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Thought Leadership White Paper

# What You Need to Know About Arc Flashes

*Understanding and mitigating the dangers of data center electrical explosions*

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## Executive summary

Arc flashes—the fiery explosions that can result from short circuits in high-power electrical devices—kill workers in the U.S. every year and permanently injure many more. They can also wreak financial havoc in the form of fines, lawsuits and damage to expensive equipment. Yet, many data center operators are perilously unfamiliar with both the causes of arc flash events and the serious dangers they pose.

This white paper aims to fill that knowledge gap by providing introductory-level information about what arc flashes are, why they're so hazardous and what steps data center managers should take to safeguard their employees, infrastructure and productivity.

### Table of contents

## What is an arc flash?

In the simplest terms, an arc flash is the energy release that occurs during an electrical fault when current flows through the air between two live conductors, causing a short circuit. In a residential setting, arc flashes usually produce little more than a brief flash of light before extinguishing themselves harmlessly. In a commercial or industrial setting, however, voltages are significantly higher, so electrical faults typically release far more energy. As a result, arc flashes in data centers routinely produce powerful explosions marked by searing heat, toxic fumes, blinding light, deafening noise and massive pressure waves.

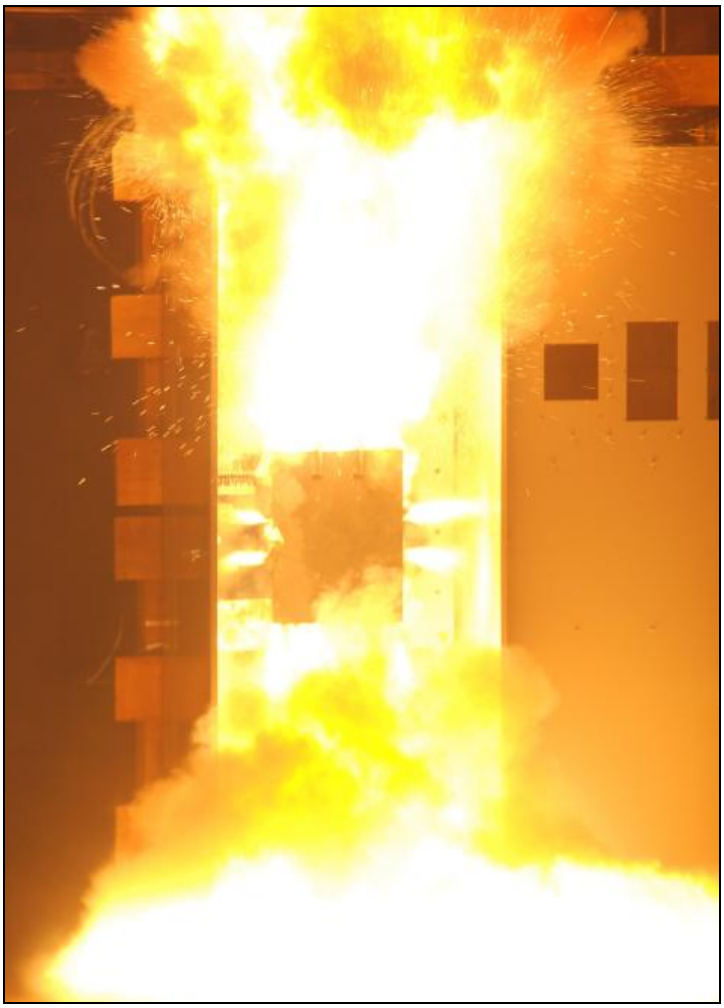

***Figure 1:*** *In a data center, arc flashes can ignite large and dangerous explosions.*

Needless to say, the human and financial repercussions of such blasts can be devastating:

- **Injuries to employees.** Without adequate protection, workers exposed to arc flash events can suffer third-degree burns, collapsed lungs, vision loss, eardrum ruptures, puncture wounds, and even death. In fact, electrical contact results in 3,600 disabling injuries annually and one workplace death every day in the U.S., according to statistics from the National Institute for Occupational Safety and Health.
- **Steep medical and insurance bills.** Covering the cost of an injured employee's medical leave after an arc flash incident can be expensive. In addition, businesses that have experienced an arc flash may have difficulty obtaining insurance and will probably pay higher rates for any coverage they do acquire until they can prove appropriate safety measures have been taken.

