Littelfuse®

Expertise Applied | Answers Delivered



AF0100
ARC-FLASH
RELAY

GENERATOR APPLICATION GUIDE

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GENERATORS

Generators are often used to ensure continuity of energy for mission-critical applications. There are five key reasons generators are vulnerable to arc flash and this guide explains how to mitigate this risk.

1. The high levels of energy from the generator and low impedance (due to being near the energy source) put the generator at risk.
2. Many mobile generators are used in cooling applications in warm, humid, and sometimes dusty geographies where the increased conductivity of the air that's insulating the exposed conductors can increase the risk of an arc flash.
3. Mobile generators used in cold environments are sources of warmth that can attract rodents and small animals that burrow into the unit and precipitate an arc flash.
4. Low zero-sequence impedance of generator windings result in arc flash on a ground fault for solidly grounded generators.

Generators also pose an increased safety risk due to the nature of their construction. Typically, generators only allow a narrow space for personnel to work and perform their maintenance. In many cases, arc flash calculations limit burn time to two seconds for workers to get clear of the danger. In a generator application, the personnel are trapped in the enclosure during an arc flash and exposed to the arc for an extended amount of time. It is necessary for arc-flash calculations in confined spaces to increase the arc duration, resulting in even higher levels of incident energy. The arc blast itself can thrust personnel into the walls of the enclosure with enough force to be fatal.

Challenges Unique to Generators:

- Available space limitations
- Two sources of energy must be disconnected:
  1. The generator
  2. Bus connecting to parallel generators or utility
- Vibration from generator operation and transport to and from job sites
- Harsh environments with extreme heat and humidity
- Section between the generator and the generator breaker has no overcurrent protection

Generators with breakers that are rated or can be set above 1200 A (even if they are set below that point) require a means of arc-flash mitigation. This would apply to a connected substation, switchgear, or other downstream equipment, but could also be considered on a generator capable of producing 1200 A or more (250 kW or higher). NEC®240.87 (B.4) allows arc-flash relays as a cost-effective means of mitigation.



Mobile generator destroyed by arc-flash.

NEC® ARTICLE 240.87 (2017)

Arc-Energy Reduction

Where the highest continuous current trip setting for which the actual overcurrent device installed in a circuit breaker is rated or can be adjusted is 1200 A or higher, 240.87(A) and (B) shall apply.

(A) Documentation. Documentation shall be available to those authorized to design, install, operate, or inspect the installations as to the location of the circuit breaker(s).

(B) Method to Reduce Clearing Time. One of the following means shall be provided:

1) Zone-selective interlocking
2) Differential relaying
3) Energy-reducing maintenance switching with local status indicator
4) Energy-reducing active arc-flash mitigation system
5) An instantaneous trip setting that is less than the available arcing current
6) An instantaneous override that is less than the available arcing current
7) An approved equivalent means

ANSI Z10 : RISK CONTROL HIERARCHY

While PPE is often the most talked-about aspect of arc-flash risk mitigation, it is also the least effective means of doing so. Work and research has been and is being carried out in the engineering controls area particularly to better mitigate arc-flash risk.

ANSI / AIHA Z10 (OHS Management Standard) hierarchy, from most effective risk mitigation to least, is as follows:

1) **Elimination**
   - Difficult to achieve
2) **Substitution**
   - Insulated bus, smaller transformers, arc-resistant gear, current-limiting fuses
3) **Engineering Controls**
   - Current-limiting devices (fuses, neutral-grounding-resistors), arc-flash relays, maintenance/instantaneous trip awareness
   - Labels, training, use of qualified persons
4) **Administrative Controls**
   - No work on energized equipment, lockout-tagout
5) **PPE**

GENERATOR PROTECTION USING AF0100

Generator to Generator Breaker Connection

While the generator breaker can protect the generator from overcurrent faults, there is often nothing protecting the connection from the generator to the generator breaker from overcurrent or arc flash.

