Maritime systems

Electrical safety and availability

Design the future
of energy

BENDER

Content

Solutions
for maritime applications

The maritime industry is confronted with high investments in a harsh environment. In order to have safety while at sea, all systems on board must be completely reliable.

Electrical safety on board of vessels

How was electricity introduced on board of ships?
In 1880, the SS Columbia, a 100 m cargo and passenger steamship, was the first vessel with electrical lighting. Radios, engine order telegraphs and board phones were the next systems to follow. Steam has been replaced by electricity as a secondary power for well over a century. Currently, the need for secondary power in reefer container vessels or cruise liners is 15 MW or more. Since this power is also needed in ports and at the same time the legal requirements for emission limits are continuously tightened, vessels will be fed by means of shore power solutions to shut down their generators – the so-called cold ironing.

By 1880, electrical propulsion was quite common, especially in smaller boats. The first diesel-electric propulsion system was installed in 1903 on a 75 m Russian tanker. Today, these systems have capacities of more than 100 MW. In 2010, the first solar-powered vessel sailed around the world. In recent years, battery and hybrid-powered ferries and tugs are getting more and more popular again and other boat types are following. 140 years ago, only lighting was powered through electricity. Now, power supply is needed across the ship, creating an urgent need for electrical safety to protect both machinery and the people onboard.

What does electrical safety on board mean?
A set of rules and standards helps engineering electrical systems and safety on vessels. One goal is to decrease electrical shock hazards by detecting and reducing leakage currents. The other is to maximise the availability of electrical systems on board, since no electrical power is a danger too. It is important to detect faults before the system fails to enable planned maintenance instead of spontaneous reaction in the worst case of a storm at sea.

Bender provides electrical safety products that contribute to optimum operational safety and reliability in power and control supplies. The extensive solutions we offer today are based on more than 80 years of experience.

Our products are developed for demanding maritime applications including power distribution, electrical propulsion, control & automation and offline monitoring of safety-relevant loads such as fire pumps.

- ISOMETER® – Insulation monitoring device for insulation fault detection
- Insulation fault location systems (EDS) for pinpointing the fault without switching the power off
- Neutral grounding resistor monitoring (NGRM) and fault detection for high-resistance grounded systems (HRG)
- Systems for the electrical safety of medical facilities on board
- Residual current monitors (RCM) for hotel services, galleys and laundries
- Alarm indicator and operator panels
- Communication solutions

Different kinds of electrical systems: Make sure that the electrical supply on board your vessel is always guaranteed.

The electrical power supply on board of ships is complex. It is divided into different systems to fulfil the respective requirements. This guarantees a high degree of availability and ensures that standard equipment can be used.

In detail:

- Primary distribution system – directly connected to generators
- Secondary distribution system – powered by transformers
- Emergency power system – powered by emergency generators
- Hotel load
- Electrical propulsion and variable-frequency drive (VFD)
- Control system – mostly DC 24 V for automation, sensor and control power supply
- Power supply of on-board hospitals
- 400 Hz system for aircraft, military and radar applications

The primary system distributes the energy of the generators throughout the vessel and electrical propulsion system if available. The voltage levels depend on the vessel size and typically range from AC 400 V to 690 V in low-voltage systems and from 6.6 to 11 kV in high-voltage systems. Mostly, they are 3-phase systems with 60 Hz but 50 Hz are also common. Currently, low-voltage DC buses get more common, so that generators can run at variable speed to achieve better fuel consumption and compliance with increasingly strict emission standards, especially for dynamic positioning in offshore applications.

The complexity of the electrical system and the voltage levels used depend on the total power demand.

Independent electrical power supply systems ensure maximum safety.

In more complex vessels, e.g. cruise liners, naval, offshore installations and support vessels, it is typical to have at least two independent electrical power supply systems that can cover most of the power requirements. This way, in case of damage, fire or water intrusion in one power supply system, it is possible to return safely to the port while keeping a maximum of the equipment available.

Secondary systems are typically at a low-voltage level between AC 110 V and 690 V and have the same frequency as the primary system. While diesel-electric propulsion systems have a heavy impact on harmonics, secondary systems which are fed by a transformer will provide better voltage and power quality. Therefore, most medium and small loads will be fed on this level. Especially hotel loads with COTS (commercial off-the-shelf) equipment for audio, video, IT and entertainment are very sensitive.

The primary and secondary electrical systems are redundantly supplied with at least two largely independent power sources and one of them additionally with an emergency source. From an electrical point of view, there is one essential detail to distinguish between earth fault protection and star point handling.

System types

Nowadays, technical installations in shipbuilding and all industries are characterised by ever-increasing complexity and automation. From highly used variable-frequency drives to computer based systems the amount of equipment that requires a reliable power supply to function smoothly is steadily growing. Therefore, the foundations for reliability and availability of an installation are already laid by selecting the right power supply system.

Electrical systems on ships and offshore platforms should be designed in such a way that:

- Operating safety and reliability of the electrical systems are guaranteed at all times
- Protection for passengers and crew in case of insulation faults is ensured
- Fire protection in case of failure is ensured
- International standards and regulations are complied with

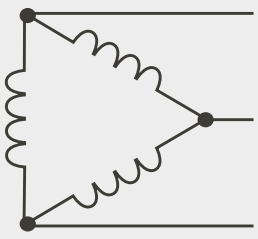
Therefore, the use of unearthed electrical systems (IT systems) with insulation monitoring is crucial in many maritime applications.
For example: IEEE – Recommended Practice for Electric Installations on Shipboard 33.7.6 Electrical installations on tank vessels. Electrical distribution systems of less than 1000 V (line-to-line) should be unearthed.

Bender system solutions support you in complying with the following standards, for example:

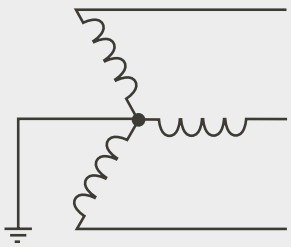
- IEC 60092-201 Electrical installations in ships – Part 201: System design – General
- IEC 60092-202 Electrical installations in ships – Part 202: System design – Protection
- IEC 60092-502 Electrical installations in ships – Part 502: Tankers: Special features
- IEC 60092-504 Electrical installations in ships – Part 504: Special features – Automation, control and instrumentation
- IEC 60092-507 Electrical installations in ships – Part 507: Small vessels
- IEC 61892-1 Mobile and fixed offshore units – Electrical installations – Part 1: General requirements and conditions
- IEC 61892-2 Mobile and fixed offshore units – Electrical installations – Part 2: System design
- IEC 61892-5 Mobile and fixed offshore units – Electrical installations – Part 5: Mobile units
- IEC 61892-7 Mobile and fixed offshore units – Electrical installations – Part 7: Hazardous areas
- IEC 80005 Utility connections in port – Part 1 & 3
- Regulations relating to maritime electrical installations: Directorate for fire and electrical safety, Norway and other international standards like: Solas, IMO, Lloyd's, IEE, NEK etc.

Three system types are available for the planning phase of a maritime installation:

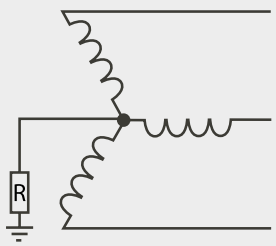
Unearthed system



Solidly earthed system



High-resistance grounded system (HRG)



Choose robust and reliable products for ensuring utmost electrical safety on board

Reliable and robust measuring device – tested and approved

Whether cruise liner, cargo or naval vessel, all types of ships face the same tough requirements at sea. Our measuring technologies have met the most challenging demands on the high seas for many years, and are still being improved to ensure electrical safety at sea. Confirmed by classification associations, Bender measurement devices have proven their measurement strength and durability, ability to withstand extreme temperatures and electromagnetic compatibility (EMC), as well as shock and vibration resistance.

All devices with the “W” option are specially hardened to withstand even the most extreme conditions, including humidity with possible condensation and formation of ice (3K5), shock up to 25 g and vibration up to 3 g (resistance class 3M7). All iso685 and EDS44x with the “W” option are able to operate in a temperature range of - 40 to +70 °C.

In addition to future operational requirements, the devices must withstand the dust and dirt caused by so-called “hot work” during shipbuilding at the shipyard. The switchgears are installed at an early stage for block building purposes, when there are still many work steps to follow. Especially the metal dust produced during angle grinding and welding can deposit on the PCBs and affect the high-precision measurements, which is why all PCBs of the “W” option are coated to minimise the influence of dust.

Classification society certificates

- Insulation monitoring: iso685 series, IR425 series, accessories (FP200, AGHs, …)
- Insulation fault location: EDS440 series
- Residual current monitoring: RCM420 series, RCMS460/490 series, current transformers, …
- System relays: VME420 series, VMD420 series
- Communication: COM465IP

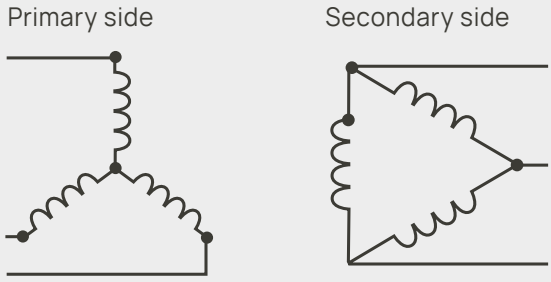
Learn about the benefits of unearthed systems

The unearthed or floating system combines high availability with lowest fault currents. A real insulation value and detection of symmetrical faults are also an advantage. What is interesting for predictive maintenance is that insulation deterioration from several 10 kΩ up to the MΩ range can be detected and monitored. This enables you to plan maintenance in the electrical system – instead of having to react to serious incidents.

