Requirements for

Surge Protection

Eltek Power Supply Systems

2024623 rev 5

ELTEK A Delta Group Company

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1	06.02.2007		Changes not tracked
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4	05.03.2009	All	Added DC surge protection
5	12.02.2016	All	Changed title Major rewording generally Introduced mandatory SPD requirements Changed requirements on DC side choke impedance

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1 Introduction

This document describes the requirements for surge protection in installations including Eltek power systems. Along with this document, the local installation regulations specific to the country of use must be followed. This document is valid for *Eltek* employees, *Eltek* partner companies, installers and customers using the equipment.

Any electrical device or system connected to an external supply is at risk of being damaged by over-voltages and surges. The Eltek equipment is designed in accordance with international standards, and it is imperative to understand that these standards form part of a larger framework. Only when sites are designed and implemented in accordance with this framework the designed levels of performance and reliability is attained, although the risk of failure due to transients can never be eliminated, only reduced. If parts of the framework are ignored, the expected reliability and service life of the power system is greatly reduced.

Type 2 surge protection installed according to these requirements is mandatory in the mains/AC supply in installations containing an Eltek power system; either located at the service entry, in the main switch board or within the Eltek power system. The surge protection device (SPD) must be installed upstream of residual current devices (RCD) to prevent nuisance tripping. Surge protection is required on the output if the wires are routed out of the building, shelter, and outdoor cabinet or similar, hence are exposed to electrical transients exceeding the levels the equipment is designed and certified to handle. If the installation or parts of the installation is exposed to direct lightning strikes, a lightning protection system is required together with Type 1 SPD and coordination with Type 2 SPD. The details for surge protection are further explained in this document.

Requirements summary

- Type 2 SPD mandatory on the AC feed, with U_p < 1.8kV and I_N > 20 kA
- Type 2 SPD mandatory on 48V DC feeds exiting LPZ3, with U_p < 0.3kV, I_N > 10 kA and 2uH coordination impedance
- Differential and common mode protection
- V-wiring
- Sufficient coordination between the lightning protection zones
- IEC61643-11 or UL1449 certified device with thermal disconnect
- Alarm monitoring of the SPD
- Replacement of failed SPDs immediately

Failure to follow the requirements including relpacement of failed SPDs could render the warranty either partially, or fully void.

To understand the requirements the technical background is explained in further details in the following chapters; lightning protection zones, impact of the installation and device requirements.

Abbreviations

Abbreviation	Description
SPD	Surge Protection Device
OVP	Over-Voltage Protection
MOV	Metal Oxide Varistor
TVSS	Transient voltage surge suppressor
SAD	Silicon Avalanche Diode
GDT	Gas Discharge Tube
PE	Protective Earth
Y-Connection	Includes a neutral line, also known as *Star* network
D-Connection	No neutral line, also known as *Delta* network

2 Lightning Protection Zones

To get the overview of the installation Lightning Protection Zones (LPZ) are introduced. The different zones refer to the level of surge current / transients that can be expected and the level of the transients the equipment in the zone has to able to withstand. The zones are illustrated in Figure 2-1.

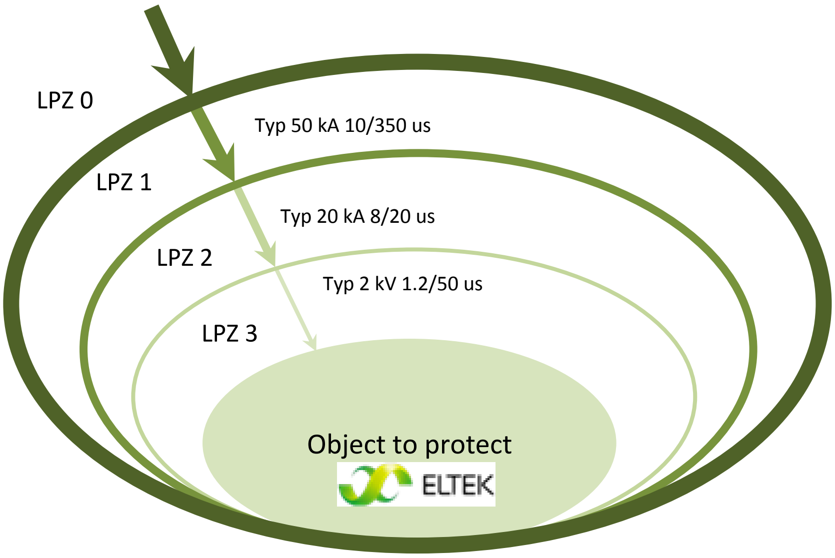

Figure 2-1 Lightning protection zones illustration with typical transient levels

The power core, i.e. rectifiers, controllers, etc, is *always* located in LPZ3. If any cable to or from the power system crosses a zone boundary sufficient protection is required. Figure 2-2 shows an example of zones in an Eltek Outdoor cabinet where the power core is installed in LPZ3 (within green boundary) and the incoming AC feed surge protection is installed in LPZ2 (within orange boundary). The LPZ3 boundary depends on the other equipment installed in the cabinet; this might be batteries or DC load equipment. Such equipment is normally installed in LPZ3, thus the boundary is increased accordingly. Expected transient levels and protection levels for the different zones are detailed in Table 2-1.

