AC & DC Surge Protection in Industrial Solar Applications (Grid Tied Solar Farms)

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Introduction

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Items for Discussion

- Grid Tied Solar Farm
- Threats
- Risks
- Regulatory
- Use of SPDs
- Box Concept
- Real world examples of damage
- SPD Technology
- Future Trends

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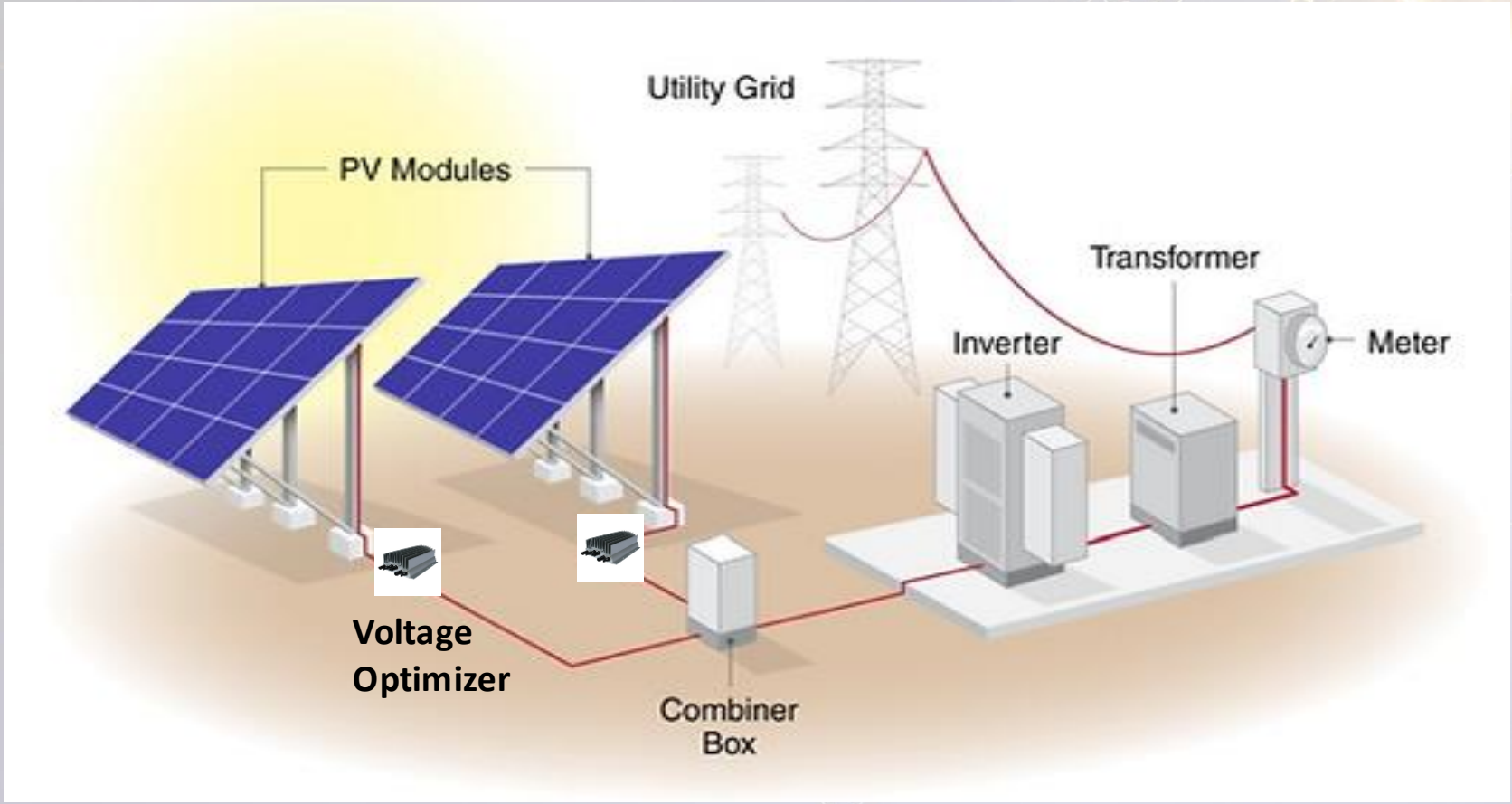
Basic Grid Tied Solar Farm Layout



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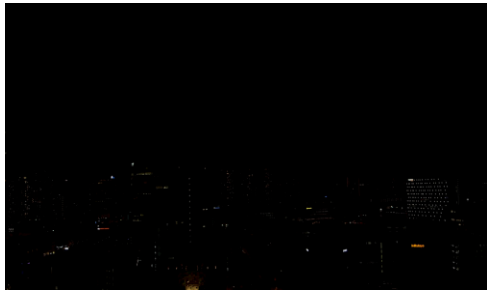
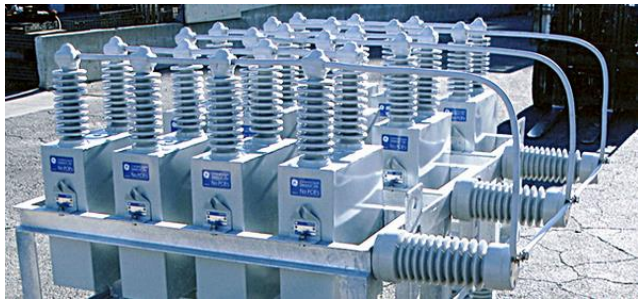
Threats to the PV Installations

- **Lightning**
  - Direct
  - Indirect
  - 20-40kA avg
  - 100kA-2% probability
- **Switching**
  - Internal
    - Motors
    - Switching loads
  - External
    - Utility Switching
- **TOV-Temporary Over Voltage**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RISKS to the PV Installation

HOW DO WE RECOGNIZE SURGES?

Catastrophic

Destruction

Immediate failure to a device due to a high level of energy from a surge.

Silent Killers

Disruption

surges can enter data lines through inductive coupling which can result in corrupt data processing.

Degradation

Repeated stress can cause component degradation and shorten the lifespan of equipment.

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Definitions

- **Surge or Transient**
  an event caused by either nature or man that produces a **very fast** (measured in microseconds) electrical impulse on to a conductive material delivering up to 200,000 amps.

