How Lightning Impacts Business and Electronic Systems

Implementing a surge protection plan is crucial to protecting assets and lives

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Introduction

The phenomenon of lightning is truly one of nature's most awe-inspiring occurrences. While the odds of a person being struck by lightning are less than one in 12,000, there are certainly incredible tales that rival Ripley's Believe It or Not describing encounters between people and a bolt of searing hot electricity. Perhaps no incident typifies the bizarre nature of man meets lightning better than the story of Maine farmer Edwin Robinson.

Blind for almost a decade following a truck accident on an icy New England highway, Robinson had adapted to his new life of darkness until it miraculously changed one stormy day in 1980. While looking for his pet chicken in the backyard, the 62-year-old Robinson was struck by lightning while walking under a tree, knocking him out. When he regained consciousness, the man staggered back into his home, took a nap and awakened to find he could see again. The next day, Robinson saw his doctor who assessed that his vision was 25 in the left eye and 20 to 30 in the right. Ophthalmologists around the country were suddenly debating the authenticity of Robinson's claims, while media outlets made him an instant celebrity being interviewed by the BBC, ABC, the New York Times and Washington Post. He also appeared in a famous 1990 television ad for Timex as the ultimate example of the watch that takes a licking but keeps on ticking.

There have also been other rare instances of people who were struck by lightning and experienced a positive outcome beyond just experiencing an interesting light show. There is the case of Mary Clamser, who in 1994, was cured of multiple sclerosis after she was struck by lightning inside her Oklahoma home while taking a shower. Or the strange events surrounding New York orthopedic surgeon Tony Cicoria who after being struck by lightning in 1994 acquired a sudden craving for piano music, buying recordings and becoming especially enamored of a Vladimir Ashkenazy recording of Chopin favorites. The sudden desire for classical piano music baffled him since he was a hardcore rock music fan. He also discovered a new-found passion for playing the piano, and an equally strange ability to write music even though he could never read sheet music.

Beyond the very few positive human encounters, much more often lightning causes devastating injury, damage and disruption – particularly to electrical and electronic systems that are increasingly important to the general economy and our lives. Lightning strikes cause fire damage as wood and other flammable construction materials can easily ignite when exposed to high temperatures, and lightning currents that travel through wires and pipelines can instantly burn them up causing total damage to property. Lightning is also apt to trigger a power surge if it chooses electrical wiring as its primary or secondary path, with the explosive surge potentially damaging all equipment in its path. Lightning may also damage structural buildings by fracturing concrete, brick and chimney stacks.

In this paper, we will cover the causes and effects of lightning, and review some of the best ways to minimize lightning damage to critical systems.

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Origins and Nature of Lightning

The debate over the definitive cause of lightning is ongoing, though the scientific community acknowledges that the interaction between positively and negatively charged ions within clouds is probably the spark of this process – much like the discharge of static electricity. Think of the unstable static electric charge that bolts from contact and discharge as you drag your feet across a carpet. The same principle is in play within a highly charged lightning cloud, but exponentially larger.

The characteristics of an explosive lightning strike are quite remarkable when you consider that the process is initiated by a high-intensity electric impulse that resides in a gaseous state in the upper atmosphere before igniting into the solid conductive medium that is hurled to earth in the shape of a bolt. Clouds are conducive to creating lightning as heated air from ground level rises and cools into vapor, creating mountainous clouds as high as 30 to 40 thousand feet. The birth of lightning is believed to occur at the summit of these giant clouds; and as water vapor passes down through the freezing layers, they turn to ice in what is now a thundercloud. As the ice dances across the cloud the collisions cause a buildup of electrical charges that eventually consumes the entire cloud.

Ice particles that are lighter and positively charged form at the top of the cloud. Heavier, negatively charged particles sink to the bottom of the cloud. As the intensity of the positive and negative charges increase, explosive sparks occur between the two charges causing a blinding flash of light. The lightning we witness is similar to static electricity sparks but on a bigger scale. While most lightning happens inside a cloud, it can also occur between the cloud and the ground as a buildup of positive charges on the ground attracts the negative charge at the bottom of the cloud. The ground's positive charge is conducted through objects that are usually higher than ground level like trees, antennas, lighting rods and people.

The visual effects of the lightning flash followed by the shockwave of thunder and the sheer thermal dynamics of the heat generated by the event, also create residual electrodynamic and electrochemical side-effects that can disrupt power, create electrical surges in office and industrial equipment, and interrupt network communications.

