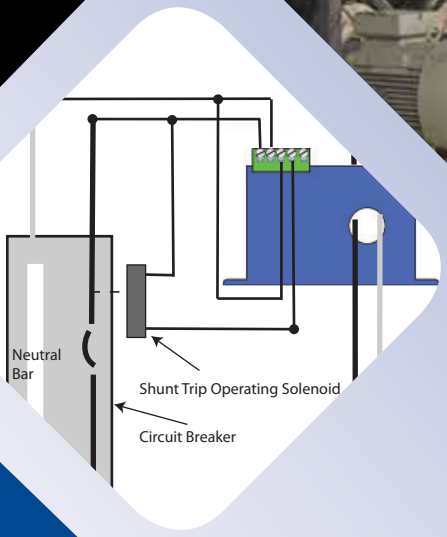
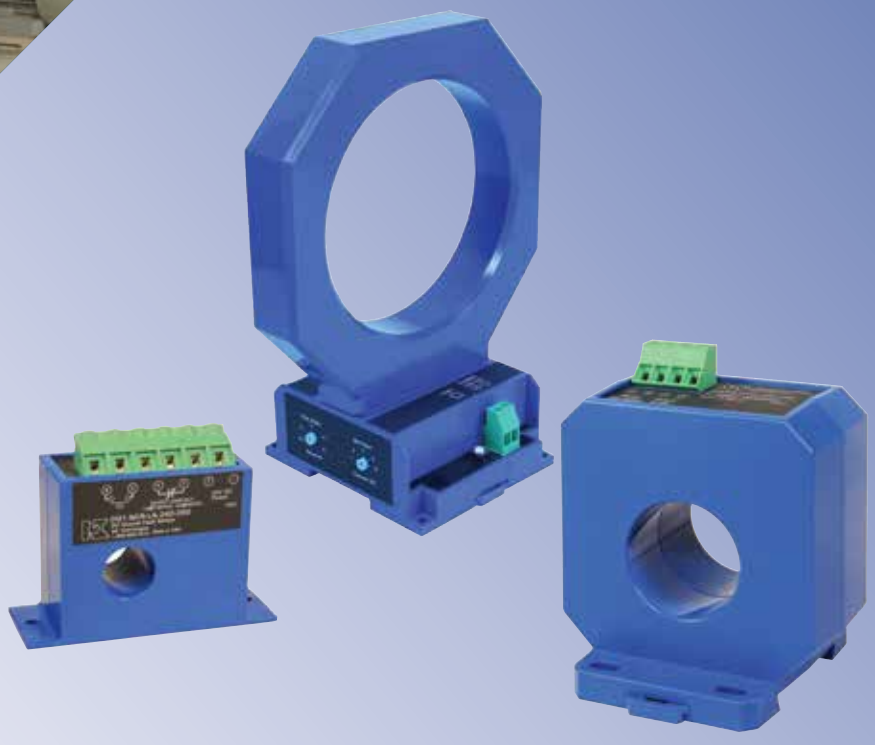
Ground Fault Considerations

Tech Guide





NK Technologies

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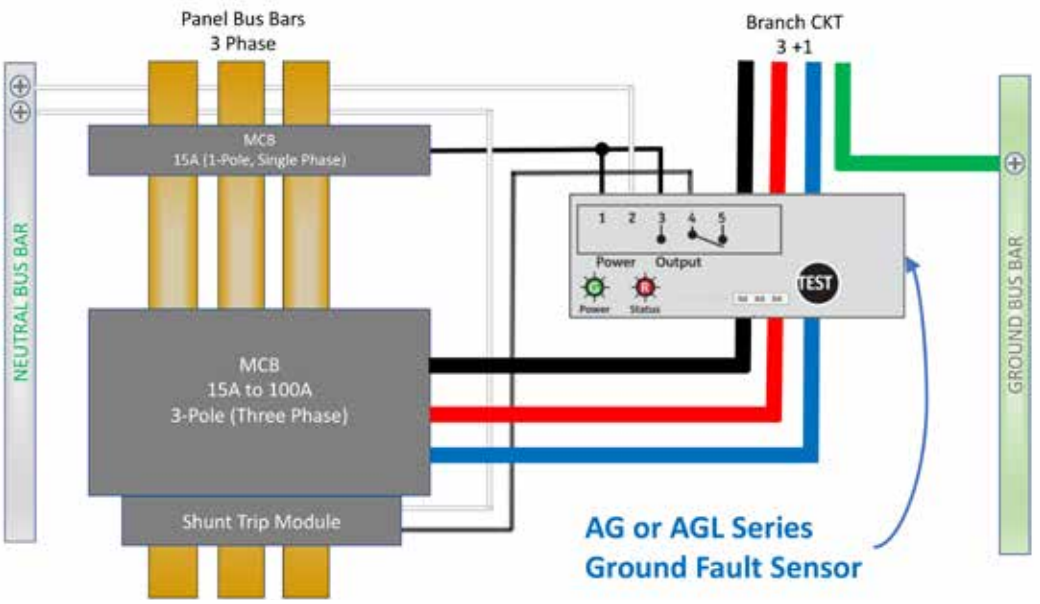
Ground Fault Protection for Your Applications

From a Company with a History of Innovation

Ground faults can be costly if not checked. They can cause a fire to erupt, damage equipment, or even shock or electrocute personnel. Numerous safety regulations and electrical codes exist to prevent and protect against ground faults. These and so much more can be found in this guide to ground fault protection.



Meets intent of 2020 NEC 210.8 defined term ground fault circuit interrupter.

With one of the broadest product portfolios in the industry, NK Technologies provides reliable, ground fault protection products designed to add value and exceed our customers' expectations. "From semiconductor wafer fabrication to commercial kitchens and electrical heating systems, NK Technologies has a family of ground fault relays to meet your application needs."

— Phil Gregory, President

Ground Fault Protection Applications

Wet Environments

Agriculture & Aquaculture

Irrigation pumping systems, filter pumps

Biotech and Biopharma

Laboratory environments that use electrical equipment tied to pumping or processing fluids, or electrically powered heating processes

Chemical Processing

Chemical pumps and mixers, heat trace cables

Food/Beverage, Bottling/Canning

Filling machinery, equipment in washdown/hygienic locations

Marinas

Docking facilities (see Ground Fault Detection for High Current Circuits at Marina Docking Facilities)

Electrical Heating Systems

Furnaces and Kilns

Heat treating and annealing

Manufacturing

Heat trace systems, process heating, annealing, drying, curing, overhead cranes

Semiconductors

Process heating (see Ground Fault Protection in Semiconductor Fabrication Equipment)

Commercial Kitchens

Steamers, grills, ovens (see Adjustable Ground Fault Detection for Commercial Kitchens)

Snow Melt

Snow melt cable to clear sidewalks, driveways and roof gutters

General Equipment Protection

Entertainment

Amusement park rides, ski lifts, electrified theater chairs, stage lighting and portable power supplies

Petrochemicals

Process control equipment, pumping systems, heat trace cables

Refrigeration and Compressors

Pumping systems, cooling towers, compressor motors

Timber and Logging

Debarking, sawing, drying, cranes

Utilities and Power Generation

Control systems, transformers, generators, solar panels, wind generators

For up-to-date product information, applications, engineering resources and more:
www.nktechnologies.com

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NK Technologies' ground fault relays allow the system designer to choose what the relay output will do if a fault to ground is sensed. The output contact can be selected to close, operating a shunt trip circuit breaker, or a contact can open the circuit to a contactor coil. Both would shut down the monitored load.

4 Industry & Commercial Applications

- Semiconductor Water Fabrication Equipment
- Electrical Heating System Protection
- Heat Trace
- Detect Earth Leakage
- PWM Driven Loads (Variable Speed Drives or Variable Frequency Drives)
- Marinas
- Renewable Energy Detect DC Current Leakage to Earth
- Detect Current Leakage for Preventative Maintenance

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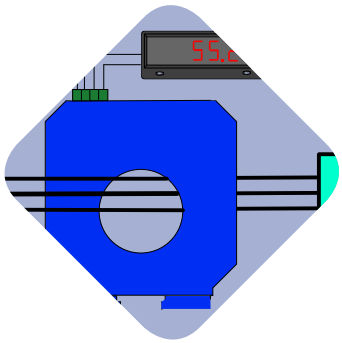
- 2020 & 2023 NEC Impact to Market
- What is a 5mA Ground Fault Protection System
- How to Select a Ground Fault Relay
- Ground Fault Relay Selection Guide
- How to Wire a Shunt Trip
- Shunt Trip Breaker Selection
- Calculating a Wire Bundle Size
- Frequently Asked Questions



24 Basics & Technical Reference

- 2020 & 2023 NEC Impact to Market
- Importance of Ground Fault Protection
- Detect Fault Current Before a Failure Occurs
- Calculating Wire Bundle
- How to Wire a Shunt Trip
- Shunt Trip Breaker Selection
- Ground Fault Protection at Distribution Panel
- Ground Fault Relay Selection

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INDUSTRY & COMMERCIAL APPLICATIONS

Ground Fault Detection in Semiconductor Wafer Fabrication Equipment

The process of making semiconductor chips is extremely complex with the size of the chips shrinking while the number of transistors on each chip continues to increase. The process involves using the purest silicon available (one atom of foreign material in one billion atoms of silicon) as any impurities can cause fallout. Much of the design of the machines fabricating the silicon wafers into chips is addressed by the standards developed by the global industry association SEMI. Its standard S22-071b provides guidelines regarding the safety of the equipment. Many hazardous chemicals are used to clean the wafers and etch the various layers of substrate so the end products are the reliable electronic devices we have become so dependent upon. The need for standards applicable to this industry points to how diverse the processes are when compared with many other industries. SEMI understands the importance of worker safety, hence the standards are more stringent than in many other industries.

A typical installation of ground fault sensors monitoring several heating circuits used in the semiconductor fabrication process. If a fault to earth is detected, the latching output sensor de-energizes the contactor coil, turning off the offending circuit.

The temperatures used in the chip making process range from dangerous (boiling water levels) to extreme. The temperatures used to cure the photoresist compounds are not unusual for other industries at 80–100 °C, but the wafers are annealed in furnaces or through rapid thermal annealing (RTA) to 1000°C or higher, nearly the melting point of steel (1350°C). Most of these processes use electrical heat sources as there is no combustion exhaust or burnt fuel wastes. The ability to control temperature precisely is very desirable. For example, with RTA the wafer is brought to a very high temperature in a few seconds using high intensity lamps or lasers, and then cooled much more slowly to reduce fracture and warping of the wafer. The processes of deposition of layers and coatings to the wafers are quite varied, and are done in the presence of specific gases or in a vacuum. The coating of the silicon has various purposes, from physical protection from damage to insulation between conducting elements.

The SEMI standards cover a wide range of issues, and many are covered by Emergency Mains Off (EMO) circuitry design. If there is any problem during the processing of the wafers, the operator is able to turn of the mains power by pushing some buttons. With the number of electrical heating elements used is various places in the fabrication equipment, the need for ground fault protection is obvious to the equipment designers. The elements are monitored in each process segment, with fault detectors set at a fairly low trip point. If there is a fault to earth through the heating element, these sensors will shut down that part of the process separately from the entire machine. If there is a major catastrophe and several heating processes short at one time, a sensor with a bit of delay and higher trip point will shut off the main power feed.

AG and AGL Series Ground Fault Sensors

AG Series ground fault detectors monitor all current-carrying conductors in grounded single- and three-phase delta or wye. Single factory calibrated setpoints are available from 5 mA to 950 mA. Field-selectable 5 mA, 10 mA or 30 mA setpoints on the AG3 "Tri-set" model makes user adjustments fast, sure and convenient. Available with a choice of N.O. or N.C solid-state switch or mechanical relay outputs systems. AGL Series detectors are large aperture ground fault relays that offer one of the largest aperture diameters in the industry while maintaining a compact overall profile. Intended for sensing earth leakage in applications up to 300 A, the AGL Series offers a choice of N.O. or N.C. latching relays or an SPDT Form C relay with auto-reset. Enclosure features integral DIN rail mounting as standard. Both series offer an optional noise-immunity coatings for applications in harsh EMI/RFI environments.

AG Series

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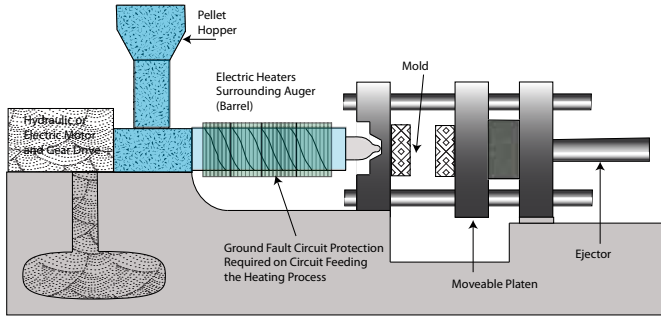
Electrical Heating System Protection from Faults to Ground

The National Electric Code requires that all (with few exceptions) electric heating sources be protected against faults to ground. While the requirement is not to protect a person from being shocked when working at the process being heated, the method of detecting the fault is the same as when electrocution or electrical shock protection is needed. Bare feet on a bathroom floor provides a dangerous path for current to flow from a hand held hair dryer, where touching equipment during a fault while standing on a concrete floor with work boots is much less hazardous. Disconnecting the circuit is the best protection in both instances, and the faster the circuit is de-energized the safer the installation.