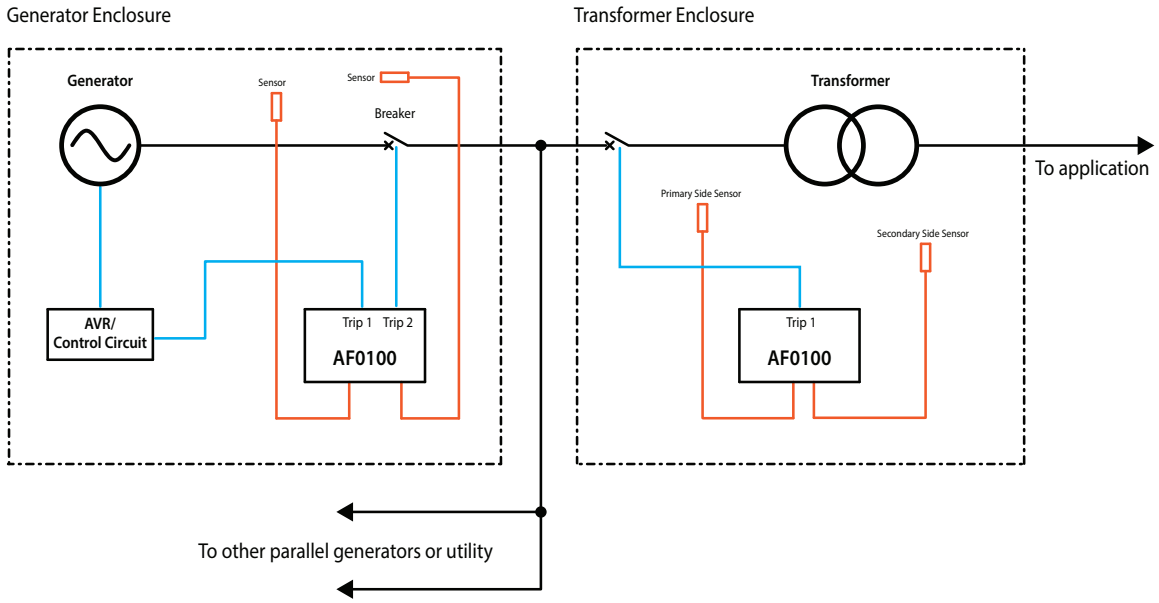
As a result, an arc in this connection will persist and its destructive energy will increase, being fed from other sources connected in parallel with the generator as well as the generator itself. Eventually, the amount of energy required may be enough to trip the generator breaker (assuming it isn't engulfed in the arc's plasma cloud) and the arc will extinguish when enough material has been vaporized that the generator cannot produce enough energy to maintain the arc, the generator is destroyed, or its fuel source consumed in the arc. Often a fault on the generator will burn the generator to the ground.

An arc-flash relay monitoring this section of the bus can dramatically reduce the total energy released and therefore the damage and risk to personnel. One or two point sensors are typically sufficient to monitor the busway/cables and the breaker cabinet. In the case that an arc is detected, all sources of energy to it must be cut off. The arc-flash relay must trip the generator breaker but also turn off the generator. The latter is usually accomplished by either connecting to the automatic voltage regulator (AVR), an emergency stop circuit, or generator controller. Often the voltages required to trip these two circuits are different and require isolated contacts.

The AF0100 was specifically designed for generator applications, with two isolated Form-C trip outputs to cut off all sources of energy from the arc. A 24-48 Vdc supply allows for power directly from the battery bank and withstands voltage sags and overvoltages, and the entire relay is designed to withstand vibration. As well, a unit health contact can be programmed for non-fail-safe so that loss of supply voltage when powering down the batteries will not cause nuisance alarms for remote monitoring. Finally, its compact design means that it can find a home in any generator control panel.

Transformer Enclosure

In applications where medium voltage distribution is required, parallel generators may be connected to a step-up transformer. It is advantageous to protect the transformer from an arc flash, particularly if there is a shunt trip that can disconnect it from supply. In this case, one or two sensors in the enclosure monitoring the primary and secondary connections can dramatically reduce downtime and repair cost for the transformer if an arc flash occurs.



