WHITE PAPER

How Current Limiting Devices for Low-Voltage Applications Can Help Save Lives for Your Organization

Are You Prepared to Mitigate Arc Flash Risk?

As the demand for electrical power increases, distribution systems are expanded to accommodate the increased demand. Stiffened transmission systems, increased substation capacity, and added on-site and distributed generation all contribute to increases in available fault currents. Often these currents exceed the capability of the electrical equipment, putting the equipment and maintenance personnel at risk for a catastrophic event.

Current limitation drastically reduces the magnitude of the peak let-through current and the system energy, protecting equipment from costly failure and protecting workers from dangerous arc flash.

For high-voltage and medium-voltage applications, current limitation methods have been well-established, but for low-voltage applications, other options have served as the last line of defense in the event of an arc flash incident.

Traditional methods to mitigate an arc flash are plagued by high detection and clearing times, which result in high incident energy. Any method that takes more than 100 ms will cause vaporizing of metals, which can severely injure people and damage equipment surrounding the affected gear.

This paper, written for those who specify electrical components, switchgear and power distribution equipment for utility, heavy industrial, healthcare, universities or offshore applications, will discuss current regulations and requirements, define arc flash and its impacts, discuss arc flash mitigation and, most importantly, how current limiting devices for low-voltage applications should be seriously considered as part of an organization's comprehensive arc flash mitigation strategy. Finally, this paper will provide key considerations and questions that engineers, specifiers, safety officers and plant managers should ask when considering the installation of low-voltage current limiters.

G&W Electric
Engineered to order. Built to last.

Arc Flash – A Catastrophic Event

At any point in time, one can log on to their computer, pick the search engine of their choice and type in the search terms "arc flash" and "OSHA" and find news stories indicating that yet another company has been cited for an arc flash incident. These occurrences happen all too often, and as their name indicates, arc flashes occur quickly. In fact, a typical arc flash event can last on average one millisecond. In that blink of an eye, the arc flash incident creates long-term and often devastating impacts. First and foremost is the loss of life or serious and debilitating injury. Second, arc flashes can create significant economic damage to an organization’s critical infrastructure.

Those near an arc flash can receive more than just burns from the superheated ball of gas, and the arc flash can also damage a person’s hearing, eyesight or organs, and can fracture bones or forcibly throw a worker across a room. Additionally, the explosion can send shrapnel flying towards a worker at speeds of 700 miles per hour. An arc flash is so catastrophic, the victim may also suffer disfigurement, cognitive loss, memory loss, behavioral changes, seizures, permanent loss of function and death. As a result, life after an arc flash event can be very difficult.

Because of the serious risks associated with arc flash, safety standards have been established to protect workers. Even with safety measures in place, approximately 30,000 arc flash incidents happen every year, resulting in 7,000 burn injuries, 2,000 hospitalizations and 400 fatalities.

In fact, 80 percent of electrical worker fatalities are due to burns, not shock.[1] Workers can be severely injured as far as 10 feet away from the arc flash center.[2]

In addition to the devastating effects caused to people's health and lives, arc flash injuries can also create an economic disaster. The average medical expense for an employee who survives an arc flash is $1.5 million USD. The price of litigation and settlement in an arc flash is between $5 million USD and $10 million USD.[3]

[1] *Industrial Safety & Hygiene News, “Arc Flash Statistics,”* May 31, 2013
[2] *EHS Daily Advisor, “Train Workers to Recognize Arc Flash Hazards and Take Proper Precautions,”* May 4, 2014
[3] *EHS Daily Advisor, “Don’t Let Arc Flash Cost You,”* August 19, 2015

Arc Flash – A Catastrophic Event (continued)

What is arc flash mitigation?

When applied to electrical workplace safety, arc flash mitigation involves taking steps to minimize the level of hazard and/or the risk associated with an arc flash event. There are governing bodies and standards organizations that have published papers and recommendations. These include National Fire Protection Association (NFPA), The National Electrical Safety Code (NESC), the Occupational Safety & Health Administration (OSHA) and the Institute of Electrical and Electronics Engineers (IEEE). Earlier in the decade, OSHA made significant changes mandating organizations to protect workers against arc flash events. Some of the more common OSHA standards cited for arc flash include:

