Industrial Surge Protection: Strategy and Benefits

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Introduction

The question is not if, but when, your industrial facility will experience a power surge. 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 constant surge activity in an industrial environment can cause significant impact.

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

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Power surges in an industrial or manufacturing facility can be caused by something much further away – for example, when electrical power plants are connected or disconnected from the grid, which happens frequently as power needs change during the day. 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, there are usually many devices with powerful motors that switch on and off during the day, including elevators, production-line machinery, massive industrial air conditioners, refrigeration systems, pumps, and similar equipment.

In residential and commercial power applications the surge implications and impact are strikingly different than they are in industrial settings. Unlike a residential single-phase power supply that employs 120 or 240 volts, or the three-phase approach that allows for a higher voltage for commercial jobs that can be 120 volts, 208/240 volts or 277/480 volts, industrial sectors like critical infrastructure, gas and oil facilities, factories, chemical plants, food processing plants and mining operations have much larger power requirements. While they also use a three-phase power set-up, instead of running MTC or MC cable, these facilities usually work with RMC conduit that can power electrical motors, turbines and other digital instrumentation or control circuitry.

Power surges in an industrial or manufacturing environment can be potentially 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.

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While many power surges are so brief they are measured in nanoseconds, microseconds, and milliseconds, that is all it takes to cause devastating losses. For high-volume industrial manufacturers, power outages caused by surges can disrupt production and have disastrous results throughout the organization's supply chain. Even power flickers that appear insignificant in industrial and manufacturing operations can escalate quickly. Industrial manufacturers are especially vulnerable to equipment damage during outages; and the electrical surges that may occur when power is restored can also result in costly damage to critical equipment that is difficult to repair.

Because of the critical nature of industrial operations, surge protection is perhaps the single most strategic element to be considered in the business continuity plan of any facility that maintains advanced machinery, sensitive equipment, advanced data and communication networks and integrated security systems. Considering the amount of complex automation typical of most industrial operations today, ensuring that all systems, networks and equipment remain online at the appropriate times is not only a liability and compliance issue, it is a security and safety concern as well.

Understanding the immediate and often costly effects power surges can cause across the industrial landscape can best be illustrated in the following real-life scenarios:

- **Addressing surge protection in explosive industrial environments:** Chemical and petrochemical facilities, with their combustible industrial processes, present a potentially explosive environment in the event of an unsuspected power surge. A spark from a sudden surge around these explosive gases, fumes and vapors could trigger a major disaster, and the problem is exacerbated in facilities like textile mills, sugar processing plants or fodder factories where vapors mix with flammable dust. For that reason, electrical devices in these potentially explosive areas are subject to strict codes and special directives.

- **Lightning protection for gas pipelines:** The construction and maintenance of pipelines is an expensive business, so ensuring a long service-life and cost-effective operation of the pipeline and ancillary equipment is a considerable concern. Strategies to protect the pipeline infrastructure include deploying active corrosion protection systems that stave off rust, in addition to requiring that all metal pipes be insulated against potential ground incursion. Engineers use isolating spark gaps to protect the pipe insulation and the insulating flanges against possible damage from surge voltages. If a voltage surge should occur as a result of a lightning strike, the isolating spark gap becomes the low resistance point and the current is discharged to the ground, protecting the system.

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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 commercial, industrial or manufacturing facility. Transients can reach amplitudes of tens of thousands of volts and generally have very short durations measured in microseconds.

The Origins of Electrical Power Surges

According to NEMA, a common source for surges generated inside an industrial building are situations where power is switched on and off. An example of this is a simple thermostat that controls the power to a high-powered heating element or HVAC system. Between 60 to 80 percent of all surges are created within a facility. These surges contain limited energy but are often the cause of system upset or cumulative damage to electronics. Surges that originate from outside the facility include those due to lightning and utility grid switching. These surges from external sources, while less common, are typically much more severe than those from internal sources.

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External Surges: The most recognizable source of 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 systems. Either scenario can be immediately damaging to the electrical system and/or the connected loads.

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.

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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.

