# Technical aspects
# IT systems

The perfect solution for a 360° power supply

For more continuity in power supply

For the 365/24 power supply



We all know that daily life has become unthinkable without electrical energy. High availability of electrical energy therefore is fundamental for the safe and efficient operation in the following areas

- **Industrial installations**
  including mechanical and plant engineering, chemicals, refinery and manufacturing in order to avoid expensive interruptions of important processes
- **Infrastructure**
  such as airports, ports, tunnels, road traffic and railways, where electrical safety and fire protection are top priorities
- **Health care**
  such as operating theatres and intensive care units, where the well-being of the patient, doctor and staff is at stake
- **Marine applications**
  for safe and environmentally friendly transport of goods and passengers by sea,
  but also for reliability in military applications
- **Energy generation and distribution**
  so that with photovoltaic, wind and water power, nuclear power and other energy sources a problem-free power "round the clock" power supply is available
- **Raw material extraction**,
  for the prevention of fires and explosions during the extraction of oil, gas and other energy sources as well as the safe operation of electrical installations in mining and surface mining and the monitoring of umbilicals to supply subsea installations.

**The claim:**
Electrical energy has to be available…

…at any time of the day or night…
…in any quantity and...

without interruption. From the consumer's point of view, the best availability is 100%. The fundamental basis for the necessary high safety requirements is standard-compliant electrical energy generation and distribution in conjunction with the correct choice of system type and practical protection and monitoring devices. It is therefore important to inform the operator about imminent hazards at an early stage and thus prevent cost-expensive production and operational interruptions. Not to forget the goal of not endangering human lives with electric current, especially in medical locations.

In this sense the N-1 principle applies: One element can fail and the supply of electrical energy remains 100% guaranteed.The term "element failure" here refers to the first insulation fault.

With these goals in mind, the IT system (unearthed power supply) is in the foreground, because this is the only system type where a first insulation fault does not lead to an interruption or failure of the power supply. With insulation monitoring devices IT systems are permanently monitored and thus provided with the information advantage in terms of information – before a malfunction results in high costs. The spectrum of Bender system's messages systems ranges from simple alarm LEDs to state-of-the-art network technologies.

The bottom line is that the fundamental characteristics of IT systems also have a positive impact on merchants. The initial somewhat higher investment costs pay for themselves quickly, because expensive interruptions to operations and unplanned ad hoc-maintenance measures usually cost many times more in terms of time, money and personnel expenditure.

**The insulation resistance**

In electrical installations and equipment, insulation resistance is the determining factor with regard to personal, system and fire protection. Without sufficient insulation resistance:

- protection against direct or indirect contact is not guaranteed
- fault currents lead to personal hazards and possible interruptions to operation
- short-circuit and earth fault currents can cause fires and explosions and destroy expensive parts of the installation
- malfunctions of the electrical equipment can lead to personal hazards, loss of production or system downtime
- high costs may be incurred due to interruption of operation, damage to property or personal injury
- the lives of humans and farm animals can be endangered.

The insulation resistance is relatively high in newly installed systems and equipment. In an electrical installation without connected equipment connected, the value is significantly higher than the required minimum value of 1 MΩ. The insulation resistance is reduced during operation for a variety of reasons. On the one hand it is the number of electrical loads. The parallel connection of the device's own insulation resistances or those of the system reduces the overall insulation resistance, but without falling below a critical value. The topic becomes more difficult when the insulation resistance drops below a critical value due to unforeseen events. Causes may be:

- **Electrical**
  - Static overvoltage
  - Transient overvoltage
  - Frequency changes
  - Lightning effect
  - Overcurrent
  - Voltage waveform
- **Mechanical**
  - Shock, impact
  - Kinks, flexing
  - Vibration
  - Ingress of foreign bodies
- **Environment**
  - Temperature
  - Moisture
- **Chemical influences**
  - Pollution, dust deposits, oil
  - Aggressive atmosphere
  - Ageing of cables and electrical equipment
- **Other effects**
  - Animals (e. g. caused by bites)
  - Plants

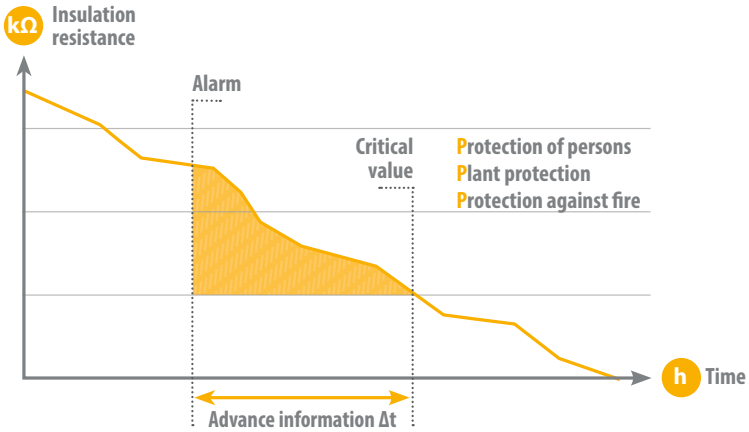



*Figure: Typical drop in insulation resistance of electrical installations*

**Safe and reliable power supply**

Depending on the respective distribution system, standard-compliant protective measures must therefore be taken to either report a drop in insulation resistance below a specified value or to switch-off the affected current circuit.

This not only requires the use of appropriate protective devices and continuous monitoring of the installation, but also regular testing of the equipment, the time interval of which depends on the type of equipment and the operating conditions.

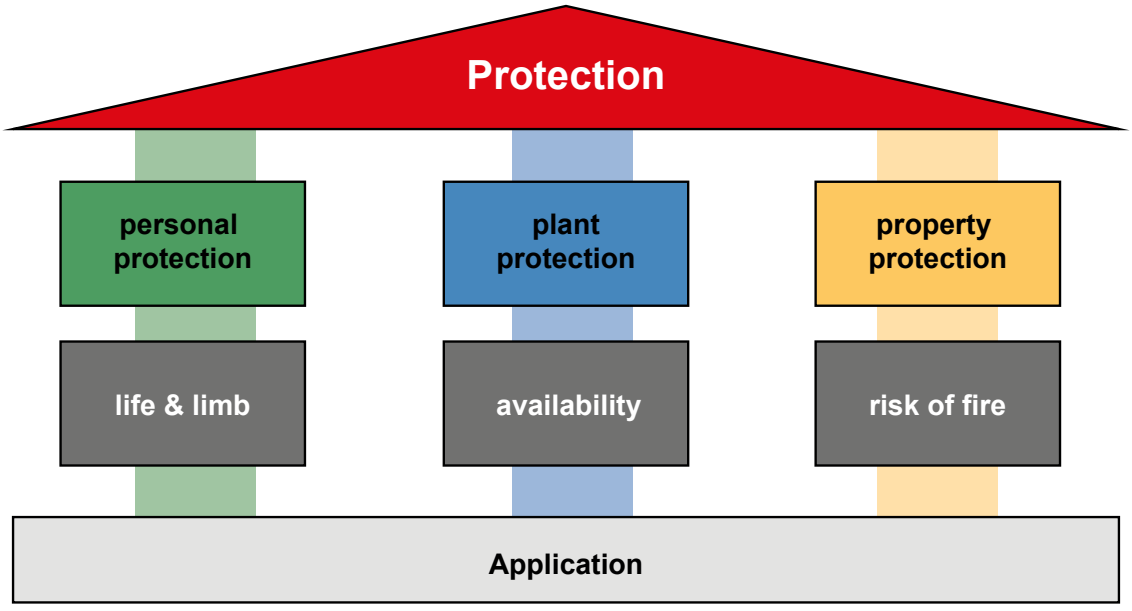



*Figure: Personal protection, property protection and operational safety*

**Personal protection**

If a current flows through the human body, circulatory and respiratory functions are impaired and severe burns can also occur. The danger for humans depends on the strength of the current, the parts of the body through which the current flows and the duration of exposure.

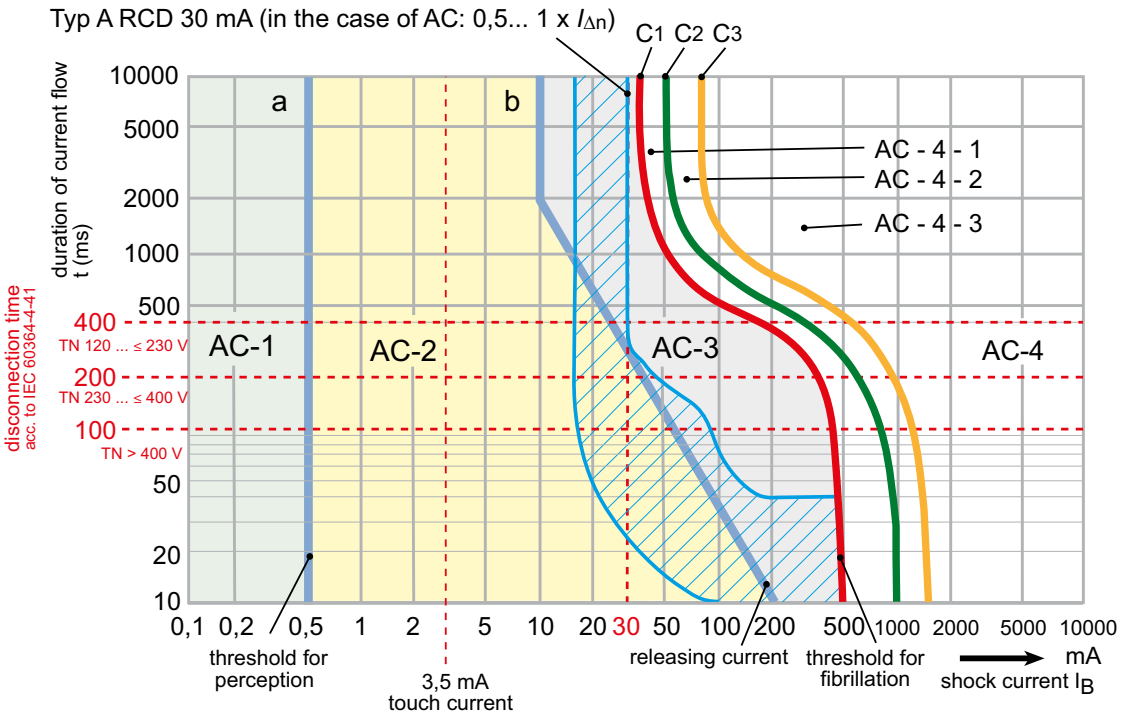



*Figure: Time-current zones with effects on the human body at alternating currents of 15…100 Hz (current flow from the left hand to both feet)*

| Ranges | Range limits | Physiological effects |
|---|---|---|
| AC-1 | Up to 0.5 mA<br>curve a | Perception possible, but usually no shock reaction |
| AC-2 | above 0.5 mA to curve b | Perception and involuntary muscle contractions probable, but usually no adverse physiological effects |
| AC-3 | Curve b to curve $c_1$ | Perception and involuntary muscle contractions likely,<br>difficulty in breathing; reversible disturbances of heart function, immobilisation (muscle cramps) may occur; Increasing effects with current intensity and flow duration; usually no organic damage to be expected |
| AC-4 | over the curve $c_1$ | Pathophysiological effects such as cardiac arrest; respiratory arrest, and burns and other cellular damage may occur; Probability of ventricular fibrillation increasing with current magnitude and time |
| | $c_1$-$c_2$ | AC-4-1 Probability of ventricular fibrillation increasing up to about 5% |
| | $c_2$-$c_3$ | AC-4-2 Probability of ventricular fibrillation increasing up to about 50 % |
| | over the curve $c_3$ | AC-4-3 Probability of ventricular fibrillation increasing up to above 50 % |

**Fire protection**

Priority is given to the prevention of fire ignited by means electrical energy,
or the avoidance of ignition sources and the detection of ignition sources before the energy acting at the point of fault has risen to such an extent that it leads to overheating which may ignite a fire. In the specialist literature a minimum performance of P = 70-100 W stipulated.

| Protective devices | Max. continuous current | $P_{Iso}$ at $U_n$ = 230 V |
|---|---|---|
| Fuse 10 A | 15 A | 3,450 W |
| MCBB B/C/D | 18 A | 4,160 W |
| RCCB $I_{\Delta n}$ = 0.5 A | 0.5 A | 115 W |
| RCCB $I_{\Delta n}$ = 0.3 A | 0.3 A | 69 W |
| RCCB $I_{\Delta n}$ = 0.03 A (30 mA) | 0.03 A | 6.9 W |

The advantage of unearthed systems (IT systems) is that only a small fault current can flow in the event of a first fault so that the power dissipation is very low. This significantly reduces the risk of fire in IT systems.

# Availability of electrical energy

The availability of electrical energy is an indispensable prerequisite in many areas. A failure of the electrical energy has a decisive influence on:

- the safety of persons
- the safety of property
- The profitability of a company or the cost-effectiveness of the production process.

Therefore, not only early detection but also fast fault clearance are indispensable. Several technical solutions with different effectiveness are available for fault clearance. These solutions can be compared in terms of two criteria following criteria:

- Availability of the power delivered
- Quality of the power delivered

The availability of electrical power can be considered as the time per year when voltage is available at the load terminals. The availability is mainly affected by power failures or disturbances of the electrical system. There are several solutions for limiting risks:

- Distribution of the system using not only one power supply system, but several power supplies.
- Subdivision of the system into circuits authorised for standby power supply and circuits not authorised for standby power supply while the power supply of circuits authorised for standby power supply can be taken over by other available power supply sources, if required.
- Load shedding, so that (if required) a smaller rated output is available to be used for standby power supply.
- Selection of a power distribution system that is designed for the operating continuity, e.g. the IT system.
- Selectivity of protective devices (selective tripping) for limiting the effects of a fault on the part of the installation affected by the fault.

It should be noted that the only way to ensure the availability of electric power in the event of power failure is to use an independent power source in addition to the above-mentioned measures, at least for loads authorised for standby power supply.

**Power supply systems**

The general principles and characteristics for the various types of distribution systems are described in DIN VDE 0100-100(VDE 0100-100):2009-06. The main distinguishing features are:

- Current type: AC, DC, 3(N)AC
- Type of system earthing: IT, TT, TN
- Type/number of active conductors: L1, L2, L3,or L+, L-

The type of system earthing must be selected carefully as it essentially determines the behaviour and characteristics of the supply system and has a decisive influence on the aspects of use.When selecting the system type, the following aspects must be considered:

- Supply reliability/availability of power
- Installation effort
- Maintenance, downtimes
- Electromagnetic compatibility
- Protective and monitoring devices

The earthing schemes defined in the IEC and VDE standards (IT, TN, TT systems) have the same purpose with regard to the protection of persons, fire and property: To control the effects of insulation faults.

They are considered to be equivalent in terms of personal protection when touched indirectly. However, this does not necessarily apply to the safety of electrical installations with respect to:

- Reliability of supply/availability of electrical energy
- Maintenance, downtimes

The IT system has a clear advantage here, because a first insulation fault does not lead to a shutdown and in combination with insulation fault location systems a tool is available that allows a precise indication of the location of fault.

**TT system**

In TT systems, one point is connected directly to earth (functional earthing). The exposed-conductive parts of the electrical installation are connected to earth electrodes which are electrically isolated from the earth electrode for earthing the system.

Permissible protective devices:

- Overcurrent protective device
- Fault current protective device (RCD)

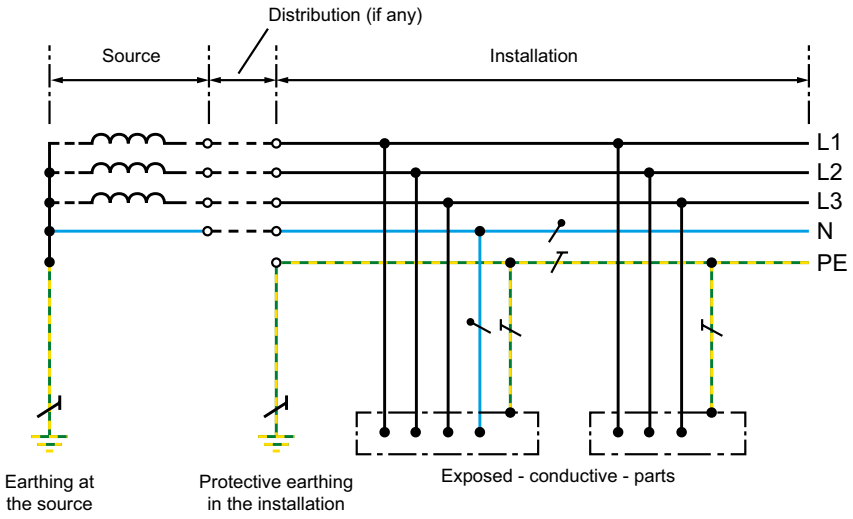



*Fig: TT system*

**TN system**

In TN systems, one point is directly earthed; the exposed-conductive parts of the electrical installation are connected to this point via protective earth conductors. Three types of TN systems can be distinguished according to the arrangement of the neutral and protective earth conductors:

- TN-S A separate protective earth conductor is used throughout the system
- TN-C The function of the neutral and protective earth conductors are combined in a single conductor throughout the system
- TN-C-S In one part of the system, the functions of the neutral conductor and the protective conductor are combined in a single conductor.

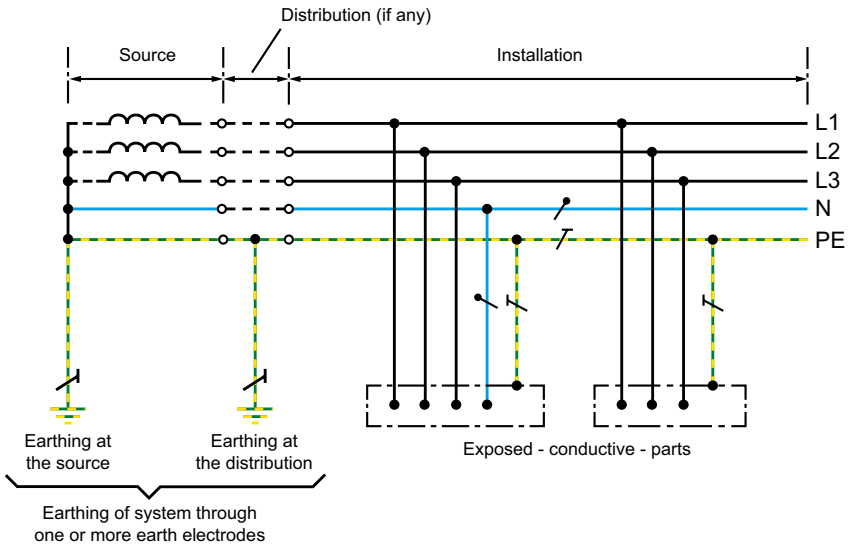



*Abb. TN-S system*

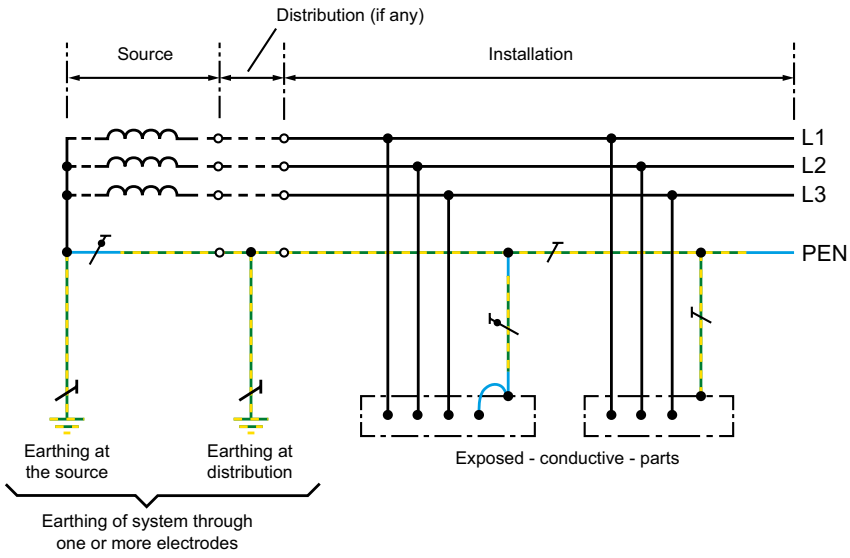



*Abb. TN-C system*

**IT system**

In IT systems, all active conductors are isolated from earth or one point is connected to earth via an impedance. On the occurrence of an insulation fault, therefore, only a small leakage current, essentially caused by system leakage capacitances, can flow. The upstream fuses do not respond. The power supply is maintained even with a single-pole direct earth faults.

The exposed-conductive parts of the electrical installation are earthed

- individually or
- in groups or
- collectively.

The following protective devices are permitted:

- Insulation monitoring devices (IMDs)
- Overcurrent protective devices
- Residual current protective devices (RCDs), also known as residual current circuit breakers (RCCBs)

Characteristic features

- A first insulation fault does not cause a fuse or RCD/RCCB to trip.
- An insulation monitoring device detects an impermissible insulation deterioration and reports it.
- An insulation fault should be eliminated as quickly as possible before a second insulation fault occurs on another active conductor, which would lead to system failure.

