# SEL Arc-Flash Detection (AFD)

Questions and Answers

## Arc-Flash Basics

### What is an arc flash?

According to the *National Fire Protection Association (NFPA) 70E: Standard for Electrical Safety in the Workplace*, an arc flash "is a dangerous condition associated with the release of energy caused by an electrical arc." In an arc-flash event, a flashover of electric current leaves its intended path and travels through the air from one conductor to another, or to ground. During such an event, the air gets sufficiently heated to become ionized; the air becomes the conductor.

Arc-flash events can cause dangerous and potentially fatal levels of heat, ultraviolet radiation, blast pressure, flying shrapnel, and deafening sound waves.

### What causes an arc flash?

Arc-flash events can be caused by numerous factors, such as the shorting of two phases, which creates a phase-to-phase fault. Common examples that cause phase-to-phase faults include dropped tools, accidental contact by maintenance personnel, the buildup of corrosion or conductive dust on conductors, and the presence of pests, like mice, rats, or snakes, that come in contact with energized conductors.

### What elements must be present for an arc-flash event to occur?

a. Air gap (from using air as an insulator or from a damaged insulator).

b. Sufficient energy (fault current available from the power source) to initiate and sustain the arc-flash event. (This is normally satisfied in low-voltage [480 V and above] and medium-voltage switchgear environments.)

c. Something to trigger the arc flash. (This could be a rodent, acting as a conductor across the phase conductors, or one of the causes listed above.)

### How does a protective relay help mitigate incident energy from an arc-flash event?

Since arc-flash energy is proportional to voltage multiplied by current multiplied by time (V•I•t), the protective relay acts to reduce the duration of the arc-flash event, or "t." (Note: In an arc-flash event, this equals the time elapsed before the relay trips plus the breaker clearing time.)

### Can you expand on the importance of time in the arc-flash energy equation (V•I•t)?

Arc-flash energy is proportional to V•I•t. Relays don't have any control over the voltage and current. The voltage across an arc is determined by the conductor gap; the arcing current is limited by the available fault current. What the relay can impact is time. By limiting the duration of the arc-flash event, the relay can dramatically reduce the amount of incident energy produced by an arc-flash event.

## Is the voltage in an arc flash proportional to the voltage in the system?

No, the voltage in an arc flash bears very little resemblance to the open-circuit voltage in the system. For example, if a 15 kV line-to-line medium-voltage switchgear experienced an arc-flash condition, the voltage in the arc is not 15 kV; it is about 250 V line to line.

## What role do air gaps play in an arc flash?

Electrical switchgear uses air as an insulator for very practical reasons. However, while air is a good electrical insulator under normal conditions, if the air gets heated up and becomes ionized, that air will become a conductor, resulting in an arc-flash event. In environments with air gaps, such as electrical switchgear, arc-flash hazards exist with exposed copper- or aluminum-type conductors; e.g., a busbar, contacts on the motor contactor, or contacts of a breaker. To completely eliminate arc-flash hazards, you need to avoid using air as an insulator; e.g., in submersible equipment used in underground vaults.

## Are there other dangers in an arc-flash event besides intense heat and light?

High-voltage arcs can also produce considerable pressure waves by rapidly heating the air and creating a blast. This pressure burst can hit a worker with great force and send molten metal droplets from melted copper and aluminum electrical components great distances at extremely high velocities.

## How much light is produced in an arc-flash?

In a very small (2,000 A) arc-flash event, the measured light intensity was 2,000,000 lux, or twenty times brighter than bright sunlight (100,000 lux), at a distance of 1 meter from the arc-flash source. For more realistic arcing currents (e.g., 17,000 A), we have recorded arc-flash light intensities of 12,000,000 lux. This is equivalent to the amount of light generated by 120 suns in the sky at one time.

## How is the current determined in an arc-flash event?

In medium-voltage equipment, the arcing current is slightly less than the bolted fault current, in most cases (~90 percent). In low-voltage equipment, say 480 V, the arcing current is about 60 percent of the bolted fault current. IEEE 1584 includes an equation for calculating the arcing current.

# Configuration

## How is arc-flash mitigation configured with SEL protective relays?

Arc-flash mitigation is available as an optional arc-flash card with the SEL-751 and SEL-751A Feeder Protection Relays and the SEL-710-5 Motor Management Relay. It can be ordered factory-installed with new SEL-700 series relays or as a field-installable upgrade kit for retrofitting. It comes standard with the SEL-849 Motor Management Relay.

