
BENDER
THE POWER
IN ELECTRICAL SAFETY
Solutions for ANSI/UL and CSA markets

THE POWER IN ELECTRICAL SAFETY

For over 70 years, Bender's mission has been to make electrical power safe. Our wide portfolio of cutting-edge electrical safety and monitoring products are used in mining, healthcare, renewable power generation, oil and gas, and many more. With more than 50 offices, representatives, and partners across the world, Bender provides customized solutions to meet our customers' individual needs.

Ground-Fault Protection

For ungrounded systems

Ungrounded systems offer an invaluable advantage - a first fault condition does not create an imminently hazardous situation. Early detection of ground faults allows critical systems to remain online while problems are resolved. Ground-fault detectors help reduce costs and maximize system uptime.

Bender devices use the latest technology to detect and locate ground faults on ungrounded AC and DC systems, including systems with power conversion equipment, such as variable frequency drives. Bender ground detectors are fully compliant with requirements such as NEC 250.21(B), NEC 250.167(A), and CEC 10-106(2).

Advanced ground-fault detection
iso685 ground detector

Features

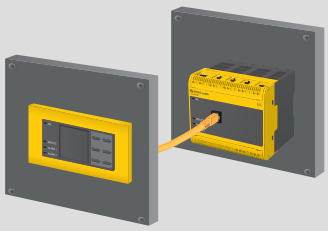
- Detects AC and DC, symmetrical and asymmetrical ground faults in ungrounded systems
- Ideal for systems with power conversion equipment
- Digital display with real-time readout and on-board data trending graphs - no software required
- Adjustable alarm values up to 10 MΩ
- Built-in web server - connect to the iso685 via Ethernet to view device status and change settings
- Modbus/TCP communication built-in

Applications

- Single-phase AC, three-phase AC, and DC systems
- General purpose 480 V and 600 V industrial systems
- Systems with variable frequency drives
- Tiebreaker configured sytems
- Many different industries, including mining, oil and gas, utilities, and marine

Detachable front panel

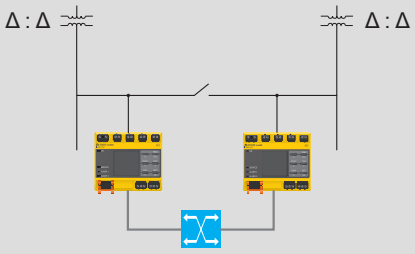
Available in models with option “S”



- Duplicates all displays and push buttons on a detachable front plate
- Ideal for panel and door mounting
- Maintain low voltage at the panel front
- Simple RJ45 cable connection

Tiebreaker support

Available in models with option “B”



- Allows connection of multiple iso685 ground fault detectors to systems connected via tiebreaker
- Ensures both sides of a tiebreaker are continuously monitored
- Simple interconnection to an Ethernet switch to automate control of system monitoring
- Connects to tiebreaker logic for manual control of monitoring

Online ground-fault location
EDS440 series

Features

- Maintain ungrounded system availability while lowering downtime and labor costs with Bender's automated ground-fault location system
- Automate fault location while the system remains online, greatly reducing time required to find ground faults
- Wide selection of current transformers available for new installations or retrofit applications
- Get fast notification of located faults over Ethernet or Modbus/TCP
- Additional portable fault location system (EDS3090 series) available, allowing for fault location with a handheld device

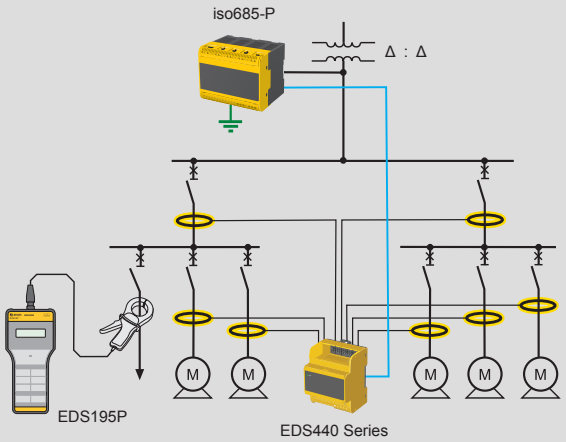
Applications

- Single-phase AC, three-phase AC, and DC systems
- Manufacturing facilities, ships, power plants
- Motor control centers

Fast, automatic ground fault location

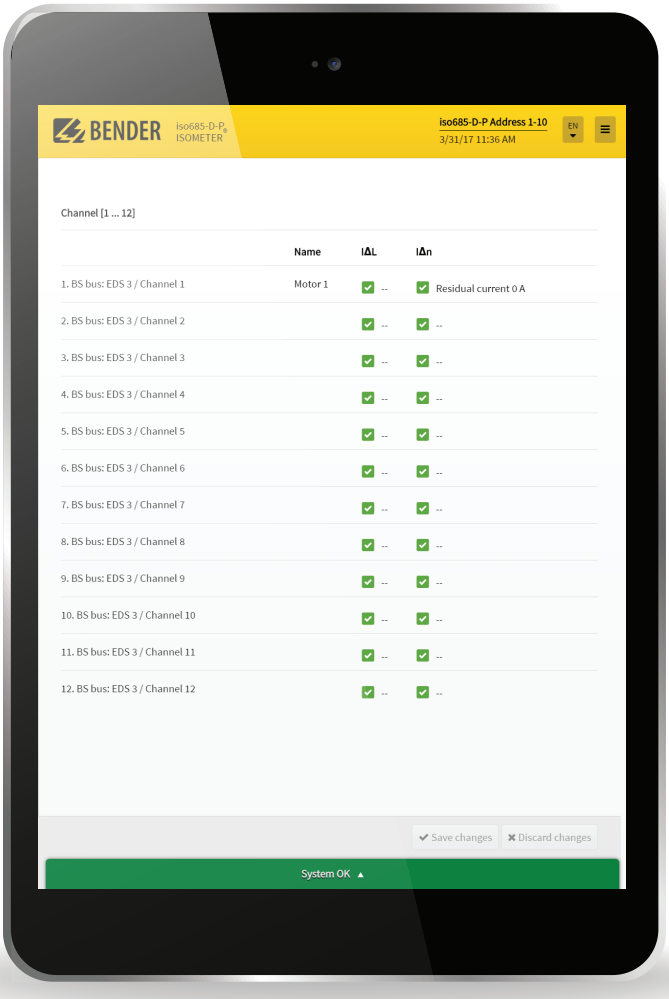
The EDS440 uses the latest technology to locate ground faults automatically in ungrounded AC and DC systems. Fault location takes place while the system remains online, without the need to open branch circuit breakers or disconnect equipment. Up to twelve circuits are monitored in parallel from a single device. Expansion is as simple as adding more modules.

