FISUEL GAM 2019
Beirut - Lebanon

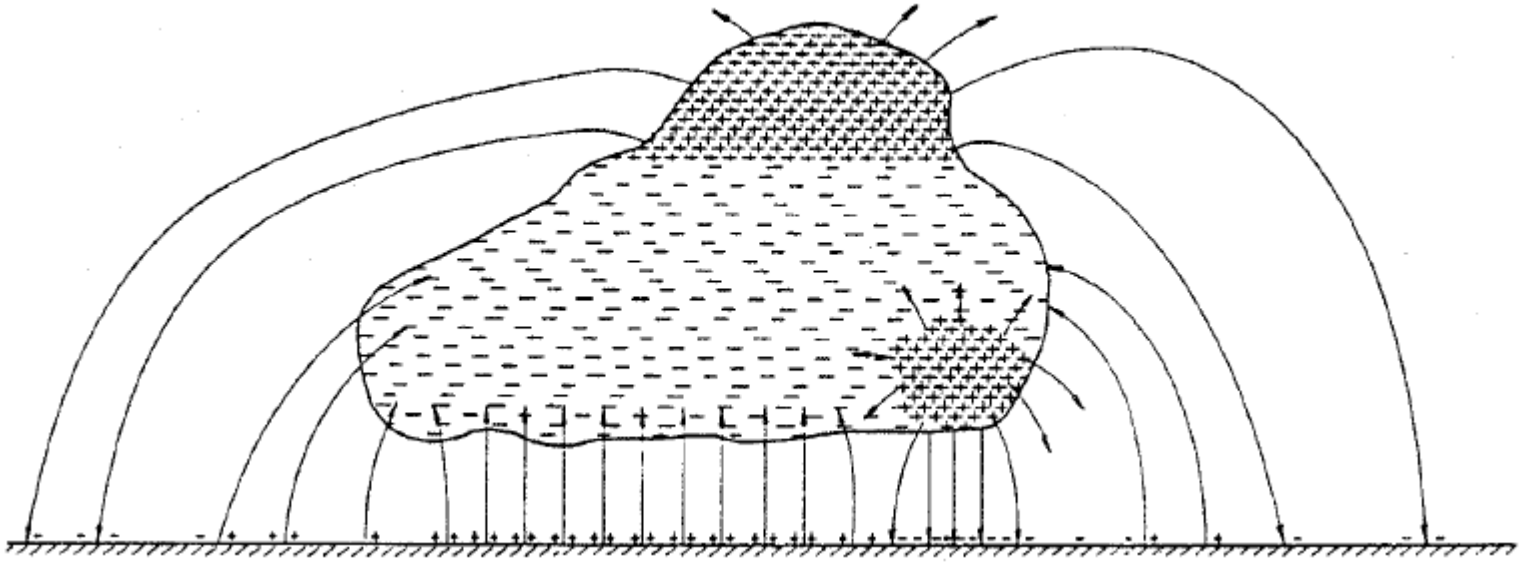
Lightning Design for Photovoltaic Solar Farm

Mohamad Nassereddine
American University in Dubai
School of Engineering
Email: mnassereddine@aud.edu

Table of Contents

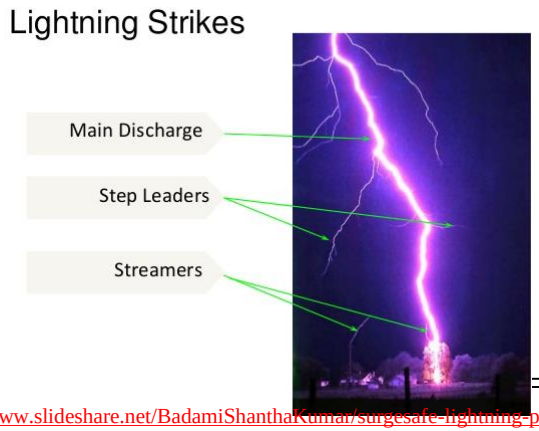
Introduction to Lightning

- Lightning Stroke Phenomena (According to IEEE 998)
  - Charge formation in Clouds
    - Numerous theories
    - Attributes charge separation to the existence of both positive and negative ions and the existence of a normal electric field directed toward the earth

