PARADISE ELECTRIC GROUP

INGESCO® LIGHTNING SOLUTIONS

WEBINAR

LIGHTNING PROTECTION

50 YEARS 1973 - 2023 | INGESCO® LIGHTNING SOLUTIONS

50 years offering comprehensive lightning protection solutions for all types of sectors

INGESCO®
LIGHTNING SOLUTIONS

MISSION

Create and globally consolidate the INGESCO comprehensive protection model as a new category of protection and total safety against lightning.

- External protection
- Internal protection
- Earthing systems
- Control systems
- Preventive systems

Index:

1. Introduction

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Laboratory test at 1MV of an E.S.E lightning rod to know its ΔT (to calculate the protection radius).

INGESCO®

Prevention and protection against lightning since 1973.

Research on the phenomenon of lightning.

Customized projects for a total protection.

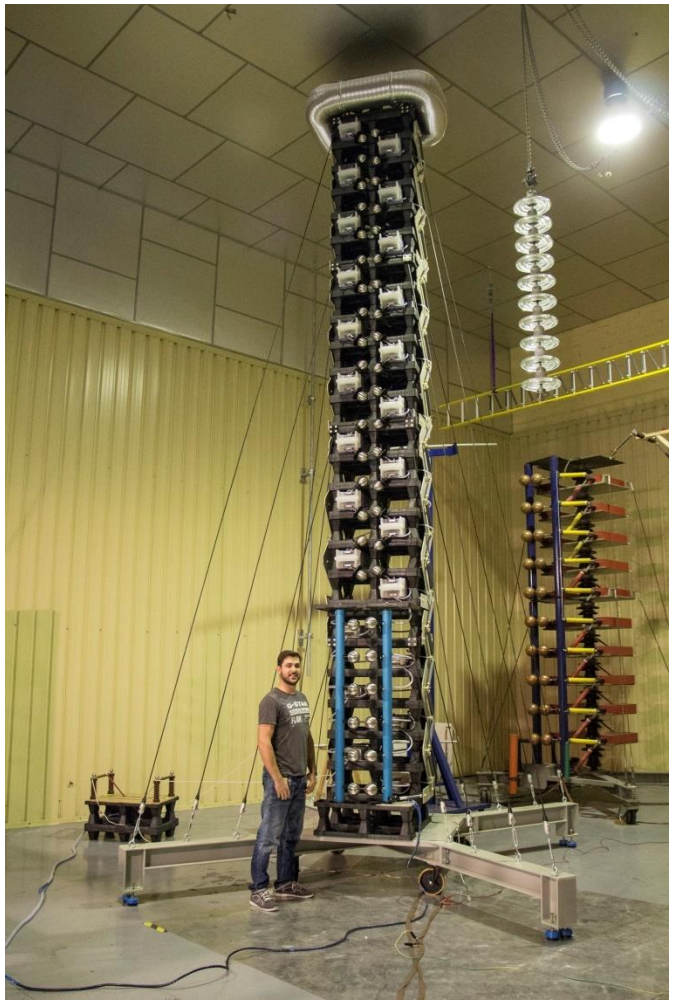
Participation in working groups to create new lightning protection standards.

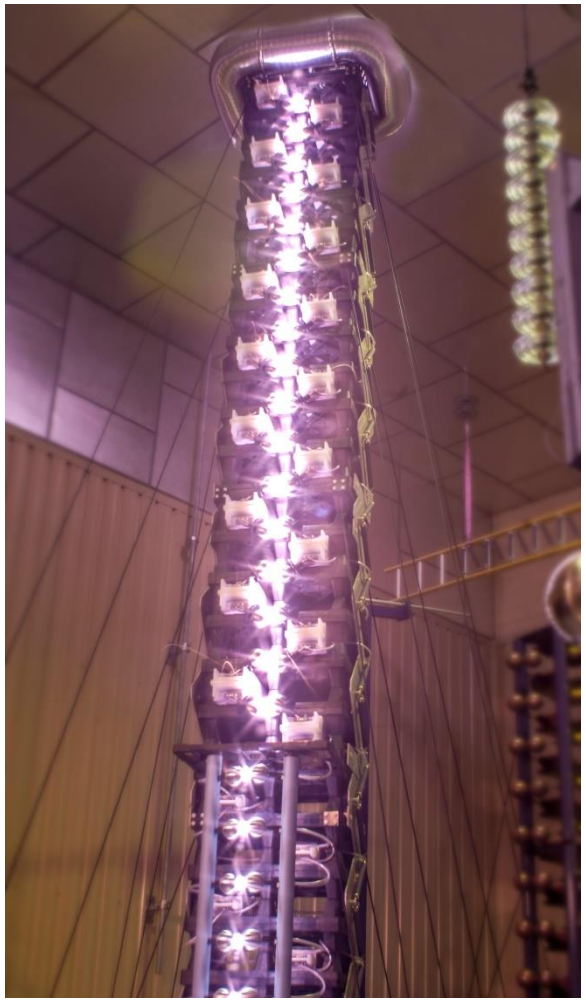
Accreditation ENAC (National Accreditation Entity) for a lightning testing laboratory.

https://www.iaf.nu/

EA-BAS (Executive Agency - Bulgarian Accreditation Service)

High voltage laboratory test:

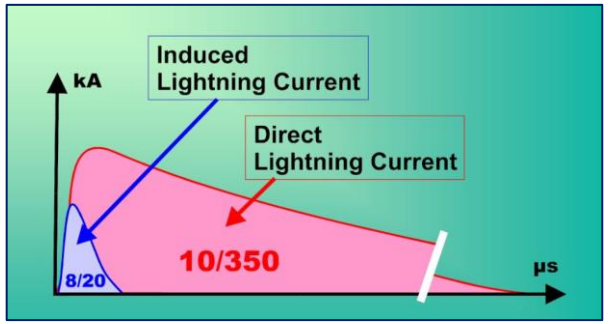




Marx Generators, 10 and 24 stages, (100 kV each capacitor)
up to 1MV and up to 2.4 MV (to test wind turbines blades).

❑ Laboratory tests:

- ➢ Up to 100kA waveform (10/350)
- ➢ Up to 37 kA (8/20)

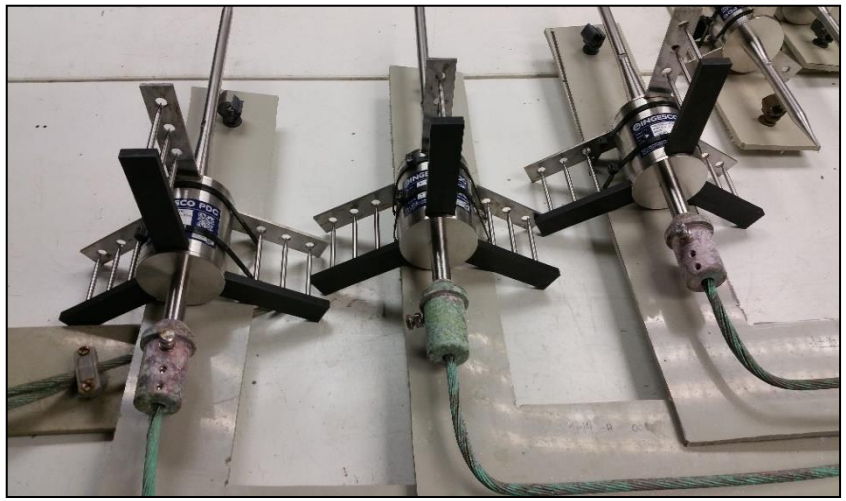


✓ Current test 100 kA (10/350) for an E.S.E lightning rod according to NF C 17-102 and IEC 62561-1 standards

✓ Never make sharp bends or angles less than 90º with the down conductor of a lightning rod installation.

Source IEC 62561-1:2017

Introduction



INGESCO arresters are made of AISI 316L stainless steel and are almost unaffected after the ageing test.

❑ Aging test on connection components according

- Salty fog chamber
- Ammonia atmosphere
- Sulphur dioxide chamber
- Humidity chamber

Ageing test for a “T” connector, before and after.

Source NF C 17-102:2011

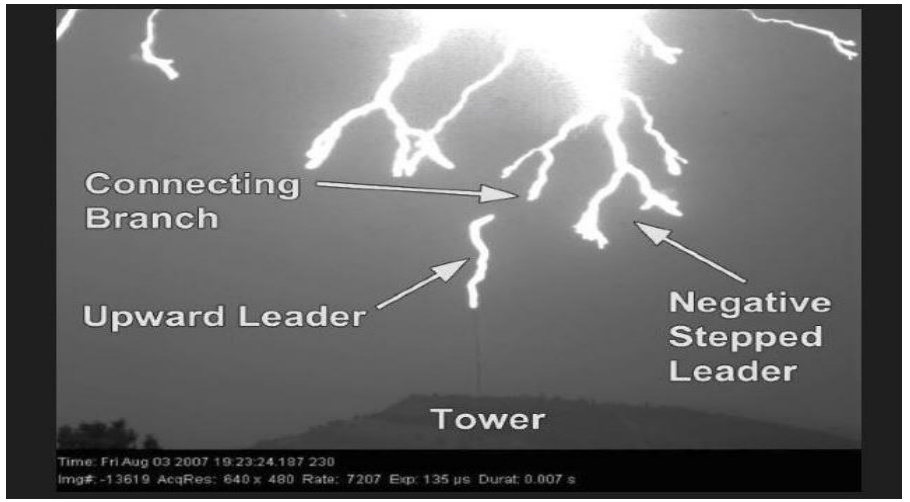
❑ High-speed videos:

C-G Cloud to ground lightning

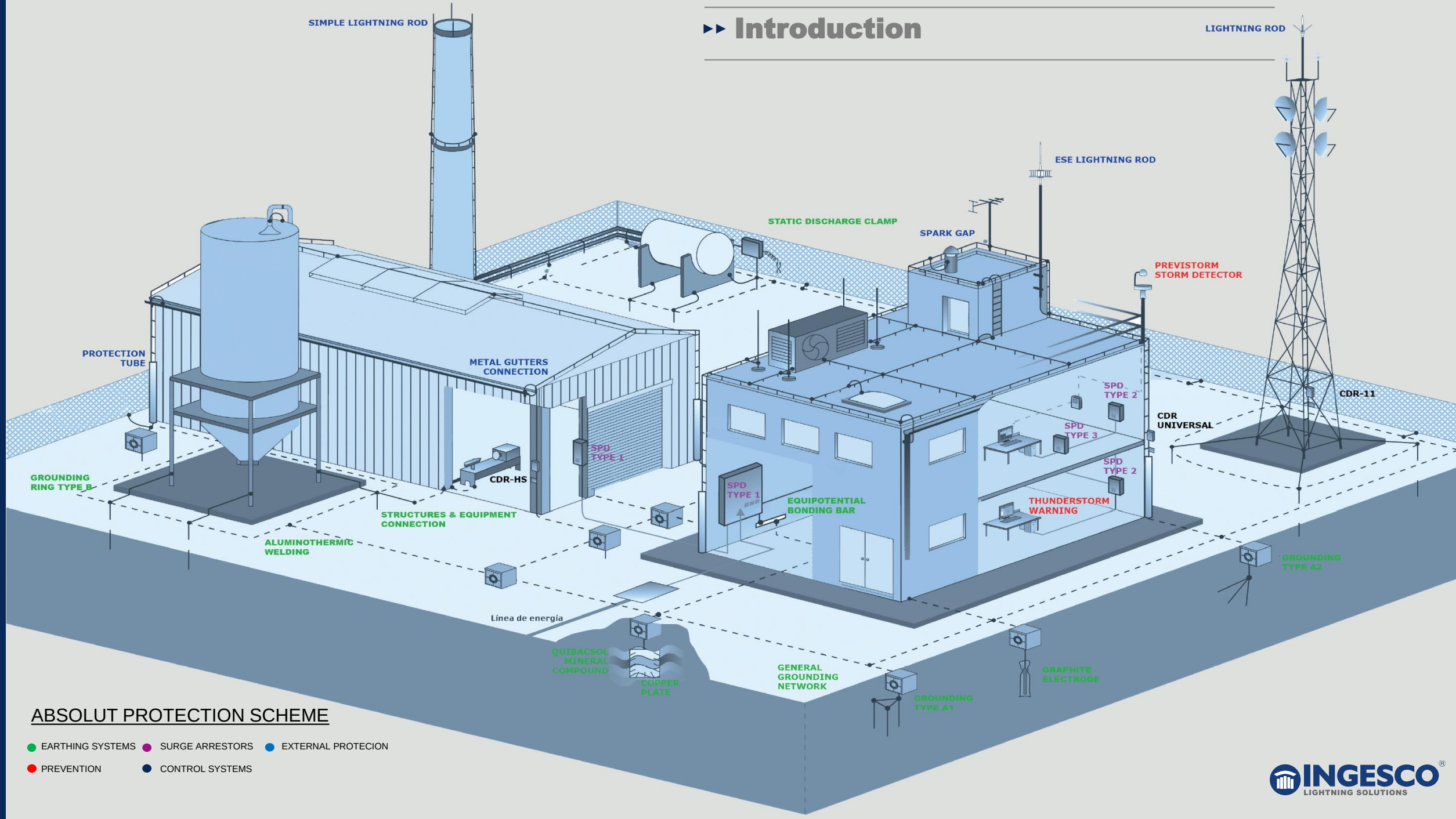
Upward leaders from many buildings - Brazil (40.000 fps)

G-C Ground to cloud lightning in a telecom tower

Upward leader from a telecom tower



▸▸ Introduction



ABSOLUT PROTECTION SCHEME

- EARTHING SYSTEMS
- SURGE ARRESTORS
- EXTERNAL PROTECION
- PREVENTION
- CONTROL SYSTEMS

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2. External protection

(Lightning rods)

