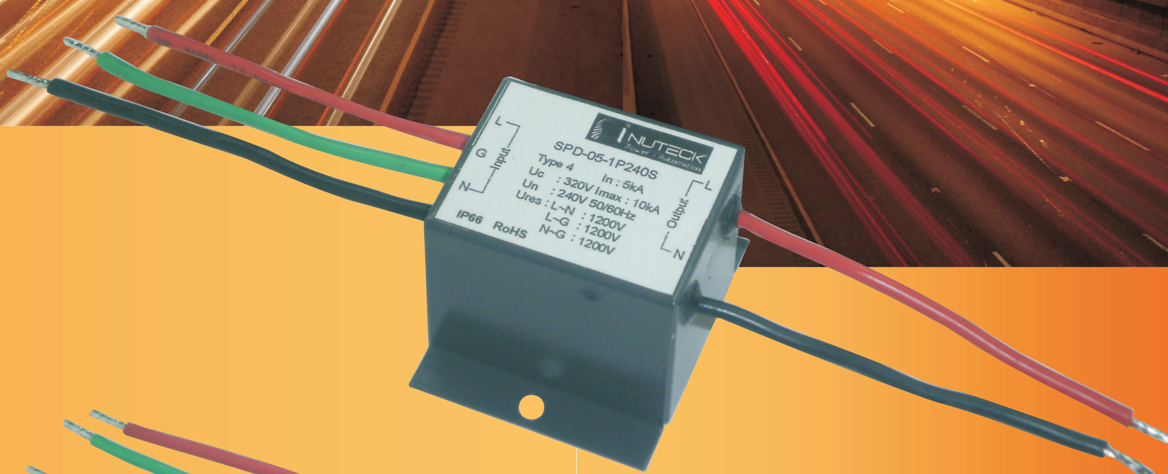
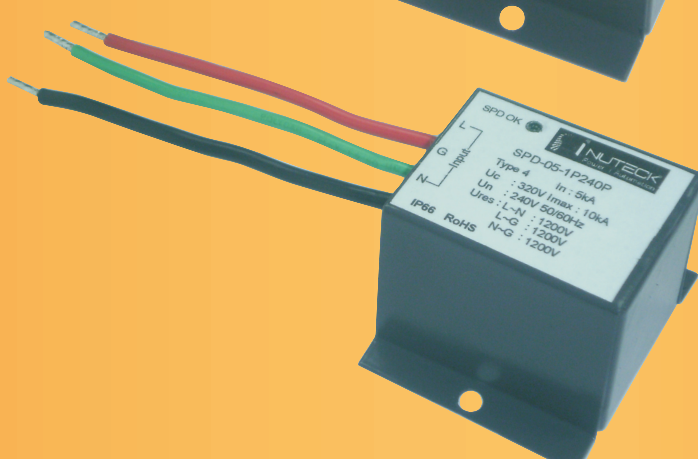
LED

Lighting Surge Protection Device





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Indirect Lightning-Induced Surge

Introduction

LED lighting is increasingly replacing legacy light sources (mercury vapor, metal halide and sodium vapor) in outdoor applications as a result o technological revolutions in LED e iciency (higher lumens per wat t), secondary optics (better lenses/re lectors), and greater thermal dissipation.
However, the initial cost o installing outdoor LED lighting can be substantial; this cost is justi ied and payback is established based on the lower wattage demand, lower maintenance cost, and longer li etime it o ers. In order to protect outdoor LED lighting rom ailing within an investment payback perio d o about ive years, the lighting must o er high durability and reliability. Transient surge event s in AC power lines, which can damage lighting ixtures, represent a signi icant threat to outdoor LED lighti ng installations.

Indirect Lightning-Induced Surge

When nearby electrical equipment is switched on or o , over-voltage transient surges can occur in AC power lines. Nearby lightning strikes can also generate transient surges in AC power lines **(Figure 1),** especially in outdoor environments.