OSHA STANDARDS

29 CFR 1910.132(d)(1)	Requires employers to perform a personal protection equipment (PPE) hazard assessment to determine necessary PPE.[4]
29 CFR 1910.332(b)(1)	Practices addressed in this standard, employees must be trained in and familiar with the safety-related work practices required by 1910.331 through 1910.335 that pertain to their respective job assignments.[5]
29 CFR 1910.333(b)(2)(iv)(B)	A qualified person must use test equipment to test the circuit elements and electrical parts of equipment to which employees will be exposed and must verify that the circuit elements and equipment parts are de-energized.[6]
29 CFR 1910.335(a)(1)(i)	Employees working in areas where there are potential electrical hazards must be provided with, and must use, electrical protective equipment that is appropriate for the specific parts of the body to be protected and for the work to be performed.[7]
29 CFR 1910.335(a)(1)(iv)	Requires employees to wear nonconductive head protection wherever there is a danger of head injury from electric shock or burns due to contact with exposed energized parts.[7]

Following those requirements by OSHA, the NFPA published new guidelines titled, *NFPA 70E: Standard for Electrical Safety in the Workplace*[8], which provide organizations with the direction to establish a five-step arc flash mitigation process.

Step 1
Develop and audit an electrical safe work practices (ESWP) policy.

Step 2
Conduct an electrical system study to determine the present degree of arc flash hazards and label the equipment.

Step 3
Ensure adequate supplies of PPE.

Step 4
Conduct regular safety training and employee assessments.

Step 5
Maintain all electrical distribution system components.

[4] OSHA Standard 1910.132 - *General Requirements*
[5] OSHA Standard 1910.332 - *Training*
[6] OSHA Standard 1910.333 - *Selection and use of work practices*
[7] OSHA Standard 1910.335 - *Safeguards for personnel protection*
[8] *Standard for Electrical Safety in the Workplace®*, 2018, NFPA Codes & Standards

Better Understanding of an Arc Flash

What is an arc flash?

Electrical arc faults result in an arc flash. It can happen in an instant, or in a flash as its name implies. When the current flows through ionized air, energy is dissipated in the form of intense light and heat, reaching temperatures up to 35,000°F — four times the temperature of the surface of the sun, which is about 9000°F.

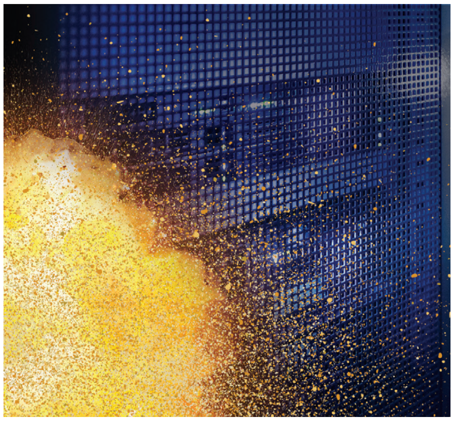
FACTORS AFFECTING THE SEVERITY OF ARC FLASH INJURY:

- The proximity to the flash, with those being closest having the most severe injuries.
- Temperature — anything greater than 1.2 cal/cm2 results in burns, etc. Anything above 40 cal/cm2 causes large enough pressure waves and incident energy to severely hurt or kill a person.
- PPE including protective clothing, helmets, goggles or other garments or equipment designed to protect the worker's body from injury or infection. Protective clothing protects from some arc flash hazards, but doesn't protect against the blast in an arc flash event.
- Amount of time of the fault current energy let through. Fewer cycles, less damage.

Even the most well-designed system running on the very best equipment can still be susceptible to an arc fault. Fault currents, even seemingly modest ones of 5–10 kA, can yield catastrophic results — arc flash on live equipment, the rupture of oil-filled gear or explosion of faulty switchgear.

COMMON CAUSES OF AN ARC FLASH:

- Insulation failure.
- Buildup of dust, impurities and corrosion on insulating surfaces, which can provide a path for current.
- Equipment failure due to use of substandard parts, code violations, improper installation or even normal wear and tear.
- Animals or insects snapping leads at connections.
- Human error, including dropped tools, accidental contact with electrical systems and improper work procedures.
- Water or other liquid spills near electrical equipment.



“Even the most well-designed system running on the very best equipment can still be susceptible to an arc fault.

Current Limiting Devices vs. Conventional Devices in Arc Flash Mitigation

Based on aforementioned OSHA requirements 4, 5, 6, 7 and NFPA 8 guidelines, it can be argued that current limiting protection devices can generally be used for different functions to not only protect underrated equipment and of course minimize damage to equipment, but ultimately to mitigate the risk and severity of an arc flash event.

In other words, the current limiting protection device is a critical piece of the arc flash mitigation puzzle, as it serves as an insurance policy for an organization's workforce and a vital piece of electrical equipment.