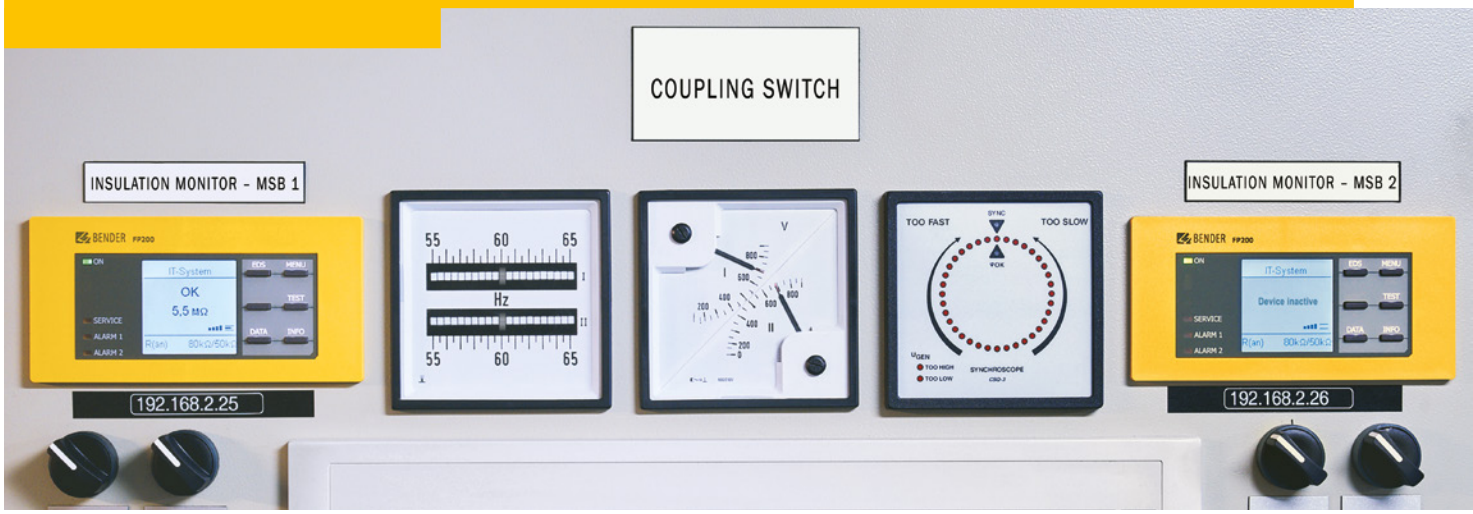
Insulation faults will be automatically and therewith instantly located – online without switching off any load. Depending on the system configuration and the leakage capacitances up to 100 kΩ, insulation fault location is possible.
The traditional way to narrow down the fault was systematic and time consuming shutdown of feeding distributions. In operation, it is more difficult because not all systems can be switched off at sea and the fault could disappear because the faulty load is already switched off. In this situation, Benders mobile EDS equipment can be an invaluable tool for engineers where a fully automatic location system is not present.

All insulated systems on board require an ISOMETER® by class and according to IEC 60092.

Earth faults in the classical star configuration cause line-to-earth voltage rises. These are dangerous for single-phase commercial off-the-shelf equipment which are typical in hotel areas. This problem can be avoided by connecting the secondary side of the feeding transformer in delta mode.



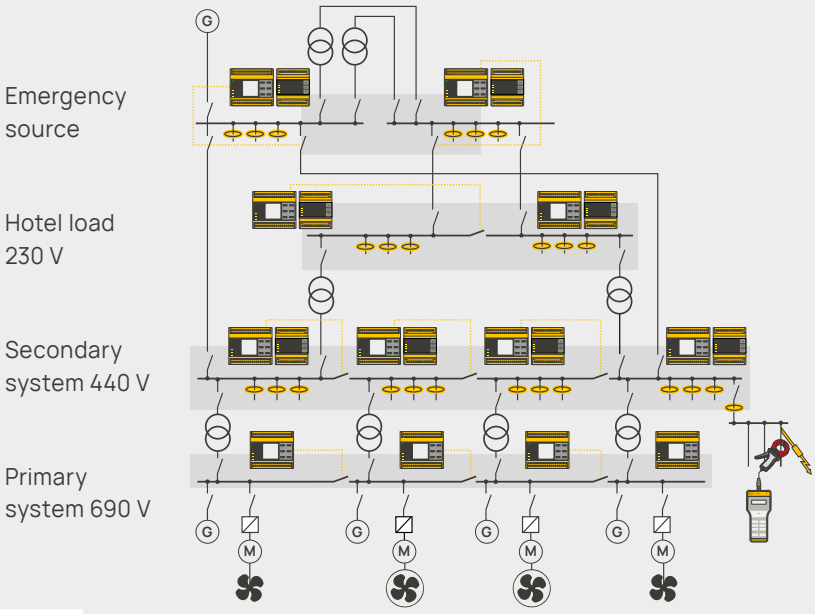
The complexity of insulation monitoring –
Our advice: Measure parallelly instead of sequentially



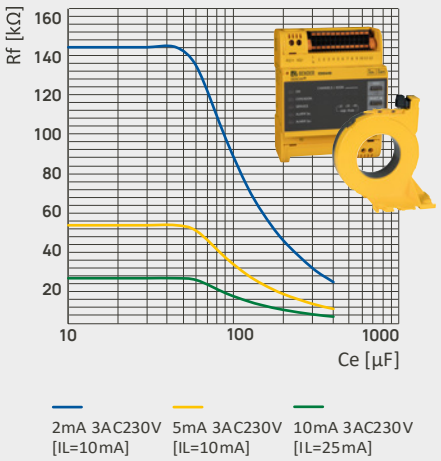
Insulation monitoring in coupled systems on board
In daily manner on board switchboard sections will be synchronised and run as one system for load sharing and to reduce the running hours of the generators. If more than one IMD is present in this galvanic system, they will interfere with one another. In this case, one monitoring device supervises the entire system and the other devices need to be disconnected.

Bender IMDs allow decoupling the measuring circuit via a digital input which is controlled by the closed signal of the main circuit breaker or via the ISONET® function. In the last case, all ISOMETER®s in one possible galvanic system will communicate with each other and only one device will measure at a time.

Often in vessels, systems run in parallel for redundancy. The circuit breaker input is preferred to monitor all active systems simultaneously. If too many lines are measured at the same time, measuring times will increase due to leakage capacitance. In large systems, the blind-spot phase will become too long.



Detection rate 3AC 230 V

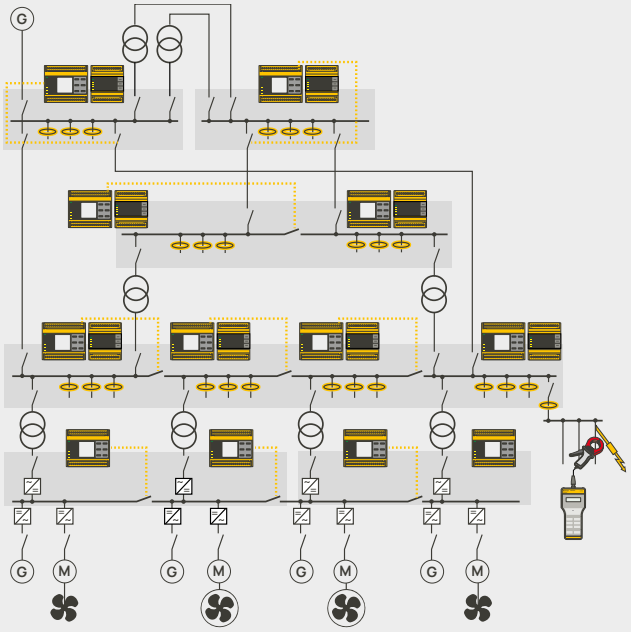


Emergency source

Hotel load 230 V

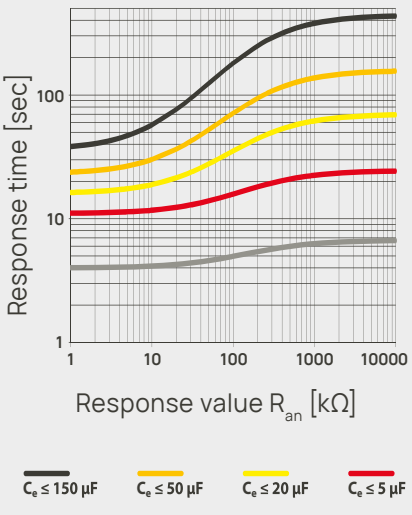
Secondary system 440 V

Primary system 1000 V DC



The importance of leakage capacitance

Measurement time depending on response value and system leakage capacitance acc. to IEC 61557-8



The larger the system in terms of leakage capacitance, the longer the measuring time. It is possible that very short-time insulation faults cannot be detected or localised. It is therefore recommended to adjust the system size to the maintenance objectives. The biggest source of leakage capacitances nowadays is not the cable network but the filter capacity of poorly chosen variable-frequency drives and switched-mode power supplies.

