videos.

MEASURING FUNCTIONS

- Temperature;
- Temperature difference.

MD 9272 Clamp meter

Multimeters and IR cameras

TROUBLESHOOTING WITH LEAKAGE MEASUREMENT AND ESSENTIAL POWER QUALITY

MD 9272 Clamp meter is a unique earth leakage clamp meter. It not just has the ability to accurately read the TRMS AC leakage current of a system, it can also detect losses in the system. Instrument is accurate even at the edges of the measuring range and has a high resolution of 10 µA. Intelligent algorithms suggest possible reasons for the loss – insulation breach, non-linear elements, or combination. The voltage and power measurements make for essential functional test of any device or part of the installation. Harmonic analysis up to 19th harmonic, power factor (PF), total harmonic distortion (THD) and crest factor measurements are functions for basic power quality test and troubleshooting. Basic memory functions enable data hold and display of minimum, maximum or average values. Peak hold makes in-rush or transient measurement easy. The small jaws (28 mm) make it appropriate for small enclosures of the distribution boards. The jaws are shielded, so work can continue undisturbed even in noisiest environments. The instrument is the basic troubleshooting tool that can diagnose a number of conditions: its power functions can give indication of functionality of the devices or parts of installation, harmonic analysis can catch outside disturbances, peak hold can catch high transients and inrush currents. Losses indicator can find troublesome points and offer the solution ideas. Leakage current measurement can point to insulation breaches or bonding breaks. Voltmeter is the essential tool to any troubleshoot. MI 9272 is an all-around tool for any engineer or electrician.

MEASURING FUNCTIONS

- TRMS AC voltage/current and DC voltage measurement;
- Frequency measurement;
- Power measurement;
- THD and harmonics measurement (up to 19th harmonic);
- Power factor and cause of losses;
- Phase displacement;
- Crest factor.

RECOMMENDED SET MD 9272

- Current clamp MD 9272
- Test lead with probe, 2 pcs
- 1.5 V battery, type AA, 2 pcs
- Pouch

MD 9070 TRMS isolation and continuity multimeter

Multimeters and IR cameras

BASIC INSTALLATION TESTING

The MD 9070 is a high accuracy insulation and continuity multimeter which may be used in a CAT IV / 600 V environment. Its dual digital display provides all the necessary data while it is the size of a multimeter enabling single-handed use. The instrument is equipped with a built-in VFD feature that allows accurate measurement of signal frequency on motor control systems. It measures for and calculates PI/DAR factors along with the insulation resistance measurement. There is a range of general multimeter functions, including TRMS voltage up to 1000 V, mains frequency measurement, low voltage resistance measurement, audible continuity and diode test. Range can be set manually or automatically. The MD 9070 has a wide range of extra features, including data hold, memory, MIN/MAX, differential measurements, auto power off, lock feature and more. It can be used in a number of situations from quick installation or device check to electric vehicle service.

MEASURING FUNCTIONS

- TRMS measurement;
- Insulation resistance measurement;
- Earth continuity measurement;
- Resistance measurement;
- Diode test;
- Mains supply frequency measurement;
- Frequency of digital signals measurement.

RECOMMENDED SET MD 9272

- Multimeter MD 9070 with rubber holster
- Test lead with probe, 2 pcs
- Insulated crocodile clip, 2 pcs
- Insulation/Continuity test lead with probe, 1 pcs
- 1.5 V AA battery (IEC LR6), 4 pcs