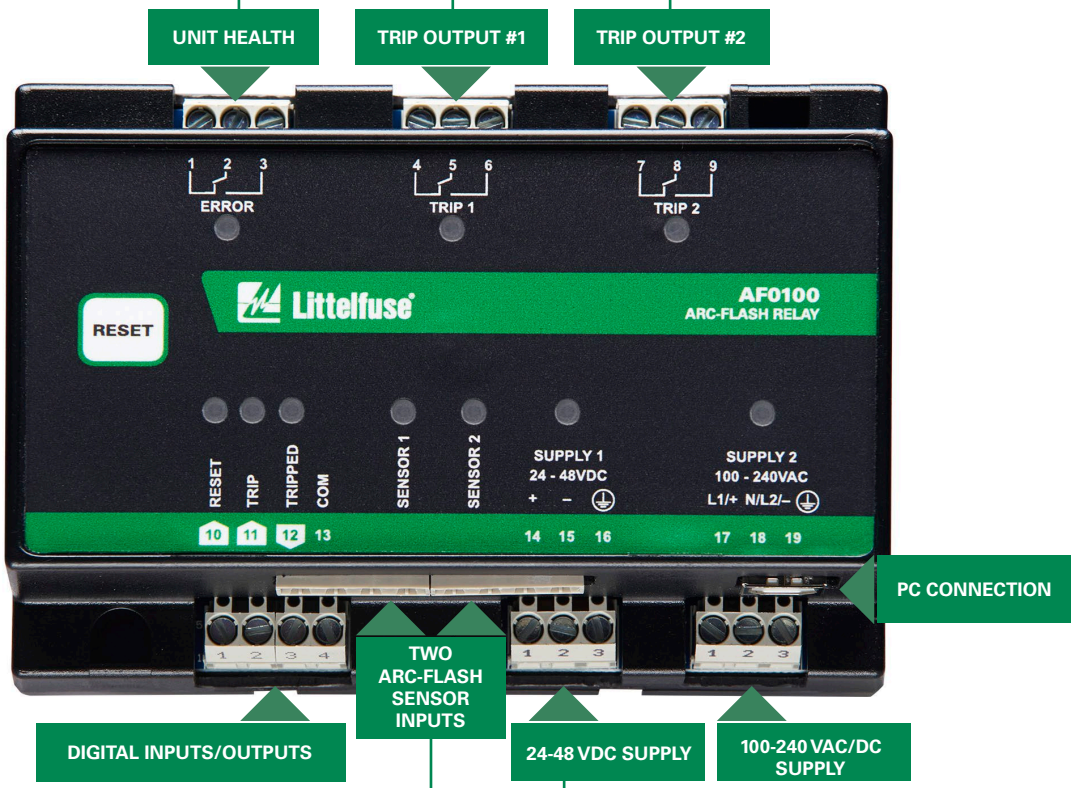
AF0100 CONNECTION DIAGRAM

Generators are often the last line of defense in powering and protecting critical applications. The generator breaker is the last line of defense protecting the generator itself: there is no protection at all between the line side of the breaker and the generator. The AF0100 includes two Form-C Trip outputs that quickly respond to an arc flash, turning off the generator using the AVR or other control circuits and disconnecting from the utility or parallel generators by tripping the generator breaker. The AF0100 can be supplied directly off a battery bank and withstand the challenging environment, vibration, and space requirements of a generator application.

Alarm on Unit Health
Configurable to non-failsafe to prevent alarms where generators/battery banks are frequently cycling on/off) in order to avoid nuisance alarms.

To Generator Breaker
Disconnect from bus which may include parallel generators or the utility.

To AVR
Shut down the generator. This could be an emergency stop or other control circuit.



PGA-LS10 Sensor
Monitors breaker compartment on the line side of the generator breaker.

24 Vdc Supply
Uses the battery banks and commonly available generator supply voltage.

Small form factor to fit in tight spaces of mobile gensets.