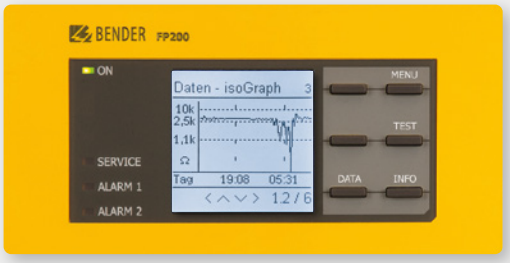
In vessels, quite often systems run in parallel. The circuit breaker input is to prefer to monitor all active systems parallely. In a galvanic system, more than one insulation monitoring device (IMD) must be present in order to couple the feed systems for load sharing and to reduce the running hours of the generators. In this case, one monitoring device supervises the entire system and the other devices need to be disconnected. Bender IMDs allow decoupling the measuring circuit via a digital input which is controlled by the closed signal of the main circuit breaker or via the ISONET® function. In this case, all ISOMETER®s in one galvanic system will communicate with each other and only one device will measure at a time.

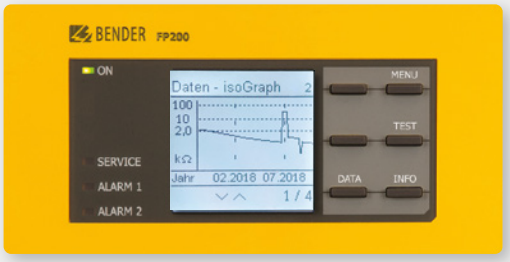
Three methods for detecting errors before serious limitations occur

Monitoring of residual currents
The EDS devices allow not only the immediate reporting and limitation of insulation faults that have occurred, but also the detection of residual currents and the alerting if they exceed limit values. In this way, a change in the system can be detected and corrected before device failures, secondary damage or even fires occur.

Insulation fault location system
Even far above the alarm value, the new insulation fault locators can be used to monitor outgoing circuits, distributions and loads. Thus, a comparison or trending is not only possible on the system level, but also on a more detailed level. This makes it possible to identify online which loads or distributions provide the lowest insulation values to the system and take targeted action.

isoGraph
In addition to displaying the current measured values, the IsoGraph also allows a look into the past to identify trends, estimate future developments and thus enable preventive maintenance – even before it comes to restrictions or a system shut down.





When considering an earthed system

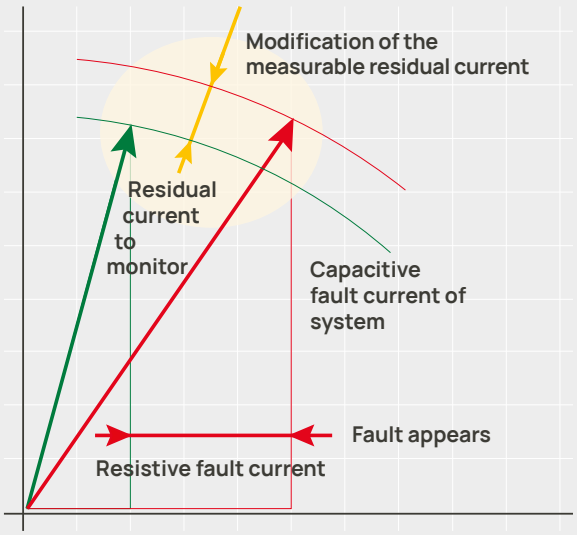
At first impression, an earthed or solidly earthed system is the simplest way to build up an electrical system on board. The disadvantages show up in the total cost of ownership analysis. In the event of an earth fault, high currents will flow, which means more damage and commonly higher repair costs. If the current is below the tripping value of the circuit breaker, this may cause a fire. Faulty loads will be out of service immediately and this means – in the worst case – downtime of the whole vessel.

While the insulation level in an unearthed system shows the actual condition, it is much more difficult to measure ohmic leakage currents in solidly earthed systems. With a residual current monitoring system (RCMS) leakage currents will be detected down to around 1 mA. This represents the vectorial sum of the capacitive leakage charging current and the ohmic leakage current. As such, changes in the ohmic insulation level are somehow hidden behind the leakage capacitance and detection is a challenging task. However, leakage current detection below 30 mA for personal protection and 300 mA for fire protection allows predictive maintenance before greater damage occurs.

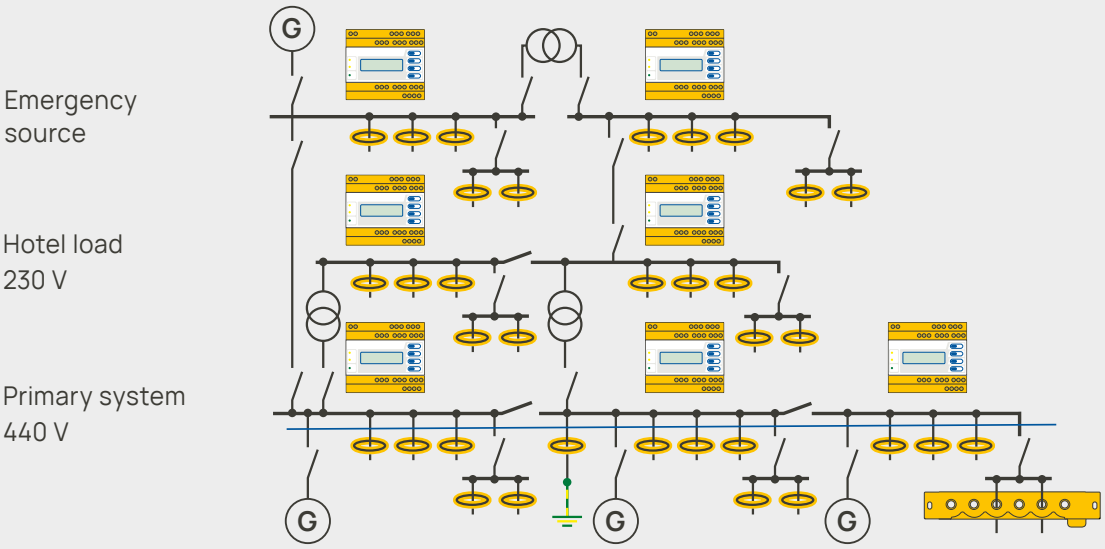
Without an RCMS, faults are simply switched off by an RCD or by overload protection; both operate without any prewarning and with large tolerances, so that predictive maintenance is impossible. An accumulation of small faults can combine, eventually causing a system shutdown. These would not be detected without an effective warning system.

Since many loads are supplied with switched-mode power supplies or variable-frequency drives, DC leakage currents may occur and RCMS type B current transformers are necessary.

Changes in vectorial sum are small



It is important to know that in solidly earthed systems only asymmetrical faults can be detected or measured to a level of 10 – 20 kΩ or less. In comparison to an isolated system this is 1/20.

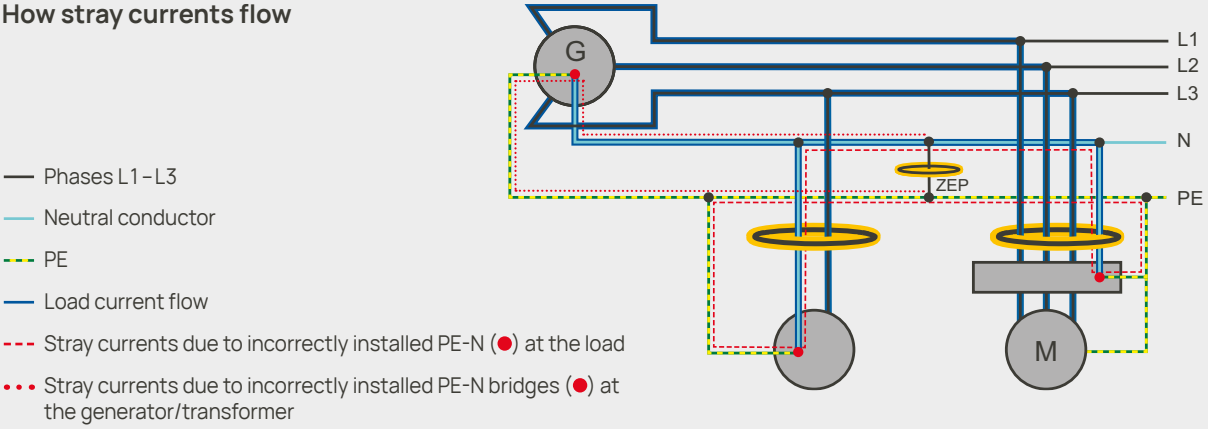


Standardised: **Central Earthing Point (CEP)**
In DIN EN 50174-2 as well as in IEC 60364-1 "Low-voltage electrical installations – Part 1: Fundamental principles, assessment of general characteristics, definitions", the standard specifies exactly one central earthing point. The result is convincing: As per Kirchhoff law for meshes, no stray currents can flow.

For example, the sum of different small leakage current deteriorations of switched-mode power supplies of audio, video or computer systems gets too high and all systems will be shut down by the feeding UPS/RCD. Unfortunately, this kind of fault is hard to find while repowering all loads. With an RCMS system, deterioration of one or more loads and additional installation of too many devices are easy to recognise and system failures can be avoided. Besides, RCMS prewarning provides the opportunity to order and install new devices when old equipment reaches the end of its life without any service interruptions.

Water or air heaters in galleys, laundries, or HVAC preheaters and reheaters are particularly prone to faults. Since each generator is solidly earthed, this must be done in the main switchboard to prevent high equalising currents over the hull. If there is not just one but several central earthing points (CEP EN 50174-2:2002-03) in the main switchboard between the hull and PE, stray currents can occur.