- **Surge Protective Component (SPC)**
  protection component used within an SPD such an MOV, GDT or SAD.

- **Surge Protective Device (SPD)**
  made up of a surge protective component(s) (SPC), thermal protector, status indicator, housing and connection mechanism.

- **Unintended Surge Protective Component (SPC)**
  In the absence of an SPC, it is the first component that fails during a surge or transient event.
  e.g. fuse, circuit breaker, trace, resistor, capacitor, optocoupler, relay, microprocessor chip, diode.

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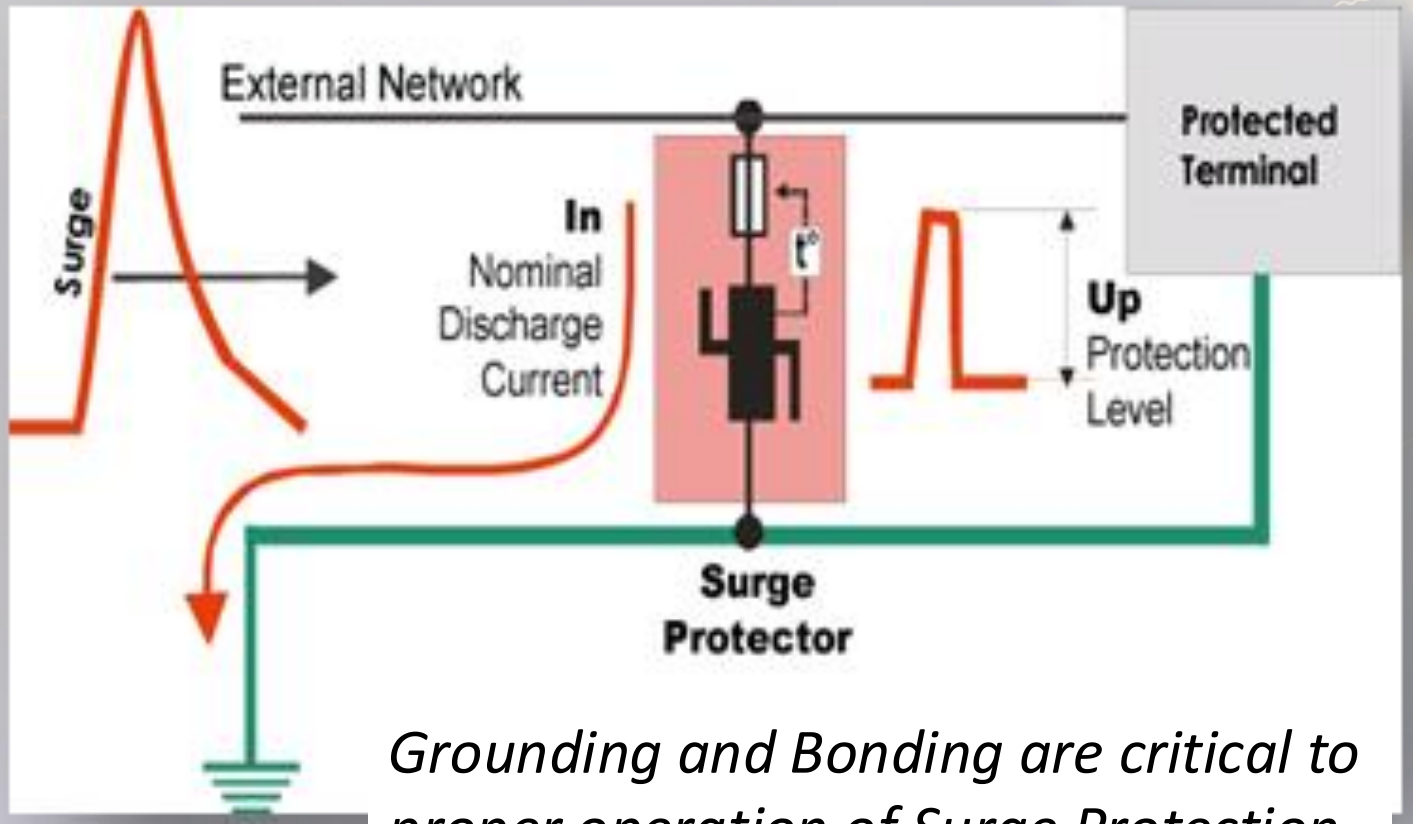
Surge Protective Device



Grounding and Bonding are critical to proper operation of Surge Protection Devices (SPD)

Current Sharing

- 90/10 Split between SPD & Equipment
- 10,000 Amp Surge
- 9,000A to SPD
- 1,000A to Equipment

Equipment and Equipment SPC must be able to handle surge remnant

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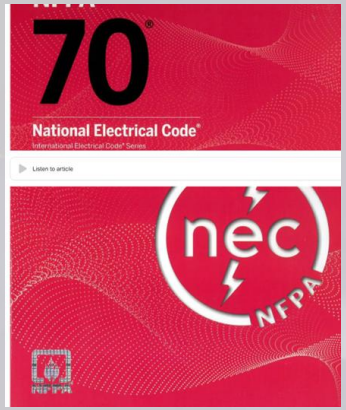
Regulatory Considerations



Article 690-Solar Photovoltaic (PV) Systems
Article 691- Large-Scale Photovoltaic (PV) Electric Supply Stations

UL Standard

UL1741-Inverters, Controllers and Interconnect Systems, Combiner box

UL1449 5th-SPD

IEC International Electrotechnical Commission

IEC61643-32:2017-PV-SPD Application Standard

IEC60364-7-712:2017-PV Application Standard

NEMA

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Multi-million-dollar investments are at RISK

- ✓ 100s of Panels, Optimizers, Inverters
- ✓ One FPL installation has 300 combiners alone

