Raycap

Overvoltage protection concept for EV charging infrastructure, covering the latest Standard updates

With the increased use of electric vehicles, including those incorporating new "High Power" charging technologies, the need for a reliable and safe charging infrastructure has significantly increased.

What's new: *In June 2019, the German national standard adopted the 2018 IEC 60364-7-722 revision that includes Requirements for Special Installations and Locations: It is now mandatory that suppliers of Electric Vehicle (EV) charging infrastructure install surge protection to ensure safe operation for the public and to protect the infrastructure from being damaged due to transient overvoltages.*

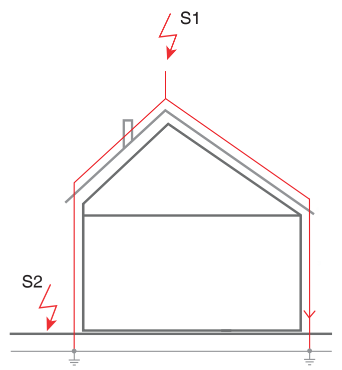
Electrical surges or transients represent a major cause of failure and loss of operation to EV systems. These surges are generally created from either direct lightning strikes or induced effects. It is clear that a direct lightning strike can have devastating impact on the sensitive electronic components used in such systems, but fortunately such events are not particularly frequent. More common are the indirect effects emanating from more distant strikes which can induce significant voltages onto the external power lines feeding the EV charging infrastructure. Another source of damage to the infrastructure is caused by ground potential rise, where a nearby strike causes the local ground to rise in voltage with respect to more distant points, such as that of the supply transformer. This in turn results in large surge currents flowing in an attempt to equalize this voltage gradient, and this can cause damage to the equipment.

From the above, it is evident that a holistic protection system is required to safeguard the capital investment in the EV infrastructure. This needs to protect the system from both direct strikes, using an external Lightning Protection System (LPS), as well as from the effects of surges and transients using industrial surge protective devices (SPDs). Unprotected systems can incur significant costs caused by lightning damage as well as system downtime, resulting in the loss of operation and revenue.

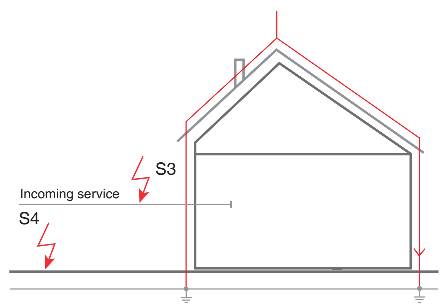
IEC 60364-7-722 mandates that SPDs be installed, not only to protect the infrastructure, but also to ensure personnel safety by limiting dangerous voltage potentials. Raycap has significant expertise in the requirements of this and other surge protection standards, and is able to work with installers to select the appropriate solution for the specific EV application and installation.

Evaluate scenarios correctly

The IEC 62305 series of standards provides the basis for protecting an infrastructure from direct and indirect lightning strikes. Part 1 of the standard details general principles of lightning protection, Part 2 deals with risk management, Part 3 deals with external LPS protection to the structure and Part 4 deals with protection of the electrical and electronic systems within the structure. Part 3 describes Lightning Protection Levels (LPLs) which assign levels of probability to the LPS adequately protecting the infrastructure from a direct lightning strike. It also describes four scenarios:



S1	Direct strike to the LPS or the structure (EV charging system).
S2	Direct strike to the line (power feeder) entering the structure.



S3	Strike near to the structure, which will induce voltage onto the internal wiring within the structure
S4	Strike near to the line entering the structure, which will induce voltage onto the line(s) and power/data lines entering the structure

Figure 1: Various lightning strike scenarios according to IEC 62305.

Lightning protection levels for internal lightning protection are divided into four categories (see Table 1). For instance, if an EV charger installation is dimensioned for lightning currents up to 200 kA (10/350) Lightning Protection Level I (LPL I), the lightning current splits so that 100 kA flows through the earth conductor and 100 kA flows via the all power supply lines. Expressed simply, it can be assumed that 50% of the direct lightning current (S1) flows away via the earthing arrangement and remaining 50% is coupled via power lines, the resulting symmetrical splitting to the individual wires in case of three-phase system is 100 kA / 4 wires = 25 kA / wire. Hence, the SPD installed must be capable of withstanding the expected lightning current.

