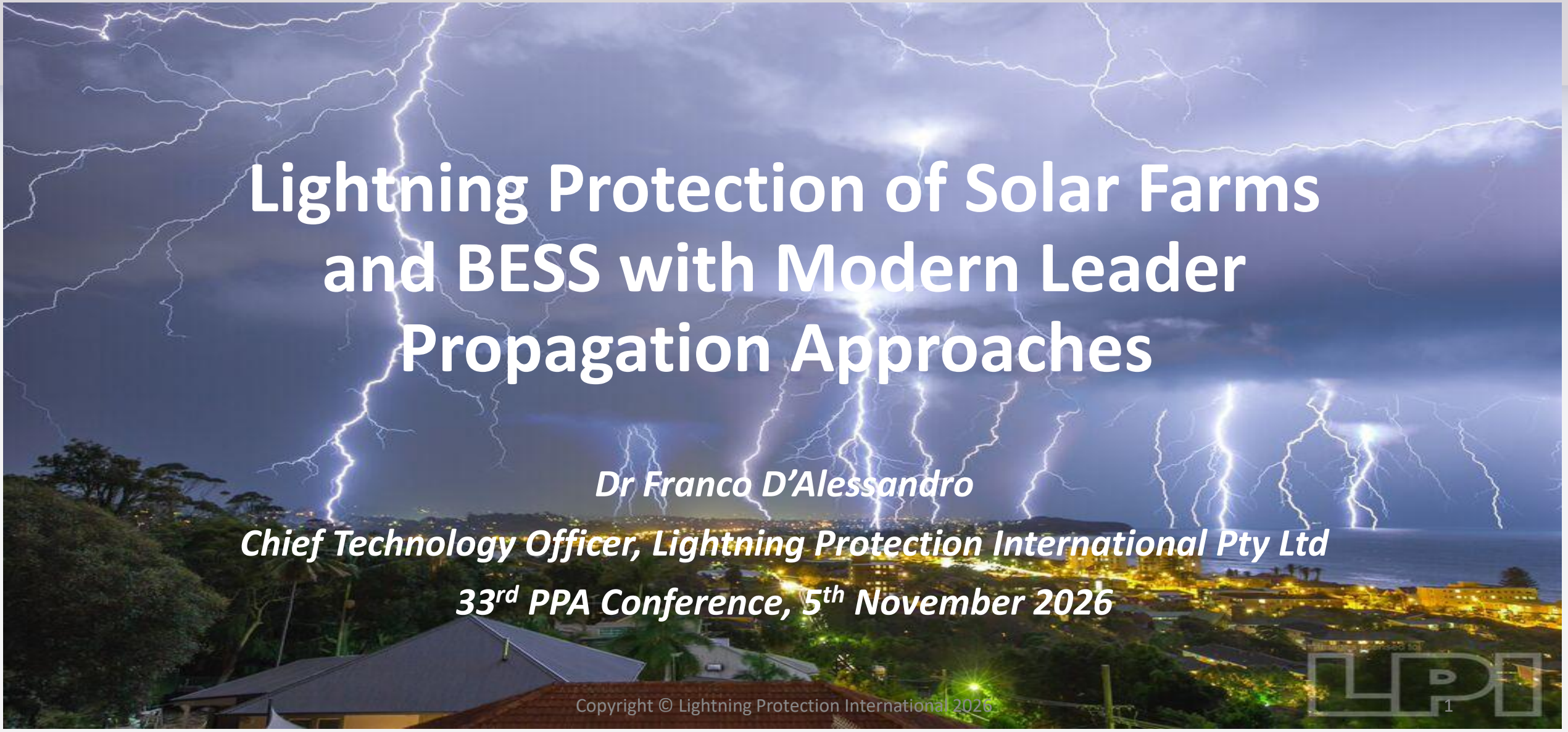


Lightning Protection of Solar Farms and BESS with Modern Leader Propagation Approaches

Dr Franco D'Alessandro

Chief Technology Officer, Lightning Protection International Pty Ltd

33rd PPA Conference, 5th November 2026

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Presentation Overview

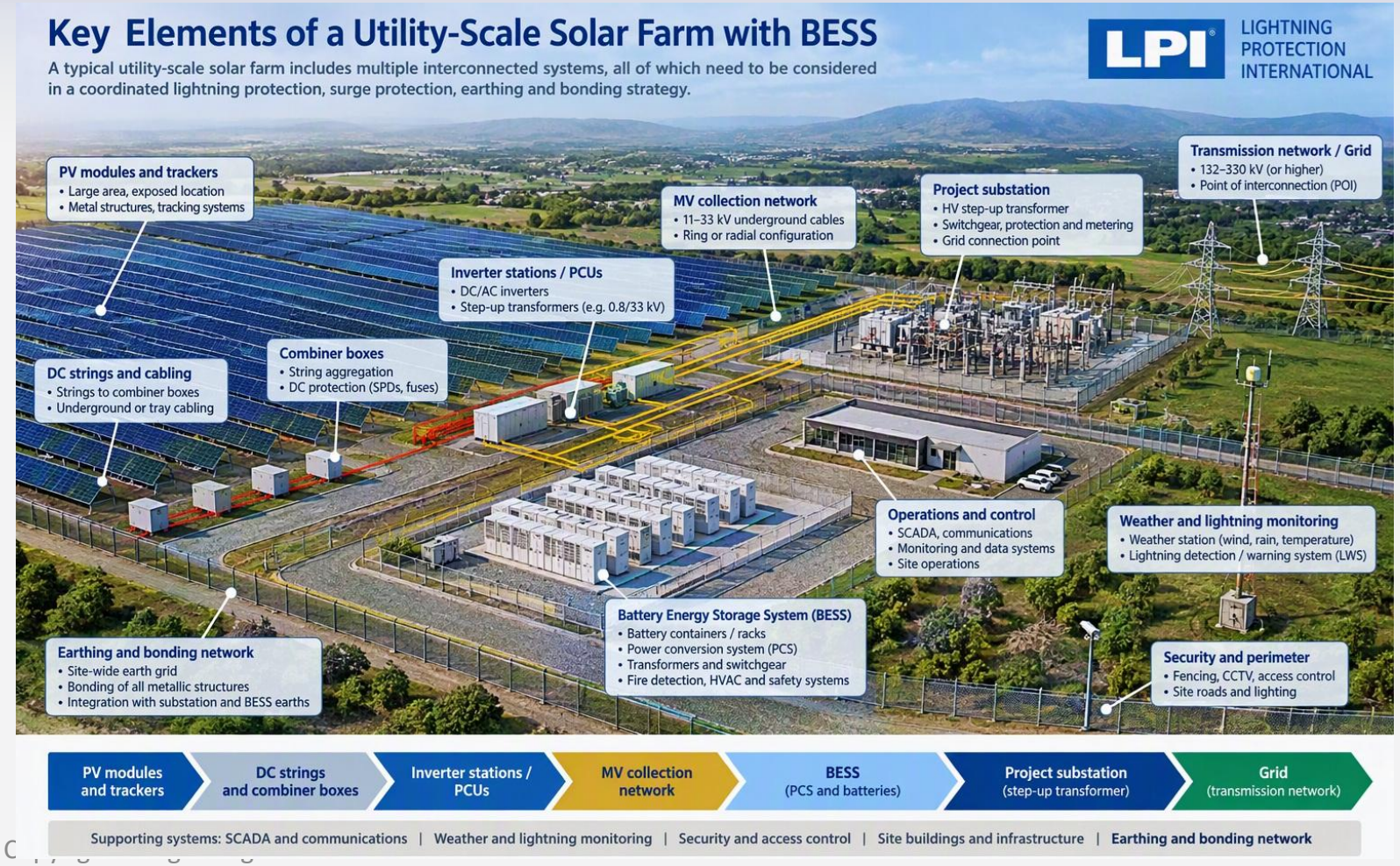
- Why are solar farms challenging ?
- Key elements of lightning protection for solar farms and BESS.
- Lightning risk assessment for solar farms.
- Overview of direct-strike, surge, earthing & bonding, personnel protection for solar farms.
- Direct strike protection – what approaches are used around the world ?
- Rolling Sphere Method, Early Streamer Emission, and Leader Inception Theory.
- Corona minimising technology.
- Case studies: (i) 26 MW Solar Farm in Central America, (ii) 300 MW BESS in Australia.
- Application summary and conclusions.

