PHILIPS

Surge protection

Public lighting

Whitepaper

The challenges of **surge protection**

The need for protection

Voltage surges have a huge destructive impact upon public lighting systems. They wear out LED drivers and distribution panels prematurely, and increase service interruptions to street lighting. Beyond material damage to the luminaires, voltage surges caused by lightning, for example, can trigger or break protective devices in the circuit boards of street lighting distribution panels. So as well as the cost of replacing hardware, the public is left without lighting – a critical safety issue in the case of, for example, pedestrian and traffic tunnels, road signs and other public lighting.

The vulnerability of electronic lighting systems to overvoltages is widely recognized in technical literature, and different European regulations and standards specify the need for lighting protection. This white paper explains the causes of lighting overvoltages and how they affect public lighting installations. It also covers the legal and regulatory framework governing protection, and proposes a solution to maximize protection performance and continuity of service throughout the installation, as sole luminaire protection might not be sufficient.

Public lighting installations are exposed to the environment. Located where continuity of service is essential, it is crucial that these installations are protected against lightning and overvoltages.

Investing in protection can extend luminaire and installation lifetime, improve public services and greatly reduce overall operating and infrastructure costs.

The surge phenomenon

What are surge overvoltages?

When analyzing the phenomenon of overvoltages, we consider surge (or transient) overvoltages and temporary power-frequency overvoltages (TOV) separately. Although they both represent an increase in voltage above an acceptable limit, their root causes, magnitude, duration and method of protection are radically different. In this white paper we concentrate on the surge phenomenon.

Surge overvoltages are spikes that can reach tens of kilovolts but last for only a few microseconds. Despite their short duration, their high energy content may cause serious problems to equipment connected to the electricity network – from premature aging to destruction – resulting in service disruptions and costly repairs.

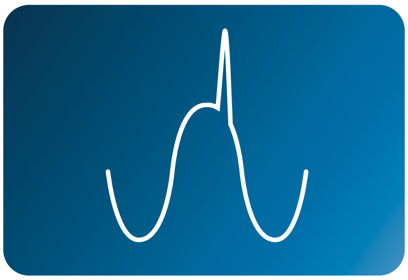


Figure 1. Transient "surge" overvoltage

Voltage surges have several causes.
For example, lightning discharges that directly strike the distribution line of a building, or its lightning rod, can induce electromagnetic fields that generate voltage spikes in nearby lighting installations.
Very long outdoor distribution power lines are highly susceptible to the direct effects of lightning strikes, with large currents from the lightning being conducted in the power lines. It's also common for non-weather phenomena to cause voltage spikes in adjacent lines – for instance, switching inside transformer cabinets, or the disconnection of motors and other inductive loads.

Surge overvoltages are voltage spikes of several kilovolts that last for just a few microseconds

Surge impact modes

Surge overvoltages have two modes of circulation: differential and common. A well-protected luminaire and installation should integrate protection for both modes.

Differential mode overvoltages circulate between live conductors: line-to-line or line-to-neutral. (Note: valid for 1 or 2 lines in place).

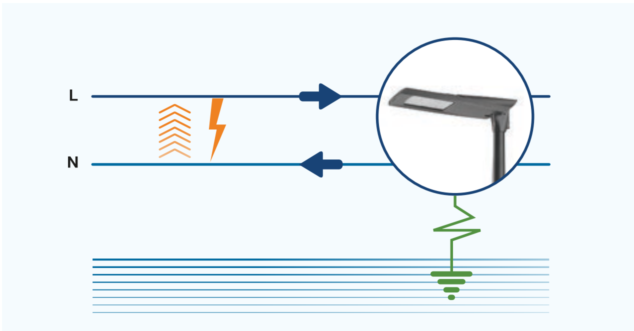


Figure 2. Definition of differential mode current flow

Common mode overvoltages appear between the live conductors and earth: for example, line-to-earth or neutral-to-earth. (Note: valid for 1 or 2 lines in place).