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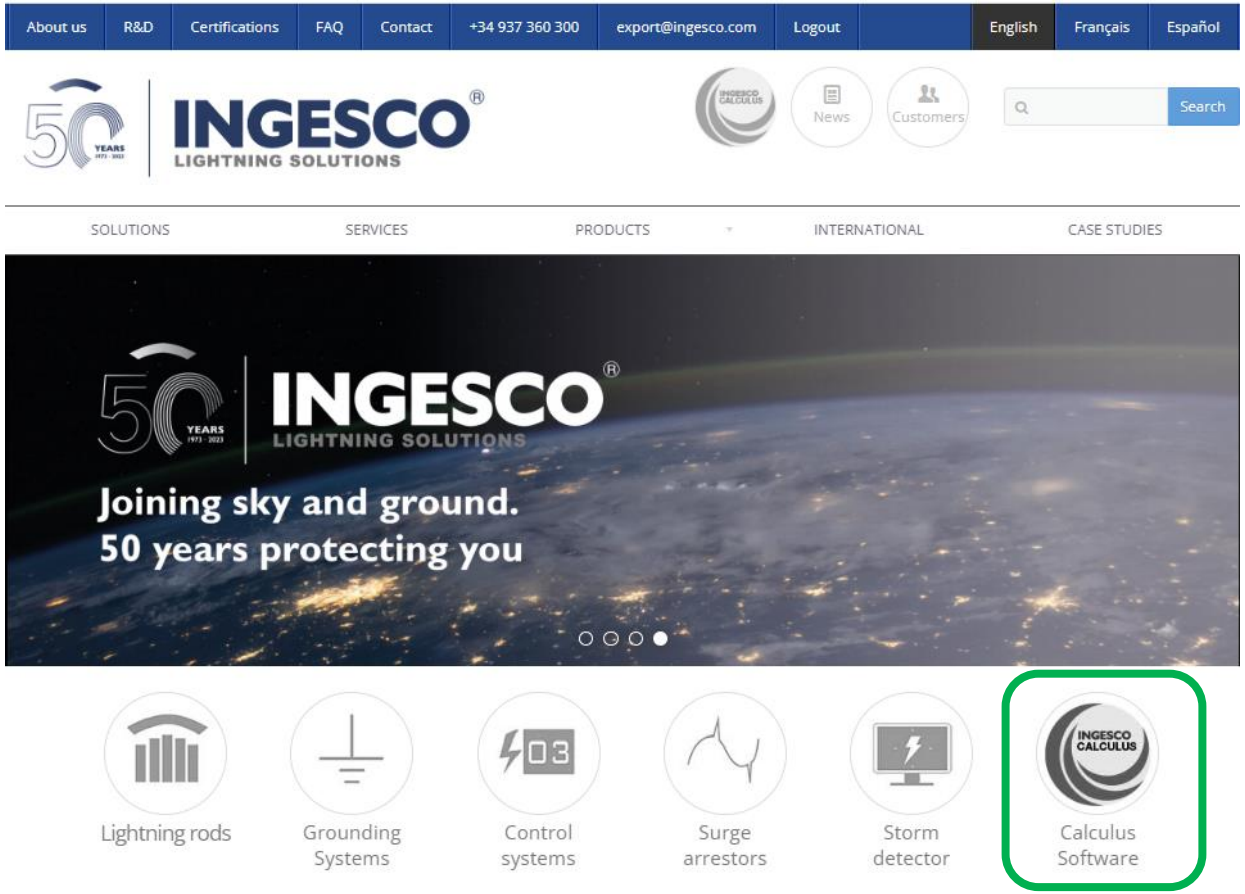


http://calculus.ingesco.com/

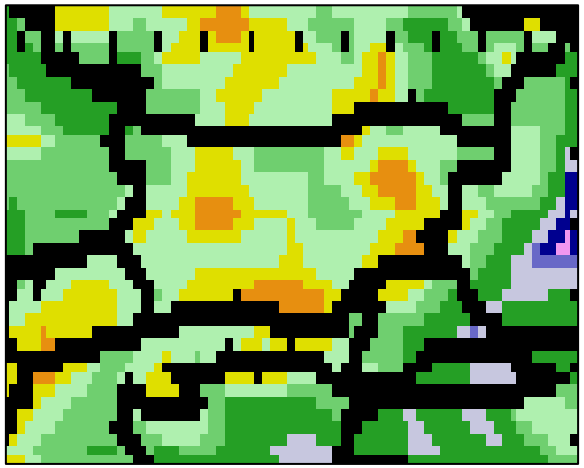
New INGESCO software online:

To calculate whether lightning protection system needs to be installed in a building or structure, we must perform a risk analysis.

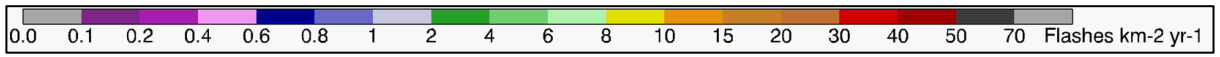
This **risk assessment due to lightning** is performed following the guidelines of the **standard IEC 62305-2: 2010** or Annex A – NF C 17-102: 2011

At your disposal INGESCO puts a new online tool with new functions to determine if the installation of a lightning protection system is necessary.

❑ Thunderstorm days – Bulgaria



(N_t) Map of flashes/year *km^2



Bulgaria keraunic levels:

- **The higher the keraunic level** of where our building or structure is located, the higher the risk of losses due to lightning.
- The isokeraunic areas which appear on the map indicate the **N_t** value.
- **N_t** = Corresponds to the total density (CG + IC) of optical flashes recorded per year and per km^2
- **N_G**= number of lightning strikes / (year* km^2)
- **T_D** = is the **number of thunderstorm days per year** – Source: IEC 62305-2:2010

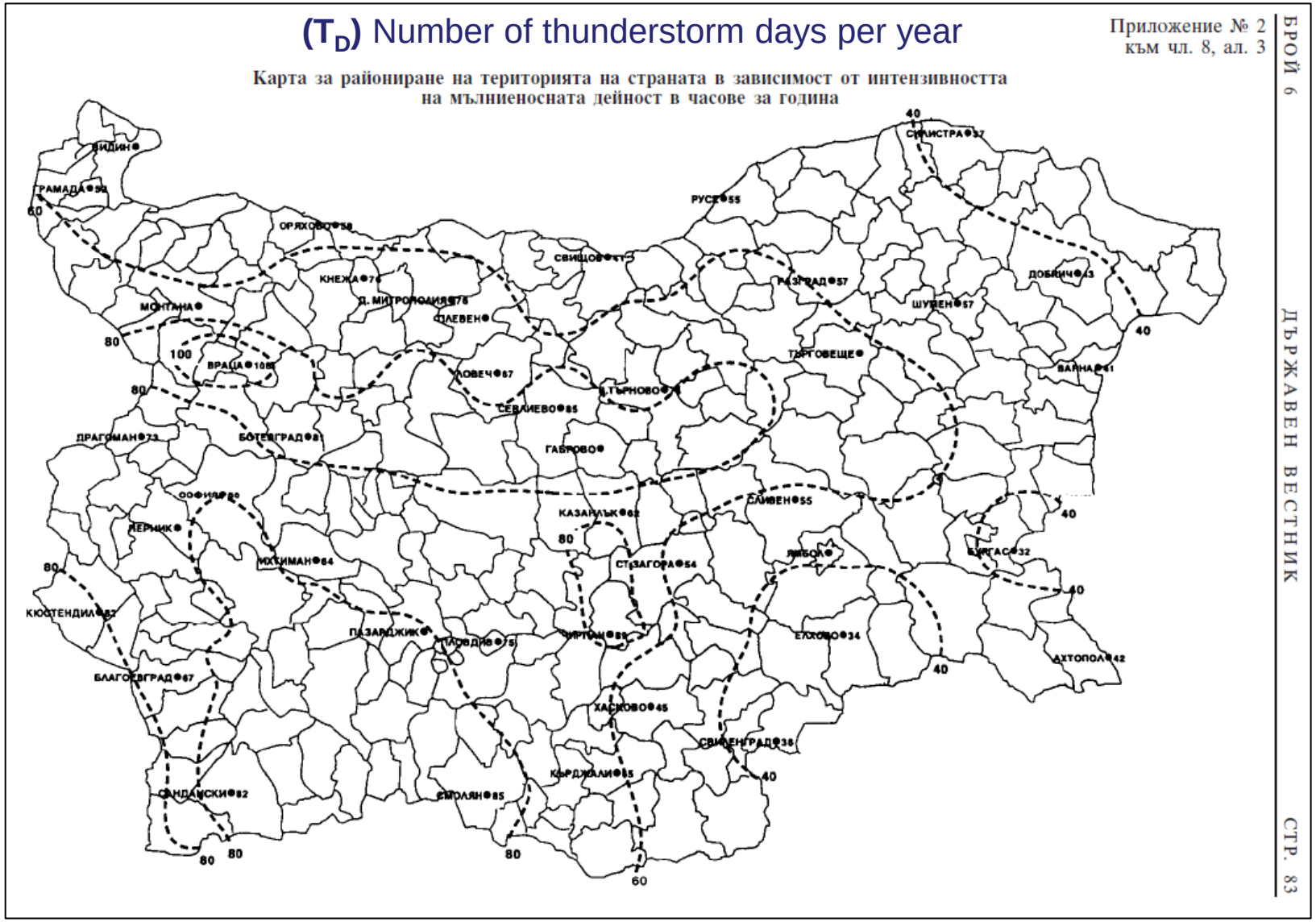
$$N_G = 0{,}25 * N_t$$

$$N_G \approx 0{,}1 * T_D$$

Source: IEC 62858:2019

https://ghrc.nsstc.nasa.gov/pub/lis/climatology/LIS-OTD/HRFC/browse/HRFC_COM_FR_V2.3.2015.png

❑ Thunderstorm days – Bulgaria



SOURCE: BULGARIA REGULATION NO 4 of 22 December 2010 - On the lightning protection of buildings, outdoor facilities and open spaces.

▸▸ 1.- When a LPS is required?

Example: Gallery Mall

7. Protective measures *

Protection level (PB) *
II

Protection type *
ESE Lightning rod

Surge protection (PSPD) *
IV

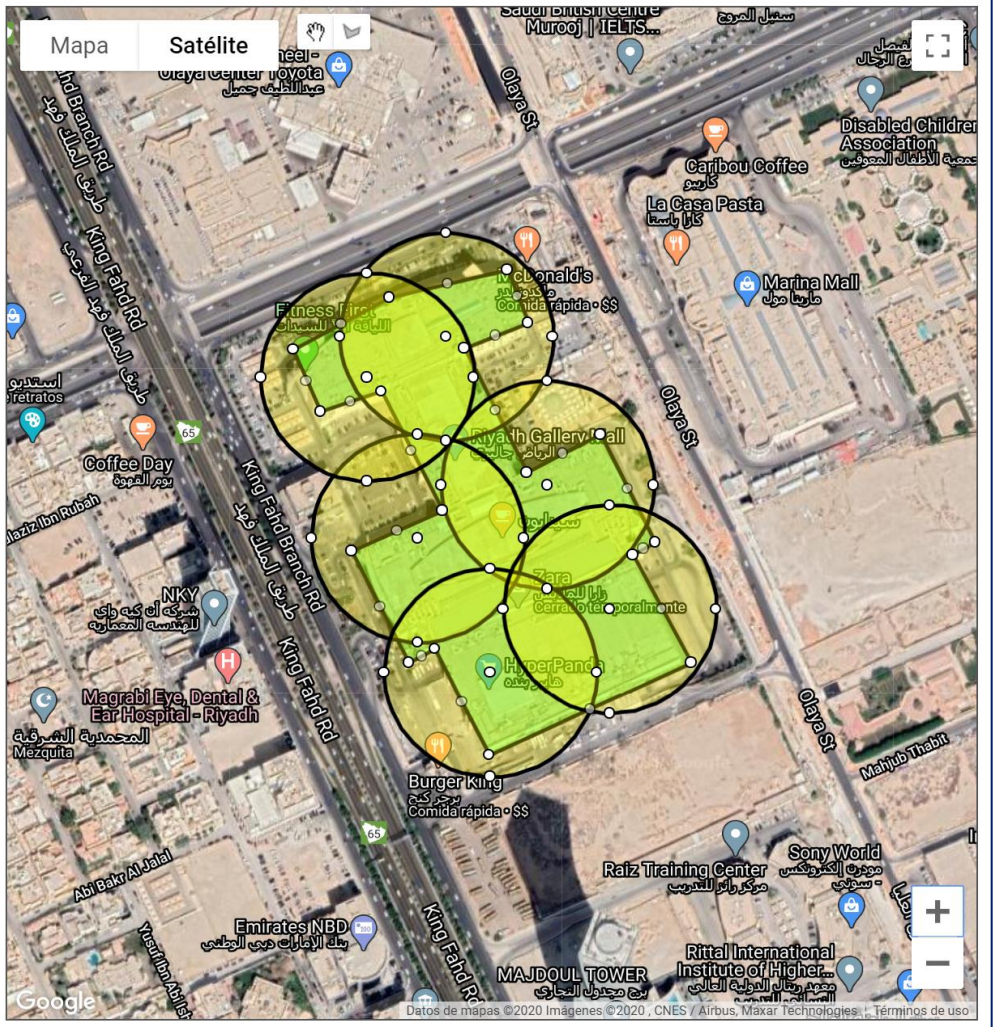
Fire protection (rp) *
Manual systems (Extinguisher, hydrnts, fire c

Complementary measures of protection (PTA) *
No protection measures

Risk of loss of human life - R1	Risk of loss of the sevice to the public - R2	Risk of loss of cultural heritage - R3	Risk of loss of economic value - R4
Tolerable: 1.0E-5	Tolerable: 0.001	Tolerable: 0.0001	Tolerable: 0.001
2.509646e-6	0.000000e+0	0.000000e+0	4.038764e-4

Save project and continue

Location of buildings



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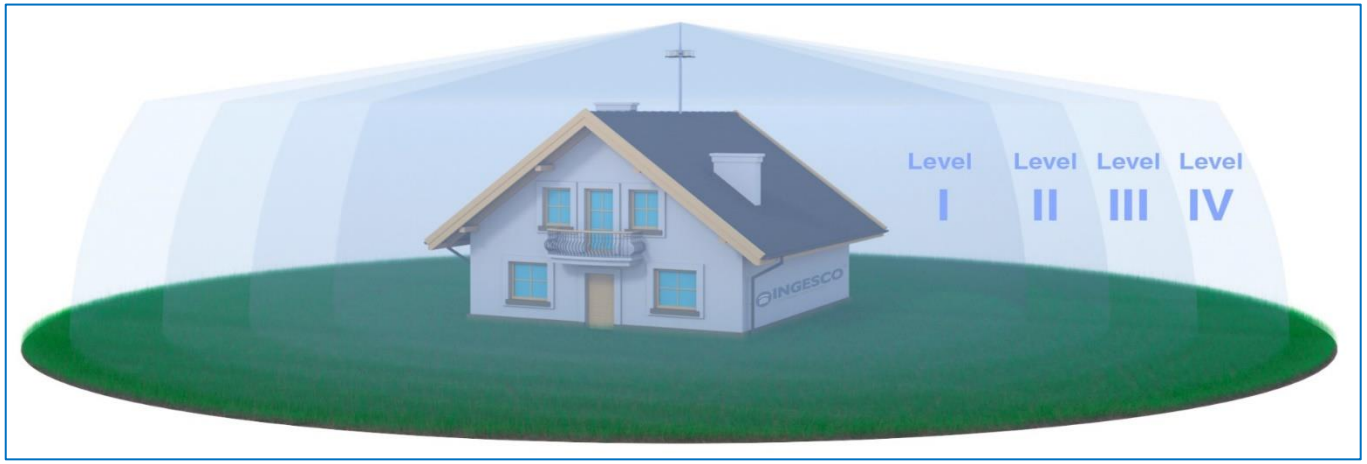
❑ Protection levels:

▸▸ 2.- Protection levels (I, II, III, IV)

Note: Level 1 offers BEST & SAFEST PROTECTION

Structure characteristics	Protection level	Probability P_B IEC 62305-2	Lightning rod efficiency
Structure NOT protected	-	1	-
Structure protected by a lightning rod installation	Level 4	0,2	80%
	Level 3	0,1	90%
	Level 2	0,05	95%
	Level 1	0,02	98%