Figure 2-2 Lightning protection zones example in an Eltek outdoor cabinet solution

	Description	Typical expected transient levels	
LPZ1	Installations in the near proximity to direct lightning strike, but not subject to direct strike, for example a building with lightning protection or shelter with installations in a tower. Protection into this zone is Type 1 SPD.	AC/Input	10 - 50 kA (10/350µs)
		DC/output	2 - 10 kA (10/350µs)
		Signal wires	Not allowed area
LPZ2	Typical an Eltek DC power system. Protection into this zone is typically a Type 2 SPD according to the requirements in section 3.	AC/Input	20 kA (8/20µs)
		DC/output	10 kA (8/20µs)
		Signal wires	Not allowed area
LPZ3	The power modules, controllers and accessories are installed in zone 3. The protection is implemented at the electrical interfaces of the modules according to the levels stated below. Some power modules have implemented higher levels, see product specific data sheets or technical specifications for further details.	AC/Input	IEC61000-4-5 level 3: ± 1 kV oc 1,2/50µs L-N ± 2 kV oc 1,2/50µs L/N-PE
		DC/output	IEC61000-4-5 level 2: ± 0,5 kV Differential ± 1 kV Common
		Signal wires	IEC61000-4-5 level 2: ± 1 kV (CAN)

Table 2-1 Expected LPZ transient levels

As Table 2-1 reveals, there are different classifications for SPDs; Table 2-2 lists definitions as described by IEC and UL.

	IEC/EN 61643	UL1449
Type 1	Lightning current arrester, combined lightning current and surge arrester	Permanently connected SPDs intended for installation between the secondary of the service transformer and the line side of the service equipment overcurrent device, as well as the load side, including watt-hour meter socket enclosures and intended to be installed without an external overcurrent protective device.
Type 2	Surge arrester for distribution boards, sub distribution boards, fixed installations	Permanently connected SPDs intended for installation on the load side of the service equipment overcurrent device; including SPDs located at the branch panel.
Type 3	Surge arrester for socket outlets / terminal units	Point of utilization SPDs, installed at a minimum conductor length of 10 meters (30 feet) from the electrical service panel to the point of utilization, for example cord connected, direct plug-in, receptacle type and SPDs installed at the utilization equipment being protected. The distance (10 meters) is exclusive of conductors provided with or used to attach SPDs.

Table 2-2 Classification of SPDs according to IEC/EN and UL

Type 1 surge protectors are heavy duty devices, designed to be installed at the origin of the AC installations equipped with Lightning Protection System. Type 2 surge protectors are designed to be installed at the service entrance of low voltage systems or close to sensitive equipment to protect against transient overvoltages. Type 3 surge protection is built into most of the Eltek equipment such as power modules and controllers.

Coordination between Zones

The surge protection into the different zones must be coordinated to make sure that most of the surge current is diverted and does not enter the zone. The surge protection in an outer zone must handle larger surge currents and more energy than an inner zone. Even though the surge current is diverted through the SPD at the zone boundary a portion of the energy will enter the next zone. Coordination between the zones is normally implemented by the means of impedance simply by a minimum cable length, typically 30 m. If the required length is not achieved in the installation additional filters may be required for appropriate coordination, such as current limiters as described in the next section.

Current Limiters

Current limiters are used for coordination between zones by adding an impedance (decoupling choke) to help diverting the surge current and prevent the surge current entering the zone. Current limiters can be made in different ways and the most effective way is to make an inductance. Due to the high levels (kA) of the surge current, it is vital that the inductor doesn't saturate. This can be achieved by making the inductor with an air core coil simply by winding up the appropriate number of turns on an insulated wire. The inductance can be calculated according to the equation:

$$L \cong \frac{31.6 * N^2 * \frac{d^2}{4}}{(3d + 9l) * 1000}$$

L – inductance (uH)
N – number of turns
d – diameter of winding (mm)
l – length of the coil (mm)

N (turns)	d (mm)	l (mm)	L (uH)
4	70	10	2.1
2	110	10	2.0
3	220	10	2.0
4	120	10	4.0

Table 2-3 Example of calculated air core coils

The windings must be held tight by e.g. cable ties. Due to the limited heat dissipation in the windings the wire gauge must be at least one dimension oversized for the maximum current of the coil. Keep also in mind the diameter of the coil must be minimum 2 times the mininmum bend radius of the wire being used.

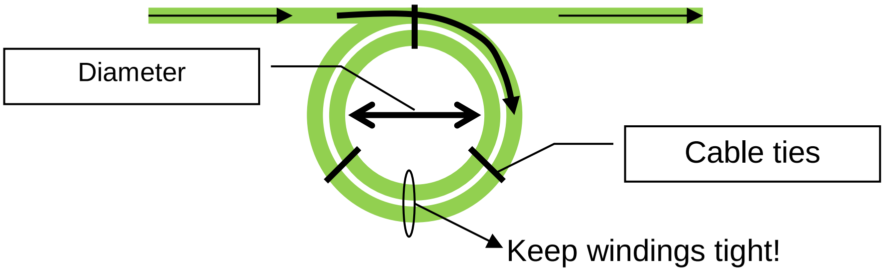

Figure 2-3 Air core coil

Decoupling chokes are also available from different manufacturers with various impedances and ratings. Other coils can also be used, as long as the current rating and the inductance of the coil is appropriate for the application.