## What is the maximum number of arc-flash sensors on a given SEL relay?

Up to 8 sensors can be supported, depending upon the SEL relay model. Both the SEL-710-5 and SEL-751 support an optional 8-input card. The SEL-751A supports a 4-input card. The SEL-849 has a single integrated arc-flash sensor.

# Installation

## Does SEL sell or provide the necessary tools to cut and install fiber-optic cabling?

Yes. SEL supplies preterminated fiber to your specified lengths. SEL also offers field-termination kits for V-pin and ST®-type fiber optic splices and terminations.

## Which products represent the SEL family of sensor-based AFD products?


**SEL-710-5**
Motor Protection Relay

**SEL-849**
Motor Management Relay

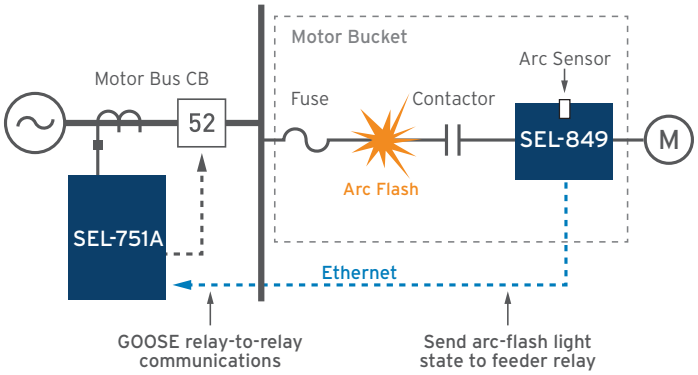
**SEL-751A and SEL-751**
Feeder Protection Relays

**SEL-4520**
Arc-Flash Test Module

# SEL Arc-Flash Solutions

## Sensor-Based AFD

SEL AFD technology significantly decreases the time it takes a relay to trip in response to an arc fault, which reduces hazardous arc-flash incident energy. SEL combines light-sensing technology with fast overcurrent protection to provide secure high-speed AFD. Combining these technologies allows high-speed tripping during arc-flash events without unintentional tripping for external faults.



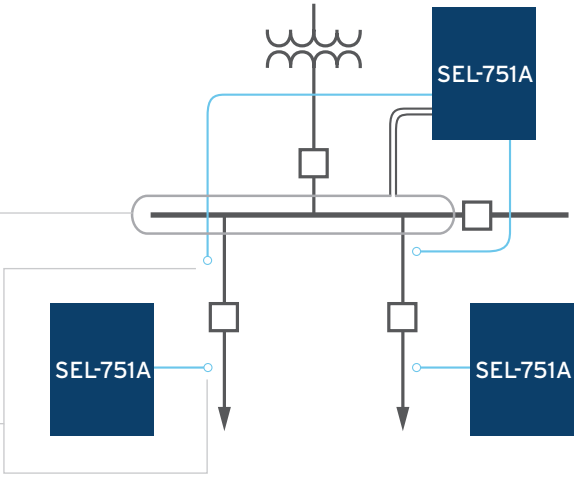

SEL AFD combines light-sensing technology with fast overcurrent protection.

## How Does It Work?

Just after a fault current begins, the arc flash produces a very bright flash of light. The relay uses point sensors and/or bare-fiber sensors to detect the intense light. The overcurrent protection makes sure the relay does not trip for other sources of light, while the light sensors ensure the relay does not trip for an external fault.

Bare-fiber sensors detect light from the arc flash over the entire length of the fiber loop. This type of sensor is used for large areas, such as busbars.

Easily mounted point sensors detect light from the arc flash. This type of sensor is used for confined areas, such as breaker compartments.




# Light Sensors

### Why do I need light sensors? Isn't the overcurrent element in a protective relay sufficient to sense when an arc-flash event occurs?

The light sensor protects against a false trip for an external fault. A protective relay with overcurrent would indeed sense the current surge from an arc-flash event, but it wouldn't know whether it was an internal fault or an external fault on the feeder or the protected equipment downstream. We can differentiate between an external fault and an internal fault inside the switchgear by sensing the light flash via light sensors. SEL AFD-equipped protective relays detect an arc-flash event by detecting the simultaneous occurrence of both the fault current and the arc-flash light, triggering an immediate trip within the first quarter cycle of the arc-flash event.

### If the switchgear is exposed to a light source, such as a camera flash, would that trigger the SEL protective relay to trip?