Source IEC 62305-2:2010

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Чл. 13. При проектирането на мълниезащитни уредби по нива на мълниезащита се прилагат следните нива на мълниезащита съобразно ефективността на мълниезащитните уредби:

1. ниво на мълниезащита I (**ниво I**) - при ефективност на мълниезащитната уредба **над 0,98**;

2. ниво на мълниезащита II (**ниво II**) - при ефективност на мълниезащитната уредба **над 0,95 до 0,98;**

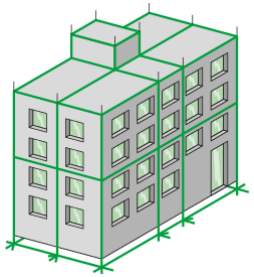
3. ниво на мълниезащита III (**ниво III**) - при ефективност на мълниезащитната уредба **над 0,80 до 0,95;**

4. ниво на мълниезащита IV (**ниво IV**) - при ефективност на мълниезащитната уредба **до 0,80**

Source: **НАРЕДБА № 4 от 22 декември 2010**

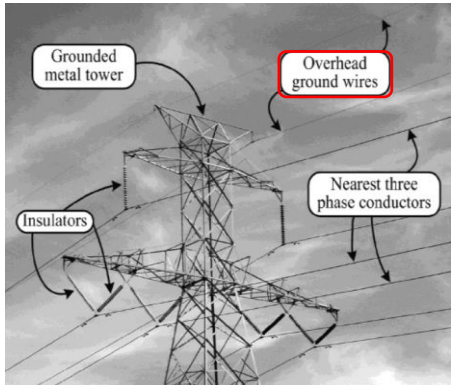
▸▸ 3.- Different types of lightning rod

Passive systems:



Faraday cage

Franklin rods

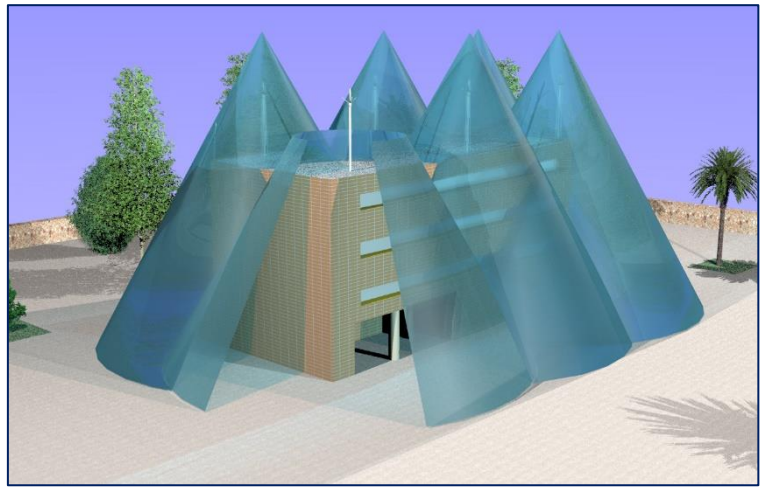


Catenary or overhead cable

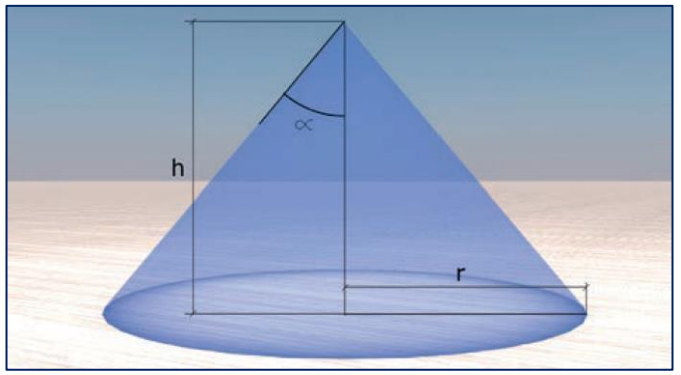
Early Streamer Emission (ESE):

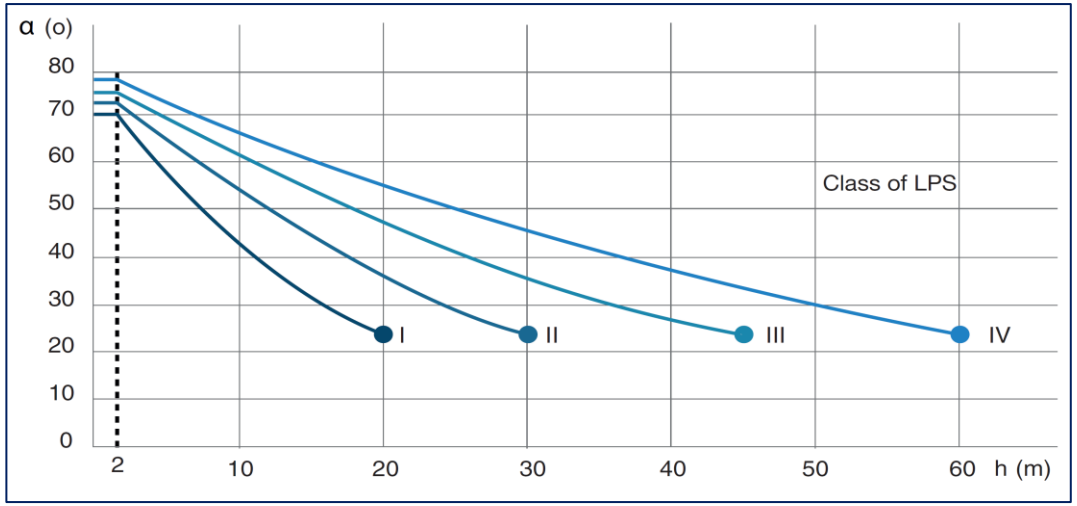
ESE AIR 60

❑ Franklin rod – Protection angle



▸▸ 3.- Different types of lightning rod





NOTE 1: Not applicable beyond the values marked with ● Only rolling sphere and mesh methods apply in these cases.
NOTE 2: *h* is the height of air-termination above the reference plane of the area to be protected.
NOTE 3: The angle will not change for values of h below 2 m.

Source IEC 62305-3:2010

Franklin rod – Example in HV / MV substations

Franklin rod

Catenary or overhead cable

Early Streamer Emission E.S.E
INGESCO AIR:

100%
Efficiency

High protection
class

200kA
Tested

ΔT= 60 µs
Maximum value permitted

AISI 316L
Stair

Electronic
System technology

QR
Authentication

Made in **Spain**

INGESCO® ESE AIR 60
Electronic lightning rod

Old radioactive lightning rods

PROHIBITION OF THE RADIOACTIVE LIGHTNING ROD – IEC 62305-3

5.2 Air termination systems

5.2.1 General

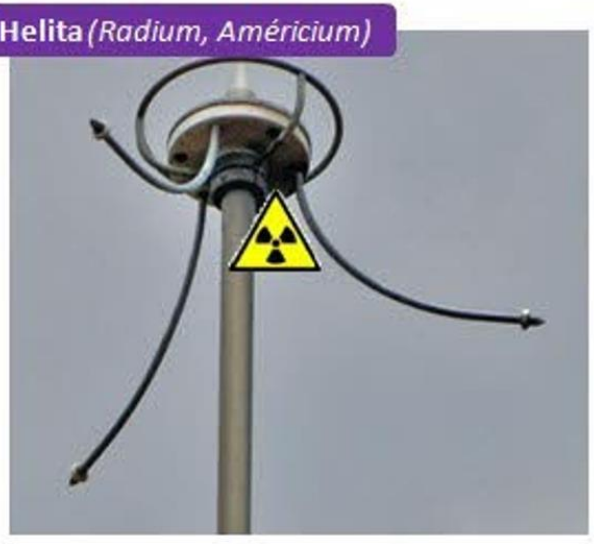
The probability of structure penetration by a lightning current is considerably decreased by the presence of a properly designed air termination system.

The air termination systems can be composed of any combination of the following elements:

a) rods;
b) catenary wires;
c) meshed conductors.

To comply with this standard all types of air termination systems shall be positioned in accordance with 5.2.2, 5.2.3 and Annex A.

Radio-active air terminals are not allowed.



ESE INGESCO – Protection radius according NF C17-102 standard

To calculate the radii of the lightning rod (depending on the building height and protection Level) we must use **2 different calculation methods:**

when 2 ≤ h ≤ 5

$$Rp = \frac{h \cdot Rp(h=5)}{5} = \frac{h \cdot \sqrt{2 \cdot r \cdot 5 - 5^2 + \Delta \cdot (2 \cdot r + \Delta)}}{5}$$

when h ≥ 5

$$R_p = \sqrt{2rh - h^2 + \Delta(2r + \Delta)}$$

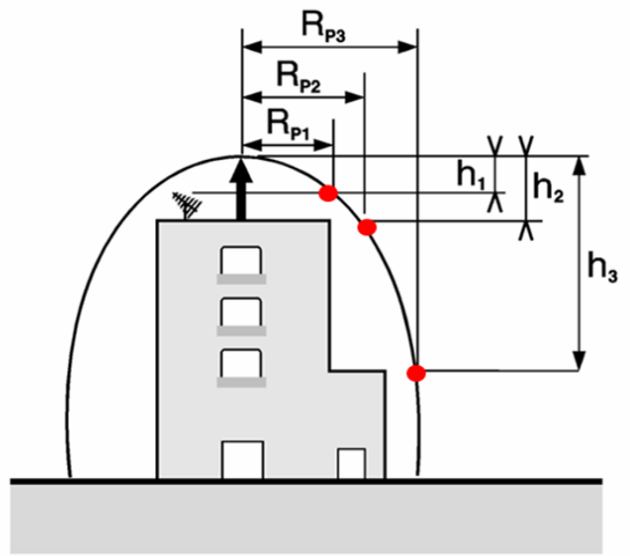
Rp (m): Protection radius

h(m): it is the height from the top of the lightning rod to the plane that we want to calculate the protection radius.

Δ(m): it is the early streamer emission (you can find this data in the INGESCO catalogue), but expressed in meters (m), because the velocity of the upward and downward leader is 1m/μs

r (m): **r = 20m** in level of protection I
r = 30m in level of protection II
r = 45m in level of protection III
r = 60m in level of protection IV

$$\Delta = \Delta T \cdot 10^6$$

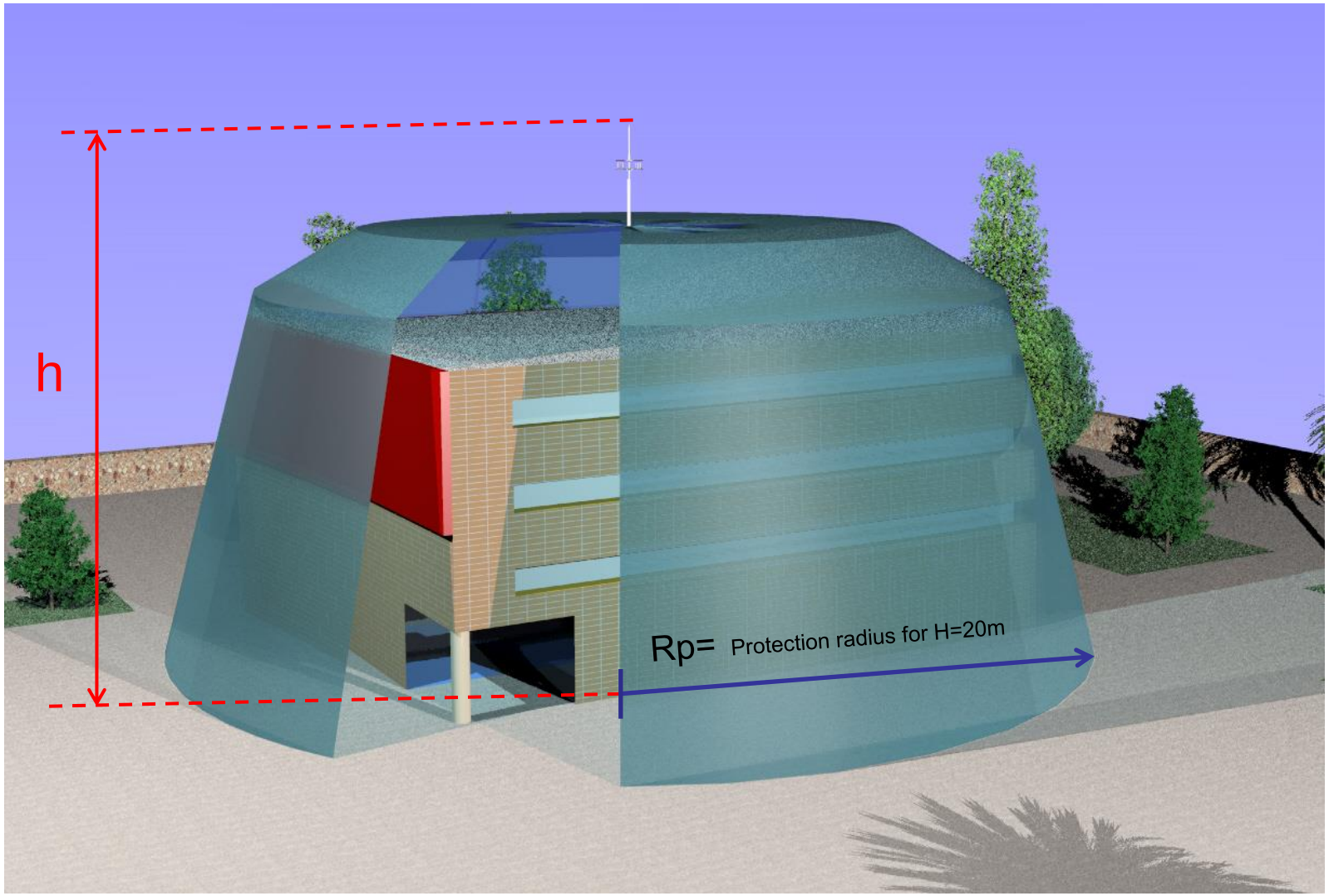


Ниво на **защита**	Съгласно норма **UNE** 21.186:2011 и **NFC** 17.102:2011		
	PDC**AIR20** *20μs*	PDC**AIR40** *40μs*	PDC**AIR60** *60μs*
Ниво I	40 m	60 m	80 m
Ниво II	49 m	69 m	89 m
Ниво III	60 m	81 m	102 m
Ниво IV	70 m	92 m	113 m