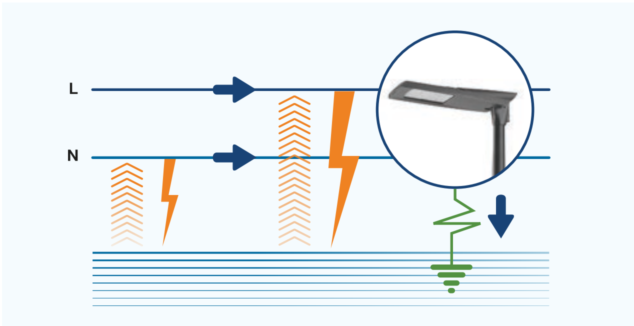


Figure 3. Definition of common mode current flow

Electrostatic discharge (ESD)

A special root cause in common mode can arise from specific weather conditions (dry air with wind, or a lightning flash) which can lead to the potential risk of electrostatic discharge (ESD) from the housing of the luminaire, either by accumulation of static charges breaking the insulation barrier or by very fast discharging during lightning flashes.

Building in protection

Protection principles against the effects of surge overvoltages in public lighting

Surge Protection Device (SPD)

Surge overvoltage protection is provided by installing a Surge Protection Device (SPD) on the vulnerable line, in addition to the basic protection provided by the luminaire and driver. Different types of SPDs can be placed somewhere in the installation, for example in a luminaire or in the cabinet, to create a good cascading of protection (see below).

SPDs in outdoor luminaires are often connected in series, when the priority is to protect the electronic components down the line from further damage. In this way they act as a fuse. When connected in parallel, the electronic components down the line – including the luminaire – continue to function even after the SPD is damaged. However, the electronic components down the line are then no longer protected. So only when this risk is accepted, can parallel connection be used.

The SPD will be damaged after weathering a number of spikes above a certain voltage level. In the event of a surge overvoltage, the protective device will divert excess energy to earth, thus limiting the peak voltage to a tolerable level for the electrical equipment connected downstream.

An SPD acts as a voltage-controlled switch. When the network voltage is lower than the activation voltage, the component is passive. On the other hand, when the network voltage exceeds the activation voltage, the SPD diverts the surge energy and prevents it from destroying the equipment. When choosing an SPD, you need to consider the equipment's exposure to the effects of lightning, along with the maximum impulse voltage that the equipment needs to withstand.

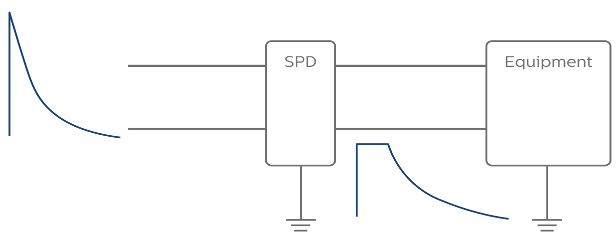


Figure 4. Working principle of a surge protection device (SPD)

Cascading of protection

In general, the most effective approach to protect large installations of lighting equipment against surge overvoltages is by cascading multiple protective stages. Each stage combines the necessary balance between discharge capacity and voltage protection level. In this way, a first stage (typically a Type 1 or Type 2 SPD) provides robustness, thus diverting most of a spike's energy, while a second stage (typically a Type 2 or Type 3 SPD) provides 'fine' protection. As a result, the peak voltage reaching the equipment always stays below the critical level.

Among the causes of surges mentioned in international protection standards, the ones most likely to affect a public lighting system are:

- Direct lightning strikes on distribution lines (conducted through the power lines)
- Lightning strikes near to a building/structure (creating induced surges).

European standards EN 60.364-5-534 and EN 62.305-1 require that protection against these types of electrical disturbance is to be provided by a Type 2 SPD. The protection solution is installed downstream of the main circuit breaker in the distribution panel circuit board, in addition to the main system. So it diverts the energy of the surge to earth, limiting the voltage peak to a tolerable level for equipment connected downstream.