In the case of arc flash mitigation, current limitation is preventing catastrophic failure of the equipment and eliminates one's exposure to the energy of an arc flash blast. During an arc fault, a current-limiting device mitigates the effects of direct exposure to released energy. A large percentage of current-limiting applications are used for limiting the energy of the exposure by reducing the PPE level. In many cases, by using G&W Electric's CLiP®-LV[9] , PPE level can be reduced to between "0" or "1."

How does it work?

Upon occurrence of a short circuit current, a sensing unit actuates a linear cutting device. This opens a copper busbar and bends it upward, forming a gap.

An arc is formed at this gap and resultant arc voltage causes transfer of the short circuit current to a small, parallel current limiting fuse.

The fuse melts and clears the circuit. As a result, current extinction occurs in the first half cycle and limitation prior to the first peak. Additionally, reliable interruption is assured without venting of ionized gases.

CLiP-LV COMPONENTS

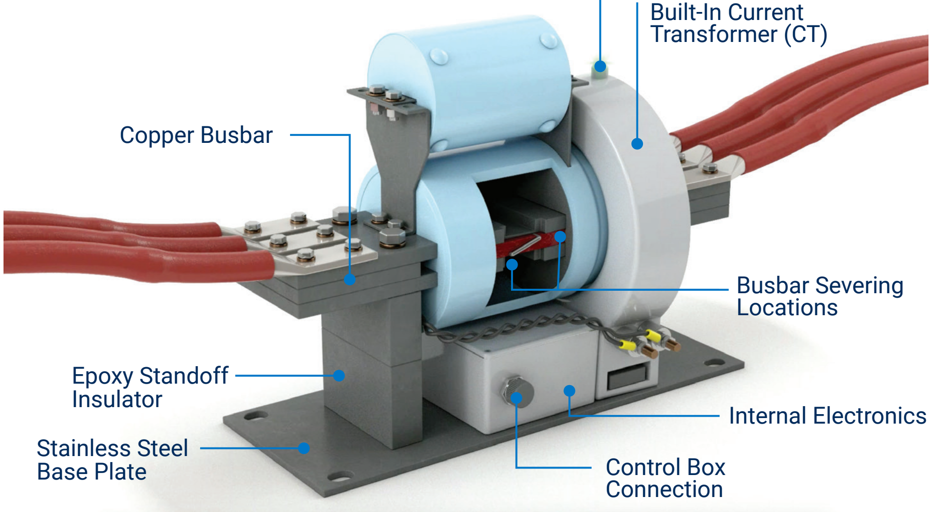


Figure 1: G&W Electric's CLiP®-LV

[9] *G&W Electric's G&W's CLiP®-LV (Current Limiting Protector) is a unique overcurrent protection device that interrupts potentially damaging fault current before the first half-cycle peak, significantly limiting potential damage. CLiP®-LV is registered trademark of G&W Electric.*

Current Limiting Devices vs. Conventional Devices in Arc Flash Mitigation (continued)

CLiP-LV vs. circuit breaker

Compare the current-limiting device to the more commonly used circuit breaker. A typical breaker would clear a fault in 5 cycles (as shown in Figure 2), whereas the CLiP-LV would clear the fault in a ¼ to a ½ cycle. The corresponding relative let-through energy (I^2t) in the breaker is approximately 220 times the let-through energy in the CLiP-LV.

As compared to other conventional methods, the fault-limiting devices and current-limiting devices certainly serve a purpose and attempt to mitigate against arc flash, but are limited in their ability to completely minimize damage. See Figure 3 for an overview of the alternatives and their limitations.

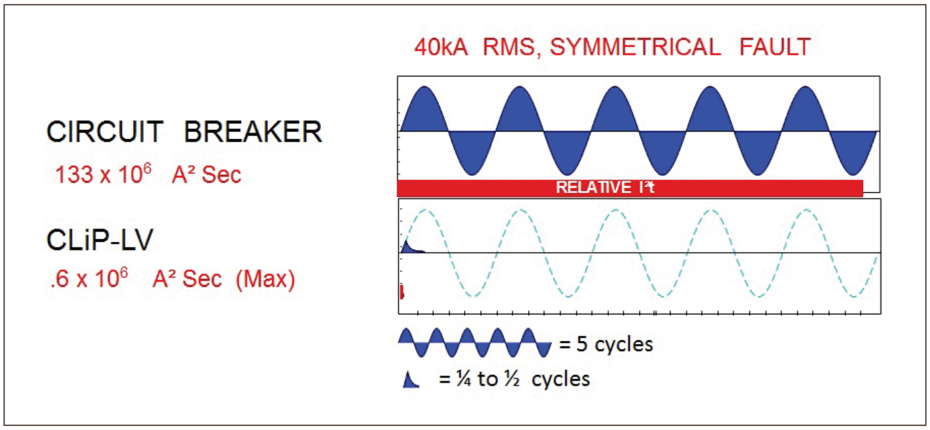


Figure 2: Fault Current Let Through Energy (I^2t)