These protection radii **Rp** have been calculated when h=20 m

Source NF C 17-102:2011

Lightning rod ESE – Protection volume

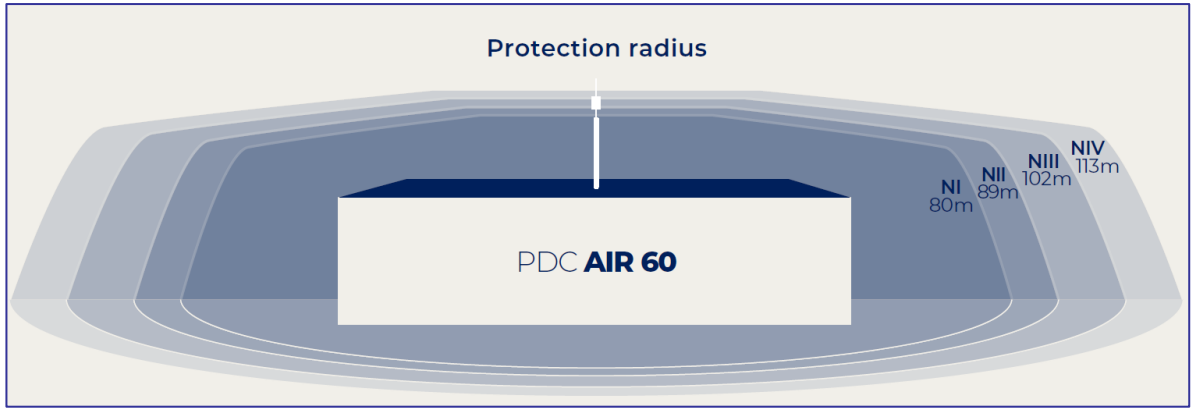


INGESCO® ESE AIR 60
Electronic lightning rod

Ниво на **защита**	и **NFC** 17.102:2011
	PDC**AIR60** *60µs*
Ниво I	80 m
Ниво II	89 m
Ниво III	102 m
Ниво IV	113 m

Source NF C 17-102:2011

Protection radius of an ESE AIR:



➢ **3 Models:**

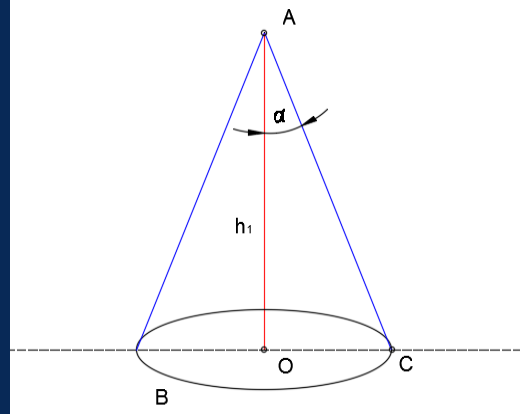
ESE AIR20 **ESE AIR40** **ESE AIR60**

Model	ESE AIR20	ESE AIR40	ESE AIR60
Δt	20µs	40µs	60µs
LEVEL 1	40 m	60 m	80 m
LEVEL 2	49 m	69 m	89 m
LEVEL 3	60 m	81 m	102 m
LEVEL 4	70 m	92 m	113 m

Source NF C 17-102:2011

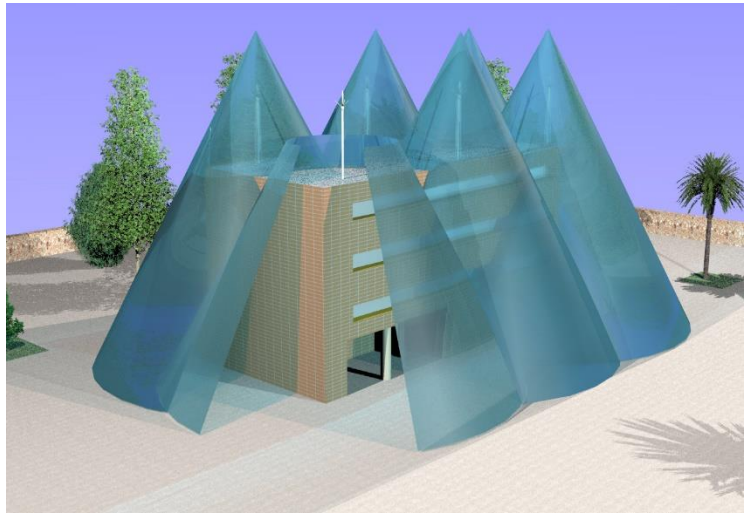
Difference FRANKLIN vs PDC :

Franklin rod
Protection angle 45º approx.



Key:

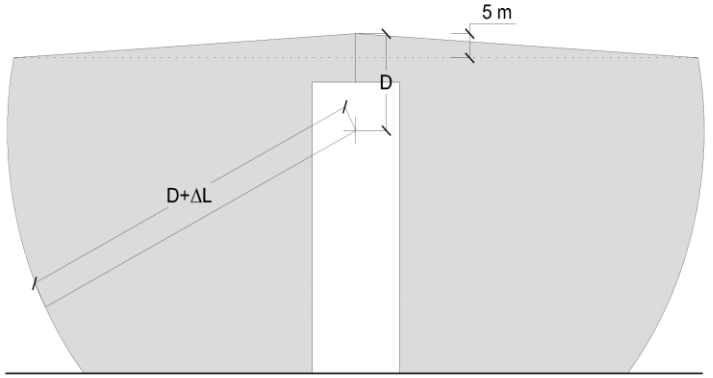
A tip of an air-termination rod
B reference plane
OC radius of protected area
h1 height of an air-termination rod above the reference plane of the area to be protected
α protection angle



Source IEC 62305-3:2010

▸▸ 4.- Calculation of protection radius

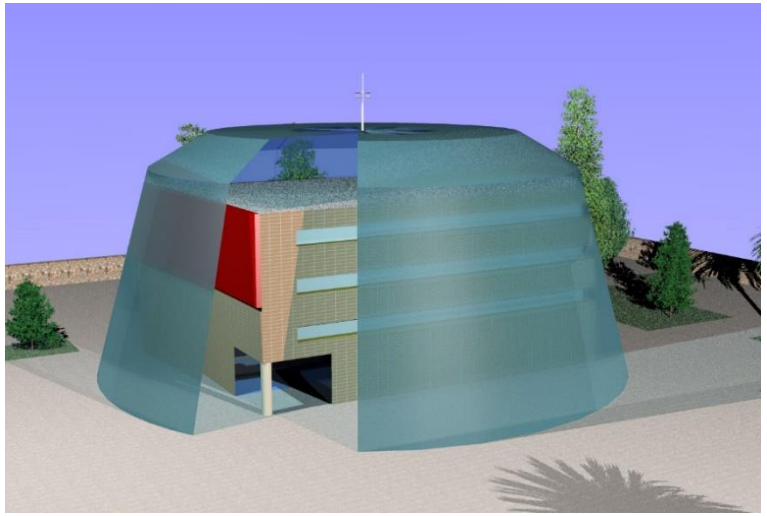
ESE lightning rod
Up to 120m protection radius in LEVEL 4



Key:

D = 20m ; level of protection I
D = 30m ; level of protection II
D = 45m ; level of protection III
D = 60m ; level of protection IV

ΔL(m) = ΔT (μs)



Source CTE DB SUA-8:2010

INGESCO®
ESE AIR 60

Product	Image	Ref.	Description	Total
1		102010	PDC AIR 60	1
2		111011	1'1/4" Ø20 round adapter piece	1
3		114065	5.8 m Ø 1'1/2"+ Ø 1'1/4 steel mast	1
4		112024	Ø1'1/2" plate anchor 15	1
5		115056	"T" Sleeve	1
6		116062	Spark gap	1
7		115097	35-120 mm² toothed flat cable terminal	1
8		117072	Cable Cu 50mm²	ml
9		118109	M8 folding clamp for 50-70mm² cable	3 por m
10		430019	Lighting counter CDR-11	1
11		119109	Galv. steel tube	2
12		256003	Safety sign	2
13		253058	PP earthing case and cover	2
14		250027	Equipot. bar of 3-terminal case	2
15		115104	Type C connection	2
16		254041	Quibacsol 10 kg	2
17		115055	Ø14 conductor-earthing rod connector for 50-70 mm² cable	6
18		252029	Ø14 steel Cu 2000 earthing rod	6

▸▸ 5.- Items for an ESE installation

1.- ESE lightning rod

2.- Adaptation piece

3.- Mast

4.- Anchoring

5.- Down conductor

6.- Fixings

7.- Connectors

8.- Lightning counter

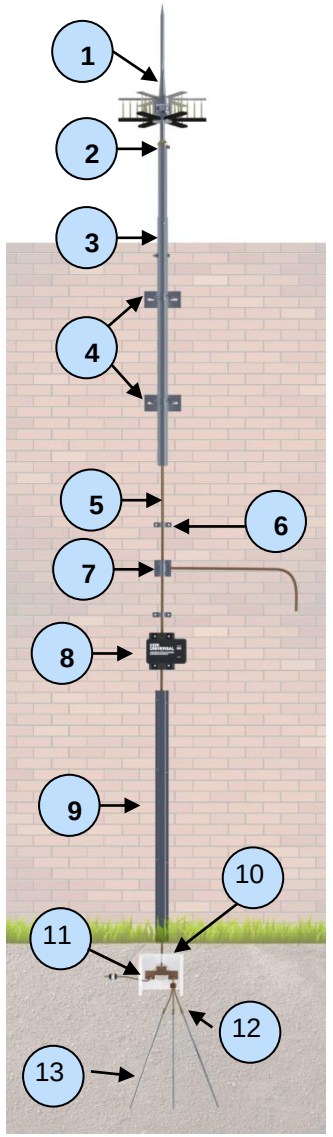
9.- Protection pipe

10.- Manhole with cover

11.- Disconnector

12.- Earthing connectors

13.- Earthing rods



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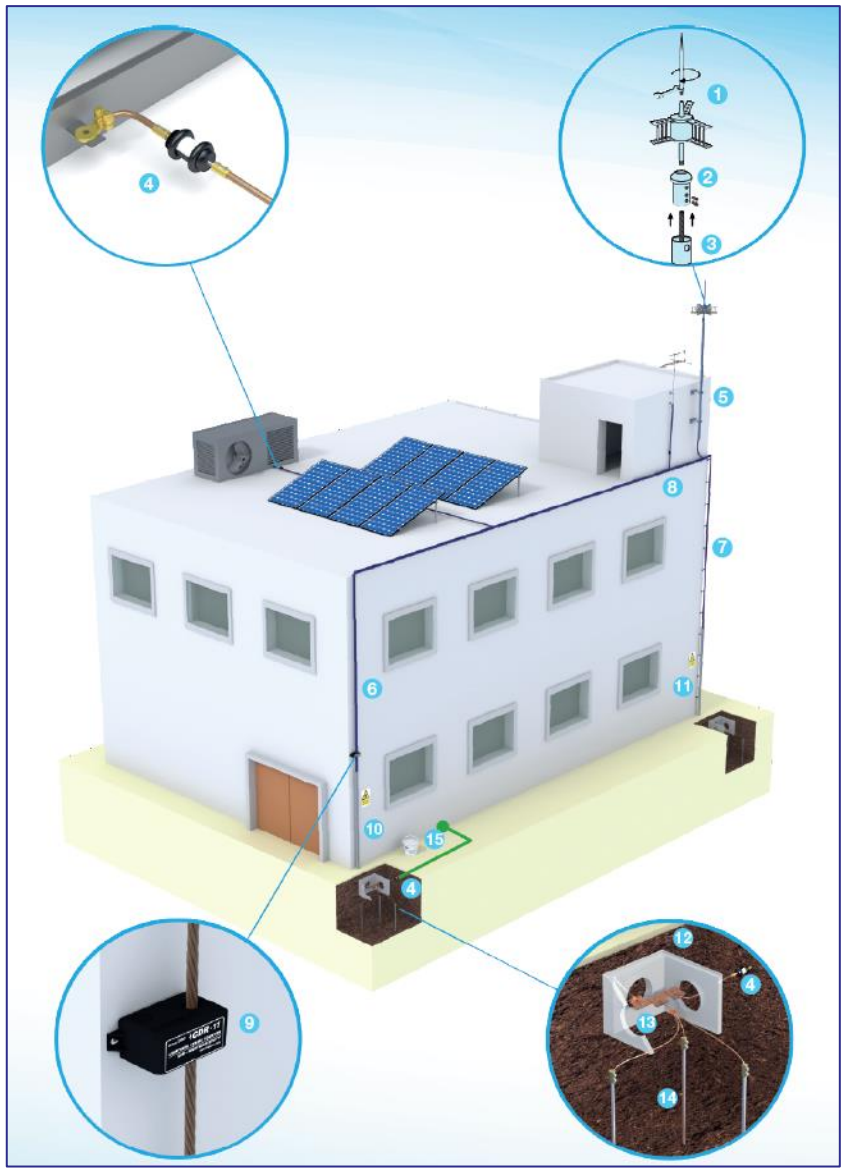
❑ ESE lightning rod installation diagram:

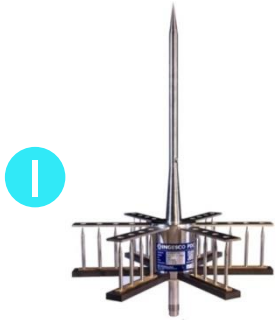


▸▸ 5.- Items for an ESE installation

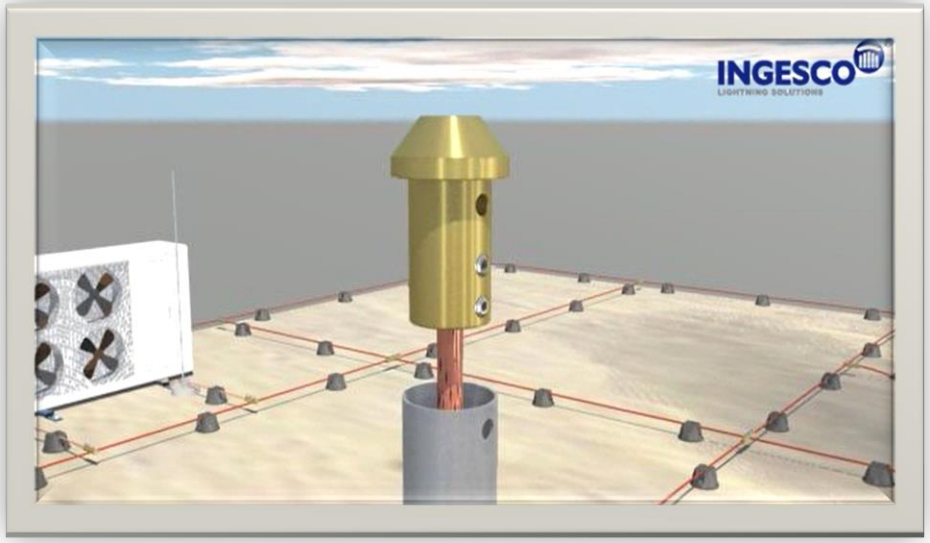
1. Lightning rods INGESCO PDC 6.4 - Ref: 101009
2. Adapter piece lightning rod to mast - Ref: 111011
3. Mast 5'8m - Ref: 114065
4. Spark Gap VX-1- Ref: 116061
5. Set of plate anchors for wall anchoring - Ref: 112024
6. 50mm² section copper cable - Ref:117072
7. Cable fixing clamp - Ref: 118082
8. "T" sleeve connector - Ref: 115056
9. INGESCO CDR-11 Lightning Counter - Ref: 430019
10. 2m protective tube - Ref: 119109:
11. Lightning protection sign - Ref: 256003
12. Registry earth case with cover - Ref: 253058
13. Equipotential bar for registry case - Ref: 250027
14. Copper steel earthing rod - Ref: 252029
15. Mineral compound QUIBACSOL - Ref: 254041

Air terminal system

➢ Installation of lightning rods on mast:



ESE 6.4



▸▸ 5.- Items for an ESE installation

Air terminal system

➢ Installation of lightning rods on mast:

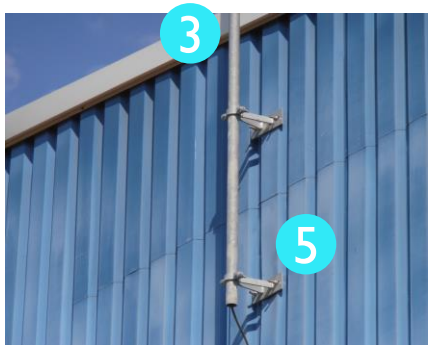
1. Fix the axis of the lightning rod with the adapter piece into the mast.

