Medical Facilities

Application catalogue

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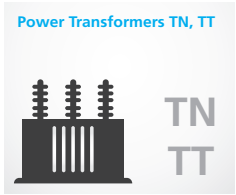
Introduction of covered fields

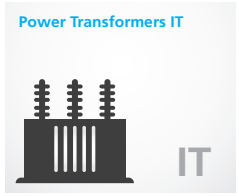
Medical Facilities

Hospital building and grounds - Challenges presented to an electrical installation in a hospital building are wide and diverse. They start outside the perimeter fence, or sometimes even a kilometer away. 3-wire measurements of the earthing system use a lot of space, and the larger the system, the further away one needs to stake the measurement electrode. In densely populated areas, this might not be possible, and alternative methods must be employed. The 2-clamp method is simple and reliable – but one has be aware of its weaknesses and situations where its results will be meaningless. It can measure the lightning system as well, but the same limitations apply. Where the building has TT system installed, contact voltage or fault loop measurement can supply some good information about safety in the case of a lightning strike. It also has relevance to the next issue which applies both inside the building and outside – earth bonding and equipotential planes. The system can be at any electrical potential as long as differences (or voltages) within it are small. Bonding and earthing design make this possible. The final component is found inside the building, in the distribution board and sub-boards: well-coordinated surge protection devices, protecting both from extreme events like a lightning strike and from transients on the supply line which are comparatively common. Power quality and availability monitoring on the main connection point secures the whole installation.

Power supply and distribution - Electrical power in the hospital is of utmost importance, both in terms of availability and quality. A number of measures are taken to achieve near-continuous power availability: two grid power supplies, backup generators, robust UPS system, having isolated rooms that will not lose power in case of a single fault. Electrical interference, noise and disruptions on the line cause imaging techniques like MRI to blur, and can interfere with sensitive monitors and regulation systems. Some locations even use Faraday cages to keep the external noise to a minimum. For the rest of the building, filters to keep harmonics down and surge protection against transients is usually enough. Power quality for the whole building and particularly for the sensitive areas should be monitored periodically and whenever a new large appliance is installed. Distribution board and sub-boards are the location of a number of protection devices and where important measurements are made, safety critical measurements such as line impedances and continuity. Connections to the isolated areas and isolation transformers can also be accessed.



Surgery room - Operating theatre is an electrically isolated area. It has no connection to the electrical ground of the building, even though the PE wire is present. This configuration enables work even in case of an insulation fault either in the installation or in appliances. Such a fault must, however, produce a warning, so the room is equipped with an insulation monitoring device and optionally a fault finder system. The main electrical hazard to all present lies in electrical equipment. Many medical appliances are meant to be in direct contact with the patient's skin or sometimes internal organs, which makes danger of electric shock much higher than usual. Main testing concern is safety of the equipment used and its applied parts. Every piece of equipment needs to have two-part protection. Options are grounding or equipotential bonding and multiple layers of insulation. Leakage currents and contact voltages must be very low. Installation takes into account that the surgery is a wet environment. Measuring equipment must sometimes, depending on the sanitising procedures, be confined to the operating room only.



Biomedical appliances - are one of the cornerstones of modern healthcare. They are used to monitor life signs, measure or observe symptoms, and treatment. In large majority of cases, they come in direct contact with the patient and often use electrical sensors to read desired values. Instrument parts that are meant to be in contact with the patient during normal use and carry electrical signals are called applied parts. There are three types, divided by safety level.

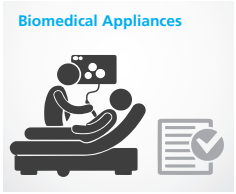
Type B: standing for 'body', they are the most basic applied parts and are generally non-conductive. They may be connected to earth and are not isolated from the power supply and enclosure.

Type BF: standing for 'body – floating', they have conductive contact or medium to long term with the patient. They are isolated from power supply and enclosure, and offer higher degree of protection.

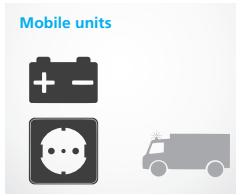
Type CF: standing for 'cardiac – floating', they have conductive contact with the heart or other vital organs, they are designed for the lowest leakage current, isolated from supply and enclosure, and offer the highest degree of protection.

These are some of the very few electrical devices designed for contact with people and for exposing them to controlled voltages. The safety measures are considerably more rigorous, the main issue being the leakage current. Other medical devices are a quite different matter. They require a lot of power and a carefully designed supply. MRI and X-ray are only the most obvious examples.

Hospital wards and patient recovery areas - These spaces are filled with medical appliances and often also drugs, other liquids and at times food. Patients can interact with all of them, making spillages and mechanical damage common. Corrosion is a serious hazard as it can cause voltage drops on bad connections or between metal parts without additional equipotential bonding. Examples include accessible conductive parts on medical equipment, appliances or beds and protective earth. Usually there is a lot of them to check, which makes simple automated testing equipment an attractive option. Patient recovery areas include recreation and physiotherapy, relaxation and common spaces. Medical appliances are partly monitoring and partly therapeutic, but almost exclusively applied to the skin. Electro-stimulation is an effective recovery therapy but must be safe as well. Swimming or whirl-pools with mineral water need to have both environmental and electrical condition checked regularly.



Public Places and safety at work - The management must provide safety and operability for workers, customers and passers-by. Electrical installations, equipment and appliances are used more frequently and intensely than at private locations. Regular inspections are obligatory to ensure safety of workers, protection against electric shock, lightning protection, and safety of portable appliances, machines and fixed equipment. Areas with greater traffic need more frequent inspections to reduce the risk. Employees should be educated about possible hazards - recognising and avoiding them. Electrical safety regulations, functional safety and risk factors calculations for the work tools and machines cover the healthcare workplace. Work procedure must be prescribed in detail and observed carefully. Work supervision, regular inspection of the equipment in use and training about particular workplaces decrease chance of accidents. Calculations and measurements of environmental conditions can predict worker's satisfaction.



Mobile units - Mobile units can be described as primarily generators on wheels. The generators are protected by insulation, optional grounding, permanent monitoring devices and RCDs. Ambulances also rely on battery power and need a power inverter to supply appliances it carries. Any tools and appliances on board must be kept in good condition and prepared to be used safely, particularly when transporting critical patients. A complete inspection of the vehicle is recommended after each intervention. The vehicles and generators must be grounded during use or permanently monitored for the possible first fault error if system is insulated from the ground. Functionality of alarms and operability of the monitoring system must be assessed frequently. Ambulance stations are the spot where any maintenance takes place.

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Medical Facilities

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Electrical Safety and Quality Bundle Case

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 your needs or preselected 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, 48 and 51 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.

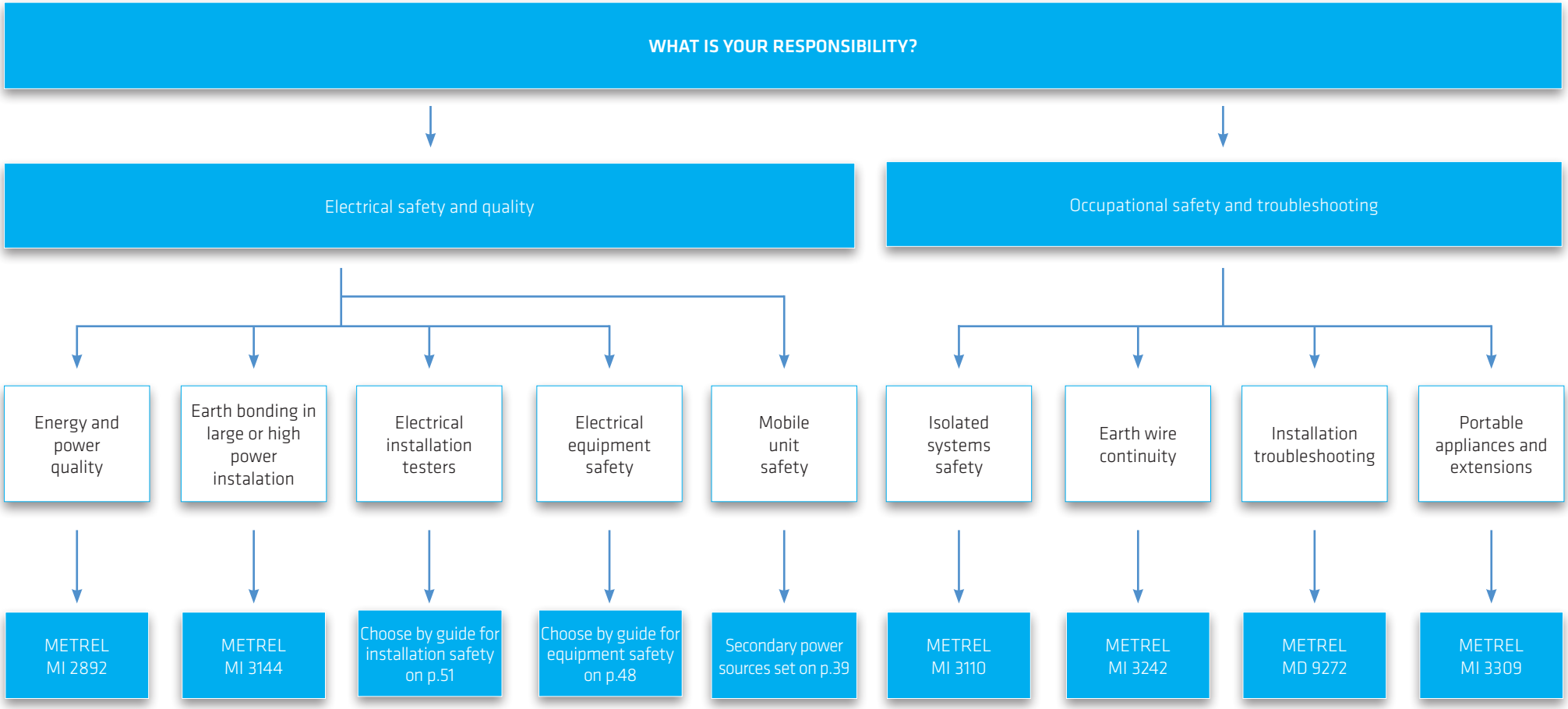
THE CASE

The sets are packed and delivered in waterproof case that facilitates the transport, protects the equipment and prolongs its life cycle. 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 lid but also the weight of the accessories stored in it. Some instruments can be used still in the case, while others are hand-held and need to be removed while in use.

By your responsibility

Selection guide

Each facility has its own work organization, but it is common to find two profiles that deal with electrical safety and functionality: an electrical engineer that has a lot of installations and equipment to care for, and an occupational safety professional that may be the first person to respond to a problem. Metrel has prepared a choice of instruments that either give very accurate results, or are particularly easy to use and can be handled by electrical laypersons. Choose the instruments depending on your responsibility and level of electrical knowledge.



Hospital earthing and lightning protection

Solutions by the Field of Use

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

Hospitals and other large building complexes (e.g. large shopping malls or factories) can become a major part of common power earthing system in the area. They can have an internal substation with earthing for the whole complex constructed with a particularly low impedance (TN part of the system), and its underground distribution has to be taken into account for the wider surroundings.

Each building in a hospital complex usually has local connection to earth for functional and safety reasons (TT part of the system). This double system can lower disturbances to the network coming from earth. 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 wide 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 local 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. Locations with sensitive equipment (medical or otherwise) need special protective measures inside the building: 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.

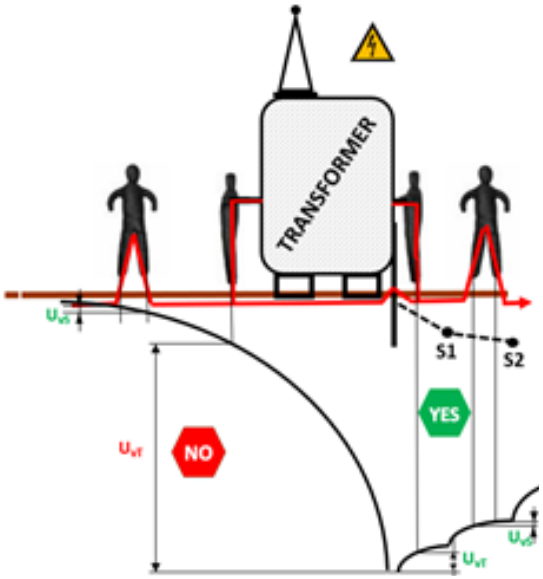
The first fault to be considered when designing the grounding system is phase to ground fault. It can cause dangerously high voltages on enclosures or any grounded conductive surfaces. Grounding system must have a low enough resistance to pull the voltage down to safe levels. Since it is a type of fault that lasts until fixed, permissible touch voltages in Table 1 are much lower than for instantaneous events. The permissible voltage is defined in regard to its danger to life.

