The Importance of Electrical Surge Protection

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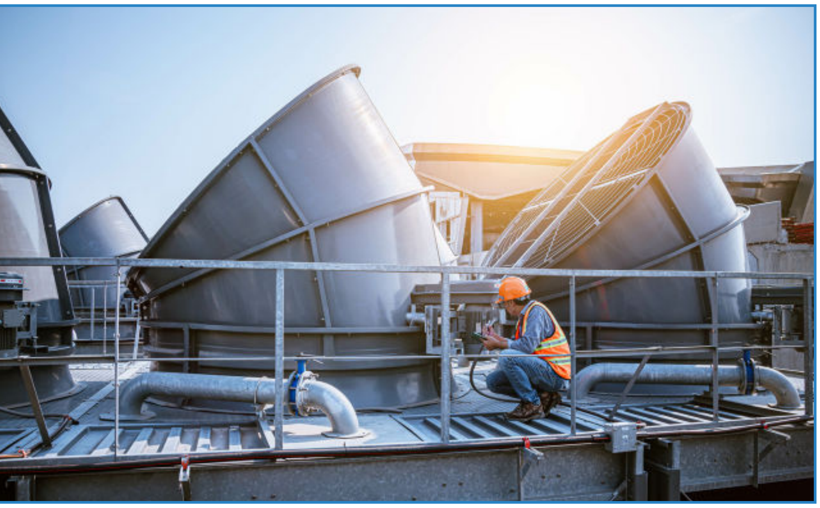
Introduction

Residential homes and industrial facilities have at least these two things in common – they both are subjected to frequent power surges, and most of these power surges go by unnoticed by the people living or working there. Only the largest and most potentially damaging surge events are noticeable, and if you believe that your home, office, or industrial location rarely, or never, experiences electrical power surges, you are definitely mistaken. Electrical professionals are in the best position to educate their customers about the nature of electrical surges and implement protection systems that will protect their electrical, HVAC and other critical systems from costly and unnecessary damage.

An average of 128.3 power-related disturbances occur in a monitored facility every month.

The question is not if surge events will happen, but how often customer homes and facilities experience power surges, what equipment and systems may be damaged, and how to protect against that damage. According to an extensive research survey of 49 cities recently completed in the United States by IBM, an average of 128.3 power-related disturbances occur in a monitored facility every month. This equates to an average of more than four power surges per day. Though most of these power surges were not intense enough to cause any immediate noticeable damage or disrupt operations, over time the progression of surge activity can cause significant impact.

While lightning strikes are most often cited by laymen as the primary source of power surges in both residential, commercial, and industrial facilities, most experts say they account for only about two percent of all surge damage. The other 98% of power surge damage comes from the hundreds of small events, most of which go undetected throughout the day. If it is not lightning causing the problem, then what?



Power surges can be caused by something much further away, or much closer - even from within the building. For example, when electrical power plants are connected or disconnected from the grid, which happens frequently as power needs change during the day, power disruptions are created that can propagate over long distances and cause surges. In addition, power experts estimate that between 60 and 80 percent of all power surges are caused by events or problems within the same building as the electronic systems they are affecting. Within industrial plants, for example, there are usually many devices with powerful motors that switch on and off during the day, including elevators, production-line machinery, HVAC and refrigeration systems, pumps, and similar equipment. All of these can cause electrical surges in common service voltages, including 120 and 240 volts in residences, 208/240 volts, and 277/480 volts in larger commercial and industrial facilities.

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Power surges in industrial and manufacturing environments can be catastrophic, damaging infrastructure and machinery, adversely impacting production lines and creating the potential for worker safety incidents. Electrical engineers and consultants estimate that these industrial losses can run into billions of dollars each from power quality issues that result in OSHA claims, fires, production disruptions, data loss and downtime.

In residences and small offices, the impact may be less costly overall, but critically important for the affected people, who depend on electrical and electronic systems for their businesses, health and safety, and their daily lives. HVAC systems, for example, must function to maintain livability in many areas, and system failures can quickly escalate to additional problems, such as freezing pipes or oppressively over-temperature interiors.