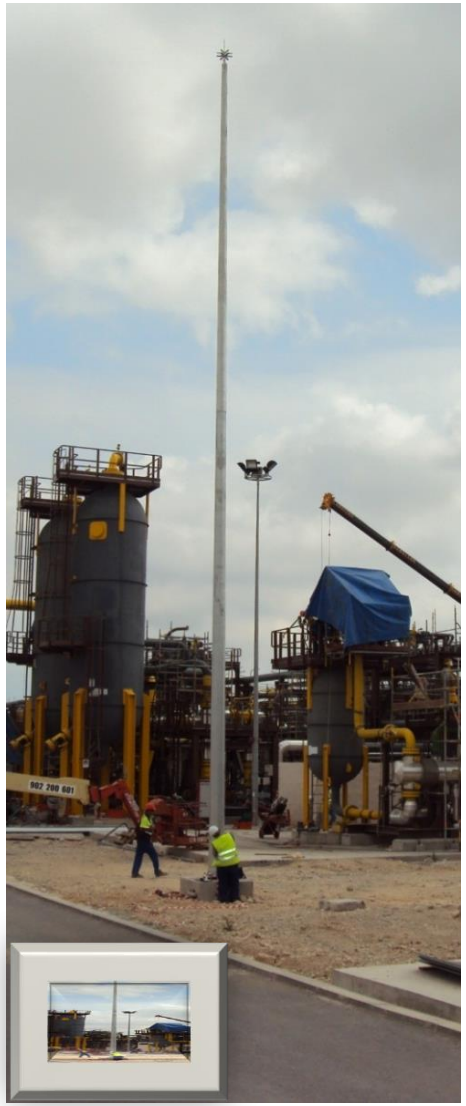
2. Pass the down conductor cable through the interior of the mast and connect it to the base of the adapter piece, fixing it with two screws that serve for cable or plate.

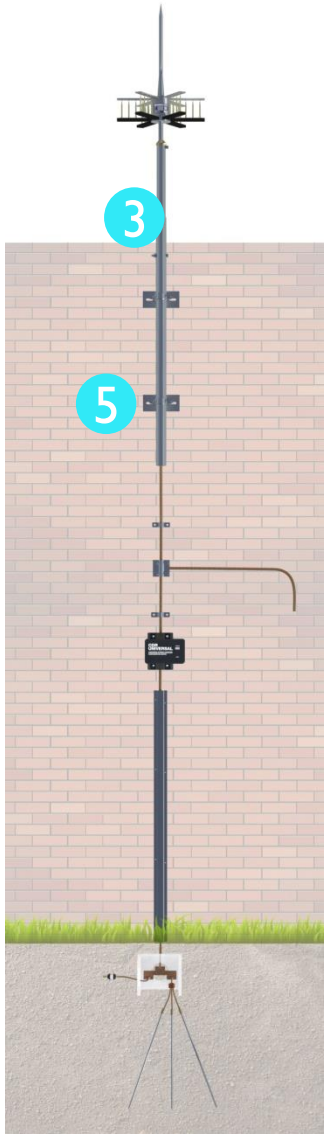
   Attach the adaptation piece inside the mast with its screw.

Video assembly of cable / plate adaptation piece

Mast anchor set







Down conductors

Table 1 – Material, configuration and cross-sectional area of air-termination conductors, air-termination rods, earth lead-in rods[g] and down-conductors

Material	Configuration	Cross-sectional area [a] mm²	Recommended dimensions
Copper, Tin plated copper [b]	Solid tape	≥ 50	2 mm thickness
	Solid round [d]	≥ 50	8 mm diameter
	Stranded [f]	≥ 50	1,14 mm up to 1,7 mm strand diameter
	Rod solid round [h]	≥ 176	15 mm diameter
Aluminium	Solid tape	≥ 70	3 mm thickness
	Solid round	≥ 50	8 mm diameter
	Stranded [f]	≥ 50	1,63 mm strand diameter
Copper coated aluminium alloy [e]	Solid round	≥ 50	8 mm diameter
Aluminium alloy	Solid tape	≥ 50	2,5 mm thickness
	Solid round	≥ 50	8 mm diameter
	Stranded [f]	≥ 50	1,7 mm strand diameter
	Rod solid round [h]	≥ 176	15 mm diameter
Hot dipped galvanized steel	Solid tape	≥ 50	2,5 mm thickness
	Solid round	≥ 50	8 mm diameter
	Stranded [f]	≥ 50	1,7 mm strand diameter
	Rod solid round [h]	≥ 176	15 mm diameter
Copper coated steel [e]	Solid round	≥ 50	8 mm diameter
	Solid tape	≥ 50	2,5 mm thickness
Stainless steel [c]	Solid tape [i]	≥ 50	2 mm thickness
	Solid round [i]	≥ 50	8 mm diameter
	Stranded [f]	≥ 70	1,7 mm strand diameter
	Rod Solid round [h]	≥ 176	15 mm diameter

NOTE For the application of the conductors, see IEC 62305-3.

[a] Manufacturing tolerance: −3 %.

[b] Hot dipped or electroplated; minimum thickness coating of 1 µm. There is no requirement to measure the tin plated copper because it is for aesthetic reasons only.

[c] Chromium ≥ 16 %; nickel ≥ 8 %; carbon ≤ 0,08 %.

[d] 50 mm² (8 mm in diameter) may be reduced to 28 mm² (6 mm in diameter) in certain applications where mechanical strength is not an essential requirement. Consideration should, in this case, be given to reducing the spacing between the fasteners.

[e] Minimum 70 µm radial copper coating of 99,9 % copper content.

[f] The cross-sectional area of stranded conductors is determined by the resistance of the conductor according to IEC 60228.

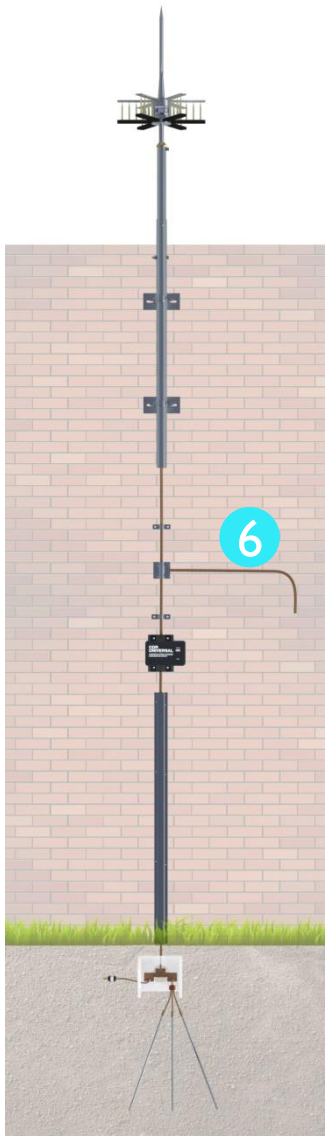
[g] If the earth lead-in rod is partially installed in soil it has to fulfil the requirements of Table 2 and Table 3.

[h] Applicable for air-termination rods and earth lead-in rods. For air-termination rods where mechanical stress such as wind loading is not critical, a 9,5-mm diameter, 1-m long rod may be used.

[i] If thermal and mechanical considerations are important then these values should be increased to 75 mm².

▸▸ 5.- Items for an ESE installation

6



Source IEC 62561-2:2018

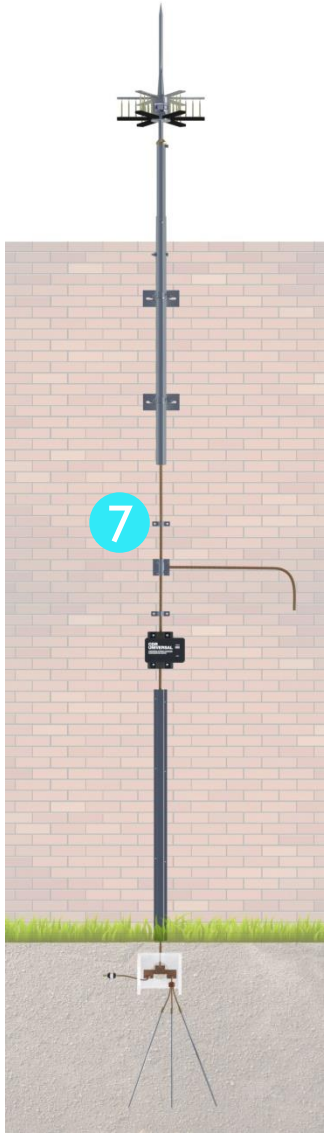
Fastening accessories:

IEC 62561-4

Folding clamps

Light clamps

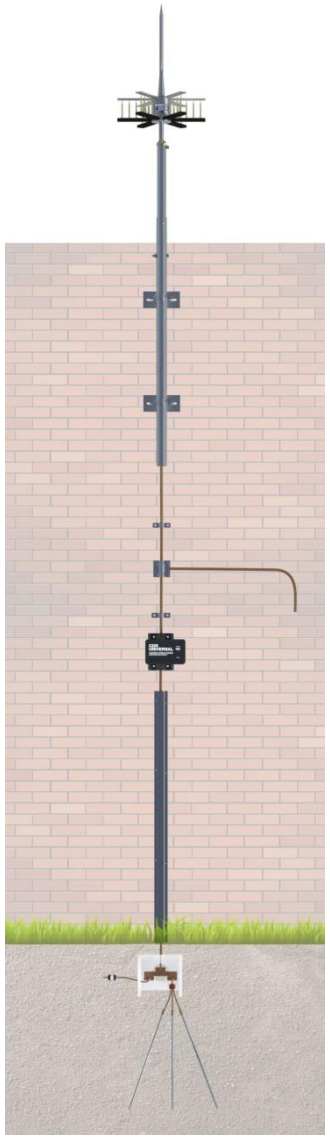
Isolated clamps



Connector types and spark gaps:

Video spark gap installation

4



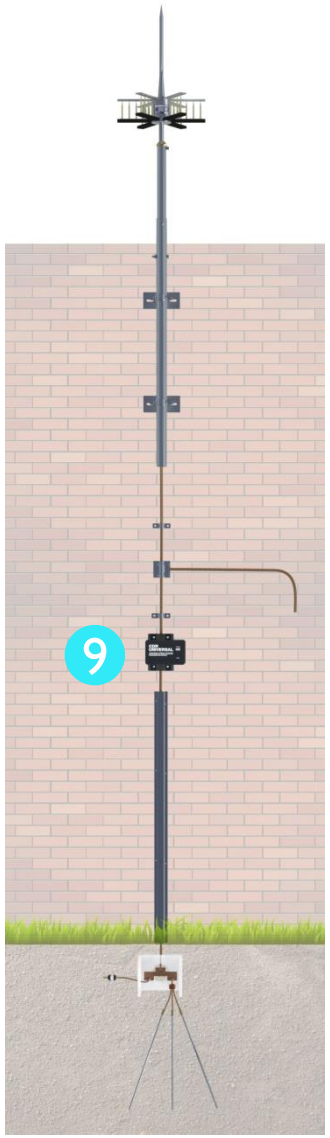
Lightning counters – According IEC 62561-6

CDR UNIVERSAL

CDR-11

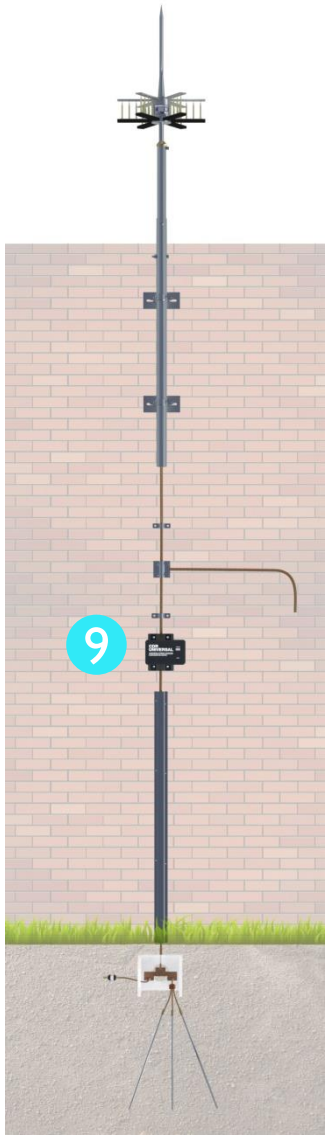
CDR-HS
For Faraday cages
(High sensitivity)

Video CDR-11 lightning counter installation



Lightning counters – According IEC 62561-6

9 Video CDR-UNIVERSAL lightning counter installation



Protection measures against touch voltages

The risk is reduced if one of the conditions is fulfilled:

a) the probability of persons approaching, or the duration of their presence outside the structure and close to the down-conductors, is very low;

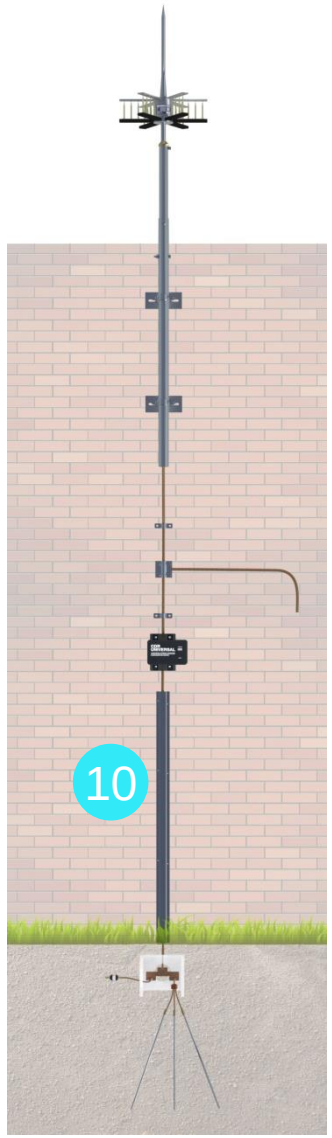
b) the natural down-conductor system consists of typically more than ten columns of the extensive metal framework of the structure or of several pillars of interconnected steel of the structure, with the electrical continuity assured;

c) the contact resistance of the surface layer of the soil, within 3 m of the down-conductor, is not less than 100 kΩ.
NOTE: A layer of insulating material, **e.g. asphalt, of 5 cm thickness (or a layer of gravel 15 cm thick)** generally reduces the hazard to a tolerable level.

