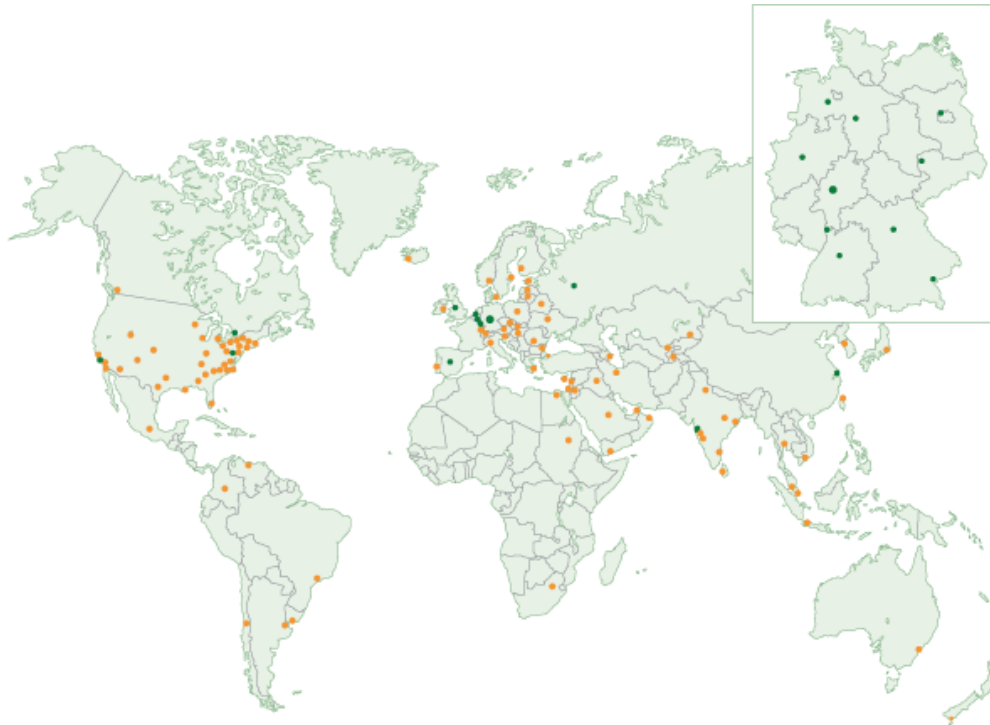


The Power in Electrical Safety

Product overview - solutions for NFPA and CSA based markets



The Power In



Global Experts in Electrical Safety

For over 70 years, Bender has been a global leader in ground fault protection. With over 50 agencies and partners across the globe, Bender has a local office to help you from the design phase through the support phase of your project. Our years of technical experience and broad portfolio of products, utilizing the latest in protection technology, will help you create the best solution to meet your needs. Top-notch service and support across the globe ensure that your electrical network remains in peak condition. From industrial plants to mines to hospitals, Bender is the right choice to protect your electrical system.

Bender online: Your electrical safety resource

- Complete listings of products with comparisons, documentation, datasheets, and technical information
- Industry specific knowledge to help you pick the right product
- Your electrical safety questions answered in our extensive knowledgebase with application notes
- Product selection tools
- Isolated power solution builder for hospitals
- Local representative information



www.bender.org • www.bender-ca.com • www.bender-latinamerica.com



Electrical Safety

Ground Fault Equipment

For Grounded and HRG Systems

High sensitivity ground fault monitoring with advanced filtering capabilities for AC/DC systems



Ground Fault Equipment

For Ungrounded Systems

Advanced ground fault detection and location equipment for virtually any AC/DC application



Ground Fault Equipment

For Renewable Energies

Special ground fault equipment for renewable industries utilizing years of experience and testing



Isolated Power Systems

For healthcare facilities

A complete solution of isolated power panels, equipment, and accessories for NFPA and CSA medical applications



Protective Relays

Voltage, Current, and Continuity Relays

Multi-function, compact digital voltage, current, and ground continuity relays



Communication Solutions

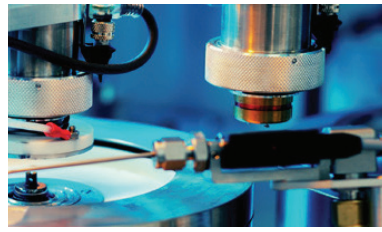
Remote notification of electrical safety issues

Remote indicating stations, and remote communication with Ethernet and Modbus



Ground fault detection and location

Ungrounded AC/DC systems



Bender ground fault detectors for ungrounded systems

Ungrounded systems offer an invaluable advantage - a first ground fault does not generate sufficient leakage current to create a hazardous situation. Early detection allows for critical systems to remain online while problems are located and resolved. Bender Ground Fault Detectors and Location Systems detect ground faults quickly and easily across all types of applications, including DC systems as well as systems containing variable frequency drives (VFD/ASD).

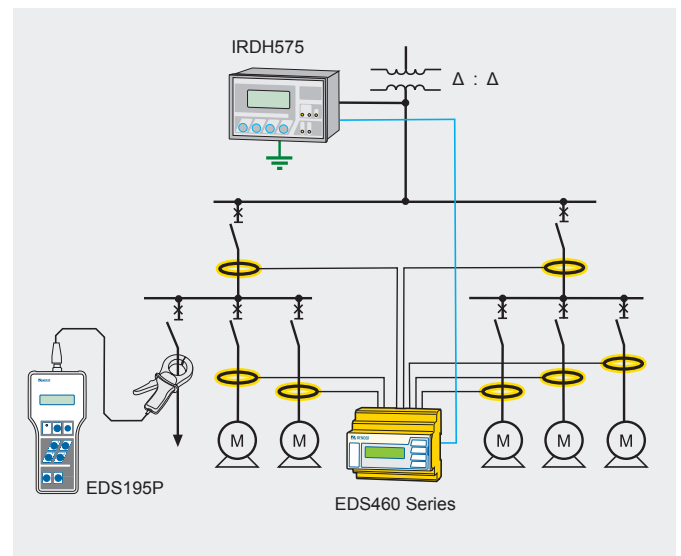
The Bender advantage

Bender's complete line of ground fault products for ungrounded systems offers impressive advantages to keep your system online and running healthy:

- Meets or exceeds requirements for NEC 250.21(B) and CEC 22.1-10-106(2) for ground detectors on ungrounded systems
- DC models meet or exceed requirements for new NEC 250.167(A) (2014 edition) for DC ground fault detection
- Detects single-fault conditions
- Works in AC, DC, and AC/DC applications up to 7.2 kV
- Works with variable frequency drives (VFD/ASD)
- Detects both symmetrical and asymmetrical ground faults
- AMP measuring principle allows for accurate insulation measurements across virtually all types of systems
- Simple and fast ground fault location in ungrounded AC and DC systems with both portable and installed equipment
- Reduce cost, reduce downtime, and protect vital equipment and processes with accurate, early warning ground fault detection and location

Online ground fault location - the Bender difference

When others say ground fault location in an ungrounded system is not possible, Bender says it is. EDS series products from Bender offer fast ground fault location in both portable and installed form. The EDS system can locate ground faults down to the load level, all while the system remains online.