3 Installation

The choice of components, physical layout and wiring is of importance when doing the installation. Due to the high peak currents and short rise times any inductance in the installation has vast impact on the performance of the protection. In a typical installation there is normally an over load protection device at the input, surge protection and a distribution board feed multiple loads as shown in Figure 3-1. These components must be carefully selected to ensure reliable operation and efficient protection. The following sections details important parameters to achieve this.

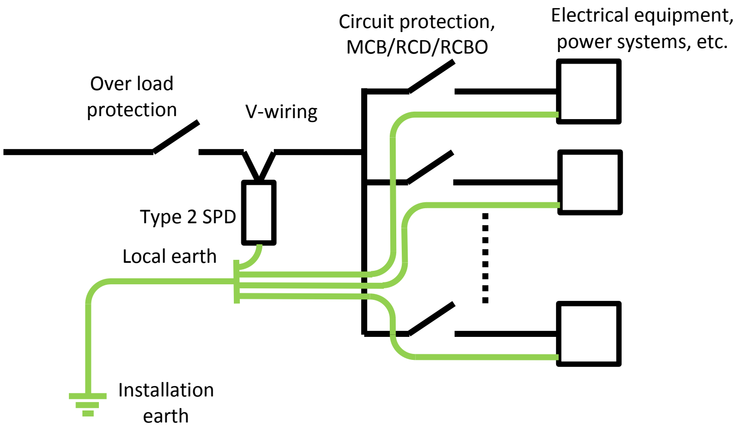

Figure 3-1 Typical electrical installation

Protection Modes

Surge currents and over-voltages can appear in two modes; *Differential mode* and *Common mode*. Differential mode appears between the feeding wires of the power system, whereas Common mode appears from feeding lines to ground. Surge currents are normally considered as common mode transients, i.e. the current is diverted to earth; however there will always be differential mode effects seen by the equipment. Eltek power supplies have high common mode impedance, thus the coordination between the type 2 SPD and the type 3 SPD internal in the power supply is easy to achieve. The differential mode impedance of a power supply is low, thus sufficient differential mode protection is important and coordination with the type 2 SPD is harder to achieve. Figure 3-2 shows how differential – and common mode protection can be implemented. The differential mode protection level of a SPD should be as close to the maximum operating voltage as possible, whereas the common mode withstand level must take into account ground faults, especially in isolated (IT) systems.

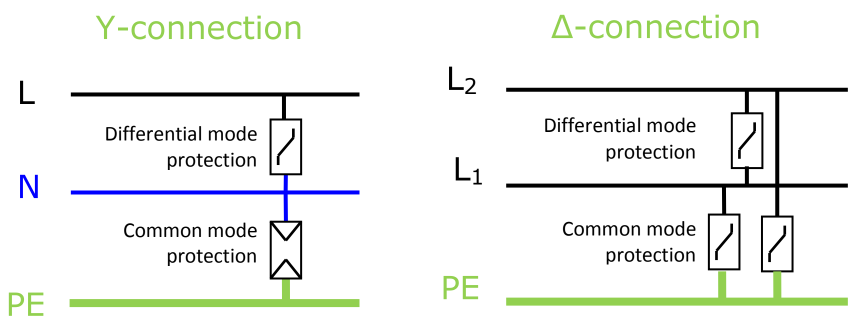

Figure 3-2 Protection modes

Wiring

The protection level *or residual voltage* seen by the equipment is crucial for the protection of the power systems. This level is given by the SPD itself, but is easily doubled if the wiring is not done properly. To eliminate any effect from the wiring, V-wiring must be used; i.e. the feed wires must be run into the terminals on the SPD, then further to the equipment to protect. It's recommended to run earth wires in a star configuration and it's important to keep earth wires short. With this wiring the impulse level across the installation to be protected is equal to the voltage protection level of the SPD.

If V-wiring for some reason is not possible, the cables to the SPD must be of the same dimensions as the input, and maximum length of 20 cm. This is important in order to limit the residual voltage seen by the power system. The effect of inappropriate wiring is clearly seen in the calculation example below and reveals the reduced performance of the surge protection.

$$V = L \cdot \frac{di}{dt}$$

$$V = \frac{1\mu}{m} \cdot \frac{10k}{8\mu} = 1.25kV/m$$

- A single wire has an inductance of approx 1uH/m independent of wire gauge (size)
- A 10kA surge current will increase the residual voltage with *1.25kV on a 1m wire*. The resistive part is on top of this
- A typical 230Vac SPD has a residual voltage (protection level) of 1.8kV at 20kA surge current

Earth Connection

The type 2 SPD should be placed in the near proximity of the local earth bar of the installation. The earth connection from the local earth bar to the power system should be of the same gauge as the feeding wires and as short as possible. A good earth connection to the installation earth is very important as this is the main path for diverting the surge current. A common rule is that the impedance should be less than 1Ω and resistive only, measured between the local earth bar and the installation earth, as shown in Figure 3-1. Grounding of equipment should be wired in a star configuration.