Many power surges are so brief they are measured in nanoseconds, microseconds, and milliseconds – but that is all it takes to cause devastating losses. Because of the critical nature of electrical and electronic systems in residences, commercial, and industrial settings, surge protection is a single strategic element that can pay enormous dividends – at modest cost – in every type of building. For businesses, it is a key part of every continuity plan. For residences, it should be a central part of every safety and security plan. Considering the amount of critical control systems in every kind of building today, every electrical and HVAC contractor can provide effective protection for these core systems, while building client confidence and relationships. Effective protection products that are made in the USA and not carried in retail stores are available to support these add-on sales and longer-term maintenance agreements.

Electrical Power Surges

The National Electrical Manufacturers Association (NEMA) defines a power surge as a transient wave of current, voltage or power in an electric circuit. In power systems in

particular – and this is likely the most common context that we relate surges to – a surge, or transient, is a subcycle overvoltage with a duration of less than a half-cycle of the normal voltage waveform. A surge can have either positive or negative polarity and can be additive or subtractive from the normal voltage waveform, often becoming oscillatory and decaying over time. Surges, or transients, are brief overvoltage spikes or disturbances on a power waveform that can damage, degrade, or destroy electronic equipment within any residential, commercial, industrial or manufacturing facility. Transients can reach amplitudes of tens of thousands of volts, but most are much smaller, and

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generally have very short durations measured in microseconds.

The Origins of Electrical Power Surges

According to NEMA, a common source for surges generated inside a building are situations where power is switched on and off, particularly for higher-powered electrical equipment such as pumps and motors. An example of this is a simple thermostat that controls the power to a high-powered heating element or HVAC system – ironically, it is this starting and stopping of the system that can create surges that damage the controller and other nearby systems. Between 60 to 80 percent of all surges experienced in a facility are created within that facility. These surges contain limited energy but are often the cause of system upset or cumulative damage to electronics. Power surges that originate from outside the facility include those due to lightning and utility grid switching, among other sources. These surges from external sources, while less common, can be more severe than those from internal sources.

Between 60 to 80 percent of all surges are created within a facility.

External Surges: The most recognizable source of power surges generated outside the facility is lightning. Although lightning is infrequent in certain regions, the damage it can cause to a facility can be catastrophic. Power surges that are a result of lightning can either be from direct contact between the lightning and a facility's electrical system or, more commonly, indirect or nearby lightning that induces electrical surges onto the power or communication cables. Either scenario can be immediately damaging to electrical systems, and any connected loads.

Some common sources of external power surges include:

- Utility company excavation activities that result in striking an underground power cable
- Oscillatory voltage transient caused by lightning
- Failure of distribution transformers
- Short circuits caused by branches, birds or squirrels contacting power lines
- Power line detachment or contact with one another
- Common power outages
- Wiring that is not up to code or installed poorly
- Nearby industrial facilities that suddenly increase their electricity use
- Utility grid switching to re-route electricity from power lines

Other external sources of surges include utility-initiated grid and capacitor bank switching. During the operation of the electrical grid, the utility may need to switch the supply of power to another source or temporarily interrupt the flow of power to its customers to aid in clearing a fault from the system. This is often the case in the event of a fallen tree limb or small animal causing a disruption on the line. These interruptions of power cause surges when the power is disconnected and then reconnected to the customer loads.

NEMA technical notes add that power quality disturbances can be delivered during the normal operation of the electric power system. Electric utilities produce electricity from several power-generation facilities and allocate the power to specific grids of users. Because the equipment used to produce power runs most efficiently at a constant speed, the utilities adjust the allocation of power, rather than making constant adjustments to the power facility's generation equipment. As utilities switch the supply of power from one grid to another, power disturbances occur, including transients or spikes, and under- or over-voltage conditions. These activities will cause transients to be introduced into a system, and may propagate into end-user equipment causing damage or operational upset. Noisy electrical neighbors such as welding shops or manufacturing facilities sharing your electrical distribution system can also be a major source of transients.

