Renewable energies

Utilising the power of nature safely and efficiently

Design the future
of energy

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Solutions for electrical safety and high availability

Safety and efficiency for renewable energies

Renewable energies are the central component of a sustainable and climate-friendly energy supply. Operators of photovoltaic, wind power, hydro power and biogas plants are faced with the task of optimising the use of natural resources while complying with the highest safety standards.
Electrical hazards or unplanned downtimes can significantly impair the availability of the systems.

Our globally proven, reliable solutions are specially tailored to the requirements of renewable energy systems:

- recognise potential electrical hazards at an early stage
- ensuring the safety of people and systems
- identify critical operating states immediately
- minimise default risks and business interruptions
- ensure high system availability through preventive intervention
- manage measurement data from systems

Wind energy plants

Early detection instead of standstill

For wind turbine operators, maximum availability and operational reliability are the top priorities. Every unexpected failure means financial losses and additional maintenance costs.
Offshore wind farms in particular are dependent on a high degree of operational reliability due to their exposed location and difficult maintenance conditions.

Electrical safety plays a decisive role here. Undetected insulation faults can not only lead to sudden downtimes, but also significantly increase the risk of fire. In addition, unplanned service calls result in high costs, as access to the turbines, particularly in the case of offshore wind farms, is often only possible with considerable logistical effort.

The most common cause of insulation faults or residual currents is inadequate insulation due to:

- Mechanical damage to the cables due to:
    - vibration
    - torsion
    - extreme temperature fluctuations
- Leakage currents caused by:
    - moisture
    - transmission and hydraulic oils
    - dirt
- lightning strike and its consequential damage

Residual currents or insulation faults usually have serious consequences such as:

- high costs due to business interruption
- increased fire hazard
- failure of safety-critical systems
- unplanned maintenance measures
- unexpected tripping of protective devices
- danger to maintenance personnel

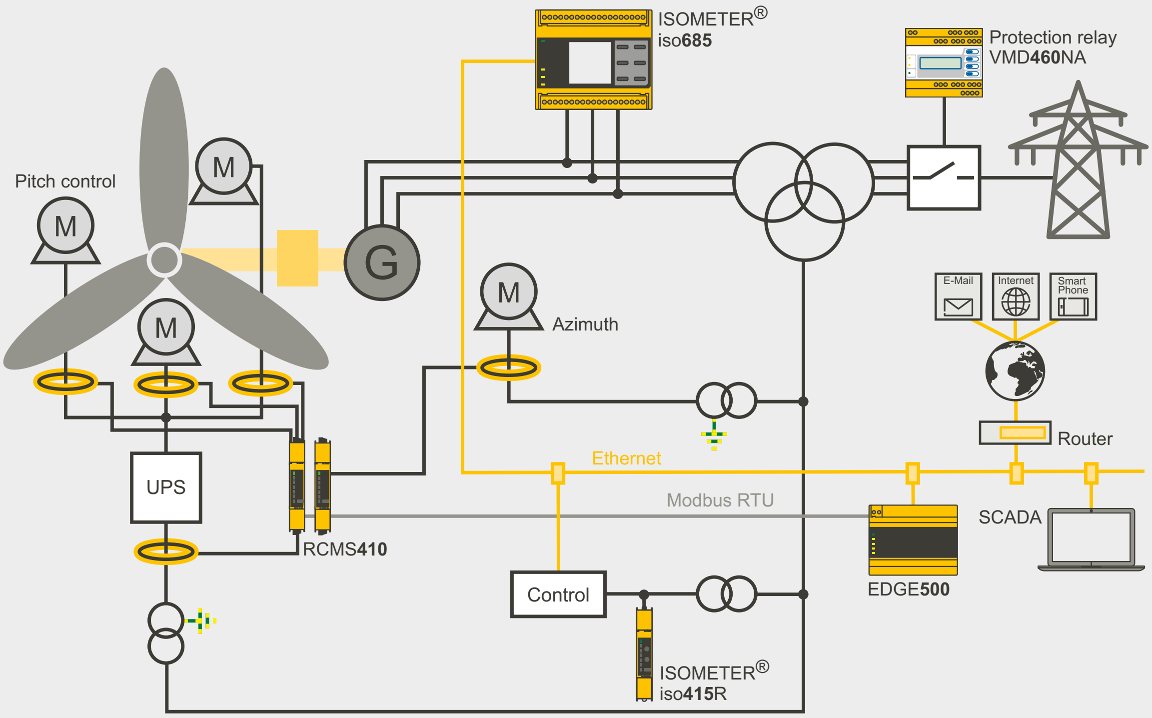


Figure 1: Illustration of wind turbine

Large-scale PV systems

Required protective measures and normative requirements

Photovoltaic systems place special demands on electrical safety, especially in an emergency. As PV generators generate electrical energy continuously during the day, automatic switch-off as a protective measure is not possible - the systems are energised almost around the clock and are only de-energised when it is dark.