Upstream Breaker

Eltek recommends using the upstream breaker also for the SPD to limit any additional residual voltage from the wiring. Also, if the SPD MCB is turned off, there is no protection for the power system and other equipment. If residual current devices (RCDs/RCBOs) are required in the installation these should be installed downstream of the SPD to prevent tripping due to the transient currents and should be of delayed type.

4 Requirements for SPDs in Eltek Power Systems

Below are the requirements for the SPD and the installation of the SPD in the Eltek Power System. The requirements are divided into AC/input-side, DC/output-side and signals due to the different topologies and voltage levels for the different connections. The bullet points below highlights the requirement for the SPD and installation.

General requirements

- Maximum continuous voltage $U_{c.}$ as low as possible; according to the operating voltage of the supply and in accordance with the local requirements/regulations
- Differential and common mode protection
- V-wiring
- Sufficient coordination between the lightning protection zones
- IEC61643-11 or UL1449 certified with thermal disconnect
- Alarm monitoring of the SPD

AC Input Side

It's mandatory to install type 2 SPD on the AC input as this normally comes from LPZ2. The device can be installed at the service entry, in the main switch board or within the Eltek power system. The surge protection device (SPD) must be installed upstream of residual current devices (RCD) to prevent nuisance tripping.

Specific requirements for AC/input side SPDs are listed in Table 4-1 and Table 4-2. In addition the following items must be taken into consideration:

- For SPDs with residual voltage Up above 1.8kV, no V-wiring or installed in exposed areas it is recommended to use protection coordination between the lightning protection zones with minimum 2 uH impedance
- It's recommended to use MOV based devices on live voltages to prevent follow currents

AC Side, Y – Connection

SPDs for Y-connection are intended to be used in 400V_{ac} TN-S and TT mains configurations

Parameter		Value
Nominal voltage		230/400 V_{ac}, L-N / L-L
Maximum operating voltage, L – N	U_c	> 275 V_{ac}
Maximum operating voltage, N – PE	U_c	> 150 V_{ac}
TOV1 – 5 sec (without disconnection)	U_{TOV1}	> 335 V_{ac}
TOV2 – 120 min (safe disconnection)	U_{TOV2}	> 440 V_{ac}
Nominal discharge current	I_N	≥ 20 kA
Maximum discharge current	I_{max}	≥ 40 kA
Residual voltage, L-N	U_p	< 1.8 kV
Residual voltage, N-PE	U_p	< 1.8 kV
Response time	t_r	< 25 ns
Wire termination dimensions		10 mm^2 min
Mounting		35 mm DIN rail
Operating temperature		-40C - +85C
Certifications		CE or UL
Applicable standards		IEC 61643-1/-11, UL1449
Ingress protection		IP 20
Configurations		3P+N, see schematic 1P+N, see schematic
Miscellaneous		Thermal disconnect Auxiliary switch (alarm contact) Field replaceable cartridges RoHS6 compliant

Table 4-1 Requirements for SPDs for 400V Y-connected systems

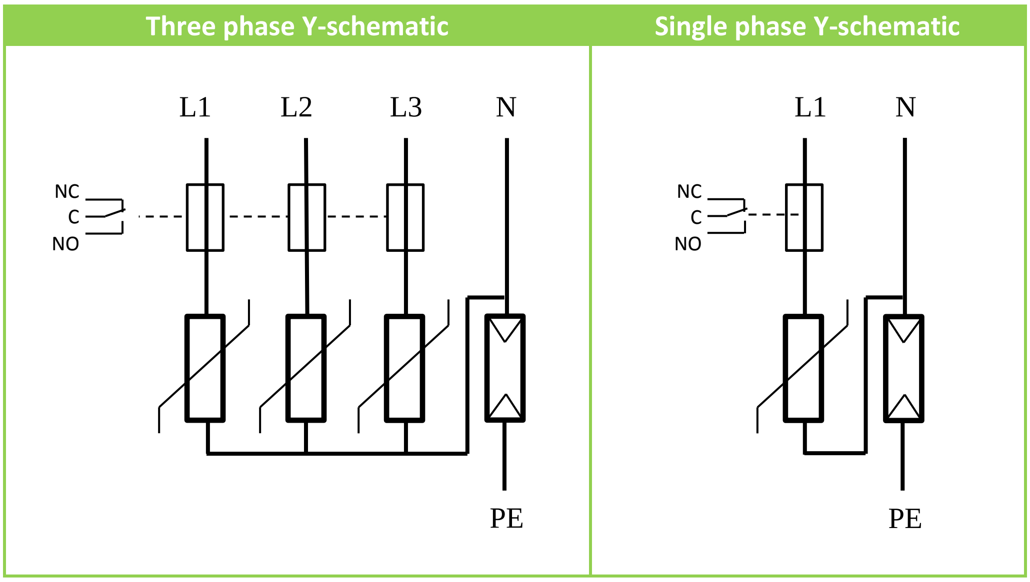

Figure 4-1 Schematics for SPDs for 400V Y-connected systems

AC Side, D – Connection

SPDs for D- connection are intended to be used in 120, 208 and 230V_{ac} IT and grounded delta configurations. For IT (floating) configurations the SPD must be able to operate in systems with a single ground fault, i.e. one of the lines connected to PE.