If it is not possible:

- insulation of the exposed down-conductor is provided giving a 100 kV, 1,2/50 µs impulse withstand voltage, **e.g. at least 3 mm cross-linked polyethylene**;

- physical restrictions and/or **warning notices** to minimize the probability of down-conductors being touched.



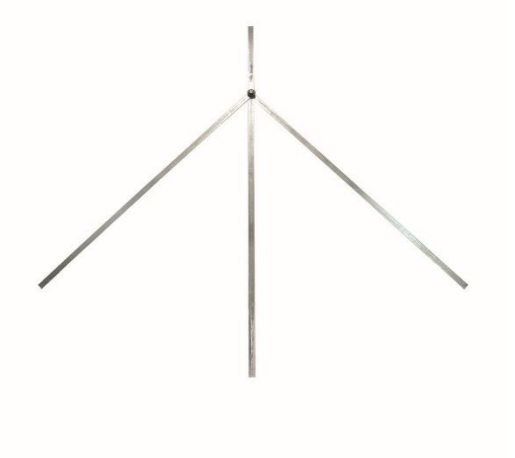
(Source NF C 17-102:2011)

Earthing system

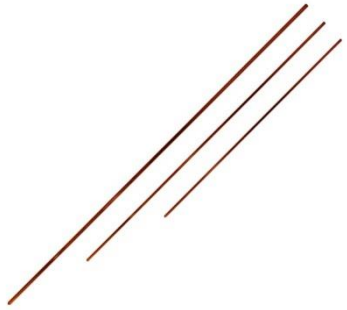
- One earthing system for each down conductor, with 2 electrodes minimum per each one.
- Earthing resistance less than 10Ω.
- Avoid earthing systems with long electrodes (> 20m).
- Earthing systems outside the building

Types:

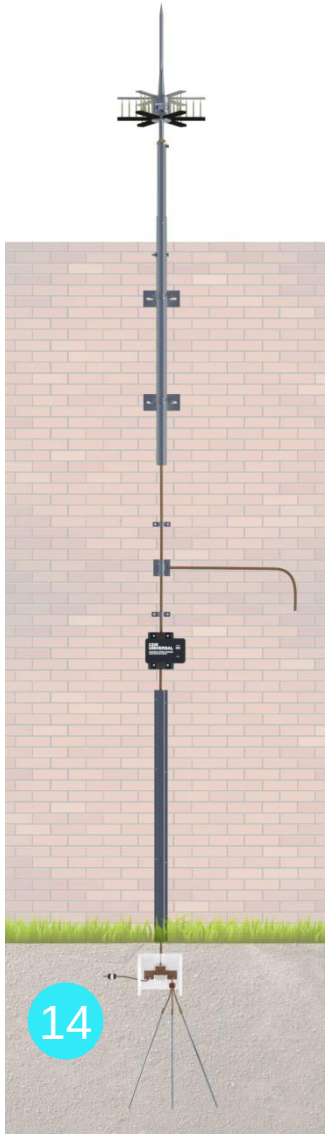
Type A1



Type A2



Type B

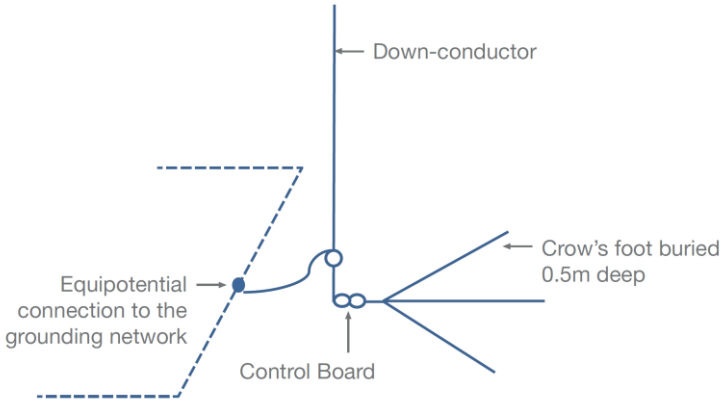


(Source NF C 17-102:2011)

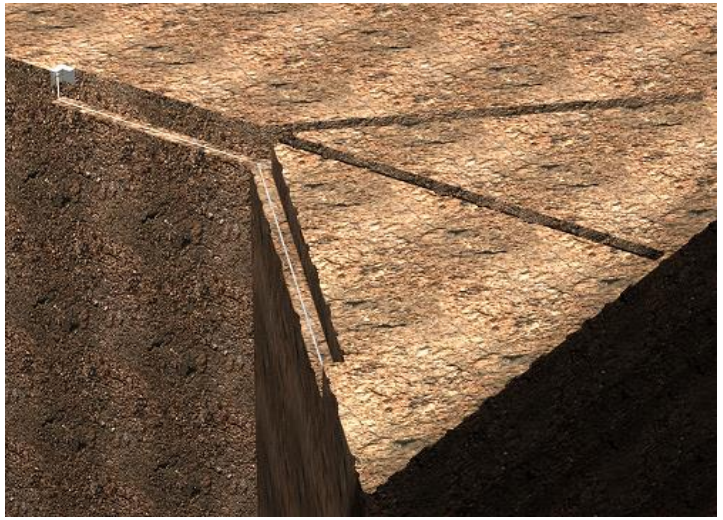
▸▸ 5.- Items for an ESE installation

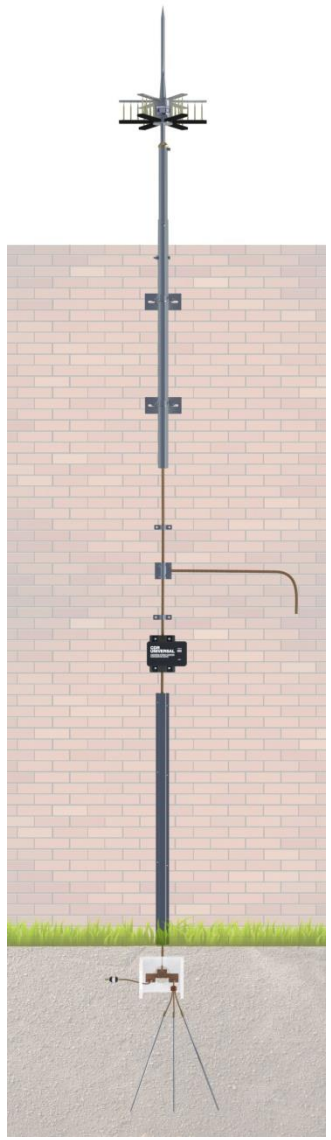
Type – A1

50cm depth



Example of earthing type A1:
*Set of **three horizontal conductors** buried horizontally at a minimum depth of 50 cm and with a length up to 7 or 8m.*

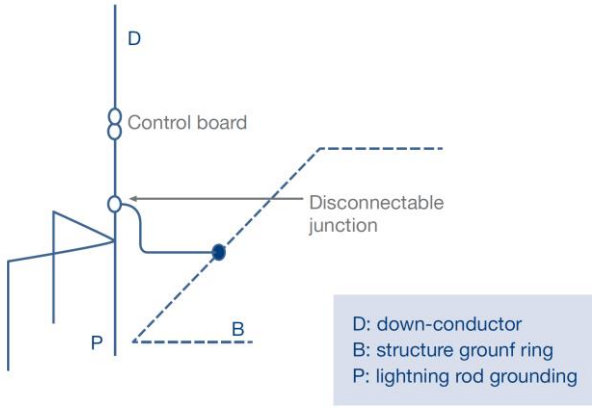




INGESCO LIGHTNING SOLUTIONS

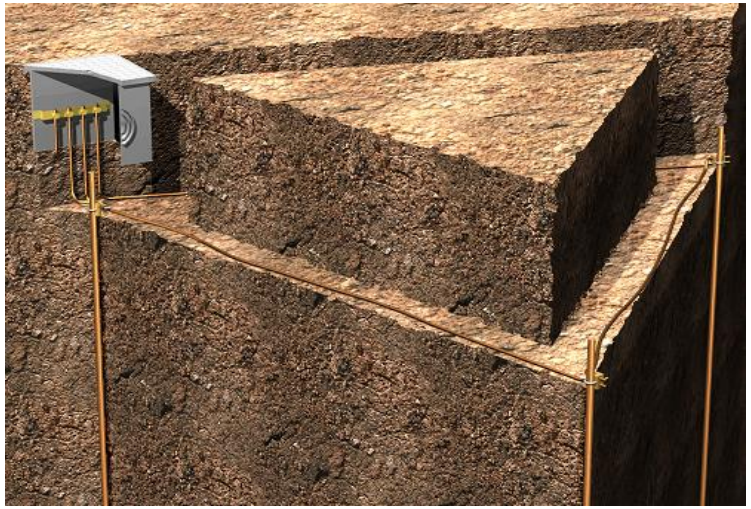
(Source NF C 17-102:2011)

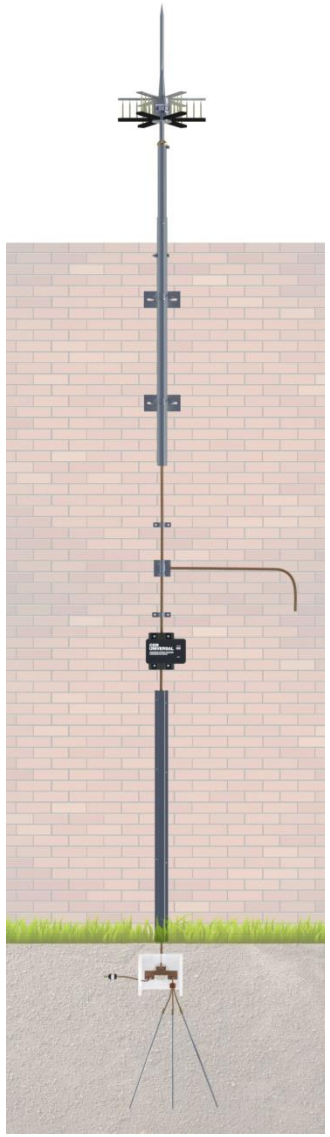
Type – A2



Example of earthing type A2:

*Set of three vertical rods with a minimum length of 6 metres at a minimum depth of 50 cm in a **triangle** and separated from each other by a distance equal to at least the buried length.*

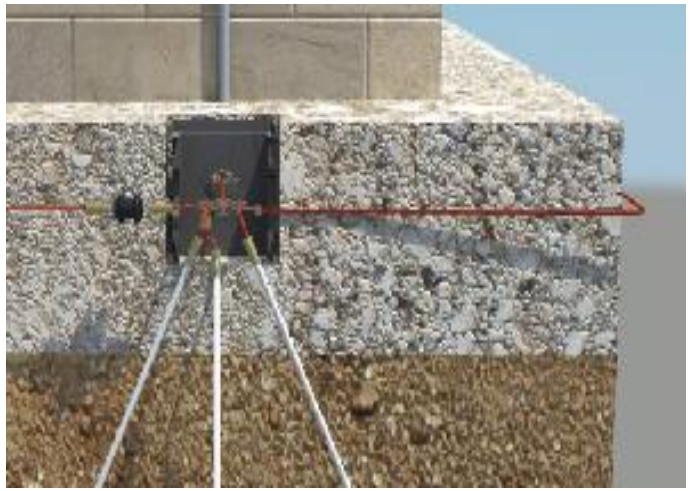




(Source NF C 17-102:2011)

Type – A2

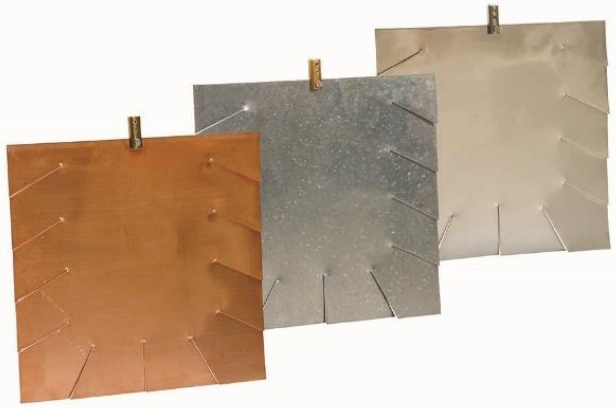
Example of earthing type A2:
set of several vertical rods with a minimum length of 6 metres at a minimum depth of 50 cm ***arranged linearly*** *and separated from each other by a distance equal to at least the buried length; interconnected by a buried conductor which is identical to or has compatible characteristics with the down-conductor.*

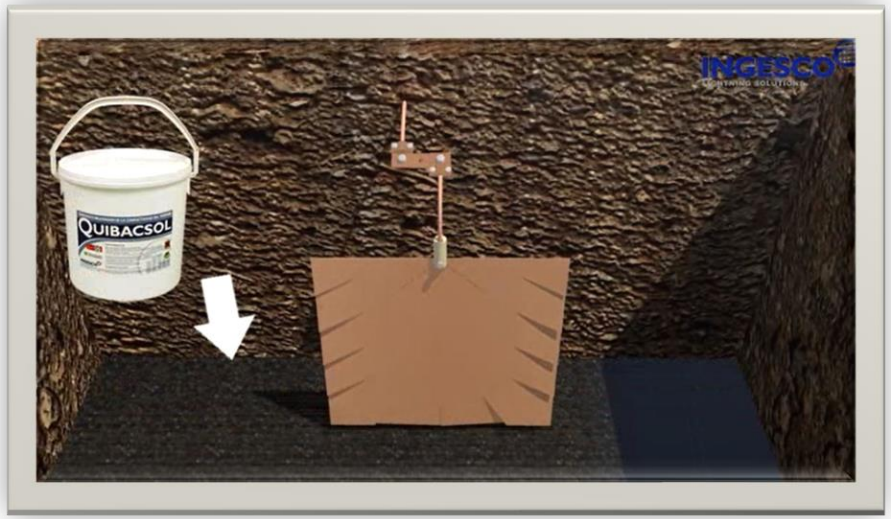


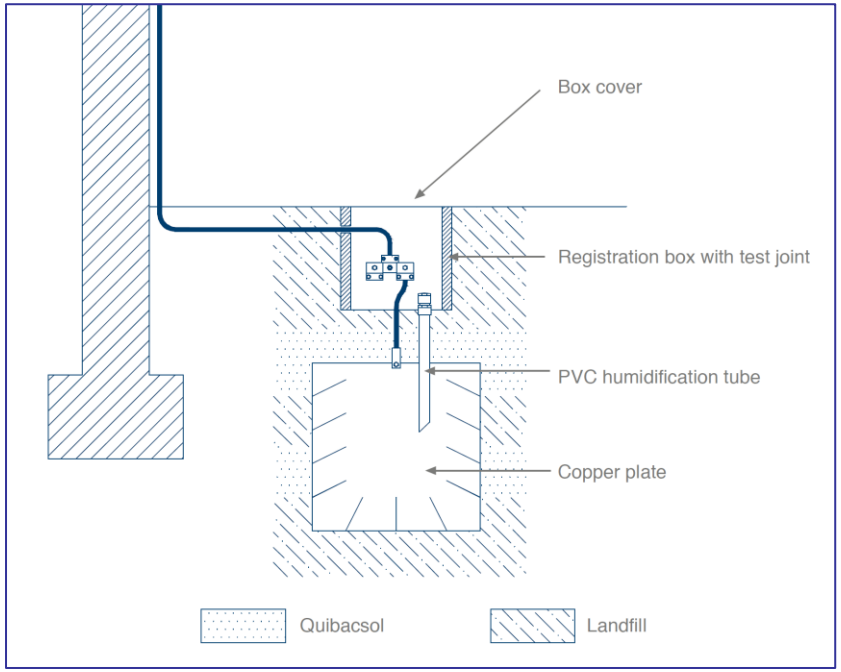
(Source NF C 17-102:2011)