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Examples of Damage

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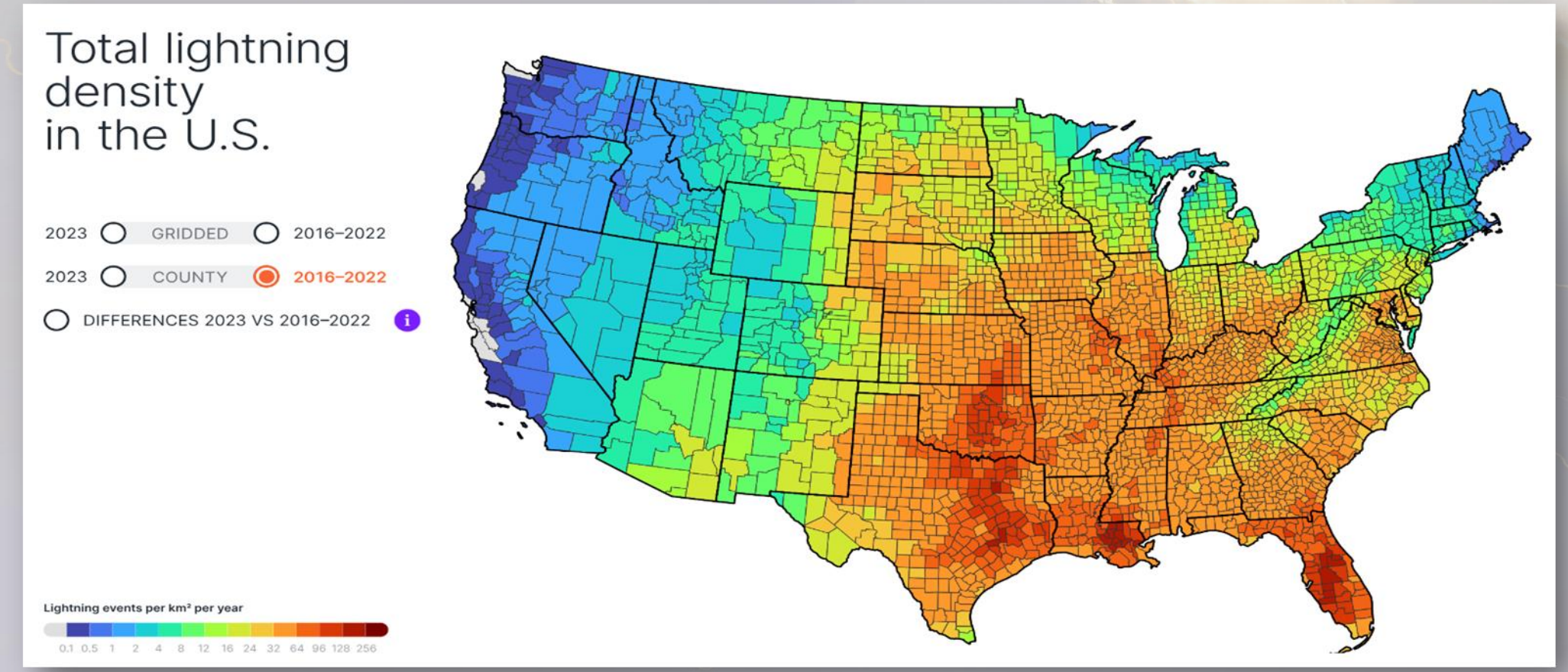
Simplified Risk Analysis



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Simplified Risk Analysis

IEC 60364-7-712

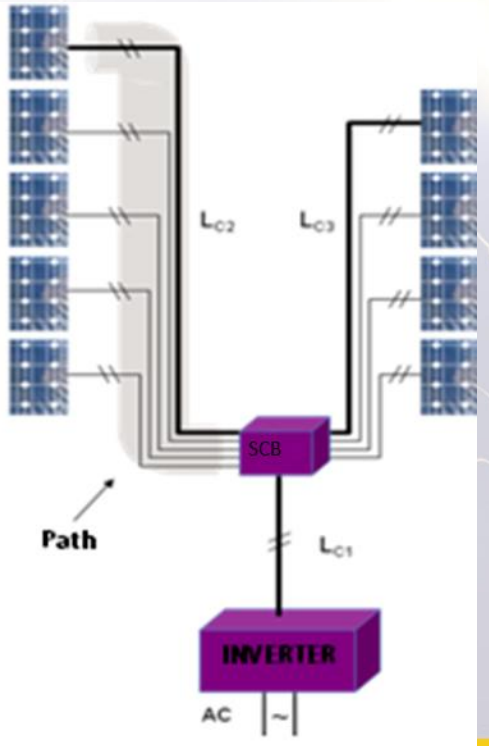
The need of SPDs on the DC side can be evaluated by calculation, using 3 criteria:

- Type of installation (PV power)
- Lightning density (Ng) of the location (flashes/km²/year)
- Length (L) of the PV grid

If length $L \geq L_{crit}$ => SPD Mandatory

	PV on domestic house	PV on business or Industrial building	PV on building equipped with LPS	PV Plant (Free field)
	Case A	Case B	Case C	Case D
Lenght (m)	115/Ng	450/Ng	*Surge protector always mandatory*	200/Ng

Length to be considered
L = LC1 + LC2 + LC3



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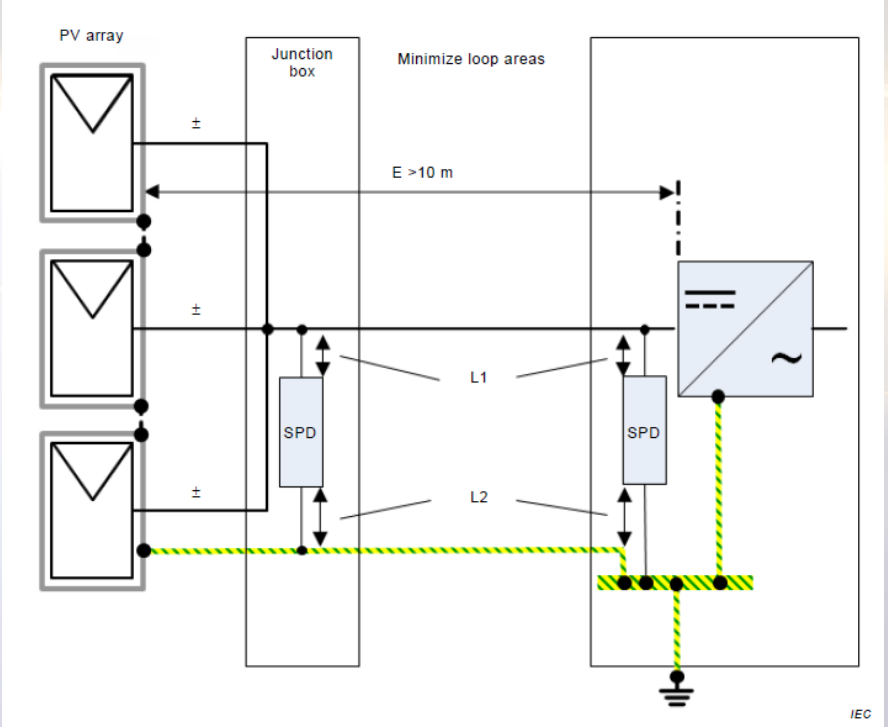
IEC 61643-32
Installation and Location of SPDs

10M RULE

➔On DC Network :

- SPD must be used at the entrance of the inverter
- Additional SPD close-by the PV modules, if they are located more than 10 m away from the inverter.