No. The overcurrent condition would not be satisfied, and the relay would be prevented from tripping.

## How does the SEL light-sensing technology work?

The SEL arc-flash point sensors, positioned inside the switchgear equipment, intercept some of the light created by the arc flash; it is conducted into one of the fiber-optic cables connected to the point sensor.

## How do I know that the arc-flash-sensing technology will continue to work over time? Do you test the sensors periodically to verify that they're working?

The SEL arc-flash point sensors are equipped with two fiber-optic cables. One is used to channel light from an arc-flash event. The other fiber has an LED that emits a specific light pattern every 10 minutes in a loopback test. A red LED light will blink signaling that this test is occurring. If the test is unsuccessful, the sensor will send an alarm to the monitoring system, indicating that there is something wrong with one of the sensors. This test can also be initiated manually.

## How do you test the arc-flash sensors during commissioning to verify that they're in working order?

Once the arc-flash equipment is properly installed, SEL will perform an onsite commissioning test to verify that the entire protection system works as designed. SEL's arc-flash detection system can be tested in two different ways: (1) Use the optional SEL-4520 Arc-Flash Test Module in conjunction with a current source. It generates a light flash at the same time it applies current to the relay, thereby testing the simultaneous application of light and current, and looks for the relay to produce a trip, thus verifying that detection functions (light + overcurrent) and the settings logic are operating correctly. (2) Connect a professional-grade camera flash and a primary current source (Omicron, Doble, etc.). The camera flash, supervised by an overcurrent from the relay test set, will exercise the 50PAF and TOLx elements in the relay. (3) Contract with SEL Engineering Services to perform arc-flash system tests for you, or to provide oversight services while your engineers conduct the arc-flash tests during commissioning.

## When would you recommend using the bare-fiber sensor vs. the point sensor? Can you mix and match them on the same relay?

The bare-fiber sensor is typically used to protect bus runs when you have a very large area to cover. It can also be installed in circuit breaker compartments, metering compartments, and termination compartments—as long as you have 0.5 meter of exposed fiber in every compartment. Point sensors are generally easier to install in retrofit applications where you have space constraints and can't get fiber from one compartment to the other. Bare fiber is normally used in new construction where you can access the compartments before the equipment is installed. Any combination of bare-fiber and point sensors can be used on SEL protective relays that support AFD. For additional details on sensor selection and placement guidelines, please refer to the SEL application guide *AG20011-01: Using the SEL-751 and SEL-751A for Arc-Flash Detection*.

## Has there ever been an arc-flash event where the arc-flash sensors were destroyed before they signaled the relay?

No. SEL tested the SEL-751A and specifically placed the arc-flash sensor in the middle of the arc-flash event to insure that the sensor was exposed to the full effects of the plasma. The sensor correctly sensed the event and sent a message to the relay within the first quarter cycle of the event. The sensor was eventually destroyed (in 2.5 cycles), but not before correctly detecting the arc flash. This testing is documented in the SEL technical paper "High-Current Qualification Testing of an Arc-Flash Detection System," which is available at **www.selinc.com**.

### Where do you recommend placing the arc-flash sensors in the compartment?

The sensors should be placed somewhere in the compartment where the arc-flash might occur and where they are not overly obscured by the equipment in the compartment. When an arc flash occurs, it is not a point source of light, but the plasma created by the event is a very large and extremely bright light source (>1,000,000 lux) that will fill up the entire compartment. For additional details on sensor selection and placement guidelines, please refer to the SEL application guide *AG20011-01: Using the SEL-751 and SEL-751A for Arc-Flash Detection*.

### Are SEL light sensors vulnerable to dust?

Not typically. At their default pickup setting of 3 percent, the sensor only needs 80,000 lux, and the arc-flash signal is 1,000,000—12,000,000 lux. So dust should not adversely affect the light sensor's ability to detect an arc-flash event.

### How does SEL recommend adjusting the sensitivity of the sensors?

We typically set up the pickup level of the light sensors as a percent of full scale (100 percent). We recommend leaving the point sensors at their default settings of 3 percent unless you have a specific reason for changing them. The only reason you would typically modify the settings (to, say, a pickup threshold of 10 or 20 percent) would be if you had a problem with too much ambient light. The relay will tell you if you have too much ambient light; as part of the diagnostic check, if the relay sees light over the pickup threshold for more than 10 seconds, it will set an alarm bit for ambient light. Normally this is not the case since the interior of the switchgear is not typically exposed to direct sunlight.