- Automatic detection and location of ground faults down to the load level
- Greatly reduce time required for ground fault hunting
- Supports many size requirements with a wide variety of current transformers
- Modular system allows for easy retrofitting / upgrading, and adding future branches



Easy to install

- Simple snap-in connection to iso685 ground fault detector using Bender's backbone communication bus
- Remotely install EDS440 fault location modules with simple two-wire connection to the iso685
- All setup and status notifications take place centrally at the iso685
- Simple two-wire connections for Bender current transformers - only one required per branch / circuit, available in a wide variety of shapes and sizes
- Split-core current transformers available for retrofit applications



Quick to notify

- Outputs for alarm notification
- View the status of the iso685 and connected EDS440 devices remotely through Ethernet
- Clear identification of fault location by branch using Bender's easy-to-use, browser-based interface built into the connected iso685, or with a connected COM465IP / CP700 communication gateway
- Custom names for individual EDS440 branches
- Modbus/TCP support - Integrate fault location into industrial Ethernet networks

Portable ground-fault location

The EDS3090 series provides a complete, portable ground fault location solution in a single package. Portable systems can be used standalone, or as a complement to installed fault location systems.

- Quickly locate and identify ground faults with portable equipment
- Works either as a standalone portable system, or in combination with Bender's installed ground fault monitoring equipment
- Multiple sizes of split-core clamps included
- Ideal for contract service technicians and facilities with preventative maintenance programs
- Complete kit includes EDS195P hand-held meter, pulse generator, and clamps of varying sizes

Ground-Fault Protection

For grounded systems

Bender's ground-fault relays provide protection for personnel and equipment in even the most demanding environments. Tailorable to a wide variety of applications, Bender relays provide accurate readings on AC and DC systems without the problems associated with nuisance tripping.

Ground-fault relays and GFCIs are fully compliant with general requirements such as NEC 250.167(B) and NEC 230.95. Bender devices are also designed for and compliant with many industry-specific requirements, including solar, mining, water features, and more.

AC and DC ground-fault protection
RCM series ground-fault relays

RCMA420/423 AC/DC ground-fault monitors

RCMS490 Multi-channel ground-fault monitor

Features

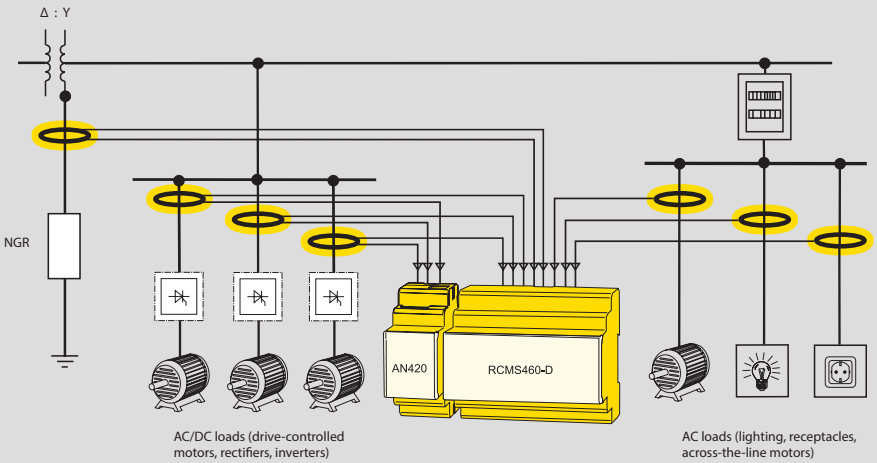
- True RMS readings
- Digital display with real-time readout
- Adjustable trip levels up to 500 mA / 3 A (vary by device)
- Wide range of current transformer sizes
- Two separate Form-C (SPDT) contact outputs

Features

- True RMS readings
- Up to twelve separate channels with individual trip level settings
- Digital display with real-time readout
- Common Form-C (SPDT) contact outputs (RCMS460)
- Separate Form-A (SPST) outputs for each individual channel (RCMS490)
- Connects to COM465IP communication gateway for web-based alarm notitications and Modbus/TCP integration

Applications

- Single-phase AC, three-phase AC, and DC systems
- Solidly grounded and high-resistance grounded systems
- Systems with AC/DC power conversion equipment, such as inverters and variable frequency drives
- Panelboards, motors, generators
- Heat trace systems



NGR and ground wire monitoring
For high-resistance grounded systems

RC48N Ground-fault and NGR monitor

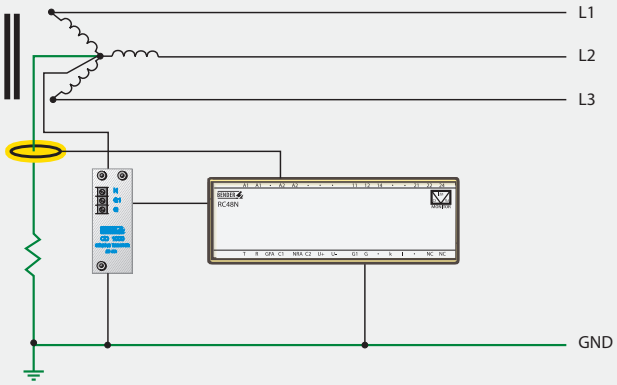
RC48C Ground-fault and ground check monitor