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

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. Some values with regard to fault duration are collected in Table 1. Lightning strike last 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: touch voltage and step voltage. Touch voltage is a voltage between point of contact, usually a grounded conductive surface, and the ground potential, usually under the toucher's feet. It depends on the impedance of the grounding system and the body resistance. Standard measurement is made with 1 kOhm probe for simulation of human body. Step voltage is the voltage over the dis-tance between the feet when walking. In standards, 1 m 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+

Main protection from lightning is a system of heavy conductors leading to the ground. Second protection is a coordinated system of surge protection devices. They need to open when voltage rises too high and transfer the energy directly to the ground.

LIST OF PRODUCTS IN THE PROPOSED ADAPTABLE BUNDLE:

- MI 3155 EurotestXD
- MI 3144 Euro Z 800V
- MD 116 Non Contact Voltage Detector
- Metrel ES Manager
- Android Metrel ES Manager
- Custom case

2-clamps method for measuring lightning and earth protection

Hospital earthing and lightning protection

Particularly in urban areas, the classic earthing measurement with rod electrodes isn't possible. There is neither space to place them at sufficient distance from the object to be tested, nor is there access to the actual soil to drive in the rod. One has to make do with what there is.

One of the options is the measurement with 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 case of a TN system, measurement is performed on incoming PEN/PE bond. There is no need to disconnect the bond.

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 wire without disconnection.

The induced voltage causes current in the whole earthing system and 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.

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

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

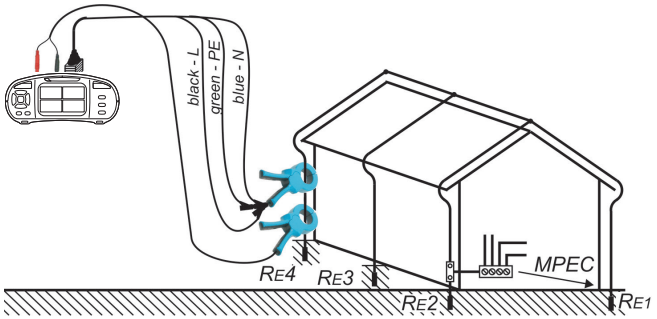
$$= 10\,\Omega + \frac{1}{\frac{6}{10}}\,\Omega = 10\,\Omega + \frac{10}{6}\,\Omega = 11.67\,\Omega$$

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. Their connectors differ: A 1018 has integrated test wire for connection to the instrument, and A 1019 has connectors for standard 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.



Circuit for 2-clamp measurement

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.

Hospital earthing measurement with fall of potential method

Hospital earthing and lightning protection

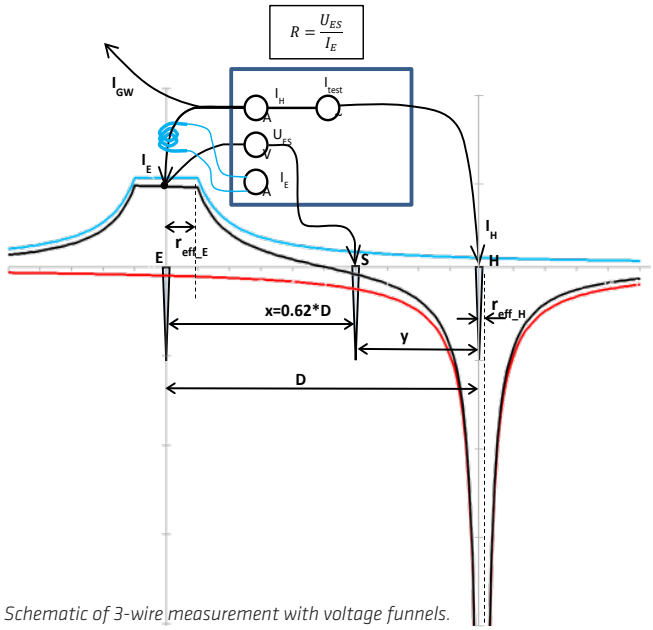
Measuring earthing resistance can be both difficult and tedious. It requires special equipment and multiple repetition of measurements, particularly on large systems with multiple earthing points.

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



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.

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 electrode under test. If there is a suspected object underground, moving the spikes to a different position would help.
It is good practice to repeat the measurement with different electrode positioning. At least they should be moved 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 the soil is also a problem. It however works well in remote areas, and it is the only method that can be when there is no parallel earths in the system.

MEASUREMENTS

MI 3155 is a multifunctional installation tester that can cover every aspect of the installation from its establishment to the 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 supplied with 20 m long cables and rods for earth resistance measurements as standard. Optional extensions are available. Software on-board and in the office give the option to set a maximum resistance limit and gives a pass/fail sign.
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, 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. The socket designations are H for current electrode, S for voltage electrode and E/ES for earthing system to be measured.

Mains bonding and touch voltages during fault current

Hospital earthing and lightning protection

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 is meant to shorten 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 relationship with 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, like in presence of water. 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 allowed 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 measuring, and testing with the Metrel Human resistance probe A 1597. Loop impedance measurement, also called earth fault loop impedance test or 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 wires 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 within 5s. In context of equipotential bonding, a similar test is performed: a current is passed into the bond, through the protective devices like fuses and RCDs, and the earthing systems to which it is connected. The measured impedance must be low enough to conform to equation: R ≤ 50/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.

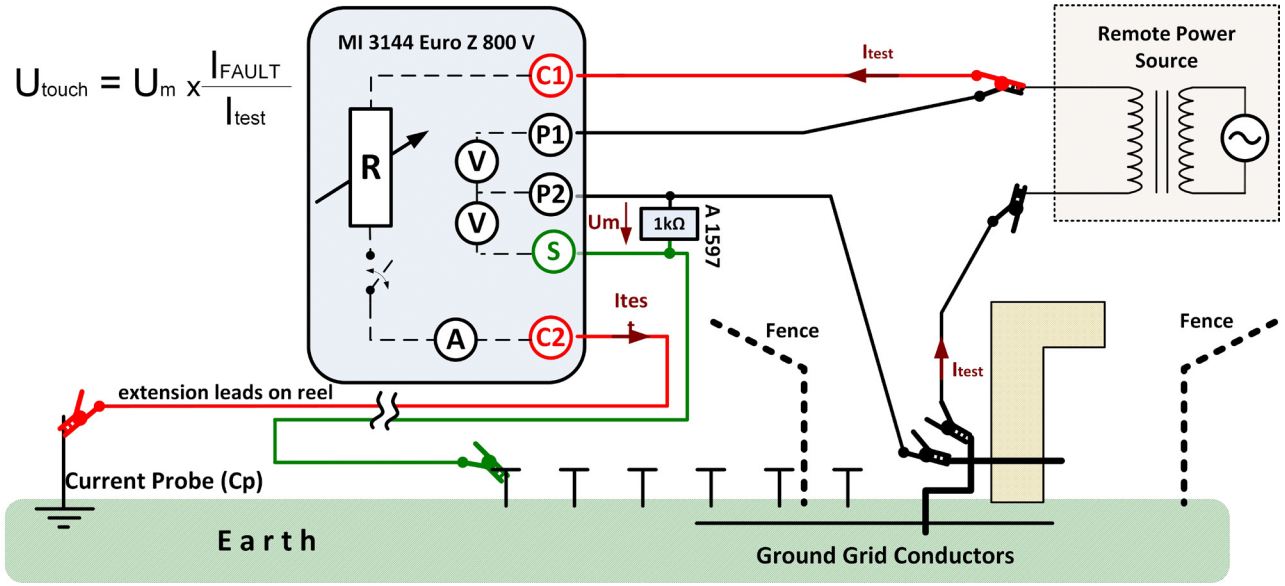
Human resistance probe A 1597 can be used to measure touch voltage, which is closely connected to bonding resistance. Touch voltage is the voltage between the item and the earth when considering the resistance of the human body in parallel to it. Measuring it gives a direct estimate of danger to life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

MEASUREMENTS

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

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

MI 3155 has pre-programmed tests with automatic disconnection



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

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.

Surge protection devices in hospitals

Hospital 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.

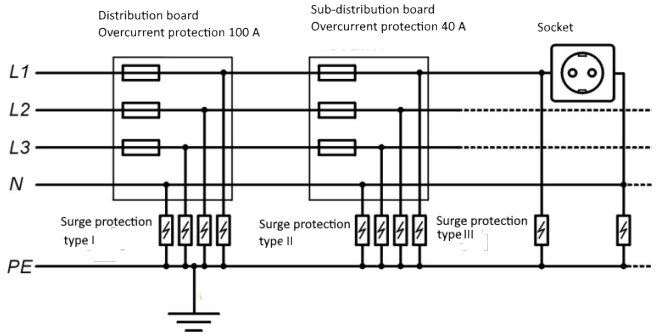
The surge protection system from top (the supply to the building) to bottom (the assets or appliances) needs to be coordinated so that they open in the right order to an incoming surge. Each level has to be chosen so that it protects equipment behind it, but doesn't age prematurely due to conducting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

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 too-small a type III device, but fail to trip the type II phase.



Connecting surge devices into the installation.

Constructions can be a combination of different elements, but the most common are varistors and gas discharge tubes. A 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 off quite 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 initial 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 the 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 ramps 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 350 V/s (for 2500 V range). The test ends when the 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.

Power supply and power distribution

Solutions by the Field of Use

The first rule of hospital power supply is continuity of supply. Therefore, there is multiple redundancies built in. There should be at least two main supplies, connected to two different feeds, preferably using separate networks (or as separate as possible in an urban area). In case of an outage, large UPS banks must immediately take over for a few minutes before backup generators can come online. The whole system has to be kept in perfect repair and the transitions tested regularly for functionality and safety.

Power supply can be considered in terms of its components, their function, and their safety features. Depending on its size, a hospital may well have its own substation. It is quite common to require special supply conditions for some of the larger machines like x-ray or magnetic resonance, so it is more cost-effective to do the step down transformation in-house. The substation houses the step-down transformer, and possibly primary switching panels and primary overvoltage/overcurrent protection. Those can also be placed inside the main building. Back-up generators are usually housed separately but close by, because of their need for ventilation, and the requirement to access the switching element of the substation. The latter also covers the most essential switching between the two supply feeds. Further switching and routing power to different locations is done using distribution boards and sub-distribution boards. Protection from overvoltage, overcurrent and residual current for each level is also housed there.

The UPS system has its own room with carefully monitored conditions to keep the batteries running at their best. Since even a very short interruption may disturb some sensitive instrument, it should be installed in online way and the output carefully filtered for current harmonics. This way, the response time is practically zero, the system is well protected from transients or other network events while leaving no disruptive trace of its own.

Measuring large busbars with Metrel kelvin clamps A 1593, MI 3155 and MI 3144.