- **Exposure to fines and lawsuits.** Any time employees die or are injured on the job, costly lawsuits are almost sure to follow. So, too, are fines from the Occupational Safety and Health Administration (OSHA). In fact, OSHA has been known to impose fines totaling millions of dollars after arc flash events, and has even fined companies that have yet to suffer arc flashes for failure to comply with arc flash safety standards.
- **Damage to equipment.** Arc flash events are likely to severely damage or permanently destroy any servers, racks, networking gear and power distribution units in their immediate vicinity. Smoke condensation can cause further harm to sensitive electrical equipment at greater distances. Additionally, should an arc flash trigger your data center's fire suppression system, you can easily end up with an entire room of valuable IT resources covered in water or thick flame-retardant foam.
- **Delays and downtime.** Companies sometimes must wait for OSHA to complete an investigation before repairing arc flash-related damage. That means organizations with insufficiently redundant data centers can suffer hours, days or even weeks of downtime after an arc flash event.
- **Impact on morale.** Attracting and retaining qualified technicians can be difficult if an arc flash incident causes current and prospective employees to view your data center as an unsafe place to work.

## Arc flash mitigation strategies

Given the grievous dangers they pose, arc flash events merit serious attention from data center professionals. Here are six of the most effective strategies for reducing the frequency, severity and harmfulness of arc flash incidents.

### 1. Perform a hazard analysis

Every arc flash mitigation program should begin with a hazard analysis aimed at calculating how much energy an arc flash could release at various points along the power chain. Accuracy is essential with such measurements, so data center managers who lack direct and extensive experience with arc flash incident energy assessment should always seek assistance from a qualified power systems engineer.

Upon completion of an arc flash hazard analysis, companies should take the following steps:

**Equip data center staff with appropriate personal protective equipment.** Technicians should never come within range of a potential arc flash incident without wearing appropriate personal protective equipment (PPE), such as flame-resistant clothing, eye protection and gloves. PPE is available in varying degrees of strength, with varying degrees of protection. Electrical engineers and fire safety professionals have developed two standards to help organizations determine how much protection their employees require:

- **IEEE 1584:** Created by the Institute of Electrical and Electronics Engineers (IEEE), one of the world's most respected technical professional associations, IEEE 1584 offers guidance on quantifying potential arc flash incident energy levels. For more information, visit http://ieee.org and search for "1584."
- **NFPA 70E:** Produced by the National Fire Protection Association, a non-profit organization dedicated to fire, electrical, building and life safety, NFPA 70E defines thresholds for appropriate PPE based on the severity of potential arc flash hazards. For more information, visit www.nfpa.org and search for "NFPA 70E."

Drawing on these two standards, as well as data collected during an arc flash hazard analysis, organizations can accurately determine their Hazard Risk Category, which will tell them what kind of PPE their employees should wear when working in arc flash danger zones. Data center managers should also ensure that personnel from any vendors or third-party service providers who perform maintenance procedures on their server infrastructure wear appropriate PPE at all times.

**A note about single-phase-to-ground faults**

While arc flash safety standards such as IEEE 1584-2002 are extremely helpful tools, they contain an important gap at present: single-phase-to-ground faults. Though IEEE 1584-2002 provides energy calculations for three-phase arcing faults, it offers no guidance on single-phase-to-ground faults, which are much more common in servers and other communications technology equipment that operates on single-phase power. Instead, the standard assumes that ground faults will ether self-extinguish or escalate into a three-phase fault.

In truth, however, the additional energy released by single-phase ground faults before they become three-phase faults can be substantial. This is because ground faults tend to be lower current faults that require more time for upstream protective devices to clear, while higher current three-phase faults are cleared quickly. Since current IEEE 1584-2002 guidelines fail to take that additional energy into account, they may significantly underestimate the amount of protection exposed workers require. Eaton and other leading companies have contributed substantial funding to a new joint NFPA/IEEE work effort aimed at updating the 2002 standard to include, among other things, single-phase arc flash testing.

**Post warning labels.** To ensure data center employees are always aware of potential arc flash hazards, companies should place warning labels on any piece of electrical equipment that poses an arc flash risk. They should also mark arc flash hazard zones on the floor so workers not wearing PPE can clearly see how far away from electrical equipment they must stand to avoid serious injury.

Note that the NFPA 70E standard explicitly requires employers to post signage notifying employees of potential arc flash dangers. Organizations that ignore this directive dramatically increase their chances of paying serious fines and losing expensive lawsuits after arc flash incidents.