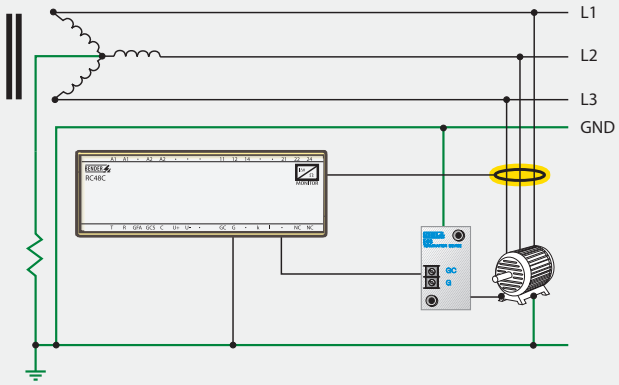
Features

- Adjustable ground-fault trip value and time delays
- Monitors integrity of the neutral grounding resistor (NGR) up to 5 kV with compatible coupling device (CD1000 / CD5000)
- Wide range of current transformer sizes
- Form-C (SPDT) contact outputs
- Switchable band-pass filter for 50/60 Hz

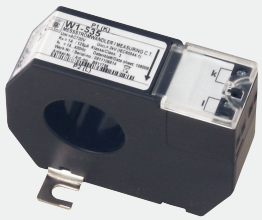
Features

- Adjustable ground-fault trip value and time delays
- Monitor integrity of ground conductor with compatible termination module (E6 series)
- Wide selection of current transformer sizes
- Form-C (SPDT) contact outputs
- Switchable band-pass filter for 50/60 Hz





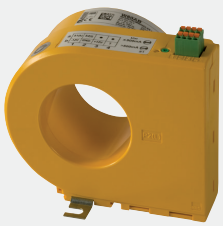
Current transformers
For Bender ground-fault relays



W0-S20 - W5-S210 Series

Features

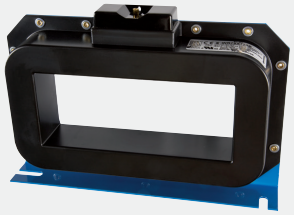
- Torodial, solid core type current transformer
- Measures AC ground-fault current
- Ideal for general purpose branch circuit monitoring
- Compatible with Bender AC ground-fault relays, including RCM420 series, RCMS series, RC48C, RC48N, and EDS440 series



WAB Series

Features

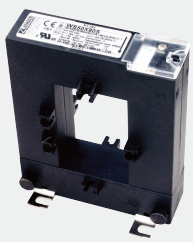
- Torodial, solid core type current transformer
- Measures AC and DC ground-fault current
- Ideal for general purpose branch circuit monitoring
- Compatible with Bender AC and DC ground-fault relays, including RCMA420 series, RCMA423 series, and RCMS series



WR Series

Features

- Rectangular, solid core type current transformer
- Measures AC ground-fault current
- Ideal for busbar and large conductor monitoring
- Compatible with Bender AC ground-fault relays, including RCM420 series, RCMS series, RC48C, RC48N, and EDS440 series



WS Series

Features

- Rectangular, split core type current transformer
- Measures AC ground-fault current
- Ideal for retrofit applications
- Compatible with Bender AC ground-fault relays, including RCM420 series, RCMS series, RC48C, RC48N, and EDS440 series

Ground-fault circuit interrupters
LifeGuard® series

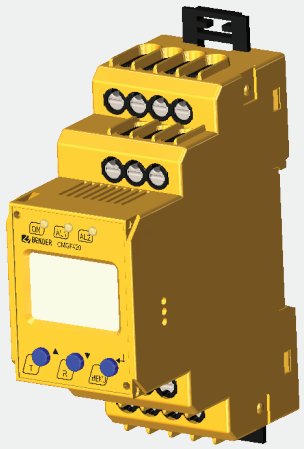
Features

- Class A listed, personnel protection GFCIs up to 100 A for 120 V, 208 V, and 240 V single-phase and three-phase systems
- Suitable for 2-, 3-, and 4-wire grounded neutral circuits
- Detects AC and DC ground faults
- Customizable, general purpose models available, including systems for 480 V and 600 V systems
- 6 mA and 20 mA options operate on inverse trip time curve per UL 943 to provide maximum protection while alleviating nuisance tripping
- Equipment protection models available, including steplessly adjustable trip levels
- CT connection monitoring
- Grounded neutral protection
- NEMA 4X polycarbonate enclosure rated for indoor and outdoor use (open chassis models available)
- Digital display option - real-time fault current readings shown on enclosure front
- Network communication available

Protection against nuisance tripping

- Inverse trip time curve minimizes nuisance tripping while maximizing personnel protection
- Trip curve exceeds requirements specified by UL 943
- Measures true RMS value
- Quicker trip time at higher fault currents
- Advanced filtering circuitry
- Grounded neutral protection - helps to prevent accidental, multiple neutral-ground bonding down-stream in the system

Service entrance fault protection
CMGF420 ground-fault relay



Features

- UL 1053 listed service entrance ground-fault relay
- Meets or exceeds requirements of NEC 230.95, NEC 700.6(D), and CEC 14-102 when paired with appropriate equipment
- Small form factor - easily integratable into switchgear
- 60 A - 1200 A adjustable trip level range
- Supports 600:1 or 1000:1 current transformers
- Digital display with real-time reading
- Simple connection to shunt trip breaker
- DIN rail, screw, or panel mounting (with optional kit)

Isolated Power Equipment

For healthcare facilities

Standards such as NFPA 99 and CSA Z32 require isolated power systems in all 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 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.