Parameter		Value
Nominal voltage		230 V_{ac}
Maximum operating voltage, L – L	U_c	> 275 V_{ac}
Maximum operating voltage, L – PE	U_c	> 360 V_{ac}
TOV1 – 5 sec (without disconnection)	U_{TOV}	> 440 V_{ac}
TOV2 – 120 min (without disconnection)	U_{TOV}	> 440 V_{ac}
Nominal discharge current	I_N	≥ 20 kA
Maximum discharge current	I_{max}	≥ 40 kA
Residual voltage, L – L	U_p	< 1.8 kV
Residual voltage, L – PE	U_p	< 1.8 kV
Response time	t_r	< 25 ns
Wire termination dimensions		10 mm^2 min
Mounting		35 mm DIN rail
Operating temperature		-40C - +85C
Certifications		CE or UL
Applicable standards		IEC 61643-1/-11, UL1449
Ingress protection		IP 20
Configurations		3-phase, see schematic 2-phase, see schematic
Miscellaneous		Thermal disconnect Auxiliary switch (alarm contact) Field replaceable cartridges RoHS6 compliant

Table 4-2 Requirements for SPDs for 230V D-connected systems

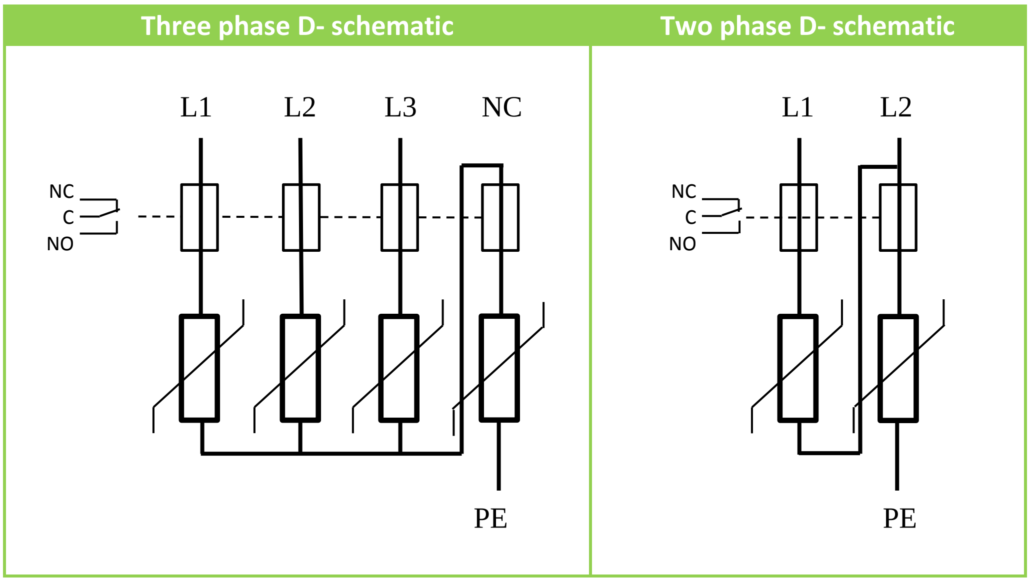

Figure 4-2 Schematics for SPDs for 230V D-connected systems

DC Output Side

If one or more of the DC circuits runs out of LPZ3, the circuit must have surge protection to protect the power system. Specific requirements for $48V_{dc}$ SPDs are listed in Table 4-3. In addition the following item is required in the installation:

- Protection coordination between the SPD and power system, minimum 2µH

48 VDC

SPDs for DC are intended to be used in 48Vdc applications for grounded or floating outputs. For floating configurations the SPD must be able to operate in systems with a single ground fault, i.e. one of the lines connected to PE.

Parameter		Value
Nominal voltage		48 V_{dc}
Maximum operating voltage	U_c	> 60 V_{dc}
TOV – 5 sec (without disconnection)	U_{TOV}	> 90 V_{ac}
TOV – 120 min (**safe** disconnection)	U_{TOV}	> 90 V_{ac}
Nominal discharge current	I_N	≥ 15 kA
Maximum discharge current	I_{max}	≥ 40 kA
Residual voltage	U_p	< 0.4 kV
Response time	t_r	< 25 ns
Wire termination dimensions		10 mm^2 min
Mounting		35 mm DIN rail preferred
Operating temperature		-40C - +85C
Certifications		CE or UL
Applicable standards		IEC 61643-1/-11, UL1449
Physical protection		IP 20
Configurations		1P, see schematic 2P, see schematic
Miscellaneous		Thermal disconnect Auxiliary switch (alarm contact) Field replaceable cartridges (preferred) RoHS6 compliant