The only effective protective measure is therefore double and reinforced insulation in accordance with DIN VDE 0100-410 (IEC 60364-4-41), section 412, in combination with permanent monitoring of the system. DIN VDE states:

> 'In cases where this protective measure is applied as the sole protective measure (e. g. where it is intended for a circuit or part of an installation to install only equipment with double or reinforced insulation), it must be demonstrated that effective measures are taken, e. g. effective monitoring, so that no change can be made that would impair the effectiveness of this protective measure.'

To fulfil this requirement, continuous monitoring of the insulation resistance is necessary. The ISOMETER® series from Bender makes it possible to measure and visualise insulation resistance over time.

Despite extensive testing as part of the type approval of PV modules in accordance with DIN VDE 0100-712 (IEC 60364-7-712) – 'Erection of low-voltage installations – Part 7-712: Requirements for operating facilities, rooms and systems of a special kind – photovoltaic (PV) power supply systems' – new weak points in the installation and operation of PV systems are constantly emerging.

Measurement supervision gives the operator a decisive information advantage and enables critical conditions to be recognised at an early stage before they lead to serious problems.

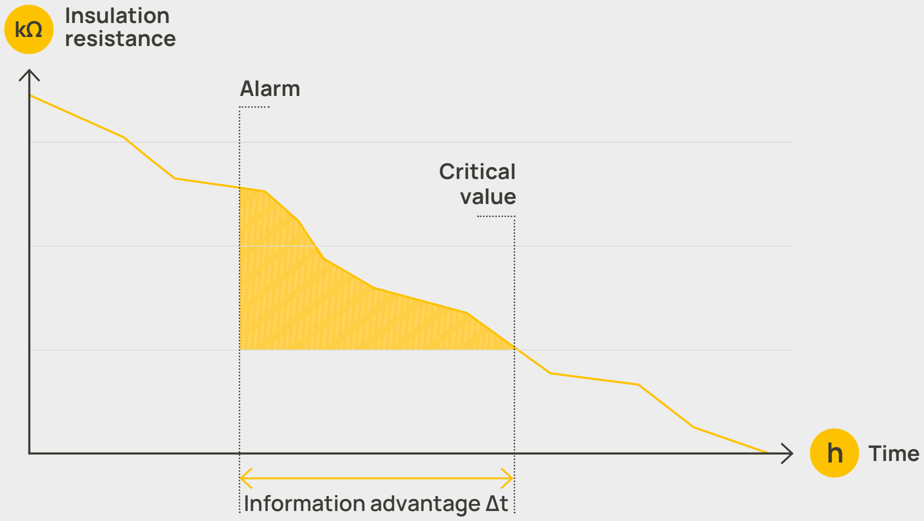


Figure 2: Change in insulation value

Practical example:

In a newly installed 15 MW PV system, consisting of several strings each with an output of 1.7 MW, morning moisture increased the leakage capacitance C_e of the strings by a factor of 10 and at the same time reduced the insulation resistance R_f by 30%. Assuming that ageing processes in the form of material wear will have an additional negative impact on the insulation value in the future, critical values can be reached very quickly.