Values are per conductor

LPL	Flash to Structure				Direct and Indirect Flashes to the Service		
	S1 (10/350)		S1 (8/20)	S2 (8/20)	S3 (10/350)		S4 (8/20)
	1 phase	3 phase	Inductive Coupling	Induced Current	1 phase	3 phase	Inductive Coupling
I	50 kA	25 kA	10 kA	0.2 kA	20 kA	10 kA	5 kA
II	35 kA	17.5 kA	7.5 kA	0.15 kA	15 kA	7.5 kA	3.75 kA
III / IV	25 kA	12.5 kA	5 kA	0.1 kA	10 kA	5 kA	2.5 kA

LPL	Iimp	Rule of Thumb for Linkage	Inductive Coupling
I	200 kA	100 kA	5 kA
II	150 kA	75 kA	3.75 kA
III/IV	100 kA	50 kA	5 kA

Table 1: Various lightning strike scenarios according to IEC 62305.

Selecting the correct surge protection for the EV infrastructure

SPDs should be installed on both the AC supply to the EV infrastructure, as well as the DC supply from the charging station to the vehicle. The schematics below illustrate a typical EV charging station when, in the first case, it is subjected to direct strikes (scenarios S1/S2), and in the second case to induced effects (scenarios S3/S4). These scenarios consider various means of surge coupling – each of which require specific lightning and surge protection measures to mitigate risk.

The following recommendations should be considered:

Charging station with various direct lightning strike scenarios (S1/S2) according to IEC 62305.

Charging station with various coupling scenarios (S3/S4).

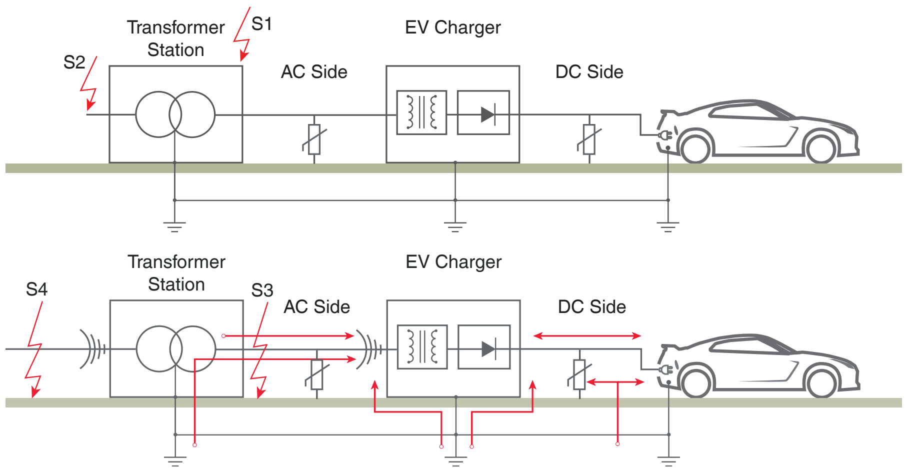


Figure 2

S1/S2 Scenarios

Under these scenarios, we consider direct strikes – either to the structure itself or to lines entering the structure. This is designated Lightning Protection Zone 0A (LPZ 0A). The risks of such direct strikes can be mitigated if an LPS is installed. In this case, we reduce the exposure to LPZ 0B, per the lightning protection electro-geometrical method, often referred to as the "Rolling Sphere" method. See Figure 5a.

When the EV infrastructure may be exposed to partial or direct lightning currents i.e. within LPZ 0A or LPZ 0B, the appropriate SPD to install is one which has been tested to the exposure of IEC test Class I as defined in IEC 61643-11. In general, such an SPD may be expected to withstand lightning impulse levels (I_{imp}) as high as 25 kA (10/350).

If such SPDs are installed at the primary service entrance of the three phase service line supplying the infrastructure, then they operate as equipotential bonding SPDs. In this case an SPD with 4 x 25 kA, total 100 kA, (10/350 μs) should be used to protect the AC/DC inverters.