**Execute an employee training program.** To ensure data center personnel understand arc flash dangers and know how to avoid them, be sure every existing and newly hired employee receives thorough arc flash safety training.

## 2. Reduce available fault current

Though not applicable to environments protected by fuses and current-limiting breakers, data centers that use non-current limiting breakers (NCLBs) can reduce the amount of incident energy released during arc flashes by reducing the amount of available fault current. The following four strategies can help data centers with NCLBs significantly reduce available fault current.

**Operate with an open tie during maintenance.** Maintaining dual electrical feeds helps data centers increase the redundancy of their power supply, and hence the availability of their IT systems. The downside of this power architecture, however, is that it can double the amount of current available when faults occur. In most cases, opening the tie between dual power feeds during maintenance procedures reduces arc flash dangers by cutting available fault current in half.

Of course, opening ties during maintenance also temporarily renders your power scheme less redundant, exposing IT equipment to heightened risk of failure. Given the devastating human and financial toll arc flashes can take, most organizations consider that a tradeoff well worth making.

**Switch to smaller kVA and/or higher impedance transformers.** In the past, server power supplies commonly generated distortion that could overheat electrical transformers. To compensate, data centers often used bigger—and hence stronger—transformers than their infrastructure otherwise required. These days, most server power supplies are “power factor corrected,” so they no longer pose a menace to transformers. As a result, data centers can now safely deploy smaller transformers better suited to their requirements. Doing so will save money and improve arc flash safety, as a smaller transformer releases less energy during faults, lowering the scale and impact of arc flash events.

**Employ high-resistance grounding.** During ground faults, high-resistance grounding (HRG) systems provide a path for ground current via a resistance that limits current magnitude. That dramatically reduces the size of line-to-ground faults and associated arc flashes. HRG can be used on systems that service only three-phase loads. The U.S. National Electrical Code prohibits using HRG on distribution systems serving

loads that are connected line-to-neutral, as are most servers. This limits the practicality of an HRG system to the portion of a data center that powers cooling plants and other large three-phase loads.

**Use current limiting reactors.** Current-limiting reactors act as a bottleneck on electrical flows, restricting current during faults. For example, low-voltage motor control centers can be supplied with three single-phase reactors that limit available short circuit current, resulting in smaller energy releases when faults occur.

***Figure 2:*** A low-voltage motor control center equipped with current-limiting reactors reduces fault current by decreasing available short circuit current.

## 3. Shorten clearing time

Just as smaller arc flashes release less energy, so, too, do shorter ones. Here are three techniques for shortening arc flash events by decreasing fault clearance times:

**Utilize zone selective interlocking.** Zone selective interlocking (ZSI) is a protection scheme that uses an "inhibit" signal transmitted from downstream breakers that see a fault to the next breaker upstream. The upstream breaker sees both the fault current and the inhibit signal and therefore delays tripping, allowing the downstream breaker to clear the fault. Should a fault occur between the downstream and upstream breaker, however, the downstream feeder doesn't see the fault or send an inhibit signal to the upstream breaker. That causes the upstream breaker to bypass any intentional time delay settings, significantly reducing arc flash incident energy.

**Implement a bus differential scheme.** These are coordinated zones of protection within an electrical system. When a fault occurs within a given zone of protection (i.e., between the main and feeder breakers), protective devices trip instantaneously, limiting arc flash durations while also confining arc flash damage to specific portions of your infrastructure. Bus differential systems are typically faster and more sensitive than ZSI, but require additional current transformers and relaying equipment. This generally makes them harder to implement and more expensive.

**Deploy an Arcflash Reduction Maintenance System.** An Arcflash Reduction Maintenance System (ARMS) shortens faults by bypassing all time delays in the trip circuit any time current exceeds a preset maximum. That enables faults to clear even faster than a circuit breaker's "instantaneous" function makes possible. Technicians must manually enable ARMS circuits before doing maintenance work and then disable them when that work is complete, employing familiar lockout/tagout procedures.

***Figure 3:*** *An Arcflash Reduction Maintenance System shortens fault clearing times by bypassing time delays in the trip circuit.*

## 4. Adopt remote operation

Executing potentially dangerous procedures remotely can shield data center personnel from injuries. Here are two ways to limit the number of maintenance operations technicians must perform while in range of arc flash blasts:

**Install remote monitoring, control and diagnostics software.** Today's sophisticated power management systems equip administrators to perform many administrative tasks remotely. They also equip companies to remotely de-energize electrical equipment before data center staff approach it.

