Field Testing of Arc Flash Point Sensors in 8 Series Relays

Technical Note

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The Arc Flash Phenomenon

An electric arc is an ongoing plasma discharge resulting from current flowing through air, a normally nonconductive media. The effects of an electric arc depend on the individual circumstances, but all are dangerous: extreme temperatures reaching up to 35,000 °F, explosive forces caused by the rapid expansion of gases and elements such as copper, intense light, high noise levels, and toxic fumes. In a low-level arc, the heat and light do the most damage, but for a high-intensity arc, shrapnel effects can be very severe. Severe burns to the hands and face are the most common injuries, but an arc flash can also cause internal injuries through inhalation of toxic and heated gases, damage eardrums, and permanently damage eyes. An electric arc is dangerous and directly affects the safety of electrical workers. Hence, Arc Flash (AF) protection is very important for all power and process industries to maintain the safety of personnel at the workplace. In addition, periodic testing of Arc Flash protection is important. This document describes testing the Arc Flash protection feature in Multilin 8 Series relays.

Arc Flash Rating

The incident energy of an arc flash is calculated based on NFPA 70 and IEEE 1584 standards. Figure 1 shows the linear relationship of arc flash energy with respect to fault clearing time when a 10kA arcing current is used for calculations, and with a sample set of panel box conditions[1]. Based on the category level, appropriate PPE is required when performing work on energized equipment. It is evident that the arcing duration plays a large role in the amount of arc flash energy produced. In some cases, depending on the maximum bolted fault current level, the ability to limit the arcing duration can be life-saving. At a minimum, the breaker takes 3 to 5 cycles (50 to 83ms) to operate. Any additional time required for detection and assertion of the relay output drastically adds to the accumulated arc flash energy. In some cases, a reduction in the overall operating time can mean a lower category of arc flash level, and thus more lenient PPE requirements.

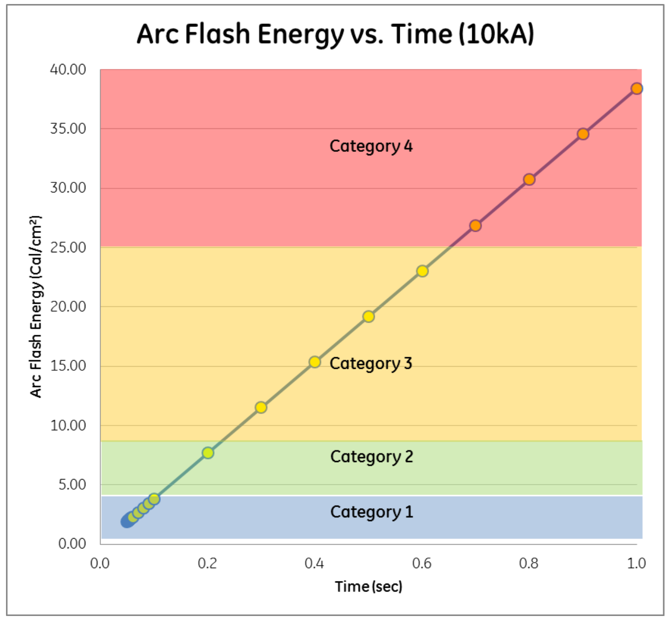

Figure 1. Arc Flash Levels and Arcing Duration

Light during an Arc Flash

When referring to low voltage or medium voltage switchgear, the breaker compartment sizes vary with the panel frame size, from a couple of cubic feet to a cubic meter and higher. Since lux (luminous emittance) is a measurement dependent on the surface area, it is difficult to estimate the amount of light at a specific wavelength. In addition, the light intensity during an arc depends on the following variables.

Table 1. Variables influencing arc flash behavior

Current level	Measurement sensor
Arcing duration	Angle of incidence
Ambient moisture	Distance from the arc
Ambient temperature	Interior surface reflectivity
Switchgear compartment size	Arcing gap

There is no unique spectrum for arc flashes. The spectrum varies strongly with different ignition conditions, voltages, currents, and other factors mentioned above. However, a typical spectrum of an arc flash is between 300nm and 800nm with maximum amplitude around 500nm as shown in Figure 2. The light also pulsates at twice the frequency of the power grid voltage.