How stray currents flow



The critical nature of leakage currents

Why is it important to detect and prevent leakage currents?
In earthed networks, earth – at sea it is the ship's hull – is connected to the neutral conductor and supervised by a central earth fault monitoring system (CEP). Without appropriate training of the installation crew, earth is often connected directly to the neutral conductor in the sub-distribution boards or loads – which creates additional earthing points. In the traditional systems of older vessels, these additional earthing points had little effect. In modern ship installations, however, various well conducting connections have been added and stray currents will be introduced throughout the vessel.

The data cables, whose shields are made of copper braid or aluminium foil, conduct the current but have only a low ampacity. In data centres, for example, leakage currents of double-digit amperes have already been measured over parallel data cables – a situation that is a clear fire hazard. In addition to affecting the data quality and bandwidth and the resulting unplanned system crashes (blue screen), the leakage currents can lead to a fire via scorched cables.

Due to these different connection points between PE and the neutral conductor, reverse currents with their harmonic parts will also flow through the earthing system instead of just via the neutral conductor. Without monitoring of the CEP, these faults cannot be detected and stray currents occur which lead to EMC problems. If they appear without being noticed and corrected, all kinds of computer network, phone, audio and video systems on board might be affected by mysterious faults. Only central earthing point monitoring allows the detection of changes due to installation faults and ageing. Therefore, there should only be one central connection between N and PE in the main switchboard which is monitored (one common neutral not switched).

DC residual current in an AC grid?
Until today, the energy on board is mainly provided as alternating current (AC) grid. Nevertheless, a large number of modern loads, such as LEDs, power supply units, etc. are operated with direct current (DC). Usually these high-quality components have integrated power supply units and are thus operated with classic AC voltage. However, if faults occur in the loads downstream the power supply unit, these are DC faults. These must also be detected and differentiated because such a DC fault can render the upstream residual current device (RCD) type A (pulse current sensitive) inoperable due to magnetic saturation. This is called "blinding" in technical jargon. Thus, even DC residual currents of 6 mA can dispose that the RCD no longer trips even with residual currents of more than AC 30 mA, which can lead to serious accidents.

Pitting corrosion: Especially in aluminium hulls, fault currents creeping through the hull are particularly dangerous because they damage it within a very short time – causing pitting corrosion. Even larger units with a weight-saving thin outer steel skin have been affected by electrolytic corrosion. This not "only" affects the hull but also rod bearings, washers, oil and water coolers, and quickly causes major damage.

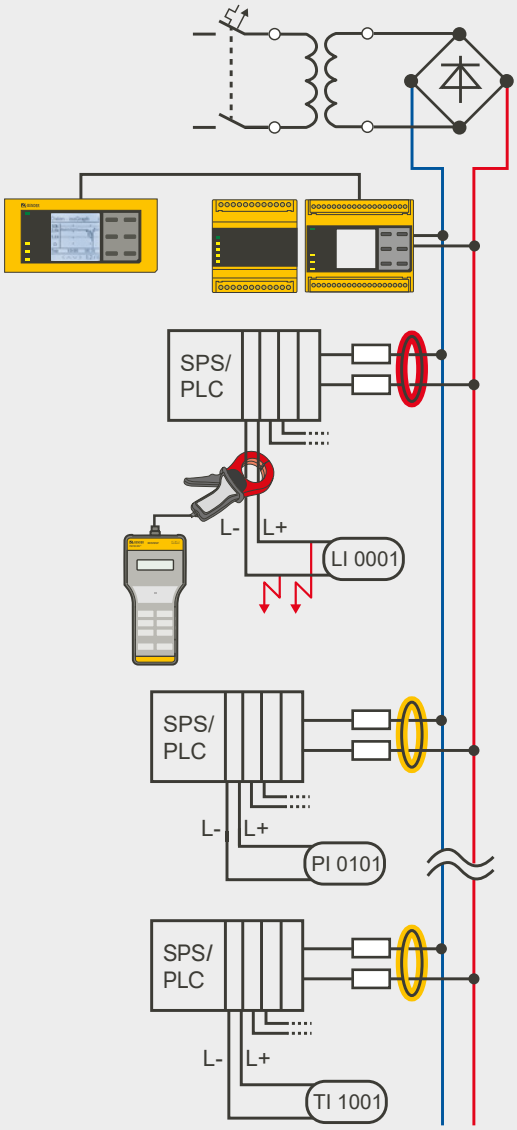
Stray currents detected

About control systems

The ship automation system and most other systems on board have an internal control voltage of DC 24 V. This is below 50 V; the permissible touch voltage is within a safe level. But for safety reasons the classification societies require for each isolated system (unearthed system) an insulation monitoring device (IMD) for continuous monitoring and alarming in the event of abnormally low levels. The advantage of this unearthed system is that if a first fault appears, the system will be fully operable without any malfunction or shutdown because of an RCD trip (TN system). Shutdown can lead to dangerous situations at sea, for example when redistributing the ballast water or fuel if the free surfaces cannot be reduced because the tanks cannot be emptied or filled completely.

The question arises as to the limits of abnormally low levels. Since most analogue sensors for tank levels, pressure etc. are working with 4 – 20 mA signals, it is a question of resolution. For example, an insulation fault of 24 kΩ at 24 V means a leakage current of 1 mA, which means 6.25 % of the % sensor deviation. Usually even more, because in most cases only part of the sensor range is used.

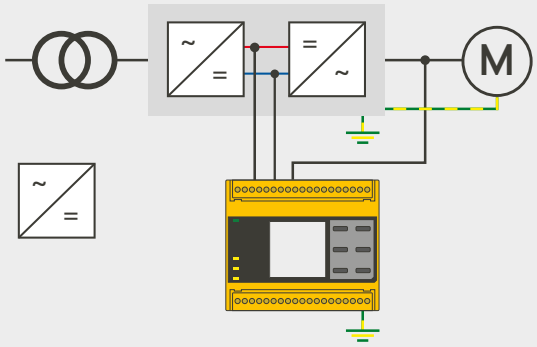
After delivering the ship, the insulation level in the “control system” is very good. However, during operation, the operating state will gradually deteriorate due to ageing and small extensions. This is the challenge because only if the first, apparently small faults are detected and eliminated, there is a chance to keep the insulation value at the same level later on. Bender insulation fault location systems, which are especially adapted to control systems, also help to avoid that the locating current sets any inputs in the “PLCs”, energises relays or causes any damage. This way, in the DC 24 V distribution systems, a fault can be narrowed down immediately upon first occurrence and the time-consuming and nerve-racking search for sporadic faults in the entire system as well as the bad feeling that “there is something” are a thing of the past.



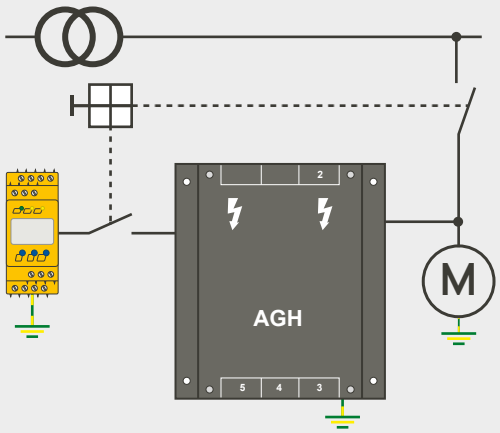
How to monitor the propulsion plant and other important loads offline

Insulation faults in deenergised loads cannot be measured with the insulation monitoring device of the feeding system. Therefore, the fault is not detected until the load is switched on and usually the circuit breaker switches off the load immediately due to overcurrent protection. This means that the load is practically not available. The insulation monitoring of the windings of the deenergised loads allows detecting insulation faults before the system is switched on and fails. This way, faults that occur in loads which are important in case of emergencies, such as bilges, fire and standby pumps or rescue cranes are immediately detected and reported by means of an offline measurement. This gives the crew the opportunity to eliminate the faults before the systems are actually needed and will be damaged. Furthermore, it enables insulation value deteriorations to be detected long before reaching a critical value and maintenance measures to be planned and scheduled without risking a failure.

Large motors, especially in propulsion plants, thrusters, winches and heavy load cranes are controlled by variable-speed drives. Especially at high power it is important to check the insulation resistance of the installation before switching on the voltage, otherwise serious and costly damage can occur. This applies not only to the windings of the drive motor but also to the DC link in the frequency converter. With the ISOgraph integrated in Bender devices, it is possible to detect long-term changes in good time and implement condition-based maintenance.



Offline monitoring of DC link in VFD and motor winding



Offline monitoring winding

Did you know that continous offline measurement can replace time consuming insulation tests? This way, nobody has to to disconnect, measure and reconnect the 100+ electrical motors for fans, pumps, etc.