Most heating protection against ground fault is termed "equipment protection" and the target fault current level that will cause the faulting circuit to be de-energized is 30 milliamperes, although this value is arbitrary and can be much higher if the need arises. In general, a heating element will either work as designed or it will short to ground, with only a few instances where insulation deteriorates causing current to leak to earth in lower quantities.

Electric Heating Applications

- Heat Trace Cable
- Snow Melt Mats
- Fuel Preheaters
- Plastic Injection Molding
- Drying
- Finish Curing
- Water Heating
- Baking



NK Technologies' Ground Fault Protection

Since the late 1980's, NK Technologies has been manufacturing current sensors made specifically for sensing fault current in AC branch circuits of 50 amps or lower. By using the zero sequence concept, a single magnetically permeable toroid surrounds all of the current carrying conductors. If there is any current over five milliamps flowing to ground, the sensor actuates a contact. The contact can be used to open the circuit of an operating coil of a contactor, close a shunt trip breaker solenoid, or in applications where turning off the offending circuit would create a major problem, the contact can be used to alarm an operator or controller.

NK Technologies makes sensors using this technology with larger circuit monitoring capacity by enlarging the window through which the conductors pass. This makes it possible to monitor conductors carrying over 200 amps. NK Technologies also manufactures sensors designed to produce an analog signal directly proportional to the fault current. This output can be used to identify areas where insulation is failing, allowing the user to take corrective measures before equipment is damaged.

AG Series

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AGT Series

INDUSTRY & COMMERCIAL APPLICATIONS

Monitoring Ground Faults of Heat Trace Systems

Many industrial processes use electrically powered heat trace systems. Installers with little experience in this application think that heat trace cable is used to keep water pipes from freezing, but this is just the beginning. Heat trace is also used extensively to keep product being transferred from one process to another, through piping, at a constant temperature. This helps to keep the material liquid, or at least the same viscosity, during the transfer. Allowing the product to cool even slightly can cause unwanted chemical reactions. There are other ways to accomplish the same task. Commonly steam is injected at low pressure into a separate tube attached to the pipe that needs to stay at a constant temperature. Heated air can be used to perform the required function in certain applications where electrically heated cable or steam trace may be dangerous or impractical. Installation is quite expensive in both forced air and steam heat.

Electrically operated heat trace cable has a number of advantages over these other methods:

* Electrical circuits can be extended for extremely long distances without much degradation, whereas steam or forced air cools rapidly as it travels away from the heat source.

* Most electricians can install cable but steam requires expert pipe fitters using a great deal of planning and time. Forced air systems are most effective in smaller, more confined areas. They also require ducting, a heat source (gas, fuel or electric) and electrical power to operate the fans at each point.

* Cable is more flexible, allowing for changes in ambient temperature to affect the installation to a smaller degree, without the need for pipe expansion joints as would be needed with steam systems.

The primary purpose for monitoring electric heat trace cable is so "leaks" can be detected before they cause irreparable harm. If steam or heated air leaks from a pipe, there may be some damage caused by excessive heat pressure or corrosion, but leaking electricity has the potential to kill. A maintenance person wearing gloves and boots will be fairly well protected against shock but it's certainly not worth taking any chances.

The most common installations use a cable connecting one phase to neutral or one phase to another phase. If both current carrying conductors pass through an NK Technologies' ground fault sensor, the magnetic field produced by the AC current in one conductor will be cancelled out by the return current in the other conductor. Over time when the cable insulation begins to break down or is damaged and the conductor is exposed, there will be some current passing to ground. When this occurs, the NK Technologies' sensor will open a contact to de-energize the operating coil of the contactor supplying the cable power. (Fig. 1)

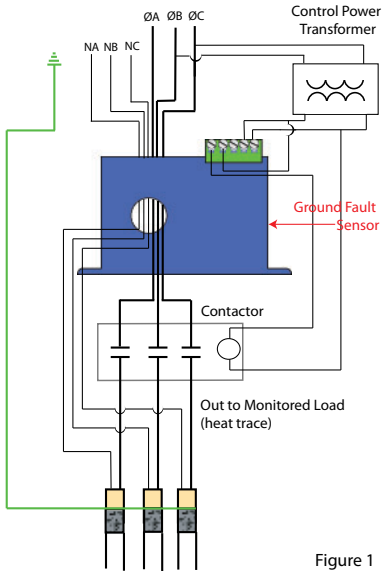

Figure 1

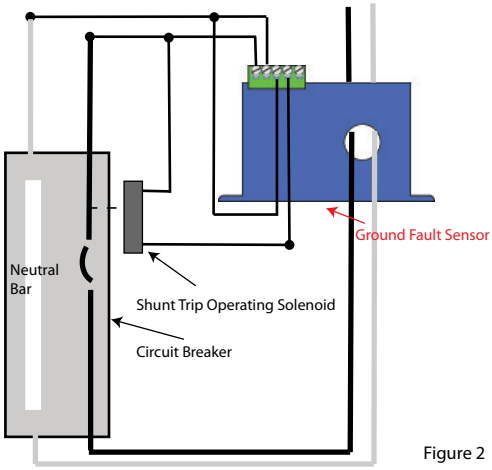

Figure 2

In the oil fields on the North Slope in Alaska, miles and miles of heat trace cable insures that the crude stays liquefied in subfreezing temperatures. There are ground fault sensors placed in a zonal pattern, so when there is a fault it can be isolated to some degree. In this application, the contact is not used to disconnect the load from the supply. What the sensor provides is a contact closing, and latching closed. This triggers an alarm, letting the system operator know that there is a problem. Since there is little chance that low level leakage current will cause harm to humans, the fault is noted. When the opportunity arises, repair crews will find the faulty cable and repair or replace it. In the interim, the low level current will just waste electricity;the heating effect will be diminished but not eliminated. Although there may be minor damage to the pipe. In other systems, the sensor will close a contact; which then energizes a shunt trip breaker operating solenoid, shutting off the power. (Fig. 2)

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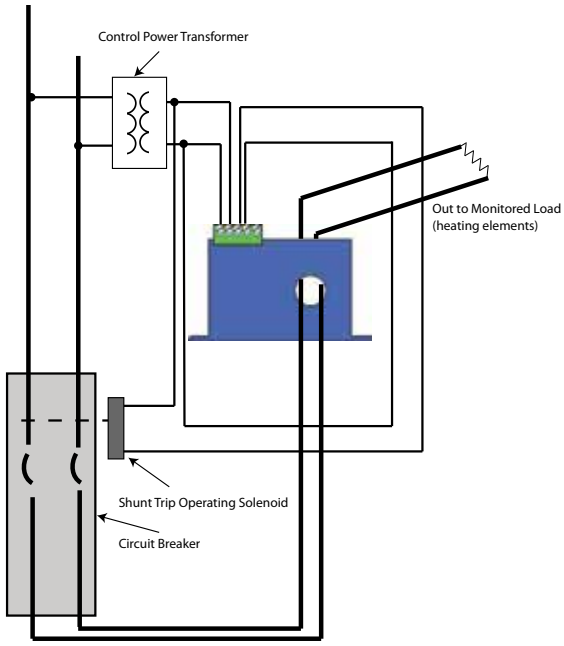
Detect Earth Leakage Easily with NK Technologies' Ground Fault Protection

The drawing to the right shows an NK ground fault sensor powered from the primary (load carrying) circuit through a control power transformer. The sensor can be powered by 120 VAC or 24 VAC or DC. The output of the sensor is a single pole, double throw relay, so when used to operate a shunt trip circuit breaker operating mechanism, the normally open contact of a normally de-energized model would be the best choice. With the -DEN model contact action, the sensor operates the output relay only when fault over the set point occurs. When power is applied to the sensor, an indicating LED will light. Another LED will indicate when the sensor has tripped. The voltage of the primary circuit can be up to 600 volts AC and meet the requirements of UL. Remember that all current carrying conductors must pass through the sensing aperture, including the neutral if the load uses one.



Ground Fault Protection Solutions

NK Technologies manufactures ground fault sensors which can be used in a wide range of applications monitoring AC circuits, from operating a shunt trip circuit breaker to sending an alarm contact to a programmable logic controller. Most models are UL recognized as a component under UL1053, ground fault sensing and relaying equipment. The trip point of the sensor is factory adjusted, so you can be assured that it will work as designed, reliably and accurately.

Some models can be adjusted for a higher or lower trip point. This is commonly used where the protected load is inductive, such as a motor or transformer. Motors are made by winding small varnish insulated wire around laminated steel cores, and small bubbles or gaps in the insulation can allow minuscule amounts of electricity to pass to ground through the motor frame. While the generally accepted equipment protection fault protection level is 30mA, these small insulation imperfections can produce fault current of 30mA easily, so the installer can adjust to a higher level to overcome spurious tripping of the sensor.

AG Series

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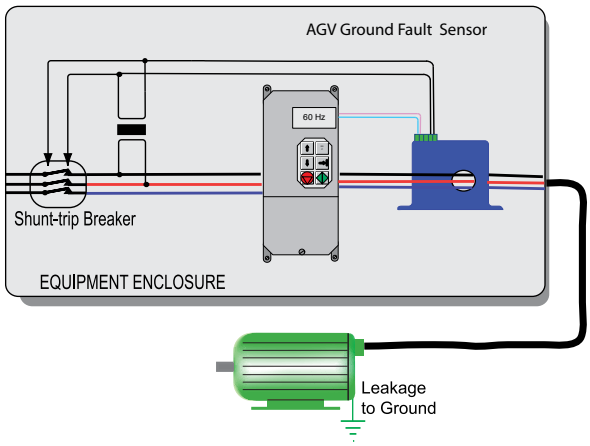
AGT Series

INDUSTRY & COMMERCIAL APPLICATIONS

Fault Detection in PWM Driven Loads

Mitigation of faults is something that all facilities must work to achieve, not only for the safety of the people working in the plant but to reduce the damage when a fault to earth occurs. There is no insulating material available at the present time that is both flexible and does not degrade over time due to environmental conditions. Oil, greases, water and other contaminates are the most common causes of deterioration of wire insulation, but excessive heat, ultraviolet radiation and voltage spikes are also major contributors. In any case, failing insulation creates short circuits from phase to phase or from phase to earth. Electrical faults to earth are by far the most common cause of motor failure according to EASA, the Electric Apparatus Service Association.

There are many locations in the workplace where ground fault protection is required to keep personnel from shock hazards, including bathrooms and break/kitchen areas. Ground fault protection is also required where electrical heating elements are used to treat metal parts or other manufacturing processes. The heating process is often accomplished with three phase power. Because the process is located where personnel have little access, the National Electric Code allows for more current to earth before the circuit is de-energized than what is allowed in bathrooms and kitchens. The conditions in heating applications are very often three phase, and can draw more current than 15 or 20 amps. Heaters do not plug into an outlet like most GFCI protected equipment does.



Protecting submersible pumps in fountains and around pools against ground faults is also required by the National Electric Code. While products are readily available to detect faults to earth in these applications, if the pump is driven with a variable frequency drive, monitoring the load side circuit of the drive is quite difficult due to the carrier or switching frequency of the controller used to modify the output.

The engineers at NK Technologies have solved this problem. By studying the output from a pulse width modulated variable speed drive, algorithms were developed to detect only current flowing to ground by filtering out the extraneous noise and distortion inherent in the power supplied from a variable frequency drive.

The AGV series earth leakage detectors can be set to trip at three field selectable points: 30, 50 or 100 mA. A delay of up to 10 seconds to the output contact action can also be added. Some drives cause zero sequence detection devices to trip when they first start; adding a delay will allow the sensor to pause until this condition dissipates, but still react quickly enough to keep the equipment from being damaged.

The sensors can be configured so the output relay changes state only when there is a fault detected (-DEN) or when a fault occurs, or the power is removed from the sensor (-ENE), as either can be used to operate the solenoid of a shunt trip breaker. The latching (-LA) models only trip when a fault is detected, and are commonly suggested when the contact is used to de-energize a contactor coil.

AGV Series
Ground Fault (Earth Leakage) Relay

AGV Series Ground Fault Detectors help protect products and processes from damage due to ground fault conditions by monitoring all current-carrying conductors in grounded single- and three-phase delta or wye systems.