MI 2892 Power Master

Power Quality Analysis

MONITORING AND TROUBLESHOOTING POWER QUALITY

Top of the line **Class A** power quality recorder for both single and three phase installations. It has a large easy-to-read graphical colour display. Simply by connecting to the system, it detects and graphically displays harmonics, phasors and waveform anomalies in the installation. Its intelligent algorithms recognise the disturbances in the network and alarms when recognising them: transients, inrush current, voltage events like dips, swells or interruptions, flickers, etc. It can measure according to standards IEEE 1459, EN 50160 or IEEE 519. MI 2892 is designed for a long-term recording and for troubleshooting power quality problems. The handy Quick Set buttons allow for faster data overview for troubleshooting. Standard Smart clamps can be detected and the instrument prepared for their division ratio automatically. Advanced PC SW package PowerView3 enables detailed analysis of recorded data, direct reading and writing to the microSD memory card up to 32 GB, which equates to more than a year of recording. Analysis of long term records and automatic creation of professional test report An 8 GB microSD is supplied as standard.

MEASURING FUNCTIONS

- Voltage: TRMS, peak, crest factor (4-channel);
- Current: TRMS, peak, crest factor (4-channel);
- Power (active, reactive, apparent);
- Power measurements fully compliant with IEEE 1459 (active, non-active, fundamental, harmonic, load unbalance) and classic (vector or arithmetic) method;
- VFD (Variable Frequency Drives);
- Unbalance, flicker measurement;
- Harmonic and inter-harmonic analysis up to 50th harmonics, THD measurement;
- Energy (active, reactive, generated, consumed);
- Capturing and recording of power supply events (shutdowns, interruptions, swells, dips);
- Inrush currents monitoring and recording;
- Waveform/inrush displaying, snapshot and recording;
- Transients recording;
- Power quality analysis according to EN 50160, IEEE 519;
- Recording up to 7 adjustable alarms;
- Temperature measurement;
- Power factor cos fi.

RECOMMENDED SET MI 2892 EU

- Instrument Power Master
- 1-phase flexible current clamps 3000 / 300 / 30 A (A 1227), 4 pcs
- Test probe, (brown, black, grey, green, blue), 5 pcs
- Crocodile clip, (brown, black, grey, green, blue), 5 pcs
- Voltage measurement lead, (brown, black, grey, green, blue), 5 pcs
- Labels for color coding
- Temperature probe
- microSD memory card 8.0GB and microSD card reader
- Magnetic clip
- Safety flat clips, 4 pcs
- Safety fuse adapters, 3 pcs
- PC SW PowerView3
- RS232, USB and Ethernet patch cable
- Power supply adapter
- 1.2 V NiMH rechargeable battery, 6 pcs
- Soft carrying bag
- Instruction manual on storage media
- Calibration certificate

Featured accessories

Accessories

Photo	Part number	Description	MI 3155	MI 3108	MI 3144	MI 3360	MI 3309 BT	MI 3325	MI 2892	MD 9070	MD 9272	MD 9930
	A 1011	3-wire test leads	•	•								
	A 1018	Current clamps for earth and lightning measurements	•	•						•		
	A 1019	Current clamps for earth and lightning measurements	•	•								
	A 1055	2-wire leads	•									
	A 1105	Barcode scanner	•			•	•	•				
	A 1160	NiMH battery charger		•			•		•	•	•	
	A 1169	Large NiMH battery charger		•			•		•	•	•	
	A 1172	Luxmeter sensor	•									
	A 1198	Magnetic contact probe	•						•			
	A 1199	Ro-adapter	•									

Photo	Part number	Description	MI 3155	MI 3108	MI 3144	MI 3360	MI 3309 BT	MI 3325	MI 2892	MD 9070	MD 9272	MD 9930
	A 1201	Insulated rod for continuity measurement in hard to reach places	•	•								
	A 1256	Plug commander	•	•								
	A 1378	PV remote adapter										
	A 1384	PV safety probe for safe disconnection in case of a short circuit		•								
	A 1385	PV fused test lead		•								
	A 1388, A 1389, A 1390	Adapters with separated wires for measurements with current clamps; Schuko-Schuko, CEE 5-P 16A – CEE 5-P 16A or CEE 5-P 32A – CEE 5-P 32A connectors.				•	•	•				