A complete ground fault location system



Ground fault detection and location

Ungrounded AC/DC systems



IR420 / IR425 ground fault detectors

Ground fault detectors - low voltage AC/DC ungrounded systems

The IR420 (AC) and IR425 (AC/DC) ground fault detectors monitors ungrounded systems up to 300 V for early indication of ground faults. A digital display gives real-time readings of the system's insulation resistance to provide predictive maintenance capability and troubleshooting for ground faults. Its compact size allows for easy installation and retrofitting.

Features:

- For AC and DC systems up to 300 V
- Digital display with real-time readout
- Adjustable setpoint from 1 to 200 kΩ
- Two separate SPDT contacts

Applications:

- Single-phase AC and DC systems
- Industrial control systems
- Remote operated vehicles
- Low-voltage motors and drives
- General low-voltage applications



iso685 series ground fault detector

Ground fault detectors - ungrounded AC/DC systems for main distribution

The iso685 series ground fault detector combines the latest in ground fault monitoring technology with Bender's extensive experience with ungrounded systems. The iso685 works on AC, DC, and mixed AC/DC systems, as well as systems with variable frequency drives (VFD / ASD). Included is the new isoGraph feature, which trends the system's insulation resistance over time, making system troubleshooting even easier. A variety of outputs are available, including contacts and analog outputs.

Features:

- For AC and DC systems up to 690 VAC, 1000 VDC (extendable via accessories)
- Digital display with real-time readout
- Adjustable setpoint from 1 kΩ to 10 MΩ
- Trend values over time
- Two separate SPDT contacts

Applications:

- Single- and three-phase AC and DC
- 480 V / 600 V industrial systems
- Variable frequency drives
- Ships and offshore platforms
- Battery backup systems



EDS3090 ground fault location kit

Portable ground fault location equipment - ungrounded AC/DC systems

The EDS3090 provides a portable location system to quickly find ground faults in any size system. The system can be used in conjunction with Bender's installed ground fault detectors or on its own as a completely portable location system. The simple clamp-on meter provides quick location of faulty loads. Installed location devices additionally provide digital communication capabilities.

Features:

- For AC and DC systems
- Installed and portable versions
- Quickly identify and locate ground faults
- Remote communication with installed equipment for remote indication

Applications:

- Single- and three-phase AC and DC
- 480 V / 600 V industrial systems
- Large motor control centers
- Ships and offshore platforms
- Power stations
- Refineries

Ground fault monitoring

Grounded and high-resistance grounded AC/DC systems



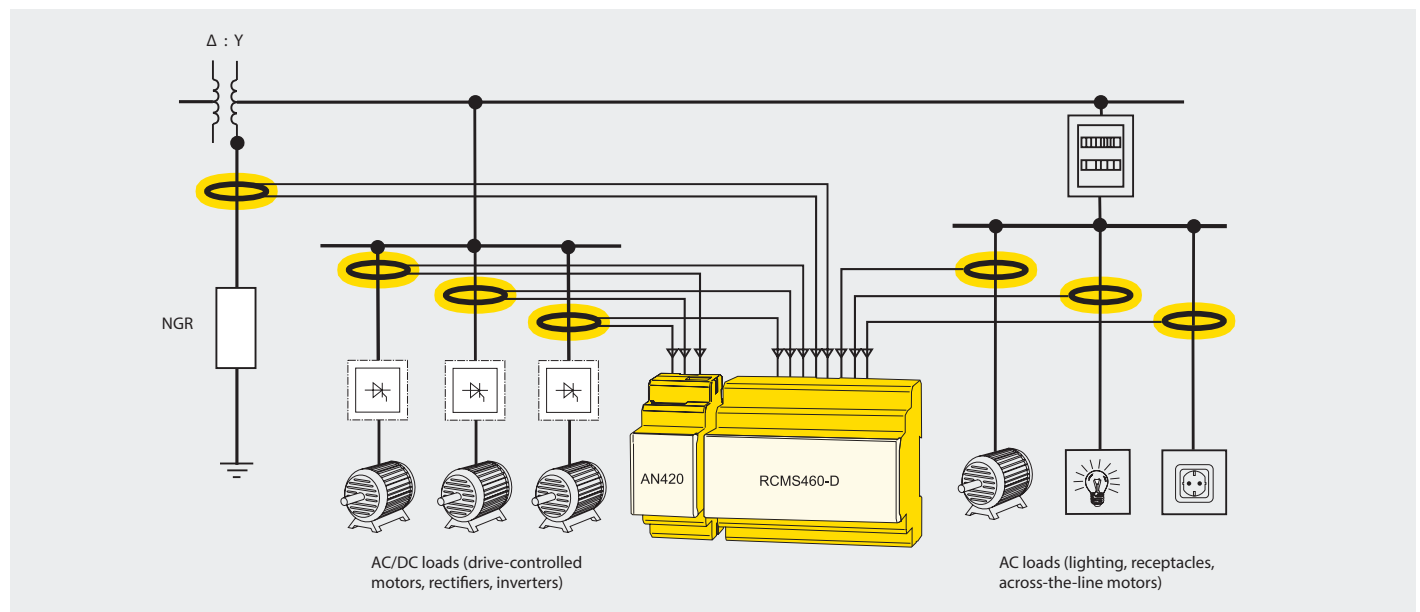
Bender ground fault monitors for grounded systems

Bender ground fault relays provide critical protection for personnel and equipment in environments where safety is a must. The RCM series provides advanced warning of ground faults without the problems associated with nuisance tripping on grounded and high-resistance grounded systems. Accurate tripping across steplessly adjustable setpoints means Bender's RCM series can easily be tailored to your particular application. Output contacts can be used for indication, interruption, or both.

The Bender advantage

Bender's complete line of ground fault products for grounded and high-resistance grounded systems offers impressive advantages to keep your system online and running healthy:

- Works on AC, DC, and AC/DC systems
- DC models meet or exceed requirements for new NEC 250.167(B) (2014 edition) for DC ground fault detection
- Utilization of a single current transformer - voltage and load current do not impact measurements
- Current transformers designed to work with Bender monitors - simple settings, no ratio calculations necessary
- Works with variable frequency drives (VFD/ASD)
- Digital models with real-time display providing true RMS readings and frequency ranges up to 2000 Hz
- Digital communication capability for remote station monitoring and integration into modern industrial comm networks
- Reduce cost, reduce downtime, and protect personnel and equipment with Bender ground fault equipment



Ground fault monitoring

Grounded and high-resistance grounded AC/DC systems



RCM420 series ground fault monitor

Ground fault monitor - AC grounded and high-resistance grounded systems

The RCM420 series ground fault monitors detects ground faults in grounded and high-resistance grounded AC systems, both single-phase and three-phase. A wide, steplessly adjustable trip range allows for flexibility in application and installation. A digital display shows measured fault current in real-time. Two SPDT contacts may be utilized for both remote indication as well as power interruption.