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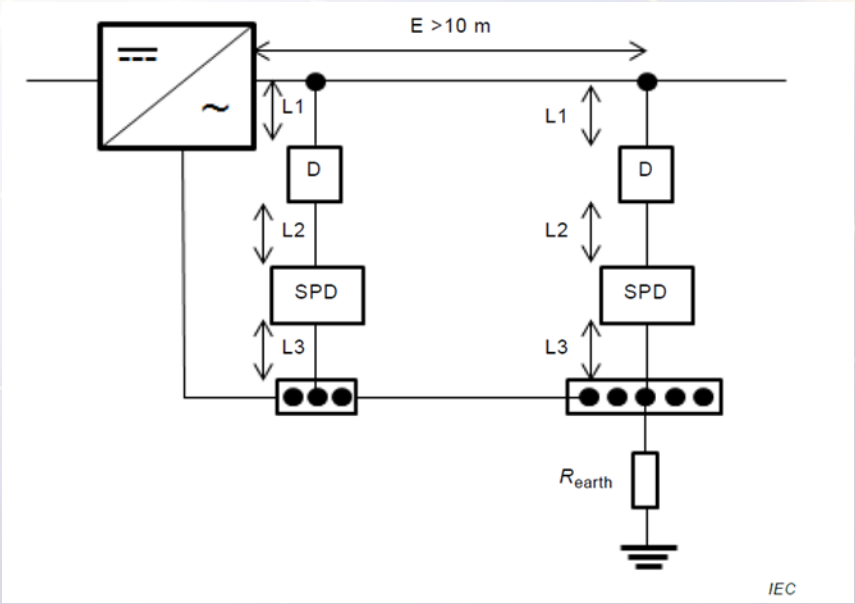
IEC 61643-32
Installation and Location of SPDs

10M RULE

On AC Network :

- SPD must be used at the entrance of the installation
- Additional SPD close-by the inverter ➔ **if they are located more thank 10 m away from the installation**



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Box Concept-Examine each element of the PV System

SOLAR PANELS, SOLAR TRACKERS & VOLTAGE OPTIMIZERS

>10

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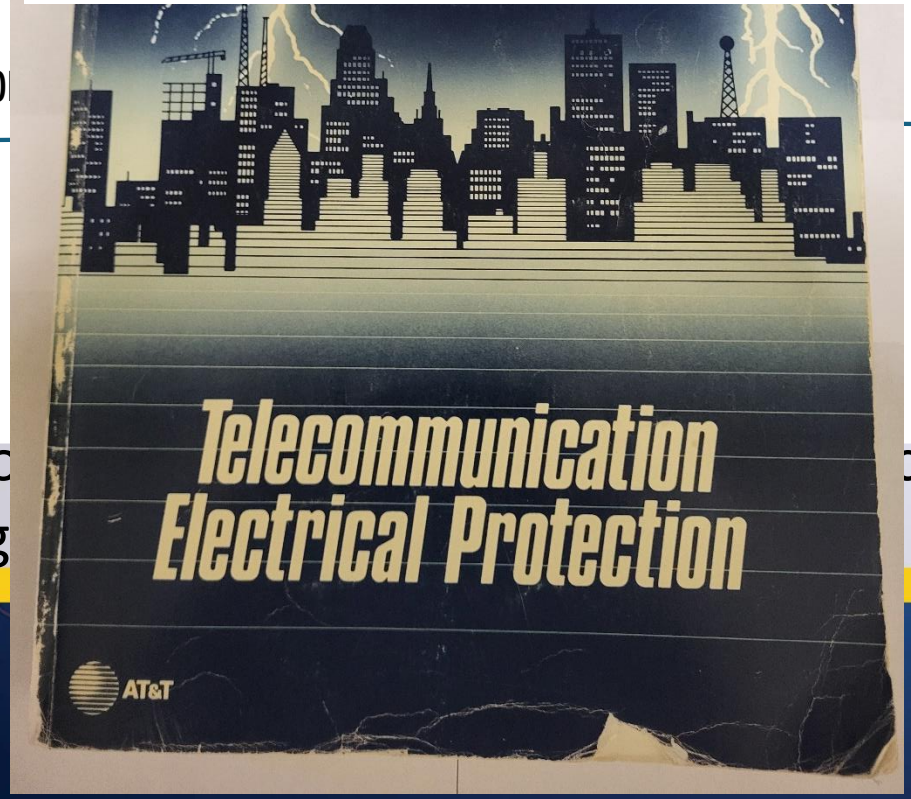
Authored by Ed Carter



AC COMBINER BOX

>10M

>10M

TRANSFORMER

Evaluate all copper pc cluding RF) coming into/out of the BOX and provide Surg

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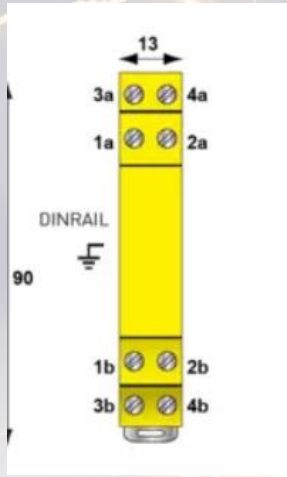
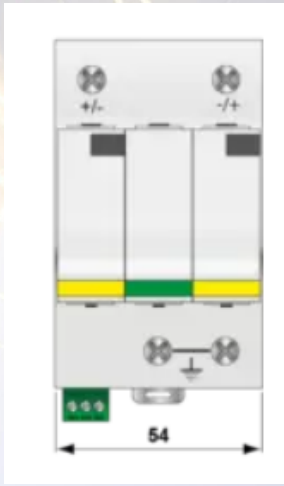
Combiner Box