**Employ remote racking devices.** Traditionally, technicians have had to stand close to equipment with live, electrical connections when racking and un-racking breakers. Remote racking devices enable operators to perform these extremely dangerous tasks from a safe distance.

## 5. Predict and prevent faults

One of the most effective ways to prevent arc flashes is to anticipate and eliminate the conditions that cause them. The following three solutions enable data centers to spot potential arc flash dangers before they have a chance to do harm and keep personnel safely away from live connections.

**Monitor insulation integrity.** Deteriorating insulation is the leading cause of arc-producing electrical failures. Identifying and repairing compromised insulation before it fails can help avert arc flash explosions. Predictive maintenance systems provide early warning of insulation failure in medium-voltage switchgear, substations, generators, transformers and motors.

**Monitor pressure junctions.** Most electrical equipment contains pressure junctions, such as shipping splits, load lugs and compression fittings. Over time, vibration and thermal cycling can loosen these connections. When current flows through a loosened connection, it can cause overheating and eventually produce an arc flash. Using non-contact thermal sensors called pyrometers, however, data centers can monitor pressure junctions continuously and receive advance notification of loose connections before they become so loose that they create an arc flash explosion.

***Figure 4:*** *Pyrometers, like the one shown here, continuously monitor pressure junctions for signs of loosening.*

**Use infrared (IR) windows.** Using contactless IR thermography technology, IR windows enable technicians to perform IR scans without removing switchgear side panels, lessening the likelihood of arc flash events caused by accidental contact with live bus.

### 6. Redirect blast energy

Equipment that directs arc flash energy away from data center personnel is called “arc resistant.” Arc-resistant switchgear, for example, utilizes sealed joints, top-mounted pressure relief vents, and reinforced hinges to contain the energy and heat released by arc flashes and channel them via ducts to an unoccupied area inside or outside the data center.

When all else fails, arc-resistant switchgear offers vulnerable data center employees a critical last line of defense from the explosive power of arc flash incidents. However, its protective qualities are effective only when equipment doors are closed, so companies should train their technicians to fasten doors securely during normal operation.

## Conclusion

Arc flash events in industrial environments can do calamitous harm, ranging from disabling or fatal injuries to heavy fines and financially ruinous lawsuits. Yet, far too few data center operators fully appreciate either the hazards arc flashes pose or the frequency with which they occur.

Fortunately, IT and facilities managers can dramatically mitigate arc flash dangers with the help of a wide range of proven technologies and techniques. Though no combination of countermeasures can totally eliminate arc flashes, utilizing the solutions and strategies discussed in this white paper can help organizations make arc flash incidents both significantly less likely to happen and drastically less harmful when they do.

## About Eaton

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distribution and control, power transmission, lighting and wiring products; hydraulics components, systems and services for industrial and mobile equipment; aerospace fuel, hydraulics and pneumatic systems for commercial and military use; and truck and automotive drivetrain and powertrain systems for performance, fuel economy and safety. Eaton acquired Cooper Industries plc in 2012. Eaton has approximately 103,000 employees and sells products to customers in more than 175 countries. For more information, visit www.eaton.com.

## About the authors

After receiving a BSEE from the University of Kentucky and MSEE from the University of Pittsburgh, Dave Loucks has served the electrical industry for 34 years. He's a 19-year Eaton veteran and currently holds the position of Manager, Power Solutions & Advanced Systems. Dave has eight patents with four additional pending and is a senior member of the IEEE. Besides being certified as an energy manager by the Association of Energy Engineers, a registered professional engineer in the Commonwealth of Pennsylvania he is also a Ph.D student at the University of Pittsburgh researching power system pattern recognition algorithms.

John Collins has more than 20 years of experience in the data center industry. He joined Eaton in January 2011 and is solely focused on ensuring the company's data center products and solution offerings evolve with the market. John previously held various roles in sales, sales management, and product management, where he was responsible for various global product offerings relating to power generation, power quality, and power distribution. He's currently involved in many industry groups, including The Green Grid, 7x24 Exchange and AFCOM. John received his bachelor of science in electrical engineering from the University of Rhode Island and served for 10 years in the U.S. Marine Corps.

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