Photo	Part number	Description	MI 3155	MI 3108	MI 3144	MI 3360	MI 3309 BT	MI 3325	MI 2892	MD 9070	MD 9272	MD 9930
	A 1391 / A1391 PQA	AC/DC current clamp / AC/DC current clamp for PQA	•	•					•			
	A 1400	PV temperature probe		•								
	A 1401	Tip commander	•	•								
	A 1436	Bluetooth dongle		•								
	A 1472	Leakage current clamp					•					
	A 1488	Bluetooth printer, battery or mains operated, supports barcode or QR code printing				•	•	•				
	A 1507	Three phase active switch	•									
	A 1530	G-clamp for perfect contact	•		•							
	A 1567, A 1568	Li-ion battery 4400 mAh, 8800 mAh	•									

Photo	Part number	Description	MI 3155	MI 3108	MI 3144	MI 3360	MI 3309 BT	MI 3325	MI 2892	MD 9070	MD 9272	MD 9930
	A 1579	Leakage current clamp				•		•				
	A 1595	Large Kelvin clip	•		•			•				
	A 1653	Bluetooth QR/ barcode scanner	•			•		•				
	S 2001 S 2002	Earth set 4-wire 20m/50m	•									
	S 2080	6-pack of NiMh AAA batteries		•			•		•	•	•	
	S 2107	Set of three A 1588 sensitive current clamps for power quality measurements and leakage							•			
	P 1102	aMESM	•		•	•		•				
		Metrel ES Manager Basic	•		•	•		•				
	A 1431	Eurolink Android		•								

Photo	Part number	Description	MI 3155	MI 3108	MI 3144	MI 3360	MI 3309 BT	MI 3325	MI 2892	MD 9070	MD 9272	MD 9930
		Eurolink PRO/ Eurolink PRO+		•								
	A 1428	Eurolink PV Android		•								
		Power view 3							•			
		Metrel Thermal Image Viewer for PC										•

Literature and education

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A key part of any solution is education on it, its usage do the user can gain maximum benefit. Metrel offers integrated training programmes that cover every aspect of the solution set. The training consists of theoretical lectures and practical work with the instruments. Both are given and overseen by the product managers. The literature for lectures and exercises for practical work are provided as part of the training. It can be kept for later reference. Theoretical part covers the standards used, reasoning behind them, advice on safe measurements, measurement methods and instrument properties.

INTERNATIONAL STANDARDS

There are many standards relevant to facility management. It depends on local regulations which ones are eventually used. Many cover similar areas, but consider different historical background. A rough overview includes the following:

- **IEC/EN 60364:** A standard family that cover everything to do with protection of users from low voltage installation hazards, from building requirements to testing methods. It has multiple parts.
  - Metrel instruments can test conformity of installation to the Part 4 – protection from electric shock (part 4-41), thermal effects, overcurrent and electro-magnetic disturbances.
  - Part 5 covers choice and erection of parts of installation, but every piece of equipment is also covered by its own standard.
  - Part 6 covers verification of the installation. It positions rules for initial and periodic testing that every electrician needs to know. It however doesn't deal with the instrumentations.
  - Part 7 covers design and specifics of installations like bathrooms, construction sites, and other that have special requirements in terms of environment and availability.
  - There are differently named local standards that cover the more or less the same requirements as IEC/EN 60364, e.g. the British BS 7671 and Australian AS/NZ 3017.
- **IEC/EN 61008** and **IEC/EN 61009**: standards for functionality, design and testing of residual current devices with or without the inbuilt overcurrent protection, meant for domestic and similar applications. They mainly protect from electric shock, or electric shock and effects of overcurrent. They are mentioned a number of times also in the IEC/EN 60364, as they are obligatory in some types of installation and very much recommended in all of them. Protection in an industrial setting is covered in a separate standard.
- **IEC/EN 61557** is a standard collection dealing with testing instruments for low voltage installations. Every instrument used for professional testing must conform to the relevant parts of it. It covers both safety and functionality of the instruments.
- **IEC/EN 60335** and **VDE 0701 – 0702**: international and German standards for safety of portable electrical equipment in general. They are practically the same with some minor differences. They are useful for most domestic, office and smaller industrial tools. The latter are the most commonly tested, as they are the most intensely used and damage can occur often. The standards define protection classes and visual and electrical testing procedure for each of them. Functional testing depend on each tool or piece of equipment, so it is only covered in general terms. Testing depends on local legislation, it can be either laymen or professionals that do the periodic testing.
- **IEC/EN 60204-1**: General requirements for safety of electrical machines. A lot of machine types are covered by their own standards, but all reference to the general one at least in some ways. It covers electrical supply, EMC, overcurrent and overvoltage protection, short-circuit current rating, protective bonding and other protective measures from electric shock, switching supply, safe emergency shut-down, necessary symbols to use. It includes inspection and testing methods for . Testing boils down to inspection of the documentation, testing status of compliance to it, verification of protection by automatic disconnection, insulation, test with high voltage, test of protection from residual voltages and functional tests. Visual inspection is always performed first to determine whether the machine should be electrically tested at all, and what tests should be performed.
- **IEC/EN 61000**: Standard family about basic rules of electromagnetic compatibility. It covers definitions and descriptions, limits, measuring techniques, installation and states the generic standards. Part 4-30 defines accuracy classes for PQA instruments as Class A, Class S and Class B.
- **EN 50160**: European standard for measuring power quality. It defines the voltage variables to monitor for limits on acceptable values (not the average, daily expected state). It only applies to normal working state of the network, not the fault, repairing or natural disaster conditions.
- **IEEE 1459**: Mathematically inclined standard for measuring power quality with descriptions of signals in sinusoidal, non-sinusoidal, balanced and unbalances conditions. It also mentions harmonic content.
- **IEEE 519**: Covers recommended practice and requirements to keep harmonic content under control in electrical power systems. It also includes interface requirements to lower interference between systems, addresses steady-state systems, sets the power quality at the point of common coupling and offers guidance for telephone systems. It excludes radio-frequency interference.
- **DIN 5032**: German standard for photometry, important for workspace environment measurements.

Depending on the facility in question, there is a further number of standards important for machine or industrial testing, e.g. IEC/EN 60974-4 for arc welding equipment.

Measuring methods and instruments

Measuring methods cover the necessary techniques that provide most accurate results under the given circumstances. There is a lot of fascinating engineering behind each of them and each has its strong and weak points that prospective users need to know. Examples are covered in the application notes in this catalogue. Instrument properties make the chosen methods possible. The lectures include presentation instruments in the chosen set.

Demonstration equipment

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Metrel instruments are feature-rich, and the features deserves to be explained. It gives users the option to resolve measurement problems in multiple ways, either through different approaches in the user interface, using different accessory, or with different levels of automation. Use of both standard and advanced accessories in any combination is an important theme. Adaptors expand an instrument's use to new areas or accuracy levels, while accessories ease the use or allow more focused approach to the problem.

The other side of the instrument is making the user's life easier. The procedures are kept as simple as possible. Data is transparently collected into a memory structure and prepared to be inserted into the reports. High level of automation can prevent human errors and make testing possible for less well trained users.

The literature
Each course is complemented by selected literature to help the users. Specially prepared guidebooks, application notes, exercises, and posters can be supplied in any quantity. Strategically positioned posters can become cheat-sheets for everyday use. Warnings, precautions and safety measures are prepared for each project separately, covering whole procedure from preparing the test site to leaving it. Extensive materials are provided to cover every aspect of operator's and user's safety.