RS485/Ethernet



DC SPD



1500VDC

1500VDC

- ✓ (1)-SPD-Din Rail
- ✓ UL1449 5th PV DC, Type 1
- ✓ MCOV-1500VDC
- ✓ SCCR-100kA
- ✓ In-20kA
- ✓ Imax-40kA
- ✓ MOV or MOV/GDT

Intelligent detection instrument, data detection feedback

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Combiner Box Failures

- ❑ Failures due to Overcurrent faults
  - Inverter failures
  - Mis-matched PV modules
  - Environmental changes
- ❑ Failures due to Overvoltage faults
  - Lightning
  - Grid fluctuations (TOV)
  - Faulty voltage optimizer
- ❑ Failures due to water ingress
  - Reduction in creepage and clearance (arc)
- ❑ Failures due to maintenance issues
  - Loose connections-(arc)

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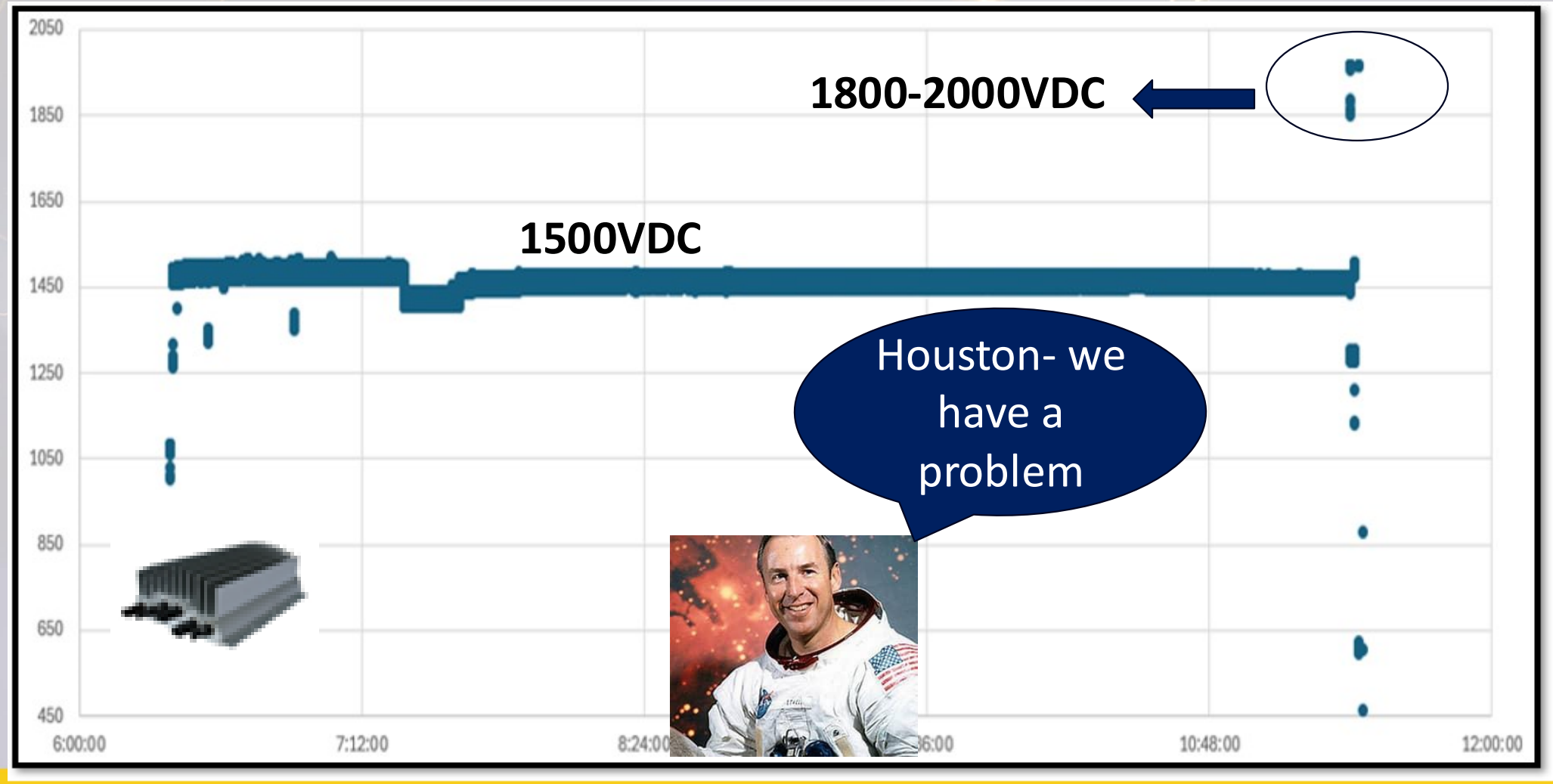
OPTIMIZER OUTPUT Example-Abnormal



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Combiner Box Catastrophic Failure

ROOT CAUSE: Upstream Voltage Optimizer malfunction. No determination of what failed in the Combiner Box