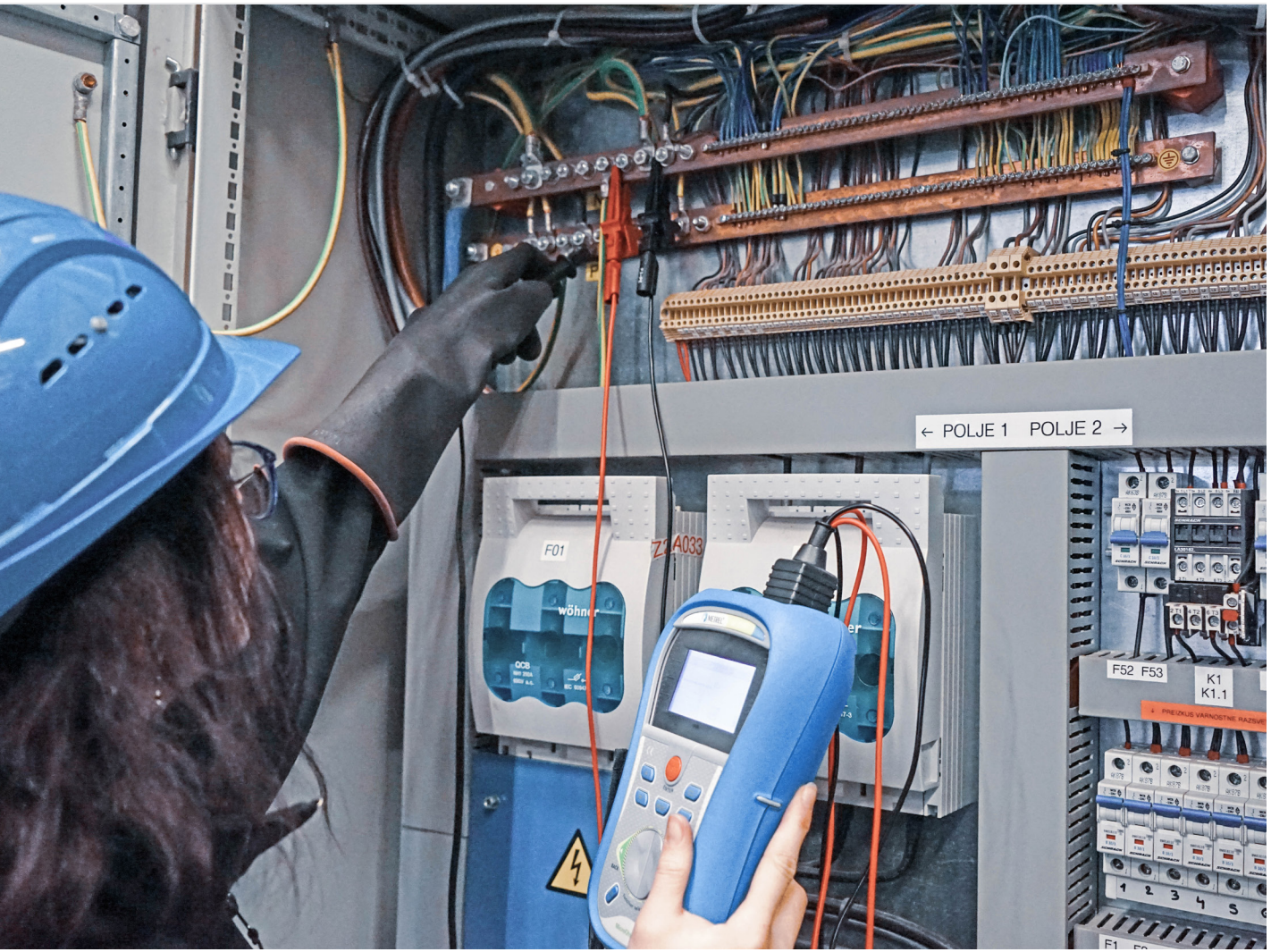
Each of the above locations has to be monitored in terms of power quality. Only properly set-up, long-term measurement can confirm the local network conforms to requirements. Power quality reports can be adjusted or expanded to their needs. Alarms in the power quality analysers can be set up to be able to respond immediately to any unexpected event from inside or outside of the building. On the inside, careful design with filtering and damping has to be implemented to lower the chances of large machines disturbing each other. On the outside, coordinated surge protection, local earth connections and filters of proper power have to be installed.

LIST OF PRODUCTS IN THE PROPOSED ADAPTABLE BUNDLE:

- MI 3155 Eurotest XD
- MI 3242 MicroOhm 2A
- MI 2893 Power Master XT
- MD 9272 Leakage clamp meter with power functions
- MD 9050 TRMS Industrial multimeter
- MD 116 Non Contact Voltage Detector
- Metrel ES Manager
- Android Metrel ES Manager
- Power View 3
- Custom case

Hospital switchboards and automatic trip-out protection

Power supply and power distribution



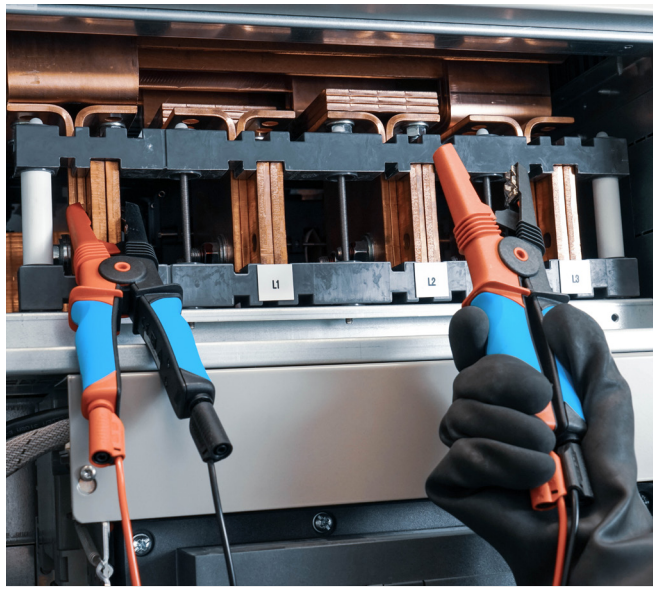
A switchboard or a distribution board is the component of installation where the single main supply line is divided to sub-circuits for different locations around the building. It incorporates the protective measures like surge protection, circuit breakers and RCD switches. It is a location where a number of measurements are made that would be troublesome or impossible to do in other places.

In particular, wires to different parts of the installation are accessible, which makes it possible to do leakage current measurements for these parts. Other measurements done at the switchboards are continuity of protective bonding, RCD tests, voltage properties tests, and power quality logging. Leakage current is not a part of periodic measurements, but it is a great troubleshooting tool.

Leakage current in installation can cause a number of problems, most obvious of them being unnecessary RCD trips and possibility of dangerous touch voltages. If very high, it can also affect thermal properties of the system. RCD trips can be prevented by using a careful design, dividing the circuits between users and switches so that expected maximum leakage for the area never reaches 20% of RCD rating.

Leakage current is a part of normal operation of installation and devices. 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. Its magnitude is usually in the order of mA.

Leakage current manifests as any current flowing through PE wire, or any difference in currents between phase and neutral wires. This gives the essential idea of the measuring methods. Direct method uses current clamps around the PE wire, while differential method clamps phase and neutral wires to measure any difference between them. In differential method, direction of each current is important. Ideally, both methods are used and the results compared.



Measuring large busbars with the Metrel high-current clamps.

Measuring leakage current at the edge of an isolated island.

Leakage current measurements in a switchboard are a basic troubleshooting procedure. Higher leakage than normal is a symptom of a weakened insulation or a failing device somewhere in the building. By following the trail of high leakage first through the sub-distribution boards, then by turning the devices on or off, the source can be located relatively simply.

Leakage current measurement can be an alternative for insulation measurement. High voltage insulation testing in a hospital often is not possible. There is a lot of sensitive equipment that cannot be taken offline. Leakage and insulation measurements however are not directly comparable. It depends on ratio of capacitive and resistive properties of the insulation material. Insulation is measured at high DC voltage and considers only resistive part, while leakage is AC and contains both capacitive and resistive properties.

There is a number of considerations to take into account when making a leakage current measurement. It is a measurement of a low current in presence of much higher currents in close vicinity. They cause notable electric and magnetic fields that can cause large errors.

MEASUREMENTS

Clamps used should be high quality, with good magnetic shielding and magnetic concentrator in the core. Similarly, they have to have good immunity to external electric fields or capacitive connections. Leads connecting to the instrument should be short. The cables being tested should be close together and in the centre of the clamp. Other cables and the devices should be positioned as far away as possible. The standard that covers requirements for quality of the leakage current clamps is IEC/EN 61557-13.
Metrel offers the clamp A 1018 in combination with a multifunctional installation tester for performing leakage current measurements in installations, or a hand-held leakage clamp meter MD 9272. In both cases, the user only has to choose current measurement function and put the clamp around the wire in question.

Power quality

Power supply and power distribution

The power delivered from a supply is specified as pure sine at country-specific RMS voltage and frequency. It should not deviate from this ideal. But does it? There is a number of effects that can distort voltage or current shapes from the perfect sine. Some disturbances can have a source inside our 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 are the following:

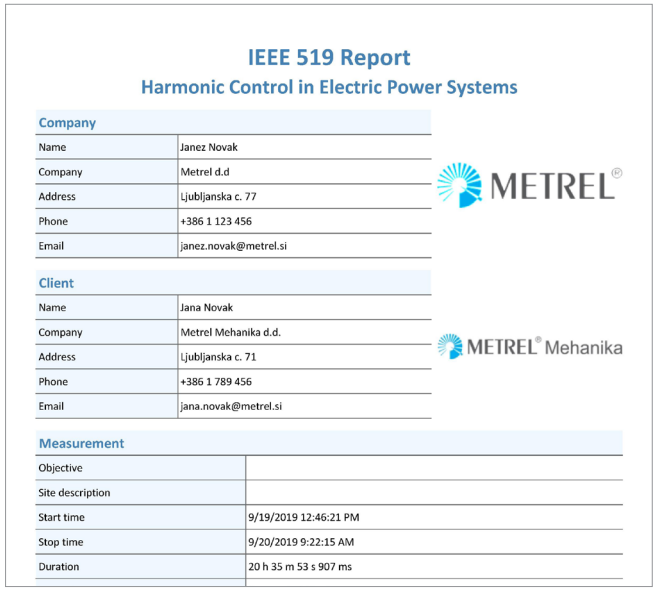
- Voltage from phase to ground. It should keep to the same RMS at all times, with no sags, swells or interruptions.
- Voltage balance. Phase difference and voltage magnitude between phases should be equal.
- Phase current, its magnitude, shape and trends.
- Frequency. Standards permit no more than 2 Hz deviation.
- Active, reactive and apparent power. They mean how much power is carried towards the energy consumer and how much away from it.
- Power factor or or cos phi 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 lightbulb 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 lightbulbs in use. It is however still part of the standard.

Most of these values have to be monitored over an extended 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 location, the main issues are reactive power or power factor and events on the network. At the second location, there will be more trouble with harmonic content. A specific point for power measurement in a hospital is the UPS battery stack. The on-line system with large rectifiers that does not include extensive filtering can be a source of serious disturbances. Filtering system generally come included, but its functionality has to be periodically checked.

The measurement has to be set up with great care. Nobody will want to repeat it should an error occur. The instrument is set up with measurement of voltage and current in all the phases at the required location, then programmed for the desired functions. Monitoring can run for the whole planned period, or it can be interrupted in case of a pre-defined event.

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 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. Hospital environment is fairly vulnerable in some points: at large machinery like X-ray or MRI, and inside the isolated areas. 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.



IEEE 519 Report

Harmonic Control in Electric Power Systems

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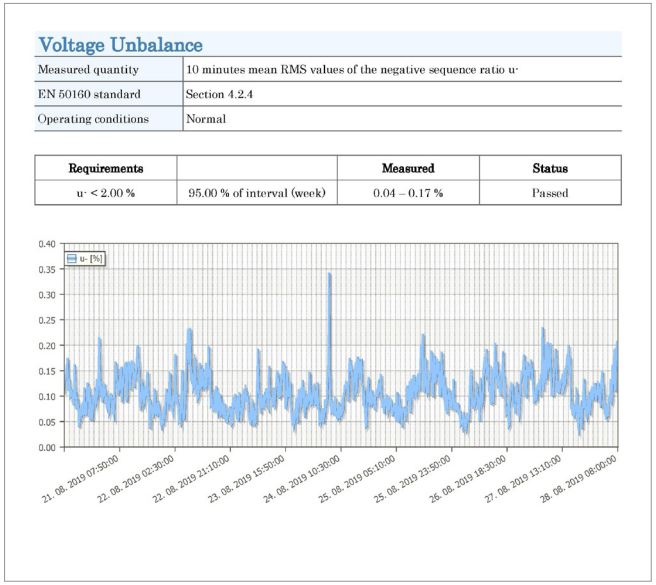
Measurement	
Objective	
Site description	
Start time	9/19/2019 12:46:21 PM
Stop time	9/20/2019 9:22:15 AM
Duration	20 h 35 m 53 s 907 ms



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

Examples of power quality reports.

MEASUREMENTS

Metrel offers a top quality instrument. MI 2893 conforms to Class A of the standard IEC 61000-4-30 with high accuracy, GPS time module, fast refresh rate and large comfortable colour screen. It can detect and display harmonics, phasors and waveforms anomalies in the installation simply by being connected to the grid. The measurements conform to standards EN 50160 and IEEE 519. It can simultaneously run multiple different recordings, for example transient and waveform. The user interface is simplified with the Quick-Set buttons. Data is saved to SD card for easy transfer to another device, but it is possible to connect to the instrument over Ethernet. The instrument is complemented by powerful software Power View 3 for in-depth analysis of long-term data and creation of professional reports. There is the option of a weather-resistant case for outside work.