[1] Davis, C., St. Pierre, C., Castor, D., Luo, R., Shrestha, S., Practical Solution Guide to Arc Flash Hazards, National Technology Transfer, Inc., ESA, Inc., 2003.

$$f_{optical} = 2 * f_{voltage}$$

(e.g. $120Hz_{optical}$ at $60Hz_{electrical}$)

(e.g. $100Hz_{optical}$ at $50Hz_{electrical}$)

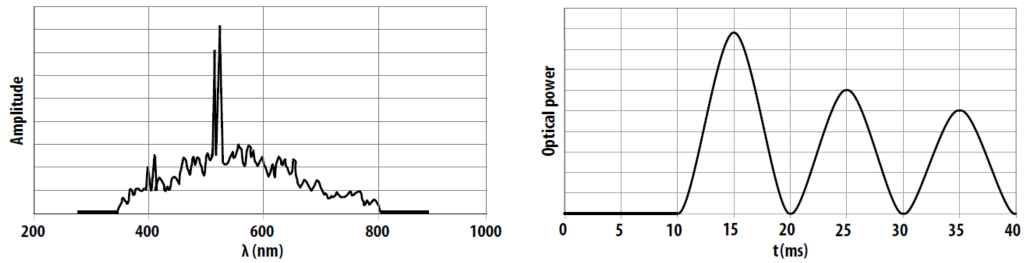

Figure 2. Arc Flash Characteristics

Using a third party high current test lab, a series of experiments were performed to validate the arc flash design of the 8 Series relays. The tests involved various current levels, arcing duration, arcing distance, and sensor positions. High current tests were conducted in a ventilated enclosed metal box with 4kA RMS current over 1 cycle. Sensors were placed 16” from the arc, and the rod gap for phase-phase fault was 4 inches. From the sensor, the light characteristics captured show the 120Hz pulsation for 1 cycle of the arcing duration.

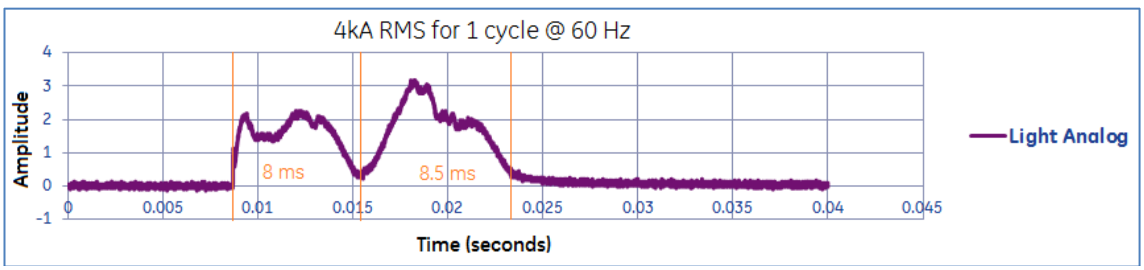

Figure 3. Arc Flash Light Intensity

A light meter was used to capture the peak light intensity during the arc. Due to light meter scale limitations, a filter was added to the meter to scale down the light intensity of the arc. The observed peak light intensity for five arc flash attempts under same conditions is shown in Table 2. The average is 13.43 Mlux, which is much higher than measurements of sunlight.

Table 2. Arc Flash Light Intensity

Arc Flash	Peak Light (Mlux)
1	8.81
2	12.15
3	11.33
4	12.73
5	22.14
Average	13.43

Arc Flash Protection in 8 Series relays

Arc flash protection in the 8 Series platform of protective relays uses a total of four 18ft (5.5m) light detection fiber point sensors and a dedicated high-speed instantaneous overcurrent element with secure Finite Response Filtering. Light from the light sensor AND logic within the high-speed overcurrent element ensures fast and secure operation. Light-only arc flash protection can also be achieved by simply assigning the light pickup operand to an output relay. These sensors are self-monitoring – the relay provides a self-test trouble indication if the sensor is damaged, cut, or unplugged. The sensitivity ranges are pre-programmed with an adequate margin such that it can be sensitive enough to pick up small arc flash events and yet be unaffected by ambient light.