AGV Series

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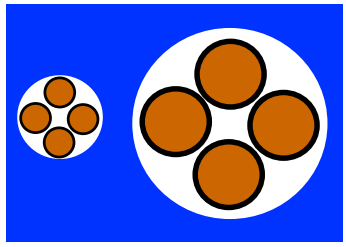
Ground Fault Detection in Marinas

Safety is essential whether in the workplace or during recreational activities to avoid the possibility of electrical shock. Boat docks and marinas are places where work and recreational activities occur in the same place. Additions to the National Electric Code (NEC) section 555.3 stipulate the electrical system powering marinas be protected with ground fault detection and interruption. The entire power supplied to docks and boats can be monitored for ground leakage current or each branch circuit can be monitored independently. If there is a fault of 100mA or higher, the power must be disconnected from the source. This low level fault current is generally not enough to trip the circuit breaker protecting the circuit or to open a fuse, but can cause a shock or can damage equipment.

While monitoring the main power would be effective, a fault would cause the main to disconnect all of the power to the marina when there is minimal fault at several of the connected loads. A better approach to detecting fault current so that the majority of the system remains operational is to use fault detection at each power pedestal.

With several boats connected to separate power pedestals, each boat could have small amounts of current flowing to earth ground. Bilge pumps, fans and transformers are common causes of low level fault leakage to earth as the insulation over the windings can develop small cracks. The moisture in the environment helps to make an electrical path to the equipment earth bond. Incorrect or damaged wiring is also common, and electric water heating elements can and do fail, shorting to ground. Each of these relatively small amounts of fault current will sum together at the main circuit protection and can easily cause "spurious" tripping. The ground fault sensor detects all fault current downstream from the point where it is installed. If five boats each have low level leakage to earth, say 20mA, the total leakage sensed at the main circuit breaker would be 100mA, and that would trip the ground fault sensor.



AG sensors have an aperture of 0.74 inches, and AGL have an aperture of 1.88 inches. To ensure the wires fit, measure the OD of one wire. Multiply by 2.15 for the OD of a bundle of three wires. Multiply by 2.41 for the OD of a bundle of four wires.

Protecting the power to each boat with a circuit breaker equipped with shunt trip mechanism is a better solution. An external fault sensing device surrounds the wires to the power receptacles. When a fault is detected the sensor closes a circuit to operate the shunt trip mechanism, shutting off power to the single pedestal and the boat or the connected equipment with the problem. The power is restored by pushing the breaker handle back to the closed condition after the problem is identified and corrected.

A contactor can also be used to disconnect the load, although we would recommend selecting a sensor with a latching output. With this type of contact action, the power to the operating coil of the contactor is de-energized after a fault is detected and the contactor interrupts the faulting circuit. The sensor is reset by a manual action after the fault is remediated.

Most marinas provide 120/240 VAC single phase power to the docks. The power supplied to each pedestal is usually between 50 and 100 amps. When selecting the proper sensor, be certain to choose one with a window large enough to allow all the current carrying conductors to pass through. The AG Series sensor is large enough to allow up to three #6 THHN to be threaded through the window. The AGL Series can accommodate up to three 300 MCM THHN. The bonding ground wire is not passed through the sensor. The wire feeding the pedestals may be larger than what might be seen in other installations as the distance from the main panel to the pedestals is significant. The wire gauge must be increased to overcome voltage drop. This reduction in voltage should be limited to 5% of the primary circuit voltage.

AG-LC Ground Fault Sensors for Monitoring Higher Current Circuits

AG-LC series ground fault sensors are the latest design innovation from NK Technologies. The NEC added section 555.3 to require ground fault protection of the main over current device feeding marinas and boat yards. These services are often carrying up to 800 amps; most sensor designs will not allow the conductors to pass through a single sensing ring.

AG-LC Series
For docks and large equipment using high current

By designing a sensor in a large solid-core housing, the conductors will not have to be passed through a separate sensing device like a zero sequence current transformer. This design makes monitoring of larger circuits a breeze, whether to protect boaters, or large equipment like amusement park rides or gantry cranes.

INDUSTRY & COMMERCIAL APPLICATIONS

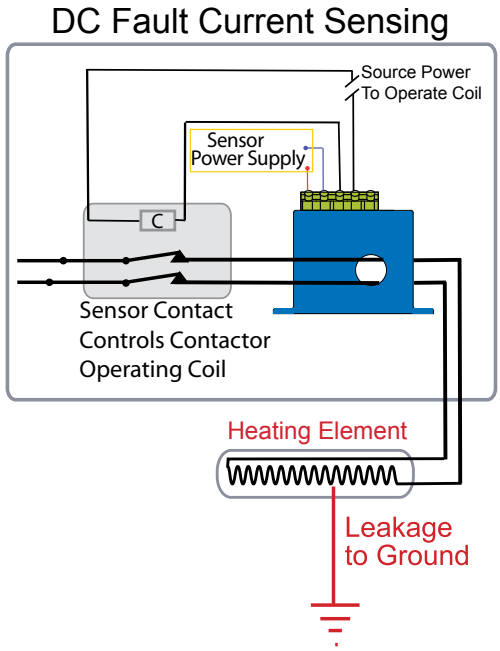
Detecting DC Current Leakage to Earth

Detecting low level AC current without adding a physical connection and added burden to the circuit is relatively easy, and quite common. In North America, all electrical outlets mounted in wet environments are required by codes to be protected with ground fault circuit interrupters; since the adoption of this requirement countless lives have been saved by turning off the power if a very small fault to earth is detected. If AC current of 5 to 7mA passes to ground, a circuit breaker or the contacts in the power receptacle open before electrocution can occur. Similar methods are used with higher shut-off levels for decorative fountains, pools and other locations. Most electrical heating elements must also be protected to keep equipment from damage in the event of a fault.

Trying to detect the same fault condition in a DC circuit with a floating ground is not as easy. With the proliferation of photovoltaic panels and other "alternative" power sources, the need for ground fault detection in DC powered systems is apparent. Some methods have been utilized, most requiring the measurement of the voltage in some manner.

With solar panels or battery operated systems, the positive and negative conductors are insulated to contain the voltage potential between each and also to earth. When connections get wet, this isolation becomes compromised, and current can pass to earth. Water is the most common cause of DC fault current, but deteriorating insulation and contaminants on battery housings are also factors.

While Charles Daziel's research in the 1960's showed that human electrocution occurs at a lower amount of AC current than with DC current, leakage to earth presents a very dangerous situation. Detecting a fault before it causes harm is obviously essential. Finding a way to detect a fault without having to hard wire to the circuit being monitored is the safest approach. NK Technologies' new DC ground fault relay can be installed at a fraction of the cost of products currently available.



DG Series Ground Fault Relay

DG Series Ground Fault Sensors keep machinery and their operators safe from accidental shocks. The one-piece, solid-core design allows for installation over wires feeding loads to about fifty amps. The output relay will change state at factory setpoint between 5 and 50 mA of DC current to earth.

DG Series

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Detect Current Leakage for Preventative Maintenance with 4-20 mA Current Transducers

Imagine having the ability to detect a leak in a pipe before the liquid or gas escapes. You could repair or replace the pipe when convenient, while the equipment was at rest or during a scheduled shut down. Sensing electrical current leakage to earth can give you this ability. Monitoring the current supplied to any AC load by surrounding the conductors with a sensing ring will show if any amount of power used is not returned to the source. This lost power is "leaking" to earth.

Faults to ground occur generally in one of two ways: (1) An energized conductor will contact a grounded point, creating sparks, smoke or fire. This will usually trip the over current protection, either a circuit breaker or fuses. But metal will incandence with a fault of just 500 milliamps. (2) Insulation deteriorates causing low level current to pass to earth. This failure will seldom create enough fault current to trip a breaker or blow a fuse. The former fault occurs instantaneously, but the latter often occurs very slowly, and it occurs very frequently. This creates hazardous conditions putting operators and maintenance personnel at risk for electrocution, and increasing the probability the equipment will be damaged, resulting in production stoppage.

Current Leakage Detection

- Monitor heating or other loads to detect increasing leakage current
- Pass all current carrying conductors through aperture to sense zero-sum current

Monitoring Very Light Loads

- Measure very small, critical loads accurately
- Current measurement gives faster response than temperature measurement

AGT Ground Fault Indicators Use Proven Zero Sum Technology to Detect Earth Leakage

NK Technologies' new loop powered sensor for monitoring earth leakage is based on proven, zero sum current technology. This new sensor produces a constant signal proportional to the leakage current. The industry standard 4–20 mA output can be connected to a PLC or data logger, with the 4 mA signal representing no earth leakage, and 20 mA representing fault current of either 50 or 100 mA (dependant upon choice of unit).

AGT Series

As the insulation degrades the fault current increases. The controller can be programmed to alarm at one level, for example, 15 mA and disconnect the load if the fault increases over 30 mA. These parameters can be established in advance by the design engineer and are easily programmed in the controller.

Monitoring residual earth leakage current is required in many applications from electrical heating elements to water fountain pumps. Using a constant signal proportional to the fault current will help protect any electrically driven machine or process.

COMMERCIAL KITCHENS - Protect Circuits to 100 Amps

2020 & 2023 NEC Impact to the Market

The 2020 and 2023 editions of the National Electric Code (NEC) section 210.8 (B) have expanded GFCI regulations in areas with sink and permanent provisions for food preparation and cooking, directly affecting commercial kitchens. The updated code covers GFCI protection for personnel in "other than dwelling" units and focuses on GFCI protection for applicable kitchen appliances powered by 3-phase power (e.g. line to line, < 250 VAC, 208 VAC typical). However, ideal GFCI solution would also be compatible with 2-pole (e.g. line to line, 240 VAC).

Both 2020 and 2023 NEC has increased GFCI requirements in more locations. What this means to architects, designers, electricians, general contractors, or program managers is a year over year increase in demand for breakers with GFCI protection. Will manufacturers of breakers continue to struggle servicing the demand for 15 A to 100 A, 2 or 3 pole, GFCI MCB's?

Commercial Kitchens

Summary of 2023 Code Changes

2023 Edition NEC article 210.8 (B) related to spaces "other than dwellings" has been rewritten to clarify and expand GFCI requirements.

a) The word "Kitchens" was added as article 210.8(B)(2) and requires all single phase (50A or less) or 3 phase (100A or less) plug-in-cord-connected appliances to have GFCI protection.

b) A new addition, article 210.8(B)(4), covers buffet serving areas, commonly referred to as break areas within commercial occupancy. The effected spaces include areas with provisions for food service. beverage service, or cooking. Any receptacles and special appliances within these areas shall be GFCI protected.

c) The specific appliances list was updated (article 210.8(D)(8) through (12)) for appliances that are commonly installed as hardwired outlets, 60A or less. Shock hazards exist whether appliances are energized from outlet (hardwired) or receptacle (cord and plug).

d) A new code (Stationary appliances, article 210.8(B)(7)) revised the code to include stationary appliances located within 1.8 m (6 ft) of the top inside edge of a sink shall have GFCI protection.

A 5 mA Ground Fault Protection System

A 5 mA ground fault protection system includes a breaker with shunt trip option and an AC ground fault sensor. All NK Technologies ground fault relays have numerous options to ensure compatibility with any shunt trip breaker (MCB or MCCB), relay or contactor. NK Technologies ground fault sensors are compact in size, easily installed within the panelboard. A shunt-trip breaker with ground fault sensor will protect 15 A to 100+ A branch circuits from both overload current and ground fault currents exceeding 5 mA.

A cost effective, compact ground fault protection system that is installed with no special hardware, no special tools, easy installation, easy setup and compatible across all OEM panel boards. AG series ground fault sensor can service up to 50 A single (120 VAC to 240 VAC) phase or up to 100 A three phase (208 VAC or 240 VAC) branch circuit.