The fireworks that take place during this celestial trip to earth can be simultaneously spectacular yet devastating. The visual effects of the lightning flash followed by the shockwave of thunder and the sheer thermal dynamics of the heat generated by the event, also create residual electrodynamic and electrochemical side-effects that can disrupt power, create electrical surges in office and industrial equipment, and interrupt network communications.

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Effects of Lightning

The devastation lightning strikes can cause must not be understated. According to NFPA statistics, local fire departments in the U.S. estimate close to 23,000 fires a year are ignited by lightning, causing an average of nine civilian deaths per 53 injuries and nearly a half-billion dollars in direct property damage – mostly associated with home fires.

But it is crucial to understand the damage and destruction brought on by direct and indirect lightning strikes. Undoubtedly, direct strikes are the most spectacular examples of lightning's sheer power. One recent example of lightning's rapid destructive capabilities happened in the fall of 2020 as California saw more than 11,000 lightning strikes in the space of 72 hours that ignited uncontrollable wildfires from the northern to the southern regions of the state.

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The unusual mid-August lightning storm that triggered the Cal Fire came ahead of the fall peak fire season. Hundreds of small blazes quickly erupted into a massive wildfire that caught everyone by surprise. This ferocious wildfire scorched more than four million acres, killed 31 people, and destroyed or damaged more than 10,000 buildings in what is being called California's worst natural wildfire in history.

However, lightning doesn't require a direct hit to create havoc. Accidents caused by direct lightning strikes to a building or a specific zone can result in considerable damage, usually by fire while indirect or nearby lightning strikes may cause power surges to enter from a utility pole into the building's electrical panel, or through any metallic conductor such as communications and signaling cables, data/internet systems and CCTV/CATV cable feeds.

Within almost every commercial office building are businesses stocked with sensitive devices that store important information and data, along with network communication systems vital to business operations like sales, customer service, inventory, and financials. All these devices and systems are susceptible to indirect lightning strikes that can initiate subtle power surges and spikes. Even though such events may not register concern and can occur unnoticed, if these instantaneous events exceed normal capacity for the building's electrical line voltage, serious damage to any connected device is likely.

The loss of expensive electrical devices or downtime to a corrupted network, security, fire or communications system can be a costly result of even the most indirect lightning incidents. Organizations that count on integrated security and fire systems to protect themselves and their staff from liabilities can't afford to have something as important as video surveillance systems go dark and fail to capture important footage in the case of incidents. From a liability standpoint, many businesses and other organizations recognize the value of video beyond security in showing where falsely claimed incidents did not actually occur.

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Preventing Lightning Damage

The ever-changing climate and rising temperatures have made conditions more conducive for violent storms and more frequent lightning strikes. However, there are lightning protection systems on the market that help minimize the effects of direct hits.

The Lightning Protection Institute (LPI) is heavily involved within the industry establishing standards and certification programs promoting viable lightning protection systems. According to the LPI, lightning protection systems for structures are typically not a requirement of national building codes, although the Standards may be adopted by the authority having jurisdiction for general construction or specific occupancies. Since lightning protection may be considered an option, it is crucial that the specifier, construction contractor, and property insurer be familiar with the national standards to provide the highest level of safety available.

The association adds that lightning protection systems have a solid track record of protecting against physical danger to people, structural damage to buildings, and failure of internal systems and equipment. However, the systems are only as effective as their design, quality installation practices, and meticulous inspection and certification. In fact, UL is also extremely active in inspecting lightning protection systems. UL lightning protection inspection certificates are issued within 48 hours of completion of the inspection or after variances are corrected.

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The Lightning Protection Institute details five elements that are critical to the implementation of any effective lightning protection system. They include:

- **Strike termination devices** must be suitable to accept direct lightning attachment and patterned to accept strikes before they reach insulated building materials.
- **Cable conductors** route lightning current over and through the construction, without damage, between strike terminations at the top and the grounding electrode system at the bottom.
- The below grade **grounding electrode system** must efficiently move the lightning to its final destination away from the structure and its contents.
- **Bonding** or the interconnection of the lightning protection system to other internal grounded metallic systems must be accommodated to eliminate the opportunity for lightning to side flash internally.
- **Surge protective devices** must be installed at every service entrance to stop the intrusion of lightning from utility lines, and further equalize potential between grounded systems during lightning events.