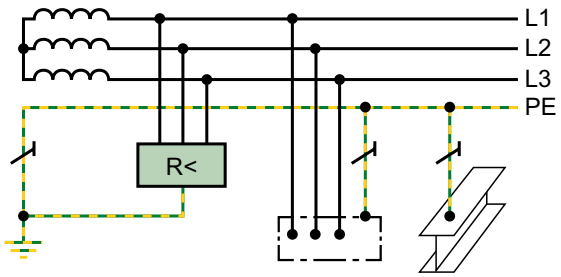
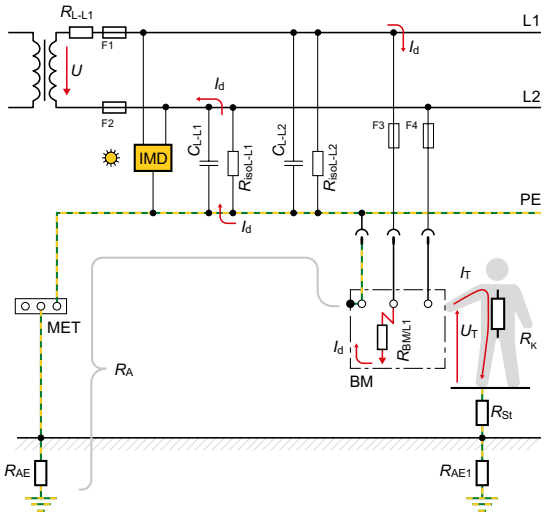


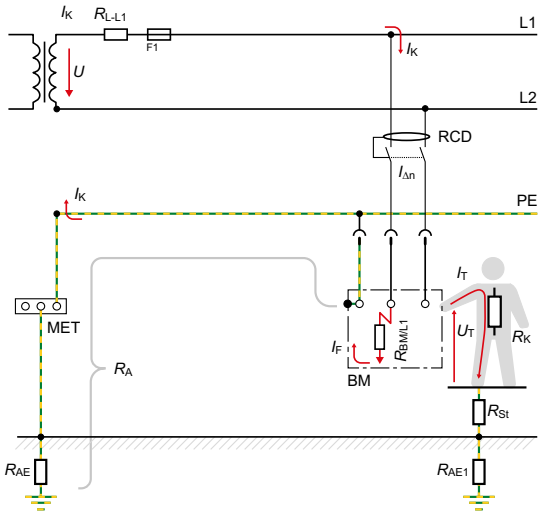

*Fig. IT system*

# Behaviour of the system forms in the event of a first fault

### IT system




### TN system




### IT system – 1stfault

a) The insulation fault $R_{BM/L1}$ causes a fault current $I_d$, which is determined by the system leakage capacitance $C_{L-L1}$ and the insulation resistance $R_{IsoL-L1}$

b) $I_d$ is very small, the fuse F1 does not respond

c) The Isometer indicates “insulation fault”

d) The power supply is not interrupted.

e) Due to the small Id and the low-resistance $R_A$, no high touch voltage $U_T$ can occur, since $R_K$ is parallel to $R_A$.

### TN system

a) The insulation fault $R_{BM/L1}$ causes a high short-circuit current $I_K$ which triggers the fuse F1.

b) If an RCD is present in the corresponding circuit, this triggers already at a fault current of $I_F > 30$ mA.

c) The power supply is interrupted

**IT system – the power source**

In IT systems all active conductors are isolated from earth or a point is connected to earth via an impedance (high-impedance earthing is not common in Germany). Likewise the primary side of the supplying power source will be insulated. Typical current sources are, for example.

- Isolating transformers
- DC voltage current sources with galvanic separation
- Motor generators (e. g. mobile generators)
- Battery systems

In the medial sector special isolating transformers are defined for the medical IT system which are defined in the DIN EN 61558-2-15: 2012-09 standard,because extremely low leakage currents are important in this area, because the heart muscle

is significantly more sensitive to current than the normal body resistance of the skin. For open heart surgery, the permissible touch $U_T$ is approx. 10 mV, while for normal skin resistance the touch voltage AC must not exceed AC 50 V/DC 120 V.

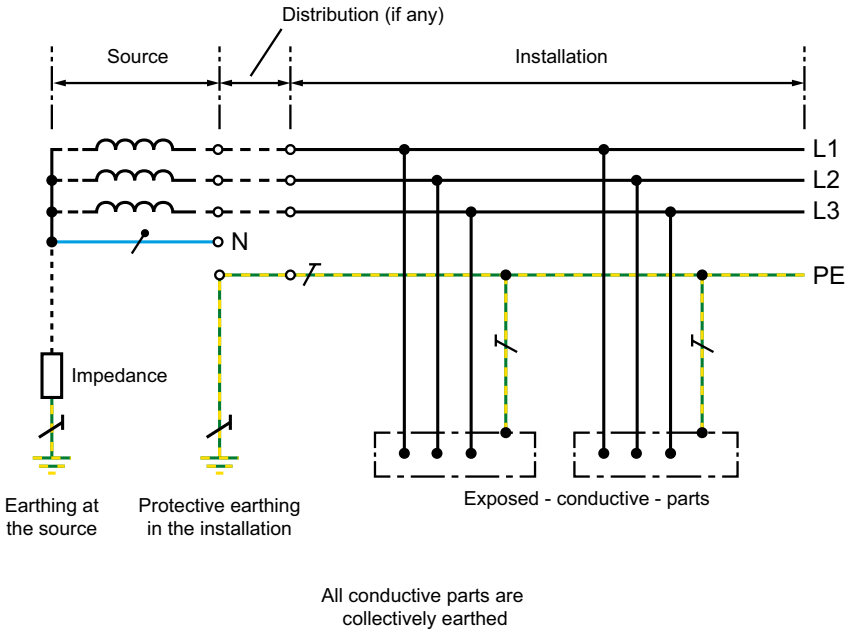



*Fig. IT system AC (single-phase, three-phase with and without N conductor*

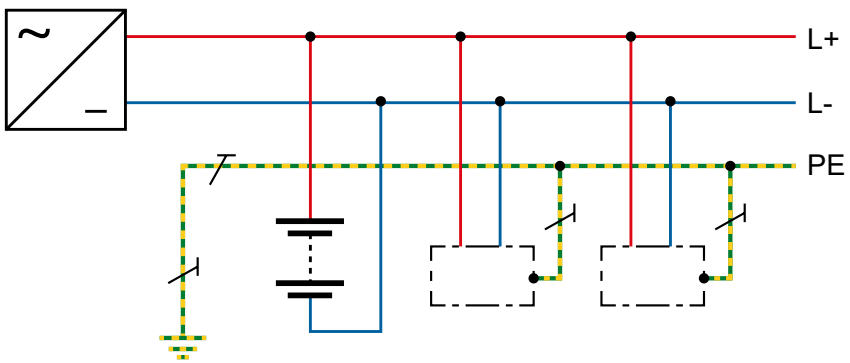



*Fig. IT system DC*

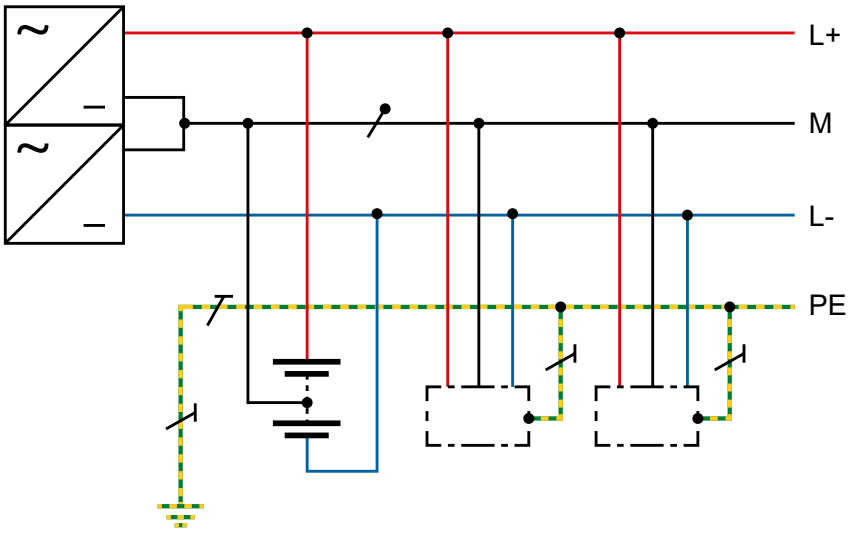



*Fig. IT system DC with central conductor*

**Earthing (of the loads) in the IT system**

The IT system is often referred to as the unearthed system. However, this is only applies to the connection between the active conductors and the earthing system. Basically, an earthing system must also be installed for the IT system. Further details on the structure of the earthing system are described in DIN VDE 0100-410:2018-10 chapter 411.3.1.1 or DIN VDE 0100-540: 2012-06. According to this standard

- exposed-conductive parts must be connected to a protective conductor under the given conditions for each system earthing according to the type of earth connection.
- Simultaneously accessible conductive parts must be connected with the same earthing system individually, in groups or collectively.
- There must be a protective conductor for each circuit which is earthed by connection to the earthing terminal or earthing bar assigned to this circuit.

The exposed-conductive parts of the electrical installation are either

- individually, in groups, or
- collectively earthed or
- share a common connection to the system earthing.

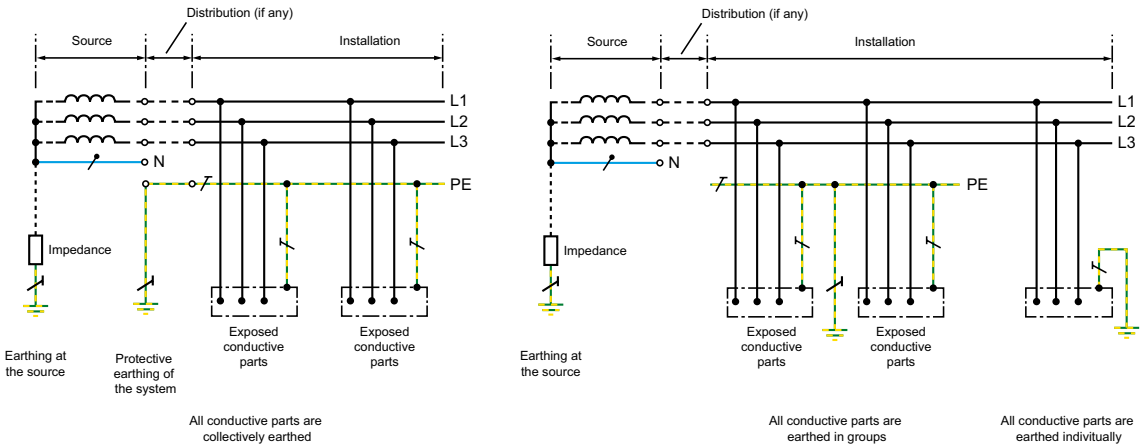



*Abb. IT system with common connection,in groups or individual connection to earth*

**Protection against electric shock**

The protection against electric shock by automatic disconnection is described in chapter 411 of DIN VDE 0100-410:2007-06. A protective measure always consists of basic protection and fault protection. In the case of protection by automatic disconnection, the protective measure is defined as follows:

- **Basic protection (protection against direct contact)**
  Basic insulation of active parts or by barriers or enclosures according to Annex A of DIN VDE 0100-410:2018-10)
- **Fault protection**
  Protective-equipotential-bonding via the main earthing rail and automatic disconnection in case of a fault according to chapter 411 of DIN VDE 0100-410:2018-10

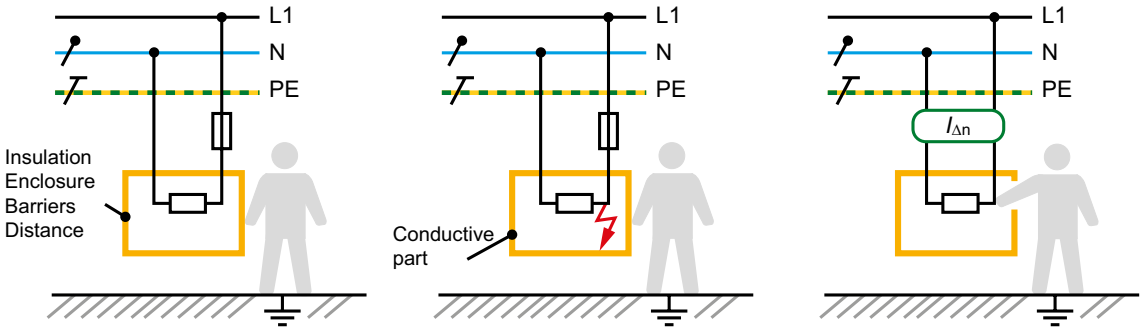



*Fig. A) direct contact* *B) indirect contact* *C) additional protection*

A proper earthing and a protective conductor is therefore an essential component for protection by automatic disconnection. In the case of a *single fault* with *negligible* impedance between

- the line conductor and an exposed conductive part of
- a protective conductor of the circuit or
- a protective conductor of the equipment

the protective device itself must interrupt the power supply within the required disconnection time. However, this does not apply for the IT system. Provided that the exposed conductive parts are earthed individually, in groups or collectively, the fault current is low in the case of a single fault to an expose conductive part or to earth and *automatic disconnection is not necessary* (DIN VDE 0100-410:2018-10 chapter 411.6.1).

However, precautions must be taken in the event of a second fault on another conductor. With common connection to earth, the disconnection conditions are comparable to a TN system, with individual or group earthing, the conditions are comparable to those of a TT system.

Permissible disconnection times (according to DIN VDE 0100-410:2007-06: Table 41.1)

| System | 50 V < $U_0$ ≤ 120 V | | 50 V < $U_0$ ≤ 120 V | | 50 V < $U_0$ ≤ 120 V | | 50 V < $U_0$ ≤ 120 V | |
|---|---|---|---|---|---|---|---|---|
| | AC | DC | AC | DC | AC | DC | AC | DC |
| TN | 0.8 s | see note | 0.4 s | 5 s | 0.2 s | 0.4 s | 0.1 s | 0.1 s |
| TT | 0.3 s | see note | 0.2 s | 0.4 s | 0.07 s | 0.2 s | 0.04 s | 0.1 s |

***Note:***

If the disconnection in IT systems is achieved by overcurrent protective devices and all extraneous conductive parts in the system are connected to the protective equipotential bonding, the disconnection time applicable for TN systems may be used.

IT systems are not listed in this table since disconnection in the event of a first fault is not required and therefore no time is can be set. The disconnection times are only to be observed in the event of a second fault. For the first fault in an IT system, there is only the specification that a first fault must be eliminated with the shortest practicable delay (DIN VDE 0100-410:2018-10 chapter 411.6.3.1), whereby this is then at the discretion of the system operator.

**Protective and monitoring devices in IT systems**
According to DIN VDE 0100-410:2018-10, the following protective and monitoring devices are permissible to be in IT systems:

- Insulation monitoring devices (IMDs)
- Insulation monitoring systems (IMDs);
- Residual current monitoring devices (RCMs);
- Insulation fault location systems (IFLS);
- Overcurrent protective devices;
- Residual current protective devices (RCDs).

In IT systems in accordance with DIN VDE 0100-410:2018-10 chapter 411.6.3.1), the first fault must be reported by an insulation monitoring device (IMD) or a residual current monitor (RCM) if the system is not disconnected at the first insulation fault. It is also required that the first fault must be reported by an audible and/or visual signal. Therefore, the planner should ensure that the insulation fault message is indicated at the appropriate point.

The use of RCDs or RCMs in IT systems is only possible under certain conditions and is not common in Germany, since symmetrical insulation faults cannot be detected.

**System leakage capacitance $C_e$ in IT systems**
The existing system leakage capacitance $C_e$ is an important selection criterion for the insulation monitoring device. The Cemax value specified for these devices is the value up to which the insulation monitoring device operates as intended.

***Natural system leakage capacitance (A)***
The natural system leakage capacitance is the share of the total capacitance $C_e$ ges. resulting from the natural (geometric) structure of the system's line system to earth.

Line capacitances depend on the insulation strength between the conductors, the distance h, the material constant $\varepsilon_f$, the electrical field constant $\varepsilon_0$ and the area of the insulation between the conductors. As a rule, this value is approx.150 pF/m.

***Artificial system leakage capacitances (B)***
In order to eliminate EMC faults caused by non-linear loads, different frequencies or high frequency harmonics and to comply with EMC standards, loads are connected to interference suppression capacitors. As a result of these interference suppression filters, the system leakage capacitances can increase or higher leakage currents can flow. Typical interference suppression capacitors in electronic devices range from 10…100 nF.

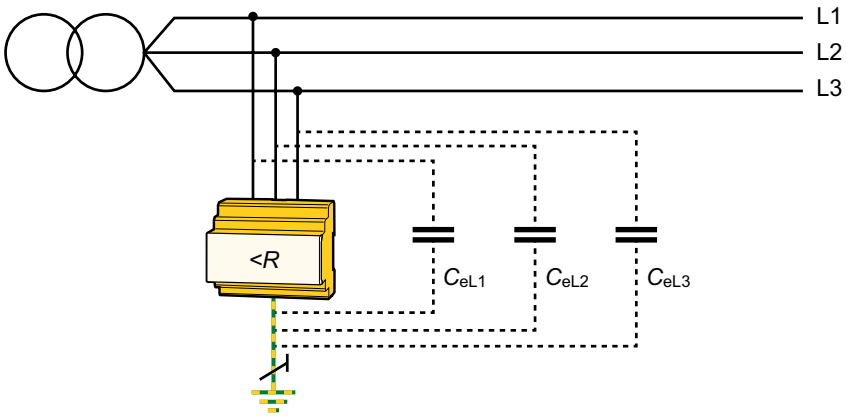



*Fig. Addition of the system leakage capacitances $C_e$ in relation to the insulation monitoring device*

**The first fault in an IT system**

In electrical systems according to DIN VDE 0100-410:2018-10, the statement applies that the electrical safety of persons is guaranteed if the touch voltage is < 50 V (AC) or < 120 V (DC). In normal operation in an IT system only the system leakage capacitances have a connection to earth or to the protective conductor, because the neutral point or the active conductors are isolated from earth or the protective conductor. Since the system leakage capacitances are all connected in parallel, their values add up to the total system leakage capacitance $C_e$. In general, one can assume approximately uniform partial capacitances $C_L$ of the conductors to earth for the overall system. For a three-phase IT system, the following applies:

$C_e = C_{L\text{-}L1} + C_{L\text{-}L2} + C_{L\text{-}L3}$

$C_e$ is also the value that must be considered when selecting an insulation monitoring device.

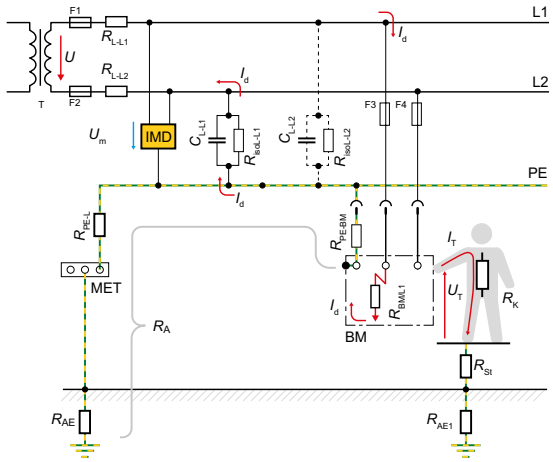



*Diagram: Single-phase IT system on the occurrence of a first insulation fault $R_F$*

In the event of a first fault, a current $I_d$ flows via the protective conductor which must not exceed a specific value. In addition to the known limit values for the touch voltage $U_T$ of AC 50 V or DC 120 V, the value Id of the earthing resistance $R_A$ of the system must also be taken into account. The lower the impedance of the earthing resistance $R_A$, the higher the permissible fault current $I_d$. The following applies:

For AC systems $R_A \text{ x } I_d \leq 50 \text{ V}$

For DC systems $R_A \text{ x } I_d \leq 120 \text{ V}$

$R_A$ is the sum of the resistances in ohms of the earth electrode and the protective conductor to the respective exposed conductive parts

$I_d$ is the fault current in A at the first fault with negligible impedance between a line conductor and an exposed conductive part. The value of $I_d$ takes into account the leakage currents and the total impedance of the electrical system.

The earth resistance must be selected so that no impermissible touch voltage can occur during an insulation fault. This means that the lower the resistance $R_A$, the higher the permissible value of $I_d$. This makes it clear that an IT system with a high earthing resistance, e.g. 100 Ω, is still safe if the fault current is correspondingly low. This is advantageous, for example, if earthing is required in rocky ground.

The earth resistance can also be determined with $I_d$:

$$R_A = \frac{U_T}{I_d} = \frac{50\ V}{I_d} = \frac{50\ V}{U\ \omega\ C_e}$$

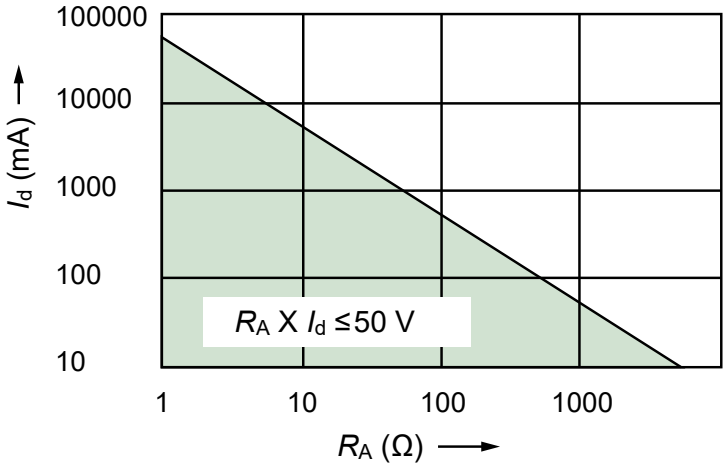



*Fig. $I_d$ depending on $R_A$*

***Single-pole insulation faults***

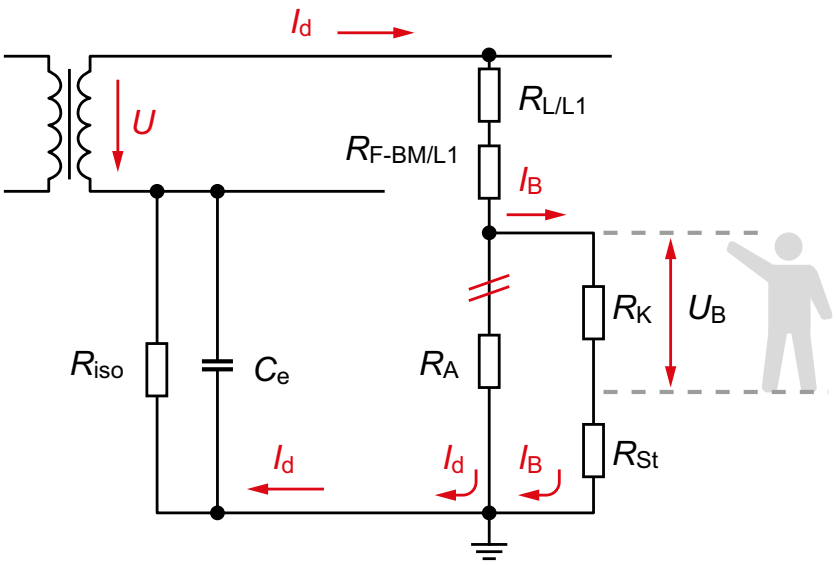
The calculation of the capacitive earth fault current $I_d$ is relatively simple for a low impedance insulation fault (dead earth fault), as this gives an indication of the system circumference as a parameter of the IT system:

$$I_d = \frac{U}{\sqrt{3}} \times 3\ \omega\ C_e = U\ \sqrt{3}\ \omega\ C_e$$

The following applies to single-phase AC systems

$$I_d = U\ \omega\ C_e$$

If the insulation resistance of the healthy conductor is taken into account, the following equivalent wiring diagram results for a single-phase IT system.