Features:

- True RMS readings (AC)
- Digital display with real-time readout
- Adjustable trip level from 10 mA to 10 A
- Varying size current transformers
- Two separate SPDT contacts

Applications:

- Single- and three-phase AC systems
- General industrial use - panelboards, motors, generators, and more
- Heat tracing systems



RCMA420 / RCMA423 series

Ground fault monitors - AC/DC grounded and high-resistance grounded systems

The RCMA420 and RCMA423 monitor for ground faults in grounded and high-resistance grounded AC and DC systems. Features include a true RMS reading, real-time values displayed on its LCD screen, and two separately adjustable alarms with an SPDT contact for each. This device is perfect for grounded and high-resistance grounded systems running variable frequency drives (VFD/ASD).

Features:

- True RMS readings (AC + DC)
- Digital display with real-time readout
- Adjustable trip levels up to 500 mA (RCMA420) and 3 A (RCMA423)
- Varying size current transformers
- Two separate SPDT contacts

Applications:

- Single- and three-phase AC and DC
- General industrial use - panelboards, motors, generators, and more
- Variable frequency drives (VFD/ASD)
- Drive-controlled mining equipment
- Solar inverters



RCMS490 multi-channel monitor

Multi-channel ground fault monitors - grounded and HRG AC/DC systems

The RCMS series detects ground faults in grounded and high-resistance grounded AC and DC systems. Up to 12 separate channels may be connected to one device. Features include a detailed LCD display of each individual channel's value, harmonics analysis, and contact outputs for each individual channel on the RCMS490 model. Digital communication is also available.

Features:

- For AC and DC systems
- Digital display indicates real-time values for each individual channel, up to 12
- Quickly identify and locate ground faults
- Digital communication compatible
- 2 common SPDT contacts; 490 series features individual outputs

Applications:

- Single- and three-phase AC and DC
- General industrial use - panelboards, motors, generators, and more
- Large motor control centers
- Heat tracing systems
- Solar combiner box systems

Ground fault circuit interrupters (GFCI)

Grounded AC/DC systems - LifeGuard® Series



LifeGuard® Series Ground Fault Circuit Interrupters

The Bender LifeGuard® series of Ground Fault Circuit Interrupters gives your system the added safety of both ground fault detection and interruption. The Lifeguard series is customizable to fit the needs of your system, from load amperage (up to 100 A standard, higher versions available upon request), voltage (including 480 V and 600 V systems), trip level, and more.

The Bender Advantage

Bender's complete line of ground fault circuit interrupters offers impressive advantages to keep your system online and running healthy:

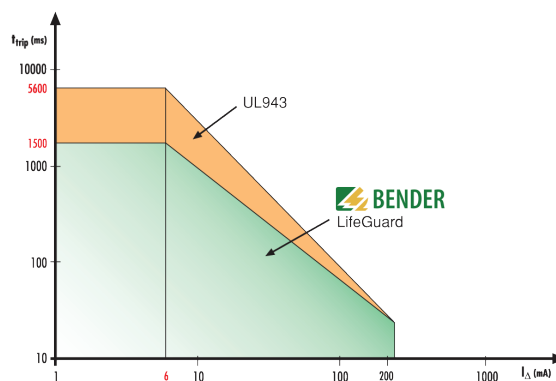
- Class A listed GFCIs up to 100 A where UL943 Class A applies
- Works on AC, DC, and AC/DC systems
- Customizable to many different types of systems, including 480V and 600V three-phase systems
- Many setpoint options available: 6 mA, 20 mA, or steplessly adjustable options
- 6 mA and 20 mA options operate on an inverse time curve per UL943
- Connection monitoring and grounded neutral protection
- Customizable enclosure options available, including NEMA 4X fiberglass and stainless steel options
- Option with digital display showing measured ground fault current in real-time
- Models compatible with Bender's Ethernet / Modbus/TCP communication system

Protection Against Nuisance Tripping

The LifeGuard® GFCI contains a special ground fault monitor that protects against nuisance tripping while still maintaining the level of protection you require.

Features of the 6 mA and 20 mA versions include:

- Class A listed versions where UL943 applies up to 100 A
- Works on AC, DC, and AC/DC systems
- Inverse time curve for tripping per UL943
- Advanced filtering circuitry
- Connection monitoring
- Grounded neutral protection



Inverse time tripping curve built into Bender's 6 mA and 20 mA versions

Features of the adjustable versions include:

- Works on AC (AC/DC version available)
- Adjustable trip level
- Adjustable time delay
- Connection monitoring

Ground fault protection products

Renewable energy systems

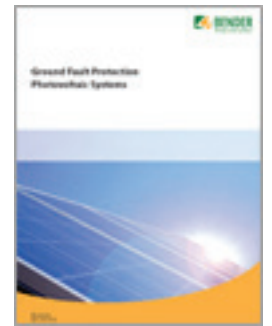


Years of Experience Protecting Renewable Energy Systems

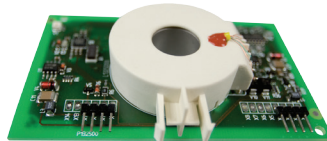
Bender's years of expertise in electrical safety have created a portfolio of products specifically designed for renewable industries, such as solar and wind. Products tailored specifically for these industries ensure that your modern energy systems are protected with the latest in electrical safety technology. Our products comply with new standards and code requirements, such as NEC 690.35, UL 2231, UL 1741, and more. From small kW inverters to large MW arrays to level 3 charging stations, Bender has the product that will ensure faults are properly detected.

Renewable Energy Solutions

See our renewable energy brochure or visit bender.org/solutions/ for more information on how Bender can protect your renewable energy system.



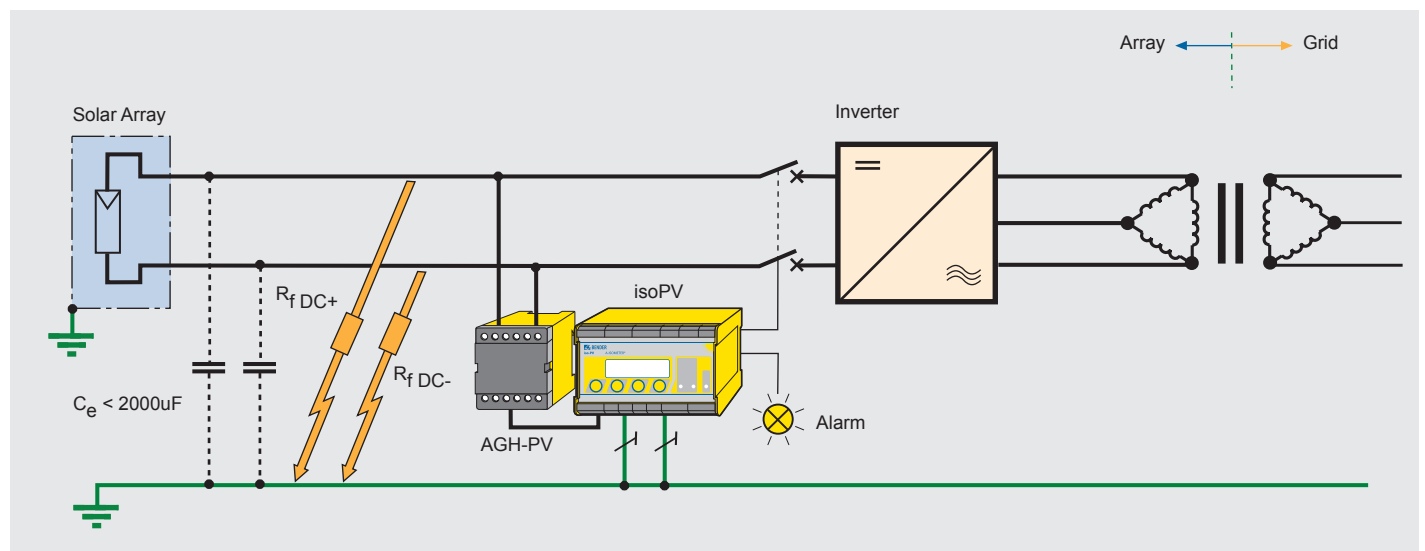
isoPV ground fault detector for ungrounded solar arrays