Arc Flash Test Methodology

There are several possibilities when testing Arc Flash protection, each with advantages and disadvantages. One method of simulating high current uses a secondary injection test with the desired pickup values. 8 Series relays with firmware older than version 1.7x require a secondary injection unit such as Megger, Doble, or GE’s RTT Desktop Test Set to inject currents. This test does not measure the timing between the light and overcurrent; this is not of major concern, because the two operands for light and overcurrent are simply passed through an AND gate without any time delay for the fastest possible arc flash detection. (The probability of having overcurrent and light at the same time under normal operating conditions is very small.) In addition, a blocking operand can be used to block the arc flash element in situations such as breaker maintenance, testing, door switch, etc.

Both secondary injection testing and light-only arc flash testing can use a camera flash as the light source. To mimic an arc flash, a camera flash is a readily available high intensity burst of light. The justification behind using a camera flash is described in the last section of this paper. There is a dropout delay of 20ms for the light sensors, thus, although the duration of the camera flash is short, the light pickup signal is held for 20ms after the flash disappears.

Some specialized test equipment designed specifically for Arc Flash is also available commercially, specifically from Omicron. Using the Omicron ARC 256x Arc Flash Initiator along with an Omicron injection unit, light and overcurrent timing can also be included in the test. The Omicron arc flash simulator provides the light, so a camera flash is not needed.

Arc Flash Testing with Secondary Injection

Follow these steps to set up secondary injection-based arc flash testing of sensors:

1. Navigate to **Setpoints > Control > ArcFlash > ArcFlash1** and set the function to "Trip". Ensure that all other elements are either disabled or configured to not interfere with arc flash testing.
   The HS Phase Pickup is the high-speed instantaneous over current (HS IOC) element. It is similar to regular IOC but with much faster pickup. Under normal operation, this setting should be set at 2xCT to 4xCT or higher. However, for testing purposes, set the HS Phase Pickup to 0.5xCT. Enable the sensor you want to test, and save the settings.
   If the sensors are enabled but disconnected, a light sensor trouble message appears in the target messages window. In the case of a light sensor trouble message, check all sensors one by one for trouble by disconnecting them from the relay to ensure that the sensor diagnostics are working properly.

SETTING	PARAMETER
Arc Flash 1	
Function	Trip
HS Phase Pickup	0.500 x CT
HS Ground Pickup	0.500 x CT
Light Sensor 1	Enabled
Light Sensor 2	Disabled
Light Sensor 3	Disabled
Light Sensor 4	Disabled
Block	Off
Trip Output Relay	Relay : Disabled
Events	Enabled
Targets	Latched

Figure 4. Arc Flash Element Settings

2. Use the secondary injection unit of your choice to inject Phase A current greater than 0.5xCT. If the relay is 1A, inject >0.5A and if the relay is 5A, inject >2.5A. The relay should pick up with "AF 1 HS Ph IOC PKP A" operand in the target messages window.
3. While the high-speed IOC element is picked up, use the camera flash (press PILOT button on the camera flash module) on each of the sensors individually. (Refer to the last section of this paper "Using a Camera Flash" for more details). The light on the individual sensor should pick up and the target messages window show "AF 1 Light X PKP" where X is the sensor number. Immediately, the relay will assert the trip output with target messages window showing "Arc Flash 1 OP" message.
4. The TRIP LED on the 8 Series relay will light up. Reset the trip and repeat step 5 and 6 for each sensor on the 8 Series relay.

In addition to testing the arc flash, the test signals can also be recorded in the transient recorder. In order to view the operation of signals, set the transient recorder digital inputs as shown (**Setpoints > Device > Transient Recorder**). Additionally, the FlexAnalog signal "AF1 HS Phase Current A" can be added to the analog channels to see the current levels.