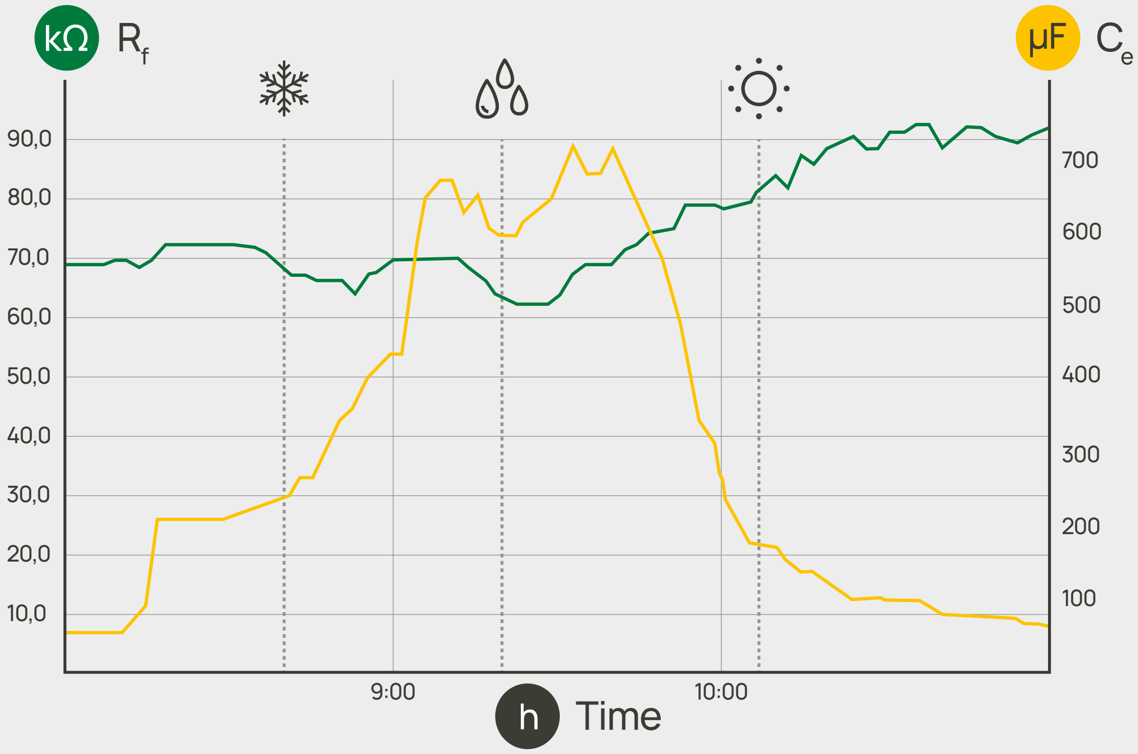


Figure 3: Measured values of insulation resistance and leakage capacitance

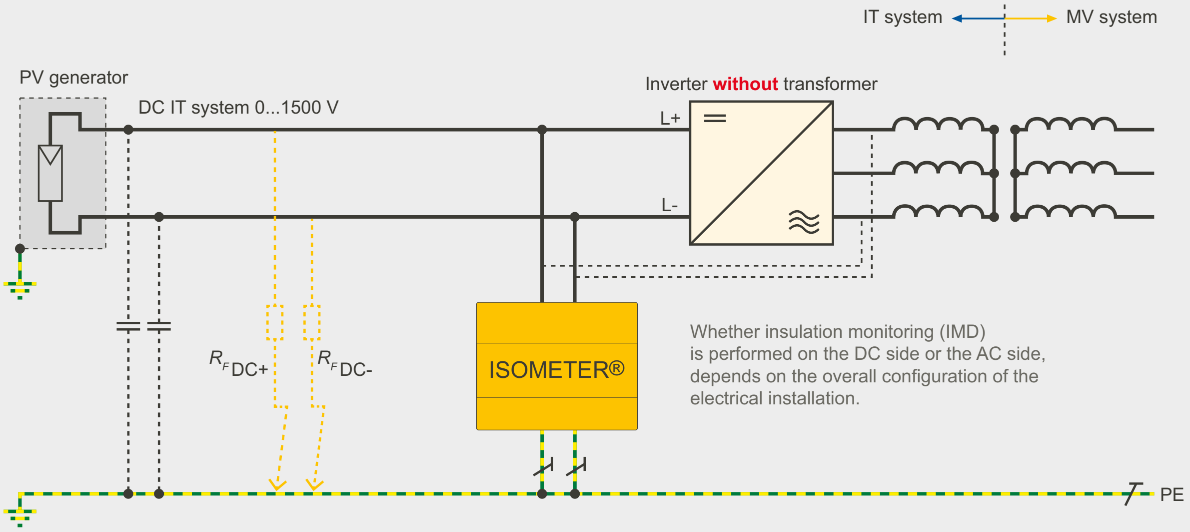