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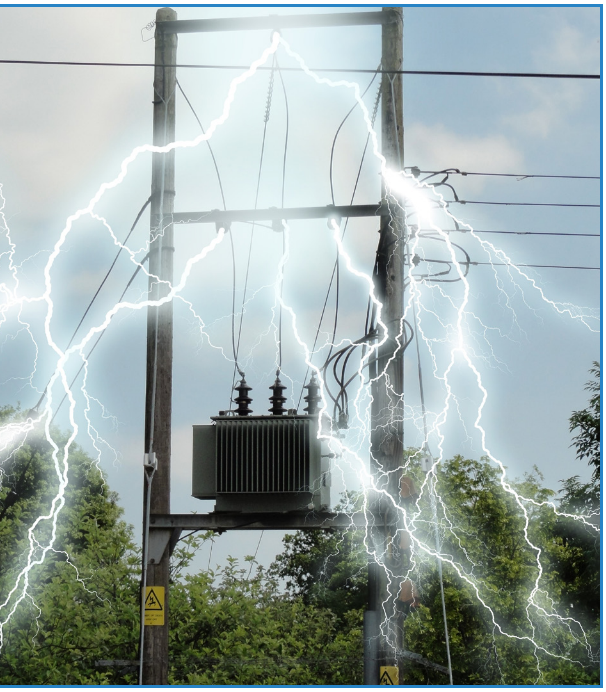

When these elements are identified properly in the design stage, incorporated into a neat workmanlike installation, and no changes to the building occur, the system will protect against lightning damage. Elements of this passive grounding system always serve a similar function, but the total design is specific for each particular structure.

Of course, insurance is not a preventative, but it can alleviate some of the financial impact resulting in a lightning event. Most insurance policies cover damage from direct lightning strikes, so purchasing additional coverage is not necessary. However, it is recommended that an organization consider the damage caused by a power surge that is not caused directly by lightning. Power surges can also be caused by lightning near your business, utility work, turning on a large piece of equipment or operating equipment during peak times like the middle of the summer. The standard insurance policy does not cover these types of events.

In contrast to direct strikes, there are measures that can be taken to prevent damage from electrical surges and spikes caused by distant lightning. The most significant threat to businesses is a power surge. A lightning bolt can strike the ground, travel three miles to reach a conductor, and transmit through cables or wires in a business. Once the lightning is transmitted into the building, the power surge causes various damage. Some of the damages that surges cause include software malfunction, data deletion and electrical fires.

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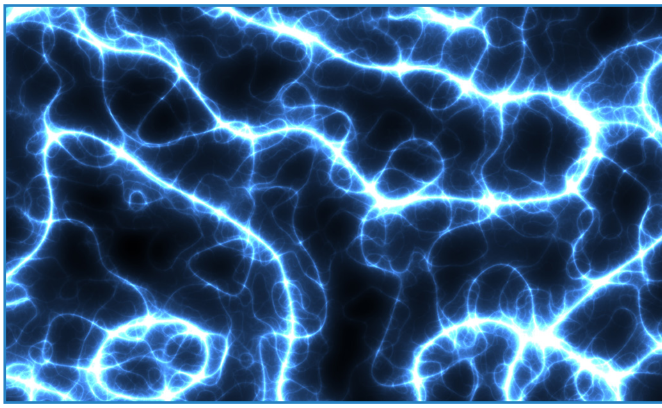
Since there are several protection options for building owners and facility managers when it comes to addressing indirect strikes, we will cover that range of solutions in the next section.

Surge Protection Solutions



Surge protection technology limits transient voltages by diverting or limiting surge current with the capability of repeating these functions as specified. Surge protective devices (SPD) are a cost-effective solution to prevent downtime, improve system and data reliability, and eliminate equipment damage due to transient surges for both power and signal lines. The use of SPDs is often specified by the end-user or mandated by code or local requirements. For example, National Fire Protection Association (NFPA) 780 and UL 96A, the Standard for Installation Requirements for Lightning Protection Systems, require the use of surge protection as an integral part of a lightning protection system.