S3/S4 Scenarios

Under these scenarios we consider the effect of nearby strikes – either to the structure itself (wiring within the structure) or to the lines entering the structure. The large electromagnetic field created by these nearby discharges can couple significant energy onto the lines via voltage induction.

Charging station without LPS with underground power source.

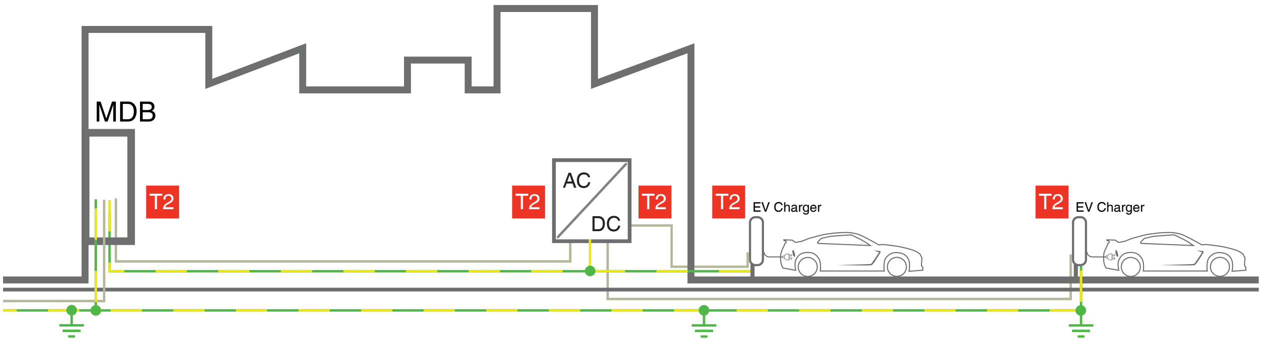


Figure 3

Charging station without LPS with overhead power source.

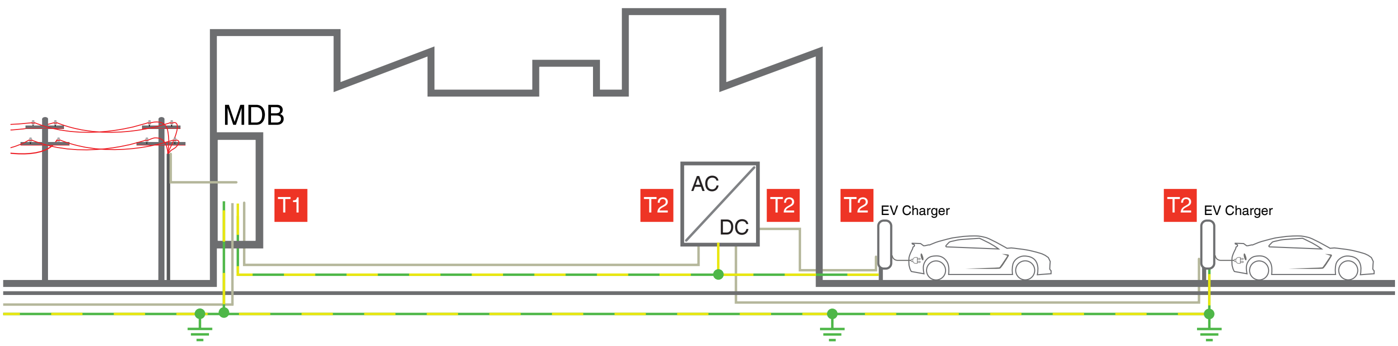


Figure 4

To mitigate the risk of such induced surges, SPDs must be installed. These SPDs once installed will create additional LPZs of lowering risk. For example, installing an SPD where the line enters the structure will create an LPZ 1 within the structure. Installing an additional SPD within this LPZ 1 zone will further reduce the exposure to that of LPZ 2, as shown in Figure 5b.

When an EV infrastructure is exposed to induced lightning currents, the appropriate SPD to install is one which has been tested to the exposure of IEC test Class II as defined in IEC 61643-11. In general, such an SPD may be expected to withstand nominal discharge currents (I_n) 5 kA (8/20).