From this, the residual current $I_d$ r the touch voltage $U_T$ can be calculated:

$$I_d = \frac{U}{R_L + R_F + R_{PE} + \frac{R_{Iso} \times X_{Ce}}{R_{Iso} + X_{CE}}}$$

$$X_{CE} = -\frac{1}{j\omega C_e} \qquad I_d = \frac{U}{R_L + R_F + R_{PE} + \frac{R_{Iso}}{1 + R_{Iso} + j\omega C_E}}$$

With assumed values of

$R_L = 0.5\ \Omega$
$R_F = 10\ \Omega$
$R_{PE} = 0.5\ \Omega$
$C_{L\text{-}L1} = 1$ uF

the touch voltage $U_T$ results as follows:

$$I_d = \frac{230\ V}{0.5\ \Omega + 10\ \Omega + 0.5\ \Omega + \frac{1\ M\Omega}{1 + (1\ M\Omega \times 2\pi 50\ Hz \times 1\ \mu F)}}$$

*at 50 Hz* $I_d = 0.0724\ A$

$U_T = 0.0724\ A \times (0.3\ \Omega + 10\ \Omega) = 0{,}745\ V$

The touch voltage $U_T$ is thus clearly below a critical value of 50 V.

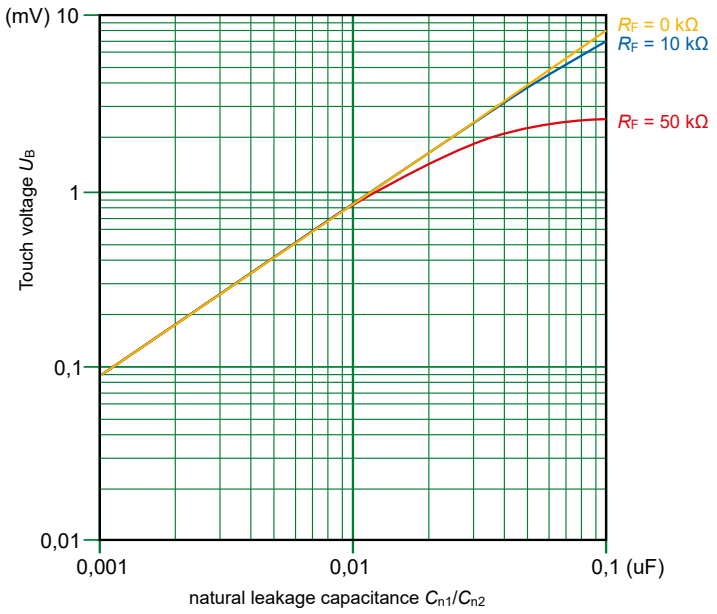



*Fig. Touch voltage in an IT system*

**Limits of an IT system**

The limits of an IT system are largely determined by its expansion. The larger the system, the smaller the impedance between active conductors and earth. This impedance is mainly determined by the line, interference suppression and natural system leakage capacitances.

Typical capacitance values are for example

| | |
|---|---|
| In medical IT systems | 0.01 uF per phase |
| In small IT systems | 0.3 uF per phase (L1, L2, L3) |
| In medium-sized IT systems | 1.6 uF per phase (L1, L2, L3) |
| In large IT systems | 10 uF per phase (L1, L2, L3) |

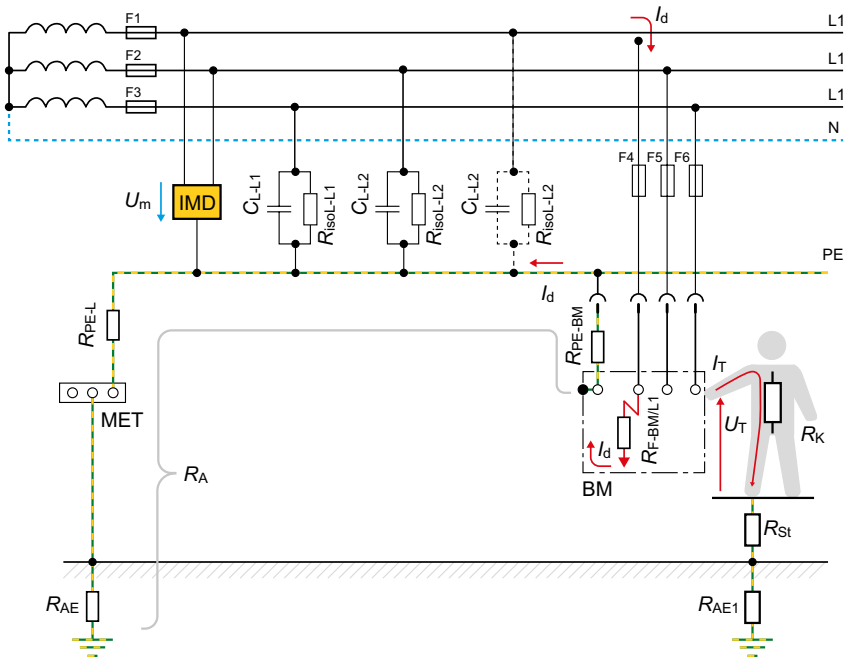



*Fig. Three-phase IT system*

Equivalent diagram of a three-phase IT system:

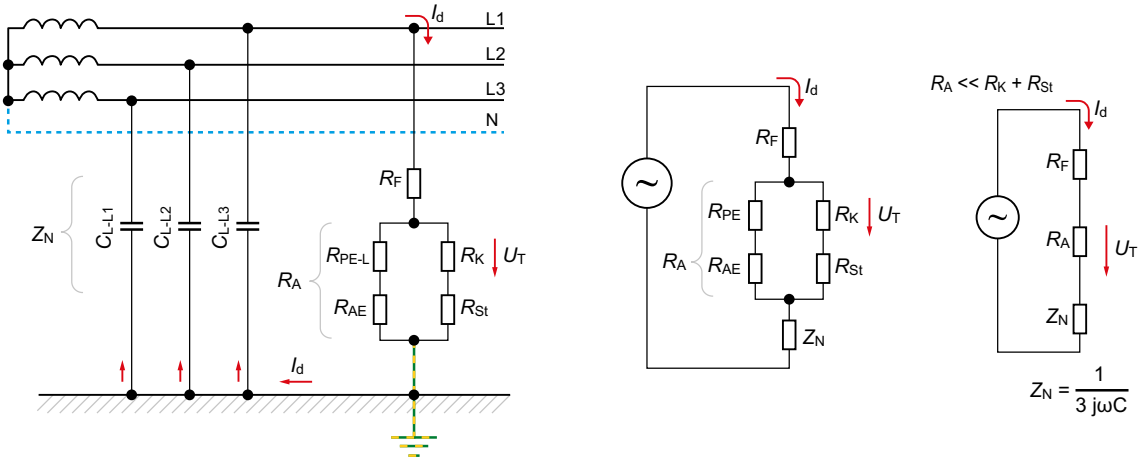
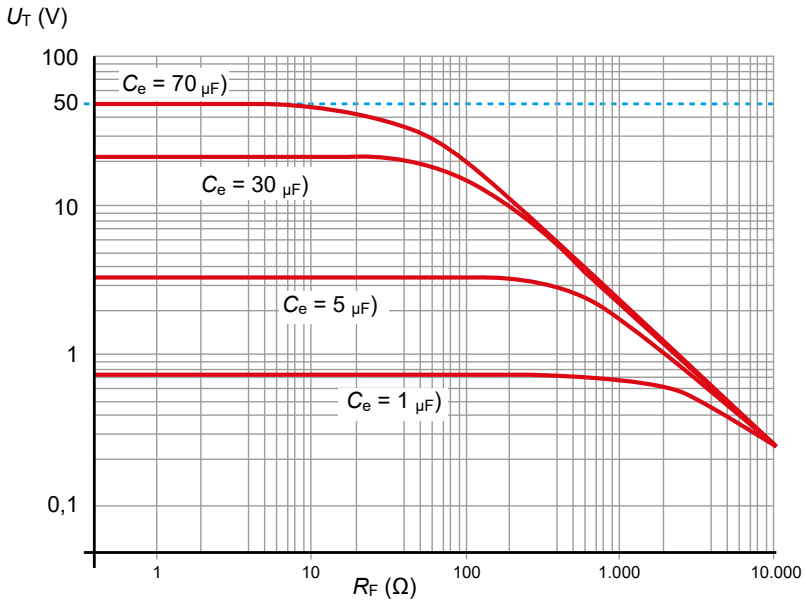



*Fig. Equivalent wiring diagram three-phase IT system with insulation fault ($R_F$)*

For the touch voltage $U_B$ the following then applies

$$U_B = U_0 \times \frac{R_A}{Z_{ges}} = \frac{R_A}{R_F + R_A - \frac{1}{3\,j\omega C_e}\,\mathrm{i}}$$

This results in the following set of curves for different system leakage capacitances $C_e$:




This means that in a three-phase IT system with a total system leakage capacitance of approx. 70 µF, the touch voltage $U_T$ can exceed the value of 50 V, but only if the insulation fault is < 100 Ω. This means that early detection of an insulation fault (e.g. > 100 Ω/V) by an IMD and insulation fault location by an IFLS, can significantly reduce the risk of an excessively high touch voltage $U_T$.

### Comparison of the system types TN, TT and IT system

| System type | Advantages | Disadvantages |
|---|---|---|
| Safety extra-low voltage/ functional extra-low voltage (SELV or FELV) | No hazard potential on contact | Limited performance with economical use of operating resources<br>Special requirements on circuits |
| Protective insulation | Highest level of safety<br>Can be combined with other types of systems | Double insulation of the equipment<br>Only cost-effective for small loads<br>Insulating material pose fire hazard on thermal loads |
| IT system | EMC friendly<br>Higher availability:<br>The firstfault is simply reported,<br>disconnectionin the event of a second fault<br>Low earth fault current in small systems<br>Influence on neighbouring installations is reduced, this in turn makes earthing easier<br>Reduced effort for laying cables and wires<br>Use of appropriate equipment facilitates fault location | Equipment has to be insulated universally for the voltage between line conductors<br>Overcurrent protection device for N conductor required<br>Potential problems with disconnection on second earth fault |
| TT system | EMC friendly<br>Protective measure independent of the system's short-circuit power<br>Little technical effort for laying cables and wires<br>Touch voltages can vary from one area to another<br>Can be combined with a TN system | Only compatible with low power ratings due to the use of RCDs<br>Regular functional test required<br>Operational earthing is complex ($\leq 2\ \Omega$)<br>Equipotential bonding mandatory for every building |
| TN-C system | Easy to set up<br>Low material expenses | Not EMC friendly<br>Building stray currents and low-frequency magnetic fields make the system incompatible for use in buildings housing information technology equipment<br>Risk to life and limb in case of PEN break<br>Higher risk of electrically ignited fires |
| TN-C-S system | A cost-effective compromise for buildings which do not house information technology equipment | Not EMC friendly<br>Low-frequency magnetic fields possible |
| TN-S system | EMC friendly<br>Low voltage rise in the healthy phases | Increased safety engineering outlay for remote multiple infeeds<br>Risk of multiple earthing going unnoticed |

# Insulation monitoring devices (ISOMETER®)

According to DIN VDE 0100-410 (VDE 0100-410:2018-10) chapter 411.6 and IEC 60364-4-41:2017-03 insulation monitoring devices are an absolutely essential component of unearthed power supplies (IT systems) in order to report a first fault between a live part and an exposed-conductive part or to earth. Insulation monitoring devices are today called "ISOMETER" for short, whereby this term is a registered trademark of Bender.

Insulation faults are defined as follows

a) *symmetrical* insulation fault: Resistive fault in the insulation of an electrical installation or a device against earth with approximately the same resistance of all external conductors to earth.

b) *asymmetrical* insulation fault Resistive fault in the insulation of an electrical installation or a device against earth with different resistances of the line conductors to earth

- *Extract from IEC 60364-4-41:*
  - Where an IT system is designed not to disconnect in the event of first fault, the occurrence of the first fault shall be indicated by either:
    - insulation monitoring device (IMD), which may be combined with an insulation fault location system (IFLS);
    - a residual current monitor (RCM), provided the residual current is sufficiently high to be detected.

  NOTE Residual current monitors are not able to detect symmetrical insulation faults.

  This device shall initiate an audible and/or visual signal which shall continue as long as the fault persists. The signal can be initiated via a relay contact output, an electronic switching output or a communication protocol.

According to the product standard for insulation monitoring devices, DIN EN 61557-8 (VDE 0413-8): 2015-12, the following requirements apply:

- Insulation monitoring devices must support a prescribed measuring principle that enables them to monitor both symmetrical and asymmetrical deteriorations in insulation.
  - A symmetrical deterioration in insulation can be said to occur when the insulation resistance of all conductors on the system to be monitored declines to (approximately) the same extent.
  - An asymmetrical insulation deterioration in insulation can be said to occur when the insulation resistance, e.g. of a conductor, declines to a significantly greater extent than that of the other conductor(s) in the system.
- Devices known as earth fault monitors, which use the voltage unbalance (voltage shift) occurring in the event of an earth fault as a sole measuring criterion, are not insulation monitoring devices under the terms of this standard.
- Under certain system conditions, a combination of various measuring techniques, including unbalance monitoring, can be used for monitoring.
- Notes: Symmetrical insulation faults are common on DC voltage systems and control circuits. If the resistance of both insulation faults is approximately equal, insulation monitoring devices operating on the basis of the principle of superimposed voltage measurement will not be able to detect these insulation faults. It is for this reason that IEC 61557-8:2015-12 or DIN EN 61557-8 (VDE 0413-8) require the use of permanent insulation monitoring devices.

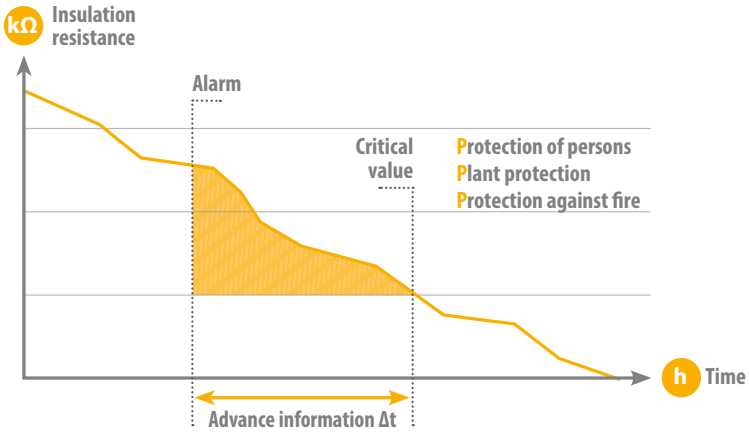



*Fig. Information advantage by message from the IMD*

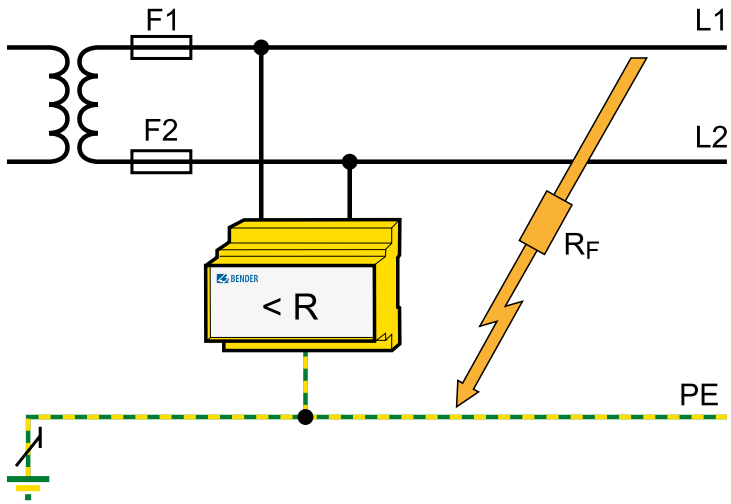



*Fig. Single-pole insulation fault*

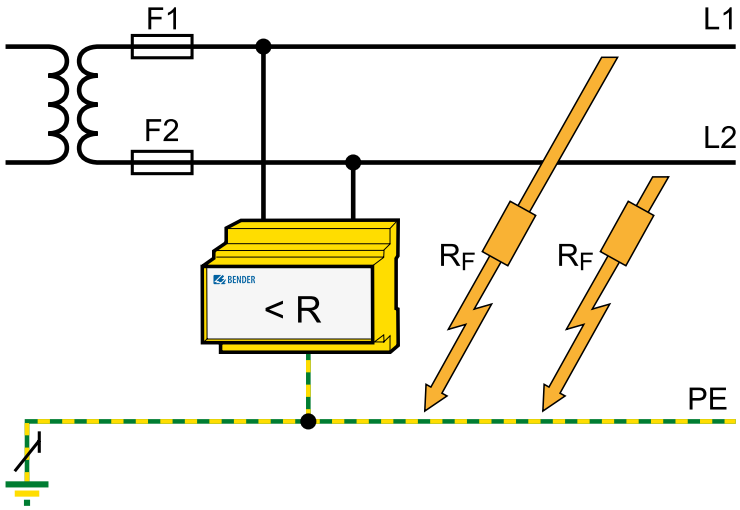



*Fig. Two-pole (symmetrical) insulation fault*

**Operating principle of an insulation monitoring device**

The insulation monitoring device is connected between the live supply conductors and earth and superimposes a measuring voltage $U_m$. In the event of an insulation fault, the insulation fault $R_F$ closes the measuring circuit between the system and earth $R_F$, generating a measuring current $I_m$ that is proportional to the insulation fault. This measuring current generates a corresponding voltage drop at the measuring resistance $R_m$ which is evaluated by the electronics. If this voltage drop exceeds a specific value equivalent to the undershooting of a specific insulation resistance, a signal will be output. IEC 61557-8 specifies detailed requirements to be met by insulation monitoring devices. Insulation monitoring devices serve as early warning systems, providing operators with the information they need in order to have appropriate maintenance measures taken in good time.

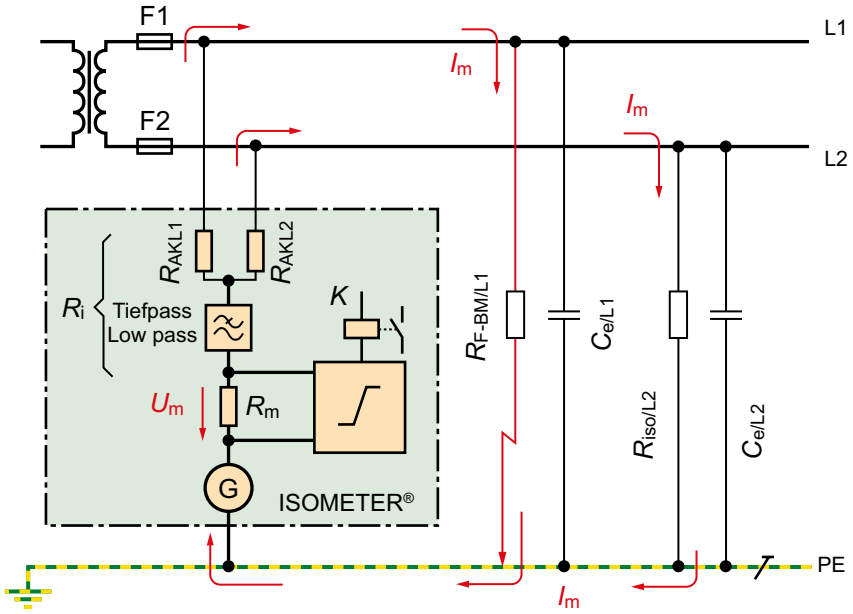



*Fig. Operating principle of an insulation monitoring device*

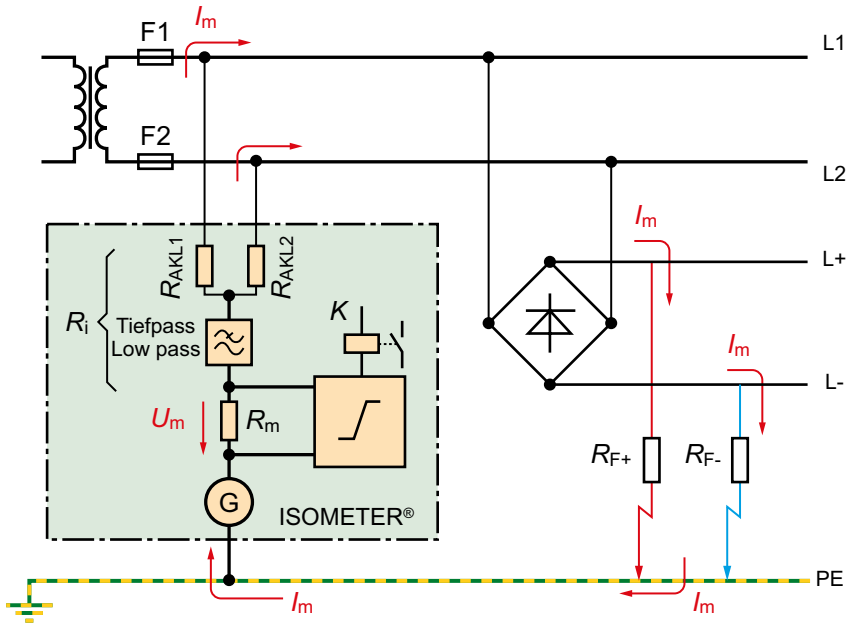



*Fig. Operating principle of an Isometer in mixed systems*

**Measuring method of insulation monitoring devices**

There is a direct relationship between the IT system, its structure, its components and the measurement method of the insulation monitoring device. Knowing which insulation monitoring device works with which measurement method is therefore important from a planning point of view. The table on the next page lists the measurement methods that can be selected on the basis of system parameters.

| Type of system | Generation | Note | Measurement method |
|---|---|---|---|
| Pure AC system | • Transformer<br>• Generator | • 1-phase<br>• 3-phase | DC |
| DC system | • Battery<br>• Rectifier<br>• Solar cell<br>• Fuel cell | • without AC component<br>• with AC component from half-wave or full-wave rectifier | AMP |
| AC system with DC components | • Transformer<br>• Generator with galvanically connected rectifiers | • 1-phase<br>• 3-phase | AMP |
| AC system with electronic actuators | • Thyristor<br>• Triac<br>• GTOs | • high harmonic content<br>• DC components | AMP |
| AC system with variable frequency | • Frequency converter | • wide frequency range<br>• DC components | AMP |

***a) Measurement method "Superimposition of measuring DC voltage"***

A popular measuring method is to superimpose a measuring DC voltage between the system and protective conductor. This measurement procedure is suitable for monitoring conventional AC, 3(N)AC systems, e.g. motors. If it is used in AC, 3(N)AC systems containing galvanically connected DC components, these DC currents will distort the measurement result i. e. insulation faults on the DC side will be signalled with an increased response sensitivity. The system leakage capacitances $C_e$ prevailing in the system are simply charged to the measuring voltage and have no effect on the measurement following a brief initial response.