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Why are solar farms challenging ?

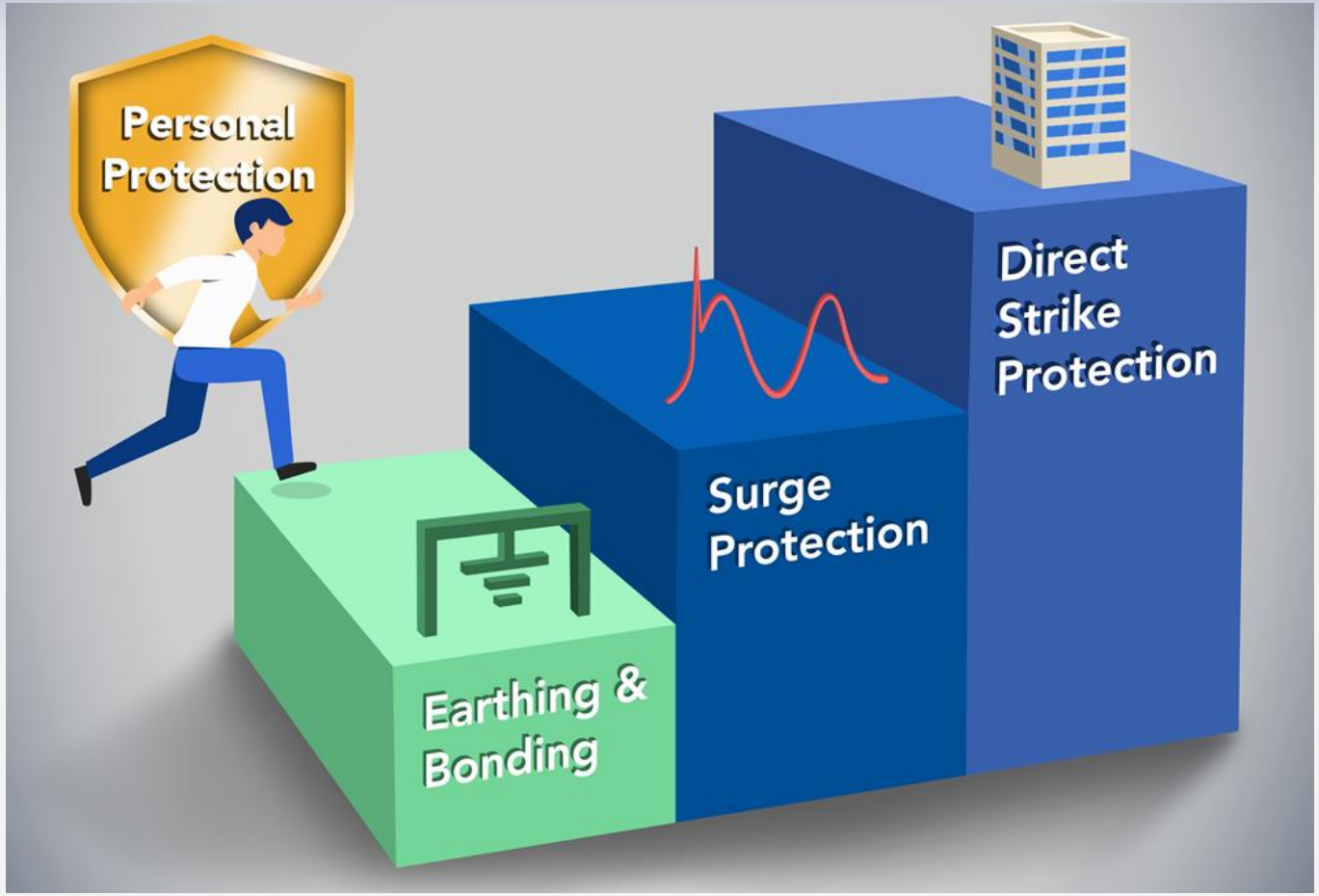
- Very large exposed footprint.
- Extensive DC, AC and communications cabling.
- Distributed power electronics and controls.
- Multiple conductive paths into and through the site.
- BESS concentrates high-value equipment and safety-critical systems.

→ Direct strikes are only one mechanism ….. induction, conductive coupling and earth-potential rise are also important.



Key Elements of Lightning Protection

- A holistic approach ensures best practice lightning protection principles are applied in a systematic manner.
- Key steps:
  1. Protect critical assets against direct strikes.
  2. Protect equipment against surges and transients.
  3. Provide a low impedance earthing system and bond all conductive elements to minimise voltage differences.
  4. Protect people / personnel.



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Lightning Risk Assessment for Solar Farms

- Which approach to use ?
  - AS 1768 spreadsheet ?
  - IEC 62305-2 ?
  - Own approach ?
- The problem with “standardised” risk assessments in LP standards such as AS and IEC is that they are designed for application to “ordinary structures”, e.g., office buildings, apartment blocks, hotels, hospitals, etc.
- Solar farms, wind farms, substations, switchyards, gas processing sites, oil refineries etc. don’t fit into this simplified view.

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Lightning Risk Assessment for Solar Farms

One approach is to simply calculate the number of direct strikes expected per annum (N_{CG}).

$$N_{CG} = GFD \times A_e$$

where GFD is the "ground flash density" and A_e is the footprint of the solar farm (latter is acceptable on the basis that structures are mostly low lying).

Considerations:

A. GFD is increasing due to climate change (~ 12% for each °C increase in global temperature).

B. Is average GFD correct to use ? $1\sigma = \sqrt{GFD}$.

C. New research is showing that multiple ground terminations are much more common than originally thought, i.e., ground strike point density is 1.7 times GFD. IEC now using a factor of 2.