Uninterruptible power supply in healthcare

Power supply and power distribution

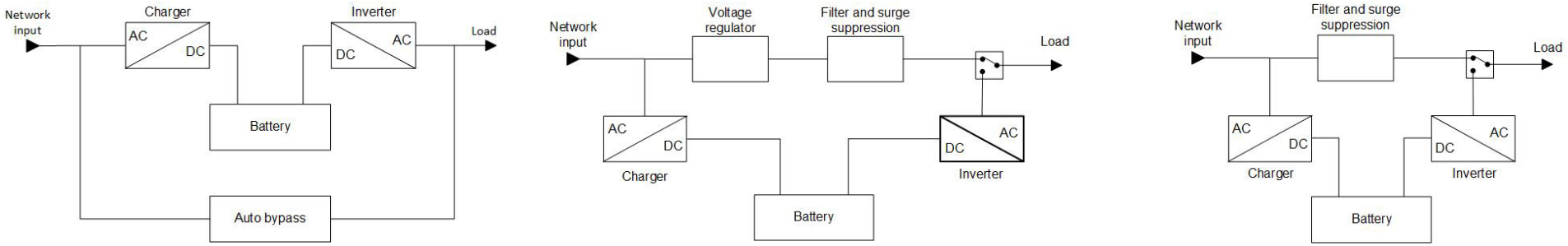
A number of processes in a hospital cannot be interrupted by a power outage. Most have backup generators or another extra power source available, but they can take a while to start. UPS system is there to bridge the gap between outage and backup source coming online.

UPS is a battery or a battery system connected to the installation, intended to start powering the protected devices or circuits immediately the main power fails. They can also provide protection from power quality issues on the network. Response time is some milliseconds. 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.

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



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

integrated active filters.

UPSs have to report their status to other devices. They can support any type of serial ports, an internet connection, or a proprietary protocol. They also perform and report regular self-check. 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. 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 tests 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 similar to the pre-installation tests, but have to be performed at zero and at full load.

Surgery rooms or operating theatres

Solutions by the Field of Use

Isolated system (IT) is a grounding system that isolates neutral wire from the ground. PE is grounded. This arrangement offers higher power availability: in case of a first insulation fault, its operation becomes similar to a TT/TN system and it remains functional and safe. Working voltage rises to phase-to-phase, raising the leakage. All the equipment used must be insensitive to that.

Therefore, it is the natural choice for locations that need high power availability, like the surgery room, or intensive care units. It offers also other advantages in terms of power quality, particularly immunity to disruptions from the PE, but also at least two serious drawbacks: cost and fault finding. Isolated systems are therefore usually built as islands in wider TT/TN system, using isolating transformers in the local distribution board to achieve it. The distribution board also houses the RCDs in case of a second fault and overcurrent/overvoltage protection.

Insulation resistance is the most important safety feature. It has to be continuously monitored, and insulation monitoring device is part of standard equipment in the isolated system. It however cannot sense the location of the fault. For that, a fault location system can be installed, but it is exceedingly expensive and therefore rare.

RCDs provide secondary protection. While the location remains functional and safe in case of a single fault, second fault can lead to very high currents that are both a fire hazard and a serious danger to life. RCDs turn the supply off in such a case. This however should be avoided, and any first faults carefully removed. It is beneficial to construct the surgery room as a wet place. Chances of liquids splashing around it are quite high. Cleaning is simplified if all parts of the installation can be at least splashed, if not actually submerged.

There are decontamination procedures at entrance or exit from the surgery room. It helps if the equipment is rugged enough for rough cleaning, have bacteria-resistant coating, or is simply cheap enough that there are 2 units: 1 can be kept and used inside the clean area and 1 outside.

Periodic testing of all equipment in use guarantees its safety and functionality.

Medical devices demand particular care. There are parts of them that bring voltage for diagnostic or therapeutic purposes to patient's skin or even internally. This makes their electrical safety a whole new world. Leakage currents have to be exceptionally low, as is the protective earth resistance. Instruments for these measurements have to support a lot of probes, have a large memory to save and organise the results, and be well interfaced with a PC to present them in a report. Standard for safety of medical equipment IEC 60601 requires testing with a high current, above 20 A. IEC 62353 on the other hand is focused on easier periodic measurement while still maintaining the safety.

LIST OF PRODUCTS IN THE PROPOSED ADAPTABLE BUNDLE:

- MI 3110 EurotestIM IT system tester
- MI 6601 MediTest Medical PAT
- MD 9273 Bluetooth TRMS leakage clamp with power functions
- MD 116 Non-Contact Voltage Detector
- Metrel ES Manager
- Android Metrel ES Manager
- Custom case

Medical IT system

Surgery rooms or operating theatres

Hospital rooms with types of machinery that directly supports life must be built with IT grounding system – isolated from the local transformer's ground. That construction has a number of advantages. First fault only generates an alarm, but the system remains functional and safe. The fault current is very low and leakage on the equipment rises very slightly. To conform the standard IEC 61557-8, voltage between accessible surfaces cannot exceed 50 V.

Normally, these are surgery rooms and intensive care units. Since the rest of the building is TN or TT for cost and ease of maintenance, the IT rooms are isolated from the rest of the installation using isolating transformers.

Isolating transformers
An isolating transformer is a transformer whose primary intent is galvanic separation of parts of installation or device. It acts as the input to an IT island in the TN/TT installation. It is usually a transformer with a 1:1 ratio, and 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 (IMD)
A monitoring device is installed between phase and PE lines. As the insulation degrades, the circuit from phase to PE closes and a current starts flowing to ground. The IMD senses a voltage drop on the measuring resistance and alarms once it is large enough. Exact measuring principle depends on the measured system 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 degradation of

a single wire, or connecting a faulty device.
IMDs are designed to be an early warning and a call for maintenance. It can have a built-in self-test, or it can be tested by changing the resistance between phases with an instrument. Limit for bad insulation in hospitals 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 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, an IT system should essentially start working as a TN/TT system, and as such needs to be protected with RCDs. Second fault current can be exceedingly high, creating both 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 multiple RCDs in other earthing systems), which can make looking for a fault a large-scale 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 live conductors via insulation fault through PE wire and back to the tester. The 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

MI 3110 is a specialized testing instrument for IT systems. It functions include testing supply properties, like voltage, frequency and phase sequence, and safety, like line impedance, prospective short circuit current, voltage drop and testing insulation monitoring devices. It has a single AUTOSEQUENCE® with adjustable limits and parameters that thoroughly tests the isolated area through sockets. It is also possible to perform each test separately. It is easy to carry and designed for use while strapped to the body, making it a perfect tool for field work in buildings or mobile units.
MI 3155 supports testing IT systems as one of its many functions. It features the same AutoSequence® as MI 3110, and can run each test separately. Both testers perform the measurements automatically after being connected to the socket or other measuring points.

Isolated areas RCDs

Surgery rooms or operating theatres

RCDs or residual current devices are a basic form of protection of the installation. They turn the power off in case the difference between phase and neutral wires becomes too big, or if there is too much current in the PE wire. This usually means that the installation is leaking intensely, some part of insulation has been breached so there is a contact between phase and neutral, or some current got diverted (e.g. through a body).

These are all dangerous situations, so the RCD trips, breaks power supply, and prevents the damage from happening. Some RCDs have overcurrent protection included, so that they can protect from high fault and high load currents. These two types of protection can also be built-in separately, as fuse and RCD or surge protection and RCD. There is a number RCD types, each sensing different current shapes. Some only cover sinus current, others also support protection from pulsed, DC, or more distorted shape. The standard describing them is IEC/EN 60364-5-53.

Installations are generally protected with multiple RCDs. They are installed following the distribution principle. When a fault occurs, only the RCD closest to it trips, making location of the fault easier. The principle is essentially hierarchical, with an RCD with higher rated current connected so that currents from lower-rated ones combine at it.

In IT systems, RCDs generally cannot activate on first fault. System is isolated from ground, so extremely little current can flow and there is no reason for them to trip. The system with an insulation fault moves to working as a TN/TT system. Nominal voltage rises to a new value that depends on system design. It is kept to non-dangerous level, but it still causes leakage to rise slightly.

The fault is detected by the insulation monitoring device. It warns the users with sound and light signal, where sound can be turned off, but light can only reset once the fault is fixed. It is possible for RCDs to trip at first fault in isolated system however – in large

Leakage current measurement at RCDs is one of diagnostic tests.

systems, leakage can rise enough to operate them, or a capacitive connection to the ground can conduct enough current for it to trip. These types of trips must be taken into design consideration. In hospital environment, they are not permissible.

On a second fault in an IT system, the situation is similar to TN/TT system. It can generate very high fault currents, so RCDs are an absolute necessity. Once the current rises above rated value, they turn the power off.
Measurements of the RCD effectiveness must cover their sensitivity to different shapes of fault current, magnitude of current that causes a trip, contact voltage on accessible surfaces at maximum permissible current, and time to trip.

MEASUREMENTS

MI 3155 offers measurement of virtually all RCD, PRCD, RCD for electric vehicles, or a special type. Measurements performed in AutoSequence® are contact voltage, rated current with a ramp and time to trip. RCD type has to be selected in advance, as are the limit values to assess pass or fail. The measurement is done in the distribution board or sub-distribution board.

Medical devices

Surgery rooms or operating theatres

Electrical medical devices serve a number of purposes. They can perform treatment, monitoring or diagnostic tasks that would be impossible to execute otherwise. They are among the very few devices that are permitted to bring electric signals directly to human body. Most such contact is with the skin, but some are designed to work internally.

As such, they pose extreme risk to the patient, and the testing procedures for safety have to be accordingly rigorous. Design and testing of medical devices is covered by two standard families. First is IEC 60601, the oldest standard in the field. It covers device design for safety, and testing procedures with limit values. The other standard is IEC 62353 that covers periodic and after service retests, but not design considerations. It takes into the consideration that some medical devices are permanently installed and their power supply cannot be easily reached. Both standards classify devices by ways of protection:

- Class I: three-pole plug, protected by insulation and bonding,
- Class II: two-pole plug, protected by double insulation,
- Class III: battery-operated or using external charger, two pole.

IEC 60601 separates electrical safety to the operator safety and patient safety. Each has specific measures that can be utilised to achieve it, and at least two have to be used for each. Examples of means of protection include insulation with high resistance, grounding every accessible metal surface, properly sized interference suppression capacitors, creepage and air clearance distances. Along with these measures, the standard requires a mechanical construction that lowers the hazard.
Operator protection covers the user in control of the device. Patient protection is essentially protection of applied parts–the ones in direct contact with the patient.They differ by their level of insulation from interference, disturbances, and leakage. IEC 62353 uses the same classification.

- Type B (Body): applied parts not isolated from power supply and enclosure.
- Type BF (Body-floating): applied parts isolated from power supply and enclosure.
- Type CF (Cardiac-floating): applied parts for cardiac applications, isolated from supply and enclosure, highest protection degree.

Both standards require extensive testing of the protective measures. The most measurements are made for leakage current. In IEC 60601, the leakage current tests have to be conducted between any two conductive surfaces of the instrument and in both directions. Leakage towards patient and between applied parts is measured separately with specific methods. This testing with no automatic help is extremely tedious. Depending on number of conductive surfaces and applied parts, there can be hundreds of tests to perform. Other IEC 60601 tests include testing the means of protection: a robust continuity of bonding test (often performed with current above 20 A), insulation test, capacitor test (can be omitted if the capacitors are certified to their own standard), and distance measurement. Some of these tests can only be performed at design stage. All tests are performed in normal working conditions and in single fault conditions. It is most practical to have a measuring instrument that can simulate a single fault. IEC 60601 can also be used as periodic test in a reduced form. The manufacturers who require it select the visual inspection contents and measurements so that they ensure continued safety. IEC 62353 is only concerned with assuring the continued safety of medical devices that can be discerned without having internal access. The most faults are discovered with a simple visual examination, the contents of which are prescribed. for any corrosion, moisture ingress, frayed contacts, and similar. It includes warning labels, symbols, and state of the manual. Electrical tests include earth bond test, insulation resistance and leakage current. Earth bond test is performed with an instrument that can deliver at least 200 mA at open circuit voltage not more than 24 V. Low test currents (1 A or less) are recommended as they can disclose degraded contacts. Testing is done on any conductive accessible surface on the device. For separate supply bonds, higher currents are recommended (at least 10 A), and any possible weak contacts should break entirely during test. Insulation resistance test is not mandatory, it is performed if there exists any doubt about its state. The device has to be disconnected from mains, but all its power switches in ON positions. Regular test voltage is 500 V, but it can be lowered to 250 V if the measuring circuit includes overvoltage protection. Non-isolated and isolated applied parts are respectively bound

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

together for the measurement. There are multiple methods available for leakage current measurement. Most are unique to the IEC 62353, but touch and patient methods derived from IEC 60601 are among the alternatives. The standard contains the method for selecting an appropriate method. In most cases, more than one is necessary to assure the device's safety. Both standards require a certain sequence of testing: first visual inspection, earth bonding, insulation, leakage, and finally any functional tests (mainly prescribed by particular standards for each type of device, but often manufacturers make changes specific to their device).