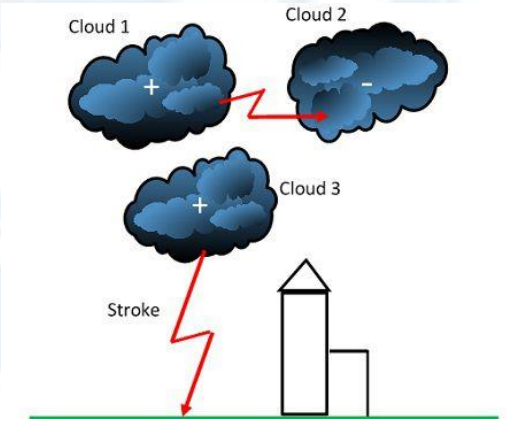


Introduction to Lightning

- Lightning Stroke Phenomena (According to IEEE 998)
  - Stroke Formation
    - Types of strokes (Strokes within the clouds, stroke between separate clouds, stroke to all structures, strokes that terminate on the ground.
      - The positive and negative strokes termination on the ground are the types of the most interest in designing shielding systems
    - Stepped Leaders;
      - Ionization of the air surrounding the charge
      - The development of the stepped leaders
      - The current with stepped leaders are small in order of 100A
    - Return Stroke; is the bright streamer that propagates upward from the earth to the cloud
    - Medium value of 24000A



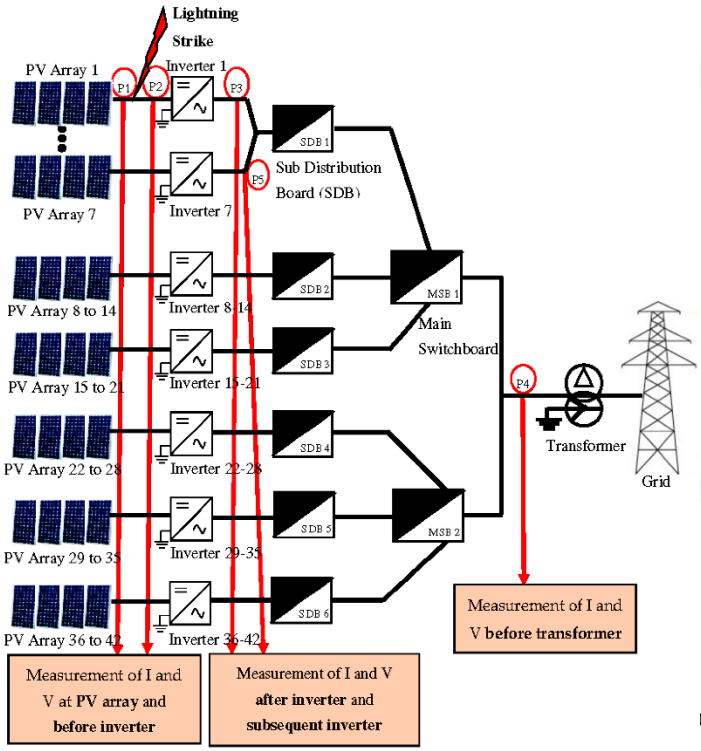
https://www.slideshare.net/BadamiShanthaKumar/surgesafe-lightning-protection-system-presentation