CONVENTIONAL DEVICES VS. CLiP-LV

		DESIGN CONSIDERATIONS
Conventional Fault-Interrupting Devices	Current-Limiting Fuse	• Reduced current-limiting capabilities at low-level fault currents • Motor starts, lightning surges and heavy transients may damage traditional fuse elements or change their response, requiring replacement • No status feedback available
	Expulsion Fuse	• Emits blasts when clearing faults and ineffective in limiting let-through energy • Lower-level fault currents may partially melt the fuse, resulting in failure or limited performance if not known or replaced • No status feedback available
	Circuit Breaker	• Much slower clearing times allow for far greater energy let-through and requires maintenance • Requires an external device (relay) to send the operational signal, which delays the circuit interruption
Conventional Current-Limiting Devices	Current-Limiting Reactor	• Large size often does not fit in retrofit applications • Adds to system losses (internal resistance in mohm range) during normal operation • Blocks VARS transfer out of generators • No status feedback available
	Three-Phase Earthing Switch	• Large size often does not fit in retrofit applications • Eliminates the arc by inducing a bolted fault on the system, which adds stresses to the entire electrical system • Equipment lifespan may be reduced

Figure 3: An overview of the alternatives and limitations between conventional fault-interrupting devices and conventional current-limiting devices.

Current Limiting Devices vs. Conventional Devices in Arc Flash Mitigation (continued)

Conversely, the latest versions of current limiting, such as G&W Electric's CLiP-LV, offers some additional features and benefits to consider in a new or existing electrical system. See Figure 4.

FEATURES AND BENEFITS

FEATURES	BENEFITS
Single-phase and three-phase protection	• Use the high-speed remote indication relay contacts (located in the control box) to trip a breaker and interrupt unfaulted phases. No need to replace interrupters in unfaulted phases
Threshold current sensing (Does not use transient susceptible rate of rise current sensing)	• Hardened transient filtering responds to actual current values, not transients or harmonics • Can directly protect capacitor banks and harmonic filters • Consistent peak let-through values, regardless of fault asymmetry level
Field-selectable trigger levels (pick-up)	• Adjust trigger levels in the field to ensure continuing protection as the site characteristics change
Remote enable/disable	• If protection is temporarily not required, it can be remotely disabled. It then acts simply as a busbar. The operation modes are PLC and SCADA adaptable
Remote trip indication	• Three-phase remote indication of operation (within three cycles) provides two Form C contacts for remote monitoring and trip of user's circuit breaker to prevent single-phasing
Outdoor duty	• Can be installed outdoors without an enclosure or mounted on a pole
No fuse aging associated with transients or inrushes	• No need to replace aging fuses, providing substantial long-term cost savings
Copper busbar	• Lower system losses, resulting in improved reliability. Lower peak let-through, resulting in better current limiting performance

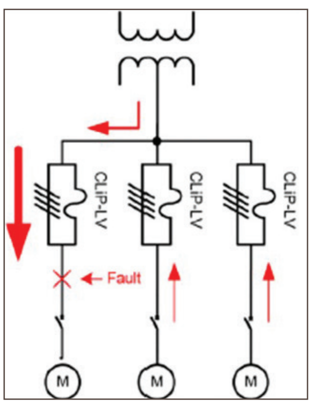
Figure 4: G&W Electric's CLiP-LV features and benefits

Current-Limiting Devices for Low-Voltage Applications

Besides the use of the CLiP-LV for an arc flash mitigation application, there are additional benefits/applications as shown below.

Helps minimize damage

Even with properly rated equipment designed to withstand the available fault duty, the let-through energy of a fault may still result in costly damage. Traditional equipment such as relays, circuit breakers and current-limiting reactors are far less effective at preventing this from occurring. At lower continuous currents, current-limiting fuses prevent this damage; while at higher continuous currents, a current-limiting device provides effective current-limiting performance of a much lower-rated fuse, but with an electronically controlled operation.



Typical minimizing damage application. Note, only the CLiP-LV closest to the fault will operate. All other CLiP-LVs will not operate.

Protects overdutied equipment

Switchgear is rated for a specific symmetrical fault interrupt rating and a peak momentary rating. With increased load, customers and industries are adding additional sources of power. With these additional sources comes increased fault current, which exceeds the rating of the equipment. Most of the time it becomes difficult and expensive to replace the existing equipment. In such scenarios, current-limiting devices like the CLiP-LV can be used to limit the fault current by selecting appropriate trip settings and thereby protecting the switchgear from being overdutied. Figure 5 provides an example where the CLiP-LV is being used to protect the equipment from catastrophic failure.