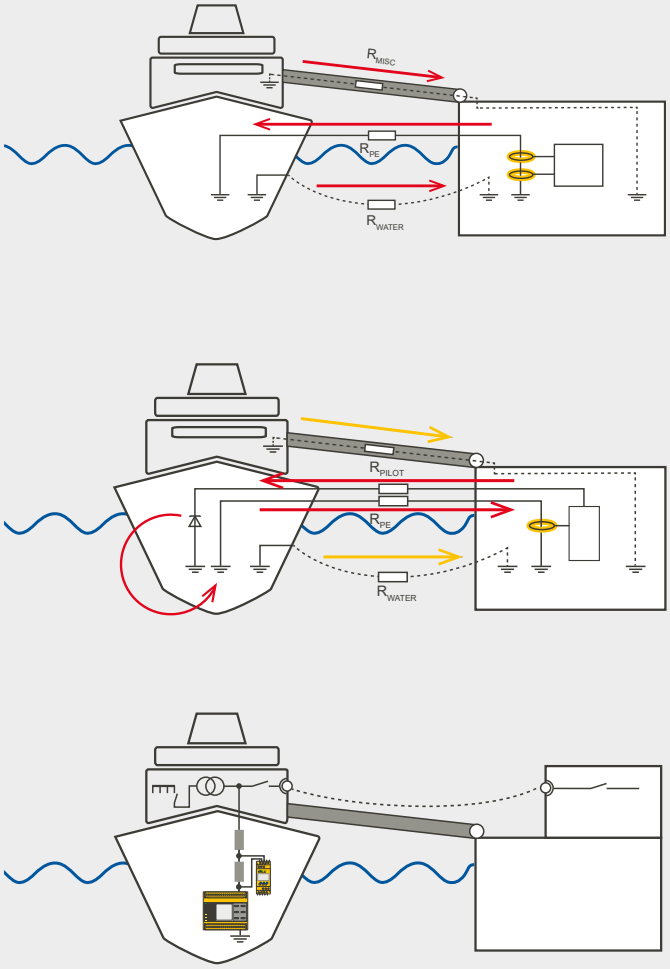
About shore to ship power

More and more ships are being supplied with onshore power in the ports in order to reduce the pollution of emissions and noise, especially in regions close to cities. This implies not only that the necessary power must be made available but also that it must be brought on board safely. Since the cables and connections are exposed to the weather and movement not only during connection but also during low and high tide and due to the movement of the ship, it is important to monitor these for damage and the resulting leakage currents. IEC 80005-1 regulates the onshore power supply for medium voltage and IEC 80005-3 for low voltage.

For medium-voltage power supplies, “continuous monitoring of equipotential bonding” must be ensured to prevent life-threatening potential differences when boarding the ship. When supplying cruise ships with one cable each for the 3 phases and PE, different measurement methods are used depending on whether the parallel resistances via gangway, supply hoses and the water have high or low impedance.

However, there are also constellations in which the ship must not be connected directly to the shore due to electrical corrosion. In this case, the insulation resistance of the feeding medium-voltage side and the cable set including the primary side of the shore connection transformer are monitored on board. A voltage relay interrupts the power supply in the event of rapid voltage shifts due to a cable break.

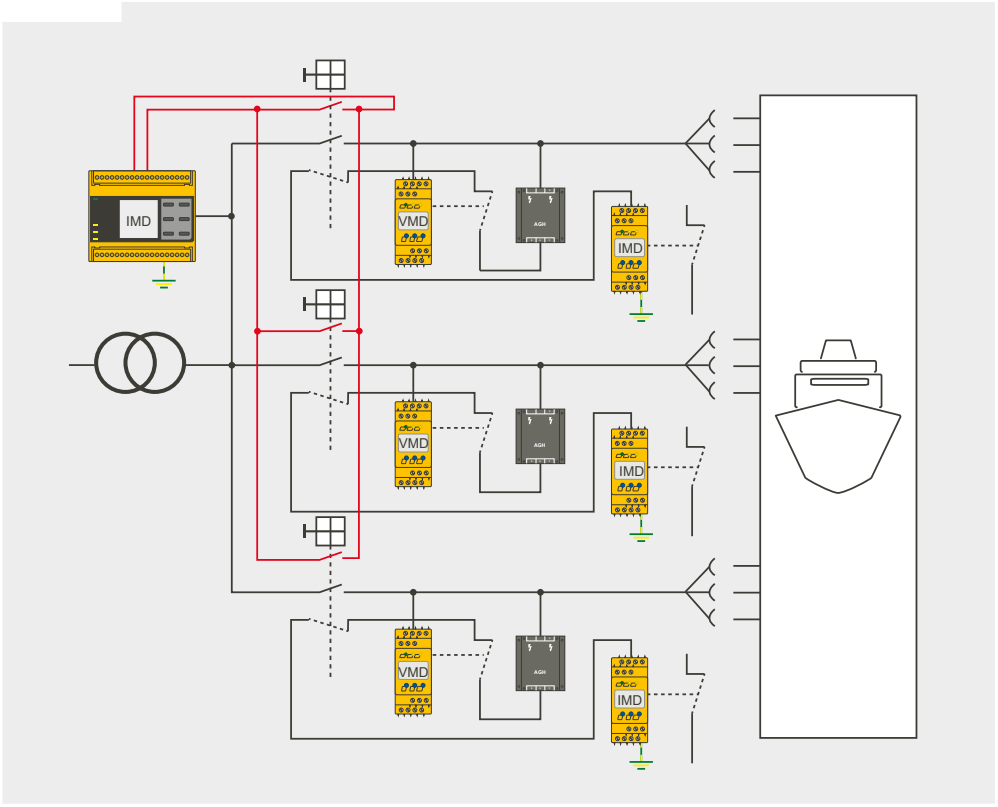
System solution GM401



Please be aware that equipotential earthing of the hull could cause electrolytic corrosion of the hull and all weaker material parts like propeller, shaft, bearings etc.

Please check whether your equipotential bonding measurement system not just inject a pulse over a pilot wire and each way back will be acknowledged as OK. A clear distinction needs to be detected between PE shore to ship and all other connections like water, screen hoses or gangways.

In low-voltage systems, usually several parallel cable sets are required to provide the necessary power. Here, the insulation resistance of the individual cables and the secondary side of the onshore power supply transformer must also be checked before switching on.



Electric Shock Drowning (ESD) and corrosion

Why does a marina need earth fault protection? The combination of water and electricity can create a hazardous situation. Boats continuously connecting to and disconnecting from shore power, poor earth bonding, “hot” conductors touching ground, and corrosion can cause electric current to flow through the hull of a ship and into the water. This situation can become hazardous for people who may come into contact with the water, resulting in severe injury or even death by electric shock drowning.

Requirements for earth fault protection

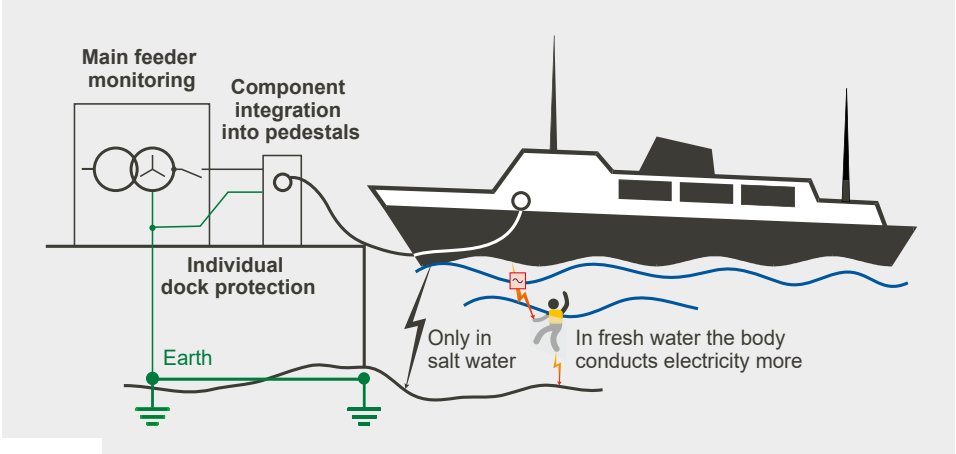
There are several standards, code requirements, and state laws that require earth fault protection for marina shore power, including but not limited to:

- National Electric Code (NFPA 70 / NEC), Article 555.3 (2011)
- NFPA 303 (Fire Protection Standard for Marinas and Boatyards)
- KRS Chapter 235, Commonwealth of Kentucky

Bender provides advanced earth fault monitoring and protection systems to assist in the mitigation of earth faults and the electric shock hazards when connecting to shore power. Alarms are activated when an earth fault is detected, including at the time a boat connects to shore power. Monitoring capabilities can be provided anywhere from the main feeder down to the individual pedestals and boats. Low-level earth fault currents can be detected, even at the “let-go” current level and below. Remote communication options quickly notify staff and technicians of earth fault issues, assisting in predictive maintenance.

Since many boats have DC loads, the potential fault currents to earth also contain a DC component. In many harbours RCDs are used with a false sense of certainty that they will trip. Since most RCDs are type A devices, they no longer trip reliably in the event of a DC fault current of > 6 mA due to electromagnetic saturation and even AC fault currents well above 30 mA no longer reliably cause tripping (so-called RCD blinding).

Bender's DockGuard provides advanced, class A GFCI protection in an easy-to-install solution designed specifically for marina docks. The DockGuard provides earth fault monitoring and circuit interruption, ideal for both new construction and refit installation.



Monitoring of safe supply of reefer containers on board and on shore

While at sea, cargo such as fruit, meat, medicine and other types of cargo needs to be refrigerated in a reefer container. Nowadays, cooling is usually powered by electricity. Electronics and other sensitive cargo must also be transported at a stable temperature. On board of container ships, the necessary power from the medium-voltage system for two to three cargo bays each is transformed to 440 V and the plug distributors are fed into the various tiers in a distributor with 6 – 8 containers each. To ensure availability, these systems are usually unearthed. However, in the event of a fault, the crew must find the first fault before a second fault current occurs. Otherwise, the fuses of two plug distributors would trip, the connected reefer containers would be disconnected from the mains and the goods would spoil.