***b) "AMP" measurement method***

The AMP measurement method patented for Bender is based on a special clocked measuring voltage which is controlled by a microcontroller and adapts automatically to the prevailing system conditions. Software-based evaluation enables system leakage currents causing interference on the evaluation circuit to be differentiated from the measured variable proportionate to the insulation resistance in ohms. This means that broadband interference such as that which occurs during converter operation has no negative influence on the exact determination of the insulation resistance. The AMP Plus measurement method takes interference suppression to the next dimension. Devices supporting this measurement method can be used universally in AC, DC and AC/DC systems, e.g. systems with varying voltages or frequencies, high system leakage capacitances or DC voltage components. This makes them ideal for use in today's state-of-the-art distribution systems, which are usually subject to this type of interference (converters, EMC).

**Selecting the right insulation monitoring device**

The following criteria govern the selection of an insulation monitoring device:

- What is the nominal voltage of the IT system?
  – 1ph, 3ph, AC, DC or AC/DC nominal voltage?
  – Main circuit, control circuit or special application?
- What is the system leakage capacitance?
- Which response ranges are required?
- (separate) supply voltage $U_S$?
- Expansion to the insulation fault location system (IFLS)?
- Special environmental conditions (temperature, vibration and shock resistance, etc.)?

At this point also the cross reference to section DIN VDE 0100-530:2018-06. According to section 538.3 insulation monitoring equipment shall meet the requirements of DIN EN 61557-8 (VDE 0413-8):2015-12. According to this standard, insulation monitoring devices must be marked with corresponding pictograms. Basically, insulation monitoring devices differ as follows:




- ***Type AC IMD***
  Device that constantly monitors the insulation resistance of unearthed IT AC systems to earth.

  *NOTE 1 on the term*: Extraneous DC voltages, which can occur in the event of insulation faults behind rectifiers that are galvanically connected to the AC system, can influence the monitoring function in such a way that the required response uncertainty is greater than required, or that in some cases even the monitoring function is not guaranteed.




- ***Type DC IMD*** Device that constantly monitors the insulation resistance of IT DC systems to earth.




- ***Type AC/DC IMD*** Device that constantly monitors the insulation resistance of IT AC systems with galvanically connected rectifiers or of IT DC voltage systems with galvanically connected inverters or of IT DC systems against earth.

An insulation fault: is a *resistive fault* in the insulation of an *electrical installation* or *equipment* against earth.

*NOTE 1 on the term*: The insulation fault can occur as a single fault from a line conductor or as a symmetrical fault from all line conductors.

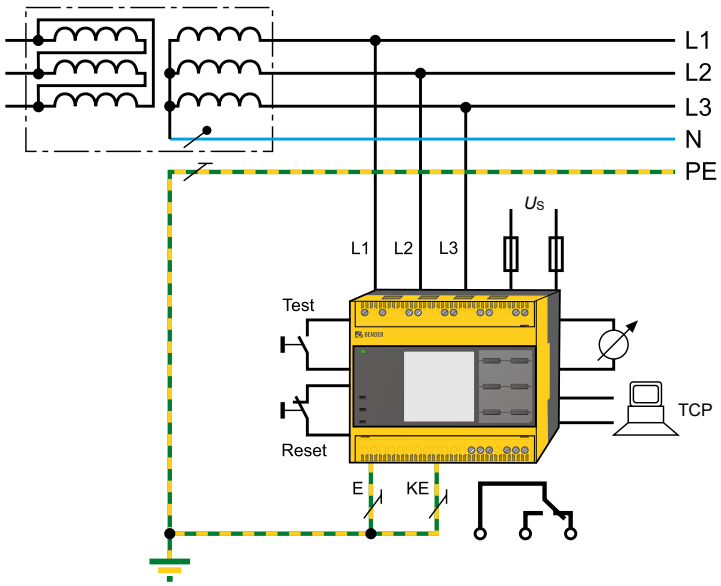
**Nominal voltage $U_n$**
In principle, the nominal voltage of a circuit is determined by its use. A distinction is usually made here between main and control circuits:

- **Main circuits**
  - Main circuits provide power supply for electrical installations or buildings. These circuits include equipment for generating, converting, distributing, switching and consuming of electrical energy.
  - Different loads in one system
  - Pure AC loads (e. g. motors)
  - Loads with electronic components (e.g. converters, rectifiers, UPS, etc.)
  - Typical voltage values 690 V, 400 V, 230 V
  - High system leakage capacitance due to spatial expansion, mechanical structure or interference suppression measures (e.g. battery-powered systems, solar-powered systems)
- **Control circuits (at Bender < 300 V)**
  - Control and auxiliary circuits are used for additional functions such as command input, interlocking, signalling circuits and measuring circuits. The operational safety of these circuits is of prime importance.
  - Spatially limited, e.g. machine control or safety lighting
  - Typical nominal voltages 24, 48, 60, 110, 230 V
  - Single loads or several loads of the same type
  - Low system leakage capacitance

The DIN VDE 0100 series of standards is primarily used for main and control circuits. Deviating from this, there are specific standards for certain areas, which deal in detail with the requirements for this area.

- **Special applications**
  - PV systems
  - Power supply for electric vehicles
  - Circuits for which special standards or requirements have been defined, e.g. auxiliary circuits
  - Portable generators
  - Medical locations
  - Medium voltage inverter drives
  - Electrical machines according to DIN EN 60204

# Connecting insulation monitoring devices

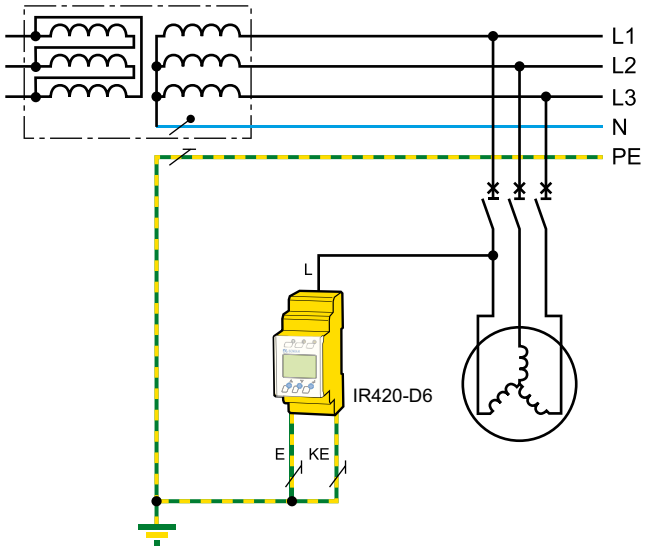



***Connections on an insulation monitoring device***

- *Connection to the active conductors on the IT system*
  - Most Bender insulation monitoring devices feature connection monitoring. This monitors the connection between the terminals (e.g. L1 and L2). A break in this loop is signalled. For this function, the insulation monitoring device must be connected to the system to be monitored using two separate lines.
  - Note: Connection to the same phase or N is permitted.
- *Connection to the power supply*
  - The supply can be taken either from the system to be monitored or, for example, from a control voltage system.
- *Connection to an external kΩ measuring instrument*
  - When connecting an external measuring instrument, make sure that the centre scale mark on the measuring instrument and the internal resistance of the insulation monitoring device are identical (e.g. 120 kΩ).
- *Connection to an interface*
  - To link e.g. to a GLT (building services control system/ZLT process control system or exchange data with other Bender systems capable of communication.
- *Alarm contacts*
  - On some insulation monitoring devices, the functional principle of the alarm relays can be configured. When the relay is set to N/C operation is set, the relay is energised in the “good state”. This means that a failure of the supply voltage (relay drops out) can be signalled (failsafe response).
- *Connection to earth/reference earth (KE)*
  - The connection to earth is made via two separate E/KE lines. This connection enables the correct function of the connection to be monitored and interruptions to be signalled.
- *Connection test/reset button*
  - Test of the device function
  - To reset the fault memory

***Connection to a disconnected IT system***

When monitoring a disconnected IT system, it must be ensured that the measuring voltage of the insulation monitoring device can be superimposed on all active conductors. This is usually achieved by the load (Note: The windings on a motor/transformer are low resistance for the measuring voltage).




***Monitoring of an IT system with multiple infeeds***

In an IT system, only one insulation monitoring device may actively measure at a time, as otherwise the measuring voltages influence each other and lead to incorrect measurement results. If two IT systems operate independently of each other, an insulation monitoring device must be installed in each system. However, it must be ensured that if the two systems are coupled, only one insulation monitoring device can ever be active at any one time. Bender Isometers have an Isonet function for this constellation.

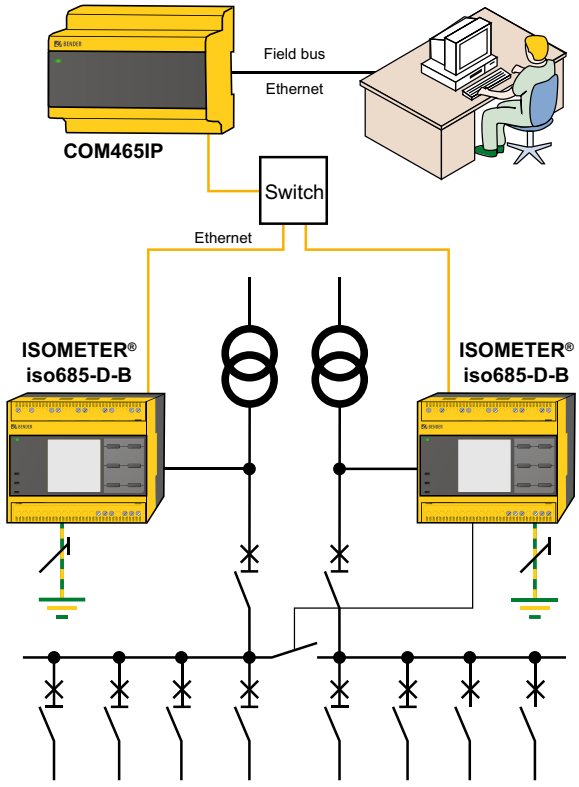



*Fig. Example for two coupled systems*

***Protection of an insulation monitoring device***

Most insulation monitoring devices are connected to the system to be monitored via two connecting cables. In principle, any type of fuse protection for an insulation monitoring device must be considered as line protection. According to DIN VDE 0100-430:2010-10, fuse protection is always required if the current carrying capacity is reduced by a decrease in cable cross-section, a change in cable installation method, a change in conductor insulation or in a change of the number of conductors. Protective devices for overload protection may be omitted in lines and cables in which the occurrence of overload currents is not to be expected, as long as they feature no taps or plugs-and-socket devices. In general, it can be assumed that these conditions can be met both where the power supply connection is concerned and in respect of the supply voltage connection on insulation monitoring devices. The situation is different with short-circuit protection.
The supply voltage terminals must be equipped with overcurrent releases for short-circuit protection. The use of 6 A fuses is recommended. Fuse protection also makes it easier to access of devices for service operation. Protective devices for short-circuit protection can be omitted for the power supply connection if the risk of a short-circuit is minimal (see IEC 60364-4-43 (DIN VDE 0100-430:2010-10). Therefore, at least a short-circuit and earth-fault proof installation is recommended here. Reducing the risk of short circuits to a minimum and deciding whether this goal has been achieved is often very difficult. In case of doubt, we recommend installing protective devices for short-circuit protection in the power supply coupling in the form of 6 A fuses. On devices with integrated connection monitoring, the blowing of a fuse is signalled as an open circuit.

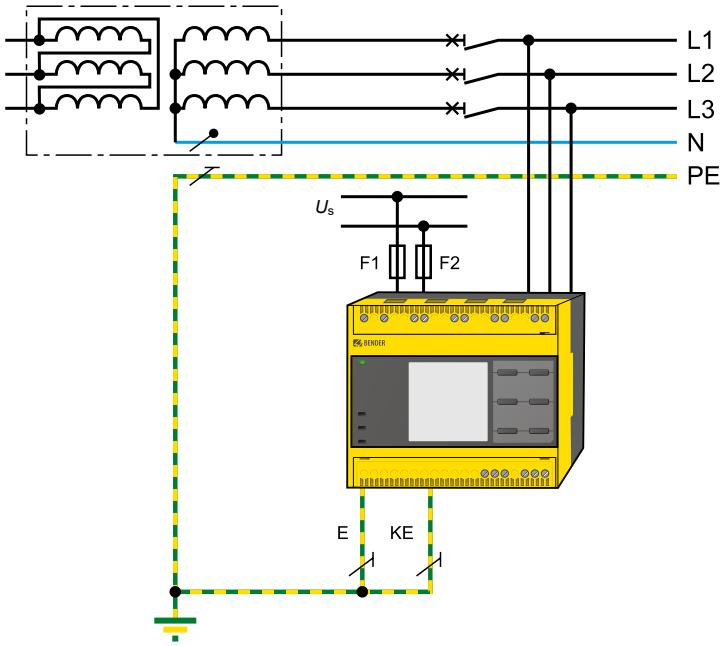



*Fig. Protection of insulation monitoring devices*

# Setting of the response values

When operating an insulation monitoring device, it must be ensured that the total insulation resistance of the respective IT system is measured. This total resistance is calculated by adding together the resistive leakage of all outgoing lines connected in parallel to earth. The response value of the insulation monitoring device should be set to approx. 100 Ω/V.

If an insulation monitoring device is used in an existing complex installation, it is recommended to set the response value to approx. 50 Ω/V.

*Note: An insulation monitoring device also signals a drop in insulation resistance without an "actual" insulation fault being present. This can be due, for example, to moisture if the installation has been out of service for a long period of time. Once the installation has been put back into operation, the insulation resistance increases automatically due to the moisture disappearing as the operating temperature is reached.*

**Response value main circuits**

DIN VDE 0100-530:2018-06 recommends a response value of 100 Ω/V or a response value of 300 Ω/V for pre-warning. If the permissible tolerance of ±15 % of the IMD in accordance with the IEC 61557-8 product standard is now taken into account, the response value should then be set to 15 % more "sensitive", i.e. higher impedance. This results in the following recommendations:

From the physics of the insulation fault, it is not necessary to calculate the decimal places. Rounding up to a higher response value is recommended.

| Nominal voltage | Pre-warning 300 Ω/V | Tolerance 15 % | Recomm.response value |
|---|---|---|---|
| 24 V | 7.2 kΩ | 1.08 kΩ | 8 kΩ |
| 230 V | 69 kΩ | 10.35 kΩ | 80 kΩ |
| 400 V | 120 kΩ | 18.0 kΩ | 140 kΩ |
| 500 V | 150 kΩ | 22.5 kΩ | 175 kΩ |
| 690 V | 207 kΩ | 31.05 kΩ | 240 kΩ |

| Nominal voltage | Alarm 100 Ω/V | Tolerance 15 % | Recomm.Response value |
|---|---|---|---|
| 24 V | 2.4 kΩ | 0.36 kΩ | 2.8 kΩ |
| 230 V | 23 kΩ | 3.45 kΩ | 27 kΩ |
| 400 V | 40 kΩ | 6 kΩ | 46 kΩ |
| 500 V | 50 kΩ | 7.5 kΩ | 58 kΩ |
| 690 V | 69 kΩ | 10.3 kΩ | 80 kΩ |

In any case it is recommended to use ISOMETER with kΩ display and to log the measured value displayed there in order to detect long-term changes.

If an IMD is combined with an IFLS, it must be ensured that the response value is set in such a way that the IFLS is also able to find this insulation fault.

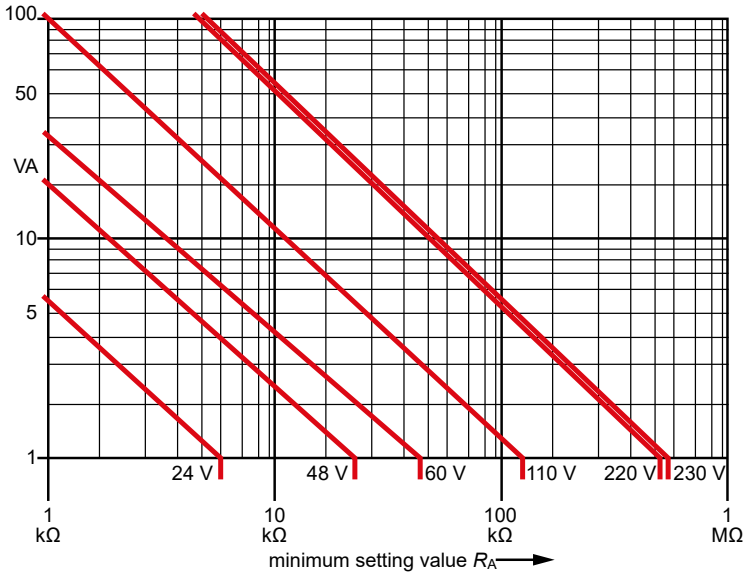
**Response values control circuit**

If, according to DIN VDE 0660 and DIN VDE 0435, the lowest withstand voltage (0.1…0.15) $U_n$ is taken as the basis for an actuating element integrated in the control, then a holding impedance $Z_H$, in series with it, which is able to prevent the relapse at 5 % overvoltage, can be dimensioned as follows

$$Z_H \approx (10.5\ldots7)\,\frac{U_n^2}{P_H}$$

$P_H$ = nominal apparent withstand power of the actuating element.

This formula can be used to calculate the following recommended response value for the insulation monitoring device in control circuits (values in Ω):



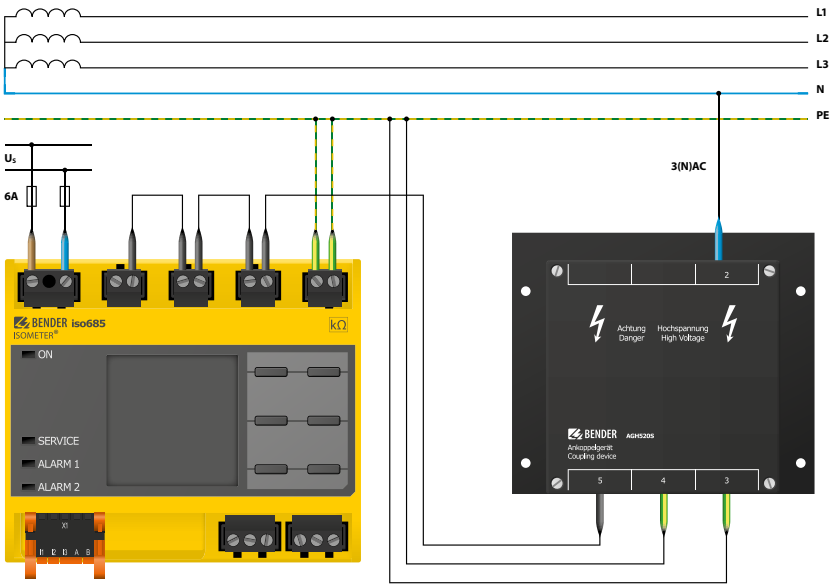

| | 1 VA | 5 VA | 10 VA | 30 VA | 50 VA |
|---|---|---|---|---|---|
| **24 V** | 6048 Ω | 1210 Ω | 605 Ω | 202 Ω | 121 Ω |
| **48 V** | 24192 Ω | 4838 Ω | 2419 Ω | 806 Ω | 484 Ω |
| **60 V** | 37800 Ω | 7560 Ω | 3780 Ω | 1260 Ω | 756 Ω |
| **110 V** | 127050 Ω | 25410 Ω | 12705 Ω | 4235 Ω | 2541 Ω |
| **220 V** | 508200 Ω | 101640 Ω | 50820 Ω | 16940 Ω | 10164 Ω |
| **230 V** | 555450 Ω | 111090 Ω | 55545 Ω | 18515 Ω | 11109 Ω |

**Normatively specified response values**

A response value of 50 kΩ is specified for medical locations.

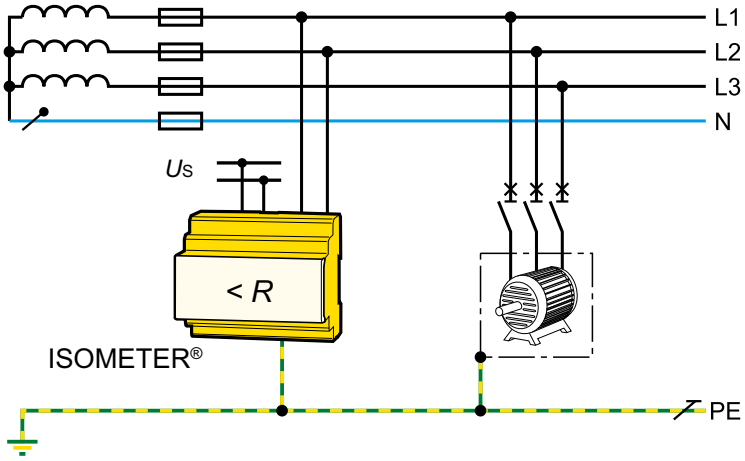
**Extension of the nominal voltage range**

Various coupling devices AGH are available to extend the nominal voltage range of an insulation monitoring device. These modules are connected between the insulation monitoring device and the system to be monitored.