RCMA278P-S CCID-20 ground fault module for integration into level 2 EV chargers



IR155-3210 ground detection module for integration into level 3 EV chargers



Ground fault monitoring of an ungrounded, large-scale array and inverter with the isoPV ground detector

Isolated power systems equipment

For healthcare facilities and critical care areas

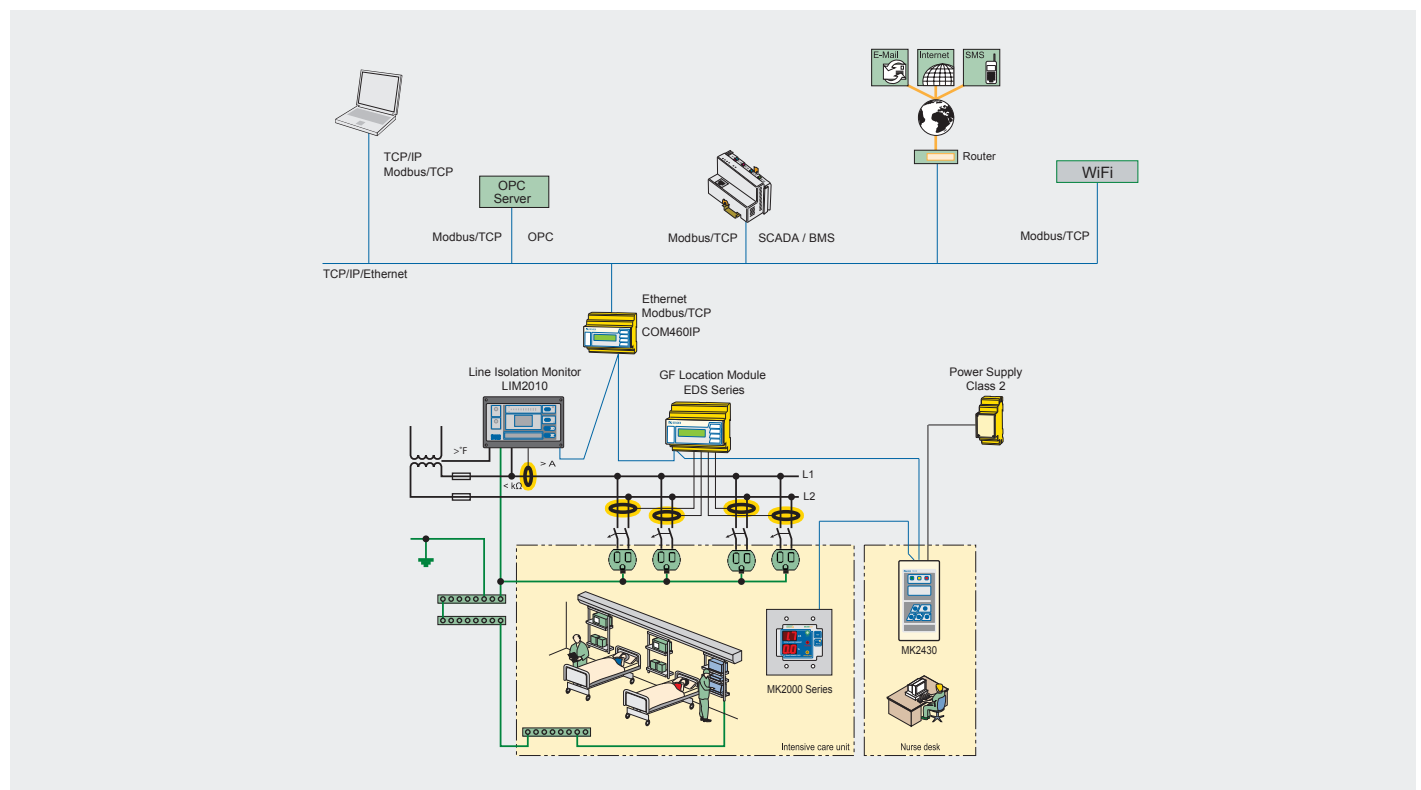


Protecting patients and staff in healthcare facilities

Standards such as NFPA 99 and CSA Z32 require isolated power systems in areas deemed “wet procedure locations” in healthcare facilities. Isolated power systems offer an invaluable advantage - early detection of ground faults allows for critical systems to remain online in a single fault condition. Bender isolated power panels provide isolated power to electrical systems in operating rooms and other critical care areas. Utilizing the latest in technology, Bender equipment ensures that electrical ground faults are detected and located fast and automatically, in compliance with the latest standards and code requirements.

Complete solutions for the healthcare industry

- The latest in line isolation monitoring technology, providing advanced warning of faults to help reduce downtime and increase operational efficiencies
- Supplemental alarms including transformer load, temperature, and voltage to mitigate risk of electrical shock and fire
- Branch location of ground faults quickly and automatically - locate faulty equipment while the system remains online
- Advanced communication to staff with modern digital remotes and communication gateways to connect to Ethernet and Modbus networks
- Support for third party conversions to protocols such as BACnet
- Complete, modular panel solutions for ease of customization and installation



A complete isolated power solution, with line isolation monitor, remote indicators, ground fault location, and remote communication

Isolated power systems equipment

For healthcare facilities and critical care areas



LIM2010 line isolation monitor

Line isolation monitor - isolated power systems in healthcare facilities

The Bender LIM2010 line isolation monitor monitors isolated power systems for a variety of alarms. Complying with the latest standards, the LIM2010 monitors the Total Hazard Current (THC) of an isolated power system, along with other alarms including voltage, transformer overload, and overtemperature. The LIM2010 is compatible with Bender's ground fault location system, as well as a variety of remote indicators.