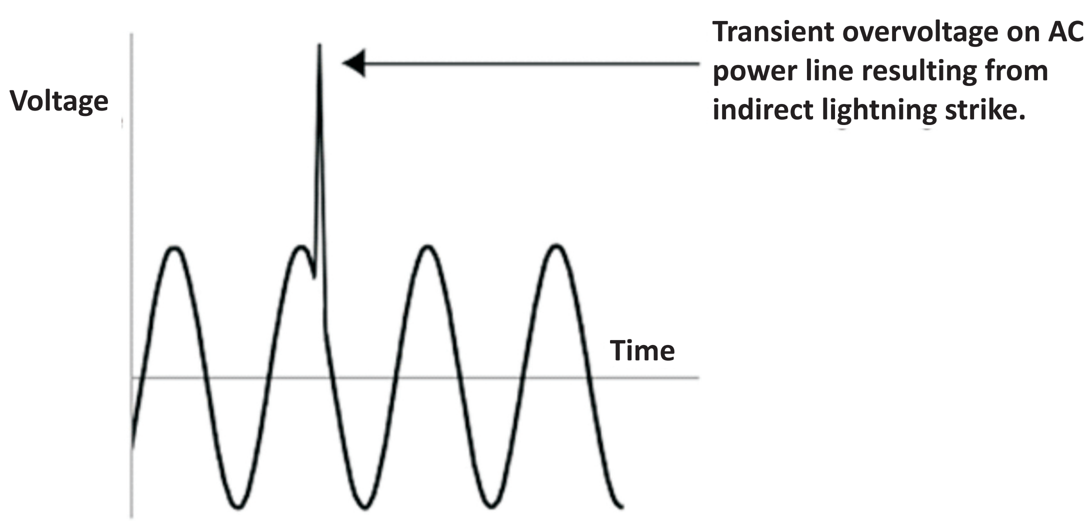


Figure 1. Transient over-voltage on an AC power line resulting from an indirect lightning strike.

Lightning strikes are electrostatic discharges,which usually travel rom cloud to cloud or cloud to the ground, with magnitudes o millions o volts **(Figure 2)**. Indirect lightning strikes, even those that occur several miles away, can induce magnetic ields that generate surges o thousands o volts through current-carrying copper wires, such as the overhead and underground cables that power electronic equipments. These indirect strikes, which produce levels o energy with magnitudes greater than $1000A^2s$, can be characterized with speci ic wave orms.

Indirect Lightning-Induced Surge (continued)

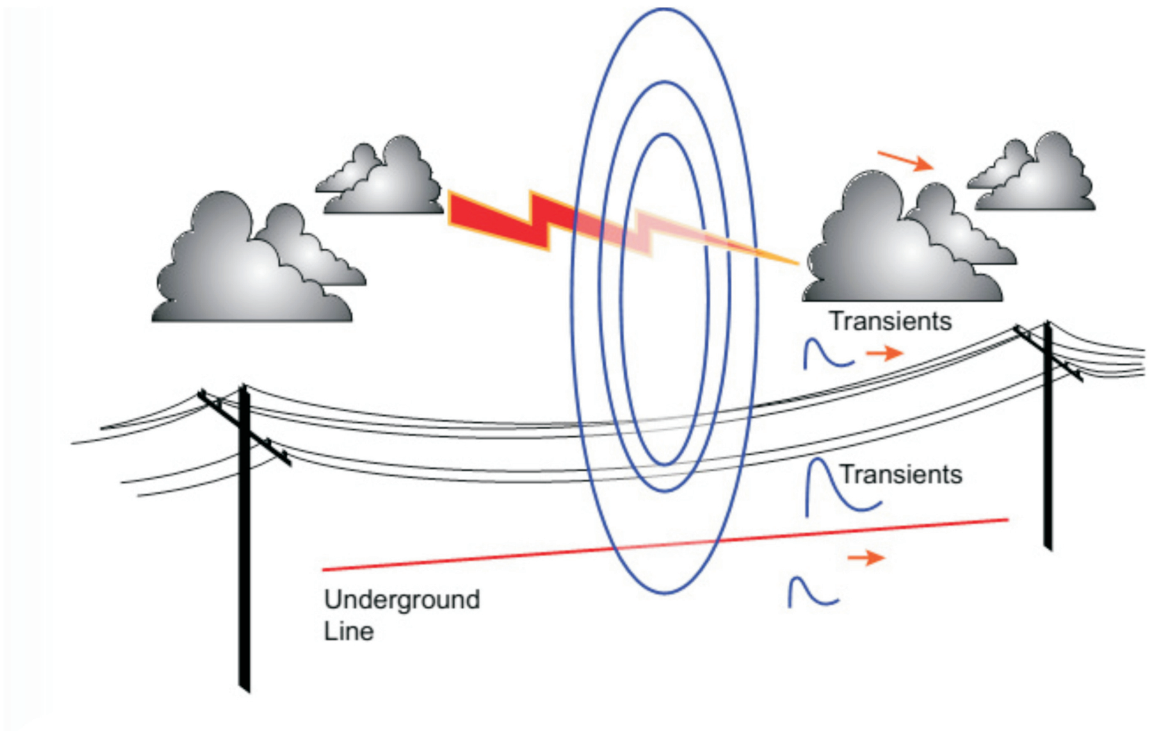


Figure 2. Indirect lightning strike can induce magnetic field in overhead and underground power lines that produce over-voltage transient surges.