Figure 4: Inverter **without** transformer

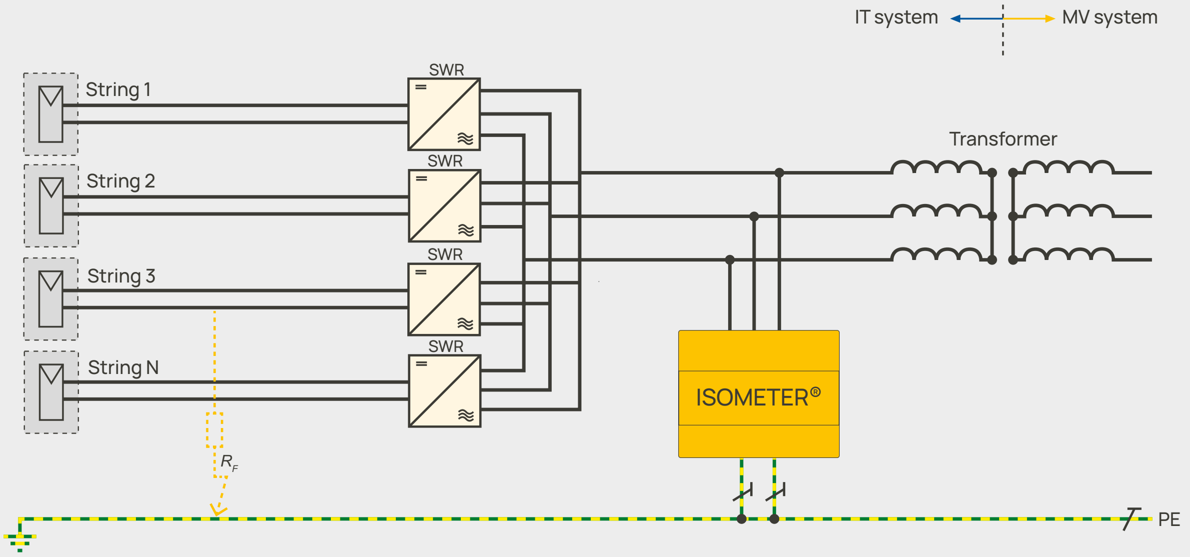


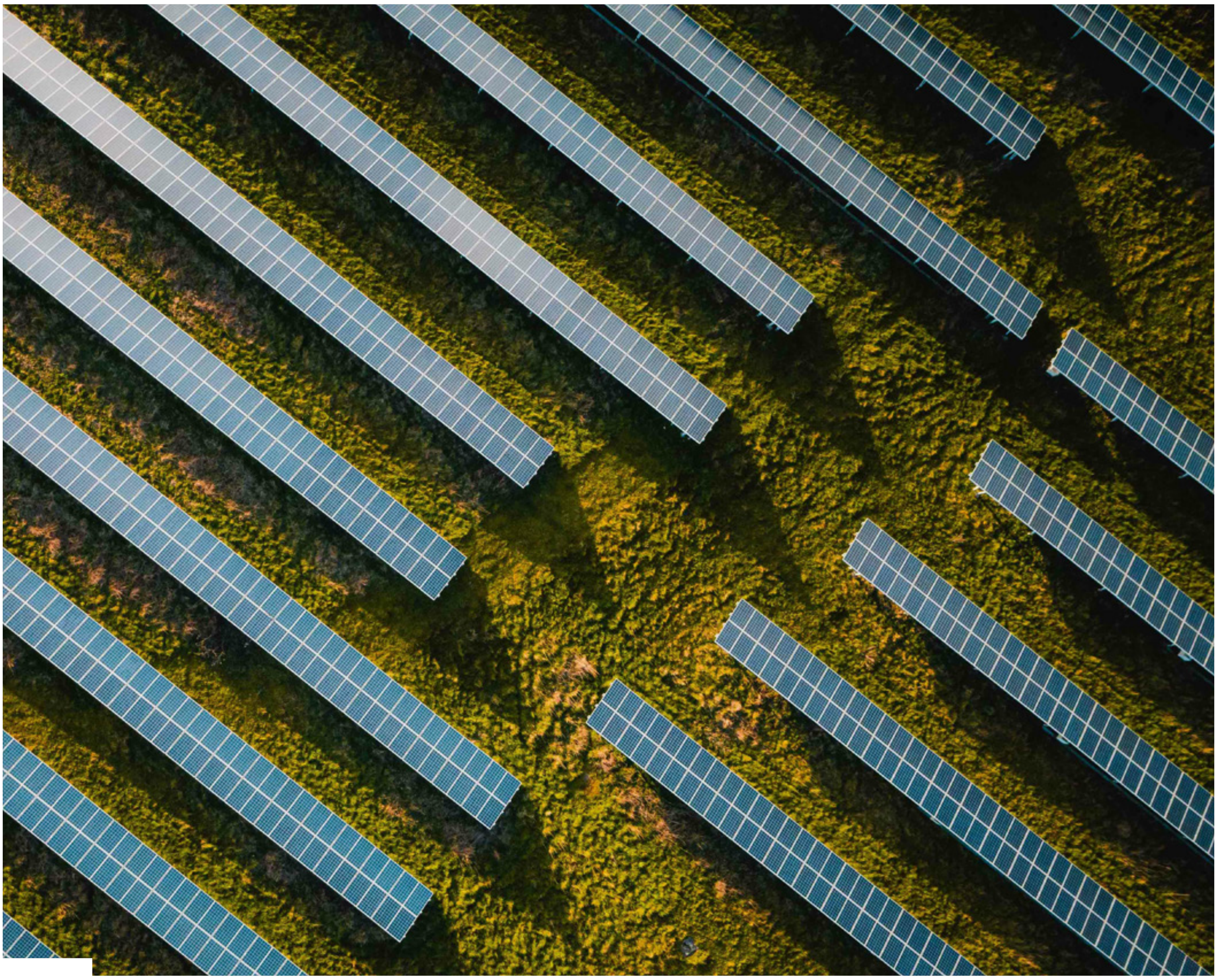
Figure 5: Decentralised string inverters