Table 3 considers typical SPD values to be installed when considering the exposure of LPL III/IV.

Even if there is no risk from a direct strike to the EV structure (because an appropriate LPS is installed, or the structure is shielded by a taller adjacent structure), the effects of an indirect lightning strike close to the lines supplying the charger, may still result in damage. The resultant electromagnetic pulse (EMP) created by a nearby lightning strike can induce energy onto the lines via capacitive or inductive coupling. Type 2 SPDs (test Class II) should be selected in such locations, and the nominal discharge current rating should be selected to be at least 5 kA, see Table 2, Scenario S1 (8/20).

Values are per conductor

	Direct Strike			Indirect Strike (Induction)		
Threat	To Structure	To Line (Service)		To Structure	To Line (Service)	
Scenario	S1	S2		S3	S4	
LPL	III/IV	III/IV		III/IV	III/IV	
SPD Class	I	I		II	II	
Rating	I_{imp} (10/350)	I_{imp} (10/350)		I_n (8/20)	I_n (8/20)	
System		1 phase	3 phase		1 phase	3 phase
Type kA/pole	12.5 kA	35 kA	12.5 kA	100 kA	40 kA	40 kA

Table 3: SPD values to be installed when considering exposure.

Values are per conductor

LPL	Flash to Structure		Direct and Indirect Flashes to the Service
	S1 (8/20)	S1 (8/20)	S4 (8/20)
	Inductive Coupling	Induced Current	Inductive Coupling
III/IV	**5 kA**	**0.1 kA**	**2.5 kA**

Table 2: LPL III/IV scenarios.

Values per conductor

LPL	Flash to Structure			
	S1 (8/20)		S1 (8/20)	S2 (8/20)
	1 phase	3 phase	Inductive Coupling	Induced Current
III/IV	**25 kA**	**12.5 kA**	**5 kA**	**0.1 kA**

Table 4: LPL III/IV scenarios per phase.

Charging station with LPS.

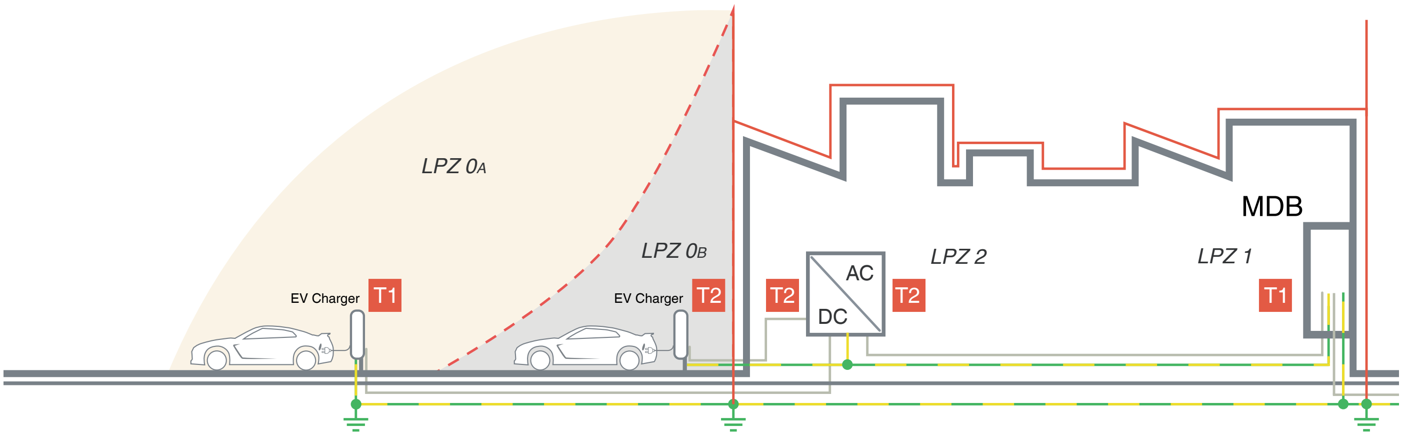


Figure 5a *Figure 5b*

It is important to note that sources other than lightning can also cause overvoltages. For example, switching operations on the electrical network can couple energy to the service lines entering the EV charging facility, while internally generated noise from the EV inverters themselves may couple energy to data and control lines and disrupt normal operation.