Sources of switching and oscillatory surges include:

- Contactor, relay and breaker operations
- Switching of capacitor banks and loads (such as power factor correction)
- Discharge of inductive devices (motors, transformers, etc.)
- Starting and stopping of loads
- Fault or arc initiation
- Arcing (ground) faults
- Fault clearing or interruption
- Power system recovery (from outage)
- Loose connections

Internal Surges:

The switching (on and off) and operation of certain electrical loads – whether due to intentional or unintentional operations – can be a source of surges in the electrical system. These surges are not always immediately recognized or as disruptive as larger externally generated surges but they occur far more frequently. These power surges can be disruptive and damaging to equipment over time and are a part of everyday operations.

Magnetic and inductive coupling is another cause of internal power surges. Whenever electric current flows, a magnetic field is created. If this magnetic field extends to a second wire, it will induce a voltage onto that wire. This is the basic principle by which transformers work. A magnetic field in the primary induces a voltage in the secondary. In the case of adjacent or nearby building wiring, this voltage is undesirable and can be transient in nature.

Examples of equipment that can cause inductive coupling include: Elevators, heating

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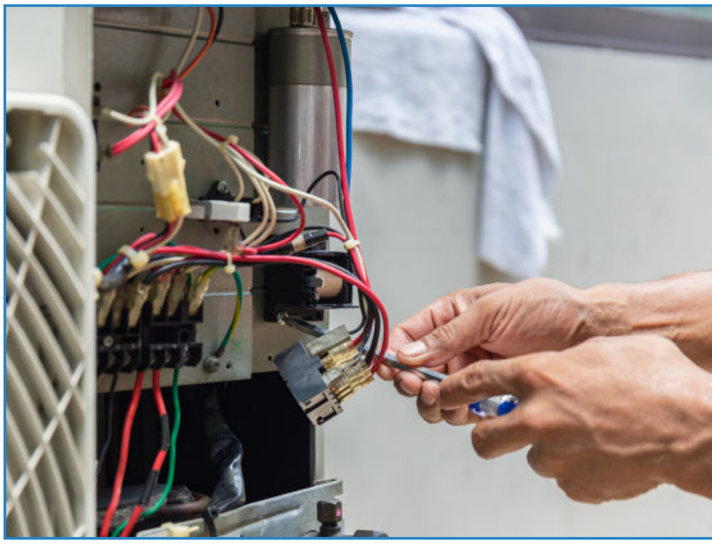
ventilation and air conditioning systems (HVAC with variable frequency drives), fluorescent light ballasts, copy machines, and computers.

Effects and Costs of Electrical Power Surges



The havoc surge events can cause is measured in both time and money. Power surges are listed as the leading cause of electrical equipment and machinery failure in the country. A 2015 IDC survey estimates that in general unplanned downtime costs Fortune 1000 businesses $2.5 billion dollars each year.

Industrial manufacturers can be severely impacted and face significant losses even during short outages and power quality disturbances, and generally they are aware of potential losses due to downtime. Residential customers are probably not aware how common power surges are, or how damaging they can be to electronic systems. They may think that power surges are only the result of lightning strikes – when in truth small, everyday power surges are far more common. They don't know that power surges are often caused by the equipment right inside or nearby their home, or unseen events on the power supply grid.

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As a professional contractor, you may receive blame for damage and downtime caused by electrical surges. While that blame may be misplaced, it is true that you know more than your customers about the cause and effects of surges and the available protection. So, surge damage can work against you in two ways: first, by causing unnecessary system failures, and second, because customers will unfairly blame you for those failures. The solution is to proactively educate your customers, and offer them low-cost, highly effective surge protection solutions that will help reduce equipment damage. In the next several sections, we will discuss how to develop protection strategies for each installation.

Strategies for Industrial Facility Protection

For residential electrical and HVAC systems, and for commercial and industrial facilities alike, the first step is to review the surge protection needs of the facility and prepare a strategy that will deliver the most effective protection at a reasonable cost. In general, best practices suggest these steps:

- Review the needs and existing systems in the home or facility
- Ensure the integrity of the grounding system
- Plan for layers of protection
- Select high quality protective devices from a reputable manufacturer
- Avoid common, consumer grade devices through retail

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Grounding the System

When planning for an SPD solution, make sure the first step in the process is a functional electrical grounding system, which will ensure the integrity of the system. Power surges are diverted to earth through the facility's electrical grounding system, so a low-resistance grounding system is a key component for the facility's surge protection strategy.

