Raycap

Overvoltage Protection of Electric Vehicle (EV) Charging Infrastructures Globally

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The recently updated and internationally accepted IEC 60364-7-722 standard now makes it very clear that connection points at electrical supply chargers for EVs that are accessible to the public are part of public services, and therefore require protection against transient overvoltages. This is a logical consequence since preventing danger to humans and damage to EV charging equipment and the vehicles themselves during transient overvoltage events should be mandatory. Electrical protection just makes sense, as ever more mission critical equipment is brought into our modern world, and 100% reliability is expected.

This paper considers the requirements of international standards, and is written to help manufacturers and operators to select the proper solutions to protect their sensitive equipment against any kind of transient voltage.

It is estimated that more than 5 million electrical cars are already on our roads and the number is increasing year by year[1]. But for leading industrial countries to successfully reach ambitious emission reduction targets, the number of electrical cars must increase dramatically in the next few years. And, in order to achieve success, charging technology must also improve. Users expect a charging operation to finish its charging process in less than 30 minutes. Since the electrical construction of most buildings is not able to deliver the necessary AC power, plus the EV's internal rectifiers cannot handle high AC currents, a strong network of powerful publicly accessible street DC chargers must be completed. These chargers are also going to be needed along the highways and will most likely be equipped with the newest Ultrafast DC charging technology. But DC charging technology is more complicated and the number of expensive components is increasing. In the case of Ultrafast charging technology, the separation of transformer, inverter, cooling and user units is common. The distances between each device can reach 100 meters or more. It is understandable that the risk of direct and indirect lightning impact in these scenarios will be increased. This is something that requires thoughtful design in order to mitigate the risk of transient overvoltages and protect the equipment.

Evaluate scenarios correctly

While it is generally agreed that safeguarding investments is imperative, manufactures and operators are often unsure about which protective devices are needed to achieve this goal. The classical approach would be to perform an assessment to evaluate the risk of a direct lightning flash onto the charging infrastructure. A good basis for understanding this is the IEC Lightning Standard, IEC 62305-1 to 4. This four part series details how an assessment can be performed and shows the different types and means of applying external and internal lightning protection to mitigate risk. The lightning protection levels (LPL – Table 1) defined in the Standard describe levels of probability that an existing lightning protection system (LPS) will shield an infrastructure from lightning strikes.

Values are per conductor

LPL	Iimp	Rule of Thumb for Linkage	Inductive Coupling
I	200 kA	100 kA	10 kA
II	150 kA	75 kA	7.5 kA
III/IV	100 kA	50 kA	5 kA

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

The LPLs describe zones of protection under each protective level, and are instructive in helping determine the type of surge protection that is needed. In order to evaluate the need for lightning protection in particular applications, it is necessary to also factor in the risk and intensity of a lightning strike and its effects. However, this calculation is time consuming and may show the need to install external lighting protection (lightning rods) and a meshed grounding system, something an operator is often unwilling to pay for unless the value of the EV charging investment is very high, as is the case with Ultrafast infrastructures.

Thus it is easy to conclude that it might be common practice by operators to risk the possible loss of the entire charging infrastructure equipment, including damages to the EV electronics, in the case of a direct or nearby lightning hit. Transient overvoltage protection is therefore limited to the protection against surges on the AC power lines. However, those should not be under estimated due to their long duration, they can contain even more energy than a transient overvoltage of atmospheric origin. They are responsible for most of the damage to equipment and can be induced surge effects from distant strikes, grid-side electrical switching operations generated by the EV charging stations themselves, or even by the cars that are connected to them. Also short-circuits and earth faults can be counted among the possible sources of damage in these scenarios.

1 *https://www.iea.org/publications/reports/globalevoutlook2019/*

The right type of SPD to choose

Table 2 below provides an overview of the different types of surge protection available.

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 2: Overview of different surge protection types.