▸▸ 5.- Items for an ESE installation

Type – A2

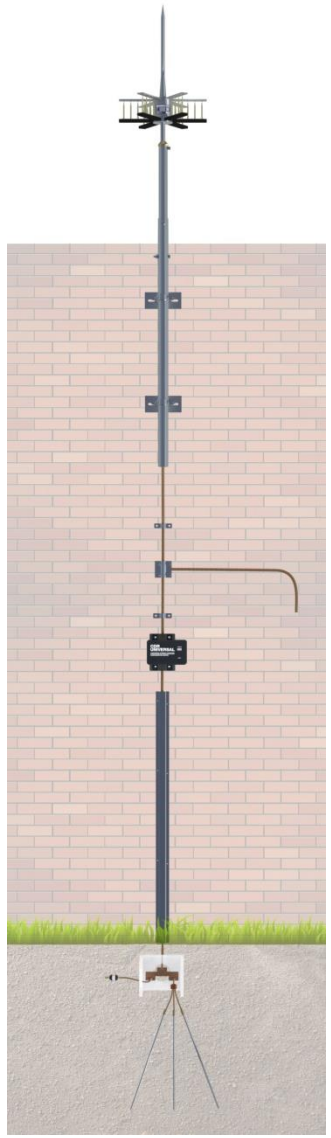






*Example of earthing **type A2:***

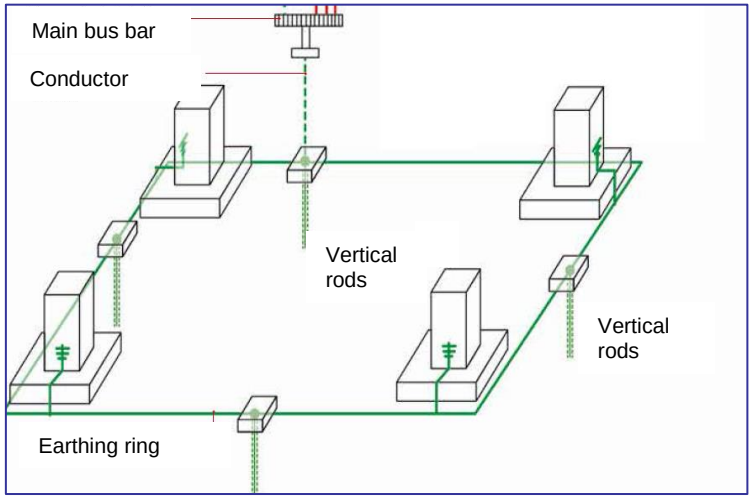
Vertical copper plate with mineral compound to reduce the soil resistivity value.

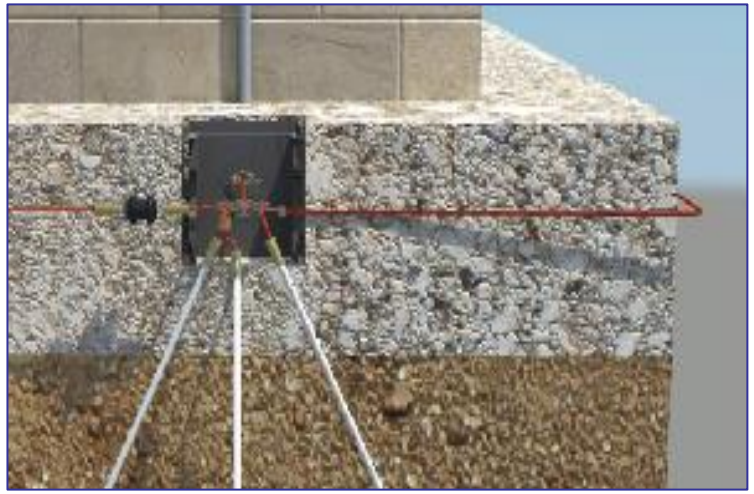


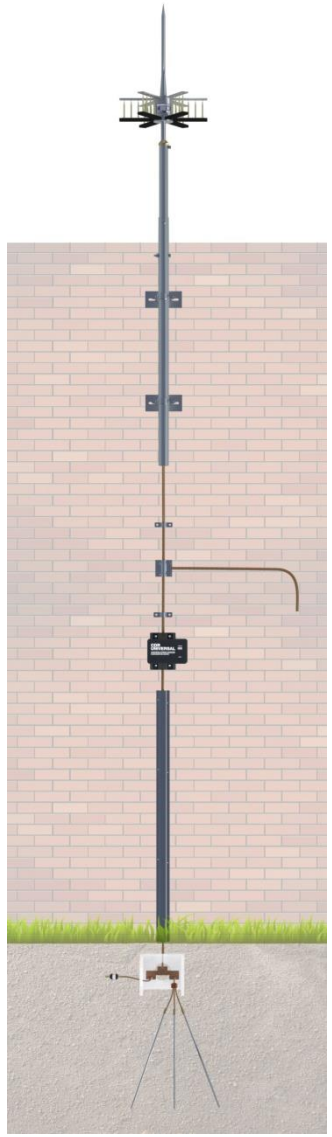
(Source NF C 17-102:2011)

Type – B

▸▸ 5.- Items for an ESE installation







(Source NF C 17-102:2011)

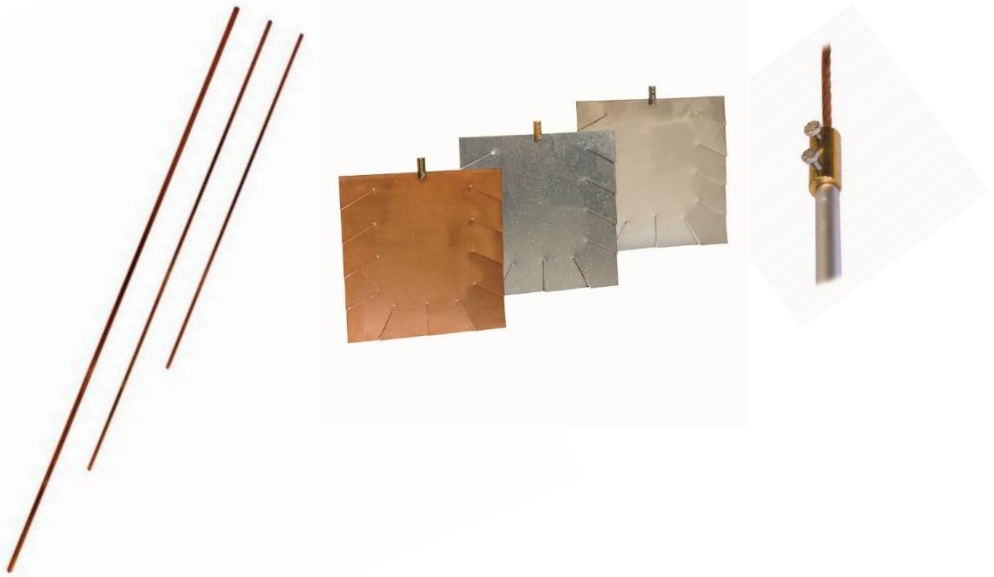
Table 3 – Material, configuration and cross-sectional area of earth electrodes

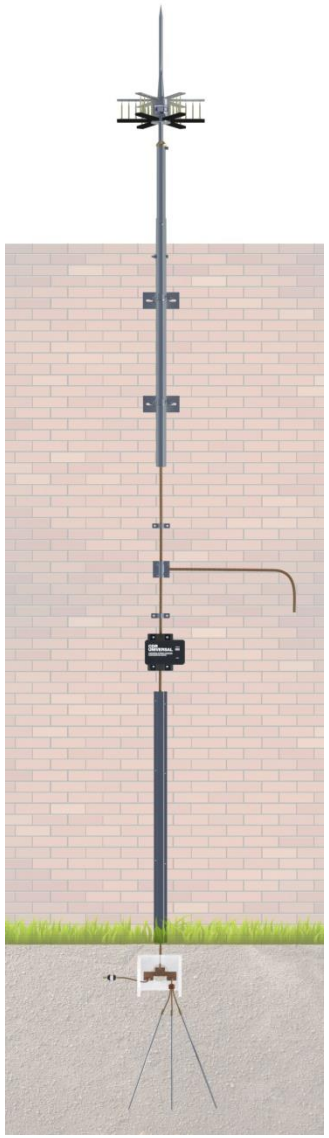
Material	Configuration	Cross-sectional area [a]			Recommended dimensions
		Earth rod mm²	Earth conductor mm²	Earth plate cm²	
Copper, Tin plated copper [f]	Stranded		≥ 50 [i]		1,7 mm strand diameter
	Solid round		≥ 50		8 mm diameter
	Solid tape		≥ 50		2 mm thick
	Solid round	≥ 176			15 mm diameter
	Pipe	≥ 110			20 mm diameter with 2 mm wall thickness
	Solid plate			≥ 2 500	500 mm × 500 mm and 1,5 mm thick[g]
	Lattice plate [g]			≥ 3 600	600 mm × 600 mm consisted of 25 mm × 2 mm section for tape or 8 mm diameter for round conductor
Hot dipped galvanized steel	Solid round		≥ 78		10 mm diameter
	Solid round	≥ 150 [b]			14 mm diameter
	Pipe	≥ 140 [b]			25 mm diameter with 2 mm wall thickness
	Solid tape		≥ 90		3 mm thick
	Solid plate			≥ 2 500	500 mm × 500 mm and 3 mm thick
	Lattice plate [d]			≥ 3 600	600 mm × 600 mm consisted of 30 mm × 3 mm section for tape or 10 mm diameter for round conductor
	Profile	[e]			3 mm thick
Bare steel [k]	Stranded		≥ 70		1,7 mm strand diameter
	Solid round		≥ 78		10 mm diameter
	Solid tape		≥ 75		3 mm thick
Copper coated steel [c]	Solid round	≥ 150 h			14 mm diameter if 250 µm minimum radial copper coating with 99,9 % copper content
	Solid round		≥ 50		8 mm diameter, if 250 µm minimum radial copper coating of 99,9 % copper content
	Solid round [l]		≥ 78		10 mm diameter, if 250 µm minimum radial copper coating of 99,9 % copper content
	Solid tape [l]		≥ 90		3 mm thick, if 250 µm minimum copper coating of 99,9 % copper content
Stainless steel [j]	Solid round		≥ 78		10 mm diameter
	Solid round	≥ 176 h			15 mm diameter
	Solid tape		≥ 100		2 mm thick

NOTE For the application of the earth electrodes, see IEC 62305-3.

▸▸ 5.- Items for an ESE installation

Earth electrodes: Source IEC 62561-2:2018





[a] Manufacturing tolerance: −3 %.

[b] Threads, where utilized, shall be machined prior to galvanizing.

[c] The copper shall be intrinsically bonded to the steel. The coating can be measured using an electronic coating measuring thickness instrument.

[d] Lattice plate constructed with a minimum total conductor length of 4,8 m.

[e] Different profiles are permitted with a cross section of 290 mm² and a minimum thickness of 3 mm, e.g. cross profile.

[f] Hot dipped or electroplated; minimum thickness coating of 1 µm. There is no requirement to measure the tin plated copper because it is for aesthetic reasons only.

[g] In some countries, the cross-sectional area may be reduced to ≥ 1 800 cm² and the thickness to ≥ 0,8 mm.

[h] In some countries, the cross-sectional area may be reduced to 125 mm².

[i] The cross-sectional area of stranded conductors is determined by the resistance of the conductor according to IEC 60228.

[j] Chromium ≥ 16 %, nickel ≥ 5 %, molybdenum ≥ 2 %, carbon ≤ 0,08 %.

[k] Shall be embedded in concrete for a minimum depth of 50 mm.

[l] Due to higher corrosion rate for solid tape earth conductors, it is recommended to use copper-coated steel with a coating of 250 µm.

Installation examples
Photovoltaic plants

ESE AIR TERMINALS

- ESE installations in photovoltaic plants

ESE lightning rod in a free-standing pole

ESE lightning rod in a free-standing pole

Installation examples
Photovoltaic plants

IEC 61643-32:2017 - Low-voltage surge protective devices – Part 32: Surge protective devices connected to the D.C. side of photovoltaic installations – Selection and application principles

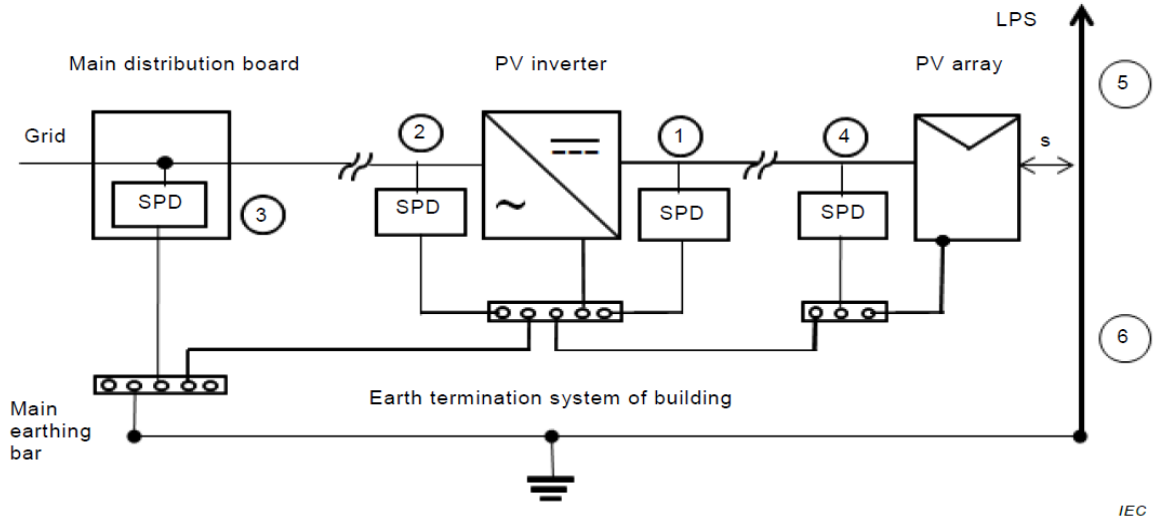
The partial lightning current which flows via the SPDs into the DC system depends on:

- The class of LPS
- For ground-mounted solar power plants LPL III is ussually sufficient.
- The earth resistivity
- A higher earth resistivity results in higher partial currents flowing into the DC system via the SPDs.
- The mesh size of the earth termination system
- Larger mesh size results in higher partial currents flowing into the DC system via the SPDs.
- impedance of the SPD (depending whether voltage limiting or voltage switching technology is used)
- Type of inverter system (centralized or distributed: several string inverters). In the case of a centralized inverter system, partial lightning currents flow in the DC cabling. In the case of a distributed inverter system, partial lightning currents flow in the AC cabling.