Metallic lines entering or exiting the structure are all potential paths for surge voltages. A risk assessment is usually carried out to determine sources of vulnerability, and appropriate protection measures adopted to reduce this below the tolerable risk R_T of the equipment installed. These protection measures include the installation of correctly selected SPDs, the improvement of grounding and bonding, and even the installation of an external LPS over the site.

Table 5 below provides an overview of the different types of surge protection:

Type Designation	SPD Types	Test Category	Reference Parameter
Lightning Arrester	Type 1	Class I	I_{imp} (Lightning Pulse Current 10/350µs)
Surge Protection	Type 2	Class II	I_n (Rated Current 8/20µs)
Terminal Protection	Type 3	Class III	U_{oc} (Open-Circuit Voltage)

Table 5: Overview of different surge protection types.

The right type of SPD to choose

In order to effectively protect the EV equipment, an SPD with voltage protection rating (U_p) less than, or equal, to the withstand voltage (U_w) of the equipment, should be selected.

Raycap's hybrid SPD technology, combining both metal oxide varistors (MOVs) and gas discharge tubes (GDTs), has been developed to provide a very low protection voltage, thus ensuring optimum protection to the equipment. In addition, the voltage switching behavior of the GDT, ensures that there is no leakage current during normal operation of the SPD. This makes such technology ideal in meeting new EU regulations governing allowable standby quiescent currents. In addition, this technology provides a level of immunity against short-duration voltage transients caused by faults in the low-voltage network, and thus resulting in a good service life of the SPD.

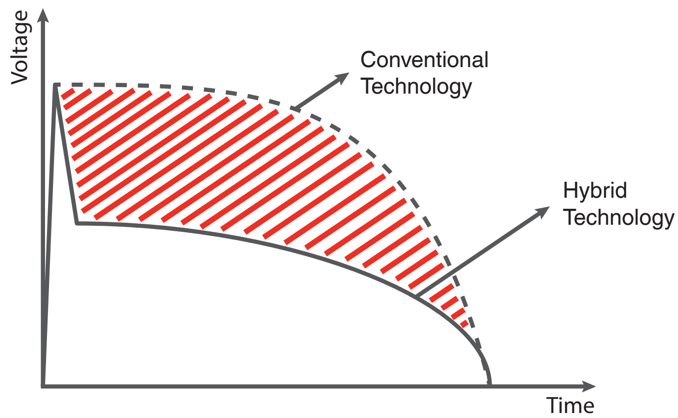


Figure 6: Compared to conventional arrester technology, Raycap's hybrid technology ensures the lowest overvoltage stress on the equipment to be protected.

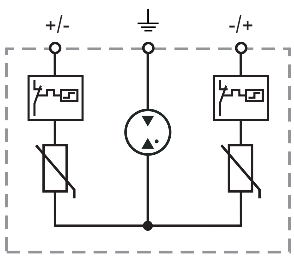
SPD protection of the inverter

IEC 61643-12, the Application Guide dealing with the selection and installation of low voltage SPDs, details the need to install a suitably selected SPD (see Table 3) at the main distribution board feeding the EV charging equipment. If this is more than 10 meters from the panel board, then additional SPDs should also be installed at the terminals of the charging station.

It is important to note that an overvoltage on the incoming service to the EV charger, may not only damage the sensitive electronics within the charger itself, but may pass through to the connected vehicle and cause damage to the onboard vehicle systems. For this reason, protection should also be applied to the DC side of the inverter.

Technologies such as fast chargers, telecom data storage centers, and advanced battery storage systems employ DC power. The SPDs used to protect these high voltage DC applications require special design features including: larger creepage and clearance distances, and special arc-quenching technologies. The latter is required to extinguish the arc which forms when a failed MOV is internally disconnected. Unlike AC power, DC has no zero-crossing point at which the arc will naturally extinguish.