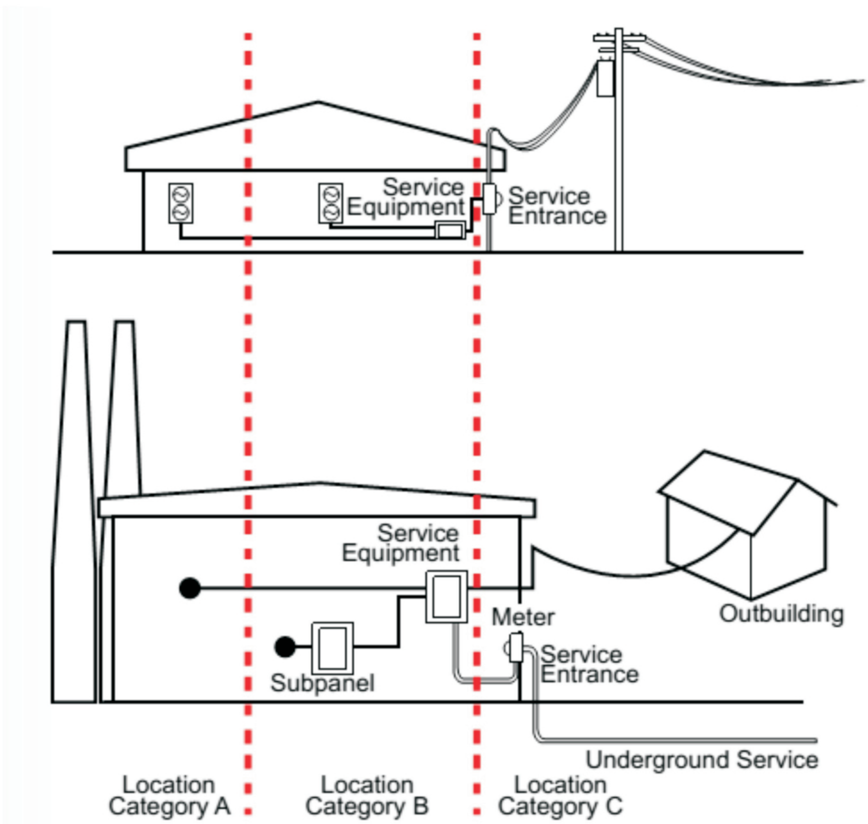
The surges produced by electrical storms can adversely a ect outdoor LED lighting installati ons. The luminaire (the combination o a module or a light engine with control gear to orm a ligh ting system) is susceptible to damage both in di erential and common modes:

- **Differential Mode**– High voltage/current transients between the Line-Neutral (L-N) or Line-Line (L-L) terminals o the luminaire could damage components in the power supply unit or LED modules board.

- **Common Mode**– High voltage/current transients between the L-G (earth) or N-G (earth) terminals o the luminaire could damage sa ety insulation in the power supply unit or LED module board, including the LED to heat sink insulation.

Based on site surveys and statistics on years o lightning strike data the IEEE (Institute o Electrical and Electronics Engineers) recommends test criteria or induced surge wave orms and energy levels or indoor/outdoor locations. The IEEE recommendations were then re erred to by ANSI (the American National Standards Institute) and the DOE (Department o Energy) when testing standards were established.

Indirect Lightning-Induced Surge (continued)



Category A: Parts of t e installation at some distance from t e service entrance

Category B: Between Category A and Category C

Category C: External part of structure, extending some distance into t e building

Figure 3. Location categories defined by IEEE standards for surge environments.

The DOE speci ication details per ormance and surge suppression requirements as shown in **Table 1** or two levels, Location Category C Low and C High.