SETTING	PARAMETER
Number of Records	1
Samples per Cycle	8 /c
Trigger Mode	Overwrite
Trigger Position	80 %
Trigger Source	Any Trip
Trigger on Any Pickup	Off
Trigger on Any Operate	Off
Trigger on Trip	On
Trigger on Alarm	Off
Digital Input 1	AF 1 Light 1 PKP
Digital Input 2	AF 1 HS Ph IOC PKP A
Digital Input 3	Arc Flash 1 OP

Figure 5. Transient Recorder Settings

NOTE: The 8 Series Arc Flash Level Set dial is not in use at this time and should remain set to 0, since only one length (maximum 18 ft) of fiber optic sensor cable is currently supported. The Level Set dial may be used in future.

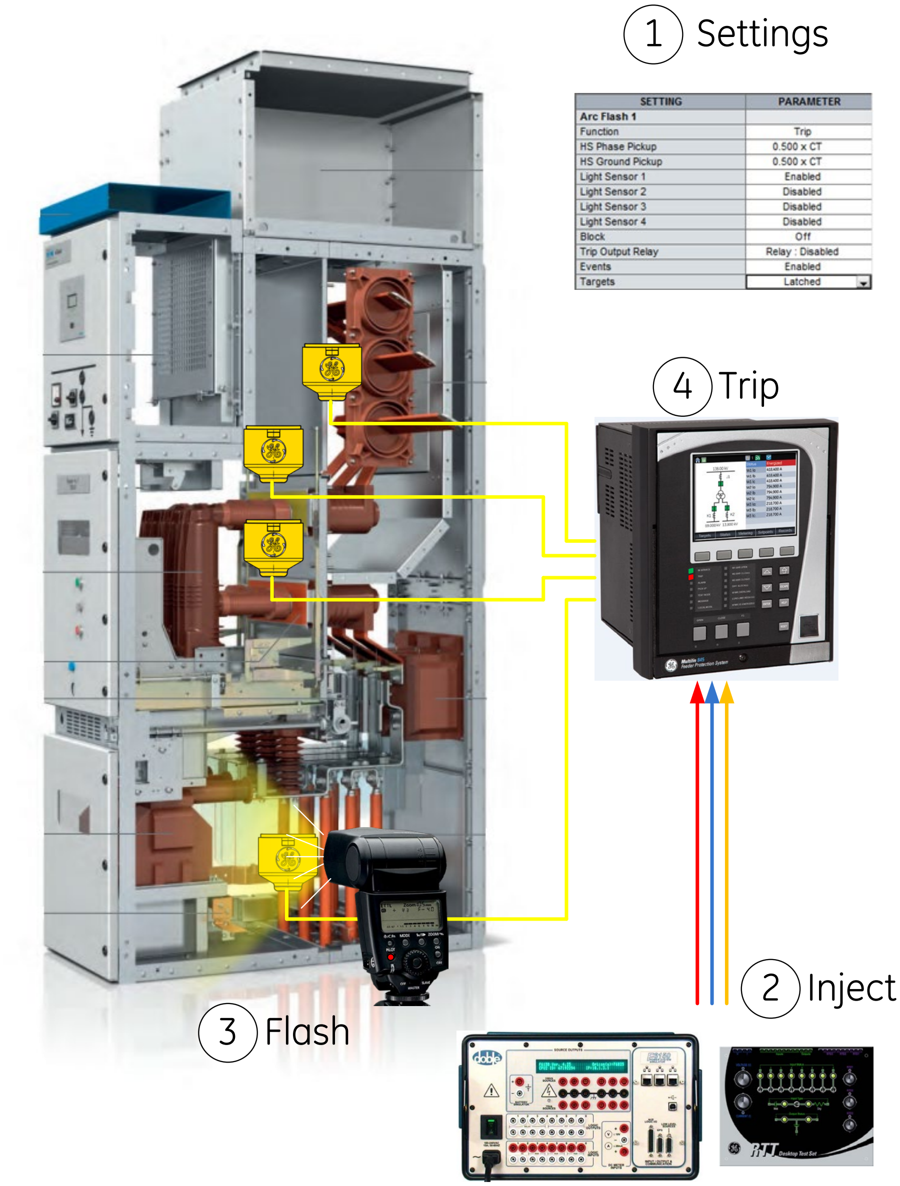

Figure 6. Arc Flash Testing with Secondary Injection

Using the Omicron ARC 256x Arc Flash Initiator

Omicron Electronics has released an arc flash simulator device ARC 256x Arc Flash Initiator[2] as an accessory for the Omicron CMC 356, CMC 353, or CMC 256PL, which simulates an arc by using a xenon tube flash with trigger capability. It also comes with 6 m (19.7 ft) cable for sensors that are far from the test unit.