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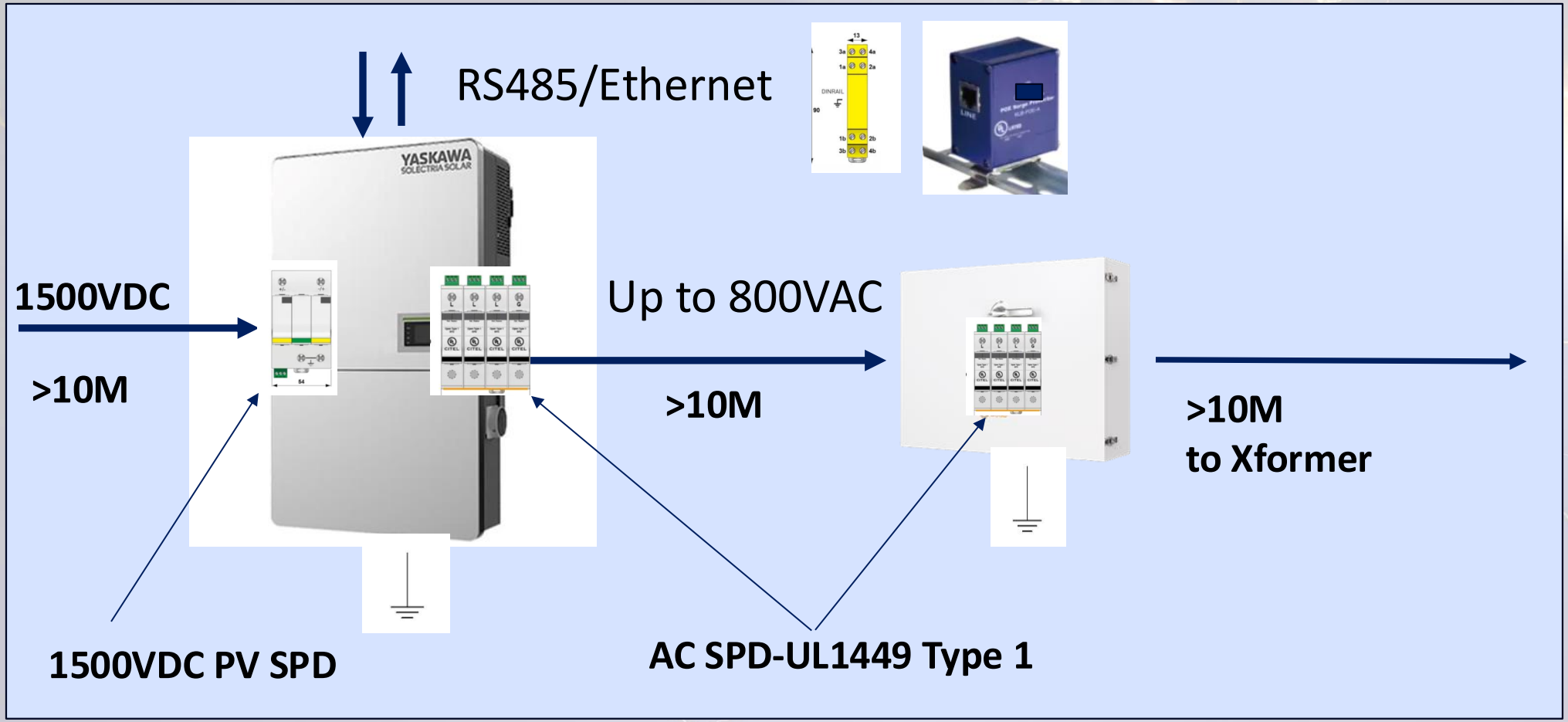
Inverter & AC Combiner



Causes of Inverter Failures

- ✓ **Inverter Grid Faults-** Unstable Grid, TOV, Switching Transients, Lightning
- ✓ **Ventilation**
- ✓ **Humidity**
- ✓ **MPPT Failure-** Max Power Point Tracker- Regulates flow of power from panels
- ✓ **General Maintenance**

Documented cases of RS485 failures on Inverters without Surge Protection installed

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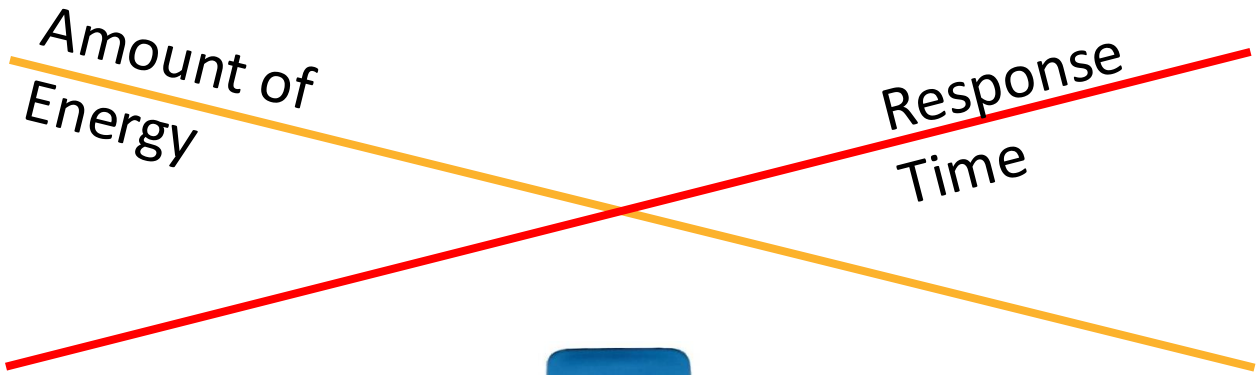
SPD Technology: Energy vs Response Time