SENSOR COVERAGE (Distance where a line-of-sight arc will be detected)

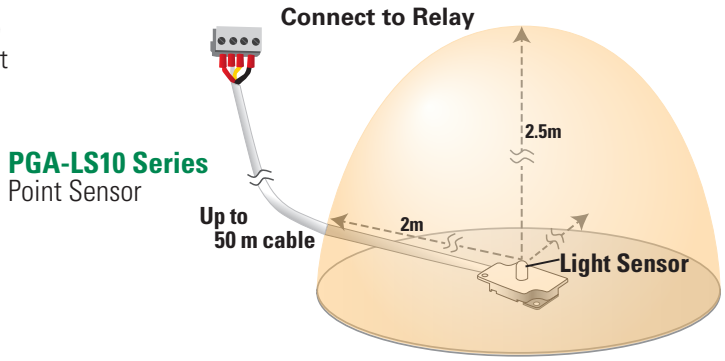
Point Light Sensor

Line-of-sight light sensor detects an arc as small as 3 kA in a 2-meter half-sphere radius.

- Visual LED indication for "Ready" or "Tripped" state to assist with fault location
- Robust sensor design can withstand a detected arc-flash event
- Sensor can be installed up to 50 m (164 ft) away from relay; electrical cable can be cut and easily re-terminated in the field



180" 2-Meter Half-Sphere Sensor Viewing Angle



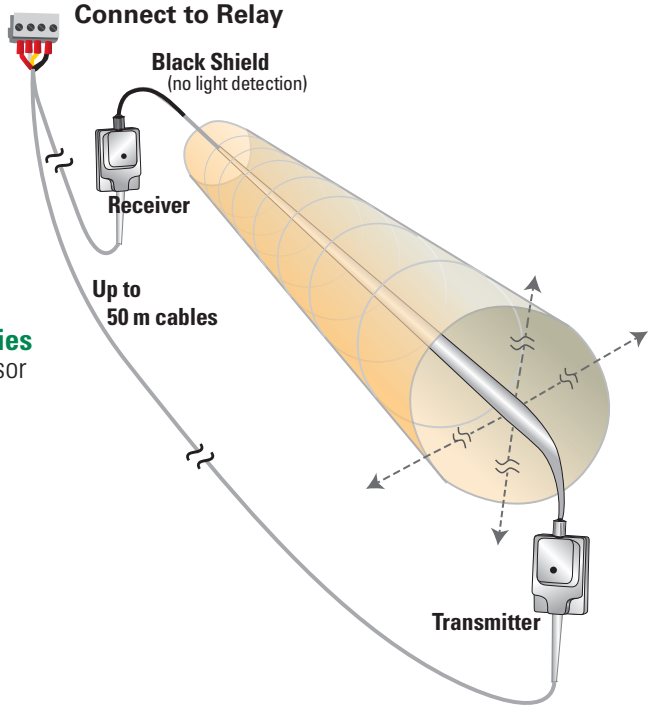
PGA-LS10 Series
Point Sensor

Fiber-Optic Light Sensor

The 360° light sensor detects light throughout the entire length of the fiber. Ideal to protect bus bars, multiple compartment installations like motor control centers, or areas with many obstructions.

- Visual LED indication for "Ready" or "Tripped" state to assist with fault location
- Durable resin fiber material allows small bending radius (>5 cm) and greater flexibility without breaking
- Ready to install from the factory, no need to terminate in the field or polish as with glass fiber
- Fiber sensors can be installed in locations up to 50 m
- (164 ft) away from relay; electrical cable can be cut and easily re-terminated in the field





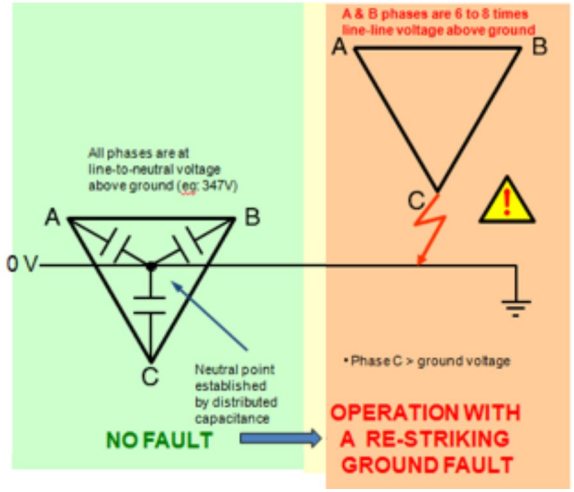
PGA-LS20 Series
Fiber-Optic Sensor

EFFECT OF GENERATOR GROUNDING ON ARC-FLASH RISK

Ungrounded Generator

A re-striking or arcing ground fault on a generator can result in transient overvoltage, a condition where phase voltages can be six to eight times the line-to-line voltage above ground as energy is stored in the capacitance of the system instead of discharging through a grounding connection. This results in insulation degradation inside the generator and can result in an explosive arc flash as the insulation fails, potentially in multiple locations.