Table 4-3 Requirements for SPDs for 48Vdc systems

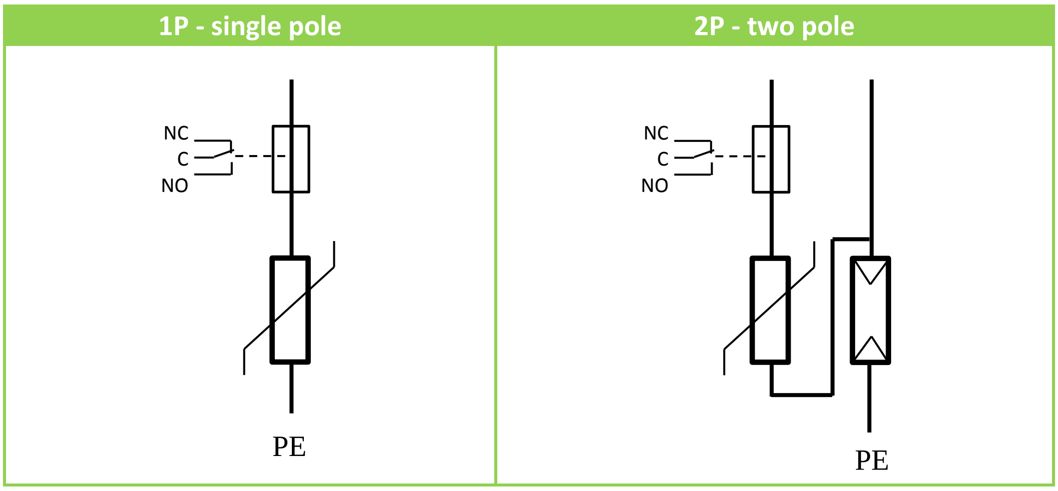

Figure 4-3 Schematics for SPDs for grounded Vdc systems

Signals

It’s not allowed to run signal cables out of LPZ 3, thus additional surge protection for signal wires are not an option.

5 Schematics for Surge Protection

This chapter shows examples of wiring diagrams for different system configurations, both on AC/input side and the DC/output side. The wiring diagrams shows the main principals and requirements for the installations. There will always be trade-offs in a practical installation, thus it is important to consider the influence on the performance of the surge protection of the system.

AC Schematics

There are several mains configurations around the world; however they are all derived from *two basic configurations;* Y-connection (with neutral) and D-connection (delta, without neutral). This is also how the feed into the power system is wired. Grounding can be different, but does not influence the principal. The next sections show wiring diagrams for the two different types of grid.