Protecting patients and staff

- Equipment designed in strict compliance with many electrical standards worldwide, including NFPA 99, NFPA 70, CSA Z32, RETIE, AEA 90364-7-710, and UL 1047
- 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 electric shock and fire
- Branch location of ground faults quickly and automatically while the system is online
- Fast notification to facility staff with modern digital remotes, communication, and integration into building networks

LIM2010 Line isolation monitor

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 include 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

ISOTROL Isolated power panels

Features

- UL 1047 listed isolated power panels for healthcare facilities
- 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
- Includes LIM2010 line isolation monitor
- Many configurable options available - receptacles and ground jacks, PLC-controlled breaker availability, load monitoring, integrated fault location, and more

Protection and Monitoring Relays

Protective relays from Bender provide a multitude of measurement options outside of ground-fault protection, including voltage, current, ground continuity, and more. Relays like the VME420 and VMD420 provide a wide range of alarms in a single relay, including over- and undervoltage, frequency, and more.

Bender monitoring relays include a number of state-of-the-art features, including digital displays with real-time measurements and highly configurable contact outputs.

Voltage and current relays
For AC and DC systems

VME420 and VMD420 Voltage relays

Features

- True RMS readings
- Models for single-phase AC, three-phase AC, and DC systems
- Digital display with real-time readout
- Precise alarm values entered via digital display and pushbuttons - no need for guesswork with potentiometer dials
- Two Form-C (SPDT) contact outputs
- Outputs are individually configurable to trip on any combination of alarm types

Applications

- Single-phase AC, three-phase AC, and DC systems
- General industrial use
- Motor protection
- Battery systems
- Dump load controllers and transfer switches
- Pumps and generators

CME420 and CMD420 Current relays

Features

- True RMS readings
- Models for single-phase and three-phase AC
- Supports direct system connection, or connection through current transformers with 1A or 5A secondaries
- Entering CT ratio allows for real-time display of primary side current
- Triggers on overcurrent and/or undercurrent
- Digital display with real-time readout
- Two Form-C (SPDT) contact outputs
- Outputs are individually configurable to trip on any combination of alarm types

Applications

- Single- and three-phase AC systems
- General industrial use
- Motor protection
- Pumps and generators
- General load current monitoring

Market Driven Solutions

Bender's success goes beyond general purpose equipment. Bender works closely with customers to create innovative products that operate in even the most unique conditions. Bender products provide added value to your application.

From mainstay industries like petroleum and marine, to newer industries like solar, wind, and energy storage - Bender products are continuously evolving to meet the ever changing needs of customers worldwide.

Solar power and energy storage

As power generation around the world evolves to meet demand, more smart grids require efficient, environmentally-friendly methods of generating and storing electricity. Advances in photovoltaics and battery storage systems bring new challenges in proper protection of personnel and equipment.

Smart grids demand smart electrical safety. Bender's monitoring equipment uses the latest technology to ensure accurate, quick readings on arrays and battery systems of all sizes. With a wide range of communication options, Bender devices integrate easily into industrial networks - including Ethernet and Modbus.

iso1685P Ground-fault detector

Features

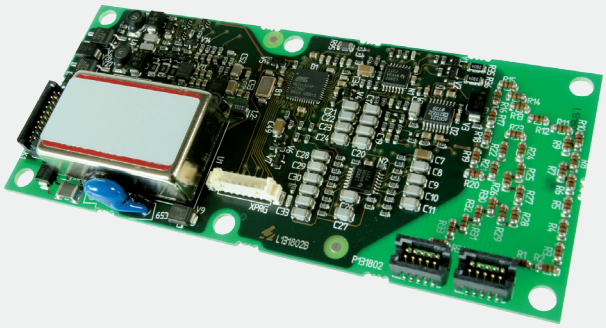
- Ideal for large-scale deployments of ungrounded solar arrays and energy storage systems
- Meets or exceeds industry code requirements, including NEC 690.41(B) (2017 edition), NEC 712.55, and CEC 64-066(1)(e)
- Works on systems with up to 2000 µF leakage capacitance
- Adjustable insulation resistance trip value of 200 Ω to 100 kΩ
- Automatic data logging on microSD card
- Works with Bender fault location devices
- Compatible with Bender's communication system

Electric vehicles (EV and EVSE)

From inside the car to charging stations, Bender devices provide a complete solution for mitigating risks of electric shock, equipment failure, and fire damage. Our devices are designed specifically for integration into electric vehicles, as well as level 2 and level 3 (fast DC) charging stations.

Designed in compliance with requirements such as UL 2231, NEC 625, and SAE standards, our equipment provides a simple, integratable solution for your electrical safety needs.

iso165C Ground-fault detector



IR155-3210 Level 3 EVSE ground-fault detector

Marinas

Today's recreational marinas are filled with potential electrical hazards, like refrigerators, lighting, and electric boat motors. Ground faults are a leading cause of death, injury, and equipment damage in marinas. Fault current leaking to the water creates risks of boat corrosion and electric shock drowning (ESD) for people swimming in the water.

Bender's MarinaGuard® is the result of years of direct involvement with the marina industry. MarinaGuard® panels can be installed everywhere from the main distribution down to individual docks. Continuous monitoring for ground faults helps mitigate the risks to people, boats, and equipment - while providing a simple, streamlined system for technicians and harbor owners to use.

