White paper

Surge protection for machines for the North American market

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Introduction

This white paper describes the requirements of the NFPA 79 Edition 2018 standard in relation to the use of surge protective devices (SPDs) in industrial machines for the North American market. It describes which machines are subject to the standard and which requirements have to be satisfied for the use of SPDs. Furthermore, it includes recommendations for implementing the standard.

Overview of the relevant US standards on the use of surge protection

Machine builders and systems manufacturers who export their products to the North American market or want to install them in this region are subject to the laws (codes) and regulations (standards) applicable there.

Along with the NEC, the National Electrical Code, one of the most important standards is the 2018 revision of the NFPA 79, which is comparable to the European standard DIN EN 60204-1, "Safety of machinery - Electrical equipment of machines".

NEC (NFPA70): 2017
Installation and electrical connection of the machine

NFPA 79: 2018
Machines

UL 508a: 2018
Industrial control cabinets

UL 1449: 2018
Requirements on surge protective devices SPDs

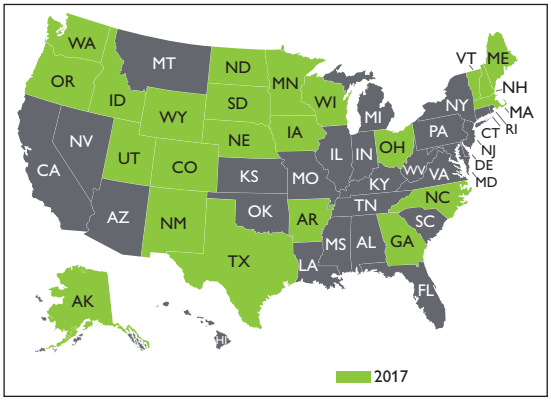
Overview of the most important codes and standards

Which machines are affected?

The NFPA 79 standard covers electrical safety for the entire machine, both in the control cabinet and the periphery. The scope of the standard includes electronic equipment, apparatus, and systems of industrial machines supplied by a nominal voltage of 1,000 V or less and starts at the electrical feed-in point of the machine (point of connection of the supply circuit) [NFPA 79A, Scope 1.1.1]. Machines affected are listed in the NFPA 79 annex [NFPA 79, Annex C/Examples]. These include:

- Machine tools
- Plastics processing machines
- Woodworking machines
- Production machines
- Handling and conveyance/supply machines
- Inspection and testing machines
- Packaging machines

The NFPA 79 is, like the UL 508a, a recognized standard in the USA and describes, among other things, safety recommendations for industrial machines aimed at protecting operating personnel against injuries. Furthermore, the NFPA 79 takes into consideration the protection of machine equipment against damage. It therefore helps to maintain the quality and safety standards of machines in the USA. In all states in which the NEC 2017 is applicable, it is mandatory to install surge protective devices (SPDs) in machines with safety-relevant circuits (safety interlock circuits) [NEC 670.6]. The NEC [NEC 670.1 Scope] then refers to NFPA 79 for information on how this is to be implemented. The definition of safety interlock circuits is also listed in one of the standard's annexes. These include emergency

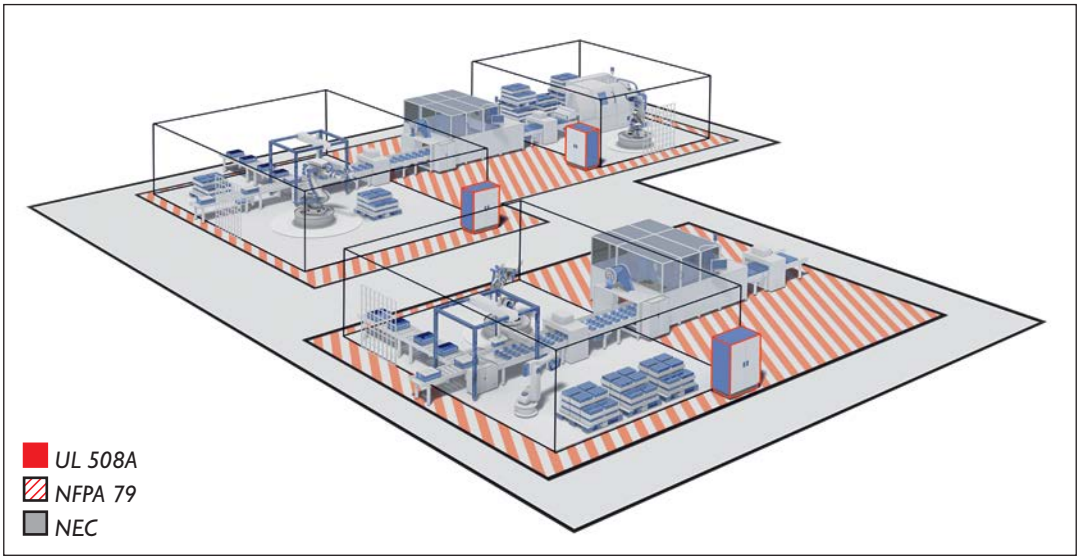


Validity of the NEC by state (2017)