Some common external source origins for industrial facility power surges may 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 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

Internal Surges:

Switching of Electrical Loads

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.

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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

Magnetic and Inductive Coupling

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

Effects and Costs of Electrical Power Surges

Power surges are listed as the leading cause of electrical equipment and machinery failure in the country.

The havoc industrial power 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.

The same survey puts the average hourly cost of infrastructure failure at $100,000, with critical system outages potentially costing $500,000 per hour.

A 2017 survey of facilities and energy managers of commercial and industrial (C&I) businesses across the U.S., done in conjunction with S&C Electric Company and the research firm Frost & Sullivan, found that more than a quarter of manufacturing businesses experienced an outage at least once a month, with 58% reporting an outage lasting longer than an

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hour. For large manufacturing enterprises, a single hour of downtime tops the $5 million mark. Another study done last year by energy consultant E Source shared that industrial manufacturers tend to suffer the most from long outages, followed by financial service companies, healthcare, and grocery stores.

Industrial manufacturers can be severely impacted and face significant losses even during short outages and power quality disturbances. Consider the ramifications of a car manufacturer whose production line turns out 1,200 cars a day retailing for approximately $50,000 each. The financial reality for just one day's line stoppage due to a power issue would cost the company $60 million. Industries like food processing plants and pharmaceuticals who deal in perishable products are also highly vulnerable to power disruptions.

Strategies for Industrial Facility Protection

The digital environment of today's industrial facility is certainly dependent on power, and is accordingly dependent on a strategic approach to managing electronic power surges. Sophisticated machinery employing embedded processors and programmable logic controls (PLCs) that are the brains of automated controls like changing tool heads and manipulating production lines and machine turbines are susceptible to power surges. NEMA also states that heavy current load switching is often to blame for large electrical surges on the power supply either as the result of inductive effects or limited regulation in the transformer. It is also noted that worn industrial motors can generate surges.

When planning for an industrial SPD solution, make sure the first step in the process is a functional electrical grounding system.

Whether the surges are overvoltage events generated by the utility grid or spikes of power from industrial machines in various location around the facility, the impacts to productivity, machine life and employee safety remain a concern. The specter of power surges within the facility and their potential negative impact to the business' bottom line should be the driving motivation for creating a facility-wide protection roadmap that can be easily integrated into every stage of the electrical distribution system from the electrical service entrance down to the single-phase loads.

Grounding the System

When planning for an industrial 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 power surge 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

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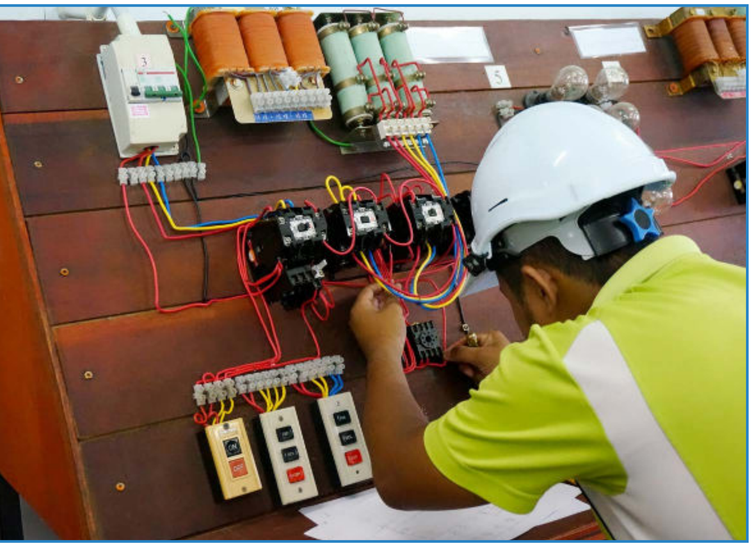
entrance and remotely grounded buildings or equipment. If the remote ground home runs back to the service entrance, it will be a relatively simple process to create a "single point ground" that will reference the initial utility company electrical ground back at the service entrance electrical meter.