Class I/Type 1 Surge Protective Devices (SPDs) are installed at locations with expected lightning current of atmospheric origin. In this paper these are referred to as “T1”.

Class II/Type 2 SPDs are installed in all other cases where transient overvoltage protection in general is requested or coordination with an existing T1 SPD is required in order to reduce the clamping voltage. In this paper these are referred to as “T2”.

Class 3/Type 3 SPDs (T3) are mainly needed for very sensitive equipment with overvoltage category I. They are not common in EV charger environments.

An interesting location to consider is near the EV itself, the maximum withstand voltage is only 2.5 kV and this counts also for the new generation of EV with DC charge supply up to 1000 V. Raycap offers a wide range of products, including the unique Strikesorb technology for industrial and mission critical AC and DC applications. Further, a new generation of leakage current free Hybrid technology, suitable for installation upstream of the energy meter, as it is mandatory in some countries. This technology can provide the lowest clamping voltages, making the coordination between SPDs of different vendors easier.

Raycap’s ProBloc B 1000 DC offers a leakage current free T1/T2 protection for DC applications. Special arc chopping technology makes the product suitable for installations at high linear DC currents, provided by the EV battery, or if battery storage is part of the infrastructure.

Installation examples

The following installation examples present different EV charger structures accessible to the public. Non-accessible to the public or private installations are not considered and with these, national regulations will need to be followed. However, installation of SPDs are a general recommendation which should be followed also for private installations.