MEASUREMENTS

MI 6601 MediTest is the new Metrel tester for compliance with IEC 60601, IEC 62353 and non-medical standards. It offers separate connections for Functional Earth and Signal Input/Output connections, and supports programming its 10 connections as applied, earthed or non-earthed parts. Full functionality of the instrument is available without using the laptop in the field, but remote control with PC is also supported. AUTO SEQUENCE®s guide the user to testing solution for each device in the field. MI 3360 M is the variant of MI 3360 with additional support for IEC 62353. While less thorough than MI 6601, it offers high portability and reliable testing for medical and non-medical devices. Both instruments come equipped with help screens, images, wiring diagrams and other additional content.

Patient recovery rooms and hospital wards

Solutions by the Field of Use

Patient recovery areas are a diverse group of places, both indoor and out. They can include everything from hospital rooms to swimming pool or parks and other green spaces. Rules of electrical safety are similar in all of them, as they are all considered public places.

Wet places are defined as unprotected from the weather or exposed to liquids, water or moisture to considerable degree. Such conditions occur in multiple places in a hospital and in patient areas: park lighting, any part of a wellness and recovery centre, surgery room, bathrooms and kitchen. Rooms can also be considered partially wet.

Wet skin is a much better conductor than dry, and sweaty or otherwise salty skin is even better. Contact voltage and leakage current must therefore be significantly lower. Insulation of any electrical equipment in or close to the water must be particularly high and always in good condition. The installation is kept as far away from the water as possible, or mechanically protected from it.

In dry areas only the items or parts that are large enough to be gripped or can contact a significant area of the body surface are considered. Smaller parts are less dangerous even if they do become live. Touching them will cause the muscle to contract away from them and break the contact. Inside a single building, it is also important to have all the protective earth wires at the same potential. For example a communication or computer system that can be constructed entirely separately must still have a protective connection to the common potential.

Public places and workplaces are similar in their general intention: they are both filled with people who are not themselves responsible for the state of installations they use (except in the sense of avoiding damaging it). 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 authorized inspector. Commissioning and periodic tests are mostly the same. Commissioning contains some extra points in the visual examination, before they are covered by décor, furniture or appliances.

MI 3360 M is covers all necessary equipment measurements in the patient's rooms.

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), insulation resistance, leakage currents, impedances in the lines 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. Great majority of problems is discovered visually. It includes everything from checking compliance to wire colours and warning inscription regulations.

LIST OF PRODUCTS IN THE PROPOSED ADAPTABLE BUNDLE:

- MI 3155 EurotestXD
- MI 3360 M Omega PAT XA
- MD 9050 TRMS Industrial multimeter
- MD 116 Non-Contact Voltage Detector
- Metrel ES Manager
- Android Metrel ES Manager
- Custom case

Public and workspace electrical safety in healthcare

Patient recovery rooms

Generally any inhabited space with electrical installation has to conform to safety standards. In Europe, they are written with protection of life as first priority. Public places have to conform to the standards and have a responsible authority confirm their safety before they are open to the public.

Recheck of the compliance is executed periodically during the lifetime of the building and installation. Following the safety standards means ensuring protection from electric shock, electrical fire and explosion.

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Earth resistance
Earth resistance is measured at the main earth electrode. If there is space available and ground allows electrode placement, the 3-wire or spike method is the best. It involves planting two electrodes at a considerable distance (the further at 5 times radius of the building complex and the closer at 62% of this distance) from the measured point and using them to inject current and measure voltage. In urban areas, more often than not this is not possible. In many such sites, 2-clamp method can do the job. 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 the resistance of the whole earthing system as a large circuit of parallel rods, the larger the system, the more accurate the result for each earthing electrode. Both methods are described in more detail in their own notes.

Continuity of PE wire and equipotential continuity
Continuity has to be tested with a 200 mA current and voltage between 4 and 24 V. This measurement is usually done between the measured point and the closest switchboard, and on the higher level between switchboards and the supply point, and eventually the substation. Every contact and switch in the distribution board should be tested. Measurement method is chosen according to situation at hand and grounding system to achieve required accuracy. Accessible metal surfaces have the bonding checked periodically, while built-in construction is only tested before first use and in case of a fault.

Insulation resistance and leakage current
Insulation is a measure of preventing unwanted contact and preventing corrosion of the wire. Insulation resistance and leakage current are alternative ways to determine its quality between phases. Insulation resistance is a test with high DC voltage (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 is measured in AC conditions. It has to consider some capacitance in 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 the PE wire (or alternately a difference between currents in phase and neutral). This way, they provide protection from electric shock. There should be multiple RCDs, 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. They 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 voltage. Contact voltage is the voltage between accessible grounded metal part and the PE contact on the RCD. If the voltage is considerable, which usually means the PE wire is broken, the RCD should trip as well.

Line and loop impedances
Line and loop impedances include creating a short circuit between phases and measuring 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 short-circuit current is calculated. It has to be high enough to operate overcurrent devices.

An electrical installation is not a simple system. The measurements mentioned above can indicate its safety, but it is important the users should have enough information be able to keep themselves safe. Warning labels, symbols and inscriptions are part of the safety as much as electrical features.

MEASUREMENTS

Metrel offers an expansive line of installation testers. They are divided to single-function and multifunction. Single-function can perform one or at most two of the aforementioned measurements. Multifunction can perform all of them, and often extra.

MI 3155 EurotestXD is the newest flagship of Metrel's most advanced line of multi-functional measuring instruments. It is designed specifically for testing in industry, but useful for any kind of installation. It boasts an ergonomic design and an intuitive user interface, encompassing a memory organizer and fully programmable AUTO SEQUENCEs. It is controlled through a large colour touch screen. As is required for any instrument in safety testing, it is fully compliant to functionality standards for instruments (e.g. IEC/EN 61557) and the reference standards for the buildings (e.g. IEC/EN/HD 60364-4-41, ...)

The instrument can perform a wide range of electrical test and measurement, including TRMS current measurements, RCD tests, line and loop impedance tests with 3 and 4 wires, earth resistance measurements, on-line voltage monitoring, phase sequence testing, varistor testing, PI/DAR calculation, luminance measurement, discharge time testing, ISFL measurements, or IMD tests. Users are guided through both visual and functional inspections to reduce chance of missed faults, and graphic help screens are available for each measurement.

The full Metrel solution for public places in a hospital includes also instruments for regular testing of medical and other devices (MI 3360 M OmegaPAT XA) and general troubleshooting multimeter MD 9050.

Electrical safety in hospital wet areas

Patient recovery rooms

Wet area is defined as any that has the potential to get in considerable contact with water. This ranges from areas of particularly high air moisture and condensation to actually submerged areas. In a hospital, such areas are mostly found in patient recovery areas like swimming pools or wellness clinics.

It is also beneficial to consider surgery rooms wet, as saline or even blood can splash to the floor or walls. Electrolyte-rich liquid, like any of those mentioned, is a good conductor, and any spillage causes considerably increased risk of electroshock. Wet skin also has lower resistance, so the consequences of stray currents can be more serious. Similar conditions can be also found outside, in parks or recreational facilities. Electrical safety in such areas must be more rigorous.

Mechanical properties

The first line of safety is mechanical and chemical compliance of any equipment used and parts of installation. Wires and devices should be coated in insulation certified for wet locations. Other types may degrade quickly. Moisture is one of the most common problems with insulation meant for dry places. The main concern is the danger of leakage in combination with water and 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, any kind of massagers, pumps for the baths ...) used in contact with water must have IPX7 or higher protection certification.

Safety areas

Safety areas are defined by the distance from actual submersion in water. E.g. inside of a bath or pool is zone 0. No electrical part should be installed there unless it conforms to the previous paragraph. 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). There is still extra caution advised when working in these areas. Any switches should 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.

MEASUREMENTS

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 monitored as well. Protection by 30 mA RCDs is mandatory, as unexpected shocks are much more probable 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 25 V.

For workers and visitors to the place, it is most important that they care for 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 on the walls and out of reach.

Bathroom and kitchen generally are the most hazardous places in both residential and public places that need thorough bonding. In a hospitals, great care must be taken with bonding the metal beds. Patients are often in a compromised state, their natural defenses are down, and they are very sensitive to even to very small leakage currents.

Helipads and other open air areas are measured as electrical wet area.

Main reasons for faulty voltage difference are a ground to phase fault or a lightning strike. Some types of piping and machinery can also get charged due to friction between moving parts or even friction between the liquid and the pipe it is flowing in. Particularly the latter can cause fires if the liquid is flammable. Once everything is bonded, it should also be safely earthed, and earth wire continuity tested as per standard IEC 61557-4. Acceptable measuring voltage is 24 V and current should be at least 200 mA. Continuity of bonding every item and earth connection has to be checked, plus earth bond and earth resistance.

Metrel offers a choice of installation testers that can work in a wet or any other area as long as it is dried for maintenance. MI 3155 is the first choice for any installation. 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 V, determining its state with high accuracy.

Secondary power sources in healthcare

Solutions by the Field of Use

Hospitals are not only immovable buildings, but can develop wherever they are required: from locations of serious car accident to theatres of war. Most such sites have similar issues. Equipment is brought in from a distance and a fundamental infrastructure must be established, starting with power supply and adequate protection for field instruments. Outdoor situations can be considered essentially both wet and dusty.

The materials are intensely stressed in these conditions and have to be chosen specifically for the job. Most temporary installations are going to work isolated from earth. It is sometimes possible to create an earth connection at the site, but in dry weather, the earth can have high resistance. On the other hand, in wet weather, moisture can lower insulation resistance. Devices are adapted to use on the road, but harsh conditions can lower their life expectancy. Safety for a mobile system has to be established depending on possibility of earth connection as IT or TT.

Safety in the field units depends on their power supply. If the installation is very short-term, it might work with battery power, which usually uses low voltage and is intrinsically safer. Even in slightly longer-term field work, small devices may remain battery-operated.

However, some devices used need natively higher supply voltages, which are impractical to power with batteries. High-power inverters are necessary, and the batteries get impractically large and heavy. The other solution is mobile generators. In terms of safety, they are similar to the fixed-installed type, but smaller, lower power, and more prone to overheating. They have to come with a mobile switching board or equivalent device included, with portable RCDs and protection from transient effects when adding and removing consumers.

Mobile distribution board is visually very similar to fixed version.

If multiple generators are in use, full galvanic separation between circuits they supply has to be guaranteed.
Ambulances are scaled down field hospitals. Every instrument has to be scaled to be portable and low-powered while maintaining as much functionality as possible. The installation is isolated and depends on the generator and battery power. Particularly the vehicles adapted from standard vans have been found to not conform to safety in these requirements, only to functionality. Regardless of their origin, all the vehicles should routinely be tested after every deployment. The predominant safety tests are similar to a fixed IT system: mainly insulation and leakage. Handheld PAT and IT tester should be part of the equipment on board.

LIST OF PRODUCTS IN THE PROPOSED ADAPTABLE BUNDLE:

- MI 3110 EurotestIM IT system tester
- MI 3309 BT DeltaGT Handheld PAT
- MI 3242 MicroOhm 2A Continuity tester
- MD 9231 TRMS AC/DC clamp meter
- MD 9272 Leakage clamp meter with power functions
- MD 9050 TRMS Industrial multimeter
- MD 116 Non-contact voltage detector
- Metrel ES Manager
- Android Metrel ES Manager
- Metrel PATLink
- Custom case

Generator safety

Secondary power sources in healthcare

Diesel or petrol generators are the main backup electrical sources. They are small, easy to obtain, easy to maintain through years of disuse, cheap and reliable. They can provide power for extended period of time: as long as they have fuel. Start-up is quick with automatic options available, even though it requires some care for electrical safety before firing it up.

They have two main uses in a hospital. First is as main backup power source in case of an outage. This has to be a large and powerful machine, able to power the emergency lights and outlets in the whole complex. Patient lives depend on its power. Usually, the emergency installation covers about half the lights and any outlets with life-support machinery.