Y - Connected Systems

TN and TT 400V utility

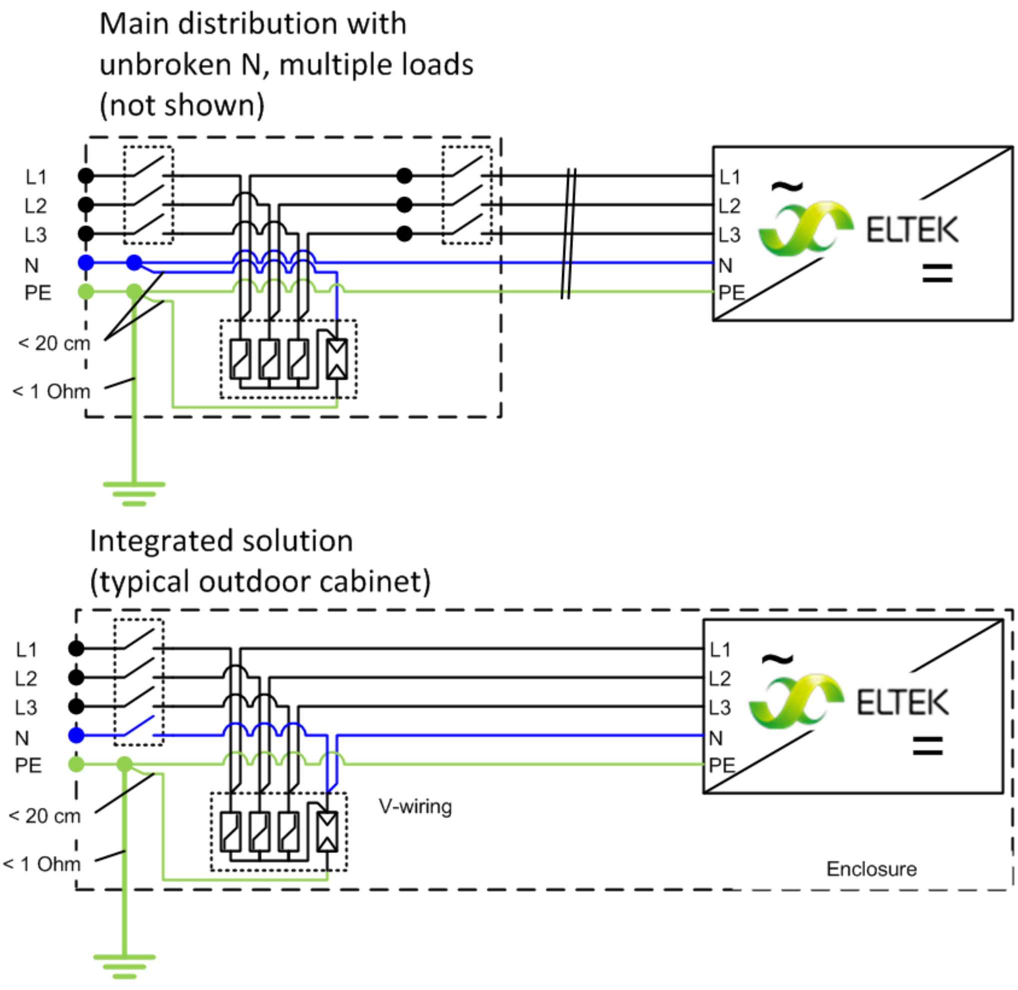

Figure 5-1 Schematics for Y-connected systems

D - Connected Systems

This type of grid has no neutral conductor; the power system is D-connected. To achieve good differential protection, it is required to have one SPD between the lines in addition to the SPD from the line(s) to earth. The SPD solution can be symmetrical or unsymmetrical. Unsymmetrical is shown in Figure 5-2.

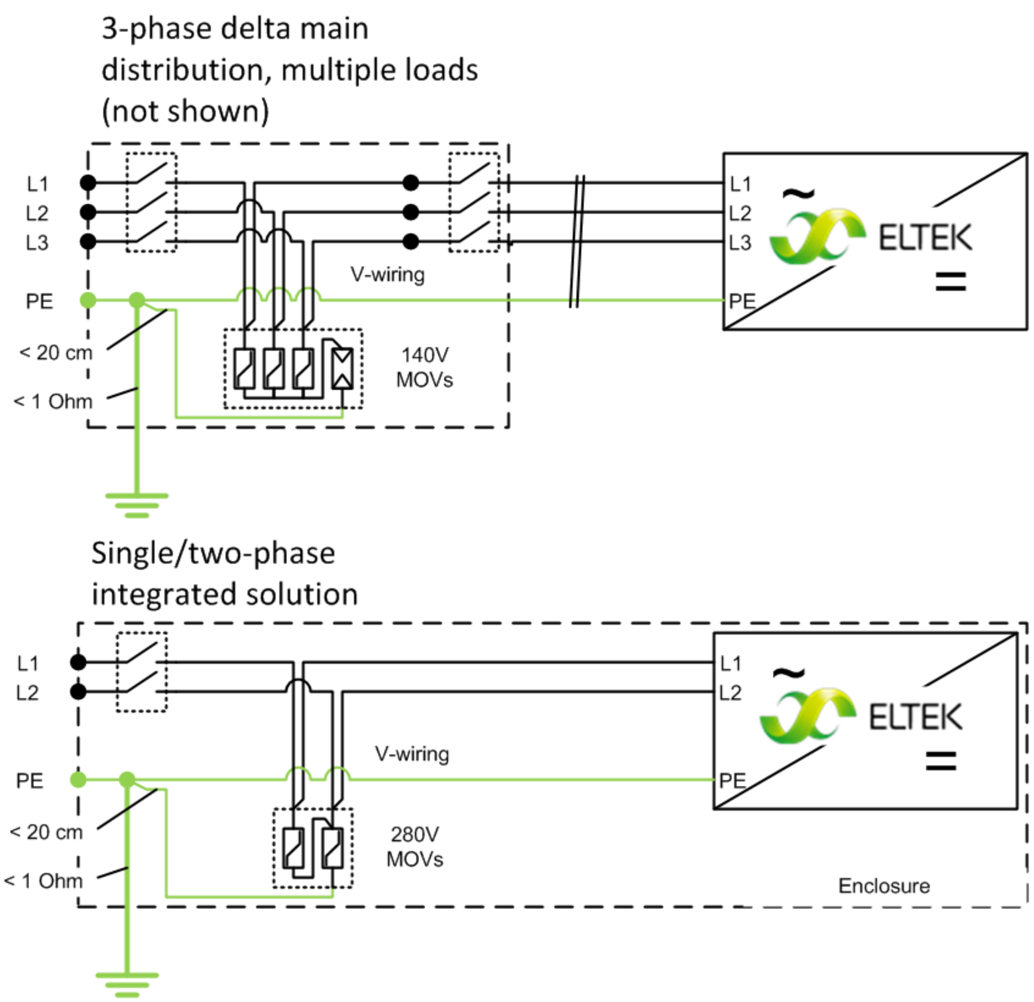

Figure 5-2 Schematics for D-connected systems

DC Schematics

The next sections show wiring diagrams for DC output; positive grounding, negative distribution DC outputs and floating output solutions.

Positive Grounding, Negative Distribution (48V systems)

This configuration is the default configuration for 48V systems (negative 48). The positive output is grounded; the load breaker is in the negative output. Two solutions are shown; single pole SPD and two pole SPD. The latter provides better total protection, due to the direct differential protection. The postive connections are protected with the GDT and the solution is similar to the solution for mains Y-configurations.