Raycap's ProBloc B 1000 DC is a Type 1+2 SPD designed specifically for DC power applications. It employs hybrid MOV/GDT technology that can be universally used to protect the DC side of EV chargers, and incorporates a patented arc-quenching technology that is suitable for high DC voltages. The hybrid technology also ensures no leakage current to ground, thereby not compromising the safe operation of ancillary equipment such as ground-fault and arc-flash detectors. An indicator on the SPD also provides a visual status of the SPD's operation, while voltage-free contacts allow for remote monitoring of the device.



ProBloc B 1000DC

Universal protection scheme

Raycap's patented *Strikesorb*® technology was also developed for use in mission-critical applications such as EV charging. It is the only surge protection solution designed to last for more than 25 years, and is considered to be maintenance-free. This technology uses a custom MOV with optimized ratings, encapsulated under 1500 pounds of pressure, in a specially engineered aluminum housing. This enables it to withstand several thousand short-duration lightning strikes, or withstand longer duration temporary over-voltages (TOVs) of the power network. It is certified to international safety standards such as IEC and UL, and when correctly installed will not explode or catch fire. The technology used ensures a controlled life-end failure mode, and the best protection level of all the Raycap SPD products. This protector is recommended for larger more complex installations powered by a central inverter – see Figure 3.