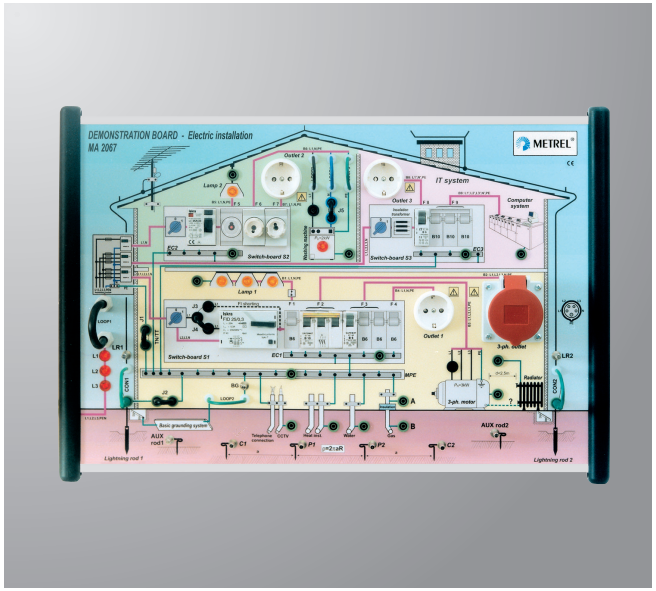
Practical and presentation work
The practical section covers pre-defined exercises with instruments and software that prepare users for real-life challenges. The exercises are prepared to cover the themes from the lectures in practice. The users are familiarised with workflow on the instrument as if they were in the field. Most of the exercises can be presented while still in the classroom, using one of Metrel's training aids. The most advanced of them is the MI 3399 Application trainer corner, the 3D simulator of real-life safety and quality situations and a great training and demonstration platform for any installation or equipment.

MI 3399 SAFETY AND QUALITY APPLICATION TRAINER

A stand-alone unit for demonstrations, training and educational purposes. It is highly suited for work with groups and for individual practice. It contains various integrated electrical elements that allow complete simulation of typical errors in the residential or public electrical installation, grounding and earthing systems, lightning protection, single- or three-phase systems, and more. It contains special locations like operating theatres or installations and equipment in vehicles.

Optional modules include photovoltaic system, power quality testing and electrical appliances.

Key features:
- Insulation resistance;
- Continuity of PE conductors;
- Line impedance;
- Loop impedance;
- RCD testing (Contact voltage, trip-out time, trip-out current, Autotest);
- IMD, ELM, RCM leakage and insulation monitors adjustment and test;
- Earth resistance (4-wire, 3-wire, 2-wire, 2 current clamps);
- Specific earth resistance;
- Lightning protection loops and legs resistance;
- Surge protector test;
- Leakage current;
- Phase rotation;
- Voltage;
- Frequency;
- AUTO SEQUENCE ® procedure for TN, TT or IT earthing system.
- Power quality.



Key features:

- 65 different measurements in accordance to EN 61557 (insulation resistance, continuity of PE conductors, earth resistance, specific earth resistance, line and loop impedance, phase rotation, leakage current, RCD testing, voltage and frequency);
- 19 different errors can be selected on a lockable distributor;
- Different types of RCD are integrated for measurement of trip-out time, trip- out current and contact voltage;
- Simulation of TT, TN and IT earth systems;
- Possibility of connection to single phase or 3-phase supply system;
- Booklet with theory and exercises for schools and training centres is included in a standard set.

MA 2067 DEMONSTRATION BOARD FOR LV INSTALLATIONS

Demonstration Board MA 2067 is an excellent demonstration and educational tool that simulates real conditions in low voltage electrical installations. The demonstration board consists of all significant elements of electrical installations like RCDs of different types, fuses, PE equalization bars, single-phase and 3-phase sockets, various consumers of electrical energy and various grounding systems (TT, TN, IT). The MA 2067 demonstration board provides simulation of different types of faults in electrical installations. Complete testing and troubleshooting of the installation is possible by using suitable instruments.