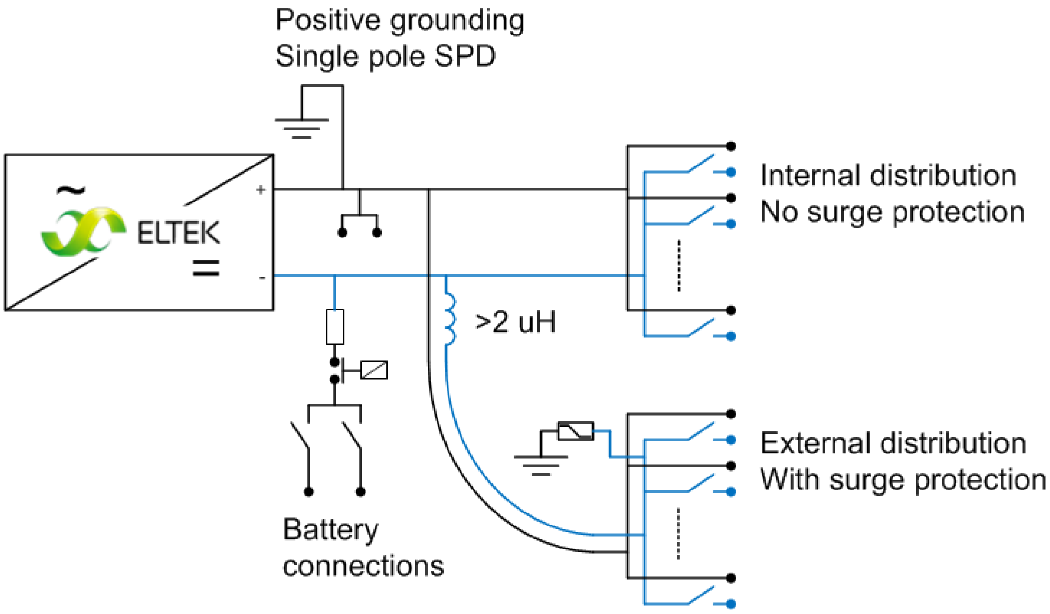

Figure 5-3 Schematics for grounded output, single pole SPD

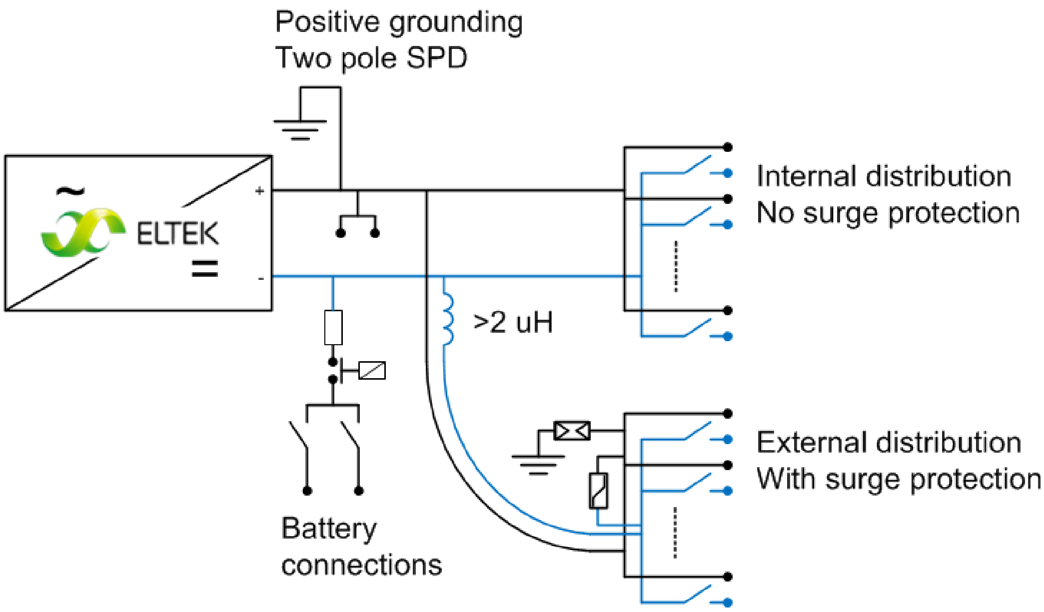

Figure 5-4 Schematics for grounded output, two pole SPD

Floating Output

This configuration is similar to a two-phase IT solution. The solutions utilises a 2-pole SPD.

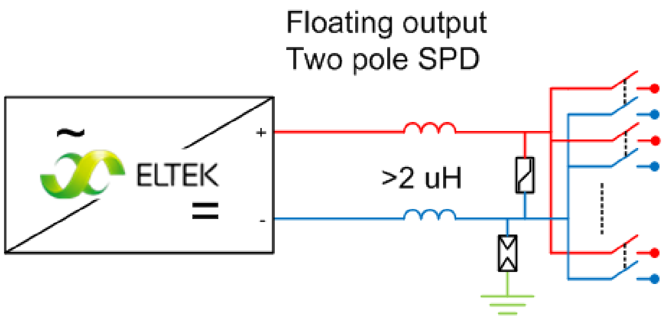

Figure 5-5 Schematics for floating output, two pole SPD

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