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Lightning Risk Assessment for Solar Farms

- Example calculation:

S.F. Output (MW)	Approx. Size (m)	Direct Strikes per year		
		GFD = 1 fl/km²/yr	GFD = 5 fl/km²/yr	GFD = 10 fl/km²/yr
5	350 x 350	0.1	0.6	1.2
50	1000 x 1000	1	5	10
500	3500 x 3500	12	61	122
1000	5000 x 5000	25	125	250

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Step 1: Direct-strike Protection (DSP)

- To prevent physical damage and fires. More on DSP in later slides.





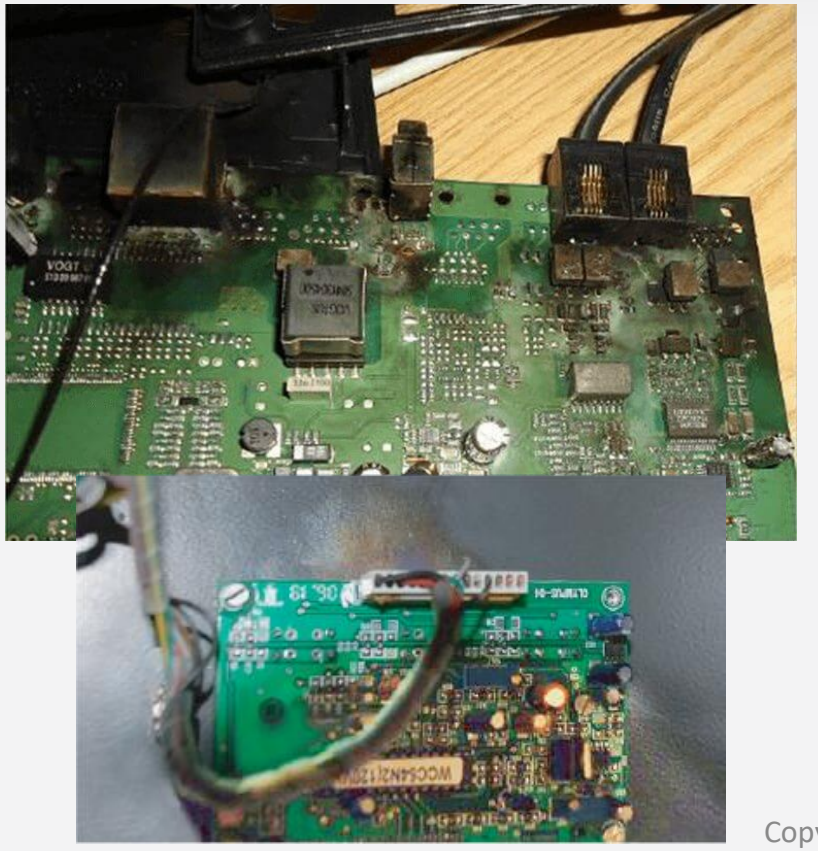




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Step 2: Surge Protection

- To prevent damage to electrical and electronic systems (also fires).



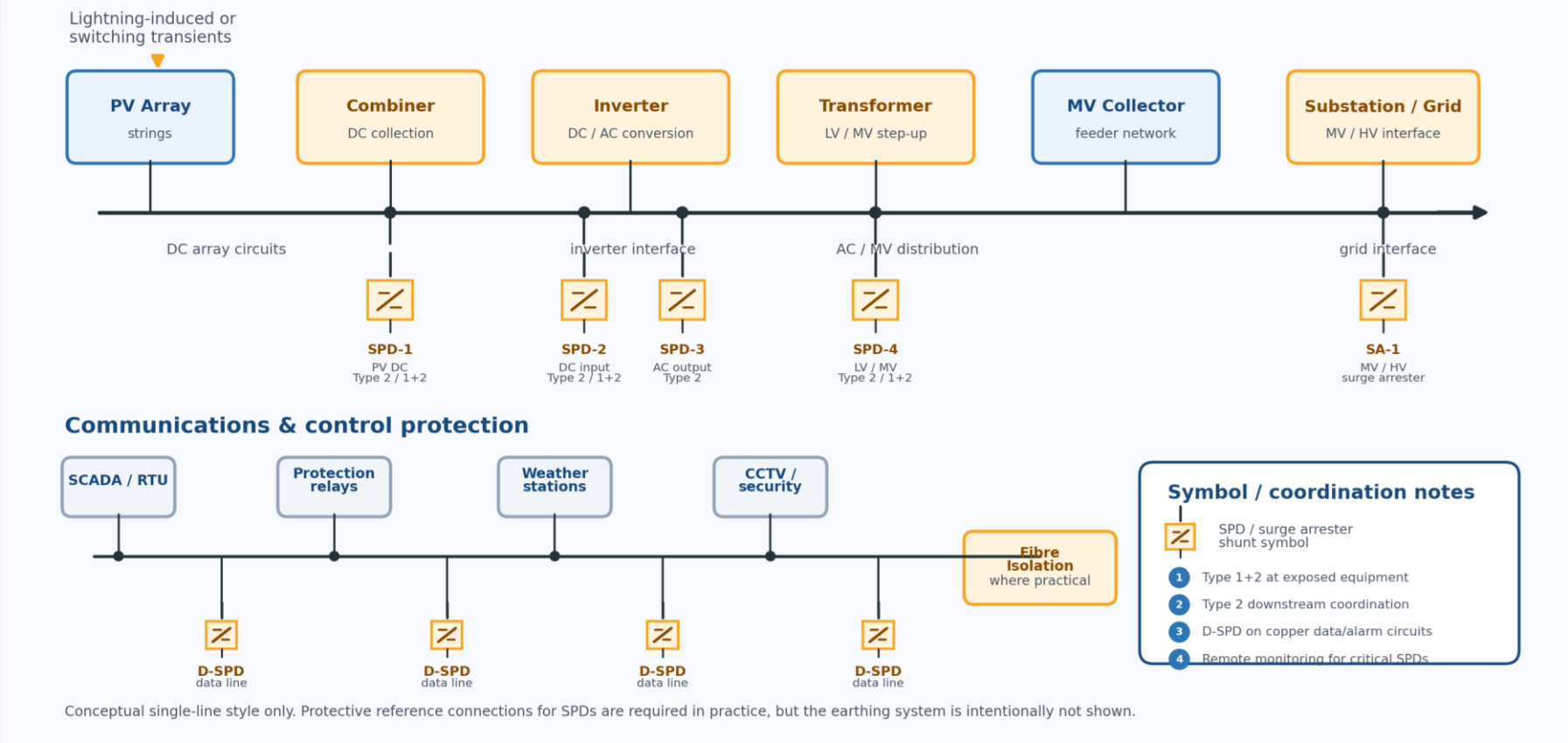




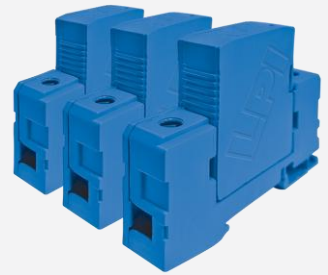
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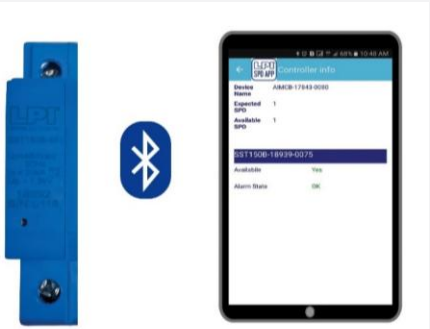
Surge Protection Coordination

- The overall surge coordination strategy is as follows …..