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What is a 5 mA Ground Fault Protection System

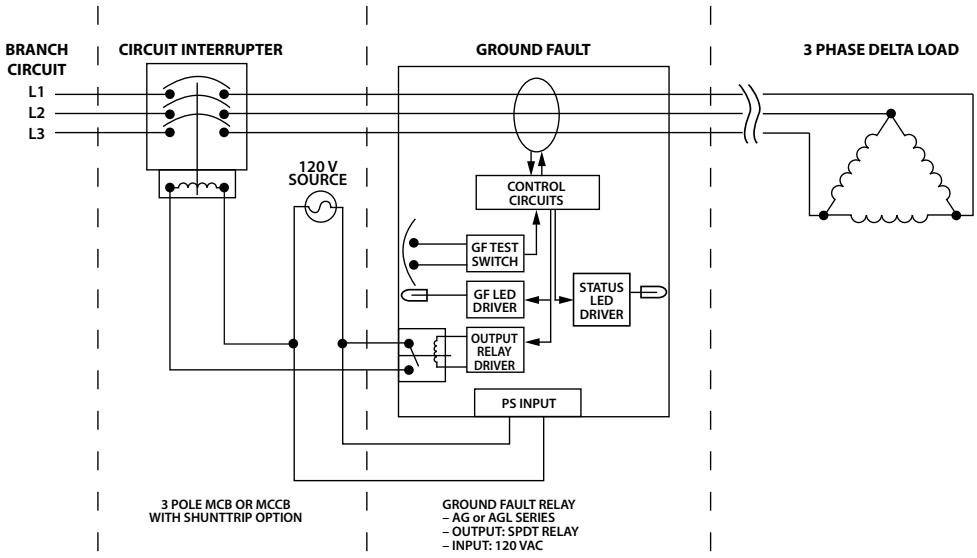
Two base models are offered:

AG Ground Fault Relay
for wire bundle diameter sizes up to 0.75 " diameter

AGL Ground Fault Relay
for wire bundle diameter sizes up to 1.82" diameter

A ground fault circuit interrupter solution that meets intent of 2020 & 2023 National Electric Code (NEC) Article 210.8 (B) through (F), ground fault protection for branch circuits within wet locations. The system includes an AC ground fault relay that trips at 5 mA and separate circuit interrupter device.

A shunt-trip breaker with a ground fault relay is a common configuration widely adopted across multiple market segments and decades of reliable operation. The ground fault circuit interrupter solution is suitable for single or three phase, 15 A to 100 A branch circuits that protects against both overload current and ground fault currents greater than 5 mA.

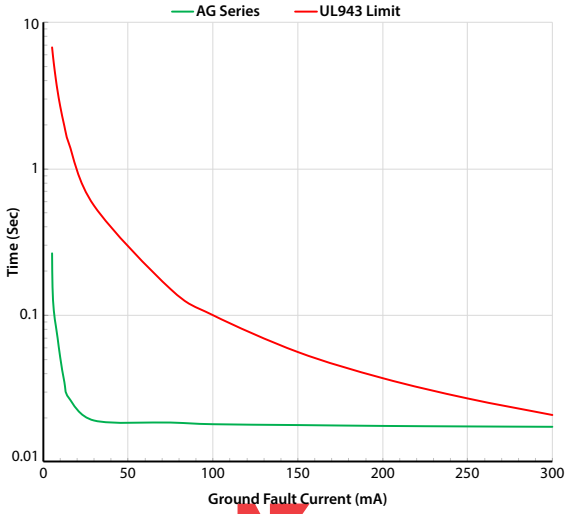


A cost effective, compact ground fault circuit interrupter solution installed in the existing panelboard. Installation does not require special hardware, no special tools, easy installation, easy setup and compatible across all OEM panel boards. Can service 30 A to 50 A 120 VAC to 240 VAC single phase or 15 A to 100 A, 208 VAC to 240 VAC three phase branch circuit. Need help selecting an AC ground fault relay for the branch circuit and appliance. Click Here to Review our Ground Fault Relay Selection Guide.

When a ground fault current exceeds 5 mA NK Technologies AG, or AGL, ground fault current relay will respond "within an established period of time", refer to figure 1. When circuit interrupter (CI) receives a fault signal from the relay, CI will de-energize the branch circuit or portion thereof.

When a shunt-trip breaker is manually reset and the ground fault current incidence has not been cleared, then the ground fault relay will command CI to de-energize the branch circuit. It is necessary to energize the branch circuit removing the ground fault defect.

ESTABLISHED PERIOD OF TIME
AG SERIES -VS- UL943



COMMERCIAL KITCHENS - Protect Circuits to 100 Amps

How to Select a Ground Fault Relay

Two base models are offered:

AG Ground Fault Relay
for wire bundle diameter sizes up to 0.75 " diameter

AGL Ground Fault Relay
for wire bundle diameter sizes up to 1.82" diameter

Which AC ground fault relay series to select is based on whether all current carrying conductors fit through the aperture window. Configuring the ground fault relay order code is dependent upon the circuit-interrupter chosen and appliance type. Included is a table, Ground Fault Relay Guide, to ease configuring the ground fault relay order code. To use the Ground Fault Relay Guide table the following details are needed:

1) Branch circuit specifications: amperage capacity and load configuration example 50A, 208 VAC, 3 Phase, Delta (3+1)
2) Circuit-Interrupter type: Shunt-trip breaker, contactor, or relay
   Note: Shunt-trip breaker is recommended
3) Optional: appliance type

Recommend either AG or AGL series ground fault relay for commercial kitchens and other wet locations per 2020 Edition National Electric Code (NEC) 210.8 (B) through (F)), and 422.5 special appliances. Which relay is best for the branch circuit is dependent upon whether wire bundle passes through aperture of the ground fault relay.

Ground Fault Selection Guide above is provided to ease the selection process and recommendations are based on using a shunt-trip breaker and THHN wire. Given numerous wire and local code variants, Ground Fault Selection Guide is reference only.

Other than THHN wire and/or non-NEC cable correction factors, use application note How to Calculate Bundle Diameter to confirm wire bundle will pass through aperture of either AG or AGL ground fault relay.

After verifying all current carrying conductors pass through the relay's aperture, Click here to select the correct model for you application.

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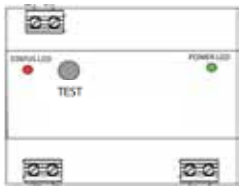
Ground Fault Relay Selection Guide

Branch Circuit Specifications & Details					Recommendation for all appliances except electric ovens		Recommendation for electric ovens or appliance is not disclosed	
Breaker Rating[1]	Wire Size[2] AWG	Corrected[3] Conductor Amperage Capacity (A)	Calculated Wire Bundle Diameter[4]	Branch Circuit Configuration	AG1-SDT1-120-DEN-005	AGL1-SDT1-120-DEN-005	AG3-SDT1-120-DEN-TR3	AGL3-SDT1-120-DEN-TR3
30 A	10	36	0.353	3 Phase, Delta, up to 480 V (3+1)	X		X	
	10	29	0.396	3 Phase, WYE, up to 480 V (4+1)	X		X	
	10	36	0.328	1 Phase, up to 240 V (2+1)	X		X	
40A	8	50	0.474	3 Phase, Delta, up to 480 V (3+1)	X		X	
	8	40	0.531	3 Phase, WYE, up to 480 V (4+1)	X		X	
	8	50	0.440	1 Phase, up to 240 V (2+1)	X		X	
50A	8	50	0.474	3 Phase, Delta, up to 480 V (3+1)	X		X	
	6	55	0.618	3 Phase, WYE, up to 480 V (4+1)	X		X	
	8	50	0.440	1 Phase, up to 240 V (2+1)	X		X	
60A	6	68	0.552	3 Phase, Delta, up to 480 V (3+1)	X		X	
	4	69	0.785	3 Phase, WYE, up to 480 V (4+1)		X		X
	6	68	0.512	1 Phase, up to 240 V (2+1)	X		X	
80A	4	86	0.700	3 Phase, Delta, up to 480 V (3+1)	X		X	
	3	84	0.852	3 Phase, WYE, up to 480 V (4+1)		X		X
	4	86	0.650	1 Phase, up to 240 V (2+1)	X		X	
90A	3	105	0.761	3 Phase, Delta, up to 480 V (3+1)		X		X
	2	95	0.932	3 Phase, WYE, up to 480 V (4+1)		X		X
	3	105	0.706	1 Phase, up to 240 V (2+1)	X		X	
100A	3	105	0.761	3 Phase, Delta, up to 480 V (3+1)		X		X
	1	106	1.168	3 Phase, WYE, up to 480 V (4+1)		X		X
	3	105	0.706	1 Phase, up to 240 V (2+1)	X		X	

Note(s)

1. Ground fault relay recommendations based on mating with a shunt-trip breaker only
2. Wire type: CU | THHN
3. Corrected conductor amperage capacity @ +40°C ambient temperature and as required correction factor for more than 3 conductors in raceway, reference NEC Tables: 310.15(B)(1), 310.15(C)(1) & 310.16
4. Reference How to Calculate Wire Bundle Diameter Application Note



AC Ground Fault Relay Relevant Features and Options

A properly configured NK Technologies AC ground fault relay will trip in range 4 mA to 6 mA and trips within an established period-of-time, meeting intent of 2020 & 2023 National Electric Code.

Standard features:

- Manual ground fault push-to test.
- Two visual indicators: power status and ground fault trip status.

User selectable output options:

- Normally Open/Normally Closed solid state switch or mechanical relay outputs.
- Normally energized or normally de-energized contacts.

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Shunt Trip Connection

NK Technologies manufactures ground fault sensors, which can be used in a wide range of applications, from operating a shunt trip circuit breaker to providing an alarm contact or analog signal to a programmable logic controller. Many models are UL recognized as a component under UL1053, ground fault sensing and relaying equipment. Others are UL listed under UL508. Contact the factory for any needed clarification.

The drawing on the right (Fig. 1) shows an NK AG series ground fault sensor powered from a separate circuit. The sensor selected can be powered by 120 VAC or 24 VAC or DC, but in this example, the shunt trip and sensor use the same power supply voltage. The output of the sensor is a single-pole, double throw relay, so when used to operate a shunt trip circuit breaker operating mechanism, the normally open contact of a normally de-energized (DEN) model would be the best choice. With the -DEN model contact action, the sensor operates the output relay only when fault over the setpoint occurs. When power is applied to the sensor, an indicating LED will light, and another LED will indicate when the sensor has tripped.

The normally-energized version (-ENE in the model number) causes the output relay to change state as soon as power is applied to the sensor terminals, so the shunt trip solenoid would be connected between terminals 4 and 5.

The voltage of the primary circuit can be up to 600 volts AC and meet the specifications of UL. Remember that all current-carrying conductors must pass through the sensing aperture, including the neutral if the load uses one. The latching output is more commonly used to control the power to a contactor coil. Shunt trip operating solenoids are designed for momentary energization.

The lower drawing (Fig. 2) shows the larger AGL series in the same application but powered with the primary (load carrying) circuit through a control power transformer. The sensor can be powered by 120 VAC or 24 VAC or DC. The terminal markings are different than the AG series above. The power supply is connected to terminals 1 and 2. Terminals 3 and 4 are open when the product is taken out of the box. The -DEN contact action allows this set of contacts to remain open when power is applied to the sensor, and to close when a fault to earth is detected. Terminals 5 and 6 are closed, opening on a detected fault. The -ENE contact action closes 3 to 4 and opens 4 to 5. When a fault is sensed or when power is removed from the sensor, terminals 3 to 4 open and 4 to 5 close.

There is no connection from the sensor power to the output relay contacts. This allows different voltages to be used to power the sensor than the voltage that will be controlled with the output relay.

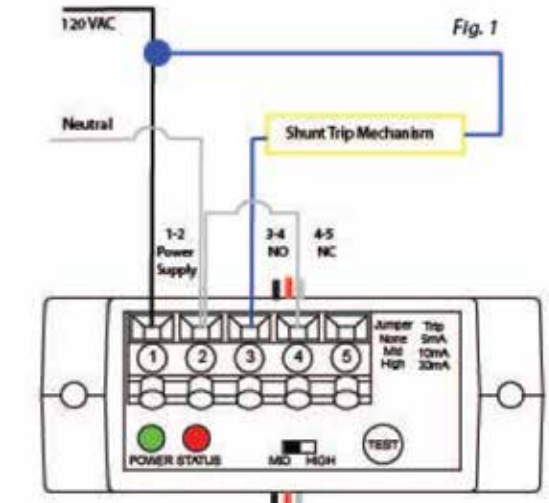

Fig. 1

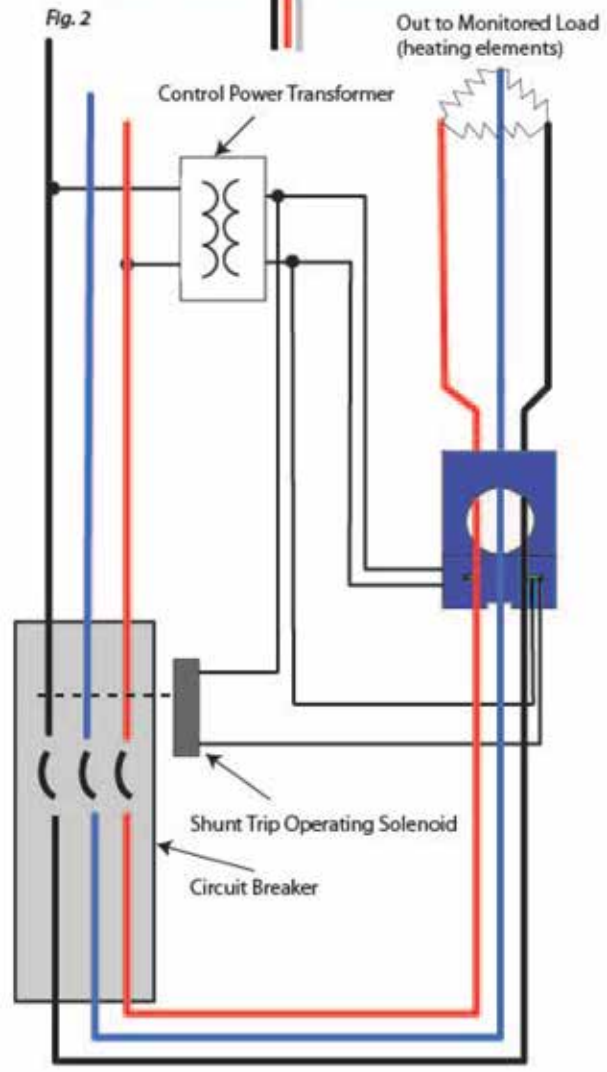

Fig. 2

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Shunt Trip Breaker Options

A Shunt Trip Beaker is required along with a NK Technologies AG or AGL Ground Fault Relay to complete 5mA Ground Fault Interrupter Solution. NK Technologies does not sell Shunt Trip Breakers. To make it easier for you complete your solution see the table below showing the correct part number for many of the leading Shunt Trip Breaker manufacturers.