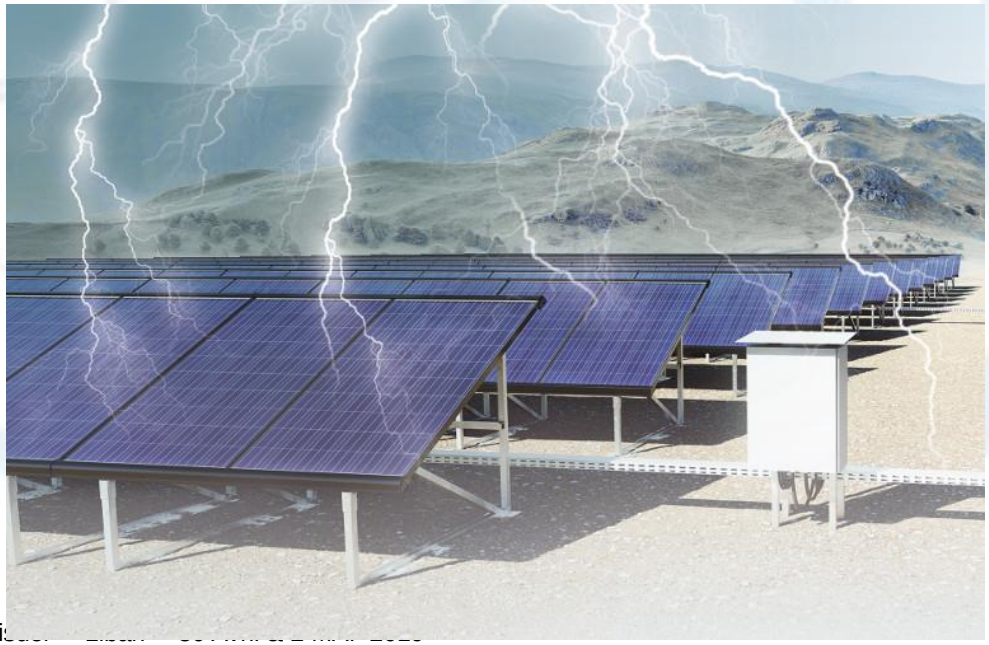


https://circuitglobe.com/lightning-stroke.html

Lightning Design for PV Farm

- Lightning design is divided to two sections:
  - Lightning Shield
  - Lightning Performance





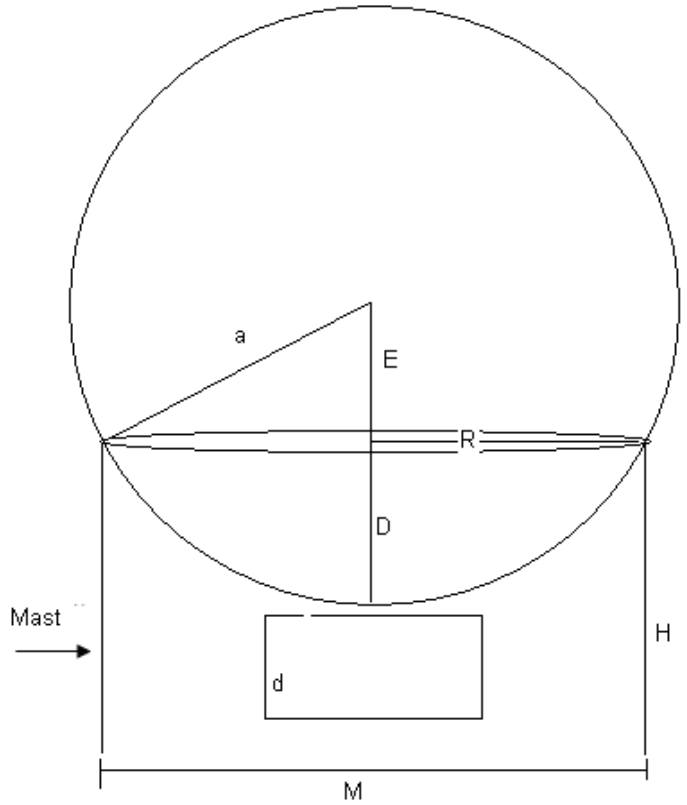
https://www.mdpi.com/1996-1073/10/12/2149/htm

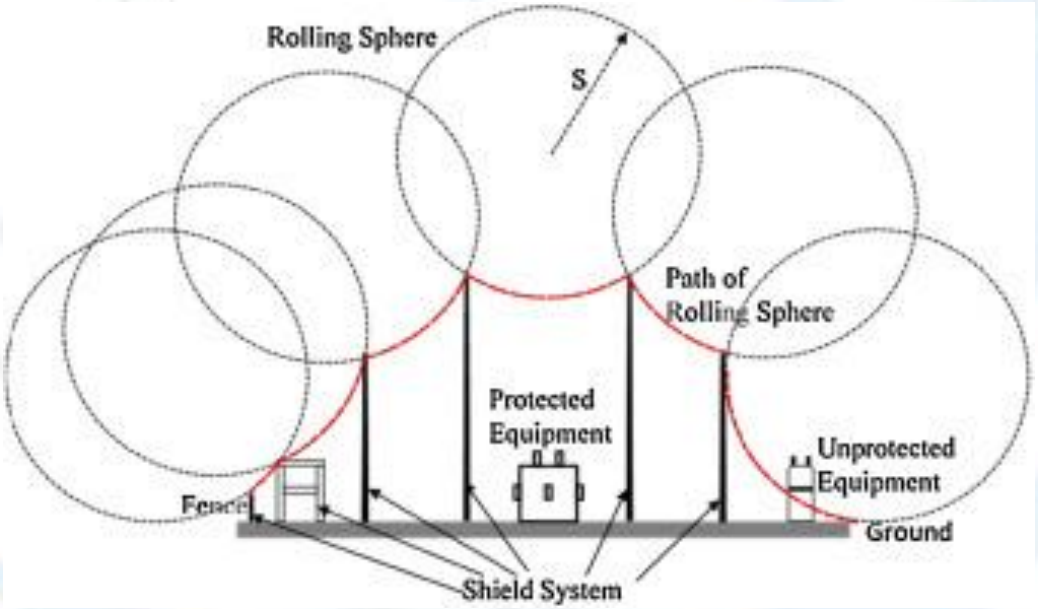
https://www.solarpowerworldonline.com/2018/10/lightning-and-overvoltages-why-solar-systems-need-surge-protection/