The Arc Flash Initiator can be used in combination with the Omicron injection unit to simulate an arc flash on an 8 Series relay with arc flash capability. Figure 7 shows the wiring diagram for setting up such simulation.

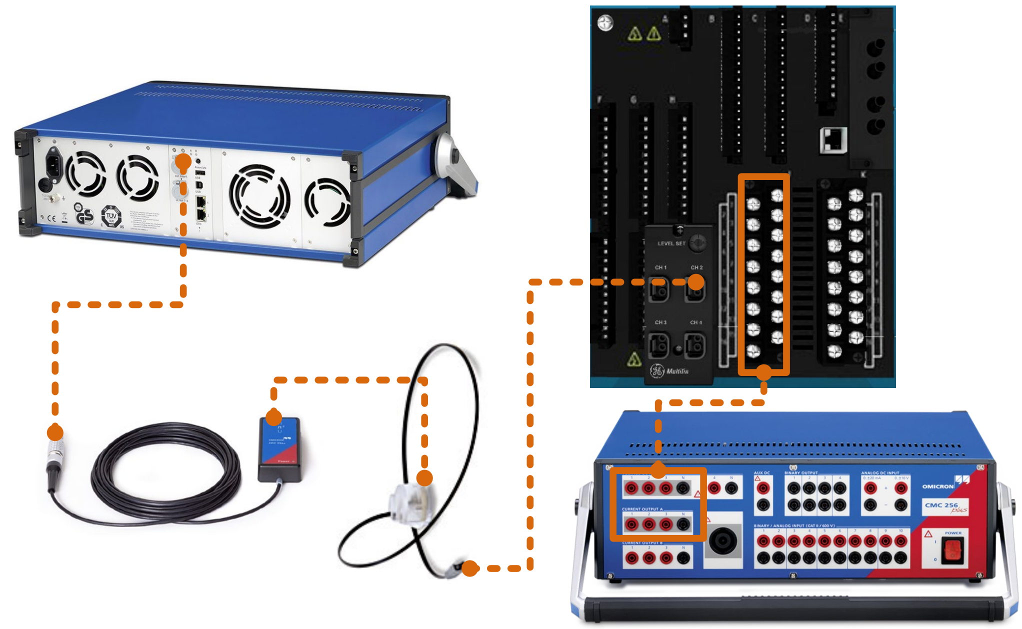

Figure 7. Arc Flash Testing with Omicron Devices

These steps show the simulation method using an Omicron injection unit and Arc Flash Initiator:

1. In the 8 Series relay, program the arc flash element with the desired sensors and pickup level.
2. Set up wiring between the 8 Series relay, Arc Flash Sensors, Arc Flash Initiator and Omicron Injection Unit.
3. Open Omicron software *Test Universe*. Connect to the injection unit by configuring “test set association” under Setup.
4. Once communication with the test unit is established, open “State Sequencer” from the list of Test Modules.
5. Program a sequence of 2 states such that the current level in the first state is below the pickup level in the relay and the current level in the second state is above the pickup level.
6. Program the binary output 12 to be open in state 1 and closed in state 2.
7. Place the Arc Flash Initiator on top of the 8 Series Arc Flash Sensor and start the injection. This will initiate the arc and the current at the same time. The relay will trip on the arc flash sensor under test.

[2] https://www.omicronenergy.com/en/products/all/secondary-testing-calibration/accessories/arc-256x-arc-flash-initiator/

The transient recorder feature in 8 Series can be used to track the current level and element status as shown in Figure 8.