Features:

- No interference with electrical equipment
- Works on both 50 Hz and 60 Hz systems (100 -240 VAC)
- Audible and visual alarm indication
- Total hazard current (THC) adjustable, 2 mA / 5 mA per local requirements
- Measures both system resistance and impedance
- Additional alarms including transformer overload and overtemperature, overvoltage and undervoltage, ground connection, and more
- Two programmable voltage-free SPDT contacts
- Colored bar graph display
- Automatic self-calibration and self-check



Isolated power panels

Isolated power panels - isolated power systems in healthcare facilities

Bender's standard hospital isolated power service and protection to operating rooms and other critical care areas. Conforms to all applicable NFPA and UL standards and requirements, such as NFPA 99, NFPA 70 (NEC), UL 1047, and UL 1022. Additional options include provisions for receptacles and/or ground jacks, circuit control via PLC, dual voltage output transformers, and more.

Features:

- Single-phase isolation transformer, with primary and secondary voltages configured at factory and rated to system requirements
- Primary circuit breaker
- Configurable for up to 16 circuits (maximum allowed by UL)
- LIM2010 line isolation monitor, featuring self-calibration, a wide variety of alarms, including total hazard current (THC, configurable for 2 mA or 5 mA), voltage, overload, and more
- Reference ground bus



ZT1590 digital clock and timer

Digital clocks and timers - isolated power system accessories

Bender complements our isolated power systems with a complete line of accessories, including digital clocks and timers. The ZT1590 is an easy-to-use dual display digital clock and timer, with both 12/24 hour time and automatic timer carryover from minutes/seconds to hours/minutes. The ZT1590 is available as a pre-built assembly into a front trim with backbox.

Features:

- Dual display for 12/24 hour clock and elapsed timer
- Elapsed time in minutes/seconds, automatically carried over to hours/minutes
- All device features and setup carried out either via onboard pushbuttons or connected MK1550 clock remote
- Plugable connectors
- Utilizes external Class 2 power supply
- Integrated power outage backup for at least 24 hours, no batteries required
- Available as complete assembly with clock and power supply, preinstalled at factory in front trim with backbox (ZT1590RS)

General protective relays

AC and DC systems



VME420 / VME420 series

Voltage and frequency relays - AC and DC systems

The VME420 (single-phase AC and DC up to 300 V) and VMD420 (three-phase AC up to 500 V) relays are powerful, all-in-one devices monitoring overvoltage, undervoltage, overfrequency, and underfrequency. Precise, explicit values may be entered in for alarms and real-time values may be viewed via the onboard LCD display.

Features:

- True RMS readings
- Digital display with real-time readout
- Precise voltage and frequency alarms entered via digital display
- Two separately adjustable alarms
- Two separate SPDT contacts

Applications:

- Single- and three-phase AC and DC
- General industrial use
- Battery monitoring and charging stations
- Dump load controllers
- Generators



CME420 / CMD420 series

Current relays - AC systems

CME420 (single-phase) and CMD420/421 (three-phase) relays monitor for overcurrent and undercurrent in AC systems. The CME420 may be directly connected or used with an X:5 ratio CT. Entering the current transformer ratio into the CME420 will negate the need for any type of calculations. CMD420 and CMD421 use three separate current transformers for monitoring three-phase systems.

Features:

- True RMS readings
- Digital display with real-time readout
- Two SPDT contacts
- Entering in CT ratio allows for real-time display of primary side current

Applications:

- Single- and three-phase AC
- General industrial use
- Motors, pumps, generators
- General load current monitoring



GM420 series

Ground continuity monitoring - AC systems

The GM420 series relay provides ground continuity monitoring in AC systems. The GM420 monitors for both a complete loss of connection, as well as the quality of the ground connection by monitoring the resistance of the connected loop. A precise resistance value may be entered via the device's digital display.

Features:

- For AC systems
- Monitors both complete loss of ground connection as well as resistive quality of connection
- Adjustable alarm for loop resistance, from 1 to 100 Ω
- Two SPDT contacts

Applications:

- Single- and three-phase AC and DC
- General industrial use
- Equipment grounding monitoring
- Motors, generators
- Loading dock conveyors

Remote indicators and communication

Remotely notify staff and technicians of ground faults

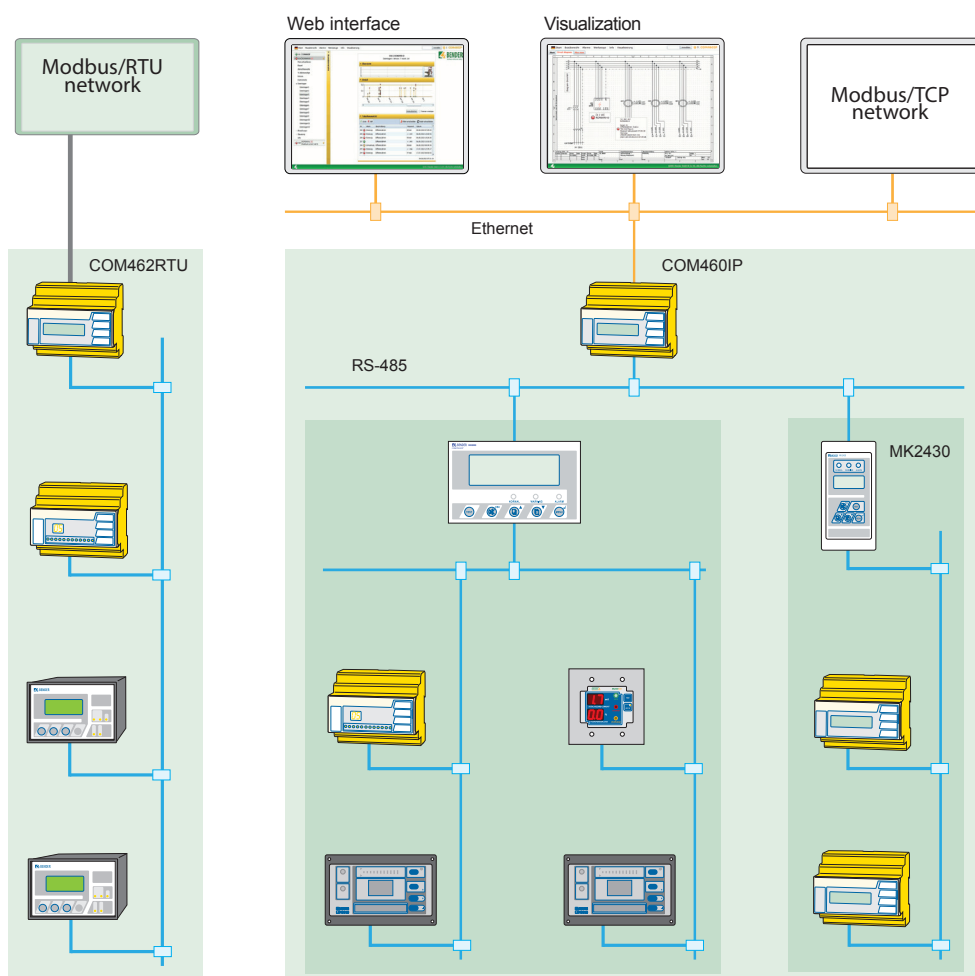


Integrate Bender Devices Into Your Safety Network

Many Bender ground fault detection devices can be linked together across a communication network for remote monitoring. Utilizing a special protocol across RS-485, these devices can give control stations detailed information as to the condition of the system. Gateway devices utilizing standard protocols such as Ethernet and Modbus ensure your Bender system is easily integrated into an existing communication system. Special remote indicators placed in critical areas and connected to the network can also display device information. Many devices also support settings changes via remote communication.