If you need technical assistance contact our Engineers by Phone, Chat, or Email.

MFR	# Poles	Voltage	Amperage	MPN (10,000A IR)
ABB (GE)	3	120/240	20	THQL32020ST1
ABB (GE)	3	120/240	30	THQL32030ST1
ABB (GE)	3	120/240	40	THQL32040ST1
ABB (GE)	3	120/240	50	THQL32050ST1
ABB (GE)	3	120/240	60	THQL32060ST1
ABB (GE)	3	120/240	100	THQL32100ST1
ABB (GE)	2	120/240	20	THQL2120ST1
ABB (GE)	2	120/240	30	THQL2130ST1
ABB (GE)	2	120/240	35	THQL2135ST1
ABB (GE)	2	120/240	40	THQL2140ST1
ABB (GE)	2	120/240	50	THQL2150ST1
ABB (GE)	2	120/240	60	THQL2160ST1
ABB (GE)	2	120/240	100	THQL21100ST1
Eaton (Cutler Hammer)	3	120/240	10	CHP310ST*
Eaton (Cutler Hammer)	3	120/240	15	CHP315ST*
Eaton (Cutler Hammer)	3	120/240	20	CHP320ST*
Eaton (Cutler Hammer)	3	120/240	25	CHP325ST*
Eaton (Cutler Hammer)	3	120/240	30	CHP330ST*
Eaton (Cutler Hammer)	3	120/240	35	CHP335ST*
Eaton (Cutler Hammer)	3	120/240	40	CHP340ST*
Eaton (Cutler Hammer)	3	120/240	45	CHP345ST*
Eaton (Cutler Hammer)	3	120/240	50	CHP350ST*
Eaton (Cutler Hammer)	3	120/240	60	CHP360ST*
Eaton (Cutler Hammer)	2	120/240	10	CHP210ST*
Eaton (Cutler Hammer)	2	120/240	15	CHP215ST*
Eaton (Cutler Hammer)	2	120/240	20	CHP220ST*
Eaton (Cutler Hammer)	2	120/240	25	CHP225ST*
Eaton (Cutler Hammer)	2	120/240	30	CHP230ST*
Eaton (Cutler Hammer)	2	120/240	35	CHP235ST*
Eaton (Cutler Hammer)	2	120/240	40	CHP240ST*
Eaton (Cutler Hammer)	2	120/240	45	CHP245ST*
Eaton (Cutler Hammer)	2	120/240	50	CHP250ST*
Eaton (Cutler Hammer)	2	120/240	60	CHP260ST*

MFR	# Poles	Voltage	Amperage	MPN (10,000A IR)
Siemens	3	120/240	15	Q31500S01
Siemens	3	120/240	25	Q32500S01
Siemens	3	120/240	30	Q33000S01
Siemens	3	120/240	35	Q33500S01
Siemens	3	120/240	45	Q34500S01
Siemens	3	120/240	50	Q35000S01
Siemens	3	120/240	60	Q36000S01
Siemens	3	120/240	70	Q37000S01
Siemens	3	120/240	80	Q38000S01
Siemens	3	120/240	90	Q39000S01
Siemens	2	120/240	20	Q22000S01
Siemens	2	120/240	25	Q22500S01
Siemens	2	120/240	30	Q23500S01
Siemens	2	120/240	35	Q23500S01
Siemens	2	120/240	40	Q24000S01
Siemens	2	120/240	45	Q24500S01
Siemens	2	120/240	50	Q25000S01
Siemens	2	120/240	60	Q26000S01
SquareD	3	120/240	15	QOU3151021
SquareD	3	120/240	20	QOU3201021
SquareD	3	120/240	30	QOU3301021
SquareD	3	120/240	40	QOU3401021
SquareD	3	120/240	50	QOU3501021
SquareD	3	120/240	60	QOU3601021
SquareD	3	120/240	70	QOU3701042
SquareD	3	120/240	80	QOU3801042
SquareD	3	120/240	100	QOU31001042
SquareD	2	120/240	20	QOU2201021
SquareD	2	120/240	25	QOU2251042
SquareD	2	120/240	30	QOU2301021
SquareD	2	120/240	40	QOU2401021
SquareD	2	120/240	50	QOU2501021
SquareD	2	120/240	60	QOU2601021

* If you prefer a CH, simply replace the CHP in the model number.

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How to Calculate a Wire Bundle Diameter that Matches the Aperture Size of a Ground Fault Sensor

CONDUCTORS UP TO 0.75" DIAMETER

CONDUCTORS UP TO 1.31" DIAMETER

CONDUCTORS UP TO 1.82" DIAMETER

CONDUCTORS UP TO 4.00" DIAMETER

Introduction: How to determine whether ground fault sensor's aperture window diameter will be the right size for your bundle of wires. Using only a few key pieces of information: wire diameter and number of identical diameter conductors to pass through the NK Technologies ground fault sensor.

Note: If all conductor diameters are not identical, then contact NK Technologies technical services at ***techsupport@nktechnologies.com*** or (800) 959-4014 ext. Services available from 7:30 am – 5:00 pm PST.

Scope: Calculation of diameter of outer circle to which multiple number of identical inner circles can be inserted. References Kravitz table and Friedman's formulas

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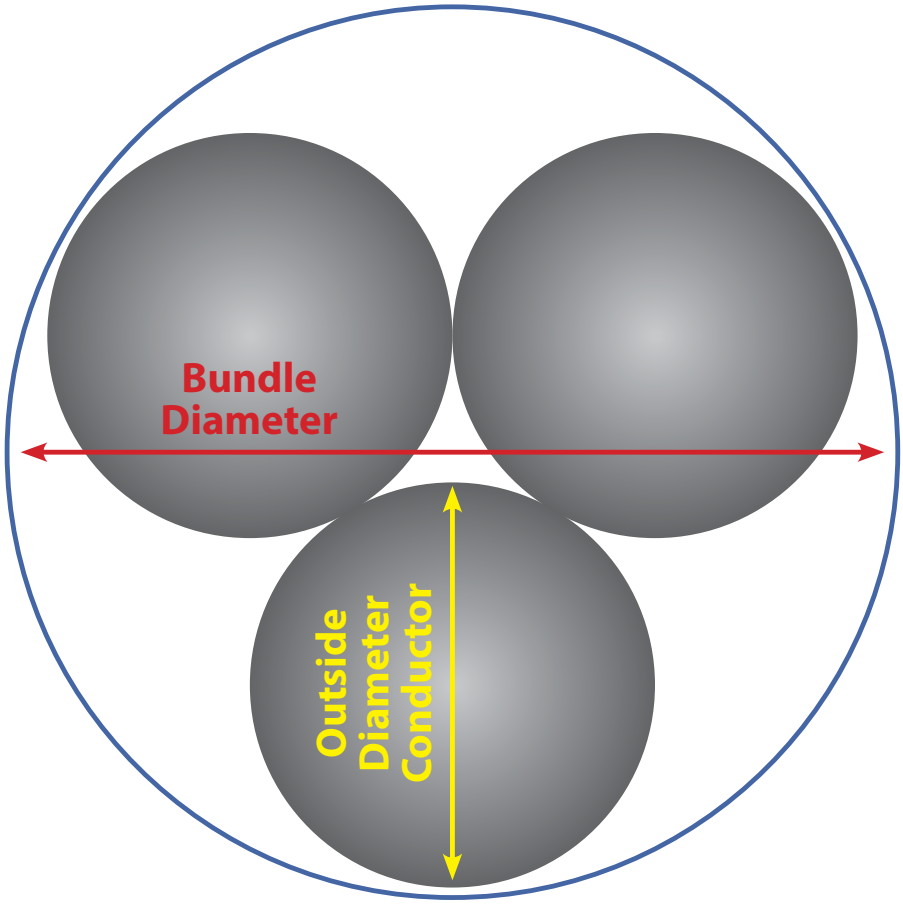
How to Calculate a Wire Bundle Diameter... continued



Overall wire bundle diameter is calculated using the following equation:

D_{BUNDLE}= CF*D_{MAX}

Where D_{BUNDLE} is diameter of bundle of conductors, D_{WIRE} is outside diameter of actual conductor, 'CF" is correction factor

Procedure

Equation 1: D_{BUNDLE}= CF*D_{MAX}

1) Locate manufacture's maximum outside diameter of the conductor **(D_{MAX})**. If conductor sizes are insignificantly different in size, then use largest outside diameter to achieve best results.

   Calculate Maximum Diameter Conductor using equation 2

   Equation 2: D_{MAX} = D_{WIRE} x (1+ 'Installation Margin')

   a) Installation Margin: add tolerance to ease assembly during installation, adding 3 % to 5 % is recommended.

   b) If unable to locate diameter of the conductor from manufacture, a table is provided for most widely used conductor type. Refer to Table 1

2) Lookup correction factor (**CF**) using Table 2, where **CF** is dependent on number of conductors to be routed through NK Technologies ground fault sensor

3) Calculate wire bundle diameter (**D_{BUNDLE}**) = using equation 1, above.

4) Using calculated wire bundle diameter (**D_{BUNDLE}**) select aperture window diameter of ***NK Technologies ground fault sensors***, Select aperture widow diameter greater than the calculated wire bundle diameter (**D_{BUNDLE}**).

COMMERCIAL KITCHENS - Protect Circuits to 100 Amps

How to Calculate a Wire Bundle Diameter... continued

Example:

3 Phase branch circuit; 208V, 50A, 3 Phase Delta load, aka '3 + 1' or '4 wire'

1) $\mathbf{D_{MAX}}$ = 0.265 x (1 + 0.05)= is **0.278 inch**,
   a. THHN wire (6-01THHN), per Table 1 nominal final diameter ($\mathbf{D_{WIRE}}$) is 0.265 inch
   b. Assembly margin= 5%
2) **CF= 2.155**
   a. Three (3) conductors will pass through the ground fault sensor aperture
3) $\mathbf{D_{BUNDLE}}$ = 2.155 x 0.278= **0.600 inch**
4) AG Series is best fit for the application.

   a. Conductors Up To 0.75" Diameter
   b. Where 0.571 inch ($\mathbf{D_{BUNDLE}}$) < 0.75 inch (AG Series aperture diameter)

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How to Calculate a Wire Bundle Diameter... continued

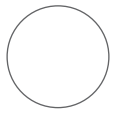
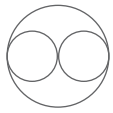
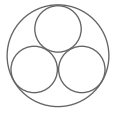
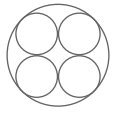
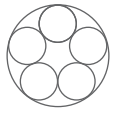
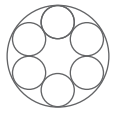
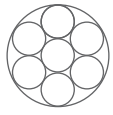
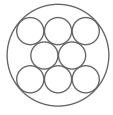
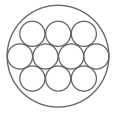
Table 1, THNN Conductor Diameter, reference USA Wire & Cable, Inc.

USAWC Part #	Size AWG or kcmil	No. of Strands	Thickness in Mils		Nom-final Diam. Inches
			PVC Insula-tion	Nylon Jacket	
Solid (THWN or THHN)					
14-01SOLTHHN	14	Solid	15	4	.105
12-01SOLTHHN	12	Solid	15	4	.122
10-01SOLTHHN	10	Solid	20	4	.153
Stranded (MTW or THWN or THHN)					
14-01THHN	14	19	15	4	.112
12-01THHN	12	19	15	4	.130
10-01THHN	10	19	20	4	.164
8-01THHN	8	19	30	5	.220
6-01THHN	6	19	30	5	.256
4-01THHN	4	19	40	6	.325
3-01THHN	3	19	40	6	.353
2-01THHN	2	19	40	6	.386
1-01THHN	1	19	50	7	.443
1/0-01THHN	1/0	19	50	7	.484
2/0-01THHN	2/0	19	50	7	.529
3/0-01THHN	3/0	19	50	7	.579
4/0-01THHN	4/0	19	50	7	.635
250-01THHN	250	37	60	8	.703
300-01THHN	300	37	60	8	.756
350-01THHN	350	37	60	8	.806
400-01THHN	400	37	60	8	.851
500-01THHN	500	37	60	8	.934
600-01THHN	600	61	70	9	1.03
750-01THHN	750	61	70	9	1.14
1000-01THHN	1000	61	70	9	1.32

Note: Manufacturer could update this table without notice, leading to potential no fit condition.