MarinaGuard® Ground-fault monitoring panel

Features

- Meets or exceeds requirements of NFPA 555.3, NFPA 303, and local jusrisdictional requirements
- Models for feeder and branch monitoring
- Trip level preset to code requirements, with ability to decrease value as needed
- Test and reset pushbuttons externally accessible
- Strobe light for easy visible alarm indication
- Form-C contact outputs for connecting to PLCs or shunt trip circuit breakers
- Outdoor rated, NEMA 4X enclosure
- Remote communication options available

Communication Solutions

Bender provides a wide range of communication products to connect systems to facility technicians and management. A wide range of protocols are supported, ensuring interoperability with continually evolving technologies.

Web browser interfaces and HMIs provide an easy-to-use gateway to your system. Integratable communication brings Bender into your industrial network. Cloud-based solutions provide a scalable, secure solution for system status and analytics across multiple facilities and locations.

Communication Gateways
COM465IP and CP700

COM465IP Communication gateway

CP700 Communication gateway and HMI

Standard features

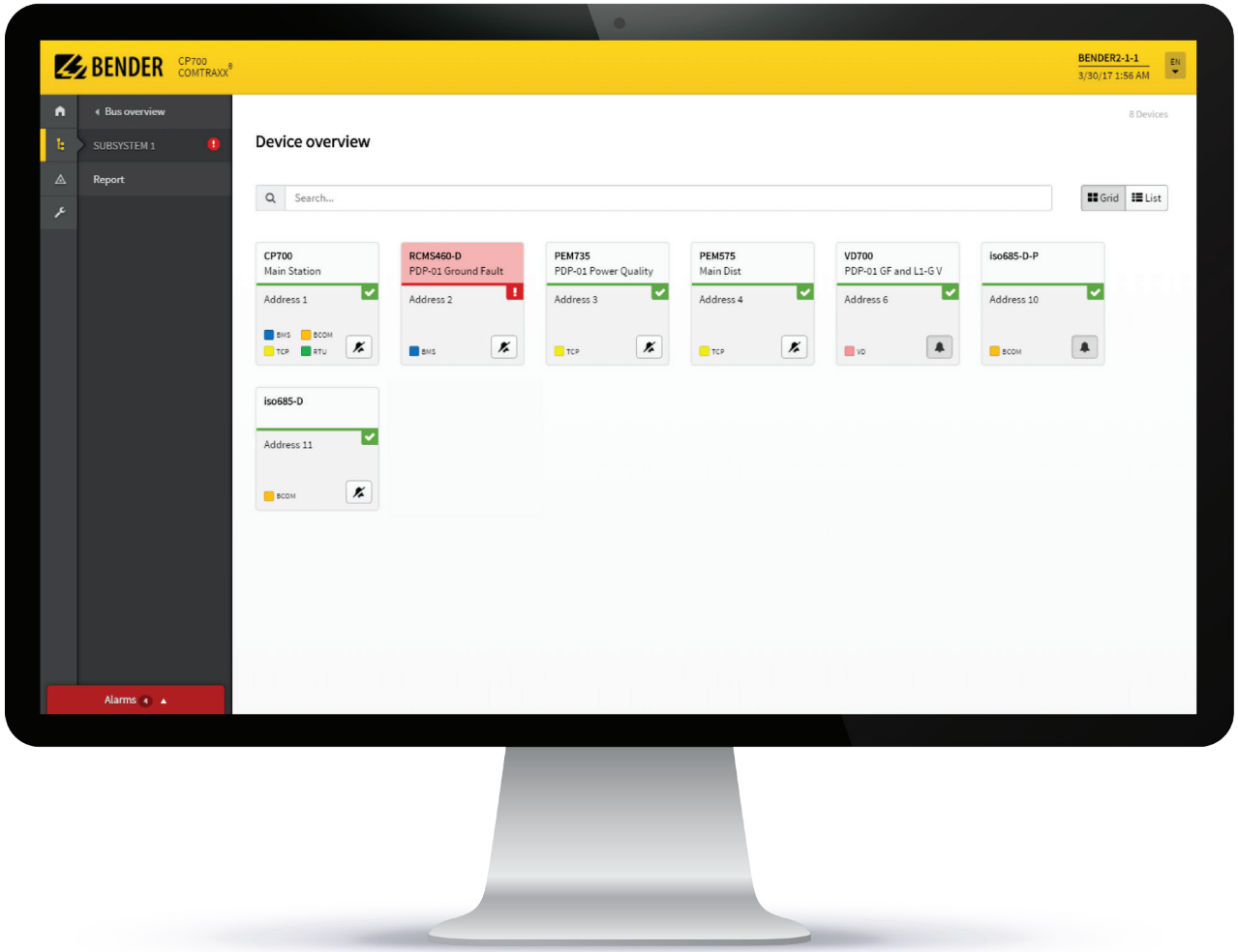
- Adds supported Bender and third party devices to industrial communication networks
- Modern, responsive web interface compatible with mouse-based and touch-base devices
- Connects to standard Ethernet networks
- Monitor the status of devices and alarms across multiple communication protocols in a unified interface
- Supports Bender RS-485 bus, Bender Ethernet bus, Modbus/RTU, and Modbus/TCP (other protocols available on request)
- Available as a browser-based only device (COM465IP) or with touch-screen HMI (CP700)

Key additional features

- Uniquely identify devices and alarm channels with custom names
- Receive e-mail notifications on specified trigger events
- Integrate Bender devices with Modbus/TCP networks
- Remotely modify settings for connected Bender equipment
- System visualizations - create visual layout overviews of systems with equipment locations; identify physical locations of alarms
- Connect third party Modbus/TCP devices to view specified data points and integrate into Bender's analytics service
- Virtual setpoints - create custom alarms using conditional or mathematical alarms, combine multiple devices, and integrate third-party equipment