Table 1. 1.2/55µs - 8/20µs Comb nat on Wave Spec f cat on

Parameter	Test Level / Conf gurat on
1.2/50µs Open C rcu t Voltage Peak	Low: 6 kV. H gh: 10kV*
8/20µs Short C rcu t Current Peak	Low: 3 kA. H gh: 10kA
Coupl ng Modes	L1 to PE, L2 to PE, L1 to L2
Polar ty and Phase Angle	Pos t ve at 90° and Negat ve at 270°
Test Str kes	5 for each Coupl ng Mode and Polar ty/Phase Angle comb nat on
T me Between Str kes	1 m nute
Total Number of Str kes	= 5 str kes x 3 coupl ng modes x 2 polar ty/phase angles = 3 totals str kes

* Th s s a MINIMUM requ rement. Note that for most comb nat on wave generators, wh ch have a source mpedance of 2Ω, the generator charg ng voltage w ll need to be ra sed above the spec f ed level (to somewhere n the v c n ty of 20kV) to obta n the spec f ed current peak.

Indirect Lightning-Induced Surge (continued)

The DOE test wave orm used to evaluate surge immunity o luminaires used in outdoor lighting **(Figure 4)** is a combination 1.2x50µs open circuit voltage and 8x20µs short circuit current wave orm.
To per orm this test, the speci ied peak current is calibrated on the surge generator by shorting the output to ground prior to connection to the luminaire.

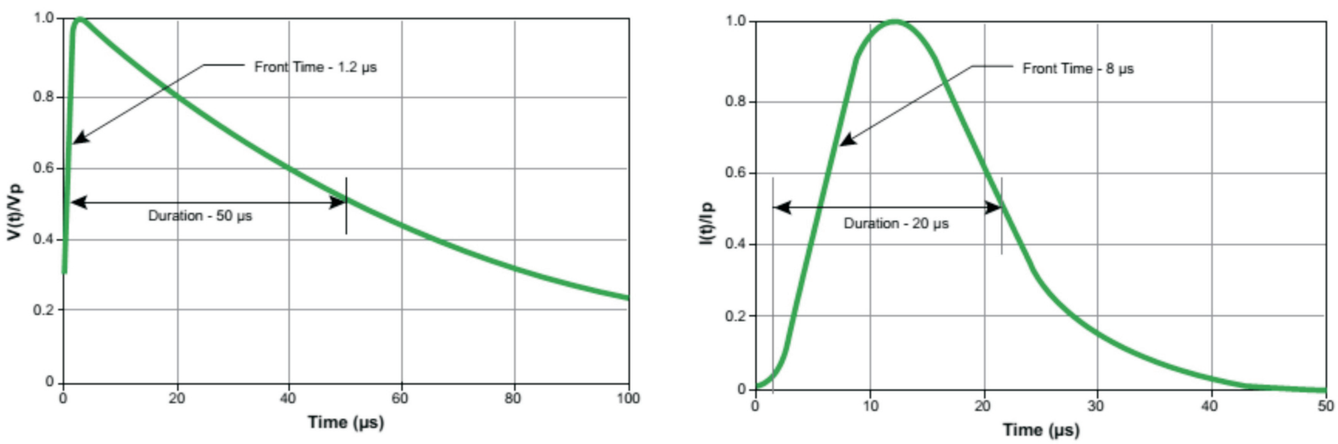


Figure 4. Open-circuit voltage and short-circuit current waveforms to represent transient surges on an AC power line. Vp and Ip represent the peak voltage and current, respectively.

Incorporating a robust surge suppression circuit in an outdoor LED luminaire can eliminate damage caused by surge energy, enhancing reliability, minimizing maintenance, and extending the use ul li e o the lighting installation **(Figure 5)** . A surge protection subassembly that can suppress excessive surge to lower voltage levels is an optimal way to protect the LED luminaire investment.