GSG

MOV

SAD/TVS

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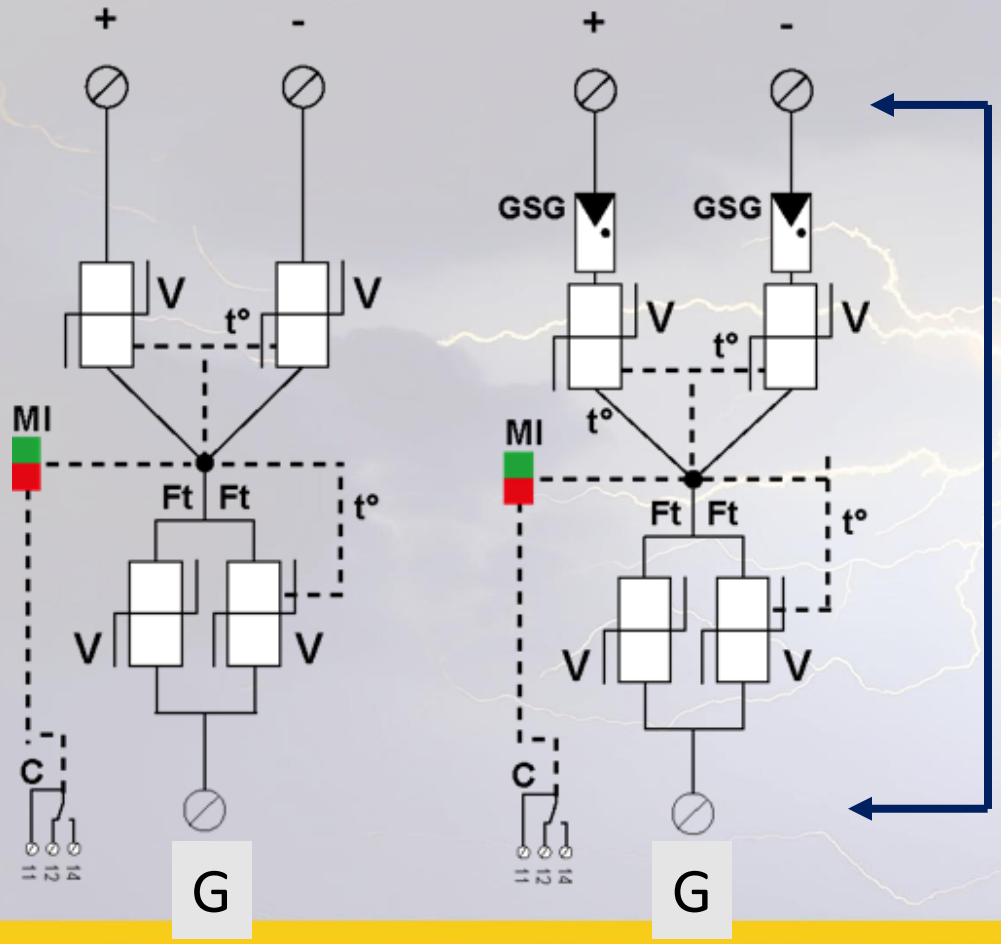
SPD Technology-DC SPD



1500VDC MCOV

- Thermally Protected MOV+MOV in Y configuration
- Thermally Protected MOV/GSG (Gas Tube) in Y configuration

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Hybrid Technology Solution-HV DC Applications

Overview:

- **Combining component technologies will optimize protection**

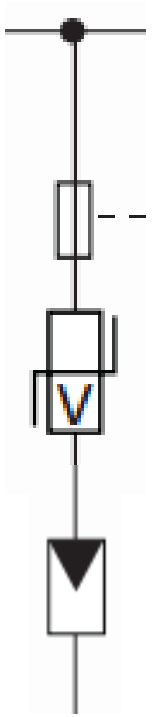
  Example: MOV and GSG/GDT connected in series

  – GSG eliminates the potential leakage current of the MOV

  – In a DC application, the MOV will help extinguish the spark over of the gas tube

  – MOV clamps the initial spike that would normally occur with only a GSG

  – The GSG handles much of the energy and protects the MOV



* Provides added benefits under TOV conditions

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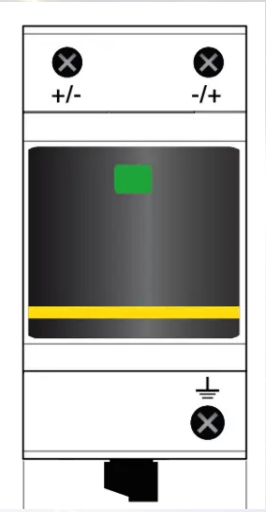
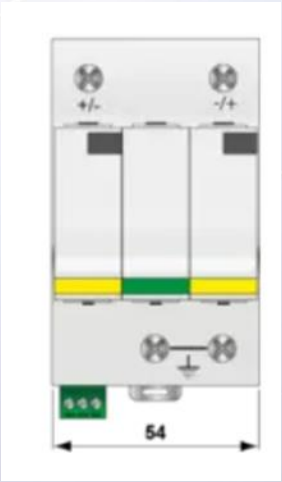
SPD Disconnection Technology

UL1449 5th Ed. DC PV Testing will determine the safety and effectiveness of disconnection in SPDs



MONOBLOCK DESIGNS- Central Thermal Disconnect



INDIVIDUAL PLUGABLE-MODULE DESIGNS

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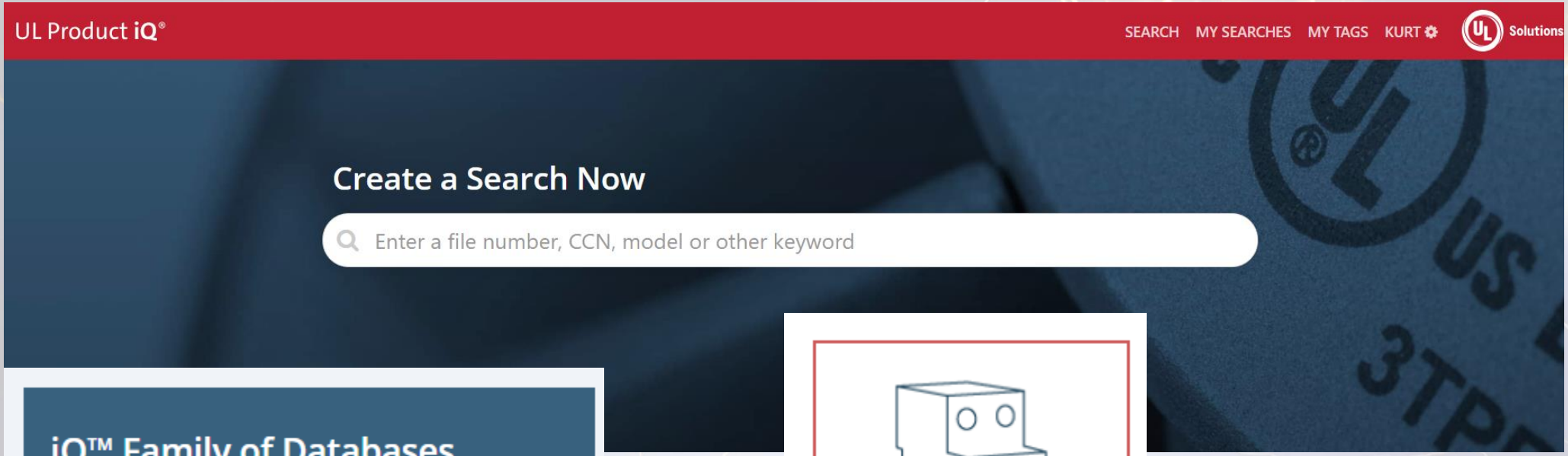
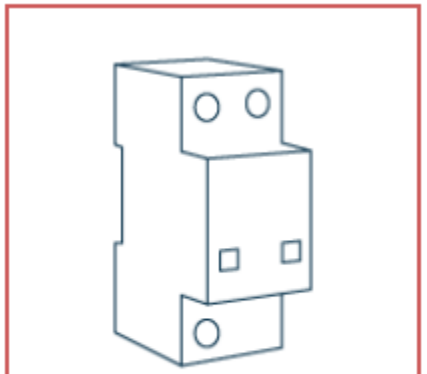
Evaluating SPD Manufacturers



iQ™ Family of Databases

For enhanced search functionality.