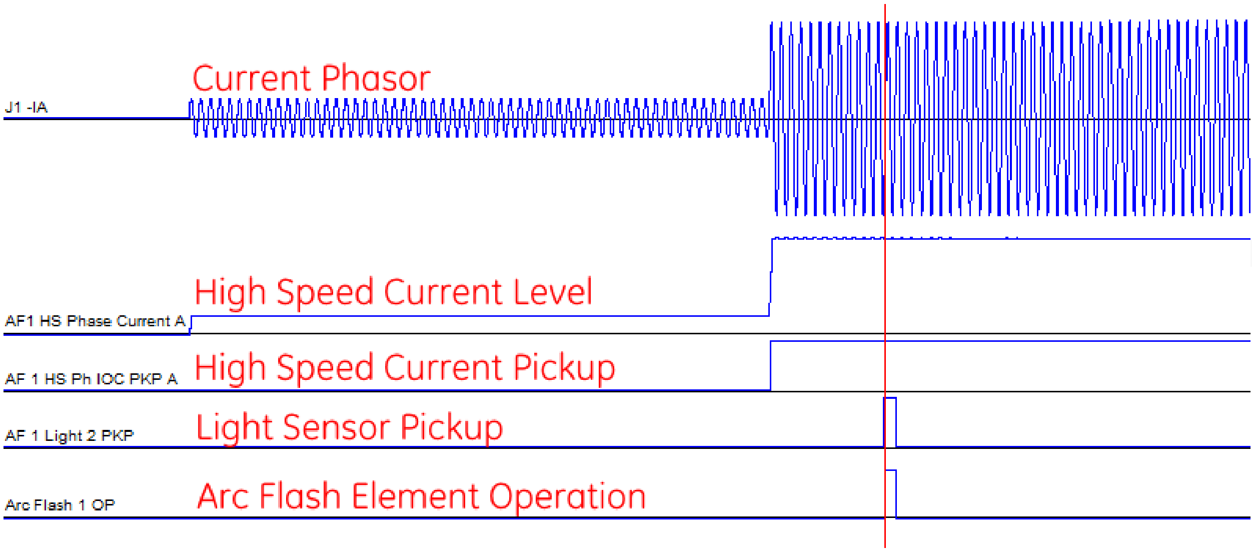

Figure 8. Arc Flash Operation Waveform for Validaiton

Arc Flash Light-Only Element Testing:

For an application where the arc flash protection is operated simply on light detection, the following steps can be performed:

1. Navigate to **Setpoints > Control > Arc Flash > Arc Flash 1** and enable the Function to "Configurable". Enable the light sensors according to their connection. The pickup values can be kept as default since they will not be used in this test. Ensure that all other elements are either disabled or configured to not interfere with the arc flash testing.
2. Navigate to **Setpoints > FlexLogic > Logic Designer** and design the logic shown in Figure 11. Arc flash light from the desired sensors can be brought together in an OR gate and taken out as a virtual output.

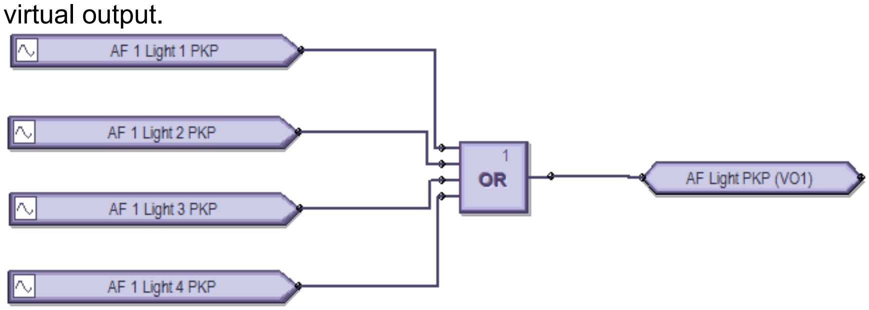

Figure 9. FlexLogic for Arc Flash Light Test

3. Navigate to **Setpoints > Outputs > Output Relays** and assign a relay to operate based on the virtual output programmed in the previous step.

Aux Relay 4	
Name	AF Light PKP
Block	Off
Operate	Virtual Output 1 On (VO 1)
Type	Self-Reset
Operation	Non-Failsafe
Events	Enabled

Figure 10. Output Relay Settings

4. Use the camera flash (press the PILOT button on the camera flash module) on the sensors individually. (Refer to the last section of this paper “Using a camera flash” for more details). The light on that sensor should pick up and the target messages window show the operation of the virtual output and the associated relay output.
5. Reset the trip and repeat the previous step for each connected sensor.