A primary concern that needs to be addressed when beginning any power quality survey is the need for a "complete" grounding and bonding system, between the electrical service entrance and remotely grounded buildings or equipment. If the remote ground home runs back to the service entrance, it will be a relatively simple process to create a "single point ground" that will reference the initial utility company electrical ground back at the service entrance electrical meter.

Electrical contractors recommend low resistance grounding systems because they protect power transformers and generators from damaging fault currents. Low resistance grounding of the neutral line limits the ground fault current to a moderate level (typically 50 amps or more) in order to operate protective fault clearing relays. These devices are then able to quickly clear the fault, usually within a few seconds. Systems that fail to integrate a low resistance grounding system into an industrial environment can create a reverse flow of power into the facility that could damage equipment, initiate additional faults and endanger workers.

Creating Layers of Surge Protection

By using multiple SPDs, facilities can employ the concept of layering to help combat power surges emanating from both internal and external sources. This layered approach strategy permits a cascaded level of protection that can dissipate energy from lightning strikes or dangerous power events inside the facility, as well as external grid switching issues.

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According to NEMA, distributed protection is the process of coordinating safeguards between the primary service entrance to a large facility and the internal branch distribution panels. Usually SPDs with high surge handling capacity are installed at the service entrance while those with lower ratings will be installed on the branch panels or dedicated supplies feeding sensitive equipment. This approach can be taken further to include point-of-use SPDs on long lines where they terminate to sensitive or critical equipment. A further

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example of such a distributed protection philosophy might include hardwired SPDs at the main and sub-panels, with additional plug-in protectors on select equipment.

A typical industrial facility could specify a Type 1 SPD at the main service entrance as the first line of protection, with either a Type 1 or 2 SPDs installed on distribution panels at several levels within the facility. If applicable, engineers often recommend that the power supply to safety circuits on industrial machinery also be protected, advising installation of SPDs on industrial devices like packaging machines, conveyor lines, industrial robotic devices, metal working and forming equipment to name a few.

Understanding Surge Protection Device Ratings

A properly designed and installed surge protection system provides two critical power quality functions. It reduces potential damage from surges and spikes caused by lightning, inductive loads, and utility “glitches” including major events like grid-shift, as well as the daily issues of capacitor switching and temporary “crossover”. SPD systems incorporate filtering in the internal components; therefore, low-level surges, line noise and EMI/RFI will be reduced or eliminated. This will lower the number of electronic “hiccups” a system experiences and increase the life of the equipment that is being protected.

How are surge protection devices rated and what do they mean? SPDs are compared by their respective energy ratings, which are calculated by using the sum of surge current, surge duration, and SPD clamping voltage. This “joules” is basically a unit measurement of energy (watt-seconds). Logic dictates that an SPD with a larger energy rating would rank as a superior device but comparing SPD energy (joule) ratings can be misleading. In fact, many manufacturers no longer provide energy ratings since there is no clear standard for SPD energy measurement.

Recent Underwriters Laboratories (UL) standards and Institute of Electrical and Electronics Engineers (IEEE) guidelines have moved away from recommending comparison of joules because ratings can be manipulated, choosing to focus on real-time performance of SPDs with more reliable criteria such as Nominal Discharge Current testing, which tests the SPDs durability along with the VPR testing that reflects the let-through voltage. This type of testing provides a better rating comparison from one SPD to another.

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According to the National Lightning Safety Institute, there are several considerations that must be made when selecting an SPD:

- **Application** - Ensure that the SPD is designed for the zone of protection in which it will be used. For example, an SPD at the service entrance should be designed to handle the larger surges that result from lightning or utility switching.
- **System voltage and configuration** - SPDs are designed for specific voltage levels and circuit configurations. For example, your service entrance equipment may be supplied three phase power at 480/277 V in a four-wire wye connection, but a local computer is installed to a single-phase, 120 V supply.
- **Let-through voltage** - This is the voltage that the SPD will allow the protected equipment to be exposed to. However, the potential damage to equipment is dependent on how long the equipment is exposed to this let-through voltage in relation to the equipment design. In other words, equipment is generally designed to withstand a high voltage for a very short period, and lower voltage surges for a longer period. The Federal Information Processing Standards (FIPS) publication "Guideline on Electrical Power for Automatic Data Processing Installations" (FIPS Pub. DU294) provides details on the relationship between clamping voltage, system voltage, and surge duration.
- **Surge current** - SPDs are rated to safely divert a given amount of surge current without failing. This ratings range from a few thousand amps up to 400 kiloamperes (kA) or more. However, the average current of a lightning strike is only approximately 20 kA., with the highest measured currents being just over 200 kA. Lightning that strikes a power line will travel in both directions, so only half the current travels toward your facility. Along the way, some of the current may dissipate to ground through utility equipment. The potential current at the service entrance from an average lightning strike is somewhere around 10 kA. In addition, certain areas of the country are more prone to lightning strikes than others. All these factors must be considered when deciding what size SPD is appropriate for your application.
- **Standards** - All SPDs should be tested in accordance with ANSI/IEEE C62.41 and be listed to UL 1449 for safety.

Integrating the proper surge protection technology into a facility is crucial to security and safety.

Considerations for Selecting SPDs

With the myriad of options on the market today, integrating the proper surge protection technology into a facility is crucial to security and safety. While there are many correct options in every category, selecting the SPD can be a balancing act between redundancy and budget constraints. Surge protectors are usually divided between power and data/telecom devices. Surge protection for electrical power follows the ANSI/IEEE C64.41.2-2002 industry standard, which divides a building into three categories – A, B and C. Category C is defined as the service entrance or main disconnect. Category B is at the distribution and sub-panel environment and Category A is at individual equipment or wall outlets. Maximum protection requires a surge suppressor at each one of these locations (A, B, C) and minimum protection requires a

UL requires certain markings be on all listed and recognized SPDs. The SPD type describes the intended location of the device regarding the main breaker as follows:

- **Type 1** – Between the secondary of the service transformer and the line side of the main breaker
- **Type 2** – Permanently connected SPD on the load side of the main breaker
- **Type 3** – Point of utilization SPD, such as a plug-in surge-protected power strip, installed at least 10 meters (30 feet) from the service panel

surge suppressor at two (B, C) of the locations that feed the sensitive load.
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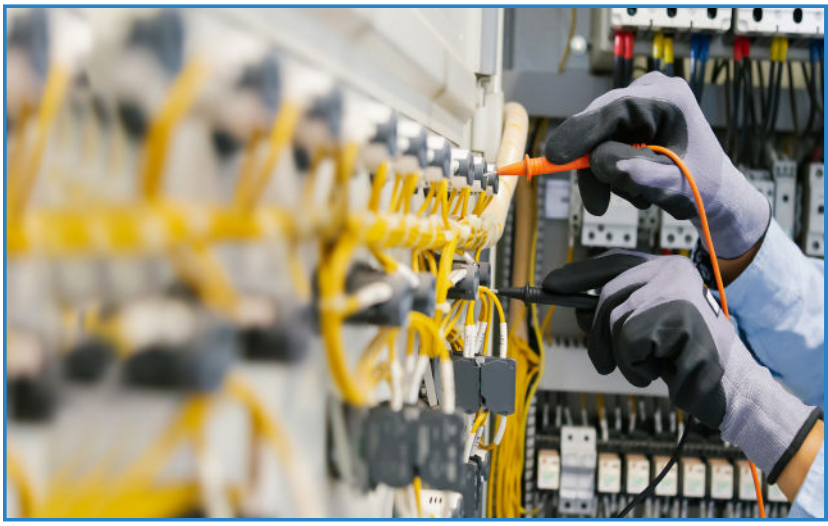
Other details that UL mandates for SPD product clarification include:



- Nominal System Voltage – Should match the utility system voltage being protected
- MCOV – The Maximum Continuous Operating Voltage, this is the most voltage allowed before the device starts to clamp. Typically, 15-25% more than the nominal system voltage
- Nominal Discharge Current – The peak value of the current through the SPD having an 8/20 waveform where the device is still functional after 15 surges. The manufacturer chooses which level to test: 5 kA, 10 kA, 20 kA
- VPR – The Voltage Protection Rating, which is the average limiting voltage of an SPD when subjected to a 6 kV, 3 kA 8/20 combination waveform generator. VPR is a clamping voltage measurement rounded up to one of the standardized table of values. All VPR tests are conducted with 6-inch leads outside of the SPD enclosure
- A short circuit current rating (SCCR) is the amount of fault current to which an SPD can be subjected and still safely disconnect from the power source
- Enclosure Type – NEMA rating for environmental conditions and locations where the SPD can be installed