Lightning Design for PV Farm

Lightning Shield

- Rolling Sphere Method:





1. Nassereddine M and Hellany A, 2009, ***Designing a Lightning Protection System Using the Rolling Sphere Method***, *Proceeding in the 2009 International Conference on Computer and Electrical Engineering*, pp 502-506
2. Q. Xie, S Baron, S. Lefebre "3D Computer graphics enhanced shielding failure evaluation by collection surface method. Electric Power systems Research. Vol 139, Oct 2016

Lightning Design for PV Farm

Lightning Shield

- For lightning Shield Design:
  - Current magnitude
  - Strike Distance

Darveniz[1] $$S = 2I + 30\left(1 - e^{\frac{-I}{6.8}}\right)$$

Love[1] $$S = 10I^{0.65}$$

Whitehead[1] $$S = 9.4I^{\frac{2}{3}}$$

IEEE[1] $$S = 3.3I^{0.78}$$

1. 'IEEE Guide for direct lightning stroke shielding of substations" (IEEE, New York, 1996).

Lightning Design for PV Farm

Lightning Shield

- For lightning Shield Design:
  - Countries set standards for current magnitude and sphere radius [1]

Protection Level	Sphere radius (m)	Interception Current (kA)
1	20	2.9
2	30	5.4
3	45	10.1
4	60	15.7

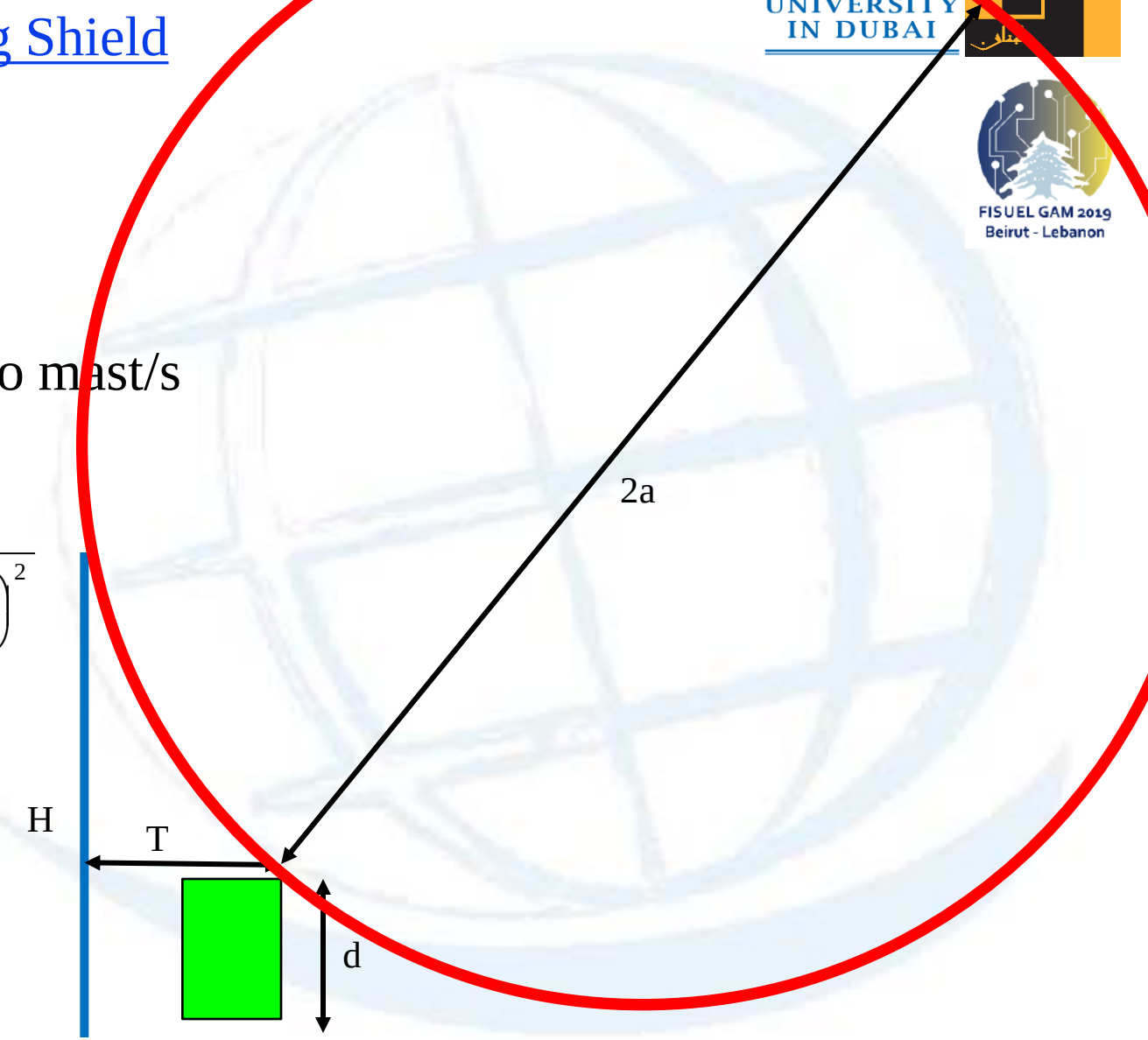
1. AS/NZS 1768:2007 Lightning protection