Bender insulation fault location systems (EDS) allow the crew to immediately and automatically detect the "distribution" of the reefer container with the first fault as soon as it occurs. Now, all that is left to do is to select the defective container in the "row".

This search is very time-consuming as the distributors of the more than 50 reefer containers have to be taken off the system individually to narrow down the fault. Since not all reefer containers are always in use at the same time, fault location is difficult.

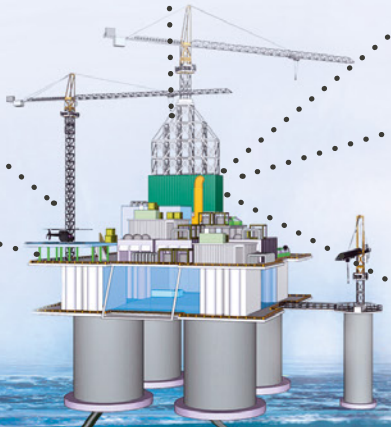
On ferries, the trailers with reefer containers are also supplied with electricity during the crossings. Also in this case, fast localisation of insulation faults is essential to avoid endangering the power supply for an entire deck with several dozen container loads. This solution makes it possible to ensure availability even in the large refrigerated warehouses on shore and detect faulty reefer containers before loading so that they can be repaired or reloaded. If these are powered by an earthed system, RCMS technology is used to detect the fault currents.

Offshore

EDS**3090**
Portable earth fault locator
- Detects insulation faults in an unearthed systems

NGRM**700**
Neutral grounding resistor monitor

iso**685**-D-P
Insulation monitoring for unearthed systems
- Personal protection
- Plant monitoring & reporting
- Shutdown systems



isoHR**685**
Insulation monitoring for unearthed systems
- Cable insulation monitoring
- Remote reporting

OEM solution
Subsea factory distribution insulation monitoring

EDS**440**

Online fault location

- Locates insulation faults
- For unearthed AC/DC systems

iso**685**W-S-P

Insulation monitoring for isolated systems

- Main machinery
- Auxiliary generator
- Pumps

PEM SERIES

Power Quality & Energy Management

- Power quality
- Reporting
- Remote Access

isoRW**425**

ROV Insulation Monitoring

- ROV protection

- Bender's earth fault location system significantly reduces system downtime and technician time by locating earth faults down to the load level – all while the system remains online. Fault location can take place automatically or manually with portable equipment. Remote communication solutions allow Bender equipment to be integrated into modern communication systems, such as Modbus TCP.
- Products for virtually any offshore application – platforms, umbilicals, ROVs, and FPSO vessels.
- Advanced warning in case of earth faults and insulation failure with 10 GΩ measuring range using the latest in earth fault monitoring technology for AC, DC & AC/DC systems and systems with variable-speed drives.
- Monitoring of cables up to 1000 µF leakage capacitance and up to 100 parallel capacitively coupled cables while limiting cross-cable disturbance of power or data cables.
- Monitoring power cables up to AC 1000 V 2 ph, AC 690 V 3 ph and DC 1300 V and frequencies up to 460 Hz.
- Communication solutions allow for remote notification of technicians or integration into modern industrial communication networks.

Non-Productive Time (NPT) is a well-known acronym throughout the oil & gas industry and subsea environment which causes substantial time and turnover losses, e.g. in petroleum production. NPT is estimated to cost upwards of $100 to $500 million annually. Equipment such as blow-out preventers (BOPs) and top drives can account for 51 – 75 % of all equipment-related NPT.

With over 70 years of experience in on-board electrical safety, Bender is a worldwide leading provider of electrical safety equipment for the oil & gas and subsea industry. Bender's advanced earth fault protection equipment continuously monitors system integrity and provides advanced warning of potential earth faults and system insulation failure.

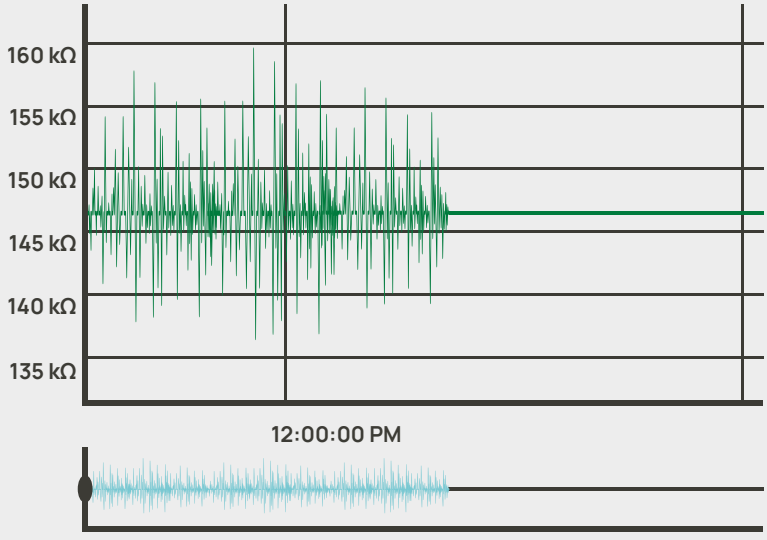
The "worldwide unique" effective measuring range of 10 GΩ makes it possible to monitor and test the system already during the installation of the subsea equipment and the connection of the individual cables. This allows potential faults to be detected and eliminated at an early stage before expensive NPT occurs. Through continuous and reliable measurement in the giga-ohm range, the first interferences and damage can be detected at an early stage in operation and safe and standard-compliant operation can be ensured by gaining valuable lead time for time-consuming procurement and installation.

Thanks to the enhanced measurement method, cables with high leakage capacitances and parallel cables with capacitive coupling in the umbilical can be monitored simultaneously without the measurements affecting each other. Coupling devices extend the range of monitorable voltage levels up to AC 12 kV and DC 1760 V and the systems can be designed cost-effectively.

Insulation monitoring of parallel supplies in umbilicals

- Early detection enhances operational safety and maintenance planning possibilities
- 10 GΩ measuring range allows preventive monitoring already during installation phase
- Synchronisation feature ensures precise measurement in parallel cables
- Universally applicable in AC, 3(N)AC, AC/DC and DC systems

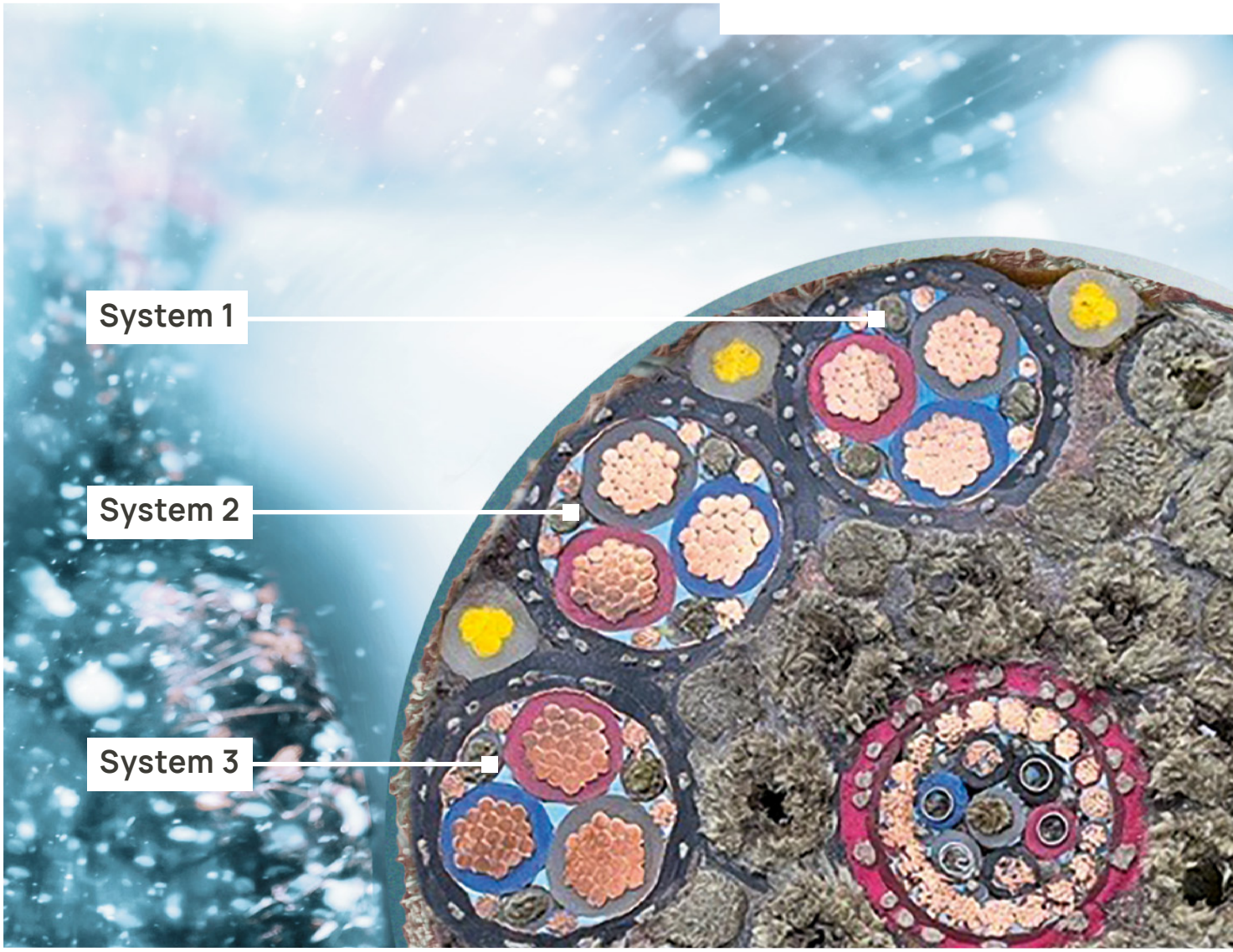
Synchronising of parallel cable monitoring activated and no influencing of parallel cable measurements



Monitoring of umbilicals

Remotely Operated Vehicles (ROV)
Remotely Operated Vehicles (ROV) and other underwater devices are supplied with electrical power via umbilicals. In order to realise a small cross-section of the supply lines, the voltage levels are set high (several kV). A power failure would usually mean the loss of the device as they navigate on their own and cannot be recovered by pulling the cable. This is why IT systems are also used here, which must be monitored properly in order to detect a change in the insulation level. In this case, the insulation oil in the ROV can be treated or, if necessary, changed.