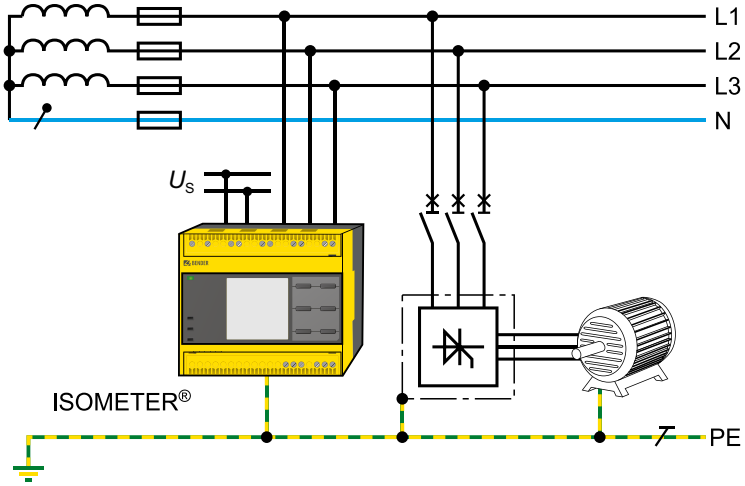


# Application examples Insulation monitoring

### Monitoring of main circuits



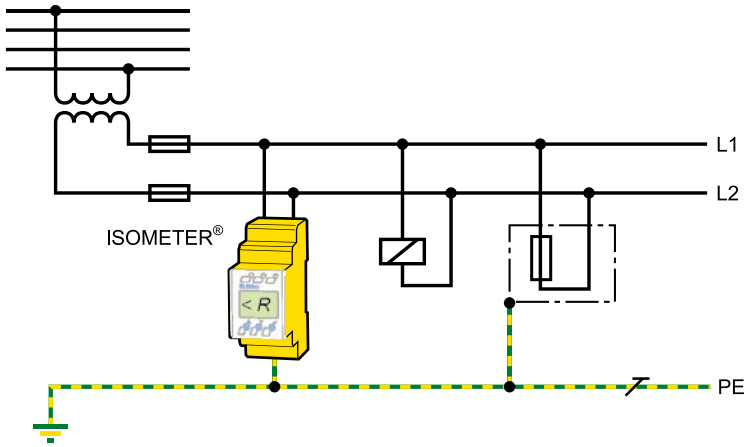

*Monitoring of a main circuit with a pure AC load*



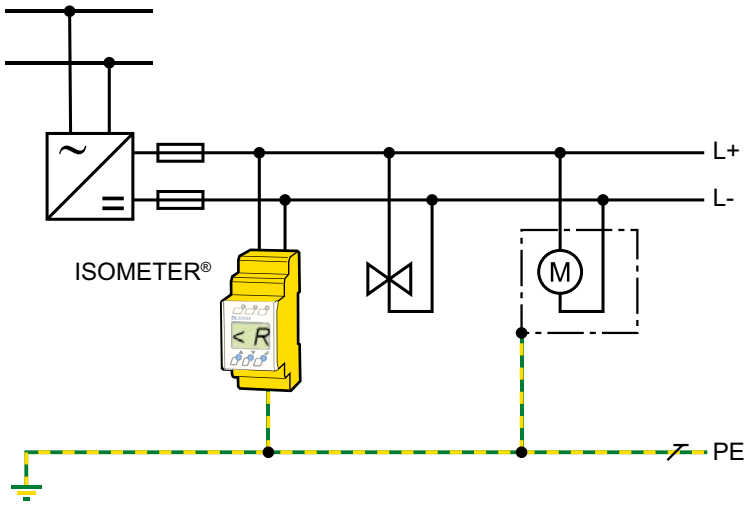

*Monitoring of a main circuit with variable-speed drive*

**Monitoring of a control circuit**

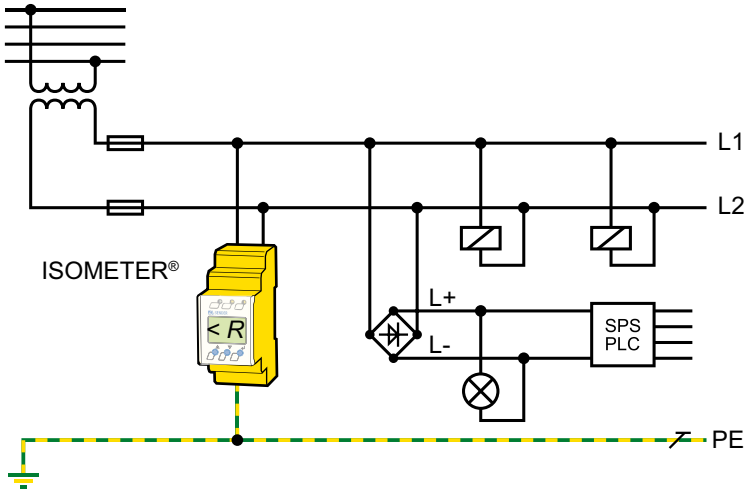
DIN EN 60204-1/VDE 0113-1 specifies that earth faults in control circuits must neither lead to unintentional starting or potential dangerous motion of a machine nor prevent a machine stopping. Generally, control circuits are supplied with power via a safety transformer with separate windings or a safely isolated power supply, whereby the secondary voltage must not exceed 50 V. The control circuit itself may be operated either as an earthed system (TN system) or an unearthed system (IT system). However, if high resistance faults go undetected on sensitive components in a control circuit in particular, this can lead to control errors. In an earthed system, these faults are not detected by a fuse because the fault current is too low to trip. If the insulation fault has a low resistance, the fuse trips and the system stops. To avoid this, control circuits are operated unearthed and monitored with an insulation monitoring device.




*Monitoring of an AC control circuit*




*Monitoring of a DC control circuit*

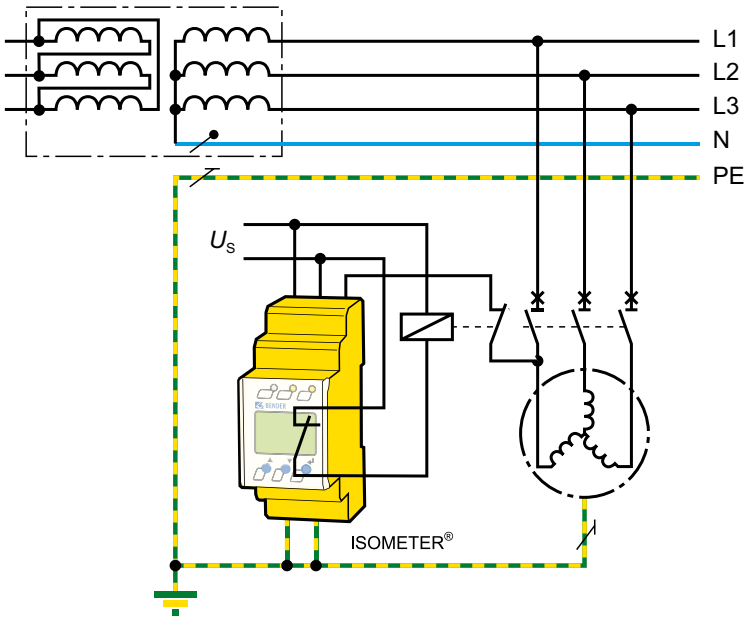



*Monitoring of an AC/DC control circuit*

**Monitoring of a disconnected load**

Many loads are only switched on in an “emergency” situation (e.g. fire pumps, valves, all types of heating systems, etc.). However, during downtime, insulation faults may occur due to moisture or other influences in the supply line or the load. When these load are switched on, the protective device responds or fires occur, thereby preventing operation.

The insulation monitoring device, also known as the offline monitor, monitors the insulation resistance during offline periods and signals insulation faults immediately. When the load is switched on, the insulation measurement based on the K contactor is deactivated.
The fault memory is also able to detect transient insulation faults. If it can be assured that all poles on the load will be taken offline, this monitoring can also be used in TN or TT systems.

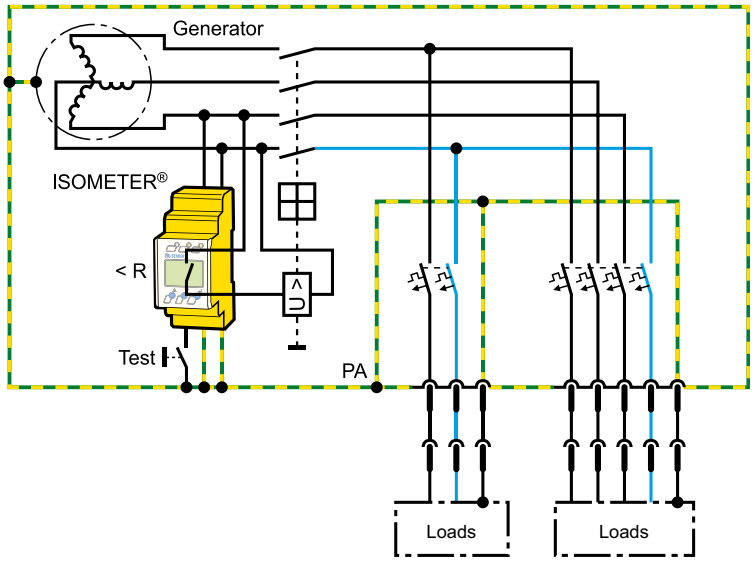


**Monitoring of mobile generators**

Electrical safety is often difficult to assure on mobile power generators.

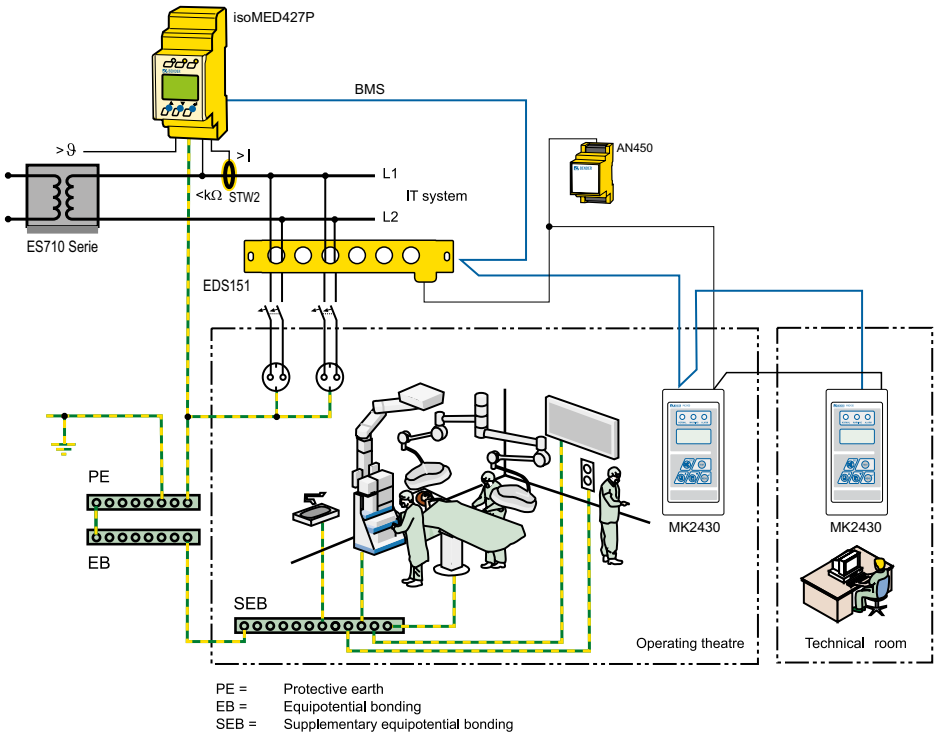
- In very few cases does the ground/environment rarely permit an earthing system to be installed (stones, rubble, rock, asphalt, etc. would have to be penetrated).
- Time is of the essence, there is not enough time to measure and check the protective measure.
- The relevant electrically skilled person is lacking.
- However, the ability to respond immediately and appropriately is vital in an emergency situation.

It is for this reason that mobile power generators feature the protective measure “Protection by electrical separation with insulation monitoring and disconnection” according to DIN VDE 0100-551:2017-02.




**Monitoring of medical locations**

DIN VDE 0100-710: 2012-10 specifies that all Group 2 rooms in medical locations must be equipped with IT system supporting insulation monitoring as well as load and temperature monitoring. The operation and alarm messages must also be displayed centrally.



# Use of insulation fault location systems

**System safety and availability**
Today's industrial, power generation and distribution plants are complex structures with sophisticated controls and high productivity. This is precisely why a failure leads to enormously high costs.Thanks to the latest technical innovations, however, optimum provisions for installation safety can now be made as early as the planning stage, ongoing operation can be continuously monitored and defective installation components can be detected quickly and reliably.

**Unearthed power supplies**
Unearthed power supplies (IT systems) have an invaluable advantage - a first fault does not lead to a failure. This ensures that complex processes and production sequences are not interrupted unexpectedly. What actually happens is quite the opposite: IT systems can continue to operate under controlled conditions and faults can be eliminated at a later stage, without incurring the costs associated with failures.

The insulation monitoring device ISOMETER® provides the basis for this mechanism. It monitors the insulation resistance of the IT system to earth and outputs a signal accordingly should a specific value be exceeded. This information advantage can then be used to determine the appropriate time for insulation fault location, e.g. in the event of disconnection for revision purposes. But here, too, the devil is in the detail. In particular where complex installations and power supplies whose circuits are distributed across a wide area are concerned, insulation fault location can be a costly activity in terms of both time and personnel resources.

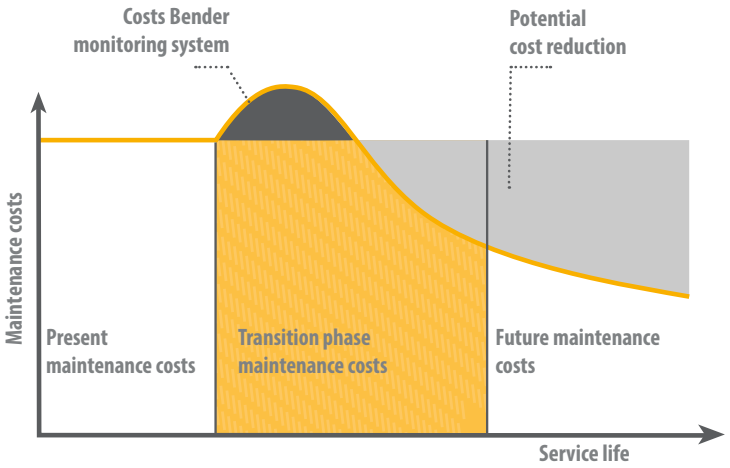
EDS insulation fault location systems can provide a solution to this problem. These systems locate insulation faults automatically during operation and indicate the faulty outgoing circuit via an LCD or other type of visualisation unit. Operators benefit as follows:

- **Installations do not have to be disconnected**
  – Insulation fault location is carried out automatically during operation
  – The fault location is identified and displayed precisely, this saves time and personnel resources

- **Modular system concept**
  – The system is optimised for the installation and can be set up in accordance with the requirements of the operator.

***Why insulation fault location at all?***
Essentially, insulation fault location is necessary for three technical reasons:

- Protection against electric shock (e.g. in the 3(N)AC 400 V system)
  – DIN VDE 0100-410:2018-10 recommends that a first fault be eliminated with the shortest practicable delay. The occurrence of a second fault will introduce the risk of electric shock, at which point the installation would have to be disconnected. The order of magnitude for insulation fault location here ranges from 5…10 kΩ.
- Avoidance of fire risks (e.g. in the 3(N)AC 400 V system)
  – A fault current generating excess heat rise at the fault location can flow in the event of undetected high-resistance insulation faults. There is an acute fire risk even at powers of ≥ 60 W. The order of magnitude for insulation fault location here is in the range of 1 kΩ.
- Avoidance of control errors (e.g. in the DC 220 V system)
  – In electrical installations, the smallest fault currents can cause PLCs or contactor controls to respond incorrectly. This exposes individuals to an increased risk of injury, e.g. on press controls or in the event of uncontrolled machine motions. The order of magnitude for insulation fault location here ranges from 10…15 kΩ.




***How does an insulation fault system work?***

An insulation fault location system comprises a locating current injector and an insulation fault evaluator connected to one or more measuring current transformers. The ISOMETER® type iso685-D-P features an integrated locating current injector.

Functional sequence:

- Start the insulation fault location by activating the locating current injector ISOMETER®.
- The locating current injector briefly connects the active conductors to earth.
- Electronic current limiting, this connection and the insulation fault create a closed circuit, in which a locating current IT determined by the system voltage flows. The locating current is limited to a maximum value.
- The locating current pulse flows back from the locating current injector via the live conductors, the insulation fault $R_F$ and via the earth wire (PE conductor) to the locating current injector.
- The locating current pulse is detected by all measuring current transformers on the circuit and evaluated by EDS insulation fault evaluators.
- The fault location can be identified using the assignment between measuring current transformers and circuit.

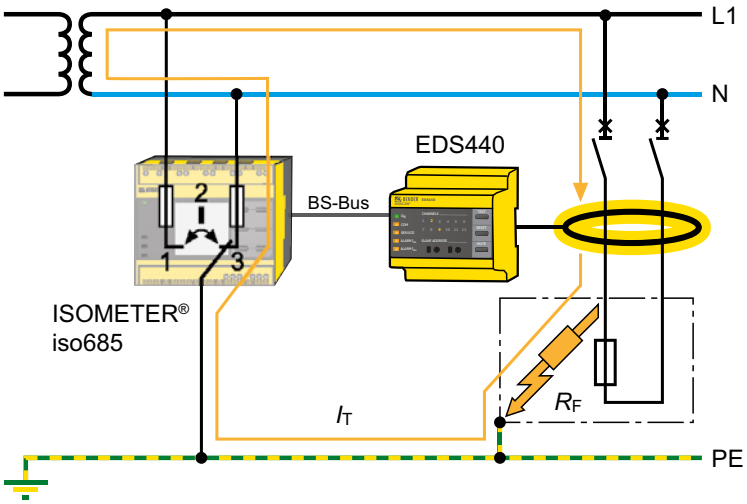



*Fig. Operating principle of insulation fault location*

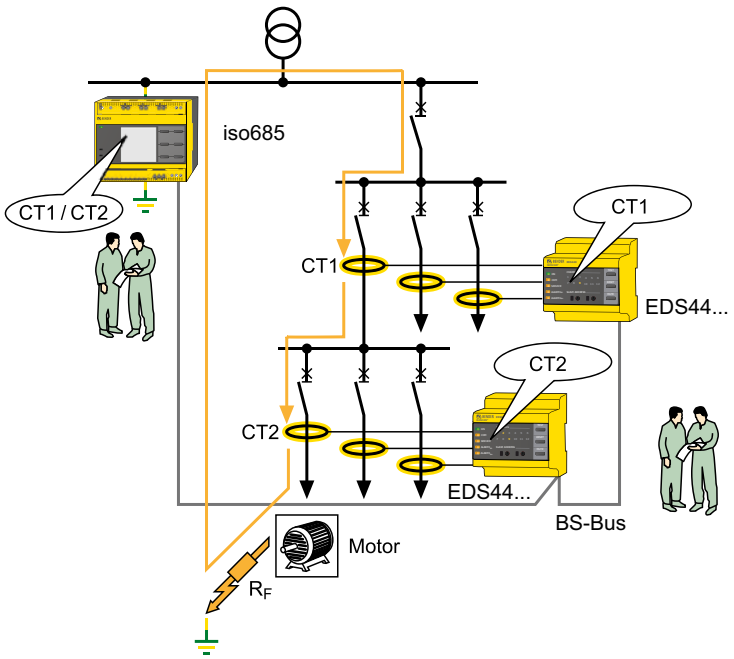
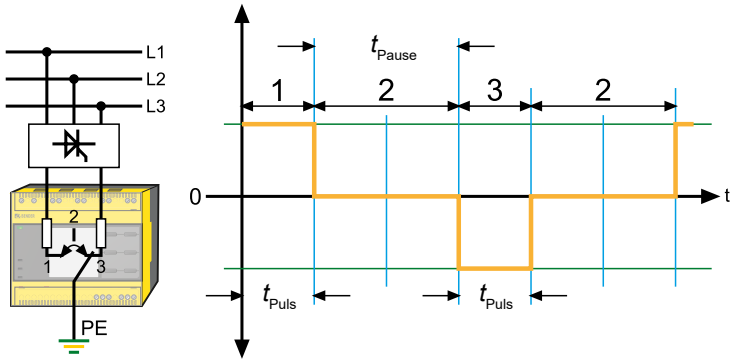
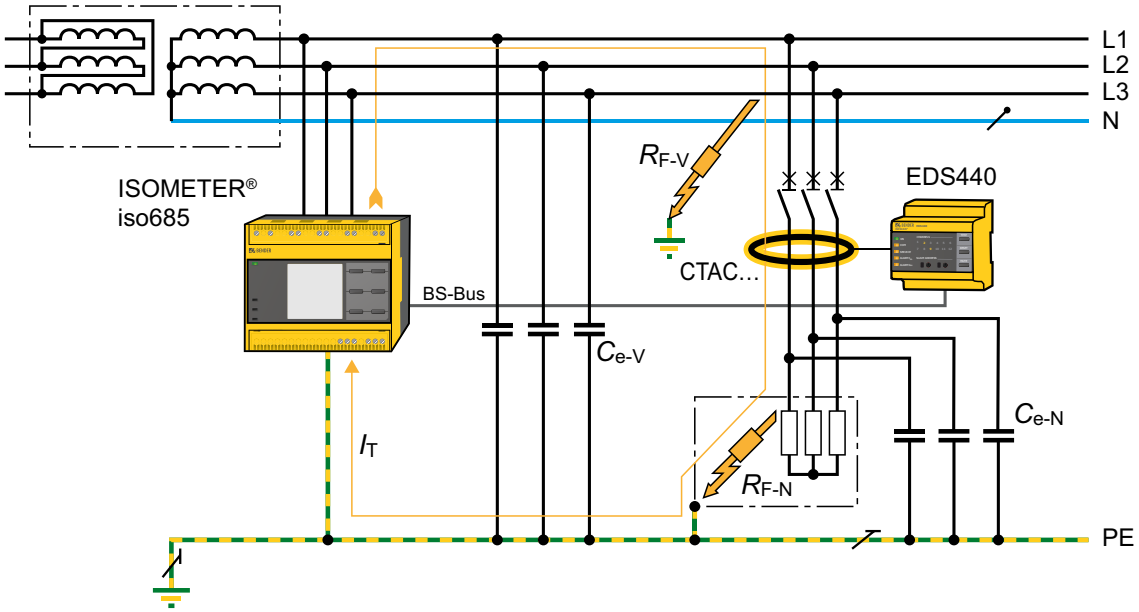



*Figure: Locating current cycle IT in the EDS system*




*Locating current cycle in IFLS systems*



**Terms for insulation fault location**

| | |
|---|---|
| iso685 | insulation monitoring device with integrated locating current injector |
| EDS4… | Insulation fault evaluator |
| W… | Measuring current transformer |
| IT | Locating current |
| $R_{F}$-V | Insulation fault upstream of the measuring current transformer |
| $C_{e-V}$ | System leakage capacitance upstream of the measuring current transformer |
| $R_{F-N}$ | Insulation fault downstream of the measuring current transformer |
| $C_{e-N}$ | System leakage capacitance downstream of the measuring current transformer |