Electrical contractors recommend low resistance grounding resistor 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 on the floor.

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 defense 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 switching issues.

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 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.

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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. 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.

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One PE recommends that when selecting surge protective devices for an industrial environment, it is important to choose devices which have the lowest possible voltage protection ratings in order to have the maximum reduction in surge voltages. VPR ratings must be less than 5x normal peak to be effective. Cascading protection is also very important to reduce large incoming surges to critical equipment as well as switching surges generated within a facility. A complete protection scheme will have SPDs located at strategic areas within the plant. Typically, 3-4 levels of SPD will offer the most protection. Critical loads should have on-board surge protection as a last line of defense.

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 RFI/EMI 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.

But 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.

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 for 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 rating ranges 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.

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.

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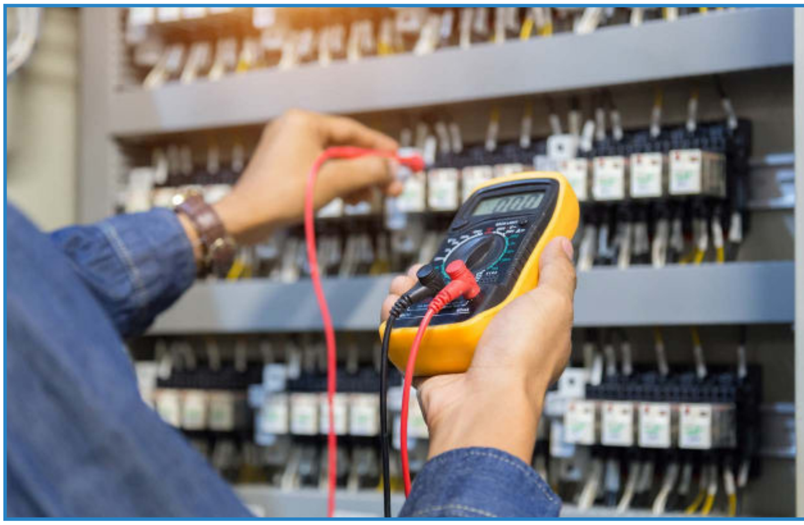
Surge protectors are usually divided between power and data/telecom devices. Surge protection for electrical power follows the ANSI/IEEE C64.41.2-2002 industry standard, which divides a building into three categories – A, B and C. Category C is defined as the service entrance or main disconnect. Category 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 surge suppressor at two (B, C) of the locations that feed the sensitive load.

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

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



- Short Circuit Current Rating (SCCR) – 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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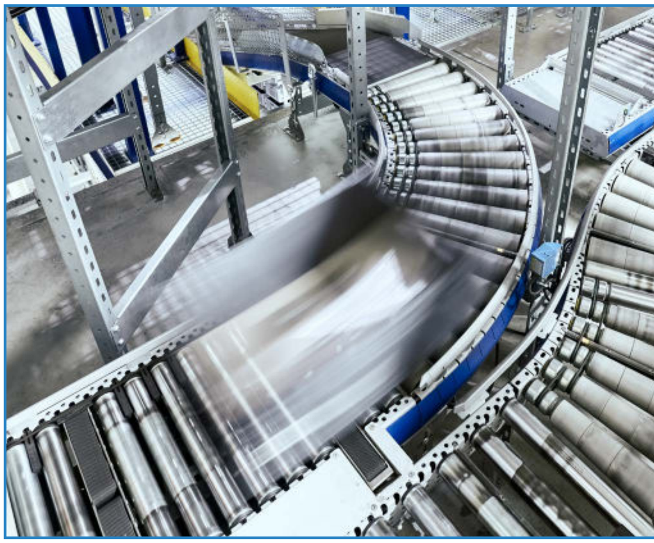
Summary

When building a successful organization, 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 revenue due to downtime on critical industrial and business systems. Maintaining consistent operation of these systems helps ensure that an organization continues to run smoothly and does not incur unnecessary costs. 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.



While many systems such as fire alarms, security and surveillance, and access control are implemented similarly across differing market segments, 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. 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.

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