The umbilicals are usually custom-made cables for the individual device and must be manufactured specifically in case of replacement. A long warning time before the failure ensures availability of the expensive underwater device as well as the Offshore Support Vessel (OSV) or the underwater production device. The new isoHR685 continuously monitors insulation changes even in the giga-ohm range and, with the new synchronous operation, enables the measurement of many parallel cables in the umbilical, which are capacitively coupled due to their length.



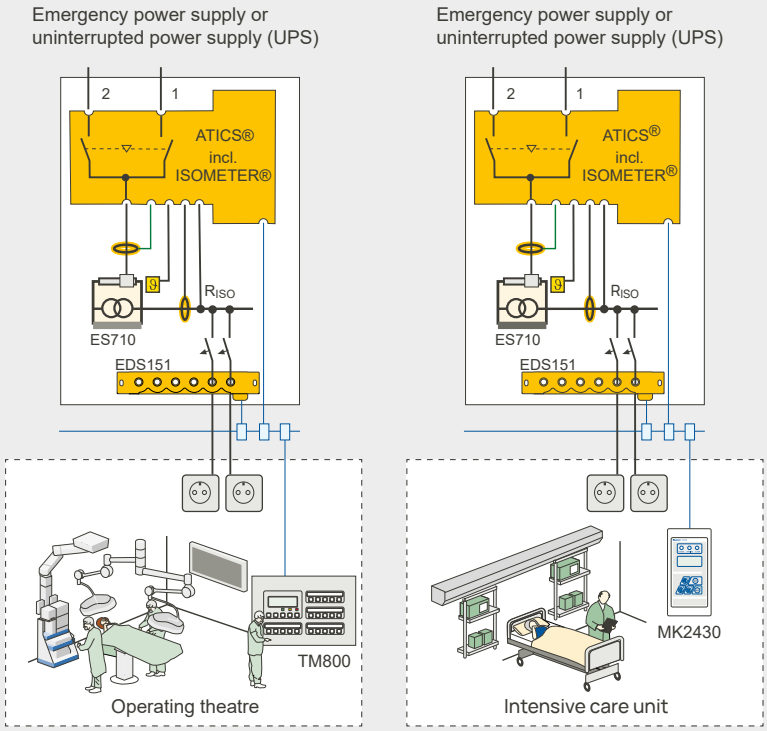
When life is at stake: Safe power supply of hospitals and medical facilities on board

At sea, the way to the closest hospital is usually very long and often cannot be covered by helicopter. Therefore, treatment rooms are usually set up on board of ships; on larger ships, these correspond to the standard of operating theatres. If there is no doctor on board, remote assistance is used to save lives in case of an emergency.

The power supply of these rooms must comply with IEC 60364-7-710 (Electrical installations of buildings – Part 7-710: Requirements for special installations or locations; Medical locations – 710.3.7 group 2).

It is important that the power supply of any medical device in operating theatres, recovery rooms and intensive care units is not only connected to the emergency power supply (power restore ≤ 0.5 s) but also galvanically isolated from it. An isolating transformer, which is required for every operating theatre in a

hospital, limits the leakage capacitance to ensure that any fault currents that occur are very small and that no fault is transferred from one system to another. In this medical unearthed system, an insulation monitoring device (IMD) indicates immediately when a fault or a transformer overload has occurred so that it can be eliminated right away after medical treatment to avoid system failure. Insulation fault locators help to detect the fault precisely so that the defective device can be quickly identified and the fault can be eliminated.

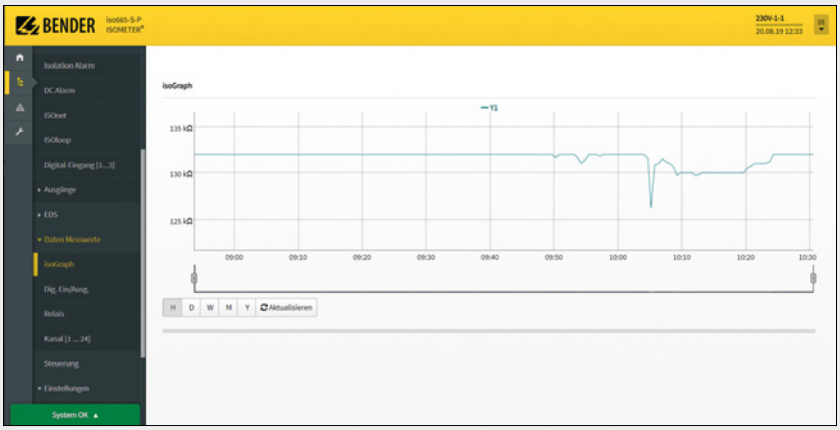


On this subject, see …
IEC 60364-7-710 as well as local directives describe the requirements.

This and national rules regulate:

- Galvanic separation by transformer (minimise leakage capacitance)
- Double power source with maximum time for power recovery
- Maximum power supply
- Maximum cable length and distances
- Maxmium supplied rooms

Visualisation and gateways



Display of device data on the web user interface (COM465IP)

Due to the complexity of the electrical system, a large number of devices must be monitored. Gateways allow easy access to all information of the ISOMETER®s and EDS devices as well as parameterisation of the devices for commissioning. Wherever the integration of all channels into the ship automation system is too expensive, the BCOM interface offers an elegant possibility to call up all messages at a central point and access the information and insulation processes.

By connecting it to the Wi-Fi, the ETO can also work on-site to further narrow down insulation faults and eliminate faults without additional support.

Interconnection and visualisation made easy

The COMTRAXX® monitoring systems are used in a wide range of applications. However, what they have in common is that the user can obtain relevant information in a fast and easy way. In the event of an alarm, the system informs actively via e-mail, switching contacts or by forwarding information to higher-level control systems. To carry out an analysis or create a report, the user accesses data points that were captured previously. The Bender system control centre allows both in one system. Data is collected from all connected measuring devices, evaluated and processed according to the respective application. In doing so, the browser-based concept offers many advantages:

- Remote access to the current measured values, status/ alarm messages and parameters via LAN/WAN Internet
- All users work live in a browser-based system
- 10/100 MBit Ethernet gateway for Modbus TCP, Modbus RTU and Profibus DP and support of third-party devices
- Central management
- The system is safe and geared toward the future through expansions

From the entire system overview with an integrated visualisation tool to detailed power quality evaluations, the Bender system control centre accompanies the user with intuitive operation and guided support during fault analysis.

Maintenance

Data basis for maintenance
Maintenance is one of the focal points in maritime operations due to the high investments and autonomy at sea. This encompasses electrical maintenance on board in engine rooms, light and power supply in exterior and hotel areas but also control & automation, navigation & communication as well as audio & video entertainment. Bender monitoring devices provide assistance in the monitoring of the electrical power supply. They continuously furnish data about the condition of the installations and are therefore indispensable for preventive and predictive maintenance.

The aim: reduce costs – increase availability
The aim of every system operator should be to detect malfunctions at an early stage and eliminate the causes economically to achieve optimal system and operational safety and ultimately reduce costs significantly. Only those who are aware of the condition of their system can fulfil the prescribed targets concerning personal, system and fire protection. With Bender monitoring devices, system operators stay on top of things.

Identifying the trend of the insulation resistance level & recognising faults before they have negative effects
When you analyse the progress of the insulation resistance, you can see that many deteriorations develop gradually and can therefore be predicted. This makes maintenance measures plannable instead of just reacting to the ISO alarm. The trend of the insulation value thus becomes the starting point for proactive maintenance. The correlation of leakage capacitances, measurement times and measurement interferences enables even better analysis.