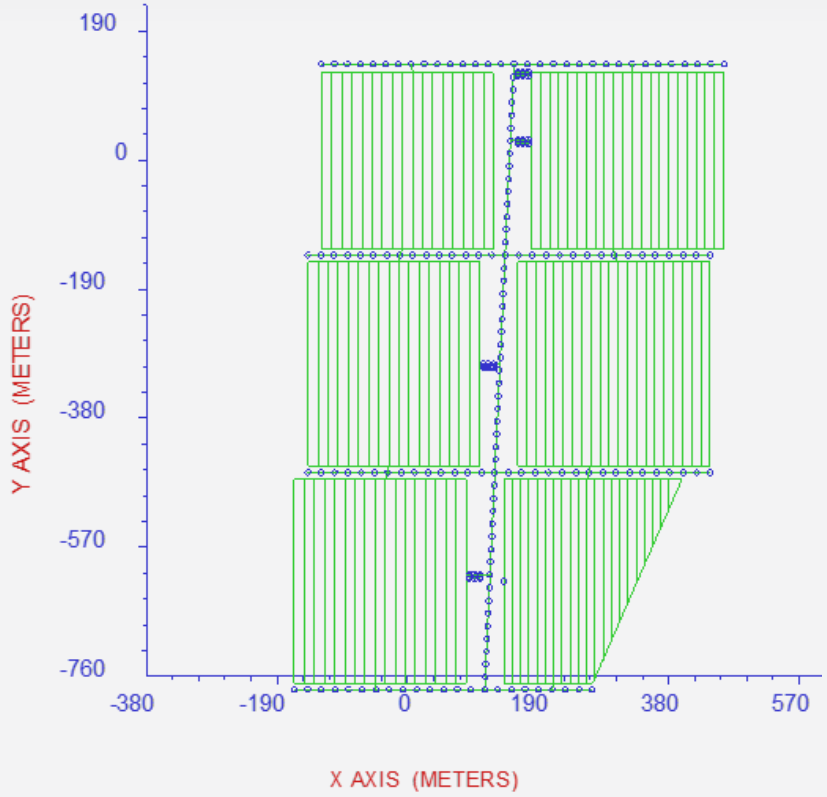
Smart SPDs





Step 3: Good Earthing & Bonding

- Integrated, bonded design using dedicated and auxiliary earth electrodes.







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Earthing & Bonding

- Electrical bonding across the site is very important.







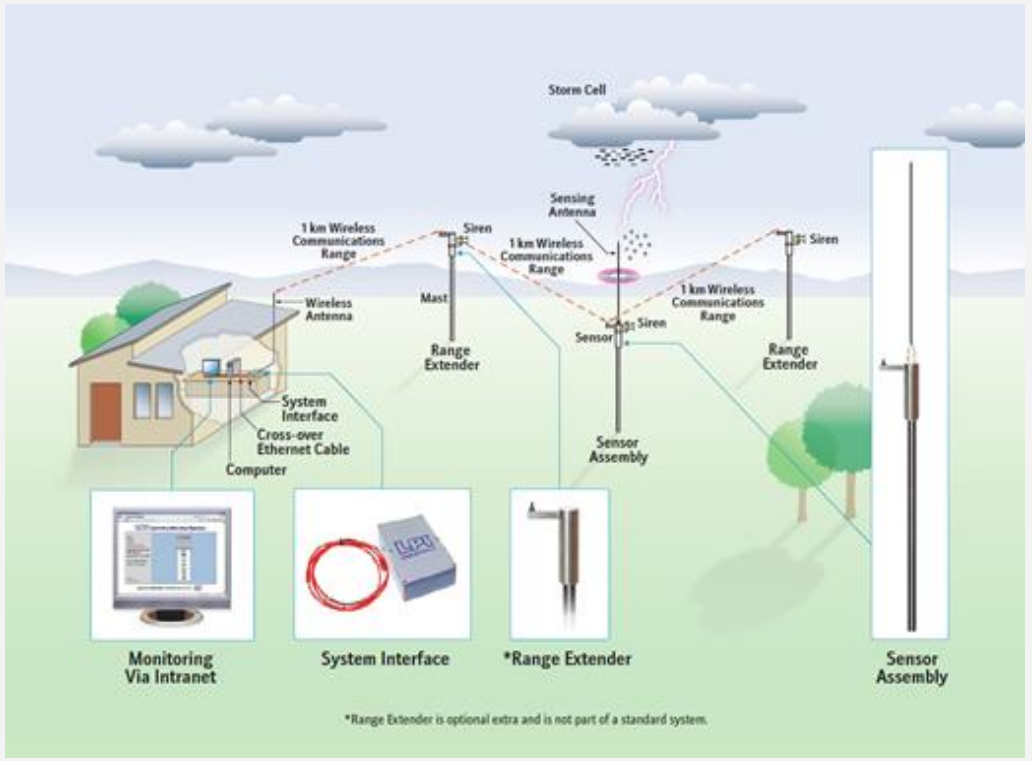
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Step 4: Personnel Protection

- Important during the Construction and Operational phases. Best safety solution is to deploy a **Lightning Warning System** (LWS).









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Direct-strike Protection – Overview

The key components of the solar farm that are the focus of direct-strike protection are:

1. Photovoltaic (PV) panels.
2. Inverter Stations / PCUs (Power Conversion / Conditioning Units).
3. BESS (Battery Energy Storage Systems).

The best approach varies across these areas.