Strikesorb 35-P-HV-M

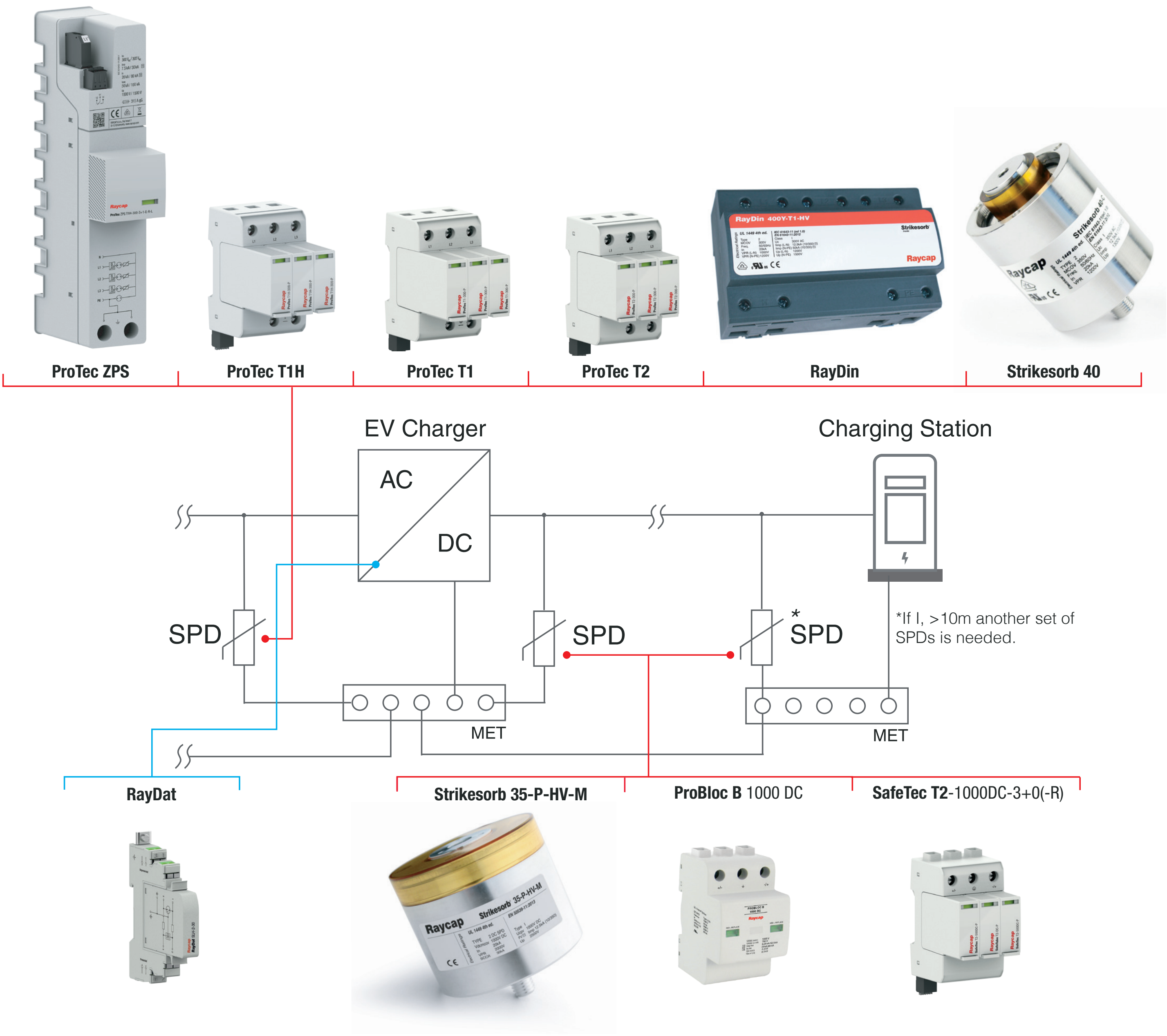


Figure 7: Possible options of lightning and surge protection devices.

Summary

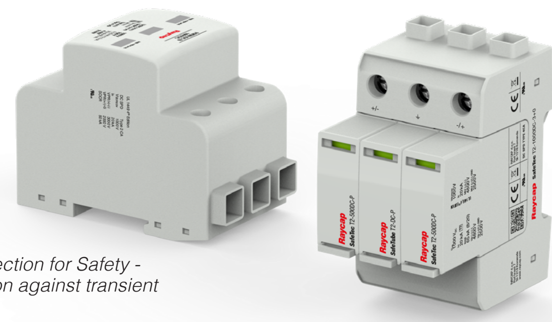
Just as a *Swiss Army Knife* cannot replace a well-equipped tool set, EV charging scenarios cannot be adequately covered by a single surge protection solution. In an EV charging environment, additional operational functions such as measurement, control and instrumentation should also be protected as part of the overall protection scheme. The experts at Raycap are available to assist and partner with you in finding the optimal protection solution for any EV charging environment.

About Raycap

Raycap is a technology leader in lightning and surge protection solutions. The company has grown steadily since its inception in 1987. With more than 1,200 employees worldwide, its own accredited and certified test laboratories and numerous patents, Raycap product quality, reliability and innovation are guaranteed. All surge protection products are tested and certified independently to international standards (Type 1 - 3) according to UL, IEC and EN.

Customers come from a wide range of industries, including building/construction, telecommunications, energy (photovoltaic, wind, power generation in general and energy storage), e-mobility, transportation and more.

More information is available at www.raycap.com and www.raycap.de.



Sources:

IEC 60364-4-44: 2007 + A1: 2005 + A2: 2018: *Low-voltage electrical installations - Part 4-44: Protection for Safety - protection against voltage disturbances and electromagnetic disturbances - Clause 443: Protection against transient overvoltages of atmospheric origin or due to switching.*

IEC 60364-7-722: 2018: *Low-voltage electrical installations-Part 7-772: Requirements for special installations or locations-Supplies for electric vehicles.*

IEC 60364-5-53: 2019: *Low-voltage electrical installations - Part 5-53: Selection and erection of electrical equipment - Devices for protection for safety, isolation, switching, control and monitoring - Clause 534: Devices for protection against transient overvoltages.*

IEC 61643-12: 2008: *Low-voltage surge protective devices-Part 12: Surge protective devices connected to low-voltage power systems-Selection and application principles.*

IEC 61643-11: 2011: *Low-voltage surge protective devices - Part 11: Surge protective devices connected to low-voltage power systems - Requirements and test methods.*

IEC 62305-1: 2010: *Protection against lightning - Part 1: General principles.*

IEC 62305-2: 2010: *Protection against lightning - Part 2: Risk management.*

IEC 62305-3: 2010: *Protection against lightning - Part 3: Physical damage to structures and life hazard.*

IEC 62305-4: 2010: *Protection against lightning - Part 4: Electrical and electronic systems within structures.*

Contact Raycap if you need technical assistance about how to protect against surge or overvoltage damage, or if you have questions about your applications.

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