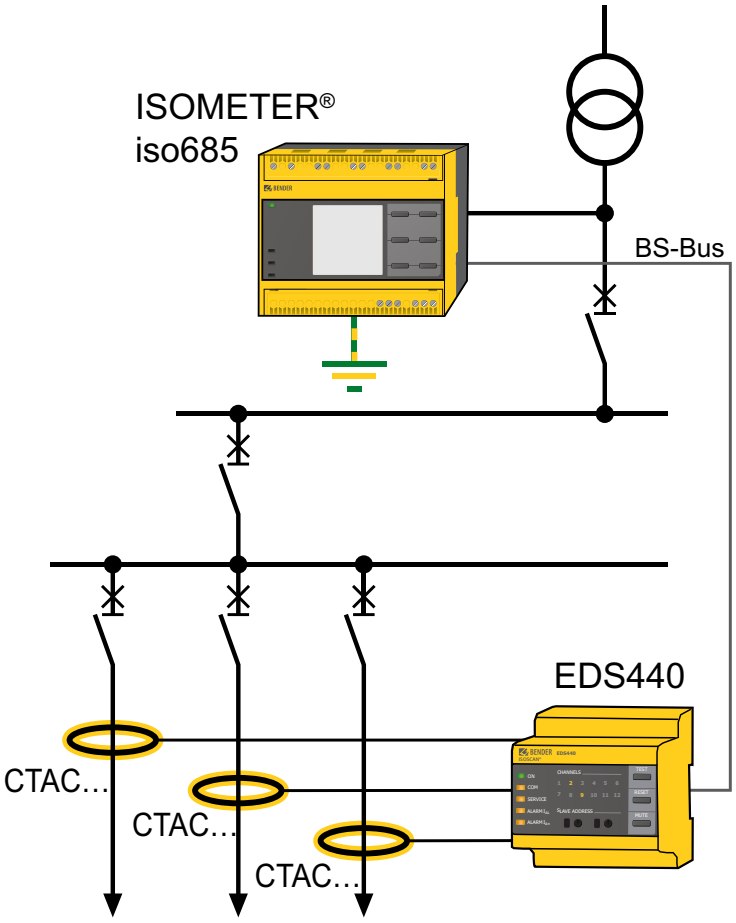
**Variants of insulation fault location**

There are essentially three different types of insulation fault location:

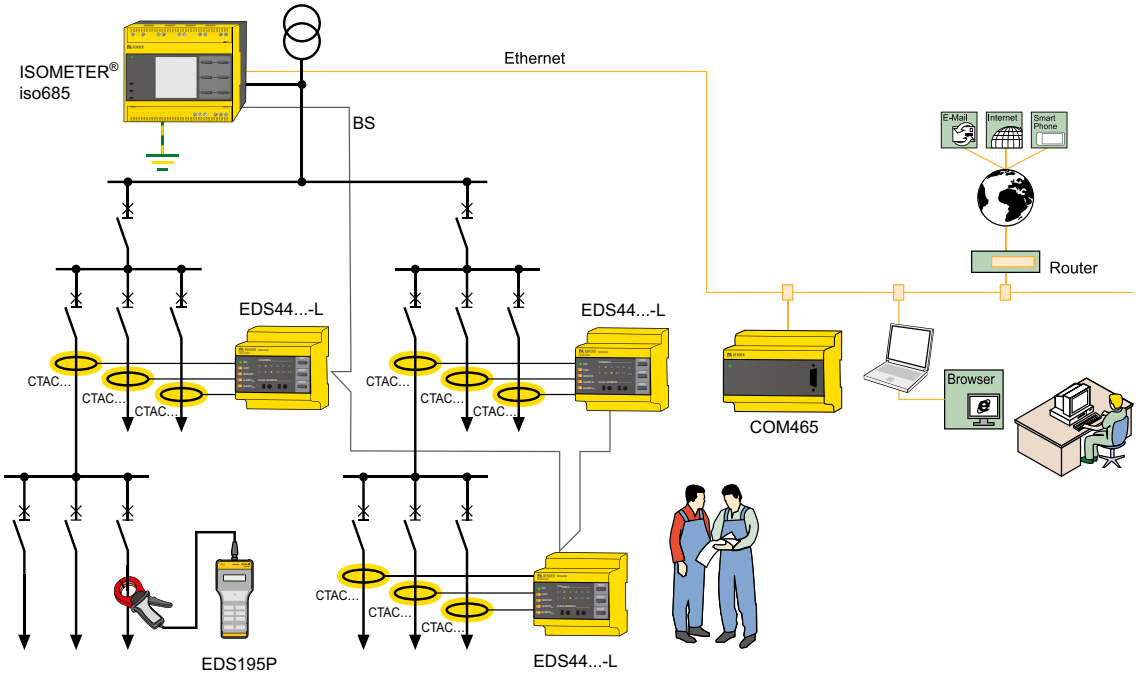
- Automatic insulation fault location/stationary systems
- Manual insulation fault location/portable systems
- Main circuit or control circuit application

***Automatic insulation fault location/permanently installed systems***

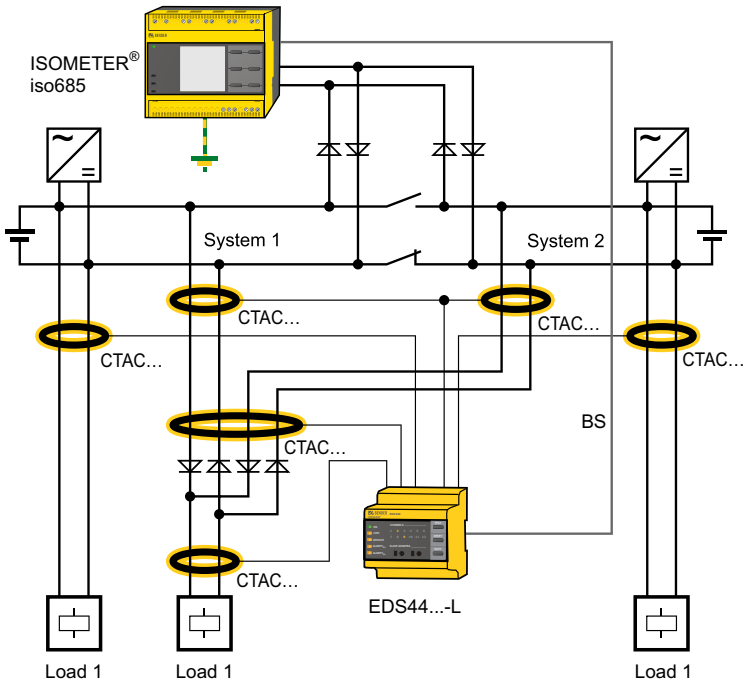
The insulation monitoring device with integrated locating current injector, the insulation fault evaluator and the associated measuring current transformers are components of the installation. Insulation fault location is started automatically by the insulation monitoring device.



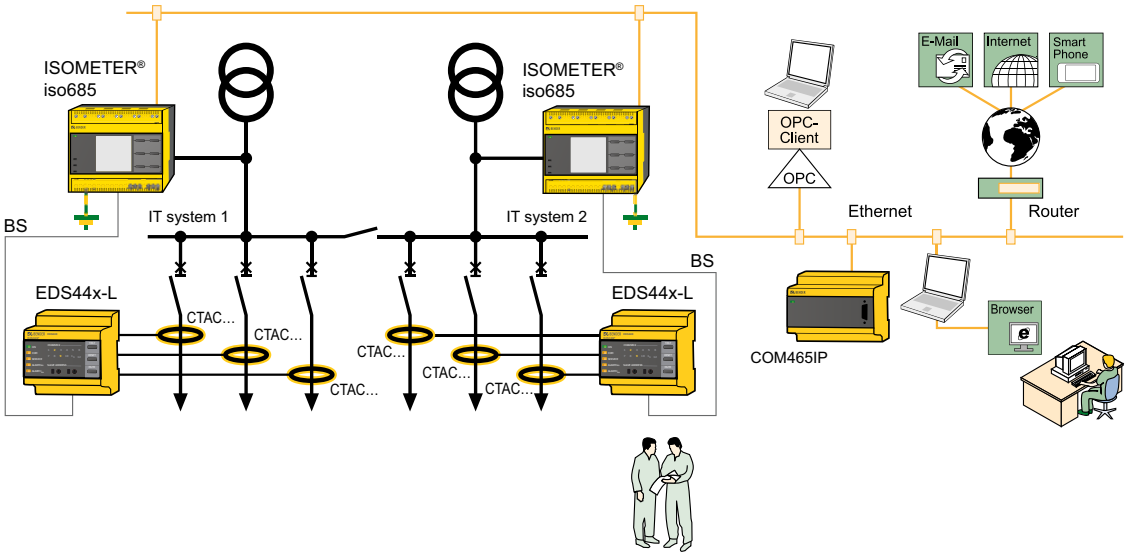

*Example for the design of an automatic insulation fault location system*




*Example for the design of an automatic EDS insulation fault location system with central administration via Ethernet/Web*




*Example for the design of an automatic EDS insulation fault location system in coupled DC systems*




*Example for the design of an automatic EDS insulation fault location system in two coupled IT systems*

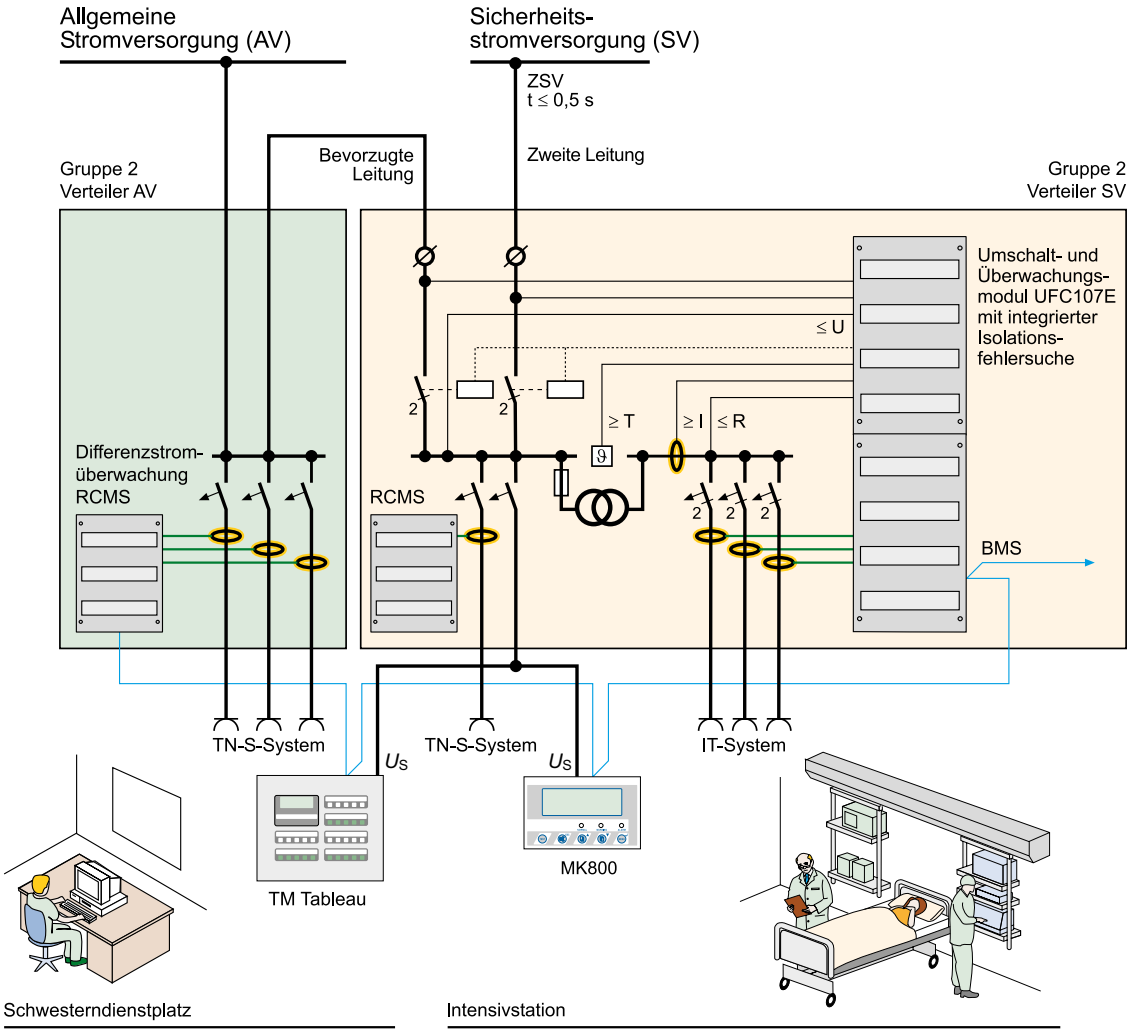



*Fig. Application in an intensive care unit in medical locations according to DIN VDE 0100-710*

**Manual insulation fault location/portable systems**

A distinction is made in manual insulation fault location between:

a) In addition to the permanently installed EDS systems, a portable insulation fault evaluator is used to search for insulation faults in secondary outgoing circuits.

b) If no locating current injector exists, a portable locating current injector fault is used.

c) When the IT system is de-energised, a portable locating current injector with integrated measuring voltage source is used.

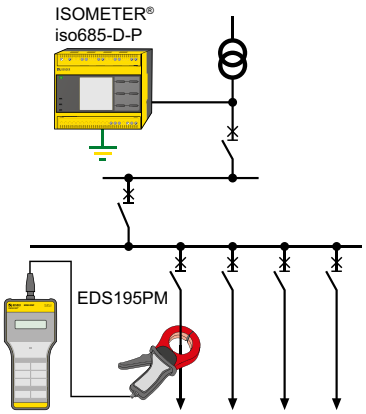
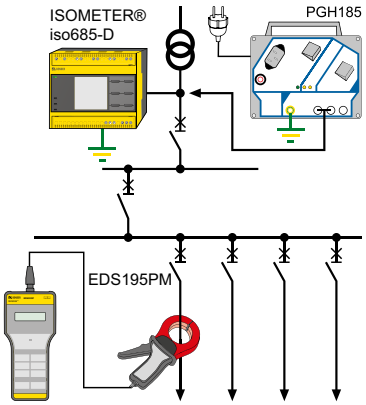
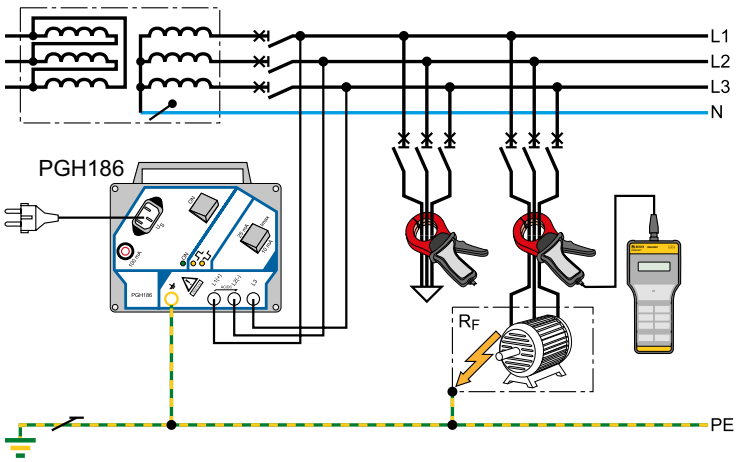



*Fig. Manual insulation fault location with an insulation monitoring device with built-in locating current injector.*




*Manual insulation fault location in IT systems with external locating current injector PGH185*




*Manual insulation fault location with portable locating current injector in a disconnected IT system (without mains voltage)*

***Note***

*IT system offline, i.e. the locating current is generated by the portable locating current injector (PGH186) if the device is also suitable for use in earthed systems (TN, TT systems), if all poles are offline and there is no direct connection of the system and earth.*

**Distinguishing features of main circuit/control circuit**

The essential difference in the two applications is the significantly reduced locating current for application in control circuits and the response sensitivity.

***IFLS systems for main circuits***

Characteristics of main circuits

- Nominal system voltage Un up to 690 V
- Wide spatial distribution, system leakage capacitance up to 20,000 µFV (product of system leakage capacitance and nominal system voltage, e.g. 400 V x 50 µF = 20,000 µFV)
- High residual currents up to max. AC 10 A
- Loads causing interferences (z. B. converters, inverters etc.)

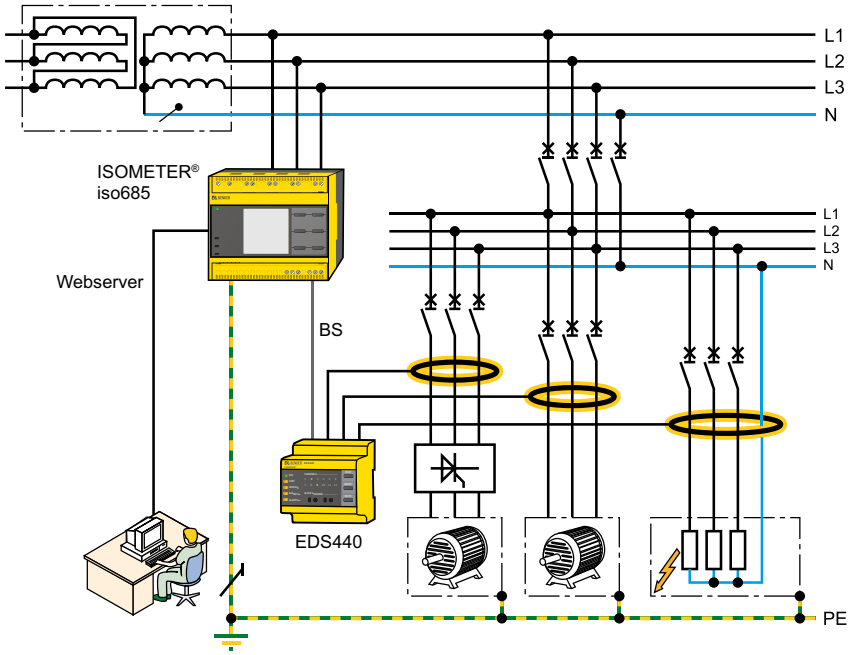



*Fig. IFLS in the main circuit*

***IFLS systems for control circuits***

Characteristics of control circuits

- Nominal system voltage $U_n$ to 230 V
- Restricted spatial distribution, system leakage capacitance up to 300 µFV (product of system leakage capacitance and nominal system voltage),
- e. g. 24 V x 10 µF = 240 µFV)
- Low residual current up to max. AC 1 A
- No loads causing interferences

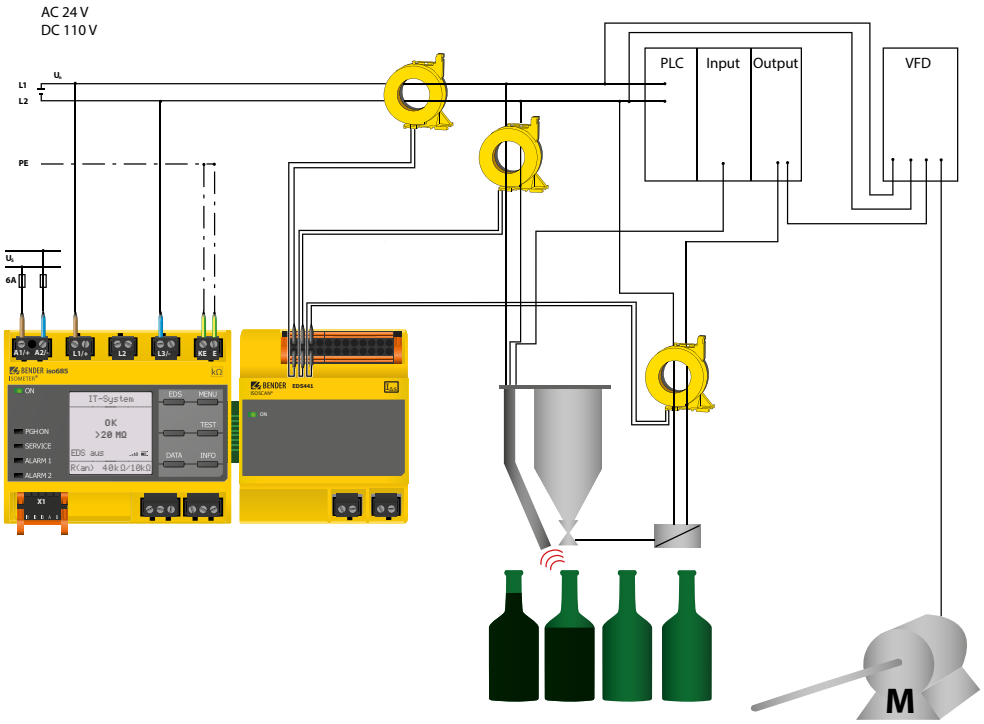



*Fig. IFLS system in the control circuit*

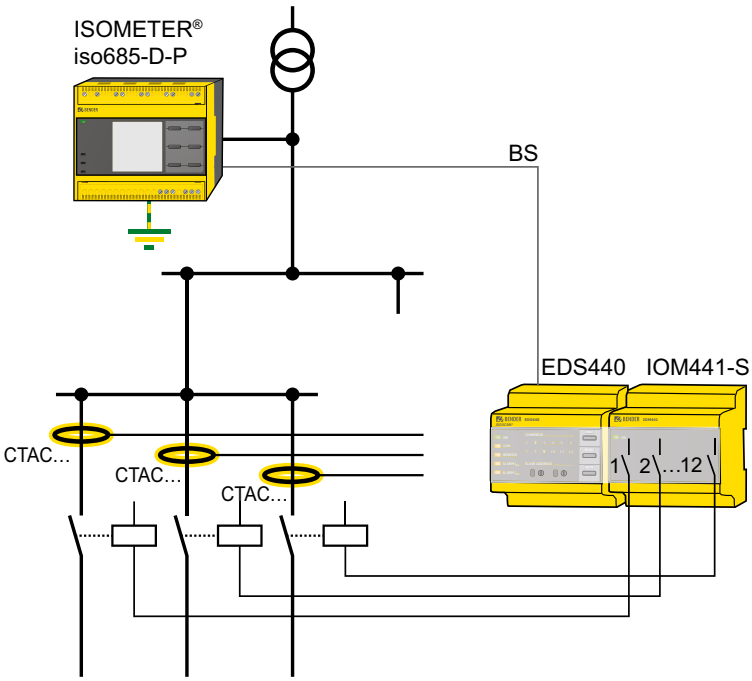



*Fig. IFLS system in control or main circuit with switching function*

Characteristics of a switching function:

- All measuring channels are scanned in parallel during insulation fault location.
- The max. scanning time is ≤ 10 s.
- At the end of this time the relay contact switches the faulty measuring channel concerned.
- This switching contact can be used to disconnect the faulty outgoing circuit via a contact element.