1. Publicly accessible street installations, service entrance underground lines

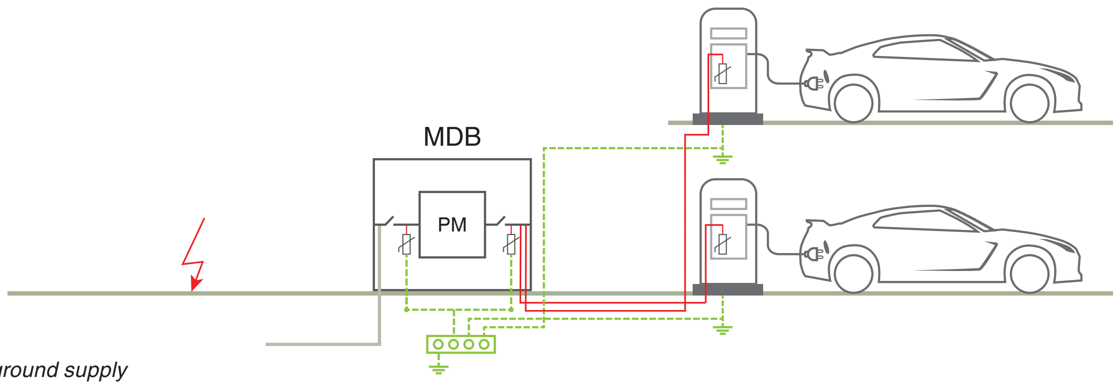

Figure 1: Street installation underground supply

2. Publicly accessible street installations, service entrance overhead lines

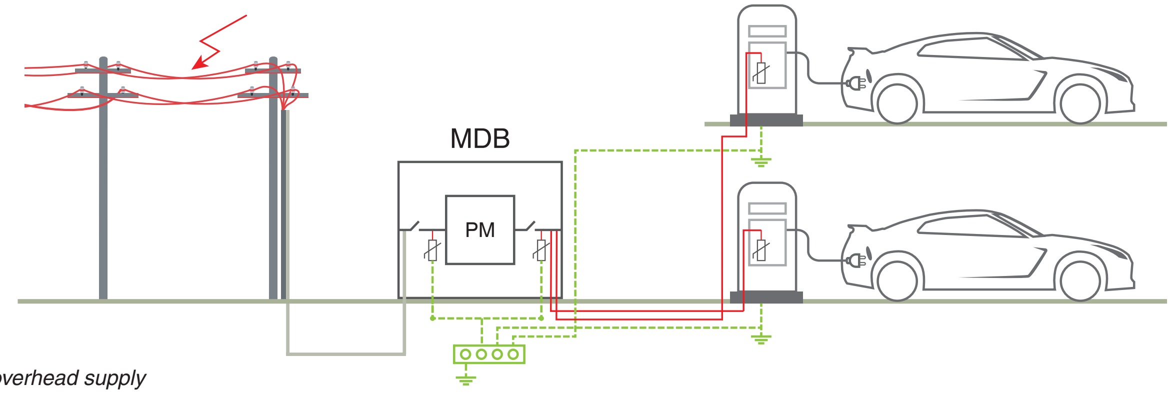

Figure 2: Street installation- overhead supply

AC supply cables in the example of Figure 1 are routed underground, a direct lightning strike to those is excluded. For these street applications a risk assessment is typically not performed, only surges including inductive currents from the grid are considered.

Since the Main AC Distribution Board (MDB) is mostly equipped with sensitive equipment as well, e.g. smart meter, gateways, installation of T2 is highly recommended here, and in some countries it's mandatory while in others, for example Germany, the installation of a T1 leakage current free SPDs at the service entrance upstream of the power meter is always mandatory. Installation of T2 SPDs at each EV charger's power lines entrance is mandatory, in case cable distance between MDB and charger is >10m, T1/T2 SPDs are recommended.

The difference in the example of Figure 2 is that the service entrance is supplied by overhead power lines. Here IEC 60364-5-53 Annex B needs to be followed; T1 SPDs shall be installed at the service entrance. The rating must have a minimum capability of 5 kA (10/350 µs) per phase to ground in a 3 ph system and shall be leakage current free if installed upstream from the power meter. Raycap offers T1/T2 SPDs for installation on various rail systems. In case a MDB is not available, the necessary T1 (better T1/ T2) SPDs shall be part of the charger units.

3. Semi-public accessible installations in buildings, e.g. parking garage.

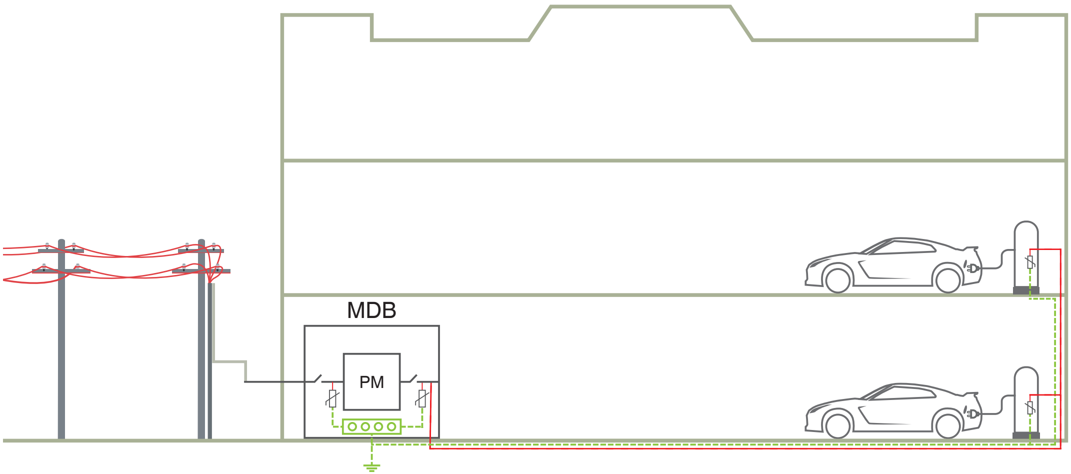

Figure 3: Parking garage.