Lightning Design for PV Farm

Lightning Shield

- Masts Details:
  - Object heights
  - Object separation to mast/s
  - Strike radius

$$H = a - \sqrt{a^2 - \left(\sqrt{a^2 - (a-d)^2} + T\right)^2}$$



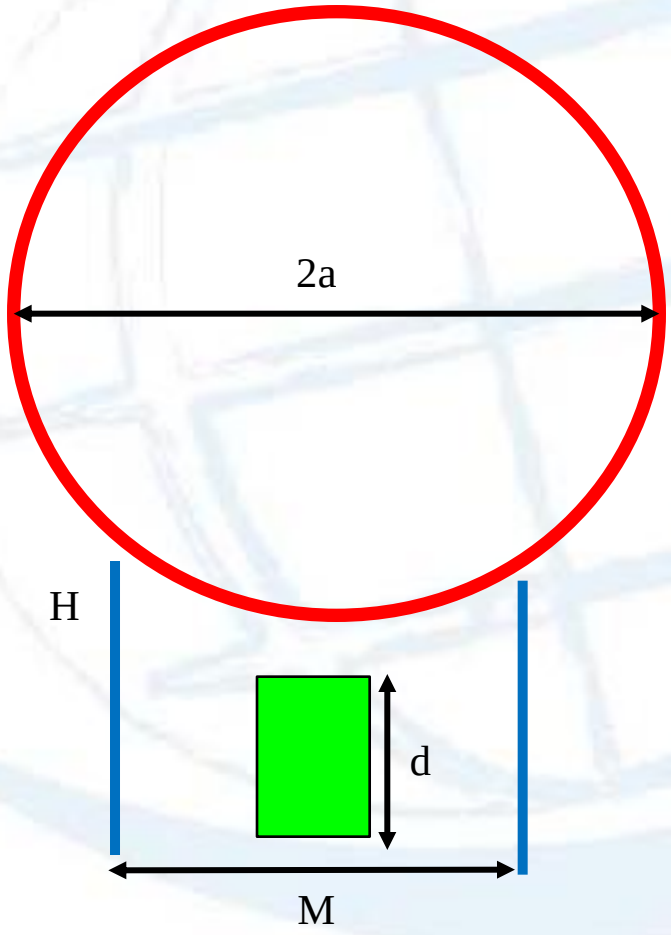
1. Nassereddine M and Hellany A, 2009, ***Designing a Lightning Protection System Using the Rolling Sphere Method***, *Proceeding in the 2009 International Conference on Computer and Electrical Engineering*, pp 502-506