Second use is the smaller generators for field work. Both ambulances (when stationary) and field hospitals need a power source, and batteries aboard can only cover a relatively short time. Generators also provide AC voltage at values similar to fixed installation, while batteries need converters. Most of the appliances in the ambulance or a temporary hospital are more suited to regular mains voltage, while others have their own batteries.

Main safety concern about a generator is not physical, like insulation or leakage, but human factor. It is sometimes not trivial to connect it to an existing installation. Circuit rules have to be followed. Main consideration is separating any parts of the installation that could be powered by other sources from parts powered by the generator. If multiple generators are used, synchronization of rotary field, frequency, phase and voltage is necessary. A hospital that must get backup power running as fast as possible will likely opt for an automatic process. The necessary device is built into the main switchboard. The emergency installation is already prepared for backup supply and the fixed connection point is available by design, making the transition easier and smoother.

Testing the control panel of secondary power source in an ambulance.

Testing the control panel of secondary power source in an ambulance.

MEASUREMENTS

Protection in case of backup power consists of overcurrent devices and RCDs. The whole temporary installation must exhibit proper insulation and low line and loop impedances. The earthing is usually reused from primary installation and must be always in a good condition. These tests can be performed by a Metrel multifunctional installation testers, like MI 3155.

Mobile generators will operate in isolated conditions or in case the powered earthed devices are galvanically separated. The generator can also have an earthed neutral point if the soil on the location allows that. In this case, they can also be used for powering an earthed installation. They can be protected by PRCDs or RCDs, must have an overvoltage or overcurrent protection, and their insulation materials and any extra equipment have to be adapted for outdoor use. Mobile generators have to be carefully chosen for their intended use. They can be sometimes designed to power only one consumer at a time. They cannot handle the disturbances caused by plugging or unplugging multiple devices in this case. Extra features of course mean an extra cost. If the intention is to have them built-in to intervention vehicle, their thermal output has to be considered as well.

To confirm the condition of the mobile installation and the appliances in it, they should be tested after every intervention. This is not a common practice, as testing is time consuming and can be expensive. Still mobility is the part of the installation that needs most frequent tests. An ambulance is a first-line intervention vehicle and lives depend on its reliability, so no error should be allowed.

Ambulances

Secondary power sources in healthcare

An ambulance is a combination of automotive, medical and utility technology, all tightly fitted in the smallest possible space, and with human lives depending on it. Electrical functionality and safety of each part must be established frequently and with highest possible confidence.

First part of ambulance functionality is plain movement. Modern vehicles contain, apart from traditional vehicle electrics, also a large amount of electronic tools and aids for keeping it on the road in any condition. There are automatic systems checking their functionality, while electrical safety is inherent due to their low operational voltage. The only danger they pose is failing unexpectedly. It is the manufacturer's responsibility to create effective fail-safes and checks.

Medical devices on board are about preserving life. They must be scaled to lowered power of the supply. Ambulances can be equipped with an extra generator to providing higher supply voltages, or with extra batteries and a powerful inverter. In both cases, maximum available power is much more limited than in a fixed supply. All equipment has to be adapted to such use, or be low-powered in the first place. The same goes for measuring instruments for keeping the medical devices in shape. Battery powered and handheld versions have a strong advantage for both power and space. Other devices are utility. From lighting to fridge for medicines or food on the way, they make ambulance work possible. They can mostly work either from the 12 V car battery or the higher voltage generator. Testing equipment for them has to take this into account.

Currents are too low to cause notable cross-talk or other wireless effects. Power quality of the output from the generator then almost exclusively depends on the inverter quality, while DC from the car battery is by definition a bit variable. Devices that run on it must be able to tolerate voltage between about 10 and 14 volts. A good quality inverter will have output filters to output nice single-frequency sine signal, or a good-enough approximation. However, cheaper types may not; their output is nearly perfectly

The fastest emergency responders usually arrive by motorbike. Any device they carry is strictly battery powered.

Entrance to the ambulance with parts of workspace visible.

rectangular, full of higher harmonics, and troublesome for supply of any sensitive device. They can be adequate for some devices that contain input filters, or are quite insensitive to harmonic content.

Ambulances can be designed for this purpose from scratch, or they can be adapted from a different vehicle. Field tests showed that adapted vehi-cles are often less reliable and their electrical integrity is questionable. They absolutely should be tested periodically and after every deployment. Designed from scratch vehicles are considered the more reliable choice. A brief check-up after deployment and a thorough test at manufacturer-advised intervals should keep it running properly.

MEASUREMENTS

Measurements are very similar to testing in isolated systems. However, instruments will often be exchanged for their smaller, more portable variants that allow the garage crew to move from one vehicle to the next fast and easily. Portability is also extremely important if the instrument is carried aboard, which may be beneficial to do. MI 3110 is the basic instrument for testing the higher voltage installation in the vehicle. It measures insulation, line impedance and voltage parameters in an Autosequence®. Lower voltages can be tested simply with a multimeter with a clamp, like MD 9231. Basic safety of devices can be established with MD 3309 DeltaPAT. It can measure insulation, continuity with 200 mA and leakage currents. It doesn't support extra measurements for medical devices, so they have to be tested separately and possibly outside the vehicle. Autosequence®s with guides to visual inspection can be created by request in any Metrel instrument and therefore the most important part of the safety is covered.

Field hospital

Secondary power sources in healthcare

The term mobile installations refers to the wiring and equipment found in cars or temporary constructions. Even private cars contain considerable amount of wiring and electronic devices, from main user-interface computer to a number of chips in the engine to the simple window-opening mechanism these days.

Special vehicles like ambulances, firefighters' truck, reporters' cars and similar contain extra appliances appropriate to their role. Other mobile installations include any kind of temporary construction, from beer tents at festivals to field hospitals.

Vehicles can be constructed with the whole installation from scratch or adapted from an existing general-purpose design. The adaptations are often inadequate in regards to electrical safety, as functionality is the first priority. Any adapted vehicle has to be thoroughly tested on commissioning and, ideally, after every deployment. The user has to be particularly aware of its limitations.

Mobile installation can be powered by either batteries or a generator. Batteries deliver power immediately, but don't last indefinitely, and only offer a limited DC voltage. A standard car battery, for example, provides output of 12 VDC. Conversion to 230 VAC is, therefore, essential. For special purpose vehicles it can be already built-in, and that is generally the best option. It is then chosen with a specific use in mind and creates the necessarily clean sine signal with the intended power. If not available in the vehicle, the units in the market vary from cheap consumer pieces that only chop the voltage and cause high harmonic content to high-quality powerful units with perfect sine output. Price and performance have to be considered for the application at hand.

Generators usually cannot be started at once, but are more powerful, can work until they run out of fuel, and produce AC voltage at the designed magnitude. They inherently pose more danger to the user with their higher voltage output. They are often designed for specific purpose, like powering a single consumer, and straying from that purpose can be dangerous. In special purpose vehicles, they can be built-in and likely to be adapted to their expected use. For temporary installations, they

Electrical switchboard and inlets for army mobile hospital's power supply.

Measuring continuity of protective earth on mobile medical equipment is no different from fixed versions.

have to be carefully chosen to be able to keep up with needs.

Regardless of the power supply, it is possible to use the mobile installation when isolated from ground, or create a temporary earthing. The latter should only be attempted if the ground is suitable for an easy stake and its specific resistance low enough. This is a relatively rare occurrence when in the field. The earth has to be measured in advance (specific resistance) or once the stake is set (earth electrode resistance), or preferably both, to establish safety of the system.
If working isolated from ground, there might be higher interference between devices. Insulation and contact voltages become the main safety considerations. It has to be taken into account that a lot of temporary installations are set up outside and exposed to the elements. Moisture, UV, vibrations and other exposure can lower insulation resistance and leads to faster deterioration.

Any temporary installation has to be protected by overcurrent devices and by RCD or PRCD switches. Battery-operated DC installations can work with only overcurrent devices I. In case of a single fault, the supply should be automatically cut off.

MEASUREMENTS

Testing mobile installations is the only way to assure safety of their users. Measurements are very similar to their counterparts in the fixed installations, but often performed with hand-held instruments that are easier to carry in the vehicle. Metrel has a set of instruments prepared for any mobile need: handheld PAT tester MI 3309 DeltaPAT, tester for isolated areas MI 3110, the clamp meter for higher currents MD 9231 with non-contact detection of electromagnetic fields and VFD, the universal troubleshooting leakage meter MD 9272, and continuity tester MI 3242 to check any problems with the wiring of the generator. If there is a reason to consider using the stake for the earth electrode, one can benefit from the MI 3121, the hand-held earth tester. Together, the instruments form a comprehensive measuring solution that should be carried on board at all times.

Selection guide by application

Selection guide

LOCATION	Application	Appliance / Machine / Switchboard Safety			Electrical Installation Safety	
		MI 6601 MediTest	MI 3360 OmegaPAT XA	MI 3309 BT DeltaPAT	MI 3155 EurotestXD	MI 3110 EurotestIM
						
HOSPITALS AND HEALTH CENTERS	Basic safety of electrical installations				•	•
	Additional safety of electrical installations				•	
MEDICAL SITES ELECTRICAL INSTALLATIONS	Transformer protection and automatic trip-out ability					
	Substation earthing and grounding					
	Patient pools and recovery areas				•	•
	TN/TT earthing and grounding systems				•	
	IT earthing and grounding systems/single fault leakage and insulation monitoring				•	•
	Surgery rooms installations testing				•	•
	Patient recovery rooms electrical safety	•	•		•	
	Troubleshooting and maintenance				•	
BUILDING LIGHTNING PROTECTION SYSTEM	Earthing and grounding measurements				•	
	Lightning protection with surge protection devices				•	
	Contact voltages on semiconductive surrounding				•	
GARAGES AND AMBULANCE CARS	Low voltage installations on vehicles				•	•
	Fixed electrical generators		•		•	
	Mobile electrical generatos			•	•	
	Troubleshooting and maintenance				•	
MEDICAL APPLIANCES, PORTABLE AND FIXED APPLIANCE SAFETY	Biomedical appliances safety	•	•	•		
	Surgery tables and towers	•	•	•		
	Electrical equipment safety	•	•	•		
POWER QUALITY ANALYSING AND ENERGY MANAGEMENT	Class A voltage quality analysis					
	EMC compatibility, harmonics and THD, flickers	•	•		•	
	Troubleshooting with preset triggers and alarms on disturbances trigger					
MEDICAL INDOOR ENVIRONMENT QUALITY	Microclimatic conditions				•	
	Noise analysing				•	

	Continuity testers	Power Quality Analysis	Multimeters and IR cameras		
MI 3144 Euro Z 800 V	MI 3242 MicroOhm 2A	MI 2892 Power Master	MD 9273 Current clamp	MD 9050 TRMS multimeter	MD 116 Non Contact Voltage Detector
					
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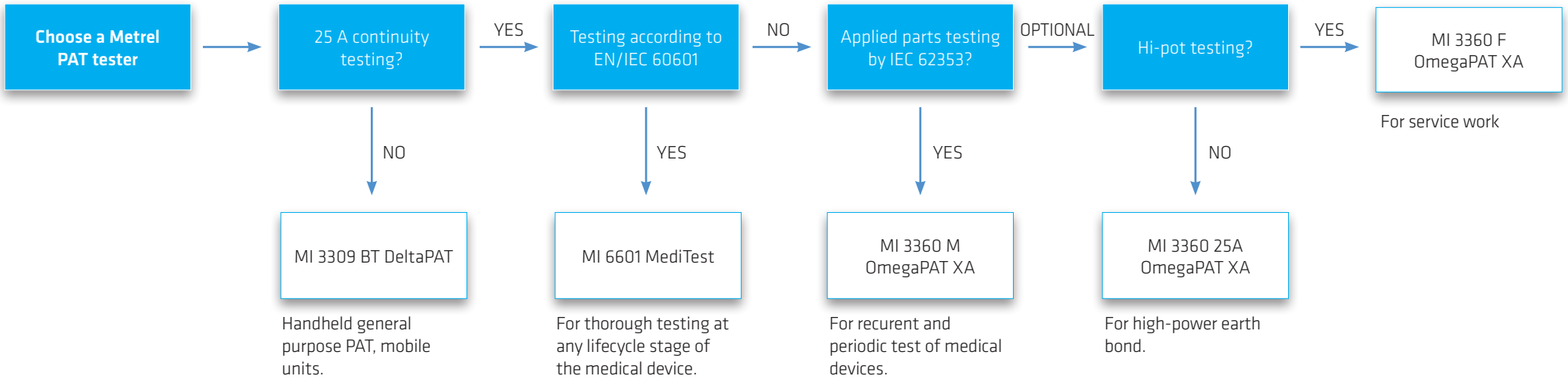
Selection guide for electrical equipment testing

Selection guide

Consider your measuring needs in portable appliance safety area. The graphical guide contains the most defining measuring capabilities and physical properties of the instrument models. There are other properties that may influence the decision. For more information, see instrument descriptions in the following chapter.