The Littelfuse EL3100 Ground-Fault Relay can detect a grounded phase on ungrounded generators up to 600-V and offers both indication and a relay output to alarm or trip the generator.



Solidly Grounded Generator

Generators have low zero-sequence reactance, meaning that ground-fault current on a solidly grounded generator can exceed three-phase fault current levels. According to IEEE Std 141-1993 7.2.2, high values of ground-fault current can destroy the magnetic core of rotating machinery. High currents also mean that ground faults (which are the most common type of electrical fault) can result in an arc flash. Mechanical bracing in generators is also typically rated for three-phase fault levels only, resulting in mechanical damage during a ground fault even if the fault is not arcing.

The Littelfuse SE-701 Ground-Fault Relay can monitor for a wide range of current levels and works with any 5-A or 1-A secondary as well as sensitive Littelfuse CTs for detection down to 50 mA. For applications where there is not sufficient space for a CT, the PGR-4300 Ground-Fault Relay connects between the generator and grounding rod to detect ground-fault currents from 100 A to 1200 A.

Resistance-Grounded Generator

High-resistance grounding eliminates arc-flash hazards on the first ground fault and reduces burning of stator windings during an internal generator ground fault. By adding a neutral-grounding resistor (NGR), the mechanical damage from low zero-sequence reactance of generators is also eliminated. Even for uptime-critical generators that might normally be ungrounded, it is permissible to continue running a generator on a ground fault so long as the current is limited to 10 A and the generator is 4160 V or less. It is critical that the NGR is monitored using an NGR monitor to ensure that the generator remains grounded at all times. Littelfuse recommends continuously monitored high-resistance grounding for generators.

Use the Littelfuse SE-704 Ground-Fault Relay for high-resistance grounded generators. As well, ground-fault protection can be combined with continuous neutral-grounding resistor monitoring using the Littelfuse SE-325 or SE-330 NGR Monitors.

ADVANTAGES OF RESISTANCE GROUNDING FOR GENERATORS

- Generator ground-fault current can be higher than short-circuit current for solidly grounded generators.
- High-resistance grounding can eliminate the possibility of phase-to-ground arc flash on the first ground fault.
- Continuity of service during a ground fault for applications below 5 kV and with a neutral-grounding resistor (NGR) limiting current below 10 A.
- Reduced mechanical and electrical damage resulting from high-current ground faults.
- Eliminate transient overvoltages from ungrounded systems.
- Multiple generators can be grounded at a single point using a zig-zag transformer.



SE-330 Series
Neutral-Grounding-Resistor Monitor

Advanced Neutral-Grounding-Resistor (NGR) Monitor with data logging and optional communications.



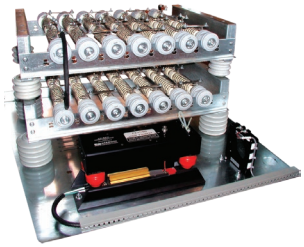
SE-325 Series
Neutral-Grounding-Resistor Monitor

Standard NGR Monitor, ideal for systems with let-through currents of 25-A or lower.



NGRM-ENC Series
Neutral-Grounding-Resistor Monitor

Enclosure with SE-325 or SE-330 NGR Monitor and optional phase voltage, metering, indication and reset.



NGR Series
Neutral-Grounding-Resistor System

Monitoring-ready NGR packages that speed deployment on site.



SE-704 Series
Earth-Leakage Relay

Earth-Leakage Relay for resistance-grounded generators.



EL3100 Series
Ground-Fault and Phase-Voltage Indication

Ground-Fault Monitor for ungrounded generators and phase-voltage indication for systems up to 600 volts.



PGR-4300 Series
Generator Ground-Fault Relay

Generator Ground-Fault Relay for solidly grounded generators. No CT required.