stopping, interlocking, speed control, and temperature monitoring systems [Annex A.9.2 NFPA 79]. Furthermore, in addition to the regulations of the NEC, the buyer or operator of the machine may also request that it be built in accordance with the NFPA 79 standard. This is also often the case because, under the OSHA Act (Occupational Safety and Health Administration), the employer is responsible for providing a safe and healthy workplace.

The AHJ

Before a machine can be commissioned in the USA, it is inspected by an AHJ "Authority Having Jurisdiction" to ensure that it complies with the relevant codes and standards. The machine may only be commissioned once it has received approval from the AHJ. If the AHJ finds any safety risks, they have the right to refuse approval for the system or machine until it has been improved and complies with the regulations. Here, the NEC applies to the electrical connection of the machine, NFPA 79 regulates the requirements for the machine itself, and UL 508a contains the regulations for the construction of the control cabinet.



Standards to be used in the USA

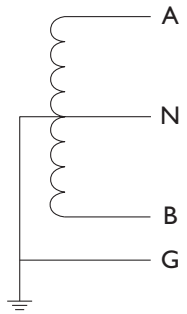
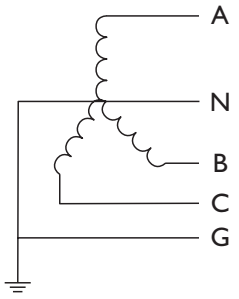
Selecting surge protective devices (SPDs) part 1:

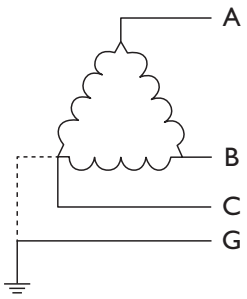
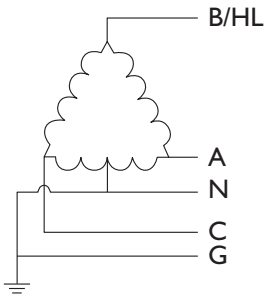
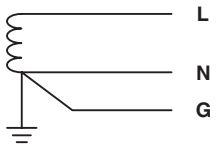
There are two key demands placed on surge protective devices (SPD) that have to be taken into consideration when selecting the right SPD for the machine in accordance with NFPA 79. First, the SPD must be suitable for the respective installation site, and second, the SPD must be UL-listed [NFPA 79, 7.8.3].

The selection of the SPD for the machine is determined by the supply system configuration (service configuration) and the mains voltage (system voltage) at the installation site. There are significant differences compared to the supply system configurations and voltages that are used in Europe.

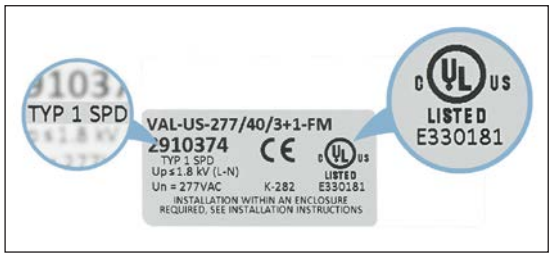
Generally, 277/480 V Wye or 480 V Delta networks are used in industrial buildings in the USA, whereas in Canada 347/600 V Wye or 600 V Delta systems are used. When selecting the surge protection system, it is important that the surge protective devices (SPDs) are rated for the rating prevalent at the installation site. According to UL 508a, SPDs with a slash rating are only permitted in grounded Wye systems (Solidly Grounded Wye). In contrast, according to the UL 508a [UL 508a 36.4.4], SPDs with a delta rating may be used in Delta and Wye systems. Wherever possible, however, consultation should always be made with the AHJ examining the site. In practice, it has proven best to only use SPDs that conform to the prevailing rating.

American grid systems

Split phase		***Split phase*** This supply system configuration is largely unknown in Europe today. It is created via a secondary-side center tap connection in a single-phase transformer. The center tap connection is grounded so that the voltage between it and one phase is exactly half of the voltage between the phases. The voltage used is 120/240 V. This supply system configuration is used in almost all households and small office buildings in North America. Small and low-power devices such as computers, televisions, and lighting are connected to the 120 V circuit. Devices with higher power requirements, such as air conditioning systems, are connected to the 240 V circuit.
3-phase Wye "Y"		***3-phase Wye*** This supply system configuration is very similar to the TN system used in Europe. The line conductors are fed from a transformer with a Wye configuration, and have a phase shift of 120° each. The neutral point is grounded. Depending on requirements, the neutral conductor may or may not be supplied. The voltages used are 277/480 V in the USA and Mexico, and 347/600 V in Canada. This supply system configuration is mainly used in industrial applications.