MI 6601 MediTest

Appliance / Machine / Switchboard Safety

MEDICAL APPLIANCE SAFETY AND MORE

MI 6601 MI 6601 MediTest is the new Metrel tester for compliance with IEC 60601, IEC 62353 and non-medical standards. It offers separate connections for Functional Earth and Signal Input/Output connections, and supports programming its 10 connections as applied, earthed or non-earthed parts. The patient connections also expand its compliance to IEC 62353. Full functionality of the instrument is available without using the laptop in the field, but remote control with PC is also supported. AUTO SEQUENCE®s guide the user to testing solution for each device in the field. The new feature for removal of tests right before starting points the user in the right direction for successful test execution. Unique in the field of medical testers, MI 6601 can be used to test non-medical devices according to EN 50699 and EN 50678.

MEASURING FUNCTIONS

- PE resistance with 200 mAAC and 25 AAC;
- Insulation resistance with test voltage 250 VDC or 500 VDC.
- All test configurations acc. to IEC 62353 are supported;
- Leakage current measurements with 1 µA resolution;
- AC, DC and TRMS value of leakage currents;
- All leakage current measurements as defined in IEC 60601-1 standard (patient, auxiliary, earth, touch);
- All leakage current measurements as defined in IEC 62353 (equipment and applied part; alternative, direct, differential method);
- Measurement according to portable appliance standards EN 50678 and EN 50699;
- Point-to-point, touch and mains voltage tests;
- Equipment power;
- IEC lead test;
- Pre-set or configurable visual and functional inspections.

RECOMMENDED SET MI 3360

- Instrument MI 6601 MediTest
- A 1080 Mains cable
- A 1758 Test lead, black, 1 m
- A 1759 Test lead, brown, 1 m
- A 1760 Test lead, green, 1 m
- A 1761 Test lead, yellow, 1 m
- A 1762 Test lead, violet, 1 m
- A 1014 Test probe, black
- A 1298 Test probe, brown
- A 1062 Test probe, green
- A 1013 Crocodile clip, black, 2pcs
- A 1297 Crocodile clip, brown
- A 1309 Crocodile clip, green
- A 1546 Crocodile clip, yellow
- A 1727 USB cable
- A 1017 Communication cable RS232
- A 1500 Bag for accessories
- Subscription to Metrel Medical Software solution:
  - Metrel Medical ES Manager
  - Metrel Cloud Reports
  - Metrel Cloud Storage


Lightning
Aquilion
TOSHIBA
0
LifePulse 110
MI 6601

MI 3360 M OmegaPAT XA

Appliance / Machine / Switchboard Safety

MEDICAL APPLIANCE SAFETY AND MORE

MI 3360 is a group of four instrument variants with different applications. Three of them are useful in medical environment with their support for high-current (10 and 25 A) continuity test. MI 3360 M Omega XA is the specialized PAT tester that supports measurements by standard IEC 62353 for periodic testing of medical devices, mainly the much more accurate leakage current measurements. 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, multifunctional 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. Large graphical LCD with backlight, the PASS / FAIL LED indicators and HELP screens for each measurement make the handling 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. Lightweight design, 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. It also 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.

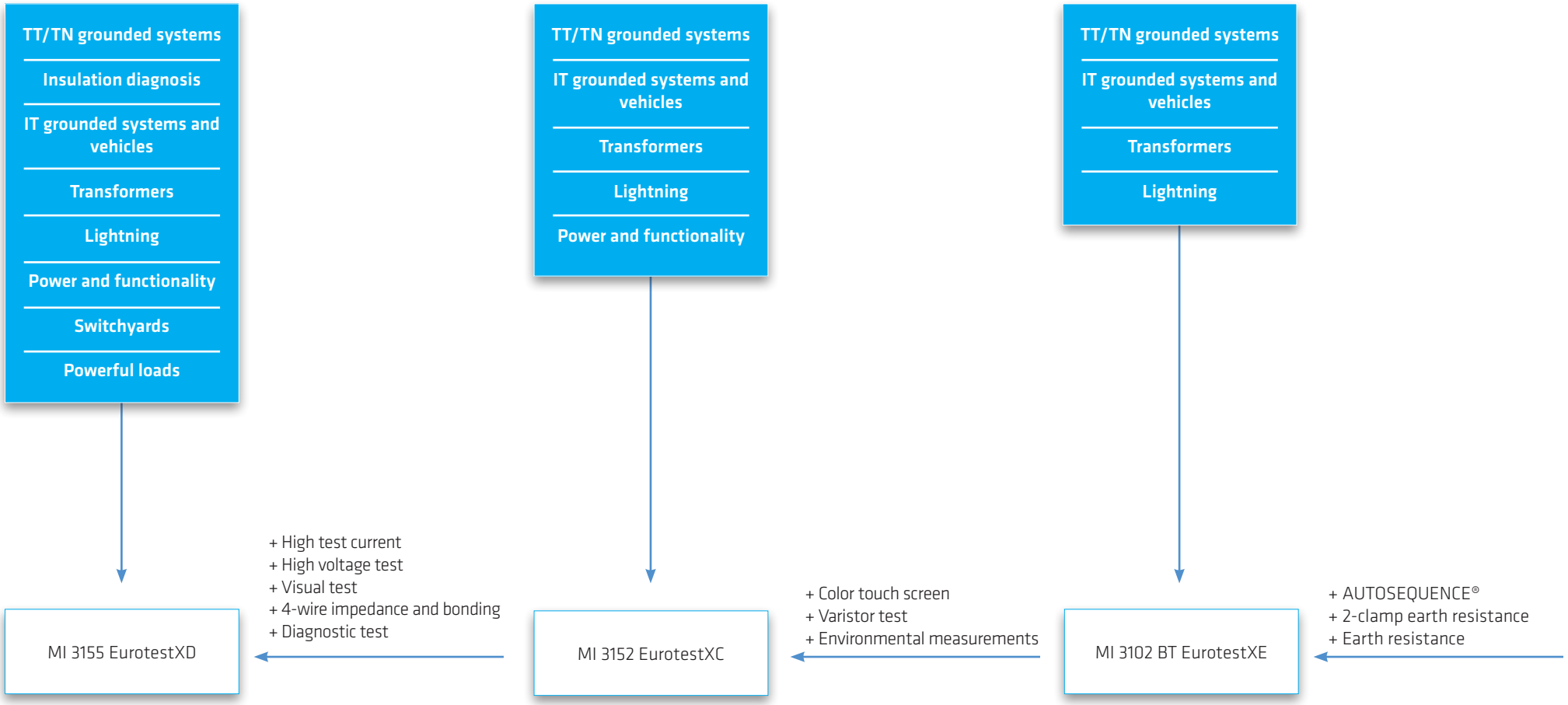
RECOMMENDED SET MI 3309

- Instrument MI 3309 BT DeltaGT
- Small soft carrying bag
- IEC cable, 2 m, 2 pcs
- 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

Selection Guide for Electrical Installation Safety

Selection guide

Metrel multifunction installation safety testers are a wide and various family that can cater to any budget and workflow. Each can guarantee basic safety, but models higher up the line can offer much wider measuring capabilities, more comfortable UI with touchscreen and colour display, and applications in much more variable environments. The guide contains some models that are not described in the span of this application catalogue, but may fit with the chosen application. For more extensive infromation, see the descriptions in the following chapter and our webpage, 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 option for earth analysis and various additional measurements. In medical environments, 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 PC software.

MEASURING FUNCTIONS

- Live Transformer's Impedance Measurement with Four Wire Test;
- High-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)

MI 3110 EurotestIT

Electrical Installation Safety

- Voltage drop;
- First fault leakage current (ISFL);
- Testing of insulation monitoring devices (IMD);
- Fuse characteristics evaluation.

RECOMMENDED SET MI MI 3110

- Instrument EurotestIM
- Soft carrying bag
- Mains measuring cable
- Test lead, 3 x 1.5 m
- Test probe, 3 pcs
- Crocodile clip, 3 pcs
- S 2058 Insulation test plates
- Set of carrying straps
- RS232-PS/2 cable
- USB cable
- Set of NiMH battery cells
- Power supply adapter
- PC software EuroLink PRO
- Instruction manual on storage media
- Handbook on storage media

ISOLATED SYSTEM SAFETY AND FUNCTIONALITY

Simple tool for specific task: automatically testing the safety of IT earthed systems, both permanently integrated or portable (e.g. vehicles, temporary installations, generators). With single pre-defined AUTOSEQUENCE® with sub-tests and adjustable limits, it is possible to thoroughly verify the safety of any low-voltage IT installation. Ease of use is the first priority, minimizing the chance of human error. The AUTOSEQUENCE ® can be started with a single press of a button and returns an array of PASS or FAIL notifications for each included measurement. It can be set to keep RCDs from tripping and the power always on. The PASS levels, as defined in standard IE/EN 61508 are saved in advance, but can be changed if the installation has special needs. Once the PASS notifications for each measurement in the series is reached, the installation is good to go. MI 3110 is easy enough to use to be the first line of troubleshooting tool. Even a layman can plug it into the socket and see whether any of the results are off.

MEASURING FUNCTIONS

- Voltage, frequency and phase sequence;
- Line impedance and prospective short circuit current;

MI 3144 Euro Z 800 V

Adapter

Euro Z 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 reach up to 300 A test current. It is mainly applicable in industrial setting, 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 3144

- 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 licence key
- Short instruction manual
- Calibration certificate
- Protective bag for accessories
- Soft carrying bag

MI 3242 MicroOhm 2A

Continuity testers

EQUIPOTENTIAL BONDING AND LOW RESISTANCES WITH 2 A CURRENT

MI 3242 MicroOhm 2A meter with current ability of 2A is a portable low resistance ohmmeter used to measure low resistances of switches, relays, connectors, bus bars, power distribution cable joints, motor and generator windings, power transformers, power inductors, rail track joints, wire and cable resistance, welding joints for industrial application, etc. It can be used for regular check of earth continuity and equipotential bonding, which importantly adds to prevention of electrical shock. In medical applications, the limit on bond resistance is very low. To test it, the instrument must support 4-wire measurement and high enough measuring current. Other features involve four measuring modes (including inductive), resolution down to 1 μΩ with the 4-wire Kelvin measurement method, quality noise rejection, battery operation, customization of pass/fail limits, 1500 places in internal memory and PC software for downloading, review, analysis and printing of test results. Battery can handle more than 800 measurements of 500 mΩ at full current. Safety of the user is assured: overvoltage protection of CAT III/600 V for measurements at locations of low line resistance and internal protective circuit that protects both user and instrument from inadvertent connection to lines. Result in full resolution can be transferred to PC for further processing. MI 3242 can be a simple and handy troubleshooting tool at suspicion on continuity problems. Its use is intuitive enough for layman to use. PASS/FAIL indicator is initially programmed with limits as defined by safety standards. When fault is confirmed, technical personnel can be alerted.

MEASURING FUNCTIONS

- Bidirectional resistance measurement from 1 μΩ up to 199.9 Ω with test current up to 2 A;
- 4-wire Kelvin measuring method.

RECOMMENDED SET MI 3242

- Instrument MI 3242 MicroOhm 2A
- Test cable with Kelvin Probe
- Test cable 4 wire, 2.5 m
- Crocodile clip, 4 pcs (2x black, 2x red)
- Test probe, 2 pcs (black)
- Power supply adapter
- 1.2 V NiMH rechargeable battery, 6pcs
- RS232 serial cable
- USB cable
- Soft carrying bag
- PC SW HVLink PRO
- Instruction manual on storage media
- Calibration certificate

MI 2892 Power Master

Power Quality Analysis

MEASURING FUNCTIONS

Top of the line Class A power quality recorder for both one 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 recognize the most typical disturbances in the network and sound the alarm when recognizing them: transients, inrush current, voltage events like dips, swells or interruptions, flickers, and others. It can measure according to standards IEEE 1459, IEEE 1448, EN 50160 or IEEE 519. The instrument is designed for a long-term recording as well as for troubleshooting power quality problems. The handy Quick Set buttons allow faster data overview for troubleshooting. Standard Smart clamps can be detected automatically and the instrument prepared for their division ratio. Advanced PC SW package PowerView3 enables detailed analysis of recorded data, direct reading from the microSD memory card, analysis of long term records and automatic creation of professional test report. Instrument supports microSD cards up to 32 GB, which makes for more than a year of recording. Standardly included is 8 GB.