Stay notified

- Easy to use, web browser interface
- Unified status screen for connected devices across multiple communication protocols, including Bender RS-485 bus, Bender Ethernet bus, and Modbus
- Drill-down for each device shows detailed readings, including values and alarms for all single- and multi-channel devices
- Modern user experience, compatible with web browsers on mouse- and touch-based devices
- Create visualizations of facilities showing real-time device information
- Integrate third party devices over Modbus/TCP
- Virtual setpoints - create custom conditional or mathematical alarms for one or more devices to tailor alarms to specific locations or applications



POWERSCOUT™

System uptime, redefined

- A comprehensive, scalable, cloud-based solution for power system monitoring and analytics
- Trend and analyze ground faults, power quality, system condition, and more
- Manage multiple systems and locations from one web interface
- Collect and analyze data over months or even years using Bender's secure, managed hosting platform
- Setup wizards - create installation reports and visualization widgets easily with pre-defined drag-and-drop utilities
- Visualize systems with dashboards - graphs, trees, heat maps, and more
- Automated reporting capabilities
- Add compatible third-party devices
- Managed hosting services and local network installations available

Technical and application info

Ungrounded systems

Ungrounded power systems

Ungrounded (also known as floating) systems are power systems with no intentional connection to ground. Typical ungrounded power sources include 480 VAC and 600 VAC transformers in a delta configuration. Ungrounded systems are typically used to supply power to critical equipment where a sudden shutdown must not occur. Examples of such systems include operating rooms in healthcare facilities, signaling systems, chemical manufacturing, and emergency backup systems.

The magnitude of fault current in an ungrounded system is dependent on the system voltage, the magnitude of the fault's resistance, and system capacitances to ground. In a first-fault condition, this magnitude is typically very small.

An example of a single-fault condition is shown in Figure 1. The circuit between the faulted system conductor and ground is incomplete, as there is no return path to the source. Fault current will flow to the unfaulted phases through the system's distributed leakage capacitance. This is known as charging current, the magnitude of which is extremely low to negligible.

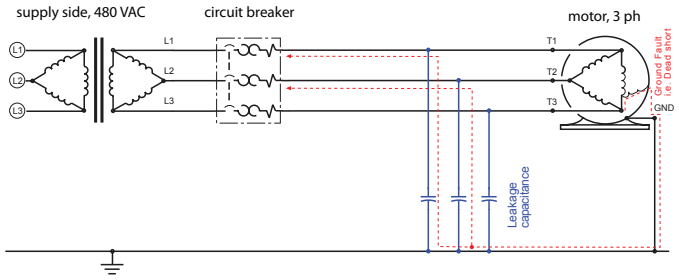


Figure 1: Ungrounded system in single-fault condition

While a ground-fault's impedance will vary, the first-fault scenario will not create sufficient fault current to trip a typical ground-fault relay. Alternate methods of detection are necessary, such as monitoring the system's insulation resistance.

The active IMD on AC systems

Instead of monitoring for ground-fault current, active insulation monitoring devices (IMD) measure the system's resistance to ground, known as the insulation resistance. Even if a ground fault is not generating current to ground, it will have a resistance associated with it. This resistance will vary based on its severity.

The insulation resistance of the system will decrease proportionally to the severity of the ground fault. Insulation resistance may drop slowly over time, due to corrosion or degredation of wire insulation. It may also drop significantly in a short period of time - for example, caused by sudden damage to a feeder cable. Both situations require continuous monitoring and trending.

An active IMD continuously monitors the insulation resistance value. The device connects between the system conductors and ground via pilot wires. A continuous, line-to-ground measuring signal is injected into the system. The signal will monitor the secondary side of the supply transformer and all connected loads. If a path to ground exists, the signal will travel through it and return to the IMD. Refer to Figure 2.

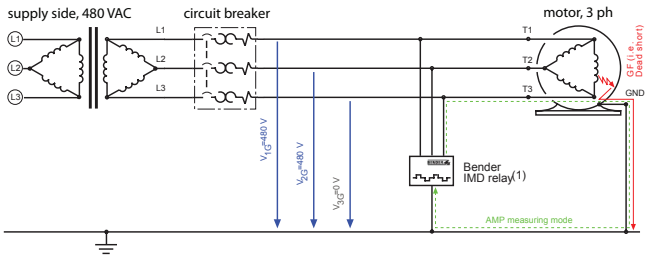


Figure 2: Ungrounded three-phase system with IMD

The IMD processes the signal and provides indication and outputs when the insulation resistance reaches a specified level. An IMD's alarm level is set in Ohms (Ω) as opposed to Amperes (A).

A quality insulation resistance level ranges from multiple kilohhms (kΩ) to megaohms (MΩ). However, acceptable levels can vary by application. Varying factors include quantity and type of loads, age of installation, environmental conditions, etc. Some industries utilize an estimation of 100 Ω/V to determine an alarm value.

Technical and application info

Ungrounded systems

The active IMD on DC and systems with power conversion equipment

Active insulation monitors function similarly on ungrounded DC systems. The device connects between the system and ground via pilot wires. The measurement signal will monitor the secondary side of the supply (such as a battery) and attached loads. An example system is shown in Figure 3.

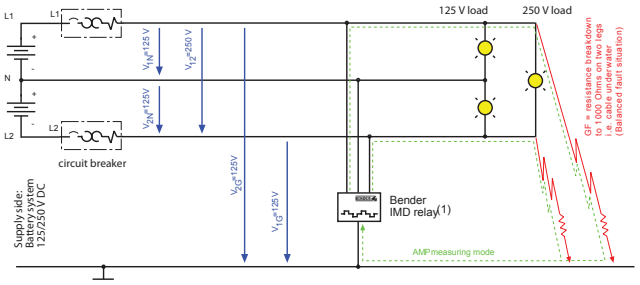


Figure 3: 125/250 VDC ungrounded system with IMD

Systems with mixed AC/DC power or power conversion equipment, such as variable frequency drives (VFD / ASD), require special measurement techniques. Measurement requires functioning properly throughout a system with no isolation on both the AC and DC side. Additionally, power conversion equipment may add significant leakage capacitance to the system. Insulation monitors must provide accurate readings while overcoming these challenges.