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Direct-strike Protection – Approaches

Review of the most common practices around the world shows that direct strike protection for solar farms falls into one of four categories:

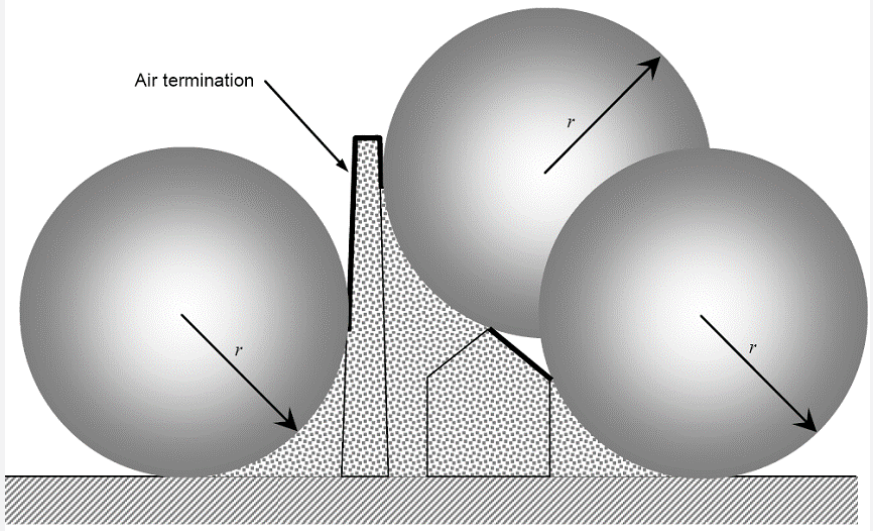
1. No dedicated direct-strike protection (air terminals).
2. Use the rolling sphere method (RSM) and protect using short “Franklin rods” mounted on the panels and other equipment.
3. Use “early streamer emission” (ESE) air terminals, per standard NF C 17-102 (2011), on freestanding poles throughout the site.
4. Use “corona minimising” air terminals for protecting power assets per IEEE Std. 998, e.g., inverter stations, PCUs, and BESS.

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Direct-strike Protection – Conventional

RSM and Franklin rods:

- Geometrical only (does not take leader propagation into account).
- Requires many rods, and hence these can cast shadows on the PV panels.



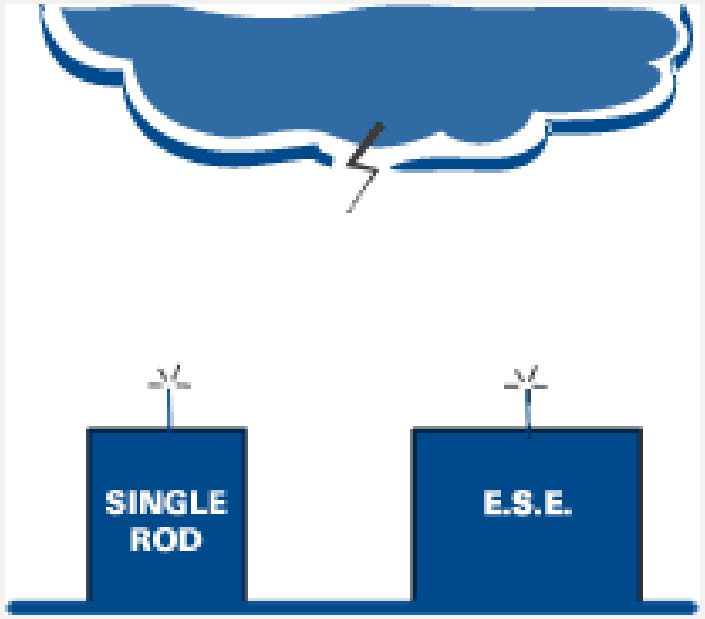


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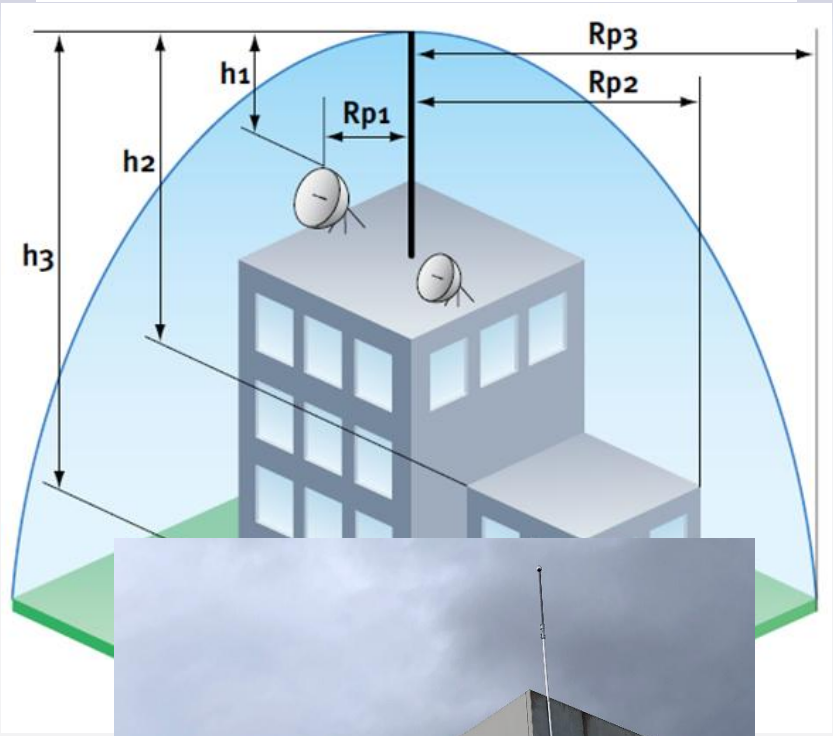
Direct-strike Protection – ESE

NF C 17-102 and ESE air terminals:

- Focuses on upward leader initiation time.
- HV lab test measures initiation time advantage, ΔT, in microseconds.
- Protection area depends on height, LPL, and ΔT.
- *Ideally suited to broad, repetitive PV arrays due to large protection areas*.