Type of distribution system: IT system

Photovoltaic systems are usually installed in the IT (Isolé Terre; no galvanic connection of the active conductors to earth) grid form. The reasons for this are both simple cable and higher availability, as the first fault in IT networks does not have to lead to a shutdown or interruption. Large-scale photovoltaic systems in the range of several megawatts [MW] are divided into individual strings. These strings either have individual string inverters (Figure 5) or are connected to a central inverter (Figure 6). Depending on the power and application, inverters are generally designed with or without a transformer (Figure 4). If there is sufficient solar radiation, a brief insulation measurement is carried out within the string inverter and only then is the system switched to 'Mains operation'. The IT grid now extends from the photovoltaicpanels to the secondary winding of the transformer. A central insulation monitor (IMD), as shown in figures 5 and 6, monitors the insulation levelof the entire IT system during 'system operation'.

PID – Potential Induced Degradation

The PID effect in PV modules with crystalline SI cells leads to a gradual reduction in output (degradation), which can reach critical levels over time and significantly reduce the yield. The known countermeasure of raising the potential of the PV generator after sunset does not contradict centralised insulation monitoring using IMD, as the inverter is no longer in grid operation at this time.



Complex measurement procedure

The current-carrying cables of the IT system represent a kind of capacitor with respect to the earth potential PE. The resulting system leakage capacitance C_e and the capacitive properties of the photovoltaic panels generate a system leakage current. This is significantly influenced by the total area [m^2] and the humidity of the system. The ISOMETER® insulation measuring devices from Bender use a measuring method specially developed for this application and adapt to the system status to determine the insulation resistance R_f.