A complete remote communication solution

- Fast, detailed information and device configuration from a central point
- Easily integratable into existing communication systems
- Compatible with modern communication networks, such as Ethernet and Modbus
- View detailed system information from remote indicating stations, or via a connected web browser
- Reduce costs and downtime by immediately notifying staff and personnel of pending electrical safety issues



Technical and application information

Ungrounded systems

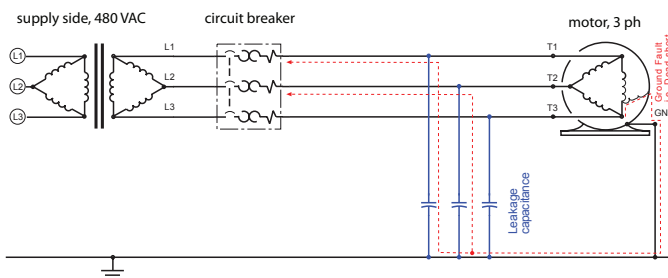


Ungrounded Systems

Floating systems are derived from a power source where there is virtually no connection to ground. 480VAC delta configured transformers are a typical supply for a floating system. Some deltas in the mining industry can be found in hoists. 480VAC deltas are also in wide spread use to supply 1000Amp - 2000Amp main feeder circuits in general industrial applications. Floating systems are often used in areas where a sudden shut down must not occur. Examples are intensive care units (ICUs) in hospitals, signal circuits, and emergency backup systems.

The magnitude of ground fault current in an ungrounded system on a first ground fault is very small. It depends on the system voltage, the resistance of the ground fault causing part and the system capacitances.

Example: If a grounded object with low resistance touches a live conductor, the resulting current flow will be negligible. The ground fault loop will be incomplete because the return path to the source is missing. Grounding may only occur through system leakage capacitance to ground. The Possible resulting current is also known as charging current.



The ungrounded system with one ground fault path.

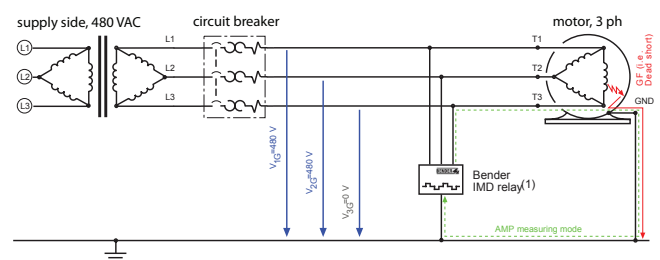
On a single ground fault, ungrounded systems will not produce the amount of fault current needed to trip a common GFR. The IMD is the device of choice for the protection of floating systems.

The Active IMD on AC Systems

An active IMD is the ground detector of choice for ungrounded systems. The active IMD can detect ground faults regardless of quantity and severity, as well as the ability to have early warnings and trending.

The active IMD is considered to be an online megger. It connects via pilot wires between the system and ground. A constant measuring signal is sent from the IMD into the power wires. It will spread out evenly into the secondary side of the transformer and the attached loads. If this signal finds a breakthrough path to ground, it will take this path of least resistance and return to the monitor. The IMD's internal circuitry will process the signal and trip a set of indicators when the resistance of the fault reaches a certain trip level. By the nature of the ungrounded system, leakage current may or may not be present at this time, however the ground fault will still be seen through the insulation resistance. Because of this, IMDs measure in Ohms (resistance) and not in Amps (current). A ground fault will be indicated as insulation breakdown.

A good insulation value for a typical system would be a value of multiple kΩ to MΩ. A low insulation value for a typical system would be low kΩ to less than one kΩ. However, the value of a system's overall resistance may vary depending on the number of loads, type of insulation used, age of the installation, environmental conditions, etc.



Ungrounded three-phase AC system with Bender IMD

Technical and application information

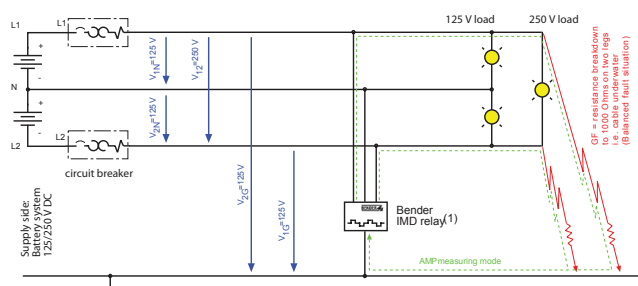
Ungrounded systems



The Active IMD on DC Systems

The active IMD is the preferred choice for ungrounded DC systems as well. As in floating AC systems, a DC IMD will be connected via pilot wires between the system and ground. A constant measurement signal will be sent from the IMD into the power wires. From there, it spreads out evenly into the secondary side of the supply (e.g. a battery) and the attached loads. Again, the signal will take the path of least resistance and return to the monitor if it finds a breakthrough to ground.

For DC systems, as well as AC systems that have varying voltages or power conversion equipment including variable frequency drives, a special measurement signal is applied. Bender's AMP Plus measurement principle, found in devices such as the IRDH275, have the ability to be used universally in AC, DC, and AC/DC systems, as well as overcoming adverse system conditions, such as high leakage capacitance.



Ungrounded 125/240 VDC system with Bender IMD

Ground Fault Location in an Ungrounded System

Locating ground faults in an ungrounded system is simple with the right technology. The techniques are different than locating ground faults in a grounded system. In a grounded system, locating faults is done via a multi-channel Ground Fault Relay utilizing current transformers to pick up on leakage current for each individual circuit/load. However, due to the nature of the ungrounded system where a first ground fault will not create leakage current, a different technique must be employed.

Ground fault location in an ungrounded system can be done via a fixed installation, portable devices, or a combination of both.

A controlling device with a pulse generator is present upstream in the system. This device sends a low level artificial signal into the faulted system. The signal will be impressed between the power wires and ground. Naturally, it will follow the ground fault path into ground and return to the pulse generator. This signal can be traced with special fixed current transformers or a special portable current probe. This method works while the system is still online, and ground faults can be located down to the load causing the problem while all systems remain in operation.

Ground Fault Location - Fixed Installation

The fixed installation is useful where 24/7 monitoring is required, as well as giving portable location a head start as to which circuit is causing the problem. The system consists of the following:

- IRDH575 Ground Fault Detector and Controller
- EDS460 or EDS490 Ground Fault Location Devices
- W series current transformers

The Bender EDS ground fault location - detection system is an excellent tool for the maintenance personnel in a large facility with extensive wiring. Faults will be located automatically during normal business operation. No shutdown is required. No hand-held tracing and/or accessing panels is required. The beauty of this system lies in its non invasive operation. The ungrounded system is only safe for its user as long as the occurring faults are immediately traced down and eliminated. If that is not the case, then the second ground will follow sooner or later and short circuit the system.