To guarantee proper protection of a luminaire, the distance between it and its protector circuit must be as short as possible. If the distance between a protected distribution panel and several luminaires is more than 20 meters, using a second protection stage (of Type 2 or 3) is recommended, even if the protection level of the first stage seems to be sufficient (see Figure 5).

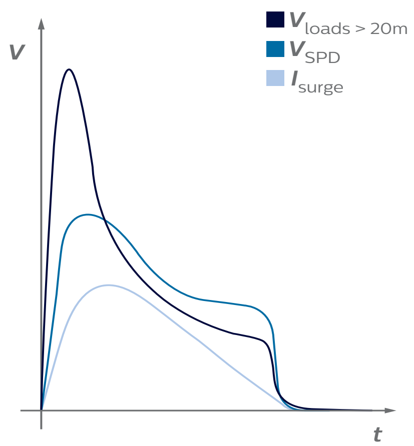


Figure 5. Effect of cable distance on the voltage protection level

This means that depending on its vulnerability in a public lighting installation, the cascading of the protection is to be built by different types of SPDs in the cabinet, mast and luminaire.

Practical approach to cascading stages

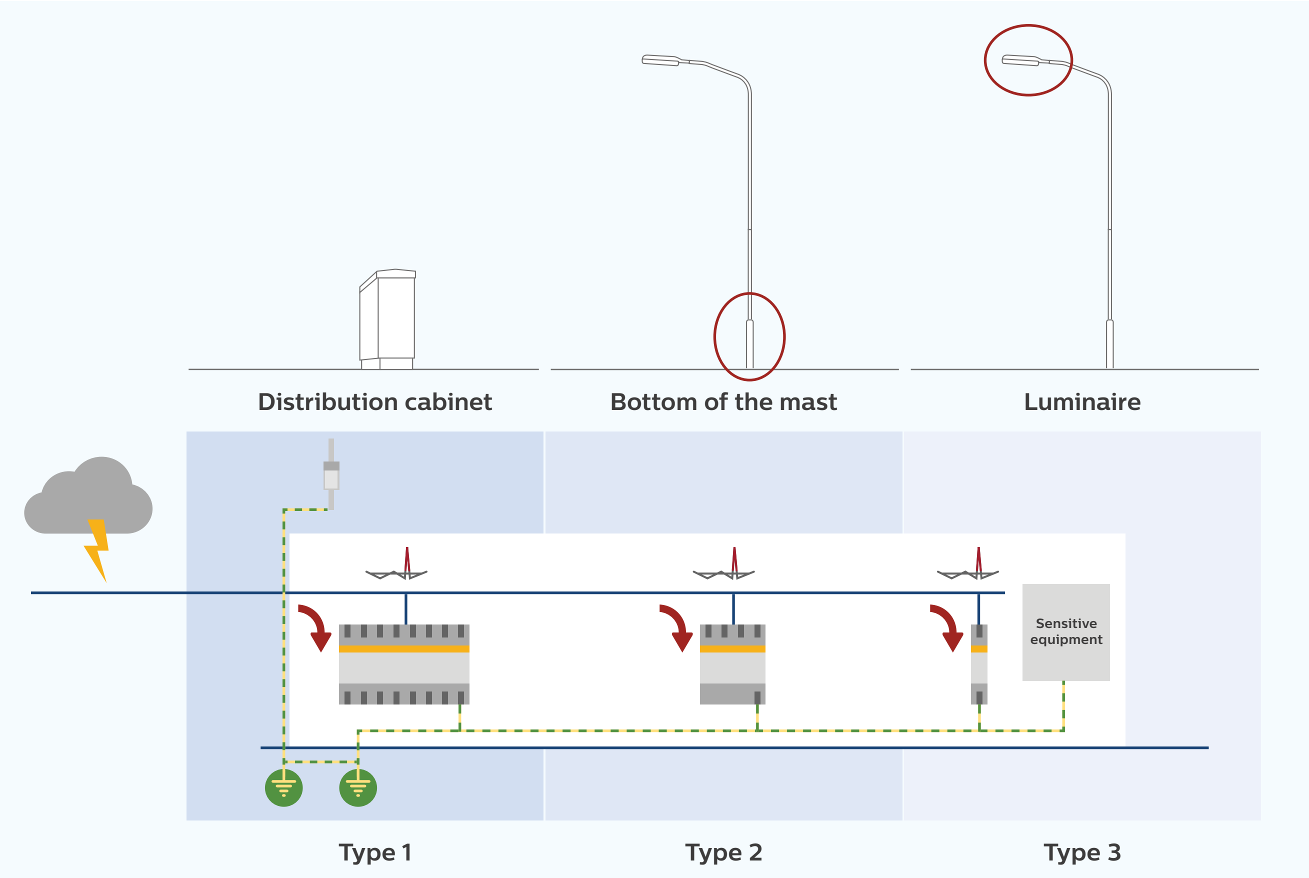


Figure 6. Typical cascading of surge protection types in a public lighting installation

Stage 1: Standard protection at luminaire level (supported by driver protection)

IEC61547 states that all luminaires should be protected from overvoltages up to 1 kV in differential mode and 2 kV in common mode. However, to match the more demanding outdoor environment, Philips has decided to exceed these requirements by gradually designing in a higher protection level. The protection at luminaire level is always a combination of the protection level of the driver and of other electronic components, and a proper equipotential link to the LED board.
As a result, by design all European Philips outdoor luminaires with integrated Philips Xitanium LED Xtreme drivers (providing 8 kV up to 10 kV common mode and 6 kV differential mode protection at driver level) have a minimum protection of 6 kV CM and 6 kV DM at luminaire level. This ensures acceptable basic protection at luminaire level for most European street lighting installations up to Class 4 (as defined in EN61000-4-5, requiring 6 kV CM/6 kV DM installation protection).

Stage 2: Additional protection of luminaires