How to Calculate a Wire Bundle Diameter... continued

Table 2, Correction Factor based on Kravitz's table and Friedman's formula

Number of Wires in Bundle	Correction Factor (CF)	Illustration
1	1.000	
2	2.000	
3	2.155	
4	2.414	
5	2.701	
6	3.000	
7	3.000	
8	3.646	
9	3.800	
10	4.000	

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Friendman, E. "Circles in Circles" ***http://www.stetson.edu/~efriedma/cirincir/***
Kravitz, S. "Packing Cylinders into Cylindrical Containers", Math. Mag 44, 65-70, 1967
THNN wire specification; USA Wire & Cable, page 2, Nom Final Diam. Inches

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5 mA Ground Fault Protection — Frequently Asked Questions

What is the difference between the AG and the AGL Series?

The main difference between to the two ground fault relays is the aperture diameter. All current carrying conductors to load must be able to pass through aperture.

- AG aperture diameter is 0.75"
- AGL aperture diameter is 1.82"

Which devices do I need to purchase?

The 5 mA ground fault circuit interrupter solution has two readily available devices.

- Quantity 1, AC ground fault relay; recommend AG or AGL series
- Quantity 1, Circuit-Interrupter; choose MCB with shunt trip option suitable for branch circuit amperage capacity. NK's AG and AGL ground fault relays have user selectable options to ensure compatibility across all OEM's shunt trip breaker, contactor, or relay.

What is "established period of time" and does AG and AGL comply?

"Established period of time" is a NEC undefined term. "Established period of time" is found in a NEC's defined term "GFCI". This definition refers to de-energizing the branch circuit within an "established period of time". NEC provides an informal note to clarify "established period of time" by referring to UL943.

Yes, both AG and AGL series response time is within the response time requirement defined by UL943. To learn more review application note 5 mA Ground Fault Circuit Interrupter Solution.

Does AG or AGL trip within ground fault current range 4 mA to 6 mA, per NEC defined term GFCI?

Yes, both AG's or AGL's have two set point options. The first option is a fixed 5 mA setpoint from the factory, refer to AG1 or AGL1. The second option is called a tri-state setpoint, refer to either AG3 or AGL3.

Does AG or AGL trip have manual push to test feature and visual indicators?

Yes, both AG or AGL have user accessible manual push-to-test button to verify operation of the relay and two visual indicators for power and ground fault trip status.

How to resolve incidence when local building inspector has objection to AG3, or AGL3, having an adjustable setpoint? (Similar objection, AG3 or AGL3 must have fixed setpoint)

NK Technologies has come across this objection and successfully resolved all incidences. Based on NK Technologies experience the local building inspector is concerned a non-authorized employee may move the ground fault setpoint jumper thereby adjusting the ground fault current trip point above 5 mA.

Resolution is to remove and discard the jumper. When jumper is not installed the ground fault relay will default to lowest fault current setpoint. Where 5 mA is the lowest fault current setpoint for both AG3 and AGL3 ground fault relays.

BASICS & TECHNICAL REFERENCE

2020 & 2023 NEC Impact to the Market

The 2020 and 2023 editions of the National Electric Code (NEC) section 210.8 (B) have expanded GFCI regulations in areas with sink and permanent provisions for food preparation and cooking, directly affecting commercial kitchens. The updated code covers GFCI protection for personnel in "other than dwelling" units and focuses on GFCI protection for applicable kitchen appliances powered by 3-phase power (e.g. line to line, < 250 VAC, 208 VAC typical). However, ideal GFCI solution would also be compatible with 2-pole (e.g. line to line, 240 VAC).

Both 2020 and 2023 NEC has increased GFCI requirements in more locations. What this means to architects, designers, electricians, general contractors, or program managers is a year over year increase in demand for breakers with GFCI protection. Will manufacturers of breakers continue to struggle servicing the demand for 15 A to 100 A, 2 or 3 pole, GFCI MCB's?

Summary of 2023 Code Changes

2023 Edition NEC article 210.8 (B) related to spaces "other than dwellings" has been rewritten to clarify and expand GFCI requirements.

a) The word "Kitchens" was added as article 210.8(B)(2) and requires all single phase (50A or less) or 3 phase (100A or less) plug-in-cord-connected appliances to have GFCI protection.
b) A new addition, article 210.8(B)(4), covers buffet serving areas, commonly referred to as break areas within commercial occupancy. The effected spaces include areas with provisions for food service. beverage service, or cooking. Any receptacles and special appliances within these areas shall be GFCI protected.
c) The specific appliances list was updated (article 210.8(D)(8) through (12)) for appliances that are commonly installed as hardwired outlets, 60A or less. Shock hazards exist whether appliances are energized from outlet (hardwired) or receptacle (cord and plug).
d) A new code (Stationary appliances, article 210.8(B)(7)) revised the code to include stationary appliances located within 1.8 m (6 ft) of the top inside edge of a sink shall have GFCI protection.

A 5 mA Ground Fault Protection System

A 5 mA ground fault protection system includes a breaker with shunt trip option and an AC ground fault sensor. All NK Technologies ground fault relays have numerous options to ensure compatibility with any shunt trip breaker (MCB or MCCB), relay or contactor. NK Technologies ground fault sensors are compact in size, easily installed within the panelboard. A shunt-trip breaker with ground fault sensor will protect 15 A to 100+ A branch circuits from both overload current and ground fault currents exceeding 5 mA.

A cost effective, compact ground fault protection system that is installed with no special hardware, no special tools, easy installation, easy setup and compatible across all OEM panel boards. AG series ground fault sensor can service up to 50 A single (120 VAC to 240 VAC) phase or up to 100 A three phase (208 VAC or 240 VAC) branch circuit.

5 mA Ground Fault Solutions for Single or 3 Phase up to 100 Amps

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Ground Fault Sensing and Protection

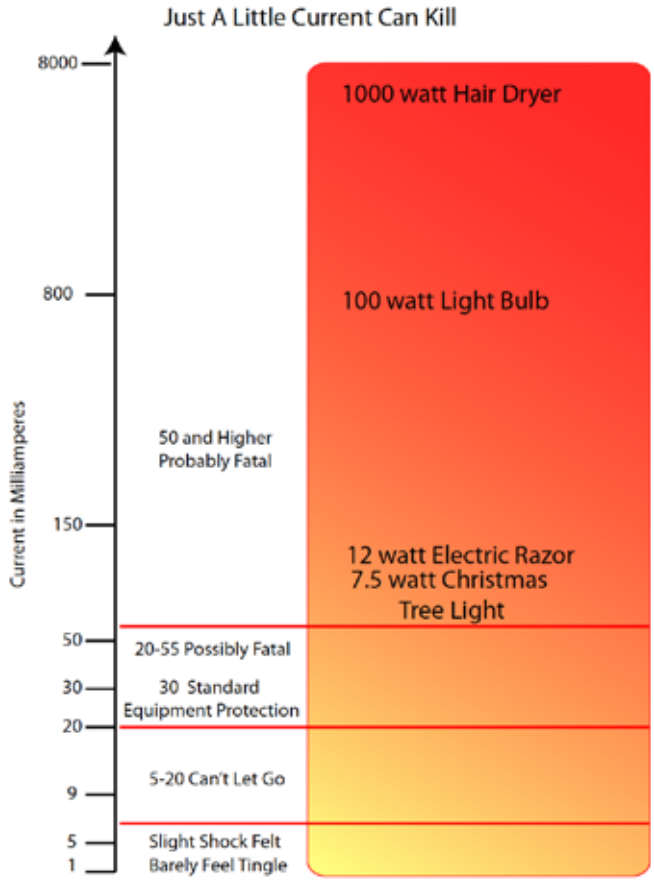
The potentially deadly dangers of electricity were discovered early in the development of the phenomenon's commercial application potential. Within a decade following Thomas Alva Edison's patent for the incandescent lamp in 1880, the first electric chair was used to execute a convicted murderer. The term electrocution was coined by combining electricity and execution, specifically to describe the effect of the chair, but now describes the result of human contact with an electrical source. As electricity usage became universal during the following half century and beyond, countless deaths occurred almost exclusively from accidental contact with energized conductors.

Finally in the 1960s, extensive research determined how much current and voltage were needed to cause ventricular fibrillation (where a heart stops beating) in humans. These studies showed that there are a number of conditions that increase the chance of death when there is contact with an energized circuit, and that fibrillation occurs with current as low as 70 milliamperes through the heart. Once the magnitude of current that the human body needed to be protected from was determined, methods of detecting this low level current and automatically disconnecting the offending circuit from the power source could be developed. The concurrent refinement of the transistor provided a solution, where current as low as 0.003 amps could be sensed, amplified and used to energize a relay.

In the years since the 1960's, sensing ground fault leakage has undergone a rapid evolution. Advances in electronic and mechanical design have provided much more sophisticated and effective protection for personnel and the equipment they operate. The result is vastly improved safety in the home and in the workplace.

OSHA has published reactions in the human body to low level currents:

- 1 mA, a slight tingle is felt.
- 5 mA, a slight shock is felt, not painful but disturbing. The average individual can let go, but involuntary reactions can lead to injuries.
- 6–25 mA, painful shock, muscular control is lost.
- 9–30 mA, this is called the freezing current or "let-go" range. At this level many humans cannot get their muscles to work, and they can't open their hand to let go of a live conductor.
- 50–150 mA, there will be extreme pain, respiratory arrest, and severe muscular contractions. The individual cannot let go, death is possible.
- 1000–4300 mA, there is ventricular fibrillation (the pumping action to the heart ceases). Muscular contraction and nerve damage occur. Death is most likely.
- 10,000+ mA, there will be cardiac arrest, severe burns and probable death.



Protecting Processes

The National Electric Code calls for ground fault protection on heating equipment in Section 427-22: "Ground-fault protection of equipment shall be provided for each branch circuit supplying electric heating equipment." There is an exception: "In industrial establishments where conditions of maintenance and supervision ensure that only qualified persons will service the installed systems, and continued circuit operation is necessary for safe operation of equipment or processes, alarm indication of ground fault shall be required."

BASICS & TECHNICAL REFERENCE

Detect Fault Current Before a Failure Occurs

There are quite a number of applications in industry where it is required or desired to monitor electrical heating elements for leakage to earth. Producing an output signal proportional to this current to earth is a way to monitor deteriorating insulation or direct shorts to ground.

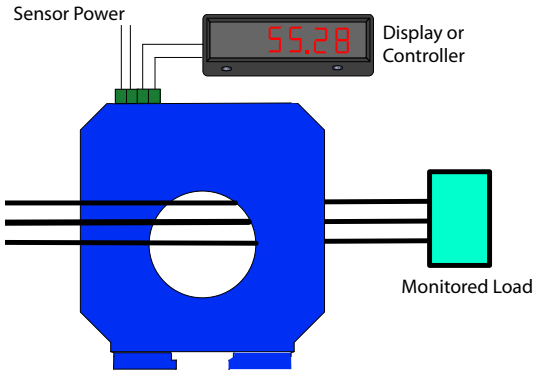
The sensor produces a signal which can be read with a panel meter or a programmable logic controller. If the fault current exceeds an allowable level, a limit alarm contact in the meter or an output from the PLC can be used to control an audible or visual signal letting the equipment operator know a problem is imminent or a hard fault to earth has occurred.

When a heating process should not be stopped until the process is completed, shutting of the power through a Ground Fault Circuit Interrupter is not an ideal approach. An example of this is annealing parts for an internal combustion engine. If the heating process is stopped before the parts are brought to the target temperature, they will not be properly hardened and must be scrapped. While letting the process complete is not as safe as disconnecting the offending circuit supply source power, it is certainly better and more cost effective than scrapping the parts.

With an analog sensor output, there can be two or more alarm points. For example, one alarm would trip if fault current exceeds 10 or 20 mA, another alarm point can be set to trigger when fault exceeds 50 mA, so that more extensive action could be taken if a higher fault current is detected.

Additional applications include, monitoring electric heating processes, semiconductor wafer fabrication, AC motor loads, plastic molding processes, heat trace cable systems, and snow melt protection.

Monitor electric motors for leakage to earth in a pump station.