In the example of Figure 3 the parking garage is not equipped with external lightning protection. A risk assessment according to IEC 62305 identifies no need to install external lightning protection. Due to the overhead service entrance supply, a T1 SPD installation at the service entrance either upstream or downstream of the power meter is required. Additional T2 SPDs shall also be installed at the supply entrance of each EV charger. Coordination between the SPD at the entrance and the SPD at the charger must occur. Attention: In case of an underground service supply, at minimum a T2 SPD installation at the service entrance is required even if a risk assessment seems to show different results. The reason is written in IEC 60364-4-44, section 443: "Protection against overvoltages shall be provided in buildings with commercial activity".

4. Semi-public accessible parking garage with external lightning protection

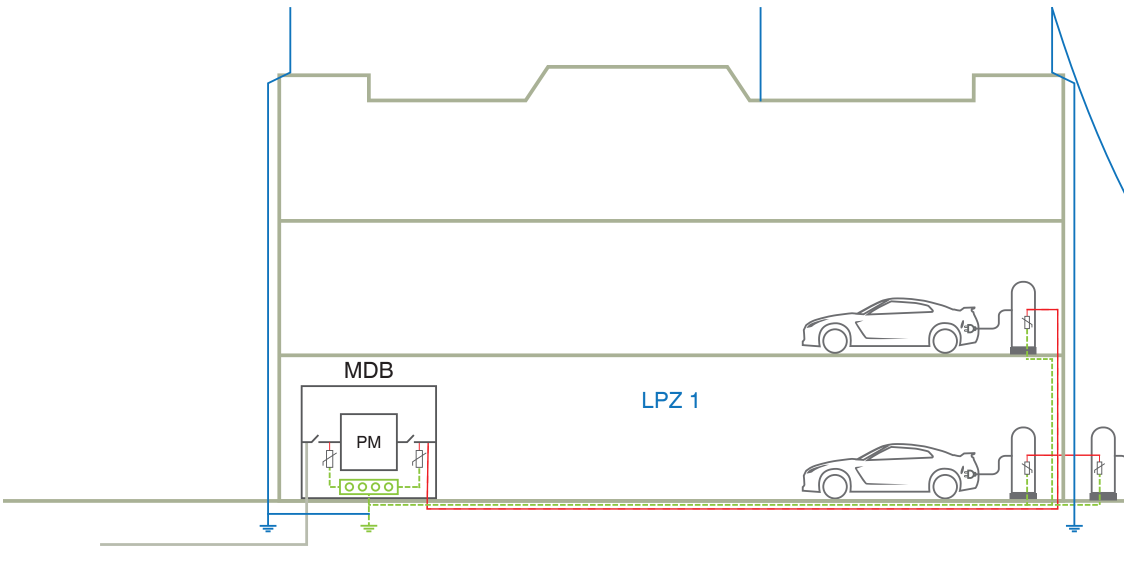

Figure 4: Parking garage with external lightning protection.

A risk assessment according to IEC 62305 identifies the need to install external lightning protection. According to the selected LPL the rating of the necessary potential equalization measures shall be calculated and is typically either a T1 SPD with 25 kA(10/350 µs) or 12.5 kA (10/350µs) rating per phase to ground in a 3 ph system and has to be placed at the service entrance.

T2 SPDs shall be installed at the supply entrance of each EV charger. Coordination between the SPD at the entrance and the SPD at the charger must occur. Chargers and EV placed outside the building but inside the LPZ 0_B area are protected against a direct flash (rolling sphere principle). Installation of T2 SPDs here is sufficient.