Lightning Design for PV Farm

Lightning Shield

- Masts Details:

$$H = a + d - \sqrt{a^2 - \left(\frac{M}{2}\right)^2}$$



1. Nassereddine M and Hellany A, 2009, ***Designing a Lightning Protection System Using the Rolling Sphere Method***, *Proceeding in the 2009 International Conference on Computer and Electrical Engineering*, pp 502-506

Lightning Design for PV Farm

Lightning Shield

- Damage due to lightning strike:

https://www.semanticscholar.org/paper/PV-panels-under-lightning-conditions-Belik/4a058913295e444f3a8233fb7743eb564822fc2d

Lightning Design for PV Farm

Lightning Performance

- Lightning performance
  - Number of flashes to earth per square km per year (GFD)
  - The average annual Keraunic Level T_d
  - Number of strikes to proposed mast/s $N_s = N_g \frac{28h^{0.6} + S_g}{10}$

Distance Between Masts

  - The designed system voltage level is capable to avoid flush-over which lead to equipment damages

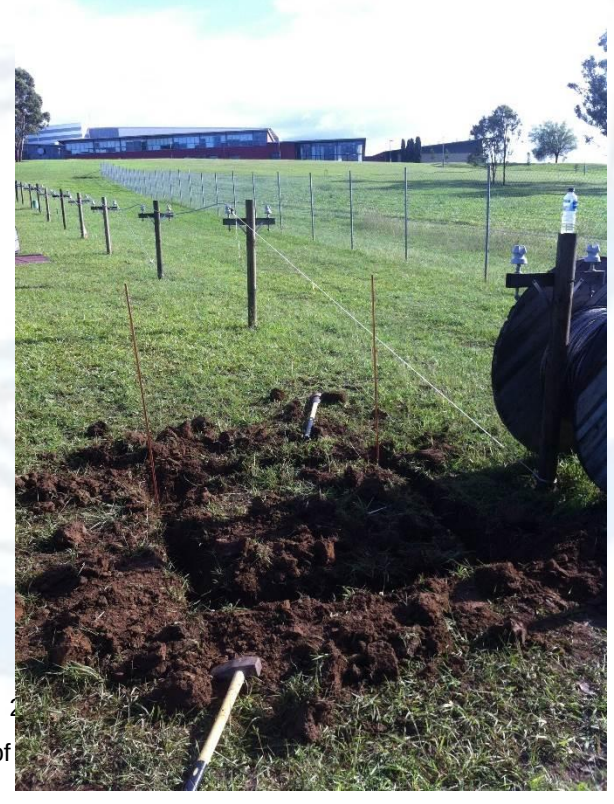
$$V_{Nominated} = V_{surge} - V_{Phase}$$

1. Nassereddine M., Rizk J., Hellany A., Nagrial M. and Nassereddine G., ***"Overhead Distribution Lightning Performance on Joint Use Concrete Poles with Transmission Lines"*** 17th IEEE Mediterranean Electrotechnical Conference MELECON 2014, April, Beirut Lebanon

Lightning Design for PV Farm

Lightning Performance

- Earth grid resistance plays an important roles to absorb the lightning energy
- Earth grid resistance is made of buried conductive materials



Avril & 2 MAI 2
April & 2rd of

Lightning Design for PV Farm

Lightning Performance

- Grid Resistance
  - Electrode resistance under low frequency (50 or 60 hz)