SE-701 Series
Ground-Fault Monitor

Wide-range ground-fault relay, especially suitable for rental units.

BENEFITS TO ADDING ARC-FLASH RELAYS

- Minimize damage to generator sets and reduce time to repair
- Save thousands of dollars on replacement costs when unit is completely destroyed (ROI on first arc flash can be enough to outfit a large generator fleet with arc-flash relays)
- Add value to end users because their personnel are safer and outage occurrences are reduced
- Meet regulatory requirements

WHY CHOOSE LITTELFUSE?

- Right product for the right application—AF0100 is purpose-built for needs of generators
- Easily added as a retrofit to existing generators or to new units
  - Our unique sensor design includes cabling that can be put through tight corners with no concern of loss of signal
  - Plug and play installation approach is unmatched in industry
  - Fast installation and automatic configuration minimize labor costs
- Seamless to your customer (no customer interaction required with arc-flash relay)
- We are a global partner for your global business
  - Global certifications
  - Global distribution and fulfillment, sell in various currencies
  - Global support personnel/office locations
- Isolated outputs allow for completely separate trip circuits
- Form C contacts give flexibility in connecting to any type of trip circuit, indication, etc.

Challenge	Littelfuse AF0100 Benefit
Available space limitations	AF0100 measures 90 mm (3.5") x 128 mm (5.0") x 60 mm (2.4")
Two sources of energy must be disconnected: 1. The generator 2. Bus connecting to parallel generators or utility	Two isolated Form-C Trip outputs: 1. Trip the generator breaker and disconnect from bus 2. Trip the AVR to shut down the generator
Vibration from generator operation and transport to and from jobsites	Extensive vibration proofing to ensure quality backed by 2-year warranty
Harsh environments with extreme heat and humidity	Conformally coated options available to protect circuitry from harsh environments

APPENDIX A: SUPPORTING MATERIALS

Littelfuse provides many supporting materials in digital format for the function and installation of the AF0100 Arc-Flash Relay.

Manual
Datasheet
FAQ Booklet
Brochure
Videos
Guideform Specifications
Workbook for Estimating Arc-Flash Incident Energy Reduction

These can be found at: **Littelfuse.com/ArcFlash**

AF0100 COMMISSIONING INFORMATION

General Installation Settings	Minimum	Default	Max	Unit	Comments	
Date Installed						
Operator						
Comment 1						
Comment 2						
General						
System Name						
Description Of This Unit		AF0100 Arc-Flash Relay				
Date and Time						
Synchronize to PC Clock		Disabled			☐ Enabled	☐ Disabled
Light Sensors						
Common Settings						
Light Immunity Lower Limit	10	10	25	klux	_____klux	
Arc Detection Time Before Tripping	0 (Effective 0.8)	1	20,000	ms	_____ms	
Light Sensor 1						
Sensor Status					☐ Sensor Present ☐ No Sensor Detected	☐ Sensor Missing ☐ Sensor Tripped
Sensor Description		Sensor 1				
Change Configuration		No Change			☐ No Change ☐ No Sensor Expected	☐ Sensor Expected
Light Sensor 2						
Sensor Status					☐ Sensor Present ☐ No Sensor Detected	☐ Sensor Missing ☐ Sensor Tripped
Sensor Description		Sensor 2				
Change Configuration		No Change			☐ No Change ☐ No Sensor Expected	☐ Sensor Expected
Configuration of Failsafe/NFS Outputs						
Trip 1		Failsafe			☐ Failsafe	☐ Non-Failsafe
Trip 2		Failsafe			☐ Failsafe	☐ Non-Failsafe
Error		Failsafe			☐ Failsafe	☐ Non-Failsafe

For more information, visit
Littelfuse.com/ArcFlash

Additional technical information and application data for Littelfuse protection relays, generator and engine controls, fuses and other circuit protection and safety products can be found on **Littelfuse.com**. For questions, contact our Technical Support Group **(800-832-3873)**. Specifications, descriptions and illustrative material in this literature are as accurate as known at the time of publication, but are subject to changes without notice. All data was compiled from public information available from manufacturers' manuals and datasheets.

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