AGT-FD Series
Ground Fault Detection - Analog Output

The AGT-FD detects faults to earth from 0 mA to 100 mA and produces 0–10 VDC output in proportion to 0–100 mA. The sensing window is large enough to allow three or four wires carrying 100 amps or more to pass through the sensing window easily. The AGT-FD can also be used to measure and monitor any low value AC circuit current by passing just one of the conductors through the sensing window.

The unit is powered with 24 volts, AC or DC, and can be mounted on a back panel with screws or snapped onto a DIN rail. The power and output terminals are mounted to the top of the sensor using fingersafe for easy access.

AGT-FD Series

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How to Calculate a Wire Bundle Diameter that Matches the Aperture Size of a Ground Fault Sensor

CONDUCTORS UP TO 0.75" DIAMETER

CONDUCTORS UP TO 1.31" DIAMETER

CONDUCTORS UP TO 1.82" DIAMETER

CONDUCTORS UP TO 4.00" DIAMETER

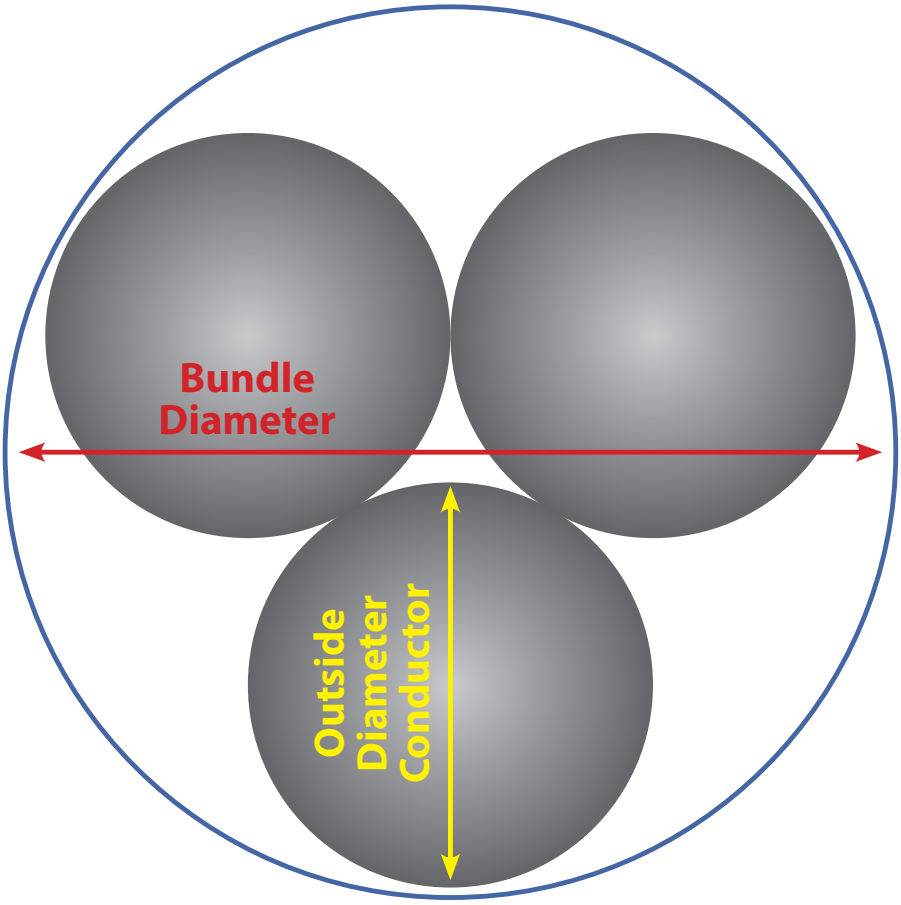
Introduction: How to determine whether ground fault sensor's aperture window diameter will be the right size for your bundle of wires. Using only a few key pieces of information: wire diameter and number of identical diameter conductors to pass through the NK Technologies ground fault sensor.

Note: If all conductor diameters are not identical, then contact NK Technologies technical services at ***techsupport@nktechnologies.com*** or (800) 959-4014 ext. Services available from 7:30 am – 5:00 pm PST.

Scope: Calculation of diameter of outer circle to which multiple number of identical inner circles can be inserted. References Kravitz table and Friedman's formulas

BASICS & TECHNICAL REFERENCE

How to Calculate a Wire Bundle Diameter... continued



Overall wire bundle diameter is calculated using the following equation:

D_{BUNDLE}= CF*D_{MAX}

Where D_{BUNDLE} is diameter of bundle of conductors, D_{WIRE} is outside diameter of actual conductor, 'CF" is correction factor

Procedure

Equation 1: D_{BUNDLE}= CF*D_{MAX}

1) Locate manufacture's maximum outside diameter of the conductor **(D_{MAX})**. If conductor sizes are insignificantly different in size, then use largest outside diameter to achieve best results.

   Calculate Maximum Diameter Conductor using equation 2

   Equation 2: D_{MAX} = D_{WIRE} x (1+ 'Installation Margin')

   a) Installation Margin: add tolerance to ease assembly during installation, adding 3 % to 5 % is recommended.

   b) If unable to locate diameter of the conductor from manufacture, a table is provided for most widely used conductor type. Refer to Table 1

2) Lookup correction factor (**CF**) using Table 2, where **CF** is dependent on number of conductors to be routed through NK Technologies ground fault sensor

3) Calculate wire bundle diameter (**D_{BUNDLE}**) = using equation 1, above.

4) Using calculated wire bundle diameter (**D_{BUNDLE}**) select aperture window diameter of ***NK Technologies ground fault sensors***, Select aperture widow diameter greater than the calculated wire bundle diameter (**D_{BUNDLE}**).

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How to Calculate a Wire Bundle Diameter... continued

Example:

3 Phase branch circuit; 208V, 50A, 3 Phase Delta load, aka '3 + 1' or '4 wire'

1) D_{MAX} = 0.265 x (1 + 0.05)= is **0.278 inch**,
   a. THHN wire (6-01THHN), per Table 1 nominal final diameter (D_{WIRE}) is 0.265 inch
   b. Assembly margin= 5%
2) **CF= 2.155**
   a. Three (3) conductors will pass through the ground fault sensor aperture
3) D_{BUNDLE} = 2.155 x 0.278= **0.600 inch**
4) AG Series is best fit for the application.

   a. Conductors Up To 0.75" Diameter
   b. Where 0.571 inch (D_{BUNDLE}) < 0.75 inch (AG Series aperture diameter)

Commercial Kitchens

Pump Monitoring

Semiconductor Fabrication

How to Calculate a Wire Bundle Diameter... continued

Table 1, THNN Conductor Diameter, reference USA Wire & Cable, Inc.

USAWC Part #	Size AWG or kcmil	No. of Strands	Thickness in Mils		Nom-final Diam. Inches
			PVC Insula-tion	Nylon Jacket	
Solid (THWN or THHN)					
14-01SOLTHHN	14	Solid	15	4	.105
12-01SOLTHHN	12	Solid	15	4	.122
10-01SOLTHHN	10	Solid	20	4	.153
Stranded (MTW or THWN or THHN)					
14-01THHN	14	19	15	4	.112
12-01THHN	12	19	15	4	.130
10-01THHN	10	19	20	4	.164
8-01THHN	8	19	30	5	.220
6-01THHN	6	19	30	5	.256
4-01THHN	4	19	40	6	.325
3-01THHN	3	19	40	6	.353
2-01THHN	2	19	40	6	.386
1-01THHN	1	19	50	7	.443
1/0-01THHN	1/0	19	50	7	.484
2/0-01THHN	2/0	19	50	7	.529
3/0-01THHN	3/0	19	50	7	.579
4/0-01THHN	4/0	19	50	7	.635
250-01THHN	250	37	60	8	.703
300-01THHN	300	37	60	8	.756
350-01THHN	350	37	60	8	.806
400-01THHN	400	37	60	8	.851
500-01THHN	500	37	60	8	.934
600-01THHN	600	61	70	9	1.03
750-01THHN	750	61	70	9	1.14
1000-01THHN	1000	61	70	9	1.32

Note: Manufacturer could update this table without notice, leading to potential no fit condition.

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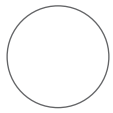
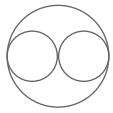
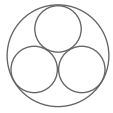
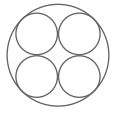
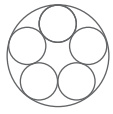
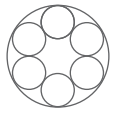
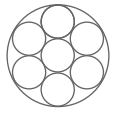
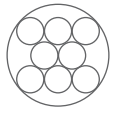
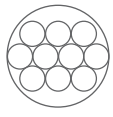
How to Calculate a Wire Bundle Diameter... continued

Table 2, Correction Factor based on Kravitz's table and Friedman's formula

Number of Wires in Bundle	Correction Factor (CF)	Illustration
1	1.000	
2	2.000	
3	2.155	
4	2.414	
5	2.701	
6	3.000	
7	3.000	
8	3.646	
9	3.800	
10	4.000	

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Friendman, E. "Circles in Circles" ***http://www.stetson.edu/~efriedma/cirincir/***

Kravitz, S. "Packing Cylinders into Cylindrical Containers", Math. Mag 44, 65-70, 1967

THNN wire specification; USA Wire & Cable, page 2, Nom Final Diam. Inches

BASICS & TECHNICAL REFERENCE

Shunt Trip Connection

NK Technologies manufactures ground fault sensors, which can be used in a wide range of applications, from operating a shunt trip circuit breaker to providing an alarm contact or analog signal to a programmable logic controller. Many models are UL recognized as a component under UL1053, ground fault sensing and relaying equipment. Others are UL listed under UL508. Contact the factory for any needed clarification.

The drawing on the right (Fig. 1) shows an NK AG series ground fault sensor powered from a separate circuit. The sensor selected can be powered by 120 VAC or 24 VAC or DC, but in this example, the shunt trip and sensor use the same power supply voltage. The output of the sensor is a single-pole, double throw relay, so when used to operate a shunt trip circuit breaker operating mechanism, the normally open contact of a normally de-energized (DEN) model would be the best choice. With the -DEN model contact action, the sensor operates the output relay only when fault over the setpoint occurs. When power is applied to the sensor, an indicating LED will light, and another LED will indicate when the sensor has tripped.

The normally-energized version (-ENE in the model number) causes the output relay to change state as soon as power is applied to the sensor terminals, so the shunt trip solenoid would be connected between terminals 4 and 5.

The voltage of the primary circuit can be up to 600 volts AC and meet the specifications of UL. Remember that all current-carrying conductors must pass through the sensing aperture, including the neutral if the load uses one. The latching output is more commonly used to control the power to a contactor coil. Shunt trip operating solenoids are designed for momentary energization.

The lower drawing (Fig. 2) shows the larger AGL series in the same application but powered with the primary (load carrying) circuit through a control power transformer. The sensor can be powered by 120 VAC or 24 VAC or DC. The terminal markings are different than the AG series above. The power supply is connected to terminals 1 and 2. Terminals 3 and 4 are open when the product is taken out of the box. The -DEN contact action allows this set of contacts to remain open when power is applied to the sensor, and to close when a fault to earth is detected. Terminals 5 and 6 are closed, opening on a detected fault. The -ENE contact action closes 3 to 4 and opens 4 to 5. When a fault is sensed or when power is removed from the sensor, terminals 3 to 4 open and 4 to 5 close.

There is no connection from the sensor power to the output relay contacts. This allows different voltages to be used to power the sensor than the voltage that will be controlled with the output relay.