$$Rp(h) = \sqrt{2rh - h^2} + \Delta(2r + \Delta) \quad \text{for } h \geq 5\,m$$



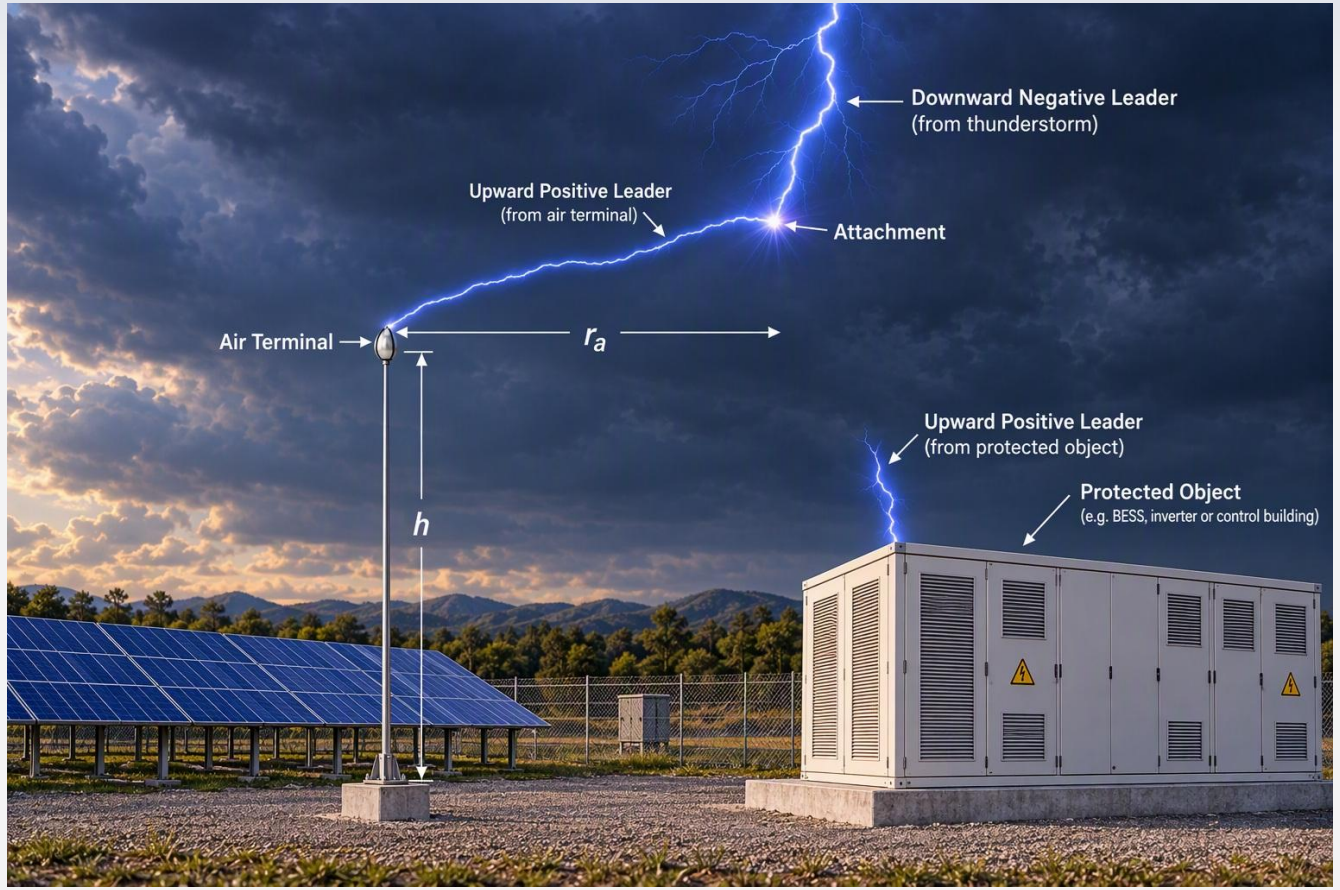


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Direct-strike Protection – Leader Inception Theory

IEEE Std. 998 LIT Method:

- Used to protect “power systems”, hence useful for inverter stations, PCUs, BESS.
- Full leader propagation method.
- Explicitly models upward-leader inception and stable propagation.
- Treats the protected object as a competing attachment point.
- Allows geometry and adjacent shielding to be assessed.
- *Particularly useful for compact, critical, variable-height power assets*.

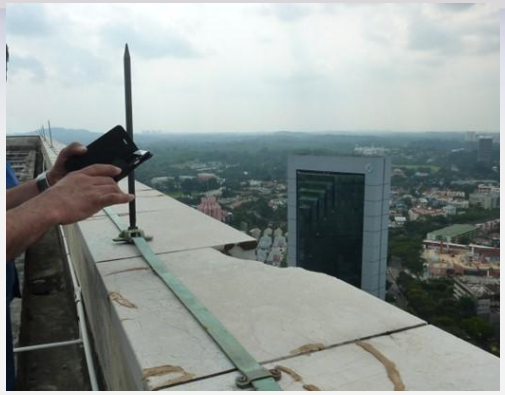


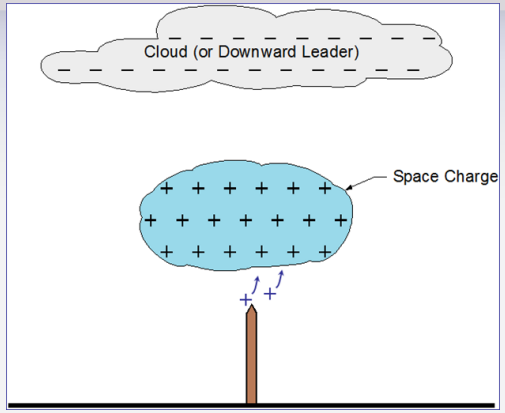
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Direct-strike Protection – Corona Minimising

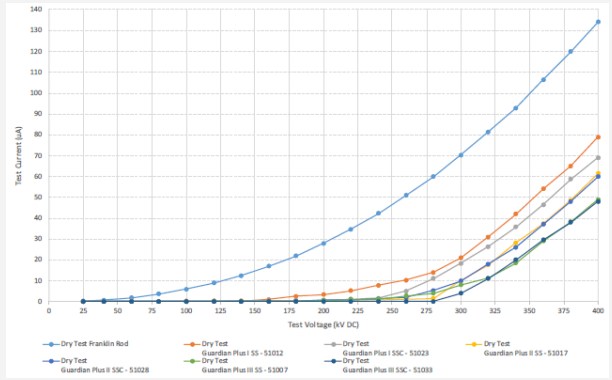
LIT applied with "corona minimising" air terminal technology:

- "Sharp" rods found to be less reliable interceptors.
- Optimum tip radius of curvature is a function of installation height and location.
- "Guardian Plus" technology developed on the back of 3 decades of international research on corona space charge.
- Three sizes to cater for a practical range of installation heights.
- *Result: more reliable lightning capture*.