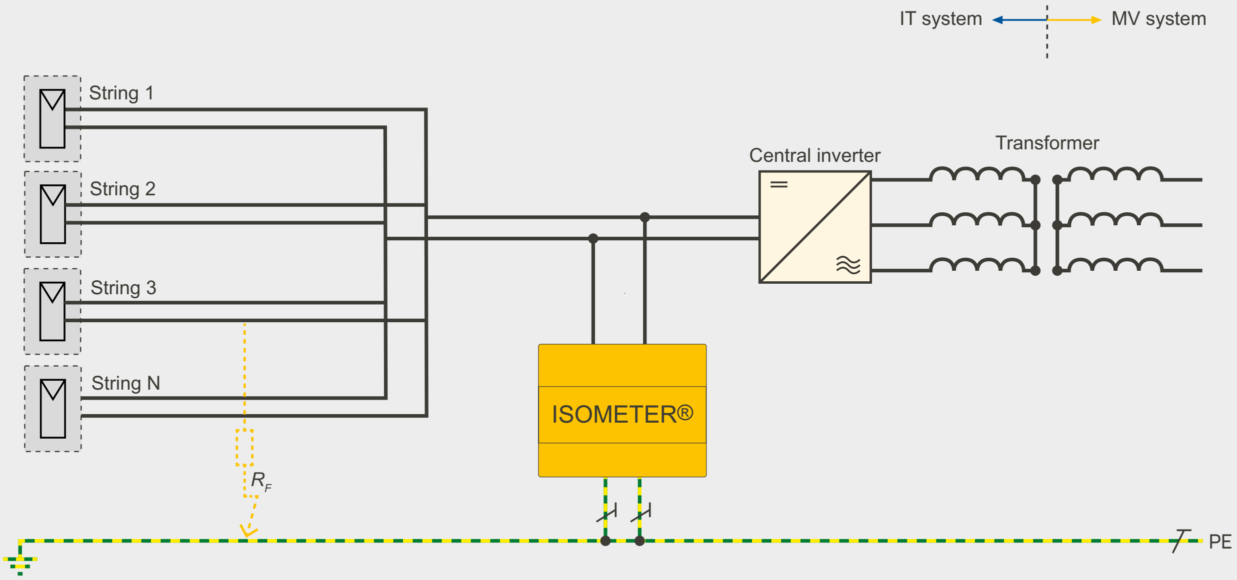
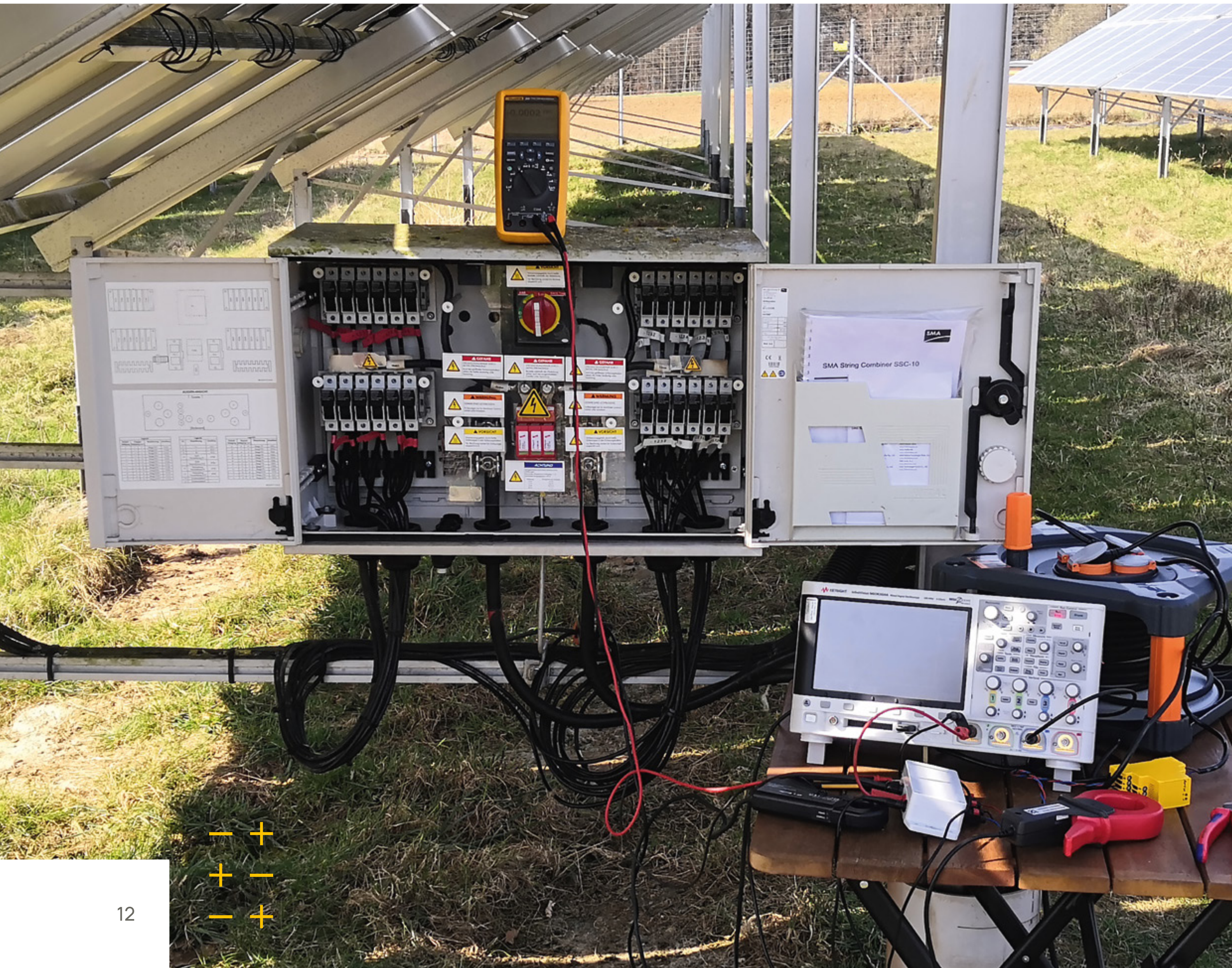