5. Ultrafast Charging Technology

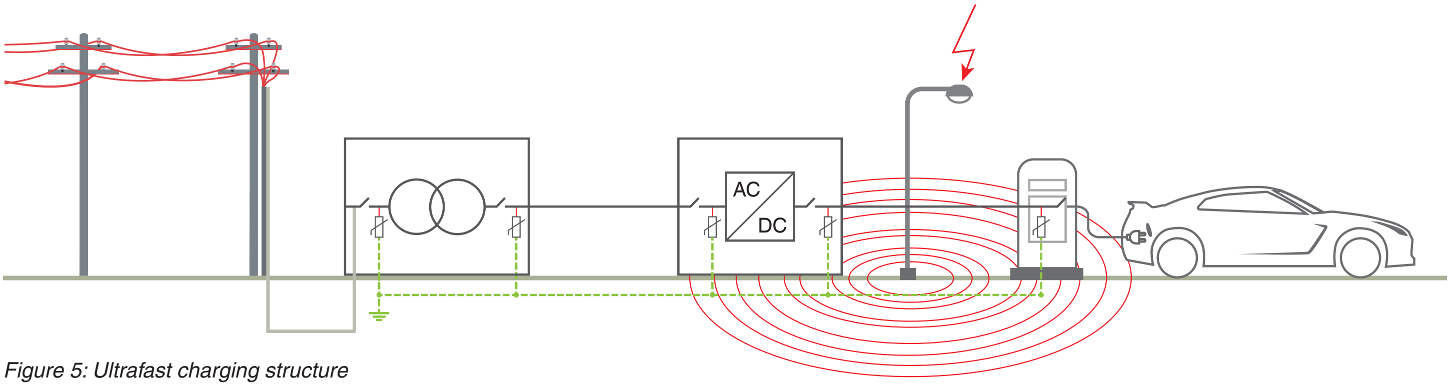

Figure 5: Ultrafast charging structure

As mentioned in the introduction, Ultrafast DC charging is a promising approach to charge an EV battery in only a few minutes, something that the public will demand be available at highway rest areas, and will make EV technology attractive for long distance travelers. One difference to typical AC or fast charging DC technology is that Ultrafast charging has a higher demand of supply current, typically not available by the low voltage grid. Therefore medium voltage transformers are installed. Further the charging infrastructure is often modular, e.g. medium voltage transformer station, AC/DC inverter and user units are located at several meters distance (Figure 5). The possible future outlook can include an additional battery energy storage system, or PV panels as part of the infrastructure. The distance between the units makes a proper overvoltage protection necessary, able to carry lightning current as well.

For a better understanding, in the examples a lightning flash hits a streetlight next to the public unit. The ground distributed current creates a high ground voltage differential of several kV between the modules of the structure, and a potential equalization is absolutely necessary. Therefore T1 or even better T1/T2 SPD installation is highly recommended. SPDs shall be installed at every cable entrance and exit, this counts for AC and for DC.

The installation of additional medium voltage arrestors is the decision of the transformer supplier. Because the highest reliability is expected and charging should be safe even during a strong thunderstorm, reliable and robust SPD technology should be used. Here, Strikesorb technology is the right approach, as well as for the DC side. This technology is currently the only UL approved Type 2 SPD for DC applications at voltage > 500 V DC. Strikesorb is the most unique surge protection solution designed to last for more than 25 years and is considered therefore to be maintenance free.

While not obligated by standard IEC 60364-4-44, it is recommended that a proper protection shall include installation of SPDs for all data and communication lines, e.g. data exchange between the EV and user unit, control and monitoring, internet access, video surveillance etc. Raycap's RayDat line covers all these needs. One additional comment regarding the streetlight poles, these can act as a lightning rod and create a small LPZ 0_B area. If located in close distance to a user unit and an EV, a direct lightning strike to both is excluded.