**Summary - Your benefits of IT systems with insulation monitoring**

***Greater economic efficiency***

- Avoiding expensive and unplanned installation shutdowns
- Reducing time and staff expenses for maintenance
- Detecting weak points in systems
- Supporting investment decisions

***Higher operational reliability***

- No operational interruptions with single-pole earth fault
- No malfunction of control systems in the event of insulation faults
- Systems remain at a high level of availability
- Monitoring systems even when they are at a standstill

***Optimised maintenance***

- Early detection and reporting of insulation deterioration
- Automatic localisation of faulty current paths
- Optimised use of time and staff resources
- Central information about the system status
- Remote diagnosis via Internet/Ethernet

***Increased fire protection***

- Early detection of gradually developing insulation faults
- Minimising fault arcs as a common cause of fire
- Disconnect areas at risk of fire or explosion due to isolating transformers
- from the rest of the system and monitor separately

***Improved accident safety***

- Low touch currents in small and medium-sized installations
- No earth-fault related malfunctions in control systems of installations and machines

***Higher earthing resistance***

- Higher earthing resistances are permissible, e.g. for mobile power supply systems

***Increased personal safety***

- Low touch voltage

# IT system applications

Apart from the typical IT system applications such as medical locations or ships, IT systems are increasingly used in areas where a power failure would lead to a cost-intensive production interruption, operational disruptions or high costs for a restart. Other applications for the IT system can be found in the area of fire and explosion protection.

- Power generation and distribution
- Traffic engineering
- EDP, data centres
- Healthcare sector
- Manufacturing, automation
- Oil, gas, mining
- eMobility
- Ships and ports

**Insulation monitoring and insulation fault location in PV systems**
In PV systems, the PV modules are usually designed in protection class II. Over the entire service life of the system, however, it may happen that the insulation resistance no longer meets the necessary requirements. Reasons for this are e.g. humidity, dust, heat, etc. This is why DIN VDE 0100-712 (VDE 0100-712):2016-10 -Photovoltaic (PV) systems- requires:

- 712.421.101.1 An insulation monitoring device (IMD) shall be installed to continuously monitor the insulation condition on the DC side during the lifetime of the PV generator field

In addition, this standard recommends the use of insulation fault location systems (IFLS) for an output of > 100 kWp.

The insulation monitoring devices themselves must meet the requirements of DIN EN 61557-8 (VDE 0413-8):2015-12, Annex C or D.

***High system leakage capacitances***
The physics of PV systems means that high system leakage capacitances in the range of several hundred µF can be present. This places special demands on the measurement technology of the insulation monitoring devices. Bender IMD of the isoPV series meet these requirements without any problems.

**Electrical safety in railway engineering**
The railway industry deals with extremely demanding tasks on a daily basis. The inspection of high-speed lines, rail construction or power supplies are just as much a part of this as the transport of dangerous goods. But despite all the pressure of time, one thing has absolute priority: safety for passengers.

In particular, IT systems with insulation monitoring are used where a first fault would significantly disrupt the operating sequence. This applies to

- Rolling stock
- Rail network
- Building infrastructure

***Rolling stock***
Monitoring devices on railway vehicles are subject to the highest demands on shock and vibration resistance.

***Rail network***
**DIN EN 50633 (VDE 0115-633) Railway applications - Fixed installations –Protection principles for AC and DC electric traction systems; German version prEN 50633:2017-03**
Section 6.2.6/6.3.5 Scaffold protection

***Building infrastructure***
Monitoring of neutral point
RCM
PQ

**Ships and ports**
On ships IEC 61892 Offshore
IEC 60092 Electrical installations in ships – Part 502: Tankers – special features

# Application examples

**Insulation monitoring for disconnected loads**
**For all earthing systems: IT, TN, TT systems**
If malfunctions occur when starting an electric motor, a wide variety of effects can occur. Electric motors are used in the most diverse areas

- Safety-relevant equipment
  - Fire pumps
  - Smoke extraction systems
  - Slider
- Industrial plants, ships
  - Winches for lifting loads
  - Motor-driven chain hoists

The risk of an electric motor failing at startup is often associated with insulation faults caused by moisture, which damage the insulation material during standstill due to the finest cracks so that the motor cannot start.

***In case of a full short circuit***
Isometers monitor the insulation resistance of the motor during standstill. Depending on the value of the insulation resistance or the response value the following can then be set

- An alarm can be reported (response value pre-warning)
- Switch-on can be prevented (response value main message).

*Example*

On a ship

**Initial and periodic verification of IT systems**

The aim of testing electrical installations and equipment is to prove that there are no defects and that proper personal and material protection is ensured after commissioning or during use. The tests themselves and the corresponding environment are described in various statutory technical rules and set of standards. The following technical paper describes the applicable requirements for unearthed power supplies (IT systems).

***Standard requirements***

The testing of power supply systems should always be distinguished between initial testing and periodic testing. In particular, the following standards have to be considered:

- DIN VDE 0100-600 (VDE 0100-600):2017-06 - Erection of low voltage electrical installations Part 6: Verifications (IEC 60364-6:2006, modified)
- IN VDE 0105-100 (VDE 0105-100):2015-10 Operation of electrical installations Part 100: General requirements

During the initial verification the installer (manufacturer) has to verify that he has installed the system in accordance with the recognised rules of technology and that there is no danger from the system. The initial test should also cover the parameters which will later serve as the basis for the periodic verification. Periodic inspection and testing is the responsibility of the system operator. As an employer, the operator is obliged to do the following within the framework of the Accident Prevention Regulations (Germany). While DIN VDE 0100-600:2017-06 contains the requirements for the initial test of electrical systems, DIN VDE 0105-100:2015-10 describes the test used to determine whether the system still meets the conditions for the initial measurement. Periodic testing must be performed by a qualified electrician who must be able to assess and evaluate changes. The associated test devices must meet the requirements of the DIN EN 61557-… series of standards. The tests are performed in the usual sequence Inspection – Measurement – Tests. It is the responsibility of the test engineer to determine the details and the necessary test steps in detail.

*Inspection*

Before starting measurements, it is first necessary for the test engineer to get an overview of the IT system to be tested:

- Structure and size of the IT system
- Type and nominal values of the current source
- Number and distribution of the existing circuits
- Type and local conditions of the earthing system
- Type of earthing of the exposed conductive parts – individually, in groups or collectively
- Type of the protective earth conductor(s) used
- Number and type of the protective and monitoring devices used

By taking a look at the existing system documentation, it is also possible to start checking it for completeness and correctness. In the case of periodic verification, earlier test protocols enable, for example, a simple comparison with previous measured values and the resulting changes to measured values.

*Before measuring – ensure fault-free condition*

Once the information about the structure and the protective measures of the IT system is known, it must first be checked whether the IT system is fault-free, i.e. that there is no insulation fault. This is done using the display of the insulation monitoring device (IMD). Alternatively, it is also possible to measure the residual voltage. Table 1 shows the offset voltage in a fault-free IT system or in the case of a low-resistance insulation fault on conductor L1. However, the offset voltage measurement should only be used in very small IT systems with small system leakage capacitance, because symmetrical insulation faults and different system leakage

capacitances between the respective active system conductors and earth influence the offset voltage, so that ultimately only an IMD reliably indicates the insulation resistance. Especially in 3AC IT systems the offset voltage measurement is not applicable with the necessary reliability, because even relatively low-resistance insulation faults can be compensated by an unfavourable distribution of system leakage capacitances.

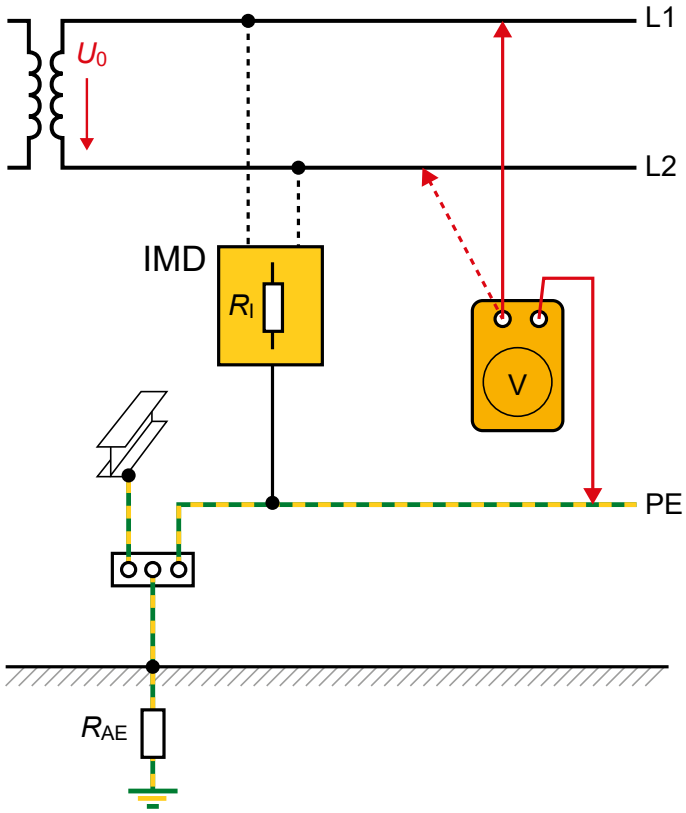
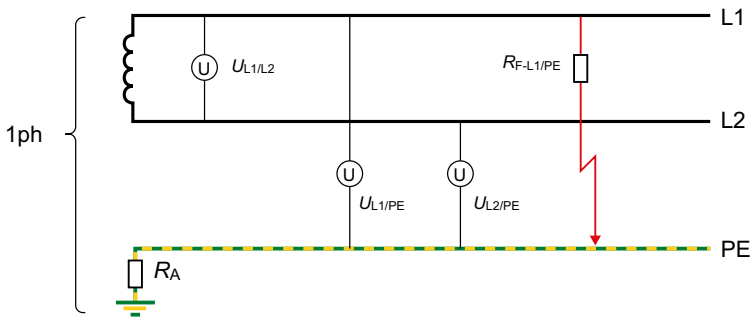
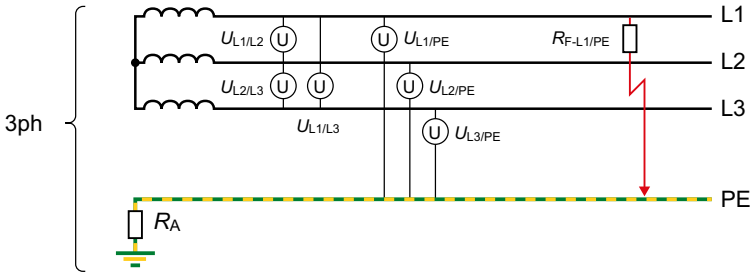


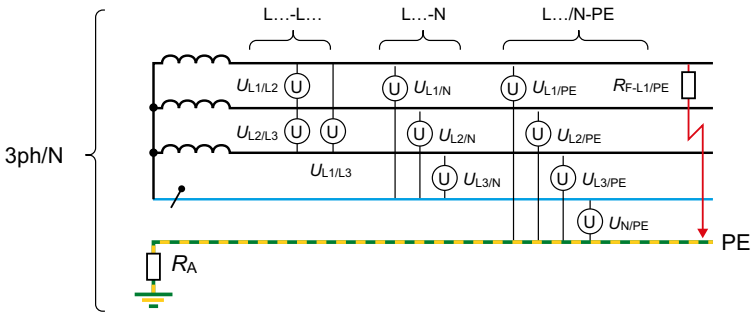

*Fig. 1: Principle measurement of the offset voltage in 1ph IT systems*




| | $R_{F-L1/PE}$ = ∝ Ω | $R_{F-L1/PE}$ = 0 Ω |
|---|---|---|
| $U_{L1/L2}$ | 230 V | 230 V |
| $U_{L1/PE}$ | 115 V | 0 V |
| $U_{L2/PE}$ | 115 V | 230 V |




| | $R_{F-L1/PE}$ = ∝ Ω | $R_{F-L1/PE}$ = 0 Ω |
|---|---|---|
| $U_{L1/L2}$ | 400 V | 400 V |
| $U_{L2/L3}$ | 400 V | 400 V |
| $U_{L1/L3}$ | 400 V | 400 V |
| $U_{L1/PE}$ | 230 V | 0 V |
| $U_{L2/PE}$ | 230 V | 400 V |
| $U_{L3/PE}$ | 230 V | 400 V |




| | $R_{F-L1/PE}$ = ∝ Ω | $R_{F-L1/PE}$ = 0 Ω |
|---|---|---|
| $U_{L1/L2}$ | 400 V | 400 V |
| $U_{L2/L3}$ | 400 V | 400 V |
| $U_{L1/L3}$ | 400 V | 400 V |
| $U_{L1/N}$ | 230 V | 230 V |
| $U_{L2/N}$ | 230 V | 230 V |
| $U_{L3/N}$ | 230 V | 230 V |
| $U_{L1/PE}$ | 230 V | 0 V |
| $U_{L2/PE}$ | 230 V | 400 V |
| $U_{L3/PE}$ | 230 V | 400 V |
| $U_{N/PE}$ | 0 V | 230 V |

*Table 1: Measured values of the offset voltage in IT systems with an almost resistance-free insulation fault $R_F$-…. on L1*

***Testing the continuity of the protective conductor connections $R_{PE}$***

If the system is to be safe, it is essential that the presence and proper condition of the protective conductors be verified or measured. A proper protective conductor is the basis for correct functioning of the protective measures against electric shock.

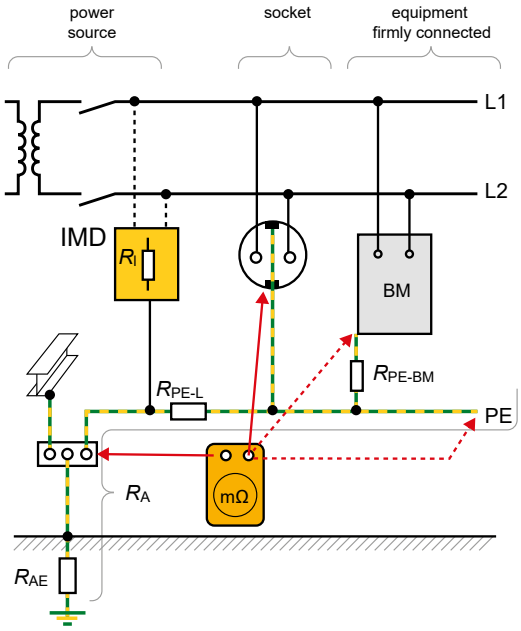



*Figure 3: Example of a protective conductor continuity measurement*

$R_{PE}$ consists of the protective conductor resistance in the installation $R_{PE-L}$ and the protective conductor resistance of the power supply cable $R_{PE-BM}$ of the electrical equipment.

**Measurement of the earthing resistance $R_{AE}$**

The earthing resistance $R_{AE}$ is the resistance between the reference earth and the connection point of the earthing system. In the IT system, the earthing system is required in particular to bring the individual system components and circuits to a reference potential as close as possible to the reference earth in the event of a second fault. There are different measurement methods to determine the earthing resistance. In practice, the earthing resistance between several earthing points and the main equipotential bonding rail is usually measured.

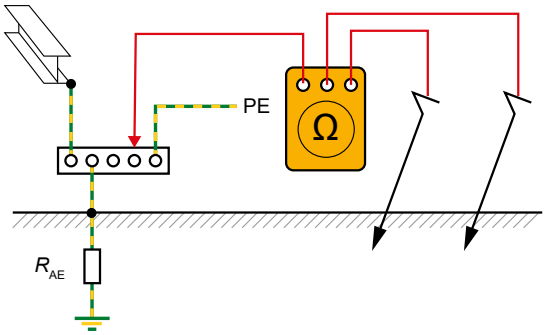



*Figure 4: Example of an earthing resistance measurement in an IT system*

***Determination of the earthing resistance RA***

The basic condition $R_A \times I_d \leq 50$ V (AC systems) applies to IT systems. $R_A$ consists of the partial resistances $R_{AE}$ and $R_{PE}$. A maximum permissible value is not specified, but the values determined, should not be higher than the value to be expected with regard to the cable data and contact resistance data. In practice, for example, DIN VDE 0100-551:2017-02 requires a total value of 100 Ω for $R_A$. Taking into account the second fault and the tripping of an RCD necessary for this purpose, the earthing resistance should not exceed the following values:

| $I_{\Delta n}$ | 10 mA | 30 mA | 100 mA | 300 mA | 500 mA | 1 A |
|---|---|---|---|---|---|---|
| $R_A$ | 5000 Ω | 1666 Ω | 500 Ω | 166 Ω | 100 Ω | 50 Ω |

***Measurement of insulation resistance***

Insulation measurement and insulation monitoring are terms that are easily mixed up, as they are very similar in principle. Insulation measurement is the test in which the insulation resistance is measured between active conductors and the protective conductor in the switched-off or de-energised system with the aid of an insulation measuring instrument in accordance with DIN VDE 61557-2:2018-02. This measurement is not a specific measurement only for the IT system but is also used for the TN or TT system. Insulation monitoring is the permanent monitoring of the insulation resistance of an IT system during operation and thus of all connected equipment.

In order to carry out the insulation measurement correctly, the installation or the part of the installation to be tested must be disconnected before starting the measurement. The insulation monitoring device must also be disconnected. If the insulation monitoring device (IMD) cannot be disconnected from the system it has to checked whether the insulation monitoring device is suitable for the applied measuring voltage. Since the internal resistance of an insulation monitoring device which is not disconnected is measured, the displayed measured value may deviate from the very high insulation resistance (≥ 5 MΩ).

The insulation resistance is measured between the active conductors and the protective conductor connected to earth. During this test the active conductors may be electrically connected to each other. The DC measuring voltage and the level of insulation resistance must meet the requirements of Table 2. The insulation resistance is considered adequate if each circuit without connected electrical loads reaches the required value. Before measurements are carried out, make sure that all switches in the circuit are closed. If circuits cannot be closed, the undetected circuits must be measured separately. Existing connections between N and PE must be open.

| Nominal voltage of the electrical circuit (V) | DC measuring voltage (V) | Insulation resistance (MΩ) min. |
|---|---|---|
| SELV, PELV | 250 | 0.5 |
| Up to 500 V, as well as FELV | 500 | 1.0 |
| above 500 V | 1000 | 1.0 |

*Table 2: Insulation resistance and measuring voltage according to DIN VDE 0100-600 (VDE 0100-600): 2017-06*

The measuring voltage is a DC voltage. This means that the ohmic resistances are measured. The level of the measuring voltage depends on the type of system or equipment to be tested and is regulated in the standards applicable to the safety tests (see table 2). For 230/400 V systems this DC is 500 V. The measuring current must be at least 1 mA or the peak value must not exceed 15 mA. Due to the level of the measuring voltage, a certain “dielectric strength“ should also be tested at the same time. Therefore, all connected equipment must also be able to withstand this DC measuring voltage for at least 1 min. During an insulation measurement, exposed, conductive parts must not be touched in order to avoid the risk of electric shock, e.g. with defective devices.

For the measurement of the insulation resistance during operation, the permanent monitoring with an IMD represents a considerable simplification, because after an initial measurement with the electrical system switched on, the IMD fulfils this measurement task (according to DIN VDE 0100-600 Ab 61.3.3). If an IMD exists, during periodic testing the single measurement of the insulation resistance is not required. This is also advantageous for electrical installations which cannot be disconnected for operational reasons. Ultimately, a selective measurement becomes a continuous monitoring. The DC measuring voltage of the insulation monitoring device is below the max. permissible touch voltage AC 50 V/DC 120 V, so that no danger can occur.

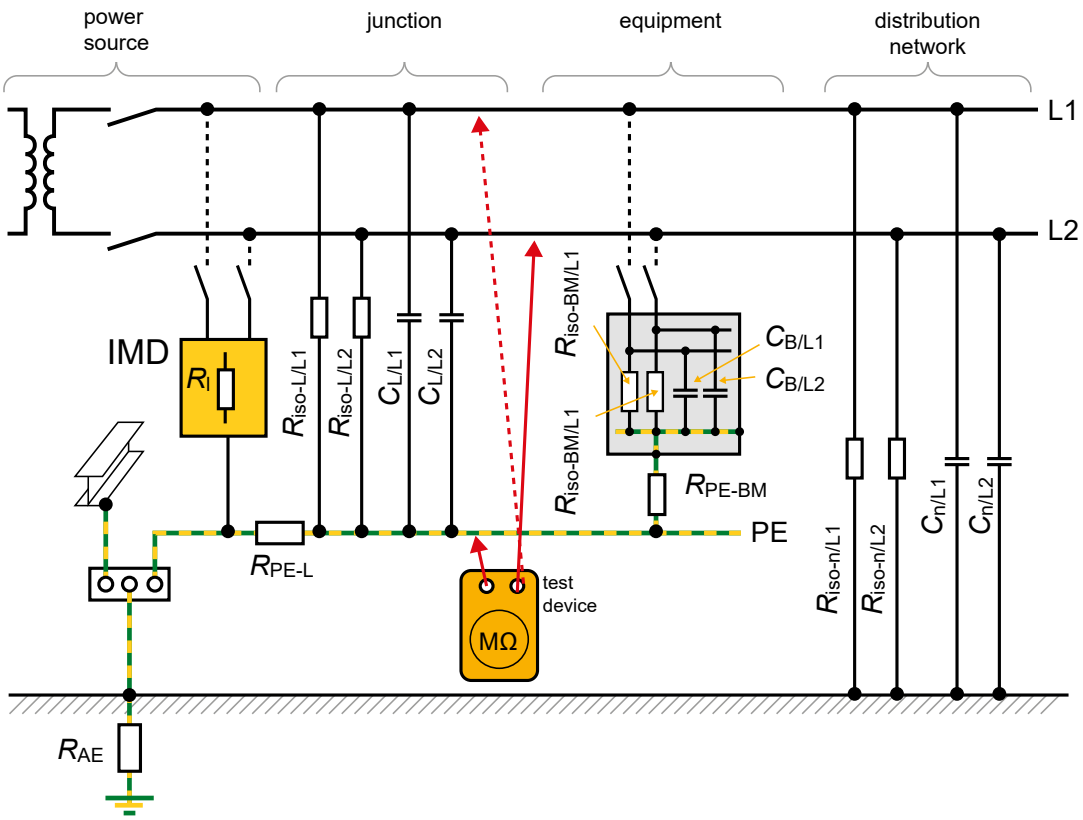



*Fig 5: Measurement of the insulation resistance using an insulation measuring device acc. to DIN EN 61557-2*

***Measurement of the fault current $I_d$***

In IT systems, compliance with the following condition must be verified.

$R_A \times I_d \leq 50$ V (AC systems)

For DC systems < 120 V are permissible.

$R_A$ the sum of resistances in Ω of the earth electrode and the protective conductor to the respective exposed-conductive part;

$I_d$ the fault current in A at the first fault with negligible impedance between a line conductor and an exposed-conductive part. The value of Id takes into account the leakage currents and the total impedance of the electrical installation. Thereby, the value $I_d$ can be determined arithmetically as well as metrologically. During the measurement, an active conductor (e.g. L1) is connected almost without resistance to earth and the current between earth and the other active conductors (e.g. L2) is measured with an ammeter. From the measured fault current $I_d$ and the earthing resistance $R_A$ the possible touch voltage $U_B$ can be calculated and compared with the locally agreed touch voltage $U_L$.