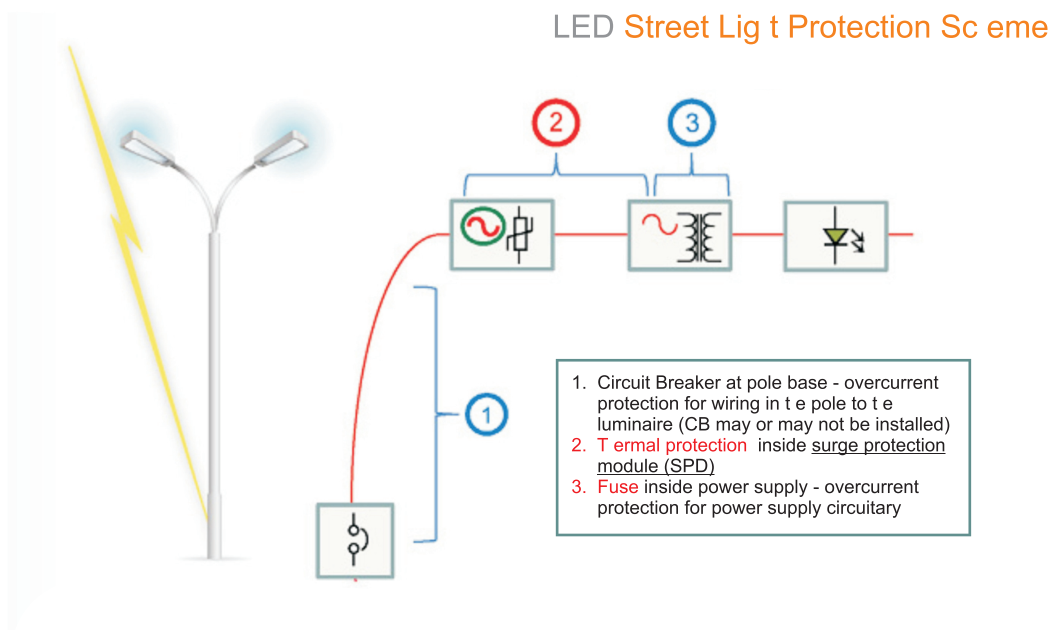


Figure 5. LED street light protection scheme.

Modular Solution vs. a Solution Embedded and Thermally Protected MOV for SPD Safety

Modular Solution vs. a Solution Embedded into the Power Supply Unit

Outdoor luminaires are easily a ected by transient surges inductively coupled into pow er lines rom lightning strikes. IEEE C62.41.2™-2002 categorizes two di erent exposure levels or outdoor locations (Ca tegory C Low and C High) with di erent suggested surge levels.

Similarly, some regions or countries may have di erent surge level requirements due to di erent lightning strike density in the area. Although some LED luminaires eature surge protection devices embedded in the power supply unit, **NPSPL** recommends that the surge protection circuit be provided as an independent module that's separate rom the luminaire power supply; in this way, the same luminaire can be easily marketed globally by attaching di erent surge protection modules to meet di ering surge le vel requirements.

MOVs are widely used in surge protection circuits or their ast response times, high su rge energy handling, compact size, and cost-e ectiveness. However, a ter MOVs absorb a certain numb er o surge strikes, they will begin to degrade and can no longer provide the same protection as new ones. Having a separate surge protection module allows or easy replacement when the original module reaches its end o li e.

Thermally Protected MOV for SPD Safety

MOVs tend to degrade gradually a ter a large surge or multiple small surges. This degradation leads to increasing MOV leakage current ; in turn, this raises the MOV's temperature, even under normal conditions like 120Vac/240Vac operating voltage. A thermal disconnect adjacent to the MOV **(Figure 6)** can be used to sense the increase in MOV temperature while it continues to degrade to its end-o -li e condition; at this point, the thermal disconnect will open the circuit, remo ving the degraded MOV rom the circuit and preventing it rom ailing catastrophically.

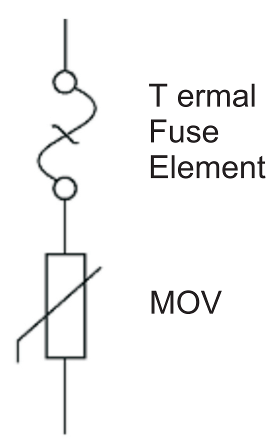


Figure 6. A thermal disconnect can open the circuit, preventing a catastrophic failure of a degraded MOV.

Modular Solution vs. a Solution Embedded and Thermally Protected MOV for SPD Safety

MOVs are designed to clamp ast over-voltage transients within microseconds. However, in addition to short duration transients, MOVs inside SPD modules can experience temporary over-voltage conditions caused by loss o neutral or by incorrect wiring during installation **(Figure 7)**. These conditions can severely stress an MOV, causing it to go into thermal runaway; in turn, this will result in overheating, smoke and the potential or ire. UL 1449 and IEC 61643-11, the sa ety standards or SPDs, de ine speci i c abnormal conditions under which devices must be tested to ensure SPD sa ety. Robust SPD module designs include thermal disconnects to protect the MOVs rom thermal runaway.