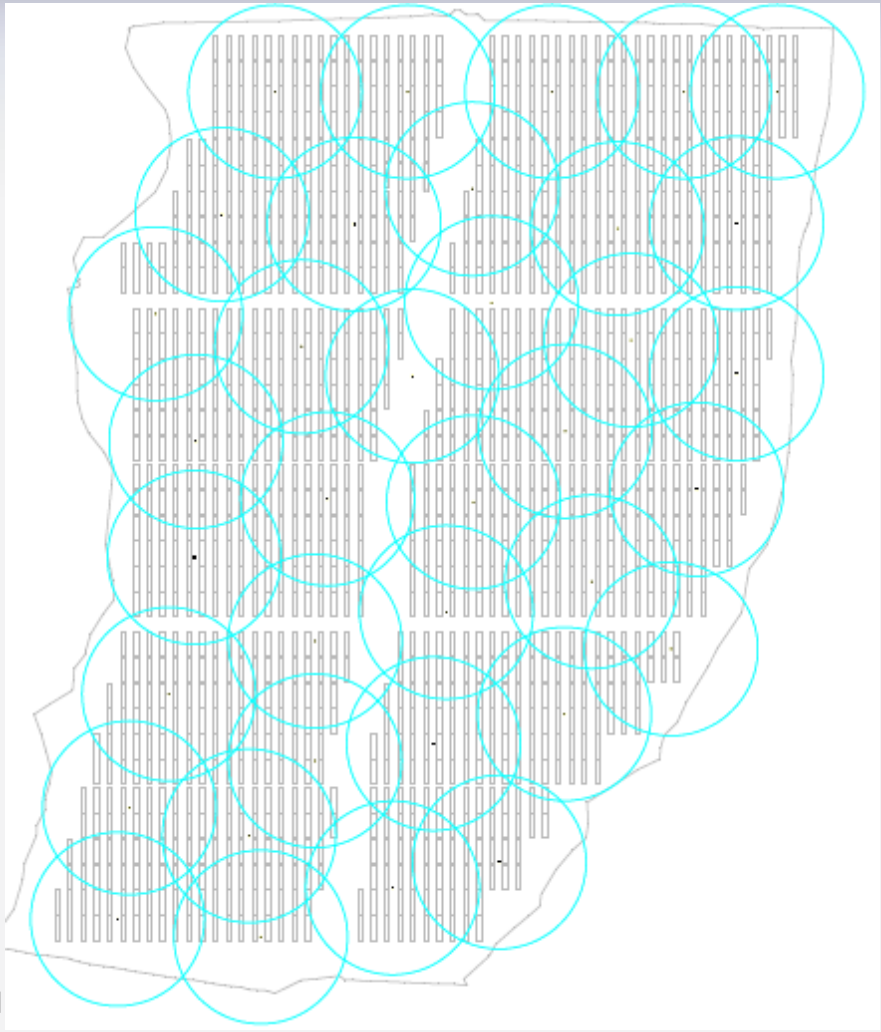


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Case Study 1: 26 MW Solar Farm, Central America

Used "Stormaster ESE 60" air terminals per NF C 17-102:

- Typical application:
  - 60 μs time advance
  - Installed on 8 metre poles
  - LPL I (99%) in this case (but II, III, or IV are used).
- Required 36 air terminals.
- Rule-of thumb: An ESE 60 on 8 m mast protects approx. 1 MW of solar panels at an average LPL.



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Case Study 1: 26 MW Solar Farm, Central America



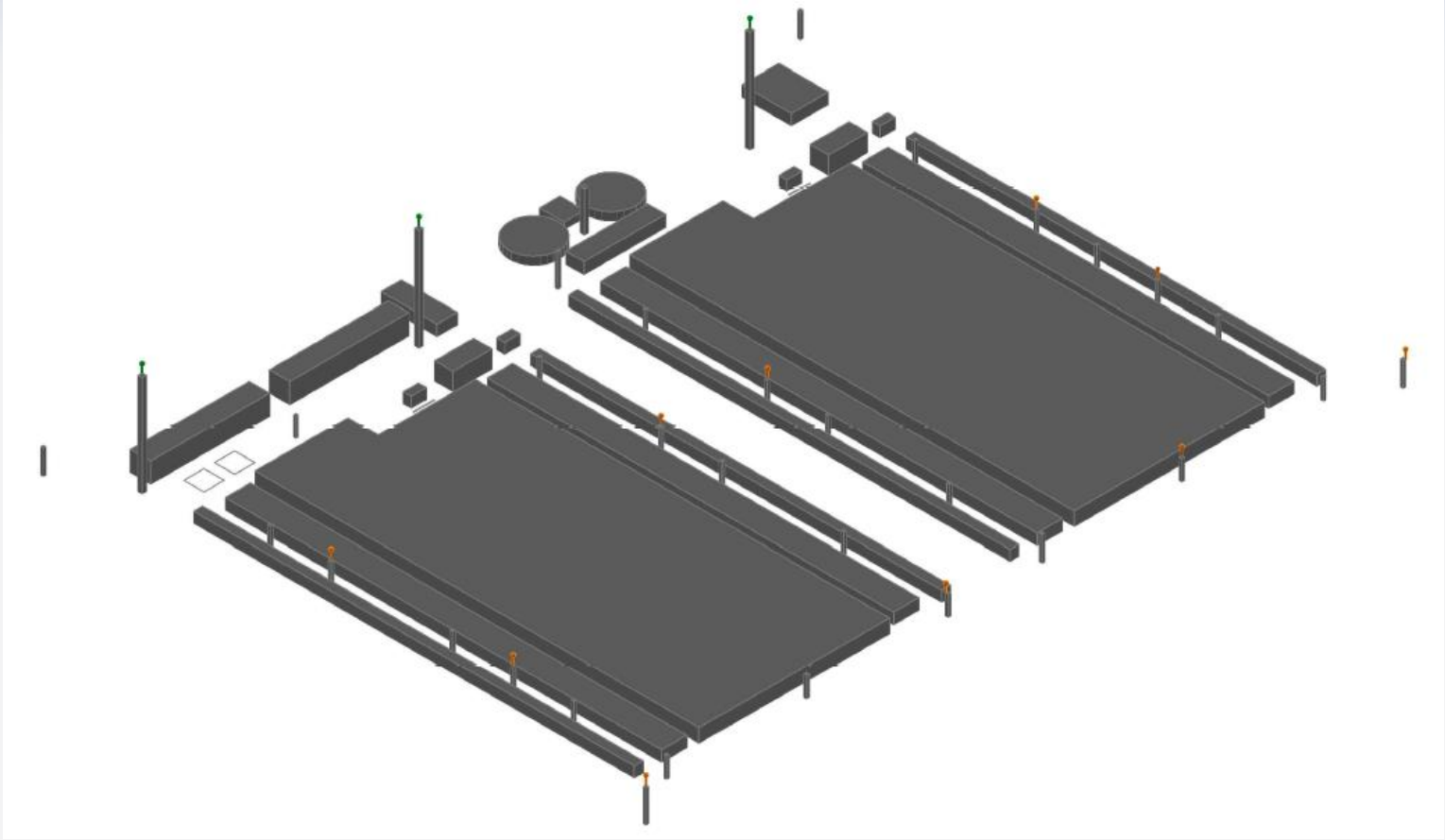




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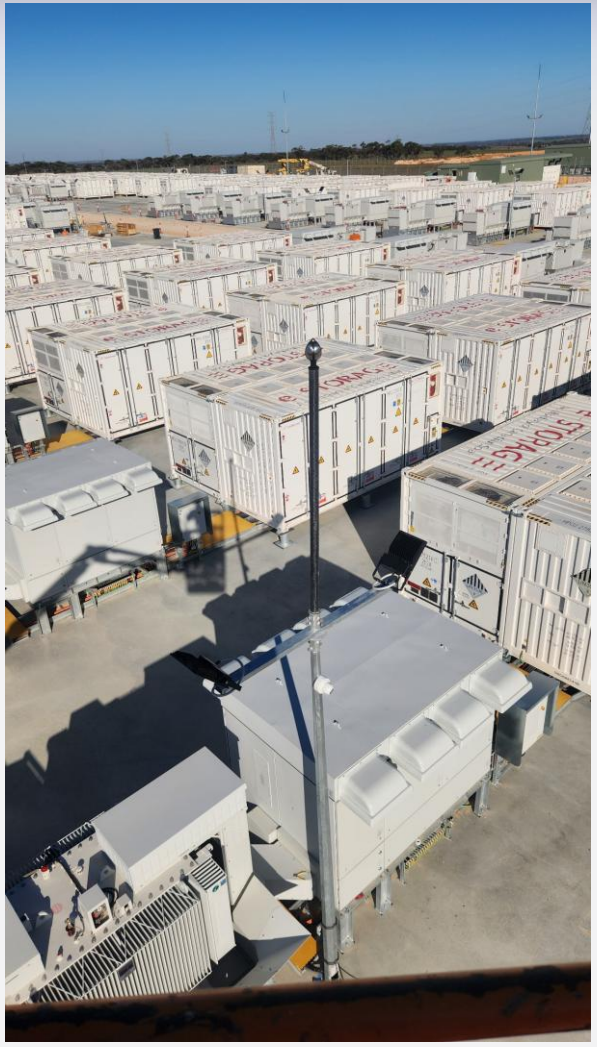
Case study 2: 300 MW BESS, Australia