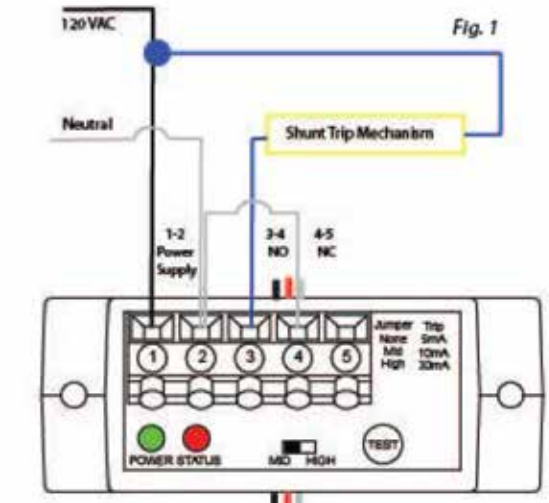

Fig. 1

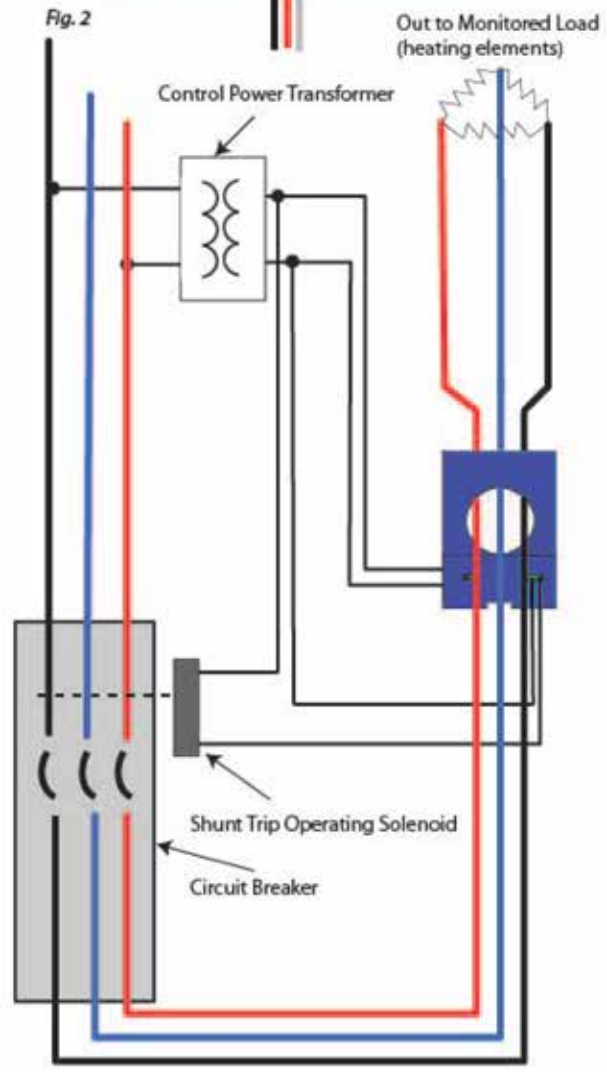

Fig. 2

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Shunt Trip Breaker Options

A Shunt Trip Beaker is required along with a NK Technologies AG or AGL Ground Fault Relay to complete 5mA Ground Fault Interrupter Solution. NK Technologies does not sell Shunt Trip Breakers. To make it easier for you complete your solution see the table below showing the correct part number for many of the leading Shunt Trip Breaker manufacturers.

If you need technical assistance contact our Engineers by Phone, Chat, or Email.

MFR	# Poles	Voltage	Amperage	MPN (10,000A IR)
ABB (GE)	3	120/240	20	THQL32020ST1
ABB (GE)	3	120/240	30	THQL32030ST1
ABB (GE)	3	120/240	40	THQL32040ST1
ABB (GE)	3	120/240	50	THQL32050ST1
ABB (GE)	3	120/240	60	THQL32060ST1
ABB (GE)	3	120/240	100	THQL32100ST1
ABB (GE)	2	120/240	20	THQL2120ST1
ABB (GE)	2	120/240	30	THQL2130ST1
ABB (GE)	2	120/240	35	THQL2135ST1
ABB (GE)	2	120/240	40	THQL2140ST1
ABB (GE)	2	120/240	50	THQL2150ST1
ABB (GE)	2	120/240	60	THQL2160ST1
ABB (GE)	2	120/240	100	THQL21100ST1
Eaton (Cutler Hammer)	3	120/240	10	CHP310ST*
Eaton (Cutler Hammer)	3	120/240	15	CHP315ST*
Eaton (Cutler Hammer)	3	120/240	20	CHP320ST*
Eaton (Cutler Hammer)	3	120/240	25	CHP325ST*
Eaton (Cutler Hammer)	3	120/240	30	CHP330ST*
Eaton (Cutler Hammer)	3	120/240	35	CHP335ST*
Eaton (Cutler Hammer)	3	120/240	40	CHP340ST*
Eaton (Cutler Hammer)	3	120/240	45	CHP345ST*
Eaton (Cutler Hammer)	3	120/240	50	CHP350ST*
Eaton (Cutler Hammer)	3	120/240	60	CHP360ST*
Eaton (Cutler Hammer)	2	120/240	10	CHP210ST*
Eaton (Cutler Hammer)	2	120/240	15	CHP215ST*
Eaton (Cutler Hammer)	2	120/240	20	CHP220ST*
Eaton (Cutler Hammer)	2	120/240	25	CHP225ST*
Eaton (Cutler Hammer)	2	120/240	30	CHP230ST*
Eaton (Cutler Hammer)	2	120/240	35	CHP235ST*
Eaton (Cutler Hammer)	2	120/240	40	CHP240ST*
Eaton (Cutler Hammer)	2	120/240	45	CHP245ST*
Eaton (Cutler Hammer)	2	120/240	50	CHP250ST*
Eaton (Cutler Hammer)	2	120/240	60	CHP260ST*

MFR	# Poles	Voltage	Amperage	MPN (10,000A IR)
Siemens	3	120/240	15	Q31500S01
Siemens	3	120/240	25	Q32500S01
Siemens	3	120/240	30	Q33000S01
Siemens	3	120/240	35	Q33500S01
Siemens	3	120/240	45	Q34500S01
Siemens	3	120/240	50	Q35000S01
Siemens	3	120/240	60	Q36000S01
Siemens	3	120/240	70	Q37000S01
Siemens	3	120/240	80	Q38000S01
Siemens	3	120/240	90	Q39000S01
Siemens	2	120/240	20	Q22000S01
Siemens	2	120/240	25	Q22500S01
Siemens	2	120/240	30	Q23500S01
Siemens	2	120/240	35	Q23500S01
Siemens	2	120/240	40	Q24000S01
Siemens	2	120/240	45	Q24500S01
Siemens	2	120/240	50	Q25000S01
Siemens	2	120/240	60	Q26000S01
SquareD	3	120/240	15	QOU3151021
SquareD	3	120/240	20	QOU3201021
SquareD	3	120/240	30	QOU3301021
SquareD	3	120/240	40	QOU3401021
SquareD	3	120/240	50	QOU3501021
SquareD	3	120/240	60	QOU3601021
SquareD	3	120/240	70	QOU3701042
SquareD	3	120/240	80	QOU3801042
SquareD	3	120/240	100	QOU31001042
SquareD	2	120/240	20	QOU2201021
SquareD	2	120/240	25	QOU2251042
SquareD	2	120/240	30	QOU2301021
SquareD	2	120/240	40	QOU2401021
SquareD	2	120/240	50	QOU2501021
SquareD	2	120/240	60	QOU2601021

* If you prefer a CH, simply replace the CHP in the model number.

BASICS & TECHNICAL REFERENCE

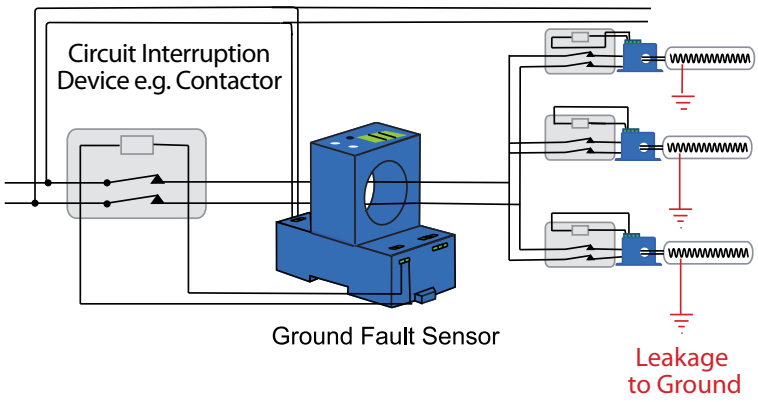
Ground Fault Protection at the Distribution Panel

Protecting your equipment against shorts to earth will help keep the plant processes safer and keep damage from faults at a minimum. The best approach is to install fast acting sensors as close to the individual loads as possible. Low level faults, quite often caused by deteriorating insulation in motor windings, are not nearly as dangerous or destructive as high level faults where one conductor contacts a grounded path with little resistance. Once there is even a minor leakage of current to earth, unwanted heating is bound to increase and with it more damage. Shutting down only the part of the process that is failing is the most sensible approach.

When the distribution panel feeds several loads such as heat trace cable runs, multiple heating elements, or a number of motors, each circuit can be passing low magnitude current to earth (5 to 10 mA) without much damage to each individual load. However if there are ten loads, each leaking 10 mA, the "normal" ground fault current is now 100 mA. This is getting into the more dangerous level, even when the equipment operators are fairly well insulated from earth with gloves and boots.

A common practice is to add another ground fault sensor at the main breaker and provide some delay to the output so that short periods of fault current will not shut down the entire process. This method improves the safety of the system and helps protect personnel who need to work on the equipment while it is energized. Some inductive loads like motors and transformers can cause a standard sensor to trip when the load is first energized, so using a sensor with some delay added will keep these occurrences from shutting down the system while keeping the equipment safe.

In the example to the right, several heating elements are protected by individual ground fault detectors connected to separate contactors. If one element faults to earth, the sensor will detect that condition and shut off just that part of the circuit, while the sensor protecting the feeding circuit remains at the ready. If the insulation of each element begins to deteriorate and starts to pass small amounts of current to ground, the sensor installed at the main panel will detect the sum of the leaking current and shut down the system after the delay. This will keep the feeding circuit from causing excess heat and the damage that heat will cause without protection.

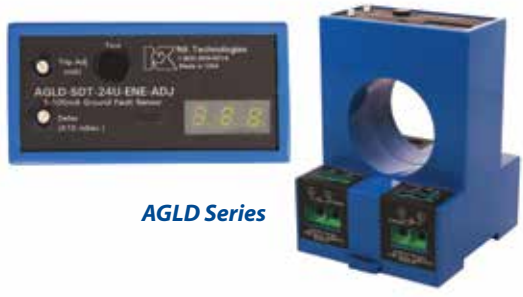


Use one ground fault sensor to protect the circuit at or near the main disconnect (circuit breaker or contactor) and smaller sensors downstream to protect each individual load.

The smaller sensor will trip before the first, so only part of the process will be interrupted. The sensor nearest the source power will remain ready if a larger fault or several small faults occur downstream.

AGLD Series Ground Fault Relay with Digital Display

AGLD Series ground fault sensors keep machinery and their operators safe from accidental shocks. The large, one piece solid-core design allows for installation over wires feeding heavy loads. The output relay will change state at any point between 5 mA and 100 mA, or 80 mA and 950 mA. The LED display will show the amount of fault current that will cause the output relay to change state. A delay can be set to allow down stream protection to activate before this sensor, keeping the main circuit protection hot and the equipment energized while the smaller faults are cleared.



AGLD Series

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Ground Fault Relay Selection

Our Wide Range of Ground Fault Relays Guarantees You'll Find Exactly What You Need.

To assist in guiding you to the right ground fault relay model for your application, please begin your selection below!

» WIRE BUNDLE DIAMETER UP TO 0.75" DIAMETER

MORE INFO	OUTPUT	SETPOINT	POWER SUPPLY	CASE STYLE	
AGT SERIES	4–20 mA, Loop Powered True RMS	Factory Set	24 VDC Loop-Powered	Solid-Core	
AG SERIES	120 VAC (66–132 V) or 24 VAC/VDC (19–29 V) or Green LED = Power On indication	Factory Set or Field Selectable	24 VAC or DC, 120 or 240 VAC	Solid-Core	
AGV Series (For VFD Drives)	Mechanical Relay	Field Selectable	24 VAC or DC, or 120 VAC	Solid-Core	
DG SERIES * DC ONLY *	DC Only Output Mechanical Relay	Factory Set	24 VDC	Solid-Core	

» WIRE BUNDLE DIAMETER UP TO 1.31" DIAMETER

MORE INFO	OUTPUT	INPUT RANGE	POWER SUPPLY	CASE STYLE	
AGT-FD SERIES	0 - 5 or 0 - 10 VDC	Up to 1500 VAC (monitored circuit)	24 VAC or DC	Solid-Core	

» WIRE BUNDLE DIAMETER UP TO 1.82" DIAMETER

MORE INFO	OUTPUT	SETPOINT	POWER SUPPLY	CASE STYLE	
AGLD SERIES	Electromechanical w/ Digital Display	5–100 mA or 80–950 mA (depending on model)	24 VAC or DC	Solid-Core	
AGL SERIES	1 A @ 120 VAC, 2 A @ 30 VDC	5–100 mA or 80–950 mA (depending on model)	24 VAC or DC, or 120 VAC	Solid-Core	

» WIRE BUNDLE DIAMETER UP TO 4.00" DIAMETER

MORE INFO	OUTPUT	SETPOINT	POWER SUPPLY	CASE STYLE	
AG-LC SERIES	Electromechanical relay 1 A @ 120 VAC, 2 A @ 30 VDC resistive	30 - 150, 80-400, 300 - 1500 mA, 1.0 - 5.0 A (depending on model) Adjustable or factory setpoint	120 VAC (108-132 V) or 24 VAC/VDC (22-28 V)	Solid-Core	

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