In the case of a manual measurement, appropriate precautions must be taken to avoid hazards in the event of a double fault. However, appropriate test devices are now available on the market which eliminate such risks.

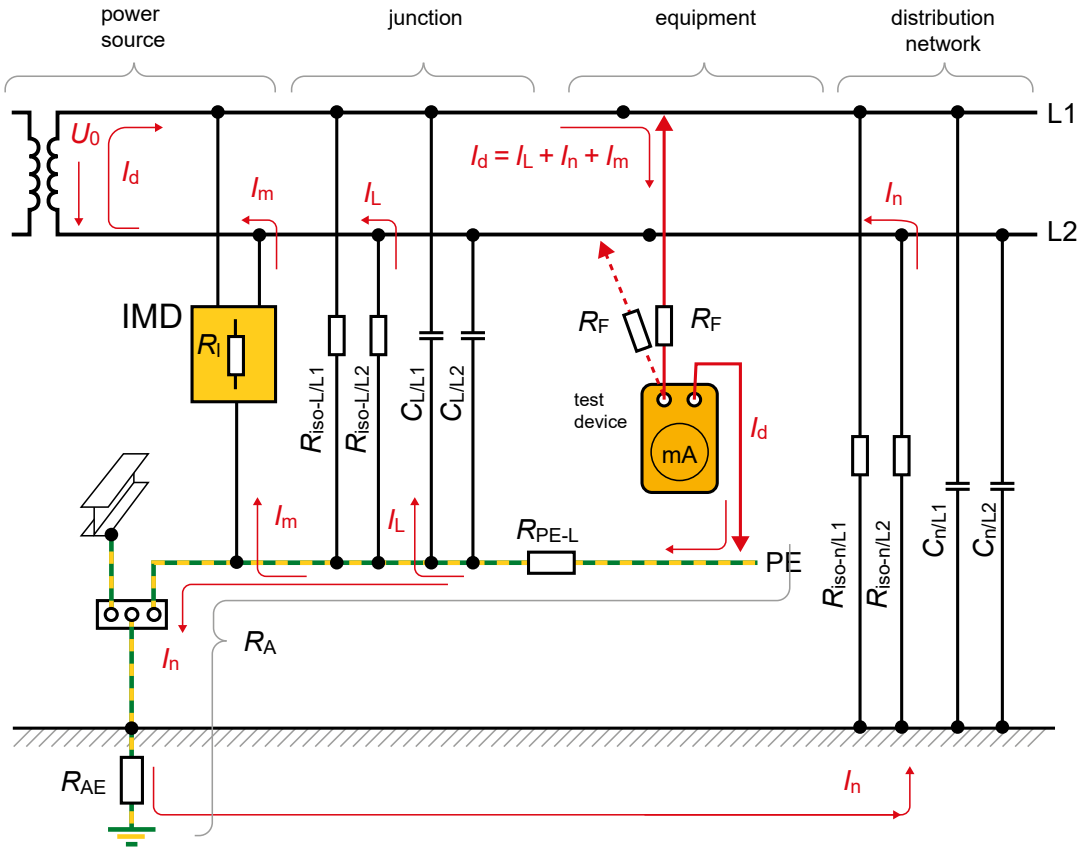



*Figure 6: Measurement $I_d$*

***Measurement and test of the disconnection conditions in the event of a second fault***

This test checks whether, in the event of two insulation faults at different active line conductors (double fault), the protective device of the circuit disconnects at least one point of fault within the specified time. If the IT system comprises only one circuit, the tester at the end of the circuit measures the system impedance $Z_s$ between two line conductors or, if the N conductor is also led out, the system impedance $Z'_s$ between a line conductor and the N conductor. With the measured system impedance and the magnitude of the possible breaking current Ia of the overcurrent protective devices can be checked. According to DIN VDE 0100-410:2018-10 paragraph 411.6.4, the following conditions apply to the fault loop

a) When exposed-conductive parts are connected to each other by protective conductors and are collectively earthed to the same earthing system, the conditions similar to a TN system apply and the following conditions must be met:

   AC systems without neutral conductor and DC systems without mid-point conductor:

$$Z_S \leq \frac{U}{2 \, x \, I_a}$$

   Systems with neutral conductor or with mid-point conductor

$$Z'_S \leq \frac{U_0}{2 \, x \, I_a}$$

where

$U_0$ is the nominal AC voltage or nominal DC voltage between the line conductor and the neutral conductor or mid-point-conductor

$U$ is the nominal AC or DC voltage between line conductors;

$Z_S$ is the impedance of the fault loop comprising the line conductor and the protective conductor of the circuit;

$Z'_S$ is the impedance of the fault loop comprising the neutral conductor and the protective conductor of the circuit;

$I_a$ is the current which causes the protective device to function within the required time for TN systems.

c) When the exposed-conductive parts are earthed in groups or individually the following condition applies

$$R_A \leq \frac{50\ V}{I_a}$$

where

$R_A$ is the sum of the resistances in ohms of the earth electrode and of the protective conductor for the exposed-conductive parts;

$I_a$ the current in A which causes the protective device to function within the time required for TT systems.

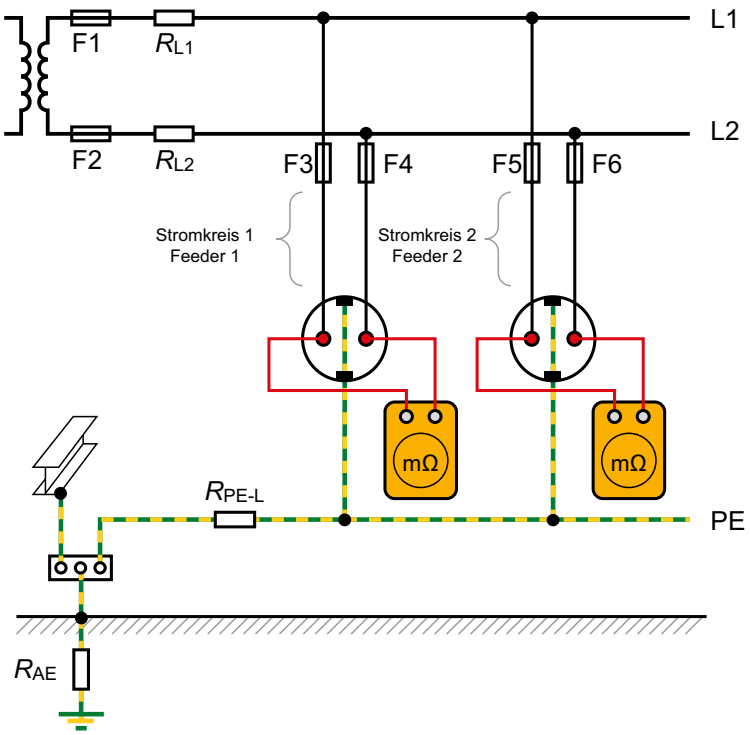



*Fig. 7 Example for the measurement of the system impedance*

The second case is an IT system with several circuits. In such a system it is not possible to predict in which circuits and certainly not in which different locations the two faults to be considered occur simultaneously. This results in different fault loops depending on the fault location and for each fault loop a special system impedance $Z_s$. The system impedance should therefore be measured at the end of each circuit. This gives a statement about the resistance conditions in the active part of the system.

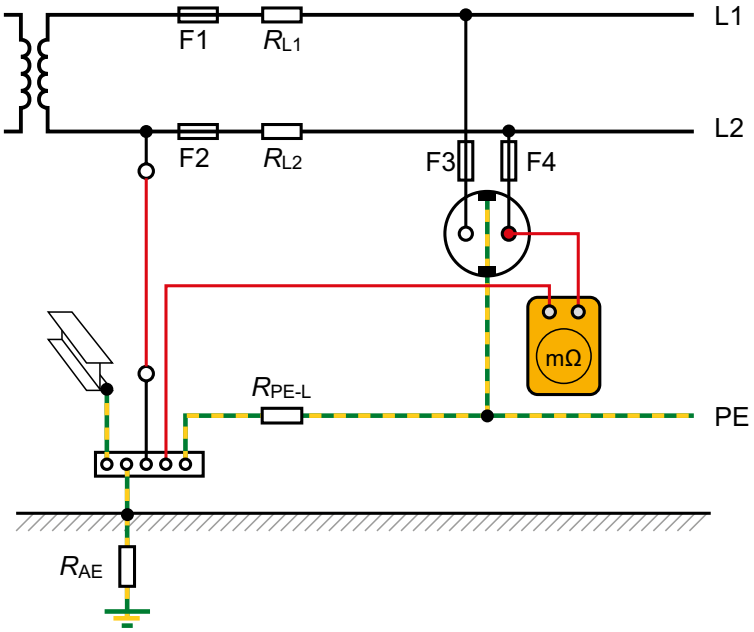



*Figure 8: Example of a loop impedance measurement after previous earthing of an active conductor*

***Testing residual current protective devices (RCD)***

The residual current protective devices RCD primarily trip in the event of a second fault on another conductor, i.e. the fault loop closes only via the protective conductor in the event of a double fault. In practice, therefore, an artificial earth fault is generated in order to be able to carry out this measurement. It should be noted, however, that in a three-phase IT system with an N conductor, the equipment is subjected to higher loads due to the fact that the voltage of the non-defective conductors to earth rises to the line conductor voltage.

After the creation of an artificial earth fault (1st fault) the proper tripping of the RCD can be tested and evaluated with an RCD tester. In principle, however, it should be noted that high system leakage capacitances can lead to an unwanted tripping of the RCD.

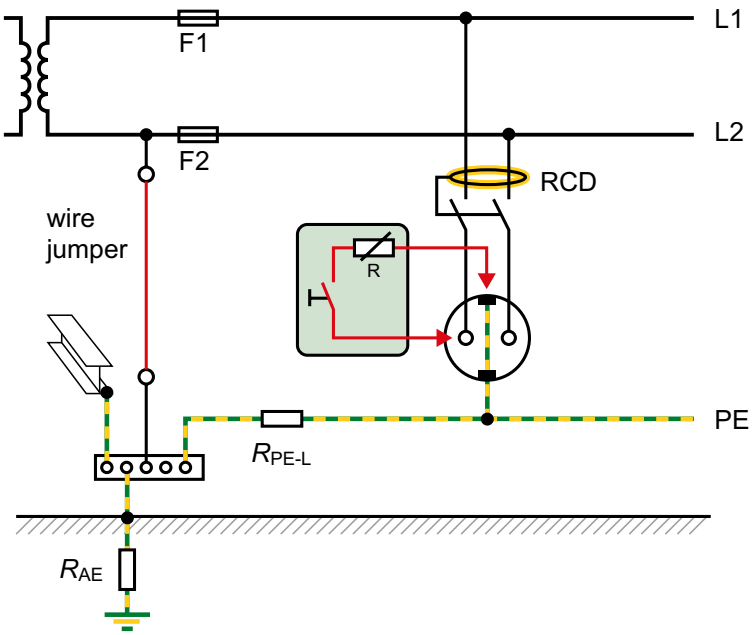



*Figure 9: Functional test of RCDs in IT systems*

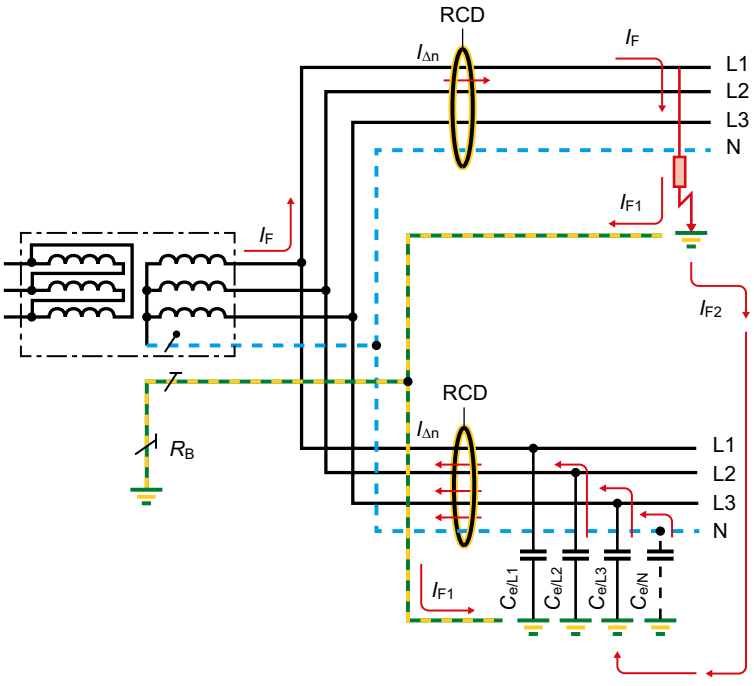



*Fig. 10: Possible false tripping of RCD due to system leakage capacitances*

***Functional and operational tests***

Assemblies, such as switchgear assemblies, drives, actuators and interlocks, must be subjected to a functional test to verify that they are correctly assembled, adjusted and erected according to the respective requirements of the standard. Where necessary, a functional test must be carried out on protective devices, to determine that they have been installed and adjusted in accordance with their intended purpose.

***Functional test of an insulation monitoring device***

The insulation monitoring device (IMD) is tested and evaluated with the aid of the device documentation or suitable test equipment. The following points have to be observed:

- Device conformity with the product standard DIN EN 61557-8:2015-12
- Suitability of the IMD for the purpose at the place of use
- Setting of the response value(s) Ran
- Execution, effectiveness and recognisability of the optical and, where applicable, acoustic signals in the event of an insulation fault
- Function of the test button on the IMD

a) *Testing of the internal monitoring functions of the IMD*
insulation monitoring devices may include internal monitoring functions to ensure proper functioning of the IMD. These are, for example, the connection monitoring to the system and to earth. These connections are at least bipolar in design. If the person carrying out the test opens one of these connections between the IMD and the protective conductor or earth, this fault has to be reported by the IMD. The same applies to the connection on the network side.

b) *Correct setting of the response values*
If no specific response value is set, a response value of 100 Ω/V should be set on the IMD as main alarm. If the IMD has a second message level, a prewarning level of 300 Ω/V can be set. This gives the plant operator the advantage of being aware of possible changes in the electrical installation at an early stage without having to take immediate action.
He can carry out the service assignment at a later, scheduled time. In medical locations a minimum value of 50 kΩ is required.

c) *Checking the response value*
The IMD tripping function shall be checked in accordance with DIN EN 61557-8:2015-12, paragraph 6.1.2. by means of a test resistance whose value shall be equal to half the set IMD response value. Testing of the response time is described in DIN EN 61557-8 (VDE 0413-8):2015-12 Section 6.1.2 Response time. Then, with a system leakage capacitance of max. 1uF, a suitable test resistance must be suddenly connected between the active conductor and earth or equipotential bonding and the delay time until the output circuit (e.g. socket) is switched off must be measured.

If higher system leakage capacitances Ce exist in the IT system, the response of the insulation monitoring device may be delayed. The response time can be estimated by the formula $5\ \tau = R_I \times C_e$ where $R_I$ is the internal resistance of the insulation monitoring device. Depending on the IMD measurement method, however, this time can also be significantly shorter. When selecting the test resistance, it must be ensured that it is suitable for the application (dielectric strength, etc.).

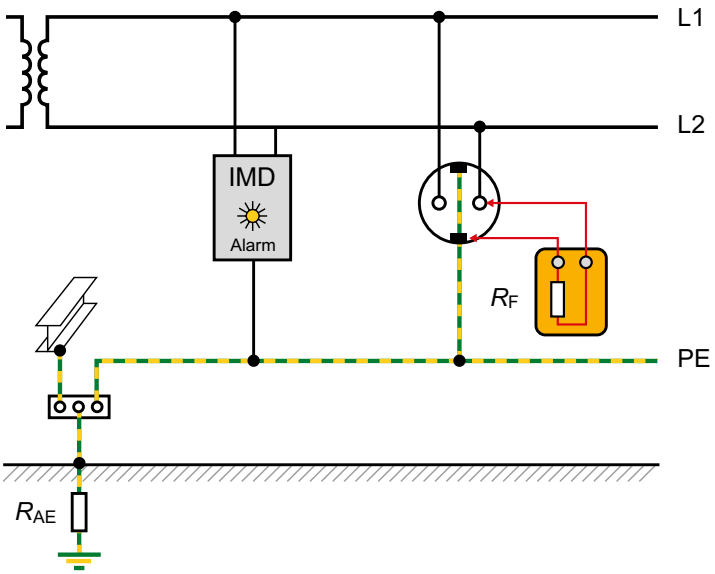



*Figure 11: Functional test of an IMD*

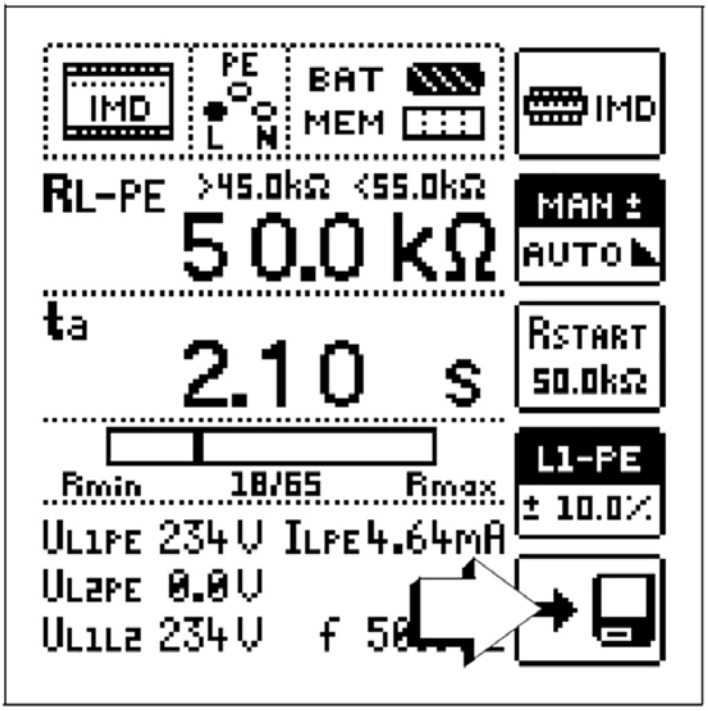



*Figure 12: Example of testing an IT system with a test system (Source: Profitest MXTRA, Gossen-Metrawatt)*

d) *Checking the correct visual and audible message*
The person carrying out the test must assess whether the messages initiated by the IMD arrive correctly at the necessary locations and can also be perceived there. In this case, for example, the messages must accumulate in a permanently occupied position in the hospital. In addition, there should be an instruction at this point on how to deal with each message.

It must also be checked whether the permissible and required changeover and switchback functions work correctly. When insulation monitoring devices utilise an automatic self test function, the effect of this warning indication has to be checked.

***Preparation of the test report***

After completion of the test of a new installation or of extensions or modifications to an existing installation, a test report of the initial test shall be prepared. This test report shall include details of the scope of the installation covered by the report, together with a record of the survey and the results of the testing and measurement.

Before the installer of the system declares that this system meets the requirements of the DIN VDE 0100 (VDE 0100) series, all defects detected during testing must of course be rectified. The test report must be handed over to the installation owner.

All errors or missing parts detected during the inspection of the system must be corrected before the installer of the system declares that the system meets the requirements of the DIN VDE 0100 (VDE 0100) series. The person or persons responsible for the safety, construction and testing of the installation must provide the contracting entity with the test report stating their responsibility, together with the necessary records.

The same applies to periodic verification. The scope and results of the periodic verification shall be recorded and a test report shall be prepared.

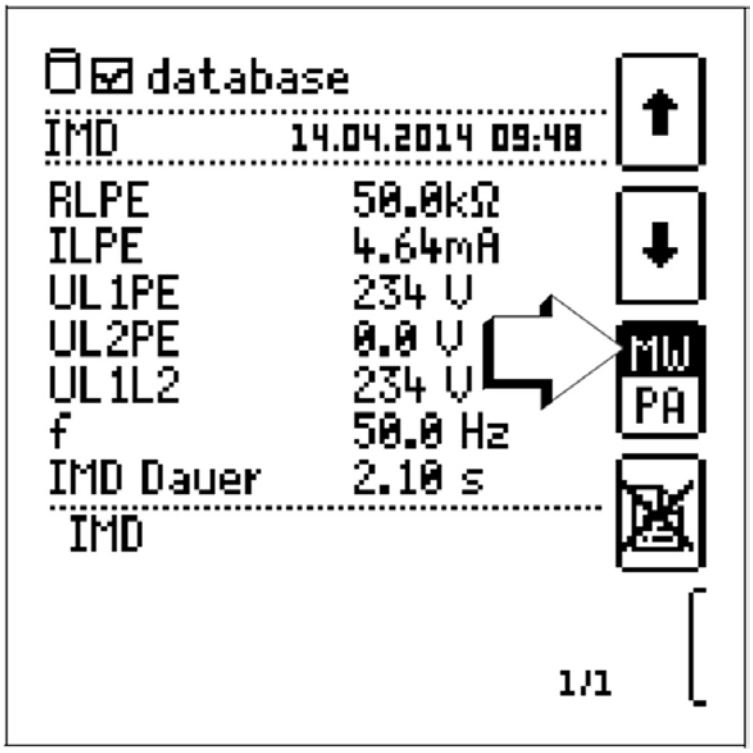



*Diagram: 13: Transfer of measurement results to a database(Source: Profitest MXTRA, Gossen-Metrawatt)*

**Summary**

Electrical installations have to be set up according to the applicable technical regulations. This has to be verified by tests in order to ensure that the user operates an installation that conforms to the rules and that possible hazards to persons and property are avoided.
DIN VDE 0100-600 and DIN VDE 0105-100 contain the necessary specifications. However, in the end the person carrying out the test is responsible for the measurement and the selection of the suitable measuring principles.

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DIN EN 61557-9 (VDE 0413-9):2015-10 Electrical safety in low voltage distribution systems up to AC 1 000 V and DC 1 500 V – equipment for testing, measuring or monitoring of protective measures Part 9: Einrichtungen zur Isolationsfehlersuche in IT-Systemen (Equipment for insulation fault location in IT systems)

DIN VDE 0105-100 VDE 0105-100:2015-10
Betrieb von elektrischen Anlagen (Operation of electrical systems)
Part 100: General requirements

DIN VDE 0100-600 VDE 0100-600:2017-06
Errichten von Niederspannungsanlagen (Erection of low voltage electrical installations)
Part 6: Tests

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