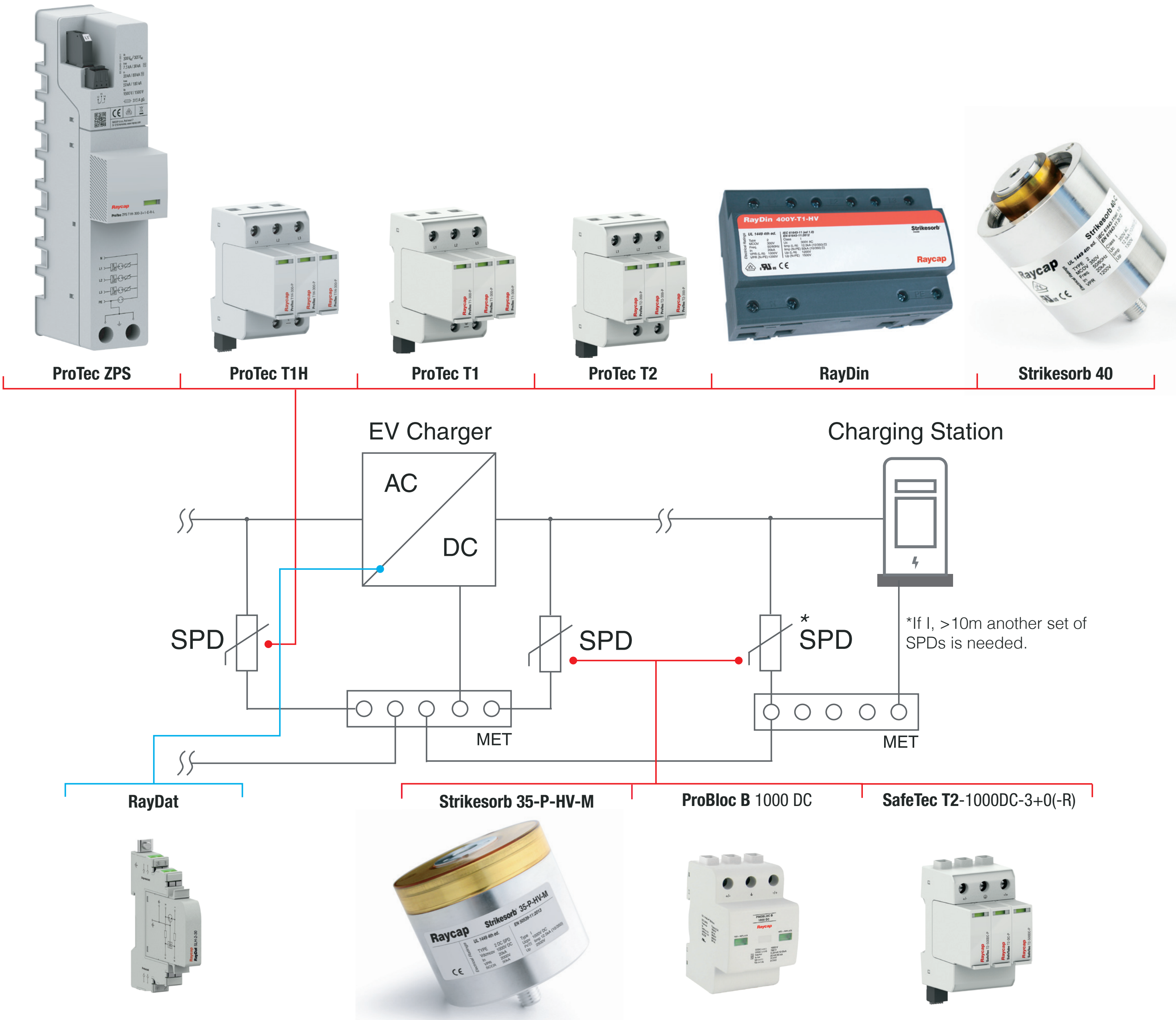

Figure 6: Possible options of lightning and surge protection devices.

Summary

EV charging scenarios cannot be covered comprehensively with a single surge protection solution. This is something that the experts at Raycap can help with. Through its wide product range of both universal IEC solutions and UL certified products, Raycap is able to offer the most comprehensive product portfolio on the market to protect power and signaling networks. It is important both to have the right equipment and to choose the right partner. If you take this into consideration, you will find a high-reliability business segment in electro mobility - and a suitable partner in Raycap.

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 (Type 1 thru 3) are tested and certified independently to international standards 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

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

***IEC 61643-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.*

***UL 1449 4th Edition:** Standard for surge protective devices.*

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