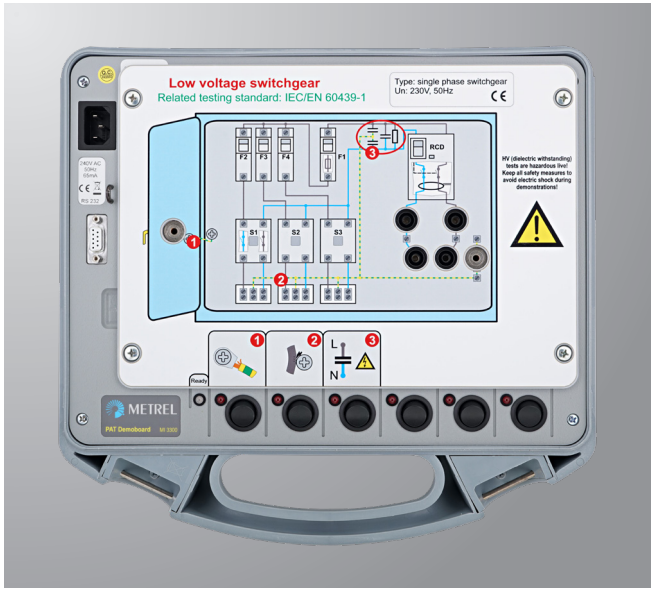
MI 2166 DEMONSTRATION BOARD FOR SIMPLE LV INSTALLATION

Demonstration board MI 2166 simulates common electrical installation usually met in houses or apartments. The demonstration board can be used by sales personnel when demonstrating operation of electrical installation test equipment, or for a demo in a crowded classroom.

Various test methods supported by different test instruments can be presented. MI 2166 is compatible with all Metrel's Installation Safety Testers.

Key features:

- A number of different measurements in accordance to EN 61557 are possible (insulation resistance, continuity of PE conductors, earth resistance (four-lead and two clamp methods), specific earth resistance, line and loop impedance, phase rotation, load current, RCD testing, contact voltage, etc.);
- Real elements of electrical installation are placed on the front panel like RCD, ON/OFF switch with lamp, mains test outlet and connection terminals;
- All standardized testing methods can be presented;
- 5 different errors can be pre-set by »fault« switches;
- TN or TT system can be simulated;
- Demonstration board is put in the strong rugged case with a handle for comfortable carrying.



MI 3300 PAT DEMOBOARD

The MI 3300 PAT demo-board is an excellent instrument for teaching or demonstrating PAT testing. The MI 3300 simulates a wide variety of portable equipment in normal operation or in fault conditions with the simple flick of a switch. The tough case with detachable lid allows the unit to be easily moved between sites.

The ability of the unit to simulate unlimited number of different equipment and the possibility to set fault conditions make the PAT demo-board the ideal unit for teaching or assessing learning in classrooms, training sessions, demonstration sessions, seminars and PAT training courses.

Key features:

- Practically unlimited number of different equipment (portable appliances, machines and switchgears) can be simulated by using different tables (eight are included in a standard set)
- The demonstration board can be simply upgraded with new tables on request;
- Normal and fault situations can be switched on and off, offering fault conditions for the assessment of learning;
- Demo-board simulates the following faults: PE continuity faults, insulation resistance faults, leakage and touch leakage faults, polarity and functional faults;
- The demonstration board is built into a strong rugged case with a handle and detachable lid for storing leads, adapters and manuals.

MI 2891 POWER SIMULATOR

The MI 2891 Power Simulator, is a multi-purpose three phase power device for modelling typical situations in low voltage power supply systems. It is an excellent tool for training, demonstration purposes, or as an electrical training tool. The simulator has some pre-programmed scenarios, and also the option of a complete manual mode. The user can decide between different load characteristics, adjustable current and voltage level with a simulation of various different faulty conditions.