When designing installations, the area should be assessed for its vulnerability to lightning strikes and ESD risk in combination with an evaluation of uptime requirements. In the relevant installation standards, assessment methods for the installation designer are available (according to IEC62305 part 4 & part 2 on risk management). For example, vulnerability, or risk of exposure to lightning strikes, is commonly assessed on the average lightning ground strike density for the area and the surrounding elements. Depending on the lightning strike density (in strikes per km2 per year), it can then be considered whether to install extra common mode surge protection. However, even more important is to define the requirements for uptime in the outdoor installation. The higher the requirements, the more protective measures should be applied, as the functionality of the installation could be more critical for some outdoor lighting installations at specific areas.

Examples of such areas can be airports, road crossings, roundabouts, pedestrian crossings and major roads. The functionality might be less critical for residential urban and suburban areas, parks and natural habitats. The requirements for the uptime can also be based on minimization of maintenance cost. If the end user requires high uptime and/or low and stable maintenance cost, additional protection should be implemented in the system. In these cases, for an already more robust protection at luminaire level, Philips offers the option to use a Type 3 SPD inside the luminaire, in addition to the standard protection (supported by the driver). The total solution (luminaire including driver plus SPD) is to be tested to the relevant standard IEC61547 (minimum number of pulses to withstand).

In Class II installations, together with insulated poles, specific weather conditions (dry air with wind or lightning flashes) can lead to the potential risk of ESD from the housing of the luminaire. In this case, protection is not supported by an SPD, but will have to come from either transforming the installation to a Class I installation or from another technical discharge solution in the luminaire. For this reason so-called bleeder resistors to discharge electro-static voltages can be applied.

Stage 3: Protection at bottom of mast and at cabinet level

In case of a high lighting strike density and/or when uptime requirements or low maintenance costs are critical, the environment will be most vulnerable.