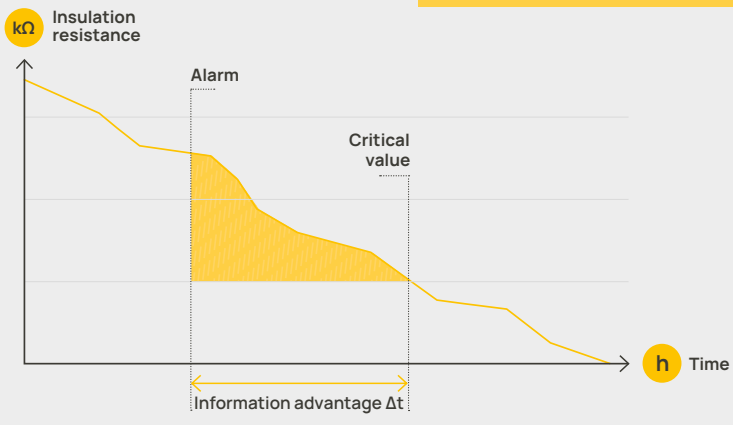
Interpreting short-time insulation fault messages correctly
Short-time insulation faults are difficult to interpret. If, for example, the insulation value falls below the alarm threshold value for only ten minutes and then rises again to a normal level, the electrician on board often does not stand a chance in finding the cause of the fault. Maintenance must then be terminated without fault elimination, and the faulty insulation remains a hazard for the system.

Avoiding additional harbour or yard days
Insulation faults at sea can lead to unplanned berthing times and thus to schedule delays as well as losses in charter rates. Traditionally, many insulations faults were located manually, which made it necessary to switch off the system supplies. Many systems can only be switched off when the ship is moored in port and so time usually runs against the crew. However, if the insulation faults are ignored, critical and dangerous conditions may arise at sea due to a second fault. Bender technology detects slowly decreasing insulation values and uses communication interfaces to enable predictive maintenance and analysis.

Fault location in electrical installations made easy
In order to rapidly find insulation faults also in the case of systems with extensive routes and distribution systems, the implementation of stationary insulation fault location systems is preferred. They are able to allocate insulation faults to individual route sections on different levels in the distribution system. A further advantage is: Bender fault location systems find insulation faults during ongoing operations, without system or load disconnection.

Good to know:
Stationary solutions for insulation fault location can also be refitted. Portable and stationary solutions from Bender comply with IEC 61557-9.

Protection of persons
System protection
Fire protection



Proactive instead of reactive: predictive maintenance
Determination of the ideal time for maintenance

Reducing risks of failure
Whether it is gradually developing insulation faults, stray currents, or malfunctions due to material fatigue of the electrical systems, often accelerated by humidity, temperature differences and vibrations but also dust and salty atmosphere: The impact of these problems, which can be detected at an early stage, is often under-estimated and range from triggering protective devices and the sudden appearance of arcs to fire damage, loss of system capabilities or even personal injuries. Those who only react once a fault has occurred are forced to accept regular downtimes with all the associated financial and image-damaging consequences.

Many installation operators test their systems at regular intervals and renew technical components as a precautionary measure. This simple model of preventive maintenance may impede many avoidable downtimes but is personnel and cost-intensive due to manual inspections and wasted residual quality of the components. Furthermore, intermittent assessments of the condition are very unreliable.

What if downtimes could be predicted and therefore prevented? What if maintenance could be cost-optimised?
This can be achieved with Bender monitoring systems as they enable monitoring with analysis capabilities and can thus determine the ideal time for maintenance. This predictive maintenance saves valuable resources: Maintenance measures can be planned, and devices and components can be used until the end of their service life. Moreover, the targeted and fast localisation of problem areas is achieved by Bender insulation fault location systems. Predictive maintenance allows you to achieve maximum cost effectiveness.

Only forward-looking planning enables foresighted maintenance Electrical devices are subject to normal wear and may be susceptible to faults during their service life. The portable insulation fault location systems from Bender can be a valuable tool in the search for insulation faults as they allow easy determination of the fault location.

Maintenance strategies

Correktive

Downtime-oriented
- Reaction after direct damaging event
- Unscheduled downtime

Preventive

Time-dependent
- Established deadlines
- Frequent exchange of intact components

Condition-oriented
- Reaction to warning thresholds concerning the system condition, still prior to downtime
- Optimum use of service life (wear margin)

Predictive

Analysis-supported monitoring
- Prediction of the ideal time for maintenance
- Maintenance measures that can be planned

Predictive maintenance
allows you to achieve maximum cost effectiveness. Bender monitoring systems help you to
- Improve the management of your assets (CAPEX)
- Optimise maintenance efficiency (OPEX)

Power quality and energy measurement
Transparency for electrical installations

Electrical supply systems are becoming larger over time. It is not rare that failures and disturbances are the consequence of overloaded systems. PEM series measuring devices can be included within the monitoring system to assess any risks due to overloads or changes in the energy consumption before any expansions are carried out.

Design of the monitoring system

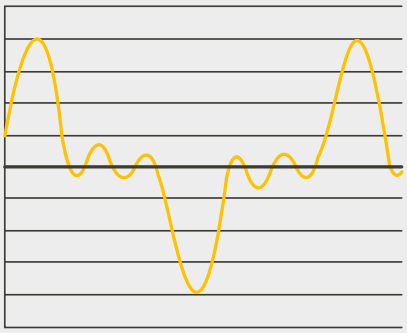
A granular design of the monitoring system allows:

- Energy data acquisition by cost centres
- Faster fault localisation in the event of a fault
- An economic pyramid structure beginnning with power sources down to the loads

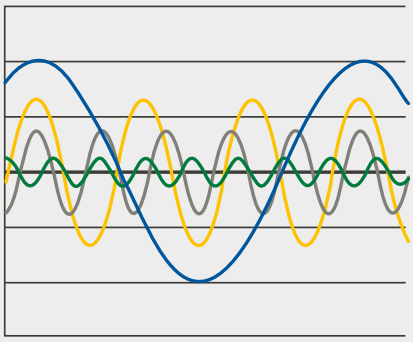
The goal of a monitoring system must be to recognise even small changes in relevant measuring quantities such as leakage current or the harmonic content and to generate a prewarning in the event of deviations at the earliest possible stage.

A single measuring point in an electrical installation is not sufficient to generate curves of relevant measuring quantities that adequately represent voltage quality or leakage currents. Several measuring points need to be installed and adapted to correspond to the structure of the system.

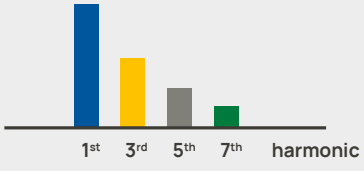
Distorted shape of current



Analysis of the harmonics



Spectrum of harmonics



Fundamental component
5th harmonic
3rd harmonic
7th harmonic

The refit: Is your system still state of the art?

When you have the opportunity to take security-relevant processes to a new level, choose the best possible solution!
Even the most modern electrical systems cannot escape the marks of time. Whether diminishing operational reliability, changed legal stipulations or increasing energy costs: Upgrading to the respective current state of the art is indispensable.

Three questions are sufficient to clarify your need for action in monitoring the energy quality on board:

- Are you able to detect a symmetrical insulation fault?
- Are you able to identify a DC fault?
- How and with what effort do you even detect your faults?

Even if you only answer “no” to one of the questions or if you should just start thinking about it, it is time for action and the Bender service crew will gladly support you with their profound know-how.

Symmetrical and asymmetrical insulation faults present a high risk potential. Bender insulation monitoring devices continuously monitor your systems, insulation faults are captured and reported. Bender insulation monitoring devices comply with IEC 61557-8.

Fault location – made easy
With portable fault location systems, existing insulation faults can be quickly located. They are the best alternative if no stationary equipment for insulation fault location is available.

Bender delivers flexible solutions for refit projects
Modern monitoring methods can be integrated in older installations as well – also during ongoing operation. Refitting is possible via devices such as divisible transformers, whereby the transformers do not even have to be shut down nor must cable installations be disconnected.

Successor devices from Bender can conveniently replace older installations. Long-term availability is thus guaranteed.

The majority of our maritime customers use the Bender EPS for detecting their insulation faults immediately and with minimal effort – making time-consuming and nerve-racking searches a thing of the past.

Use our Bender know-how area to get detailed information about our product lines and training possibilities. We look forward to your enquiry!

Support during all stages: Comprehensive service for your installation: remote, by phone, on site

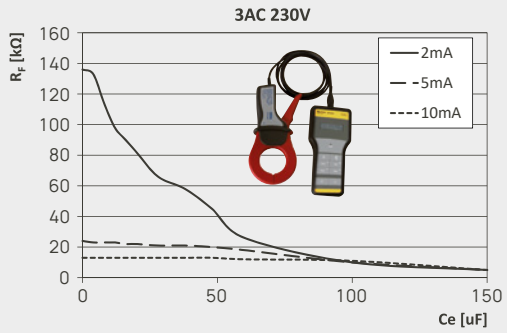
From planning to modernisation
Our extensive know-how is at your disposal during all project phases.

Furthermore, with our first-class service we guarantee maximum safety for your electrical installations.
We offer services ranging from support over telephone to repairs and on-site service – with modern measuring devices and competent employees.

Secure yourself:

- High availability of your installation thanks to fast reaction to fault messages
- Increased profitability of your capital expenditure (CapEx) via optimised maintenance processes
- Targeted operating expenditure (OpEx) due to less downtimes and shorter service visits
- Support for your prospective system monitoring and regular tests of your system/power quality/ monitoring devices
- Automatic control, analysis, correction, new settings/updates
- Competent assistance with setting changes and updates

Mobile earth fault detection rate



Bender Remote Assist
Bender Remote Assist offers you support via remote access, high-quality service and advice for your challenging task consisting in ensuring consistent high safety in your systems.

Many service visits, fault clearance but also analysis and controls can be carried out remotely – without the expenses of time and money that an on-site visit of a technician implies.

This fast, efficient help and advice by our expert network enables the highest possible availability of your system.

Competent service for maximum safety and high availability of your installation

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