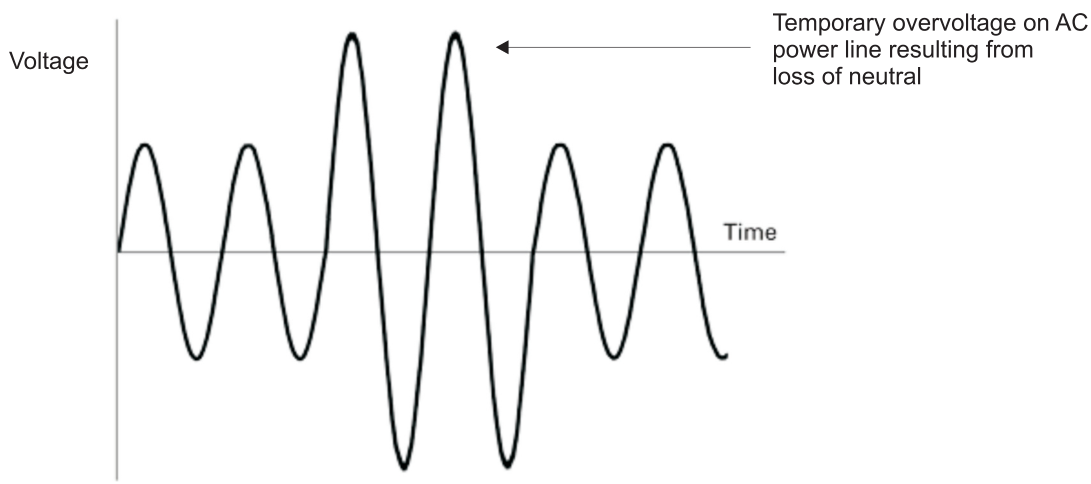


Figure 7. Temporary over-voltage conditions can severely stress MOVs,leading to thermal runway

End-of-Life/ReplacementRIndication for SPDs

When an MOV becomes overheated due to temporary over-voltage or excessive leakage current, a thermal disconnect may be used to help remove it rom the AC circuit. However, with the MOV removed rom the circuit ,the SPD module no longer provides surge suppression. There ore, it's important to supply proper indication so that maintenance personnel will know the SPD is not working and requires replacement.

Luminaire designers can choose rom two main types o SPD module con igurations based on their maintenance and warranty strategies. Those are parallel- and series-connected surge protection subassemblies.

- **Parallel Connection** – The SPD module is connected in parallel with the load. An SPD module that has reached end-o -li e is disconnected rom the power source while leaving the AC/DC power supply unit energized. The lighting still remains operational, but the protection against the next surge to which the power supply unit and LED module are exposed is lost. In a parallel-connected SPD module, Green LED indication is used to indicate the SPD module status to the maintenance technician. A Green LED indicating an online SPD Module.

- **Series Connection** – The SPD module is connected in series with the load, where the end-o -li e SPD module is disconnected rom the power source which turns the light o . The loss o power to the luminaire serves as indication or maintainance call. The disconnected SPD module not only turns the lighting o to indicate the need or replacement but also isolate the AC/DC power supply unit rom uture surge strikes. General pre erence or this con iguration is growing rapidly because the luminaire investment remains protected while the SPD module is awaiting replacement. It's ar less expensive to replace a series-connected SPD module than the whole luminaire as in the case o a parallel-connected SPD module.

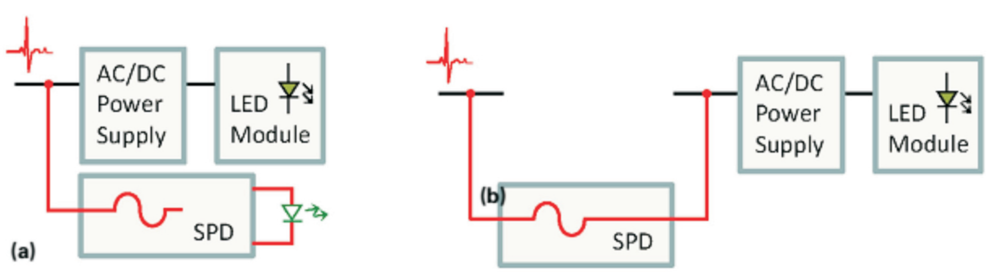


Figure 8. An SPD module that's parallel-connected to a luminaire (a) and an SPD module that's series-connected to a luminaire (b).