$$R_g = \frac{\rho}{2\pi L}\left(\ln\frac{8L}{d} - 1\right)$$

  - Electrode resistance under lightning strike

$$R_{Lightning} = \frac{R_P}{\sqrt{1+\frac{I}{I_g}}}$$

  - Ig is the current limit that initiate sufficient soil ionization

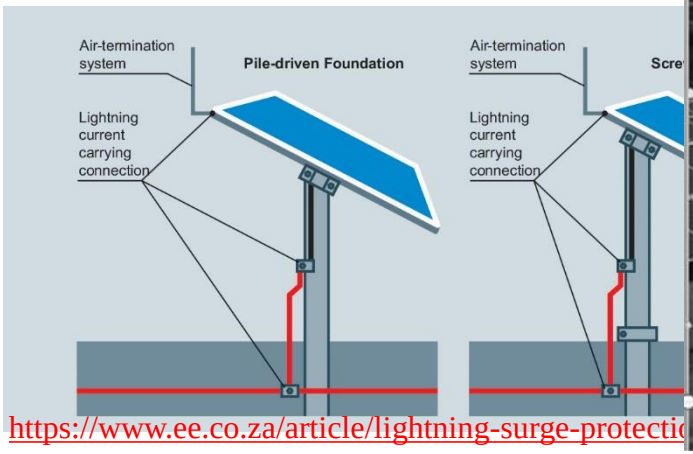
Soil Ionization Grading

$$I_g = \frac{300kV/m \times \rho}{2\pi R_P^2}$$

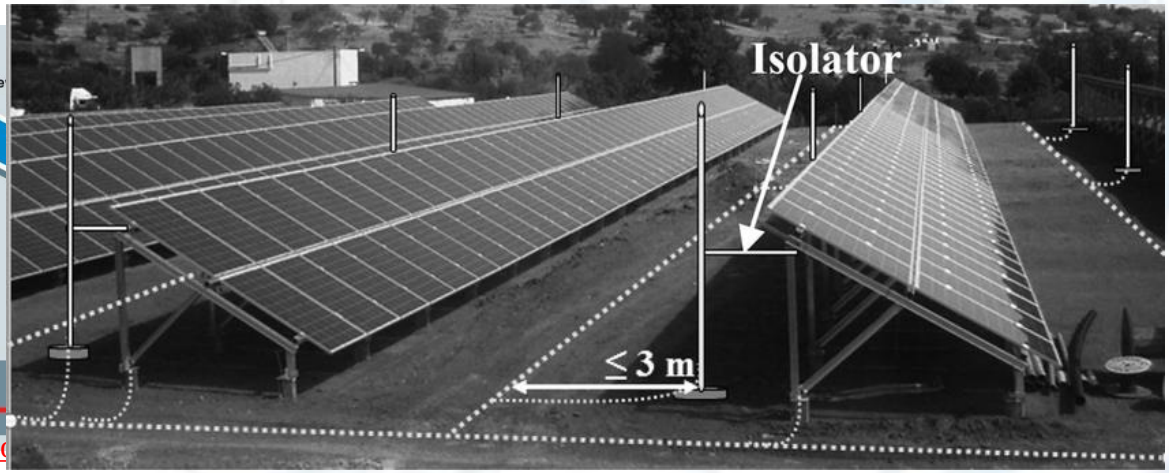
Lightning Design for PV Farm

Lightning Protection Layout and Products

- Lightning protection layout & Product
  - Depending on data (soil resistivity , GFD, Insulation levels, etc..)