Ground Fault Location - Portable

The EDS3090 portable ground fault location series can be used as a completely standalone location system or used in tandem with installed units. Pulse generation is done either by an installed IRDH575 or a portable pulse generator that can be connected up to the main system. The pulse is traced via a hand-held clamp. The general process for this system is by starting at the point of pulse generation, and tracing the pulse down to the load causing the ground fault with the clamp. Ground faults can be located quickly and easily while the system remains online and operational. Using the EDS460 and EDS490 installed ground fault locators in tandem with the portable EDS3090 system gives technicians a head start as to where to begin clamping.

Technical and application information

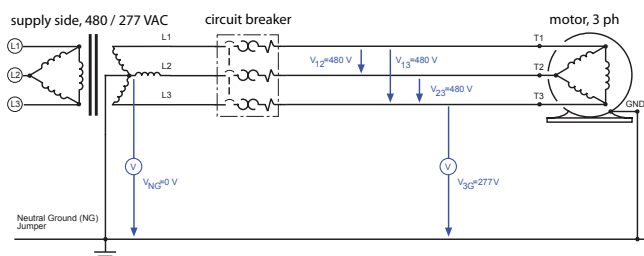
Grounded systems



Grounded Systems

Grounded systems are derived from a power source where the neutral is solidly tied to ground via a ground neutral bonding jumper (NG). Often encountered is the typical three phase 208/120VY or 480/277VY configuration. Another possibility is a single phase transformer where the neutral is tied into ground or sometimes, in very rare occasions, corner-grounded delta configurations are employed. The general public is very familiar with solidly grounded systems due to the fact that nearly every residence in the U.S. is derived from a 240/120V transformer with center tap. The center tap is bonded solidly to ground.

As always, there are advantages and disadvantages to the grounded power system. One disadvantage is the high amount of possible fault current in a ground fault situation. Fire damage or personnel injury can occur. Nevertheless, a tripped overcurrent breaker or a GFCI will enable the electrician to quickly identify a faulty branch. Action will often be taken after a fault has occurred. Preventative maintenance is not necessarily associated with the grounded system.



The grounded system.

The magnitude of a ground fault current in a solidly grounded system can be very high. Its magnitude depends on the system voltage and the resistance of the ground fault causing part itself. The ground fault current can easily reach a value which is multiple times higher than the nominal load current. A simplified calculation will explain how the high amounts of current are generated:

$$I_F = \frac{V_{3G}}{R_{GF} + R_{GR} + R_{NG}}$$

I_F = Fault Current

V_{3G} = Voltage between faulted phase and ground

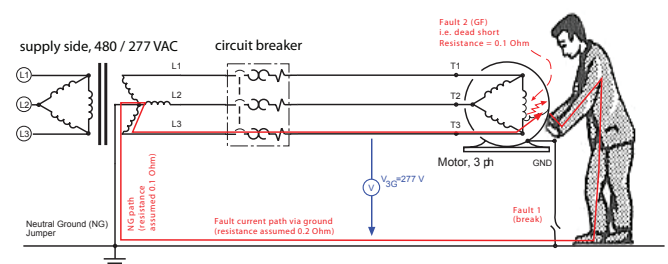
R_{GF} = Resistance value at shorted point

R_{GR} = Resistance of ground path

R_{NG} = Resistance of neutral ground bonding jumper

$$\frac{277 \text{ V}}{0.1 \Omega + 0.2 \Omega + 0.1 \Omega} = 692.5 \text{ A}$$

A theoretical fault current will be devastating if a dead short occurs. Nevertheless, a ground fault relay or overcurrent protective devices should trip immediately and interrupt power from the load. How many Amps would flow if a human would touch the same circuit? Answer: Replace the dead short value of 0.1 Ohm with a more realistic figure for a human body part. Lets assume that a person is resting on the frame of a motor. For example, assume 1000 Ω of resistance from phase L3 and a human body. The current is a multiple of 15 mA, which is considered to be the let-go value for humans. 50 mA is considered to be lethal.



The grounded system with a single ground fault and broken ground.

Ground Fault Relays on Grounded Systems

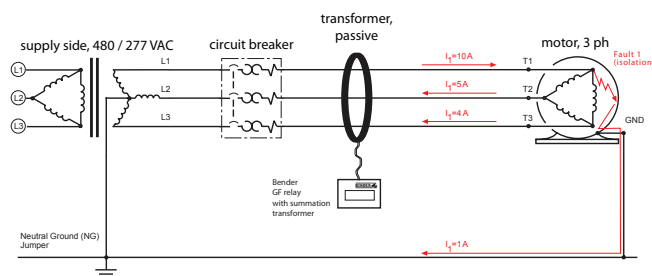
Most technicians are very familiar with a current transformer based ground fault current relay. Even non-technical personnel encounter them on a daily basis in public restrooms protecting a wall outlet in a wet area. The operating theory behind the relay is as follows. A current transformer (CT) or "donut" is placed around the power wires leading to the protected load. It is important that hot and neutral wires are fed through the CT. This goes for both, single phase and three phase systems. One might come across a three-phase system without a neutral, feeding a pump or an industrial motor. In this case the three phases only will be fed through the CT. For three-phase systems, if a neutral is carried out to the load, it should be fed through the CT. The ground fault relay will still function properly when monitoring a load not using the neutral.

Technical and application information

Grounded systems



The current transformer will always read zero current in a healthy system even under a full load condition. In accordance with Kirchhoff's laws, incoming and outgoing currents will cancel each other out. Assume a 10A load connected to a 480/277VAC system. 10A will be fed from the source into the load, therefore 10A will have to return from the load back to the source. The CT will measure both simultaneously since it is placed around all conductors. The schematic below is a typical application of current transformer based ground fault detection. In a healthy system, the current across all three phases will equal zero.



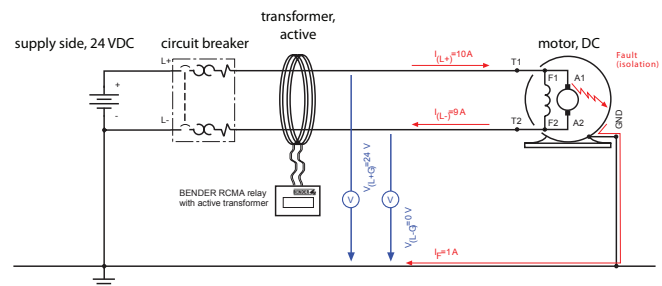
The grounded system with single ground fault with ground fault relay.

A ground fault (as an example, 1 A) will divert some of the current from the arrangement and bypass the CT via the ground wire, a frame or the building ground and return back to the source.