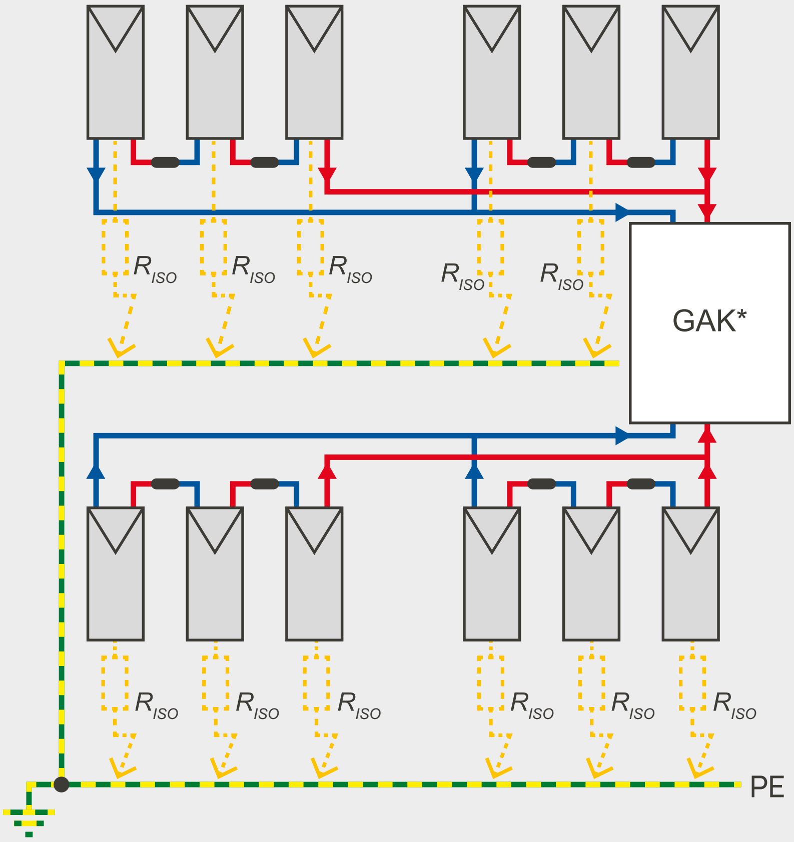
Figure 6: Central inverter

Low insulation level – challenge and solution

Photovoltaic systems consist of a large number of modules that are electrically connected in series and in parallel. However, the insulation resistance is connected in parallel to earth, which considerably reduces the overall insulation level of the system. According to IEC 61215, the minimum insulation resistance of a single PV module is at least 40 MΩ*m². In large-scale solar parks with an output of several megawatts, however, this value can drop to a few kΩ due to the large number of PV modules.

Reliable monitoring of the insulation resistance is essential in order to detect faults at an early stage and minimise safety risks. The ISOMETER® isoPV series from Bender offers precise and continuous measurements to determine the condition of the insulation.
Our technology guarantees maximum safety and availability – a decisive advantage for the safe and efficient operation of large-scale PV systems.





*Generator connection box

Figure 7: Illustrative example of insulation resistance R_{ISO}

1. The insulation resistances of the individual PV modules represent a parallel connection to earth and add up according to Ohm's law.
2. The total resistance of the entire PV system decreases with the number of PV modules.
3. According to the international standard **IEC 61215**, the **minimum insulation resistance** of a PV module must be ≥ **$40\ M\Omega * m^2$**.

Example calculation:

A 5 MW solar power plant consisting of PV modules with an output of 400 W each.

Area of a PV module: $1m \times 2m = 2m^2$ / nominal power: 400W

$$R_{ISO} = \frac{40M\Omega * m^2}{2m^2} = \mathbf{20M\Omega} \text{ (per module)}$$

5MW / 400W = **12,500** modules (200MΩ per module)*

*Experience shows that new modules have a **10-fold higher** value

$$R_{ISO} = \frac{1}{\frac{1}{R_{module\ (1)}} + \frac{1}{R_{module\ (2)}} + \frac{1}{R_{module\ (n)}}} = 16k\Omega!$$

In the most favourable case, the R_{ISO} of a newly installed 5MW solar park is approx. 16kΩ.

Battery storage systems

With the increasing demand for environmentally friendly energy, power generation and smart grids are constantly evolving. Advances in photovoltaic and battery storage technology open up new possibilities, but at the same time place high demands on the protection of personnel and systems.

Battery energy storage systems (BESS) are generally operated as unearthed IT systems in which all active conductors are deliberately insulated from earth. This configuration allows the systems to continue operating even in the event of an initial earth fault. Nevertheless, it is crucial to recognise, report and rectify this error at an early stage. If the fault persists, a second fault can lead to a dangerous overcurrent situation and jeopardise the safety of the entire system.

Benefits

Fault detection without interrupting operation
Insulation faults or problems with insulation breakdowns can be detected at an early stage and localised precisely – without interrupting system operation.

Reduced maintenance costs
The high accuracy of fault detection reduces the need for manual intervention and thus minimises maintenance costs considerably.

Automatic fault location
Automated fault location eliminates the need to open branch switches or switch off devices. This saves time and reduces the risks during error analysis.

Increased safety
Precise earth fault detection on battery stacks or battery strings minimises the risk of electric shocks for employees. Fast repairs also help to prevent fires and further damage.