Table 2. Absolute Maximum ating

	SPD05	SPD10	Units
Continuous:			
AC Voltage Range (VM(AC)RMS)	320 to 510	320 to 510	V
Continuous Current (or Series Connection only)	5	5	A
Transient:			
Maximum Discharge Current 8/20µs Wave orm (Imax)	10,000	20,000	A
Nominal Discharge Current 8/20µs Wave orm (In)	5,000	10,000	A
Operating Ambient Temperature Range (TA)	-45 to +85	-45 to +85	°C
Storage Temperature Range (TSTG)	-45 to +110	-45 to +110	°C
Isolation Voltage Capability (When the thermal disconnect opens)	600	600	V
Insulation Resistance	>1,000	>1,000	MΩ

Table 3. SPD05 Device ating & Specifications

Model Number	Nom nal Operat ng Voltage (VAC) / Un	MCOV (VAC)[6]	Max mum D scharge Current (Imax)(A)[2]	Nom nal D scharge Current (In)(A)[2]	Ures (V)[4]	Up (V)[5]
SPD05-1P240L	240	320	10,000	5,000	L-N : 1200 L-G : 1200 N-G: 1200	1500 1500 1500
SPD05-1P240H	240	460	10,000	5,000	L-N : 1940 L-G : 1200 N-G: 1200	2000 1500 1500
SPD05-1P240U	240	510	10,000	5,000	L-N : 2020 L-G : 1200 N-G: 1200	2100 1500 1500

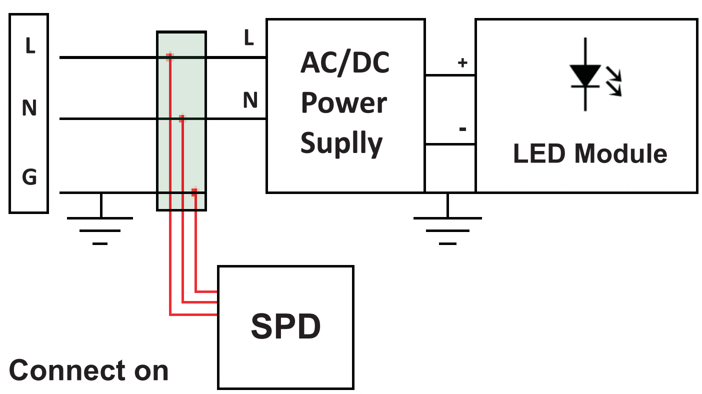
Table 4. SPD10 Device ating & Specifications

Model Number	Nom nal Operat ng Voltage (VAC) / Un	MCOV (VAC)[6]	Max mum D scharge Current (Imax)(A)[2]	Nom nal D scharge Current (In)(A)[2]	Ures (V)[4]	Up (V)[5]
SPD10-1P240L	240	320	20,000	10,000	L-N : 1200 L-G : 1200 N-G: 1200	1500 1500 1500
SPD10-1P240H	240	460	20,000	10,000	L-N : 1940 L-G : 1200 N-G: 1200	2000 1500 1500
SPD10-1P240U	240	510	20,000	10,000	L-N : 2020 L-G : 1200 N-G: 1200	2100 1500 1500

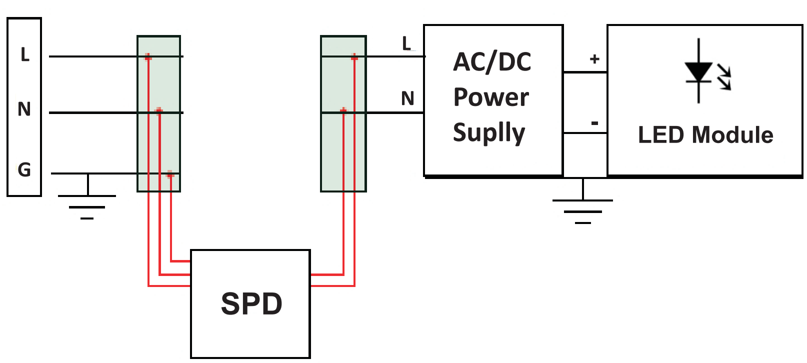
Note:

1. Nominal Discharge Current (In)(A) : The nominal discharge current is a measure o the SPDs endurance capability; 15 impulses o discharge current uses the 8/20uS current wave orm.
2. Maximum Discharge Current (Imax)(A) : The maximum discharge current is a measure o the SPDs maximum capability; Single impulse o discharge current uses the 8/20uS current wave orm. All Devices pass maximum discharge current with possible, sa e opening o thermal disconnect.
3. Residual Voltage Vres: UL1449 Measured limiting voltage; the highest value o residual voltage measurement during the application o impulses o 8/20uS nominal discharge current (In); an average voltage value o 15 impulses.
4. Voltage Protection Level Up: IEC61643-11 Voltage protection level; the highest value o residual voltage measurement during the application o impulses o 8/20uS nominal discharge current (In); a rounding voltage value o maximum measurement.
5. Maximum Continuous Operating Voltage Uc: Maximum r.m.s. voltage that could be continuously applied to the SPD.
6. 5A max. continuous current or series connection.
7. Speci ications are subject to change without prior notice due to constant improvement in design & technology.

ApplicationiSchematic

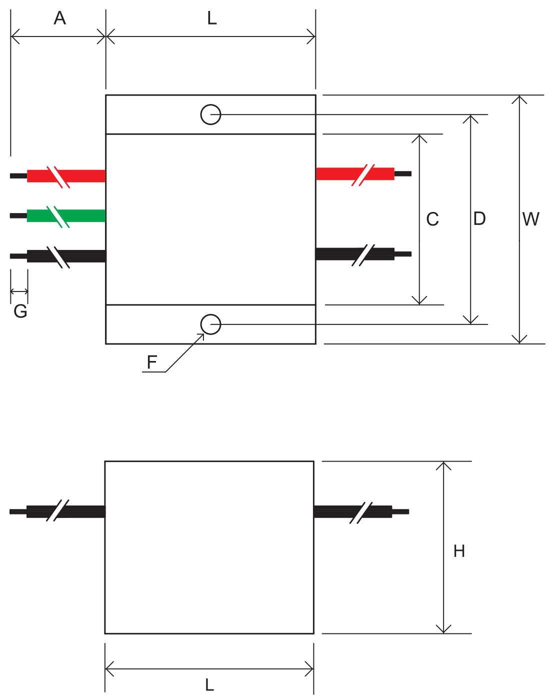


(a) Parallel Connect on

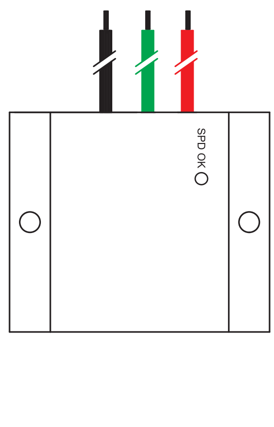


(b) Ser es Connect on

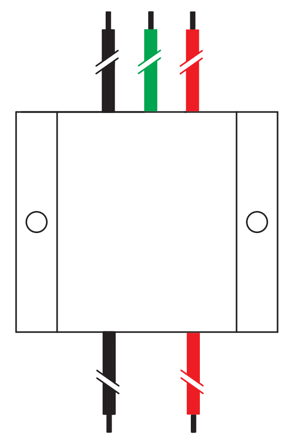
Dimensions



DIMENSIONS (mm)		
	For SPD05 Series	For SPD10 Series
L	44 ± 1.5	54 ± 1.5
W	54 ± 1.5	59 ± 1.5
H	36 ± 1.0	45 ± 1.0
D	46 ± 0.5	51 ± 0.5
A	100 ± 20	100 ± 20
C	38 ± 1.5	43 ± 1.5
F	ø 4 ± 0.2 x 2nos.	ø 4 ± 0.2 x 2nos.
G	6 ± 2.0	6 ± 2.0



(a) SPD Parallel



(b) SPD Series

PartiNumberingisystem

SPD 05 - 1P 240 L P

DeviceiFamily
Surge Protection Device

NominaliDischarge Currenti(In)

1Øii: 1P
3Øii: 3P

NominaliOperatingiVoltagei(VAC)

Max.iContinuousiOperatingiVoltage betweeniL -iNi(Uc)
L - 320Vac
H - 460Vac
U - 510Vac

P : Parallel Connection
Sii: Series connection