3-phase Delta "D"		***Corner-grounded/ungrounded Delta*** This supply system configuration is not used in Europe. The feeding transformer has a delta topology on the secondary side; the phase shift between phases is 120° each. A neutral conductor is not present due to the circuitry. The voltages used are 480 V in the USA and Mexico, and 600 V in Canada. Depending on the grounding system, there are two different versions: Ungrounded delta: The transformer is not grounded on the secondary side. This system behaves similarly to the IT system used in Europe. Corner-grounded delta: One line conductor is grounded directly. This supply system configuration is often used where high power is required, for example for large motors.
High-leg Delta "HLD"		***High-leg Delta*** This supply system configuration is not used in Europe. It is a Delta and Split-phase hybrid. The Delta system has a phase to phase voltage of 240 V. In addition, one of the three windings also has a grounded center tap connection. As a result, there are three voltages: Phase A – N = Phase C – N = 120 V Phase B – N = 120 V * √3 = 208 V Between all phases = 240 V This supply system configuration is used in large office buildings and small industrial buildings. As in the split-phase system, low-power devices (computers, household appliances, etc.) are connected to the 120 V circuit, and higher-powered devices (air conditioning systems, etc.) are connected to the 240 V circuit. The 208 V circuit is normally used for lighting.
Single phase		***Single phase*** This is used in the private sector (residential). Phase L – Neutral = 120 V

Selecting surge protective devices (SPDs) part 2:



The SPD used must have at least the SCCR value (Short Circuit Current Rating) that is expected at the place of installation of the SPD. NFPA 79 also defines that the installation instructions of the SPD manufacturer must be observed. The instructions also provide the technical data of the SPD. These include the voltage rating and the service configuration, the material of the conductors to be connected, as well as the permissible cross-sections and information on the listing of the surge protective devices. The UL type and the listing must also be marked on the SPD.

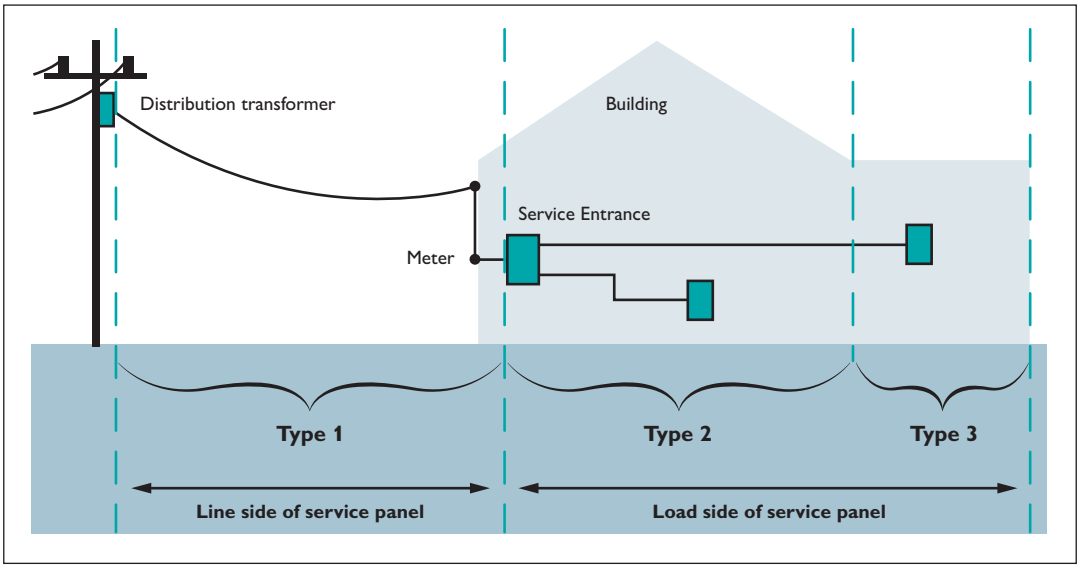
SPD type locations in accordance with NFPA 79

According to UL 1449, SPDs are classified into type 1, type 2, and type 3 protective devices (arresters). The classification according to UL 1449 is based on the max. short-circuit current the SPD can safely be operated on. This is a major difference to the IEC standard 61643-11 which classifies the SPD based on the surge discharge performance. The max. short-circuit currents in turn are grouped into locations which are called "type locations".

UL type 1 SPDs may be installed directly downstream of a transformer but still upstream of the main fuse or the main disconnector (service entrance) of the installation.