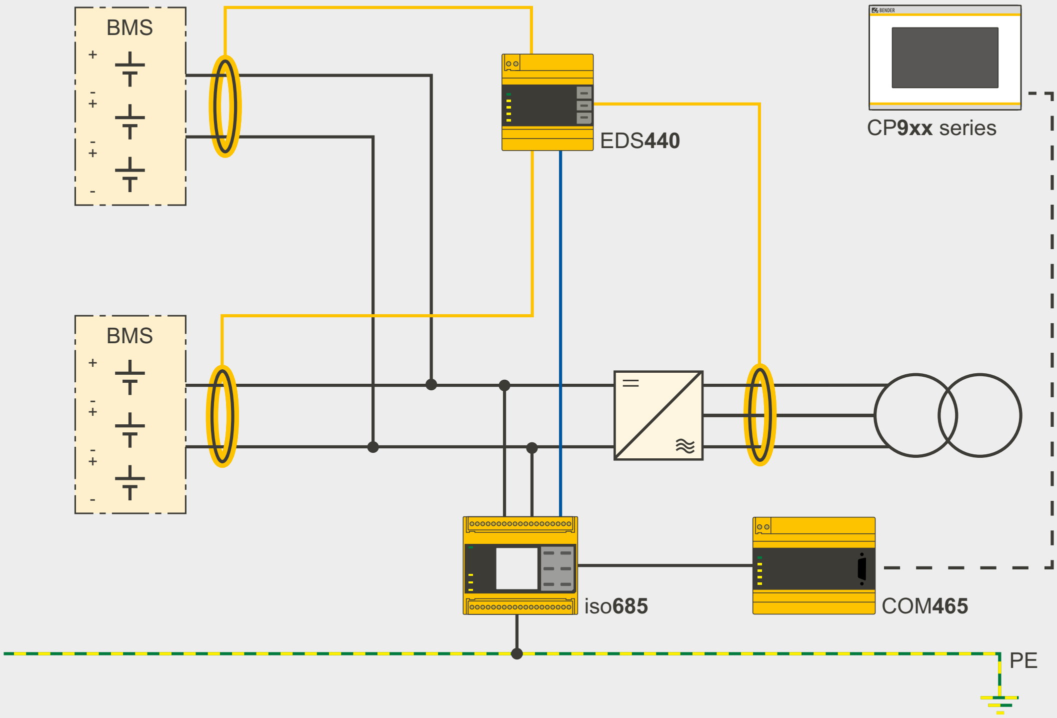


Figure 8: Example of an unearthed system

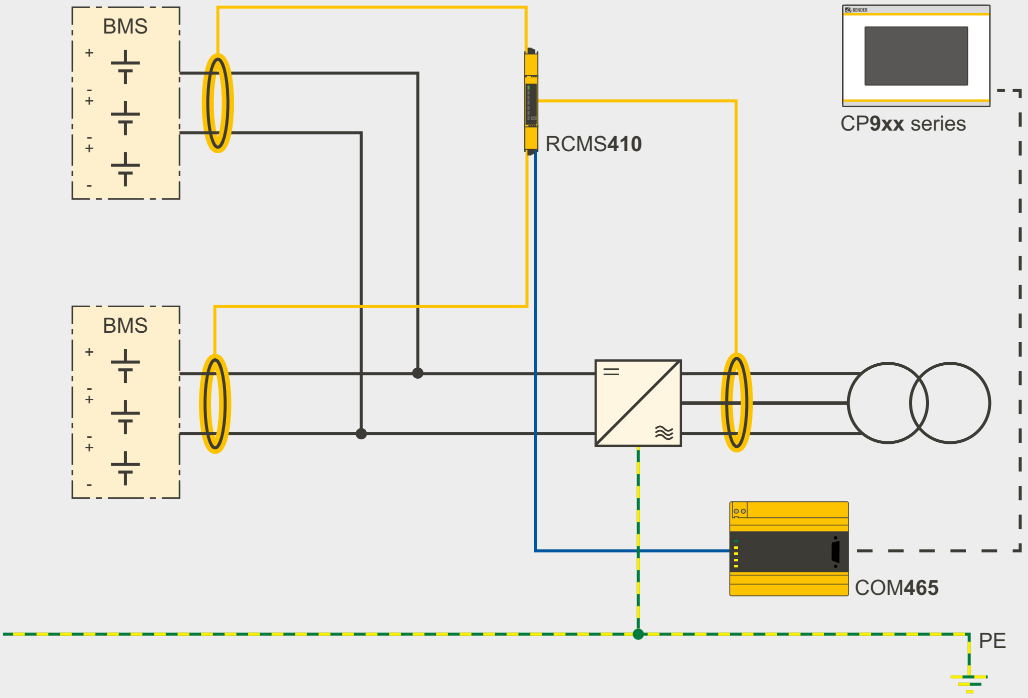


Figure 9: Example of an earthed system

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