SURGE PROTECTIVE DEVICES

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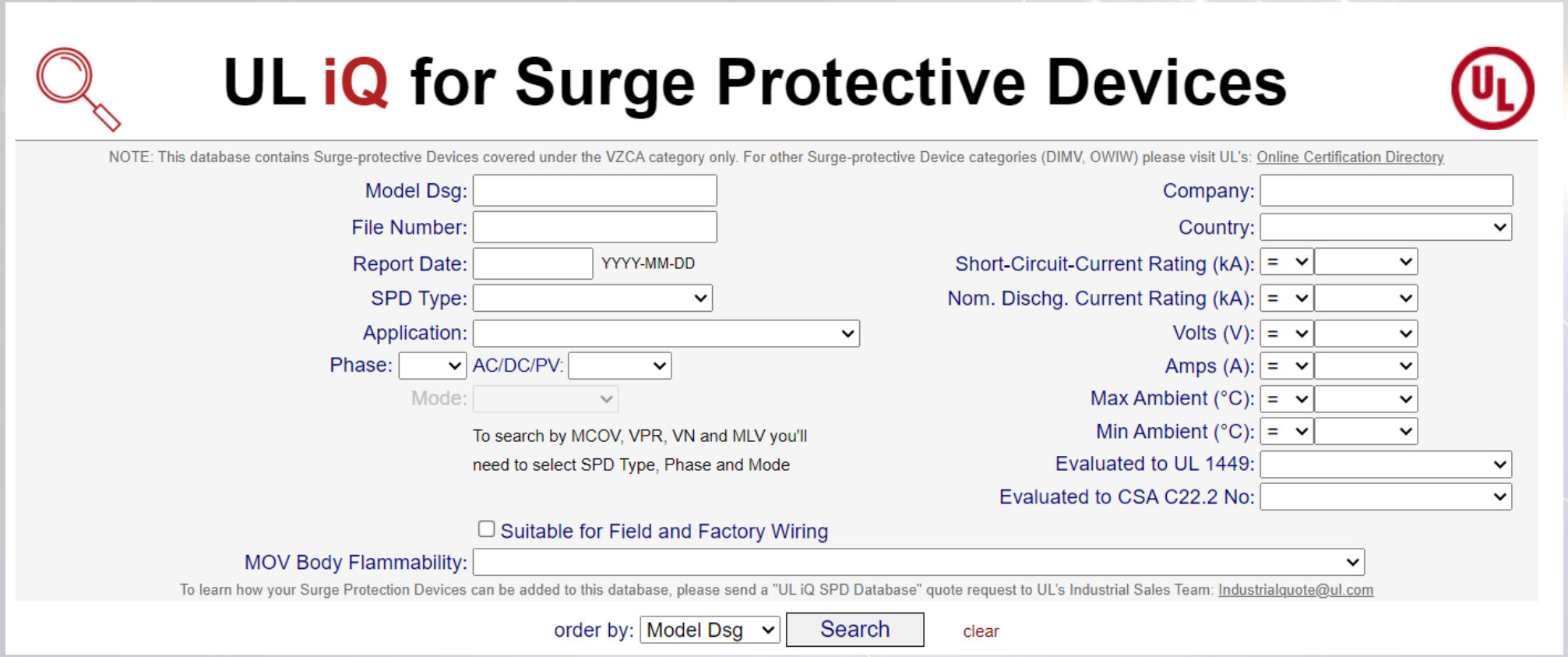
UL iQ Search Function



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UL Certification card for specific SPD and Manufacturer

UL iQ for Surge Protective Devices

Surge Protective Devices

Guide Information

Cat No(s):

SPD Type	Volts (V)	AC/DC DC PV	Phase	Amps (A)	Ambient Min(°C)	Ambient Max(°C)	Mode	VPR (Vpk)	MLV (Vpk)	MCOV (V)	Vn (Vdc)	In (kA)	SCCR (kA)	Notes
1CA	1500	DC PV	-	n/a	-40	85	DC+-DC-	4000	-	1500	-	10	100	1
							DC+-G	4000	-	1500	-			
							DC--G	4000	-	1500	-			

Evaluated to: UL 1449 5th Ed. Rev: 2022-12-15

Note 1 - Suitable for Factory wiring only.

SPDs investigated for Type 1 applications are automatically suitable for Type 2 applications and may be marked for SPD Type 1 and/or Type 2 applications. SPDs only marked "SPD Type 2" are not suitable for Type 1 applications.

Where a minimum ambient temperature is not specified, assume 0°C unless the product is marked otherwise or with an Outdoor use Environmental Rating. See Electrical Equipment for Use in Ordinary Locations (AALZ) for details regarding Environmental Ratings.

Report Date: 2015-04-30
Last Revised: 2024-01-31

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TRENDS: 2000VDC Inverters

NEWS STORY

First-Ever Certification Issued for 2000 VDC PV Module

Jinko Solar's Tiger Neo series photovoltaic module earned certification to UL 61730-1 and UL 61730-2.

RE+ 2024 SPECIAL PRODUCT ANNOUNCEMENT

GE Vernova proudly Introduces the FLEXINVERTER 2kV

In addition to our widely deployed 1.5kV FLEXINVERTER platform, GE Vernova is proud to introduce the brand new FLEXINVERTER 2kV Solar Power Conversion Station at RE+ 2024 in Anaheim, California

UL 1449 5th – SPD
1000VAC/1500VDC

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Thank You-See you in 2026