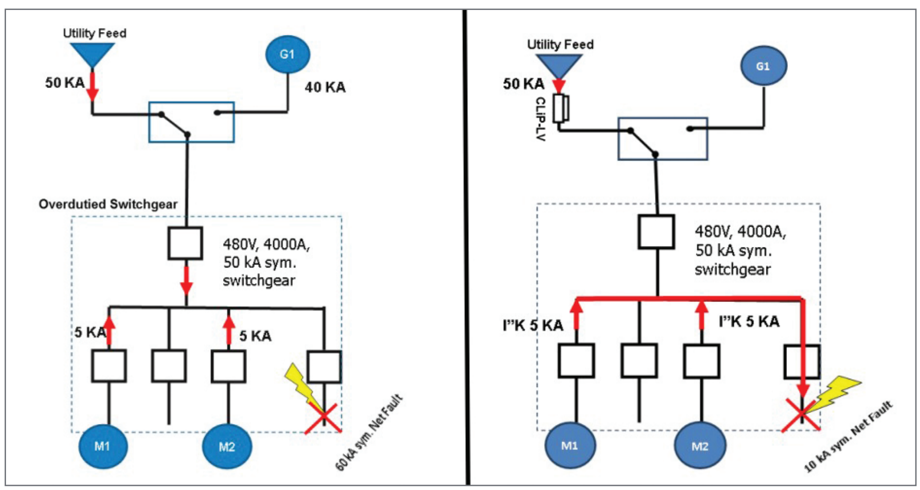


Figure 5: CLiP-LV protecting overdutied equipment

Source limitation is a common application where a low-voltage CLiP-LV can be used. In the example shown in Figure 5, the utility feeder is feeding an industrial load via a switchgear rated for 50 kA sym. In the event of a fault as shown above, the fault current contributed by the utility feeder pushes the switchgear beyond its ratings.

To protect the equipment from being overdutied, a CLiP-LV can be added downstream of the utility feeder. In the event of fault, the CLiP-LV triggers and the net fault is reduced to 10 kA sym, thereby protecting the equipment from being overdutied.

The CLiP-LV can be used for the above applications at various industries, including but not limited to: chemical plants, paper mills, cement plants, mining, refineries, pharmaceuticals, universities, hospitals, waste water treatment plants and data centers.

Key Considerations

Based on the key applications for the CLiP-LV, an engineer (consultant or OEM) should consider the following when specifying or proposing a solution.

- The CLiP-LV has been certified by Underwriters Laboratories, a globally recognized agency, and now complies with Standard(s) for Safety: UL 3801, Outline of Investigation for Fault Limiters.[10] When integrating with other UL certified equipment (example UL-891 LV switchboards or UL-1558 LV gear), consideration should be given to series rating requirements, along with other industry codes.

- The CLiP-LV is suitable for outdoor and indoor applications. It is also possible to install in a stand-alone indoor or outdoor enclosure. When integration with existing equipment is required, consideration should be given to location, space requirements, cable routing and ease of integration.

- When new equipment is being purchased, consideration should be given to lower-rated equipment integrated with the CLiP-LV to optimize the cost of the project with regards to the gear and cable ratings.

- When arc flash-resistant gear is specified, consideration should be given to the benefit of the CLiP-LV over the arc flash-resistant gear. Since the CLiP-LV significantly reduces the let-through energy and minimizes or prevents any damage, the cost and time to restore the system (after an arc flash incident) is minimal compared to that of arc flash-resistant gear.

- When arc flash mitigation is specified, consideration should be given to the fault-clearing time of the CLiP-LV (¼ to ½ cycle) compared to a breaker/optical arc flash protection scheme (five cycles or more, for most breakers).

- Partner with the experts. Arc flash and arc flash mitigation is a serious matter and partnering with those who understand how to install current-limiting equipment and take a customized approach to your organization's arc flash mitigation strategy is paramount.

[10] *UL 3801 – Outline of Investigation for Fault Limiters*

Contact us today

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Engineered to order. Built to last.

This white paper is published by the experts at G&W Electric. Since 1905, G&W Electric has been a global supplier of electric power grid equipment. The company's product offerings include overhead and underground distribution switchgear, automation solutions, reclosers, distribution and transmission cable accessories, and current-limiting system protection devices. The products are designed to the latest industry standards and backed by more than a century of engineering expertise. The result is time-proven, reliable performance.