UL type 2 SPDs are installed downstream of the main fuse or main disconnector of the installation.

UL type 3 SPDs must be installed at a cable length of at least 10 m to the upstream overcurrent protection or disconnector.



SPD type locations in accordance with NFPA 79

If type 4 CA (Component Assemblies) are used, these components are UL-recognized. For the user, this means that restrictions apply to the use of these components, which are marked in the CoA (Conditions of Acceptability), which in most cases means considerable testing work.

As described in NFPA 79, [NFPA 79 7.8.3.3], a UL type 3 protective device is usually sufficient for a machine or the control cabinet of this machine, because in most cases, the machine is positioned more than 10 meters away from the service disconnect. If the machine is to be connected directly to the service entrance, a UL type 2 protective device must be used. As an alternative, however, according to NFPA 79 [NFPA 79 7.8.3.3], a UL type 1 protective device can be used at all three type locations, which greatly simplifies device selection. This means that the variety of components and also storage costs for surge protection can be reduced to one type.

Connecting SPDs

Another important point is the connection of the surge protective device in the application. As already stated, the manufacturer's installation instructions must be complied with. With UR devices (UL-recognized devices), only the tested backup fuse may be used according to the CoA. With UL-listed type 1 SPDs, a separate backup fuse is not necessary according to UL 1449. However, it may be required by local standards and regulations to use a fuse to protect the cables connecting the SPD.

If a backup fuse is not used for connecting the SPD in the feeder area, this can be covered taking into account the feeder tap rule in accordance with UL 508a [UL 508a 32.4] or NEC 2017 [NFPA 70 240.21]. The main criteria here are: The branch line is no longer than 10 feet (3 meters). The current carrying capacity must not be less than the calculated current of the loads and not less than the fuse value of the connected end devices or the fuse that may be used at the end of the branch line. Furthermore, the manufacturer of the surge protective device must specify the smallest connection cross-section of the SPD, and the branch line must not leave the control cabinet. Because SPDs are usually connected in the branch and therefore do not carry any load current, there is no need to calculate the loads or take connected loads into account. Therefore, only the connection cross-section of the manufacturer and a sufficient SCCR value for the SPD have to be taken into consideration.

Because some AHJs always require a backup fuse to protect the connected conductors regardless of the feeder tap rule, and because SPDs can only be replaced when the power is off, it may be sensible to always use a backup fuse.

The fuse rating is to be based on the SPD connection cable. To this end, the NFPA 70 (2017) [NFPA 70 310.15 (B) (16) ff.] includes tables that can be used to determine the fuse rating depending on the cable type, number of conductors, conductor material, cross-section, and ambient temperature. Because the SPD is connected in the branch, overload events do not have to be taken into account.

When selecting the fuse and the fuse holder, it should be ensured that UL-listed components are used that have at least the SCCR value of the control cabinet or the machine.

Summary

Since 2017, the NEC has stipulated that SPDs must be used in industrial machines with safety-relevant circuits. The implementation of the standard is described in the 2018 version of NFPA 79. The key differences to the IEC standard include the supply system configurations, the mains voltages, and the SPD type locations. According to the NEC, SPDs are not classified and selected according to their surge discharge performance, but according to their short-circuit current rating (SCCR). Depending on the SPD type, these can then be installed as UL type 1 protective devices directly downstream of a transformer but still upstream of the main fuse or the main disconnector. UL type 2 protective devices may be installed downstream of the main fuse or main disconnector, and UL type 3 protective devices must be installed at least 10 meters cable length away from upstream overcurrent protection systems or disconnectors. The SPDs used must be UL-listed and installed in accordance with the manufacturer's specifications. As an alternative, UL type 1 protective devices can be installed in all three type locations, which greatly simplifies SPD selection. According to UL 1449, UL-listed type 1 SPDs do not need to be fused if they are installed in accordance with the manufacturer's specifications, i.e., if the recommended conductor cross-section is used. However, local standards such as the NEC may demand a backup fuse for protecting the conductors used.

For further information on the topic of surge protective devices for the North American market, please visit our website at: phoenixcontact.com/nfpa79

References

NFPA 70, 2017
NFPA 79, 2018
NFPA 79 Handbook 2018
UL 508A, July 2018
UL 1449, August 2018

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Phoenix Contact is a global market leader based in Germany. We are known for producing future-oriented components, systems, and solutions in the fields of electrical engineering, electronics, and automation. With a global network reaching across more than 100 countries with over 17,400 employees, we maintain close relationships with our customers, something we believe is essential for our common success.

Our wide variety of innovative products makes it easy for our customers to implement the latest technology in a variety of applications and industries. We focus on developing the fields of energy, infrastructure, process, and factory automation.

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