The AMP Plus measurement principle, used in devices such as the iso685, can be used universally in AC, DC, and mixed AC/DC systems. The measurement technique is able to overcome system conditions adverse to measurement, such as high leakage capacitances.

Fault location in ungrounded systems

Previously, fault location on ungrounded systems was a cumbersome process, requiring techniques such as opening and closing branch circuit breakers - taking equipment offline to see if faults cleared. However, special tools are available to locate ground faults while keeping the system and its loads online.

A control device equipped with a pulse generator are installed in the system. This device may be permanently installed as part of a fault location system, or temporarily added to the system as part of a portable fault location system.

The device sends a low-magnitude signal into the system. The signal will flow through a fault to ground, and return to the pulse generator via a pilot wire.

The signal is detected with special monitoring devices, either with fixed current transformers or a hand-held current probe. Using this method, ground faults can be located down to the faulty load while the system remains online.

Fault location with fixed equipment

A permanently installed system is ideal for systems where 24/7 monitoring is desired. Such systems mitigate the need for regular fault location maintenance, as located faults are reported automatically as they occur. A typical system consists of the following components:

- iso685 ground-fault detector and controller
- EDS440 series ground-fault location modules
- W series current transformers

The iso685 is the ground-fault detector as well as the fault location system controller. Once a fault is detected, the iso685 begins generating a tracer signal. Each EDS440 device monitors up to twelve branches via current transformers. The EDS440 monitors each channel for this tracer signal. Once the signal is located, an alarm is activated.

Fault location with portable equipment

Portable fault location equipment can be used as a complement to a fixed system or standalone. Pulse generation is initiated either automatically from an installed iso685, or from a portable pulse generator. The tracer signal is located using a hand-held sensor. Portable systems are ideal for service technicians and facilities with preventative maintenance programs.

Technical and application info

Grounded systems

Solidly grounded power systems

In a solidly grounded power system, the neutral is connected to ground via a solid neutral-ground bond. Solidly grounded systems are common in North America. Typical single-phase configurations include center-tapped 240/120 V transformers, powering most residential homes. Typical three-phase configurations include 208/120 V and 480/277 V, wye-configured transformers. In three-phase wye configurations, the neutral point is bonded solidly to ground. Refer to Figure 4 for an example of a solidly grounded three-phase system.

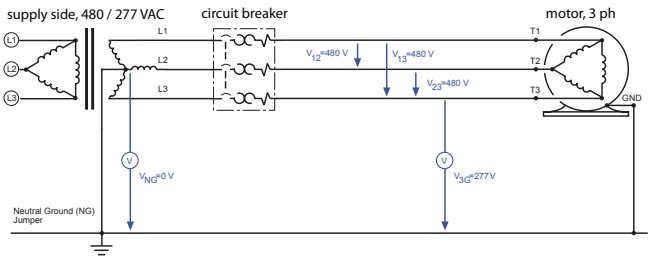


Figure 4: Typical wye-configured, 480/277 V three-phase system

In a solidly grounded system, current will flow in a first-fault situation. Whereas fault detection in an ungrounded system is intended to be more of a preventative action, fault detection in a grounded system is designed to be more of a reactive action. Fault current is detected quickly by conventional current monitoring devices, such as ground fault circuit interrupters (GFCI), ground fault circuit breakers, and ground-fault relays.

The magnitude of fault current is dependent on the system voltage and the resistance of the ground fault. Even in a first-fault scenario, severe ground faults can be orders of magnitude higher than the nominal load current. Consider the following formula for calculating fault current:

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

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 bond

Using the formula, consider a near-complete short on a 480/277 V system:

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

Without proper system protection, a ground fault can be devastating, creating risks to personnel and equipment, or causing electrical fires.

Ground fault relays on grounded systems

A common method of ground-fault detection on grounded systems is known as the “zero-sequence” method. A current transformer connected to a ground-fault relay is placed around all active conductors (including the neutral, if one is used) for a circuit or system. Refer to Figure 5.

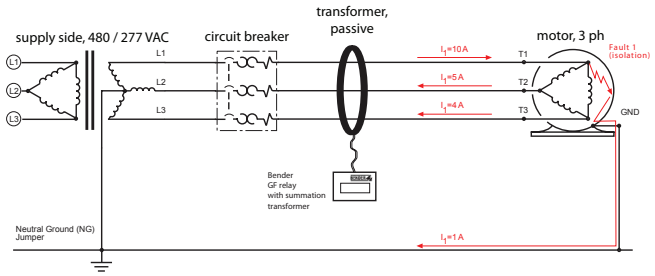


Figure 5: Three-phase grounded system with zero-sequence relay

In a healthy system, according to Kirchhoff’s law, the current going out to a load will be the same as the current coming back to the source, in opposite directions. To the current transformer, these equal and opposite values cancel, and the current transformer measures zero.

However, when a ground fault occurs, some current will travel through ground and “bypass” the current transformer. This creates an imbalance in the zero-sequence measurement equal to the fault current. The ground-fault relay will measure this imbalance and respond accordingly. Typical actions include tripping a circuit or providing notification to a PLC or industrial network.

Figure 5 shows an example of a 10 A load with a 1 A ground fault. In this scenario, 10 A goes out to the load. However, 1 A travels to ground via a ground fault. Only 9 A returns to the source over the power conductors. The current transformer measures an imbalance of 1 A in this scenario.