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Typical SPD applications within industrial, commercial and residential include:

- Power distribution
- Electronic motor controllers
- Metering
- Back-up power
- Communication circuits
- Security systems
- Entertainment center or stereo equipment
- Control cabinets
- Equipment monitoring
- Medical equipment
- UPS
- Telephone or facsimile lines
- Alarm signaling circuits
- Programmable logic controllers
- Lighting circuits
- Critical loads
- HVAC equipment
- Cable TV feeds
- Kitchen or household appliances

According to the National Electrical Manufacturers Association (NEMA), there are three main types of SPDs that are National Electrical Code (NEC) and ANSI/UL 1449 compliant.

- **Type 1:** Permanently connected, intended for installation between the secondary of the service transformer and the line side of the service disconnect overcurrent device (service equipment). Their main purpose is to protect insulation levels of the electrical system against external surges caused by lightning or utility capacitor bank switching.
- **Type 2:** Permanently connected, intended for installation on the load side of the service disconnect overcurrent device (service equipment), including brand panel locations. Their main purpose is to protect the sensitive electronics and microprocessor-based loads against residual lightning energy, motor generated surges and other internally generated surge events.
- **Type 3:** Point-of-utilization SPDs installed at a minimum conductor length of 30 feet from the electrical service panel to the point-of-utilization. Examples include cord connected, direct plug-in and receptacle type SPDs.

There are also Type 1, 2, 3 Component Assembly SPDs (Component Recognized) that are intended to be factory installed into electrical distribution equipment or end-use equipment. Finally, there are two more types to consider which are also component recognized. The Type 4 component assembly SPD consists of one or more Type 5 SPD components together with a disconnector (integral or external) or a means of complying with the limited current tests in UL 1449, Section 39.4.

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These are incomplete SPD assemblies, which typically are installed in listed end-use products as long as all conditions of acceptability are met. These Type 4 component assemblies are incomplete as an SPD, require further evaluation and are not permitted to be installed in the field as a stand-alone SPD. Often, these devices require additional overcurrent protection. The Type 5 SPD is a discrete component of a surge protection device, such as an MOV that may be mounted on a printed wiring board, connected by its leads or provided within an enclosure with mounting means and wiring terminations. Like the Type 4 SPDs, Type 5 SPD components are also incomplete as an SPD, require further evaluation and are not permitted to be installed in the field as a stand-alone SPD.

It is also critical to consider the most fundamental parameters when considering deployment of your SPD strategy; ensuring that networked electronics are properly shielded from power surges and spikes. The three most common solutions for voltage transients are Metal Oxide Varistors (MOV), Silicon Avalanche Diodes (SAD) and Gas Discharge Tubes (GDT). Each of these is engineered with differing core components to perform the “dirty work” of dissipating surges away from an organization’s critical devices.

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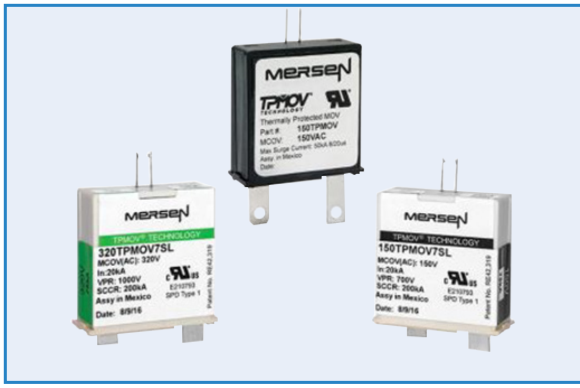
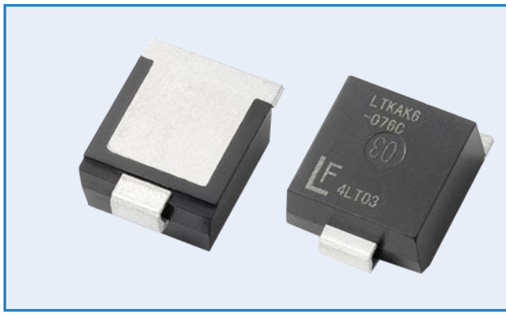
These three technologies typically define the surge protection capabilities of the components, which may also include hybrid multi-stage models that improve overall coverage. Understanding the various levels of coverage of the three will enable you to select the SPD that fits your application. Here is a brief overview of the three technologies:

- A **Metal Oxide Varistor** (MOV) is a bipolar, ceramic semiconductor device used in power supply circuits that is directly connected to and powered by the AC mains. MOVs are the most commonly used technology for surge protection and are most often found in the widely available surge protection power strips intended to protect consumer devices plugged into outlets. This type of surge protection technology cannot handle sustained overvoltage – they can only be used for short duration surge protection. And while MOVs are fairly sturdy components, capable of absorbing strong surges at the beginning of life, they do degrade over time.