## Technology

### If the relay sees the fault current, why does it need the light sensor to trip faster?

When the relay sees the fault current, we don't know if it is an arc-flash event or whether it is an external fault or even a nonfault condition (e.g., transformer inrush or motor start inrush). The presence of the arc-flash light verifies that an arc flash is occurring and prevents a false trip from occurring.

### Does the overcurrent supervision that SEL uses slow down the AFD speed?

No, it doesn't. Current is the input to the arc flash, so you need to have current first, and the light actually lags behind the arc-flash current. When we performed arc-flash tests, we observed the current leading the light by 1.5 ms.

### What communications were used in SEL's arc-flash testing for a motor control center (MCC)?

SEL's arc-flash MCC testing configuration consisted of an SEL-849 communicating via IEC 61850 GOOSE messaging to an SEL-751 upstream on the main breaker.

### What if only an overcurrent condition were to occur?

If an overcurrent condition (e.g., a transformer inrush or a motor-starting load) exists, if that current level is higher than the arc-flash pickup level, the SEL arc-flash protective relay will not trip because both conditions (light + high current) are not present.

### Is AFD needed for low-voltage MCCs?

Arc-flash events do occur in low-voltage motor control circuits. Neither the contactor nor the molded-case circuit breaker are able to interrupt an arcing fault that occurs inside the MCC bucket. The fault must be interrupted by an upstream device with a breaker on the incomer to the motor bus. With an optical sensor inside the MCC bucket connected to an SEL-710-5, SEL-751, or SEL-751A Relay, the relay will issue a trip in a quarter cycle (4 milliseconds typical relay operate time) or as fast as 2 milliseconds after detecting both overlight and overcurrent. With an SEL-849 inside the MCC bucket, the relay will detect overlight from the arcing fault and send an IEC 61850 GOOSE message to an upstream relay in three-quarters of a cycle (7 to 14 milliseconds typical relay operate time).

NOTE: The relay operate time does NOT include the breaker operation time. A three-cycle breaker adds as much as 50 milliseconds to the total trip time.

### How is the arc flash mitigated inside of an MCC bucket?

Using hardwired connections or communications, the SEL-849 sends a signal to the SEL-751 or SEL-751A on the incoming feeder, acknowledging that an arc-flash light source has been detected in the MCC bucket. The SEL-751 or SEL-751A will see the fault current going into the motor bus, and it will make the trip decision, clearing the bus and thereby removing the arc-flash hazard from the MCC.

## Other Mitigation Technologies

### What other types of arc-flash mitigation are available in addition to SEL's combination of light-sensing detection and overcurrent supervision?

- Light-Sensing Only—We do not recommend this approach, as it is vulnerable to unexpected light sources (flash photography, lasers, etc.).
- Light Flash, Supervised by Pressure—We do not recommend this approach, as sound pressure is very challenging to test during commissioning.

### Is maintenance switching sufficient to mitigate against arc flashes, or is more required?

A lot of SEL customers use a maintenance switch (a button on the front of the relay) that, for instance, changes the settings group from inverse time overcurrent protection to instantaneous trip mode. This takes 1.5 cycles to trip, but with arc-flash detection, the relay can respond in 0.25 cycles. One of the disadvantages of the maintenance mode is that it is process-dependent; it only works if someone turns it on. It does not protect against unforeseen events, like a rodent climbing in the switchgear.

# Personal Protective Equipment (PPE)

## Should a worker rely on AFD when selecting PPE, or is it for equipment protection only?

Arc-flash mitigation using protective relays is used to help protect both personnel and equipment. Relay behavior is always used in the calculation to reduce potential incident energy levels. The light plus overcurrent technology used by SEL protective relays is simply another technology integral to the relay, which is used to reduce potential incident energy levels. We have examples where customers have determined that a reduction in PPE was warranted due to substantial reductions in arc-flash-generated potential incident energy. Reductions in PPE selection should only be done after a detailed arc-flash and short-circuit study is performed by a qualified electrical engineer following federal and state guidelines.

## What does SEL offer that would show that the PPE category has been reduced in an area when SEL equipment is installed?

SEL Engineering Services can perform an arc-flash study and provide an arc-flash hazard warning plan, which includes customized arc-flash and shock hazard labels. If an arc-flash study was previously performed (i.e., prior to installation of the new protective equipment) and safety stickers are in place but the equipment configuration (including protection) has changed, then new calculations need to be performed that take those changes into account, and new stickers should be produced.



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