Technical and application info

Grounded systems

Grounded DC systems

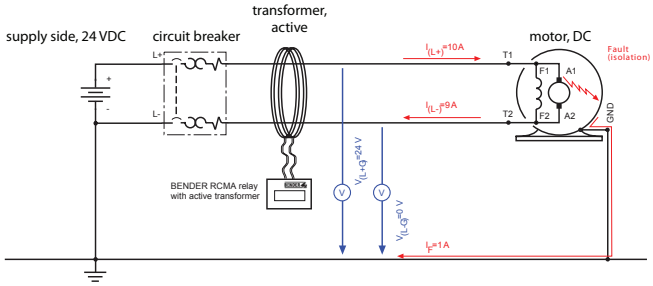


Figure 6: Typical grounded DC power system

Refer to Figure 6 for a typical grounded DC system. Typically, the negative pole of the DC power supply is connected to a chassis or building ground. Zero sequence detection is principally the same as an AC system - a ground fault will cause a load current imbalance, which is measured and processed. DC systems however, require special active current transformers for proper monitoring. Bender equipment, such as the RCMA420, combined with special current transformers, are able to accurately measure DC current.

Variable frequency drives

Typical ground-fault relays for 50/60 Hz systems may encounter problems when monitoring systems with variable frequency drives (VFD / ASD). A drive converts incoming AC power internally to DC. It then converts the DC back into variable cycle AC, which goes out to the load. Issues that typical ground fault relays may encounter include:

- Inability to detect DC ground fault internal to drive
- Inability to detect low-frequency AC faults
- EMI filter circuitry adding to overall system leakage
- Interference from carrier frequencies
- Harmonic content interfering with readings

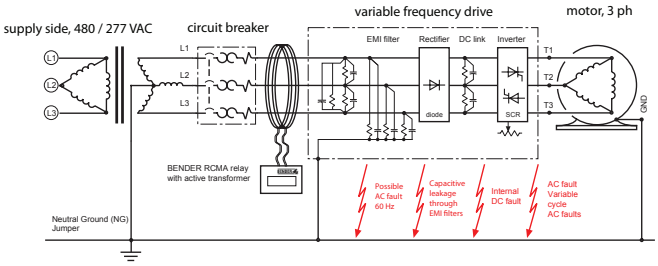


Figure 7: Grounded system with variable frequency drive

Bender's RCMA and RCMS series relays employ active monitoring technology and built-in filtering to accurately measure ground faults throughout the entire power conversion process found in low-voltage variable frequency drives.

Resistance grounded systems

In a resistance grounded system, a purpose-built neutral grounding resistor (NGR) is connected between neutral and ground. This is opposed to a solidly grounded system, where a solid bond is utilized. In a solidly grounded system, severe ground faults can cascade to high orders of magnitude. An NGR will limit ground-fault current to a known, maximum value. In a low-voltage system (up to 600 V), limiting current to 10 A or less is commonly known as high-resistance grounding (HRG).

An HRG system functions as a hybrid of ungrounded and solidly grounded systems. An HRG system can typically continue to operate in a single-fault condition, while having sufficient fault current for detection by ground-fault relays. On systems utilziing circuit interruption, multi-channel relays such as the RCMS series can isolate faulty circuits while allowing the rest of the system to continue operation.

Neutral-grounding resistors can be susceptible to failure, caused by factors such as thermal-cycling stress and corrosive environments. Additional monitoring of the NGR is required to ensure proper operation, as an NGR loss will render conventional ground fault protection inoperable. Devices such as the RC48N provide a combination of ground-fault and NGR monitoring.

Code and standards reference guide

General purpose

Description	Requirements	Applicable Products
Ground-fault detection for ungrounded AC systems	USA: NEC 250.21(B) Canada: CEC 10-106(2)	iso685 series
Ground-fault detection for ungrounded DC systems	USA: NEC 250.167(A)	iso685 series
Ground-fault detection for grounded DC systems	USA: NEC 250.167(B)	RCMA420 / 423 series RCMS series
Ground-fault protection for electric heat tracing systems	USA: NEC 427.22 Canada: CEC 18-120(2)	RCM420 series RCMS series
Service entrance ground-fault protection	USA: NEC 230.95, UL 1053	CMGF420
Ground-fault protection for transfer equipment (standby generators, etc.)	USA: NEC 700.5(D)	CMGF420
Ground-fault circuit interrupters (GFCI) for personnel protection	Various NEC and CEC requirements UL943 Class A	LifeGuard® series

Healthcare facilities

Description	Requirements	Applicable Products
Installation and monitoring requirements, isolated power systems	USA: NEC 517.160 Canada: CEC 24-200	LIM2010 Isolated power panels
Requirements for use, isolated power systems	USA: NFPA 99 Canada: CSA Z32	LIM2010 Isolated power panels
Product standards, isolated power systems	UL 1047, UL 1022	LIM2010 Isolated power panels

Code and standards reference guide

Renewable energy supply and storage systems

Description	Requirements	Applicable Products
Grounded solar arrays	USA: NEC 2017 690.41(B), 2014 690.5 Canada: CEC 64-064(4)	RCMA423 series RCMS series
Ungrounded solar arrays	USA: NEC 2017 690.41(B), 2014 690.35 Canada: CEC 64-066(1)(e)	isoPV series iso1685P series
Electric vehicle charging stations (EVSE)	USA: NEC 625, SAE J1772, UL2231-2	RCMB101 (Level 2) IR155-10 (Level 3 / Fast DC)
Energy storage systems, DC microgrids	USA: NEC 706.30(D), 705.32, 712.55	RCMA423 series iso1685P series
Ground-fault protection for inverters	UL 1741	RCMA278P-S RCMA423 series

Other industry-specific requirements

Description	Requirements	Applicable Products
Marinas and shore power	USA: NEC 555.3, NFPA 303	MarinaGuard® series
Mines and mining equipment	USA: MSHA CFR 18.47(d)(2) Canada: CSA M421	RC48N / RC48C series RCMA423 series
Fountains, spas, submersible pumps	USA: NEC 680.51(A) Canada: CEC 68-068	LifeGuard® series

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