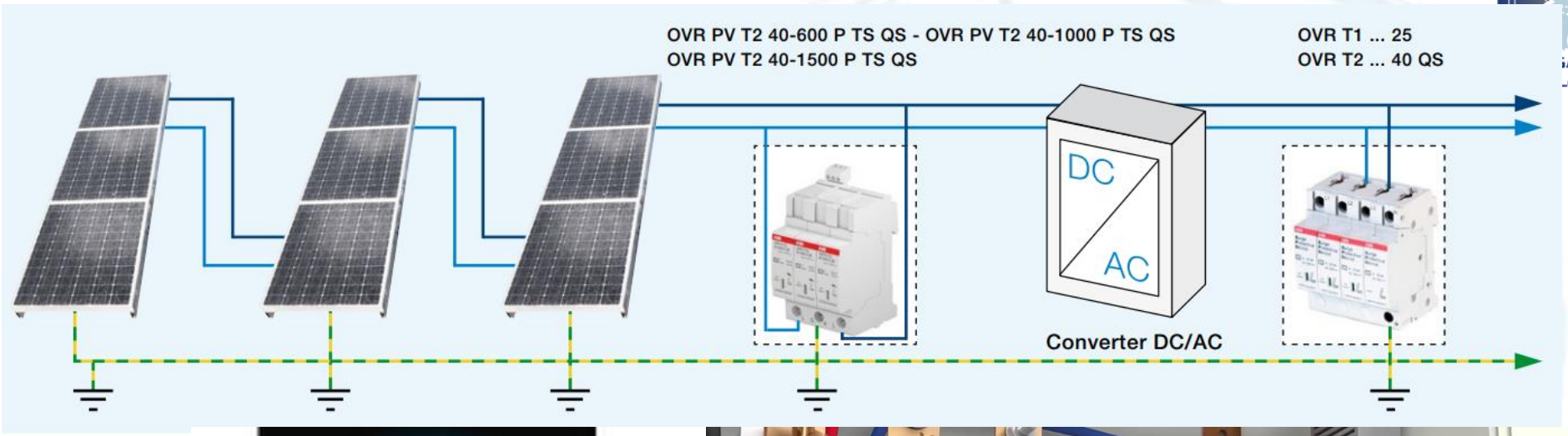


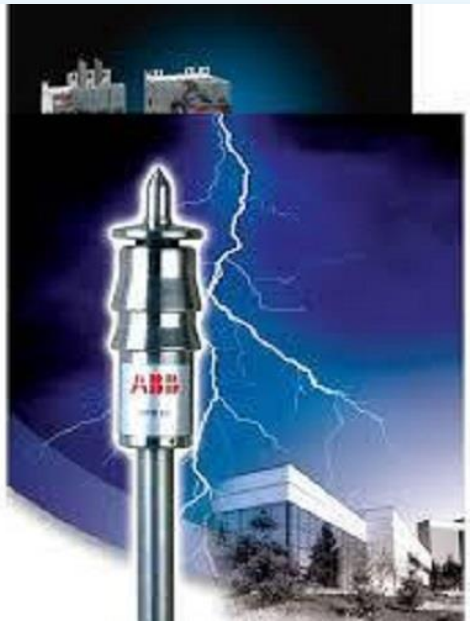
https://www.ee.co.za/article/lightning-surge-protecti

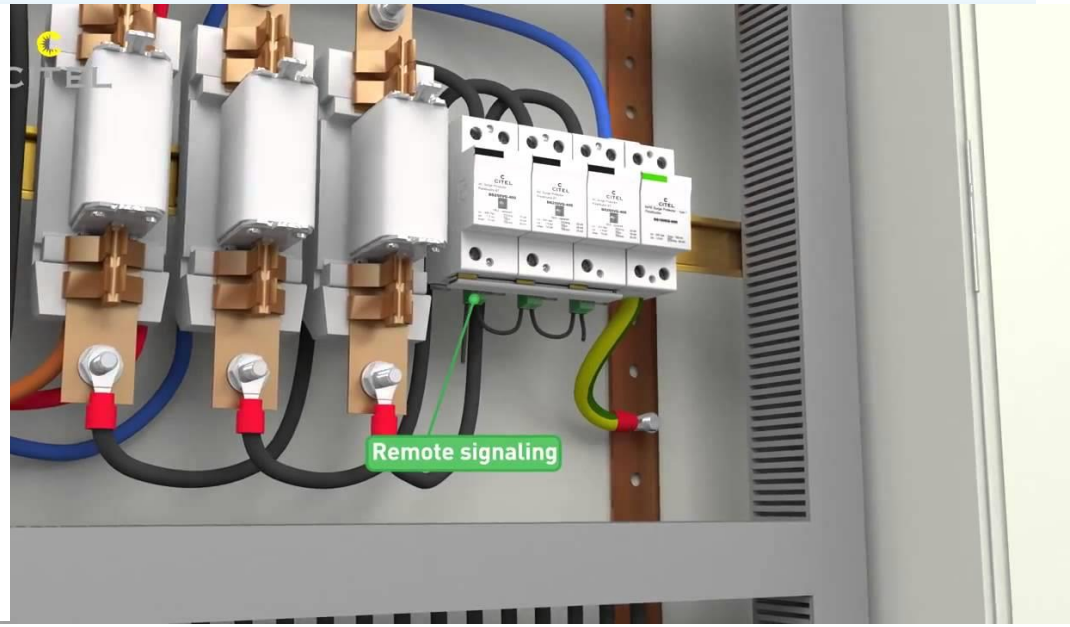


Lightning Design for PV Farm

Lightning Protection Layout and Products







Lightning Design for PV Farm

Lightning Design Steps and Recommendations

- Data Gathering:
  - Soil Resistivity
  - Current earth grid layout
  - Solar infrastructure details
  - Installed apparatus surge impedance levels
  - Installed insulation levels if applicable
  - Ground flash density
  - Average Keruanic Level

Lightning Design for PV Farm

Lightning Design Steps and Recommendations

- Lightning Masts:
  - If possible, install the mast away from the solar structure
  - If possible, install separate earthing system for the lightning masts
  - Determine the masts numbers and heights to suit the rolling sphere method
- Lightning Performance
  - Compute the surge impedance
  - Compute the surge voltage
  - Verify the current installed insulation and surging levels
  - Design report

FISUEL GAM 2019
Beirut - Lebanon

THANK YOU

MERCI