The new equation for the CT is now: $10A - 5A - 4A = 1A$ where 10 A goes into the load, 9 A returns to the source via the phase L2 and L3, and 1 A returns to the source via the ground wire. The CT will step the current (1A) down and forward it to the Ground Fault Relay (GFR). The GFR will then alarm when its set point has been increased. The GF relay in combination with a zero sequence CT will work in resistance grounded systems as well. It will run into its limitations in circuits where waveform modifying equipment, such as Variable Frequency Drives (VFD/ASD), or rectifier components are installed.

Grounded DC Systems

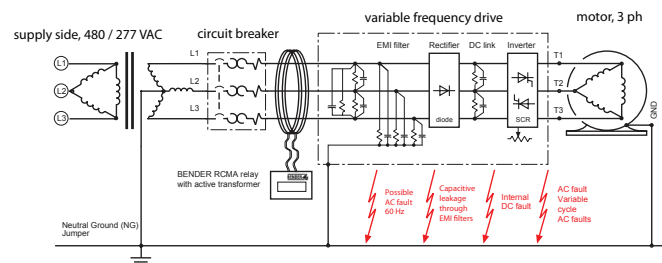
Bender RCMA devices monitor DC and mixed AC/DC systems. The unique measuring principle can be used for protection if the DC system is grounded as shown below. In this case the negative pole of the DC power supply or the battery is tied into a chassis or the building ground. The active CT would be placed around both, the negative and positive conductor leading to the load. A DC leakage current will bypass the CT through ground.



Grounded 24 VDC system with single fault and RCMA technology

Variable Frequency Drives

60 cycle GFRs have limitations when the circuitry involves VFDs (Variable Frequency Drives). A variable frequency drive converts the incoming AC internally into DC, which will then be modulated again into a variable cycle AC leading to the load. Internal VFD - DC grounds can not be detected with conventional GFR technology. The common "passive" CT needs alternating currents to detect a ground fault, therefore DC currents will go unnoticed. Some drives may be equipped with their own internal scheme to detect ground faults which will eventually trip in the high Ampere range. Early warning or personnel protection cannot be guaranteed in this case.



The grounded system with drive and RCMA technology

Other issues include: EMI filters sometimes incorporated into drives can provide a leakage path to ground and add to the overall system leakage; multiple KHz carrier frequencies used can cross the gap between insulation and ground; and harmonic content. The solution: Protect by means of an active current transformer with built-in filtering technology. RCMA devices employ a double-coil system which enables them to accurately measure AC, DC, and mixed AC/DC currents from 0 to 2000 Hz.

Reference guide

Sample applicable codes and standards



General purpose

Name	Description	Recommended Products	Notes
NEC 250.21(B): USA CEC 22.1-10-106(2): Canada NOM-001-SEDE-2012 250-21(b): Mexico	Ground fault detection for ungrounded AC systems	IR420 / IR425 Series	For systems less than 300 VAC
		IR470LY / IRDH275 / IRDH375 / IRDH575	Main distribution networks & VFDs
		isoLR275 Series	Large systems / high leakage capacitance
NEC 250.167(A): USA (As of 2014 edition)	Ground fault detection for ungrounded DC systems	IR425 Series	For systems less than 300 V
		IRDH275 / IRDH375 / IRDH575 Series	Main DC distribution
NEC 250.167(B): USA (As of 2014 edition)	Ground fault detection for grounded DC systems	RCMA420 / RCMA423 Series	General grounded DC power
		RCMS Series	Multi-channel DC protection
NEC 427.22: USA CEC 22.1-18-120(2): Canada NOM-001-SEDE-2012 427-22: Mexico	Ground fault protection for electrical heat tracing systems	RCM420 Series	Single channel monitoring
		RCMS Series	Multi-channel monitoring
		LifeGuard Series	Detection and interruption panel
Requirements where ground fault circuit interrupters (GFCI) are required	Use of ground fault circuit interrupters (GFCI) in various applications	LifeGuard Series	Many options available
UL 943	Ground fault circuit interrupters (GFCI)	LifeGuard Series	Many options available

Solar / photovoltaic

Name	Description	Recommended Products	Notes
NEC 690.5(A): USA CEC 22.1-64-018(1)(e): Canada NOM-001-SEDE-2012 690-5(a): Mexico	Ground fault protection for ungrounded solar arrays	isoPV425 Series	Ungrounded arrays less than 100 kW
		isoPV Series	All size ungrounded solar arrays
NEC 690.35(C): USA NOM-001-SEDE-2012 690-35(c): Mexico	Ground fault protection for grounded solar arrays	RCMA420 / RCMA423 Series	Single channel monitoring
		RCMB20-500 / RCMB35-500 Series	Combiner box monitoring
		RCMS Series	Master combiner box monitoring
NEC 690.5(A)(1) and NEC 690.35(C)(1): USA (As of 2014 edition)	Array isolation testing prior to startup for grounded and ungrounded arrays	isoPV Series	Works for both grounded and ungrounded arrays for startup isolation testing
UL 1741	Inverters for use in solar applications	RCMA278P-S	For inverters 10 kW or less
		RCMA420 / RCMA423 Series	For inverters greater than 10 kW

Reference guide

Sample applicable codes and standards



Hospitals / healthcare facilities

Name	Description	Recommended Products	Notes
NEC 517.160: USA CEC 22.1-24-200: Canada NOM-001-SEDE-2012 517-160: Mexico	Installation and monitoring requirements for isolated power systems in healthcare facilities	Isolated Power Panels LIM2010	Complete solutions for isolated power systems available
NFPA 99: USA CSA Z32: Canada	Requirements for use of isolated power systems in healthcare facilities	Isolated Power Systems Equipment	Complete solutions for isolated power systems available
UL 1022	Standard for line isolation monitors (LIM) in healthcare facilities	LIM2010	--
UL 1047	Standard for isolated power panels in healthcare facilities	Isolated Power Panels	--

Electric vehicle charging stations (EVSE)

Name	Description	Recommended Products	Notes
UL 2231-2	Protection devices used in electric vehicle charging systems (EVSE)	RCMB101	Level 2 EV chargers
		IR155-10 Series	Level 3 EV chargers

Marinas / shore power

Name	Description	Recommended Products	Notes
NEC 555.3: USA NOM-001-SEDE-2012 555-3: Mexico	Ground fault protection for marina shore power	MarinaGuard Series	--

International product standards

Name	Description	Recommended Products	Notes
IEC 61557-8:2007-5	Insulation monitors (ground fault detectors for ungrounded systems)	IR series products	--
IEC 61557-9:2009-01	Insulation fault location systems (ground fault location for ungrounded systems)	EDS series products	
IEC 62020:2003-11	Residual current monitors (ground fault monitors for grounded systems)	RCM series products	
IEC 61010-1:2010-06	General purpose relays (voltage, current, etc.), communication equipment, remote indicators	Voltage relays, current relays, continuity relays, communication gateways, remote indicators	



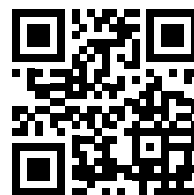
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