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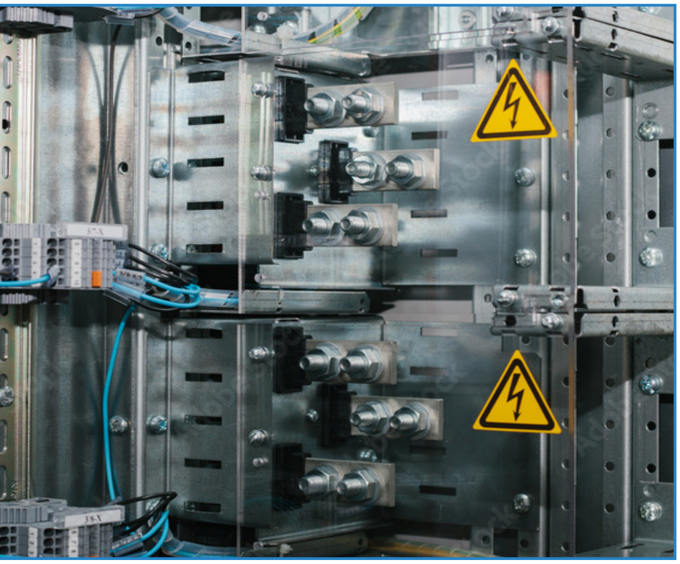
Sourcing SPDs for Maximum ROI

When it comes time to source the SPDs appropriate for your installation, thankfully it is more straightforward than all those requirements! Protective devices are not all alike! The advice is the same as for any critically important system element – the best approach is to select high quality protective devices from a reputable manufacturer. How do you choose a reputable manufacturer? That part is easy – DITEK leads in every important factor:

- Focused on SPD technology: Surge protection has been DITEK's primary business since its inception
- Established, long-term business: DITEK is no fly-by-night! They have been leading the surge protection market more than 30 years
- Leading technologies: DITEK offers multiple technologies to fit the needs of every installation
- Reliable supplier: DITEK products are made in their own factory in the USA, and stocked for immediate delivery
- Stand behind their products: DITEK SPDs are backed by a 10 year limited warranty
- Integrator/Installer support: DITEK supports professional electrical contractors and system integrators with outstanding pre- and post-sales support, including system design review, site surveys, selection advice, and training
- Not available in the consumer market: Don't confuse DITEK products with cheap retail consumer items – DITEK SPDs are only available to professional contractors to ensure code compliance, effective system protection, and professional installation



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Summary

Whether you are building a successful organization, or building a home, protecting it from risk, liability, and other costly problems is essential. One of the most fundamental elements of this protection is to prevent the loss of use or revenue due to downtime on critical electrical and electronic systems. To accomplish this, installing surge protection should be a mandatory part of any proactive planning.

Should a power surge cause damage or destruction to any element of an organization's infrastructure or business systems, it could lead to downtime, which in an industrial environment could prove disastrous in terms of business continuity, employee safety and financial liabilities. Downtime in a home could range from inconvenient all the way to intolerable, depending on the specific needs of the homeowner and the current environment.

While many systems such as fire alarms, surveillance, and access control are implemented similarly across building types, the outcome of their being non-functional presents several specific threats to various industries including industrial, manufacturing and critical infrastructure. With the advent of the Internet of Things and networked systems, it's possible for a surge to be carried along the system from one device to another.

Taking a proactive approach to installing surge protection ensures the security of your data, employees and facility assets during an unpredictable electrical event. Not only will it protect the valuable equipment and systems that support your business, it also protects from the ancillary costs of downtime, operational delays, and reputational damage. In nearly every case, the cost of surge protection is small when compared to these potential losses – normally less than the sales tax on the installed system. Ideally, surge protection should be an integral part of the design plan from the start with collaborative efforts from the end-user, consultant, systems integrator and a qualified electrical power solutions vendor.