- **Silicon Avalanche Diodes** (SADs) are the most commonly used surge protection technology for high-speed data transmission, low-voltage DC applications and networked devices. This SPD has a faster response time than MOVs and are built to experience avalanche breakdown, which is a type of electric current multiplication that may cause a sudden and swift increase in current. SADs are built to handle this type of surge, that can otherwise result in failure of typical diode devices.



- **Gas Discharge Tubes** (GDTs) are traditionally the strongest surge protection component available. They provide a connection between the power line and the ground line, with an inert gas as the conductor between the two lines. When the line voltage is below a certain level, the gas does not conduct electricity. But when there is a power surge or spike, the gas molecules will break into positive and negative ions and the now-ionized gas becomes an extremely effective conductor. The current surge will be passed through to the ground line, diverting the surge away from the device it is protecting. Once the surge has passed, the ions recombine to become gas molecules. While the GDT is ideal for protecting against extremely large surge events, it is less effective reacting to fast traveling and sudden surges.

With the technology primer complete, let's now discuss how to plan and implement a surge protection roadmap.

Surge Protection Strategies

Like any good security plan, creating a strategy for protecting the power resources in your organization should follow a layered approach. Adding surge protection prevents damage from electrical surges and spikes. Best practices indicate that implementing several layers is the best way to protect all your essential electronic networks.

A Layered Approach: It is critical to protect the first layer of incoming power to the facility because this is the primary entry point for power surges and spikes that originate outside the facility. Progressing to the second layer should entail protecting the network equipment power connections that can shield against power surges that are generated from within the facility, as well as providing extra protection from external and accidental sources. A third layer of protection should include other electrical pathways into the system, such as cables that pass outdoors, that could carry damaging power surges. Examples of these include wired connections to networked devices such as outdoor surveillance cameras, signaling line circuits, and telephone lines that are connected to fire alarm panels, ATMs, and point of sale devices to enable communication and notification.

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Residential versus Industrial Solutions: The differences between electrical surge protection for residential structures and industrial facilities are significant, beginning with the power distribution. Residential and non-industrial environments Typically use single-phase power service at 120 or 240 volts, while the primary electric service requirements in commercial buildings is 120/208 volt three-phase power. The service may go up to 277/480 volts in larger facilities. Industrial sectors like critical infrastructure, gas and oil facilities, factories, chemical and food processing plants and mining operations have much larger power requirements such as three-phase power with nominal service voltages of 240, 480 and 600.

There is also a substantial disparity in the potential impact of industrial surge events compared to a residential setting. Residential electronic equipment such as personal computers and entertainment systems are the usual victims of power surge events in the home. While damage to these devices can be costly to residents, they aren't life threatening or impactful to business operations when considering the cost of industrial equipment and potential downtime.

Whole-House Protection: As the smart home revolution expands into almost every home system from security to home entertainment, HVAC to data networks, the importance of protecting these investments can't be understated, especially since most homeowners are not aware how common power surges are or the extensive havoc they can cause.

Many electrical contractors are now offering whole-house surge protection as part of their normal residential electronic system installation. Whole-house protection that is initiated at the service entrance of the residence is intended to prevent externally generated surge events from entering the house. By utilizing a second layer of surge protection at the electrical outlets, or "point of use", the chances that internally generated surges will be passed throughout the rest of the house systems will be greatly reduced.

Protecting Data Networks: With a more network-centric approach to most vital facility systems, the increased risk of damaging surges migrating to other parts of a facility necessitates putting surge protection in place at both ends of these connections, and especially at locations where the network moves from outside the facility to the inside. Taking these steps can help prevent surges from spreading across a network and damaging or destroying multiple devices and systems.

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It is critical to remember that every networked sensor that provides input to a security system requires power and some form of communication, whether it is wired or wireless. Even wireless networks require power at the access points and depend on wired connectivity to function. Any networked system is vulnerable to the

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damaging effects of surges and spikes from the supplied electrical power. These systems are also susceptible to electrical disturbances transmitted via communications and signaling cables that can carry unwanted voltages directly to sensitive electronic circuits.