MEASURING FUNCTIONS

- Voltage/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 IEEE 1459, IEEE 1448, EN 50160 or 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 1502), 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

9272 Clamp meter

Multimeters and current clamps

TROUBLESHOOTING WITH LEAKAGE MEASUREMENT AND ESSENTIAL POWER QUALITY

The **MD 9272 Clamp meter** is a unique 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 troubleshooting. MD 9272 is an all-around tool for any engineer or electrician.

MEASURING FUNCTIONS

- TRMS AC and DC voltage measurement;
- TRMS AC current measurement;
- Frequency measurement;
- Power measurement;
- THD and harmonics measurement (up to 12th 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 AAA, 2 pcs
- Pouch
- Instruction manual
- Warranty

MD 9050 TRMS multimeter

Multimeters and IR cameras

ESSENTIAL MEASUREMENTS

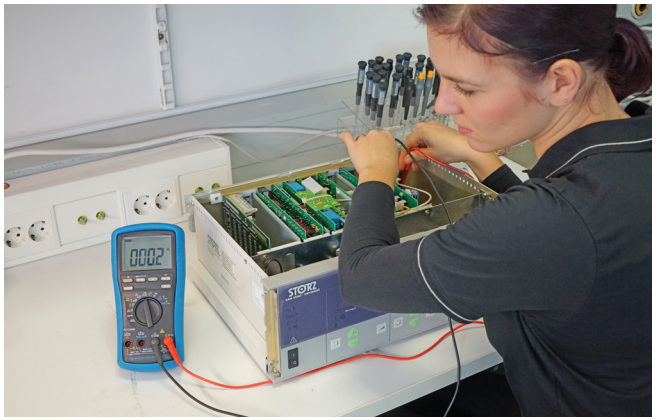
Every electrician's best friend, the universal **MD 9050 TRMS multimeter**. MD 9050 is feature-packed and easy to use, even with one hand, and has a large easy to read screen with two lines. The bar graph allows tracking fast changes while slower screen keeps high accuracy and resolution. It offers non-contact voltage detection that enables quick fault-finding.

MEASURING FUNCTIONS

- TRMS AC, DC voltage/current measurement;
- Capacitance/Resistance measurement;
- Diode test;
- Mains supply frequency measurement;
- Frequency of digital signals measurement;
- Continuity test (acoustic signalling);
- Conductance measurement;
- Electric field detection;
- Temperature measurement.

RECOMMENDED MD 9050

- Multimeter MD 9050 with rubber holster
- Test lead with probe, 2 pcs
- Thermocouple probe, type K
- 9 V battery
- Instruction manual
- Warranty



MD 116 Voltage Detector

Multimeters and IR cameras

BASIC SAFETY CHECK

The **MD 116 is a non-contact voltage tester** that features an optical, acoustical and a vibrating indicator. It comes complete with a pocket clip. It is easy to operate and is an essential tool for both home handymen and professionals. The MD 116 can detect live-voltage wires in splices, cable plugs, cable drums, sockets, switches and junction boxes. The operation of the MD 116 is self-tested automatically after power up. No extra button required. It supports switching between low and high sensitivity (12 / 90 V AC) and has an integrated LED flashlight for working in dark conditions. The Metrel MD 116 uses a capacitive measuring process. In contrast to inductive measurements, no flow of current is required.

MEASURING FUNCTIONS

- Non-contact voltage detection from 12 V AC;
- High performance LED flashlight;
- Optical, acoustical and vibrating indication in case of power.

RECOMMENDED SET MD 116

- Non-contact voltage detector MD 116
- 1.5 V battery, type AAA, 2pcs
- Instruction manual
- Warranty

Featured accessories

Accessories

Photo	Part number	Description	MI 3155	MI 3123	MI 3360	MI 3110	MI 3309 BT	MI 3242	MI 2892	MD 9050
	A 1011	3-wire test leads	•			•				
	A 1018	Current clamps for earth and lightning measurement	•							•
	A 1019	Current clamps for earth and lightning measurement	•							
	A 1055	2-wire leads	•			•				
	A 1074	Mini current clamp 200 A/0,2 A	•							
	A 1160	NiMH battery charger				•	•	•	•	
	A 1169	Large NiMH battery charger				•	•	•	•	
	A 1172	Luxmeter sensor	•							
	A 1198	Magnetic contact probe	•						•	
	A 1199	Ro-adapter	•							
	A 1201	Insulated rod for continuity measurement	•							

Photo	Part number	Description	MI 3155	MI 3123	MI 3360	MI 3110	MI 3309 BT	MI 3242	MI 2892	MD 9050
	A 1256	Plug commander	•							
	A 1272	Plug commander for Smartec				•				
	A 1391	AC/DC current clamp	•							•
	A 1401	Tip commander	•			•				
	A 1408	Kelvin probe				•	•	•	•	
	A 1436	Bluetooth dongle					•			
	A 1488	Bluetooth, battery-operated printer			•	•				
	A 1105	Barcode/QR scanner			•		•			
	A 1556	Medical adapter for MI 3360 M			•					
	A 1567	Li-Ion battery 4400 mAh	•							
	A 1568	Li-Ion battery 8800 mAh	•							

Photo	Part number	Description	MI 3155	MI 3123	MI 3360	MI 3110	MI 3309 BT	MI 3242	MI 2892	MD 9050
	A 1579	Current clamp			•					
	A 1588	4-wire test lead							•	
	A 1610	Continuity test adapter			•					
		Metrel ES Manager Basic	•		•					
	P 1102	aMESM	•		•					
	S 2001	Earth test set 4-wire 20m	•							
	S 2002	Earth test set 4-wire 50 m	•							
	S 2058	Insulation plates	•		•					
	S 2080	NiMh batteries			•	•	•	•		
	CS 2099	Eurocheck	•							
	AMD 9023	K-type thermal probes								•

Literature and education

Academy@Metrel®

A key part of any solution is education on it and its usage so 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 product managers. The literature for lectures and exercises for practical work are provided as part of the training.

THEORETICAL PART

Theoretical part covers the standards used, reasoning behind them, advice on safe measurements, measurement methods and instrument properties.

In medical settings, the typically applied standards are counted below.

Equipment standards:
- IEC/EN 60601: The first standard covering electrical safety of medical equipment. Any instrument in medical use needs to conform to at least edition 2, although 3.1 is the latest. It is now mainly used for type testing and commission testing.
- IEC/EN 62353: Covers the periodic testing of electrical safety of medical equipment. It is less comprehensive than 60601 and the tests it includes are designed for installed machines.
- IEC/EN 60335 and VDE 0701–0702: International and German standards for safety of portable electrical equipment in general. They are useful for most household or office equipment.

Installation standards:
- IEC/EN 61008 and IEC/EN 61009: standards for functionality and design of residual current devices with or without the inbuilt overcurrent protection.
- IEC/EN 60364: Standard family that covers LV installations in buildings.
  - Part 60364-4-1: Covers safety of LV installation and defines earthing systems,
  - Part 60364-5: Covers generator use,
  - Part 60364-7: Covers special locations, including medical special locations and mobile units.
- BS 7671: British IET Wiring Regulations
- AS/NZS 3017: Australian and New Zealand's verification guidelines for electrical installations.

Other:
- IEC/EN 61557: Measuring equipment for safety in LV electrical installations. Part 9 covers also the search for insulation damage in IT systems.
- DIN 5032: German standard for photometry, important for workspace environment measurements.

PRACTICAL PART

Measuring methods cover the necessary techniques that provide most accurate results. There is a lot of fascinating engineering behind each of them and each has its strong and weak spots that prospective users need to know. The lectures include also use of both standard and advanced accessories in any instrument combinations. Instrument properties make these methods possible while also being user friendly, simplifying the procedures and preparing data for reports.

Practical part covers pre-defined exercises with instruments that prepare users for real-life challenges. Metrel offers a wide choice of demonstration tools that make presenting use of instruments and measurement methods interactive. Students can try them out during the lessons. Application trainer corner is possibly the most powerful 3D simulator of real-life safety and quality situations and a great training and demonstration platform for any installation or equipment.

Demonstration equipment

Academy@Metrel®

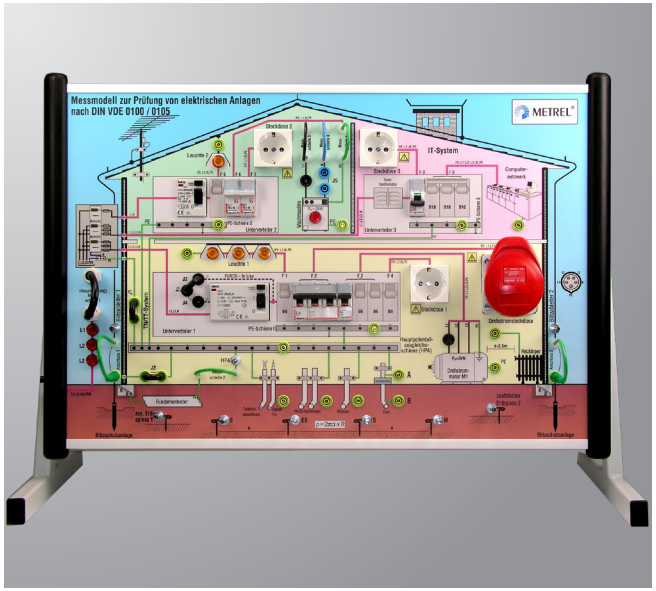
MI 3399 SAFETY AND QUALITY APPLICATION TRAINER

A stand-alone unit for demonstrations, training and educational purposes. It is highly suited for work with groups as well as for individual practice. It contains various integrated electrical elements that allow for complete simulation of typical errors in the house or public electrical installation, grounding and earthing systems, lightning protection, one- or three-phase systems, and more. It contains special locations like surgery rooms 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 RCDs 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 in-stallations. The Demonstration board consists of all significant elements of electrical installations like RCDs of different types, fuses, PE equal-ization bars, 1-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.

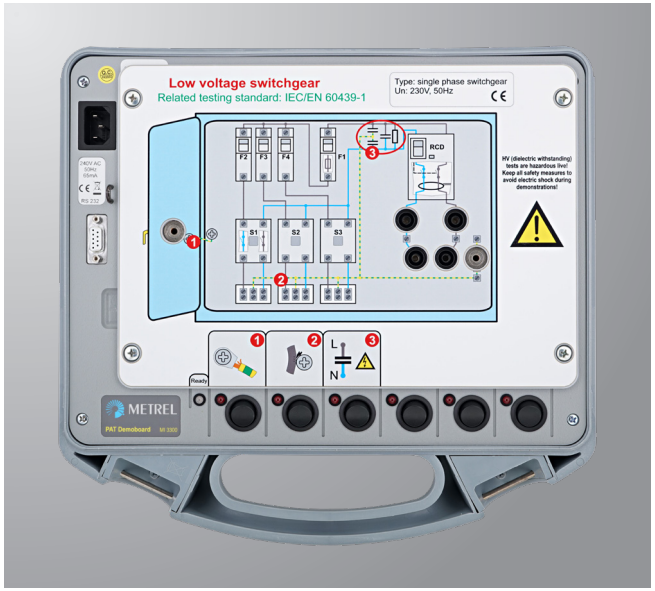
MI 2166 DEMONSTRATION BOARD FOR SIMPLE LV INSTALLATION

Demonstration board MI 2166 simulates common electrical installation usually met in houses or apartments. 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 strong rugged portable 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 Demoboard the ideal unit for teaching or assessing learning in classrooms, training sessions, demonstration sessions, seminars and on 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);
- On demand the demonstration board can be simply upgraded with new tables;
- Normal and fault situations can be switched on and off, offering fault conditions for the assessment of learning;
- Demoboard 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/CALIBRATOR

The MI 2891 Power simulator/calibrator is a multi-purpose three phase power simulator for simulating typical situations in low voltage power supply systems. It is an excellent tool for training, demonstration purposes, or as an electrical didactic tool. The simulator has some pre-programmed scenarios, and also the option of a complete manual mode. The user can decide between different load character adjustments, 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.

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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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