Alternatively, the trip bus element can also be used in the relay if the FlexLogic feature is not present. The trip bus element can be programmed by simply setting the function to “Trip” and configuring the light pickup operands for each light sensor as the inputs to the trip bus. Once the trip bus is configured, step 4 from above can be repeated to see the relay output.

Using a camera flash

Since the arc flash protection in 8 Series uses light and current for detection purposes, it is important to understand how the light is measured. In photometry, “luminous flux” or “lumen” is a standard SI unit for the quantity of visible light emitted. This differs from “radiant flux” which is the total power of electromagnetic radiation including infrared, ultraviolet, and visible light.

Lux on the other hand is the standard SI unit for illuminance. 1 lux = 1 lumen per square meter. The lux measurement of sunlight varies from 30K to 200K lux; this broad spectrum of lux values for sunlight comes from the variability in the ambient environment. Hence, using a fixed lux value for sunlight is incorrect. In addition, most measurements use readily available light meters which have a range of 0 to 400 kLux after which they saturate and require filters to scale down the light level. These light meters vary in accuracy from one meter to another but are still within the limits of the illumination measurement standards for accuracy, and hence acceptable to use for arc flash light measurement.

Following are some common light measurement units (lumen=lm, lux=lx, foot candle=fc):

- 1 lx = 1 lm/m^2 = 0.0001 phot = 0.0929 fc
- 1 phot = 1 lm/cm^2 = 10000 lm/m^2 = 10000 klx
- 1 fc = 1 lm/ft^2 = 10.752 lx

Ideally, the source of light should mimic the optical behavior of an arc flash with equivalent brightness. However, this type of light source is not readily available since it requires separate control for brightness, duration, and pulsation with decay. The most readily available and cost-effective alternative is a camera flash used with professional cameras. The brightness of a camera flash is adequate for arc flash testing. The only other parameter of concern is the duration of the flash.

The duration of light from camera flashes is measured in two ways: the t0.5 and t0.1 methods. The t0.5 is the time between rising and falling of the curve at 50% of the maximum curve height. Similarly, t0.1 is the time between the rising and the falling curve at 10% of the maximum curve height. A typical Canon Speedlite Flash has a t0.1 duration of 1/200 s (5ms) at full power and 1/20,000 s (50μs) at the lowest output levels.[3]

[3] http://speedlights.net/speedlite-test-details

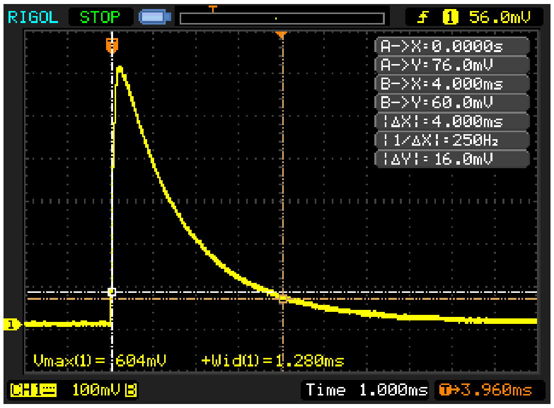

Figure 13. Camera Flash Duration[4]

Figure 14. Canon Speedlite

Ideally, the camera flash should have a t0.1 duration of 8 to 10ms, however a 4ms pulse is adequate for testing purposes. The camera flash must have a “PILOT” button to test the flash. This is a great feature for sensors that are far from the relay. On most camera flash modules, settings allow adjustments to the output power. The flash must be set on the highest output power and the longest flash duration possible. This can generally be done by selecting the “mode” button to switch from “ETTL” to “Manual” mode. Once in the manual mode, the output power can be adjusted to “1/1” for full power and longest duration. Using a light meter, the camera flash gives on average 1430 klx of light at 16” from the flash. The light level is not as high as the real arc flash but it is adequate for test purposes.

For further assistance

For product support, contact the information and call center as follows:

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[4] http://www.gock.net/wp-content/uploads/2012/01/580ex-full-power.png