Protecting Sensitive Electronic Systems: Where sensitive security, communications, business and data systems are concerned, the same rules apply when creating a strategic protection plan – use the layered approach. Any unprotected electronic system including fire and life safety, access control, surveillance and intrusion detection figures to suffer some damage during its lifetime from power surges and spikes. And many of these unprotected systems will ultimately fail as a result. A proper surge protective device should be an automatic expenditure for all essential security and life safety systems.

When designing a surge protection plan for a facility system, matching the application and need is a key element to mitigating power surge issues. Here are three examples of meeting the need:

- **Access Control:** An access control system is an essential component of any safety and security program. The reasons for controlling access points vary from facility to facility. One facility might be looking at the safety aspects by keeping people away from hazardous machinery or chemicals. In other cases, it might be to prevent theft, provide a secure workspace, keep non-residents out, or to make sure members have paid their fees. In every case, these systems are implemented to ensure that only authorized people can enter these protected areas.

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  Best practices dictate that every access control system have surge protection to its supplied power connection as well as to the surge protection that is installed at the facility power entry point. Include surge protection at both ends of all connected network equipment, as the network cabling provides a conductive path for electrical

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power surges. This is especially critical for cabling paths that run to exterior areas including outdoor access control readers, gate control panels, electronic locks, or any other networked electronics or sensors.

- **Convenience Stores:** Convenience-store operators may spend tens of thousands of dollars providing customers a seamless buying experience with enhanced functionality and upgraded systems striving for the ultimate in customer satisfaction and repeat business. Unfortunately, all it might take is a lightning strike and an undetected power surge to ruin that experience. It is these types of surges that gradually degrade and damage expensive equipment until a system finally fails.

The impact of a power surge or spike in a retail environment can be catastrophic. Business operations dictate that crucial systems like Point of Sale (POS), refrigeration, food and beverage machines, fire and security systems, fuel pumps, ATMs and back office and inventory management systems stay online at all times. Investing in surge protection for all network-centric systems is a good investment.

- **Schools:** Public and private schools are keenly aware that as active shooter incidents and on-campus violence continue to rise, secure entrances, visitor management, and video surveillance systems have an important role to play in providing safe places for students to learn. It makes good financial and practical sense to protect all safety and security systems to ensure they will work when needed.

School districts that have installed surveillance systems report that maintenance issues are a recurring problem and increase multiple risks. Not only do troublesome systems become a drain on maintenance resources, but if either access control or video surveillance systems fail during an incident, districts are putting staff and students in danger and facing potential liabilities. Protecting safety and security systems from power surges and spikes is a small but highly effective investment.

Since surge protective devices deliver a critical defensive function for electronic equipment and systems used to run businesses and organizations, it is key that efforts be made to maintain the devices and monitor their health.

SPDs should not be a ‘set and forget’ method of protecting a business. Many SPDs are designed with a high threshold, so the lifespan of your SPD will depend on how often they are called

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upon to protect certain devices, along with the severity of the applied power surges. That means that the shelf life of an SPD depends on consistent and regular visual inspections that are, concurrent with other maintenance. Some SPDs are designed with visual and/or audible indicators, such as LED lights and sounds, that alert you when a device is no longer functioning and needs to be replaced. Some SPDs also can provide remote notification of surge protection status to your systems.

Conclusion

This white paper has explained some of the basics of lightning, demonstrating that it is a natural occurrence that can have disastrous results when it is up close and personal, but is also insidious in that it may attack from a distance without warning. While there are no guarantees when implementing a lightning protection strategy for a business, not having a plan is a certain recipe for disaster.

Implementing a comprehensive surge protection strategy can mitigate that risk, and should be a top priority for all security and facility managers.

Steps can be taken to protect critical electronic devices and life safety systems by performing a simple risk assessment to highlight the facility's weak points across the network and in its myriad electrical connections. Direct lightning strikes and residual and gradual surge events can damage or destroy your critical systems. Implementing a comprehensive surge protection strategy can mitigate that risk, and should be a top priority for all security and facility managers.

The cost of a proactive surge protection plan is usually less than the sales tax on the system. When you think about how much it will cost to replace a full system, or even just certain elements of a system, it becomes clear just how cost-effective a proactive surge protection plan really is. Surge protection should be an integral part of the design process from the start with collaborative efforts from the end-user, consultant, systems integrator and a qualified electrical power solutions vendor.

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