Surge protection Class I: **installation level**

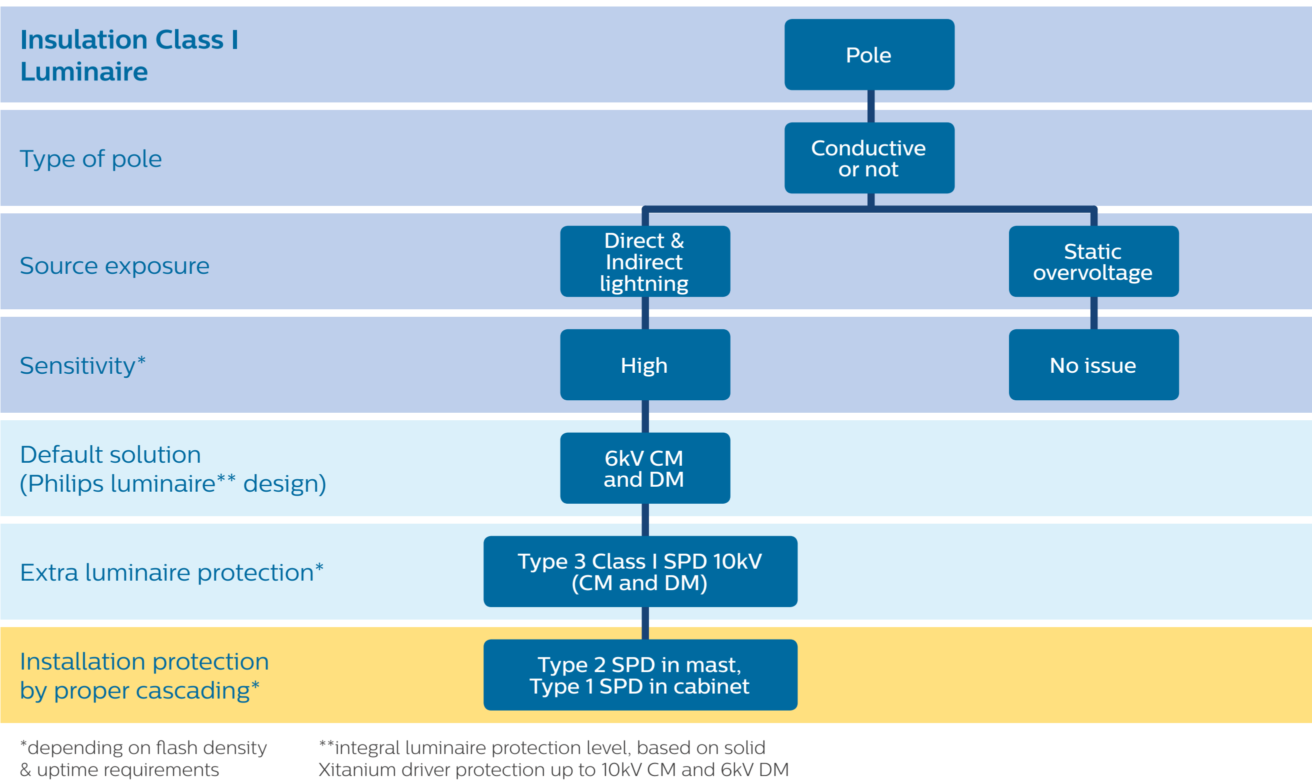


Figure 7. Surge protection class I: Installation level

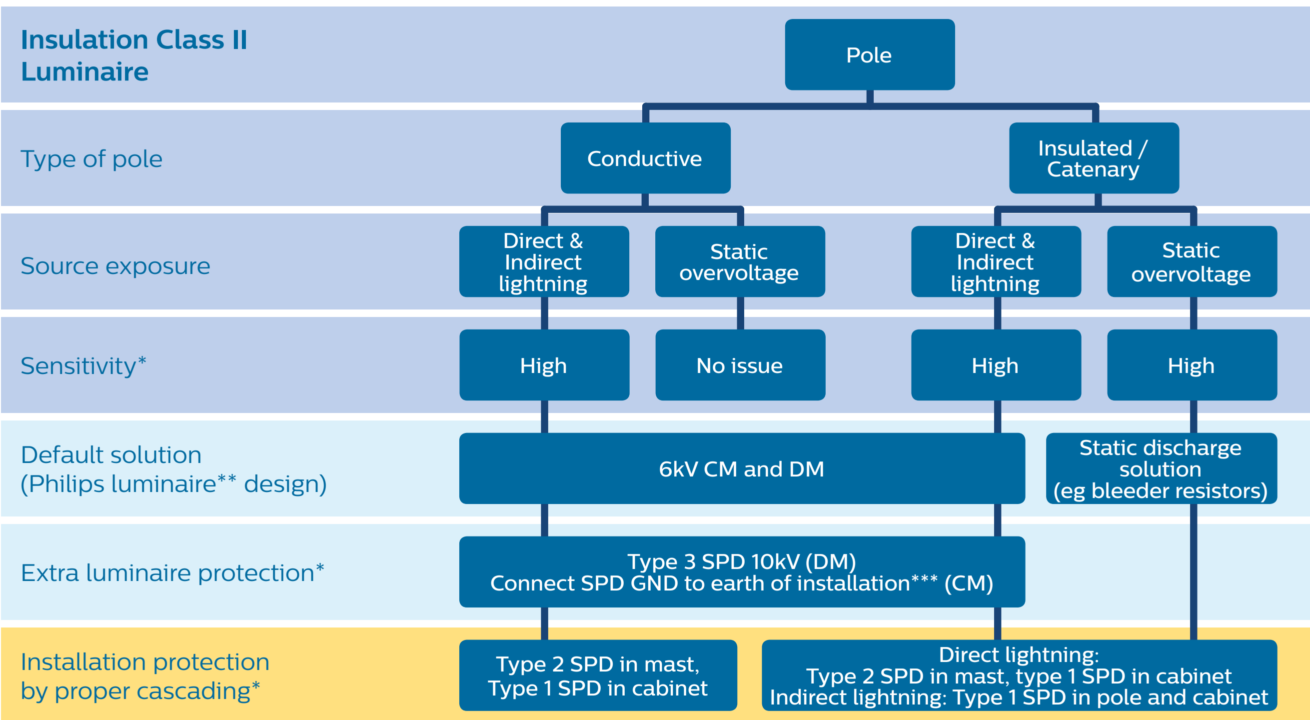
In that case it is recommended to protect the full lighting system also outside the luminaire. It is not advised to increase surge protection within the luminaire (or driver) to higher levels as described under stage 2. This is because external research shows that cascading multiple protective stages within the complete street lighting system is in general the most effective approach, as in this way the current impact is decreased step by step before reaching the luminaire. This means that a Type 1 or Type 2 SPD within the cabinet is required to handle the initial energy related to high lightning currents. Type 2 SPDs should be considered for installation within masts or in front of luminaires. When installing surge protection measures it is also important to consider whether or not the protection components should last for a longer period handling multiple lightning and surge events. Nevertheless, the responsibility for – and the decision about – whether lightning and surge protection is required (and the type) should be taken in an integral way by the system designer and/or the system owner from a full street lighting system perspective.

Various brands offer Type 1 and Type 2 SPD devices. Typical solutions can be installed on a DIN rail of four modules.

Class I and II installations

In summary, Figures 7 and 8 provide a decision tree for both Class I and Class II installations and visualize which levels of protection could be considered to protect against surge overvoltages from an integral system perspective.

Surge protection Class II: **installation level**



*depending on flash density & uptime requirements

**integral luminaire protection level, based on solid Xitanium driver protection up to 10kV CM and 6kV DM

***Connect SPD GND output to PE of installation if available (only possible in few countries where metallic mast is to be interconnected to earth whatever the luminaire chassis)

Figure 8. Surge protection class II: Installation level

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