Measuring functions

- Voltage;
- Current;
- Frequency;
- Harmonics (U,I);
- Phase angle (U,I);
- Flicker;
- Phase sequence (U,I).

Key features:

- Simple and powerful waveform generator with various settings
- 4 voltage channels with wide simulation range: up to 350 Vrms
- 4 current channels with current clamps simulation up to 2 kA
- Simultaneous voltage and current (8 channels) simulation, 16 bit DA conversion for accurate signal generation
- Dip, swell, interrupt, signalling, transient and inrush events simulation
- Voltage and current harmonics waveform simulation
- Unbalanced voltage and current waveform simulation
- Square flicker simulation
- Various character load/character type combination simulation
- Thorough signal parameters settings
- Saving current system settings on power off
- 4.3'' TFT colour display.

Notes

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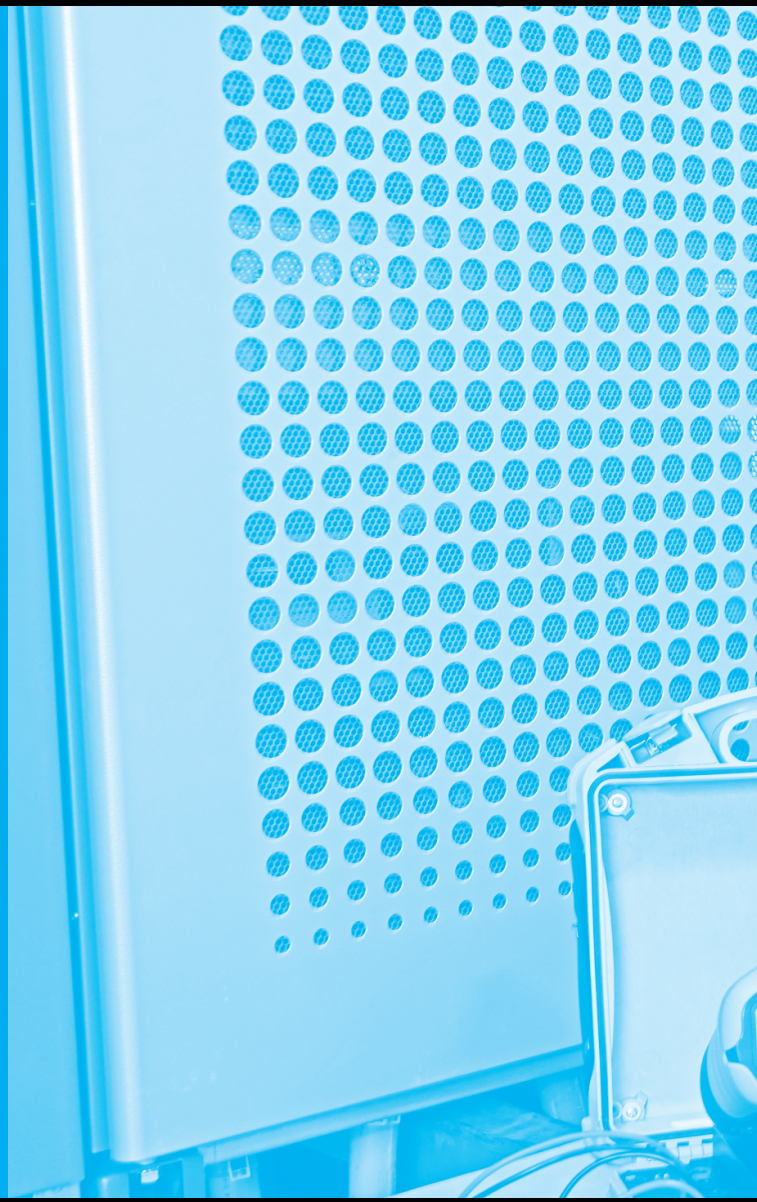

Note! Photographs in this catalogue may slightly differ from the instruments at the time of delivery.
Subject to technical change without notice.

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