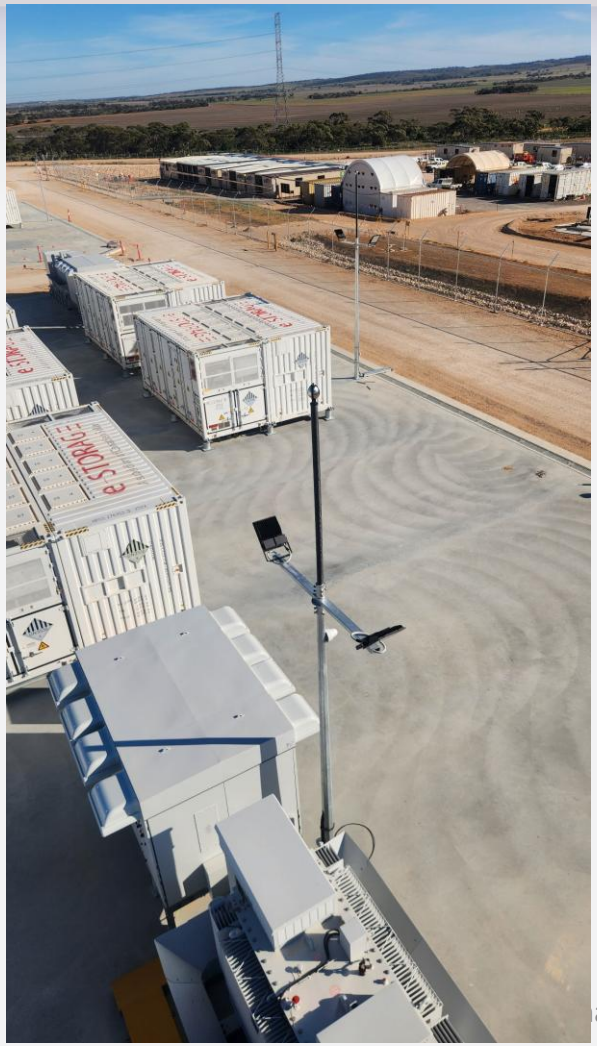
- 13 Guardian Plus terminals (10 x GPLUS1 and 3 x GPLUS 2).
- LPL III / 91% interception efficiency.
- 3D strike-probability assessment and then LIT was applied.
- Protection by isolation where masts are container-mounted (using HVSC Plus insulated downconductor).

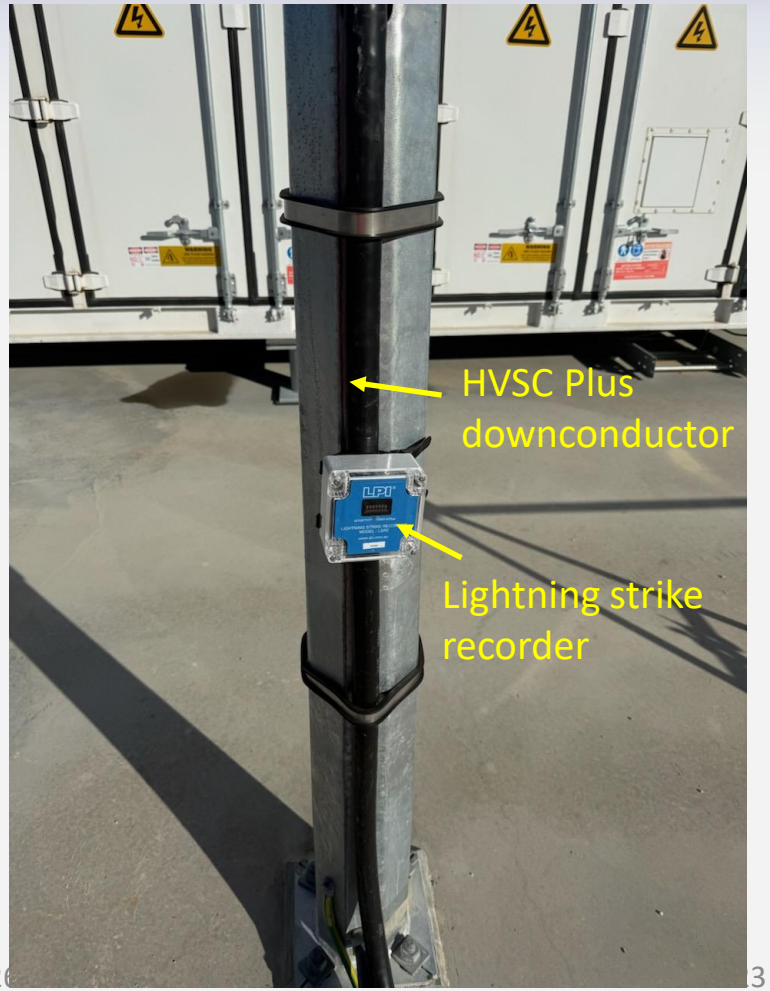


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Case study 2: 300 MW BESS, Australia







Method / Technology Application Summary

PV Plant Section	Method	Technology
PV arrays (“structures”)	ESE per NF C 17-102	Early Streamer Emission (on freestanding poles positioned to minimise shading effects)
Inverter stations, PCUs	LIT per IEEE 998	Corona minimising (on station with insulated cable or freestanding poles)
BESS	LIT per IEEE 998	Corona minimising (on container with insulated cable or freestanding poles)
Substations	LIT per IEEE 998	Corona minimising (on freestanding poles)

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Engineering Efficiency and Cost Reduction

The more targeted “leader propagation design” outlined in this presentation reduces:

- Number of air terminals and masts.
- Supporting structures and foundations.
- Downconductors and associated installation work.
- Shading and interference with PV plant.
- Unnecessary complexity.

….. while maintaining the required lightning interception objective.

- *Cost reduction is not achieved by omitting protection. It comes from more efficient use of materials / technologies through more appropriate modelling and method selection*.

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Conclusions

- Lightning protection of solar farms and BESS requires an integrated design approach.
- Modern leader-propagation concepts improve the physical basis for lightning attachment assessment.
- ESE and LIT have different strengths and applications.
- Current-path control, SPDs, earthing & bonding remain essential.
- Tailored designs can improve both engineering efficiency and installed cost.
- **In summary: use the right protection approach for the right asset and integrate it with surge protection, earthing, bonding and operational safety.**

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Thank you for your attention.
Question time ☺.