Source: IEC 61643-32:2017

Installation examples
Photovoltaic plants

- **ESE AIR TERMINALS:** to protect all the structures and facilities
- **SPDs:** to protect the inverter in the DC side and AC side



Legend

1 Class II tested SPD according to IEC 61643-31

2 Class II tested SPD according to IEC 61643-11

3 Class I tested SPD according to IEC 61643-11

4 Class II tested SPD according to IEC 61643-31

5 LPS air termination system

6 LPS down conductor

Figure 2 – Installation of SPDs in the case of a PV installation with an external LPS where the separation distance (*s*) is maintained

Source: IEC 61643-32:2017

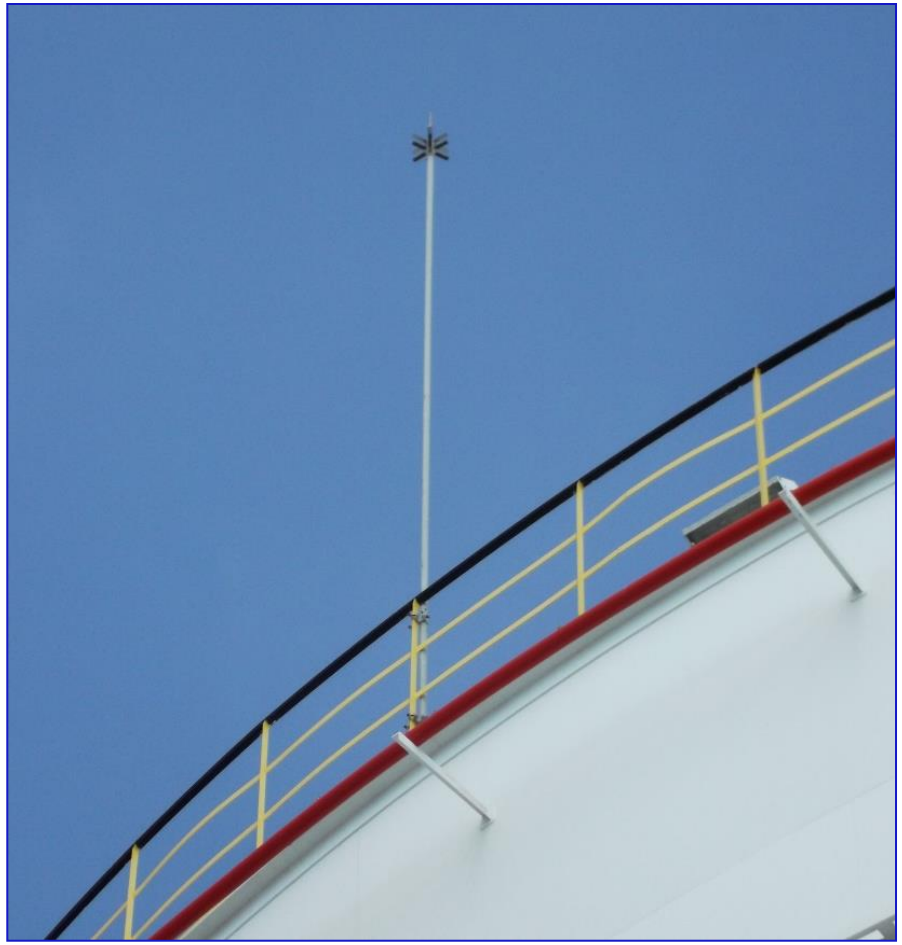
Installation examples
Telecommunications towers

ESE in Telecom tower

ESE in Telecom tower

Installation examples
Oil & Gas companies

Lightning rod in a tank



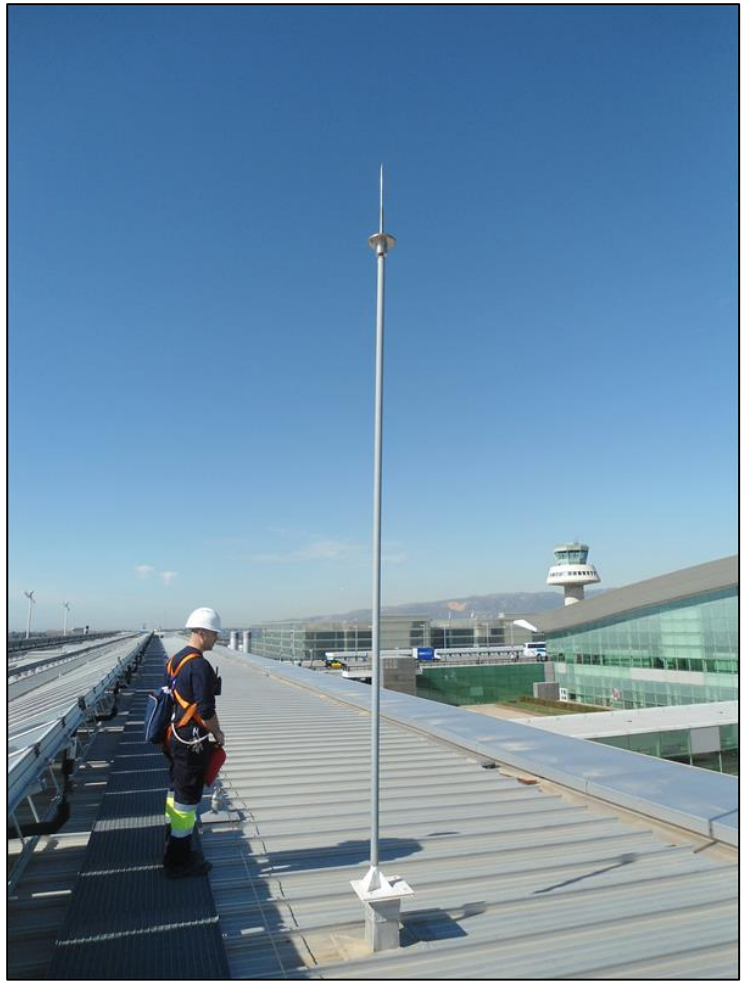
Lightning rod in a tank

Installation examples
Oil & Gas companies

Lightning rod in a free-standing pole

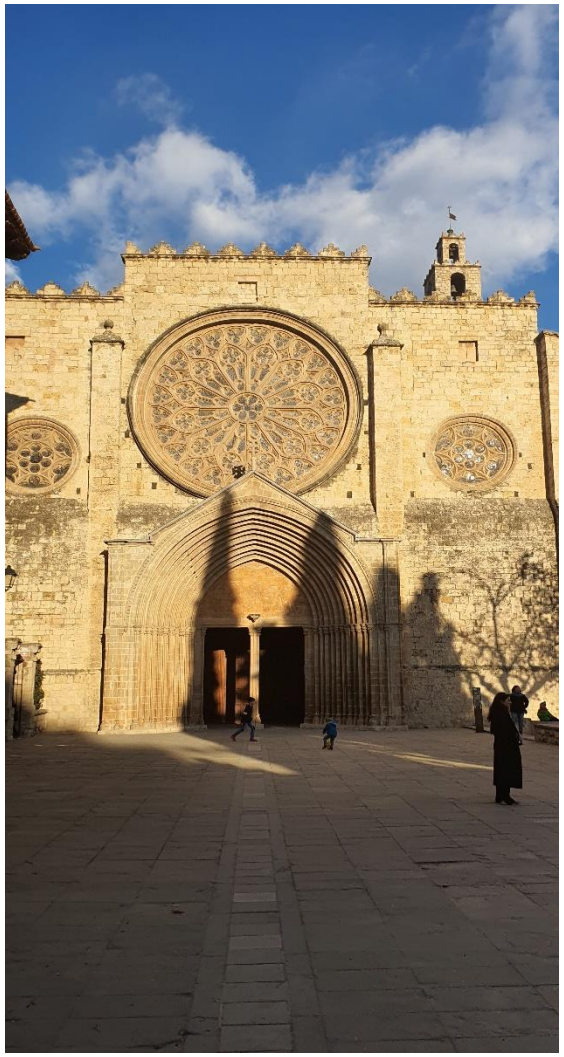
Lightning rod in a free-standing pole

Installation examples
Airports - Barcelona Terminal T1



Barcelona airport Terminal 1 - (Spain)

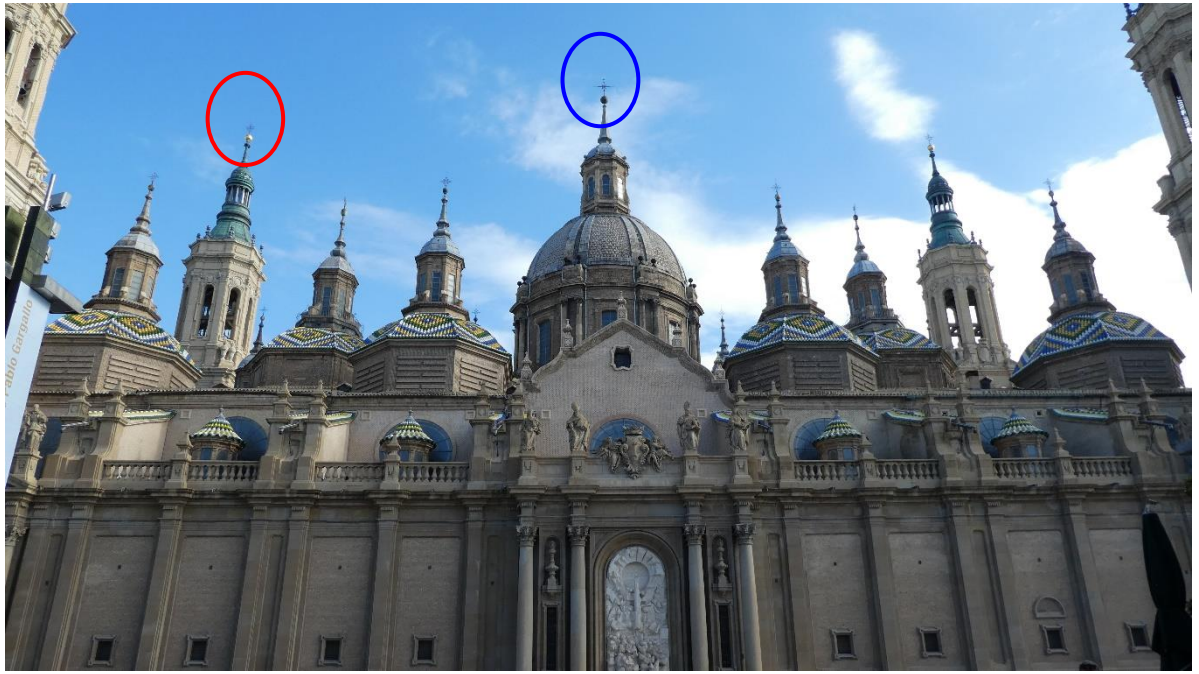
Installation examples
Churches



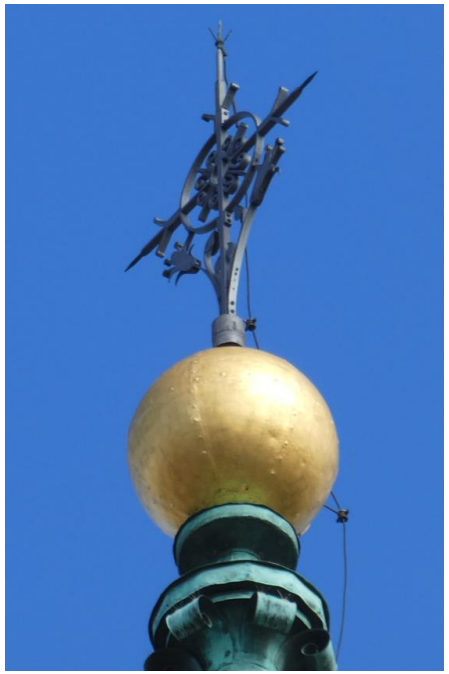
Monasterio de Sant Cugat (Spain)

Masía Freixa Terrassa (Spain)

Installation examples
Churches



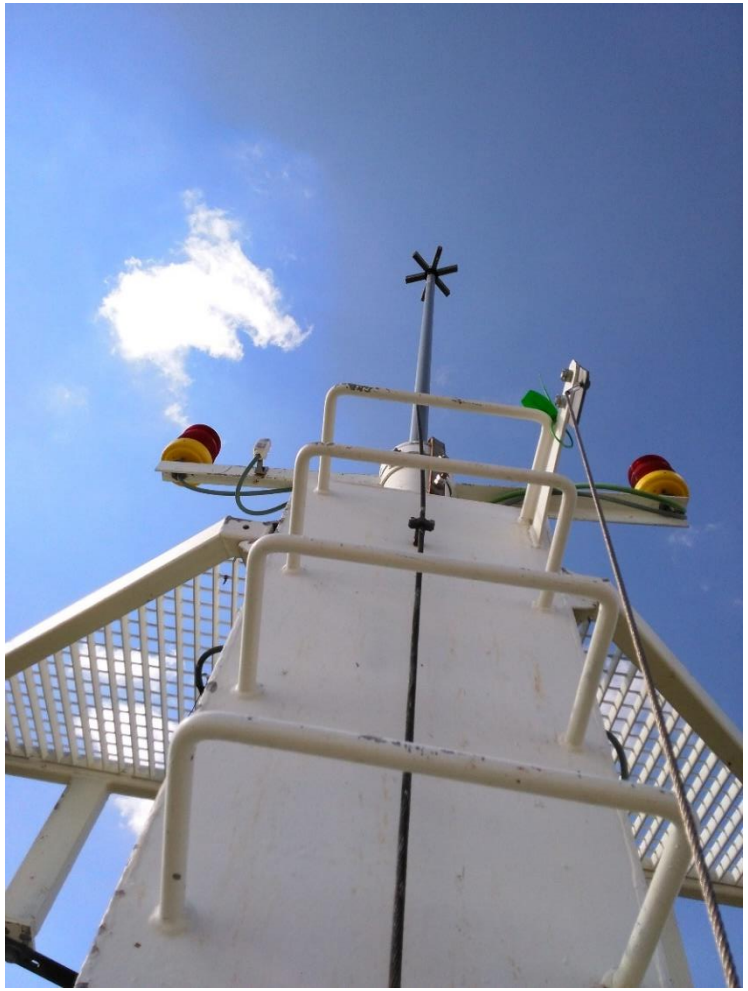
Lightning protection in Basilica del Pilar (Spain)

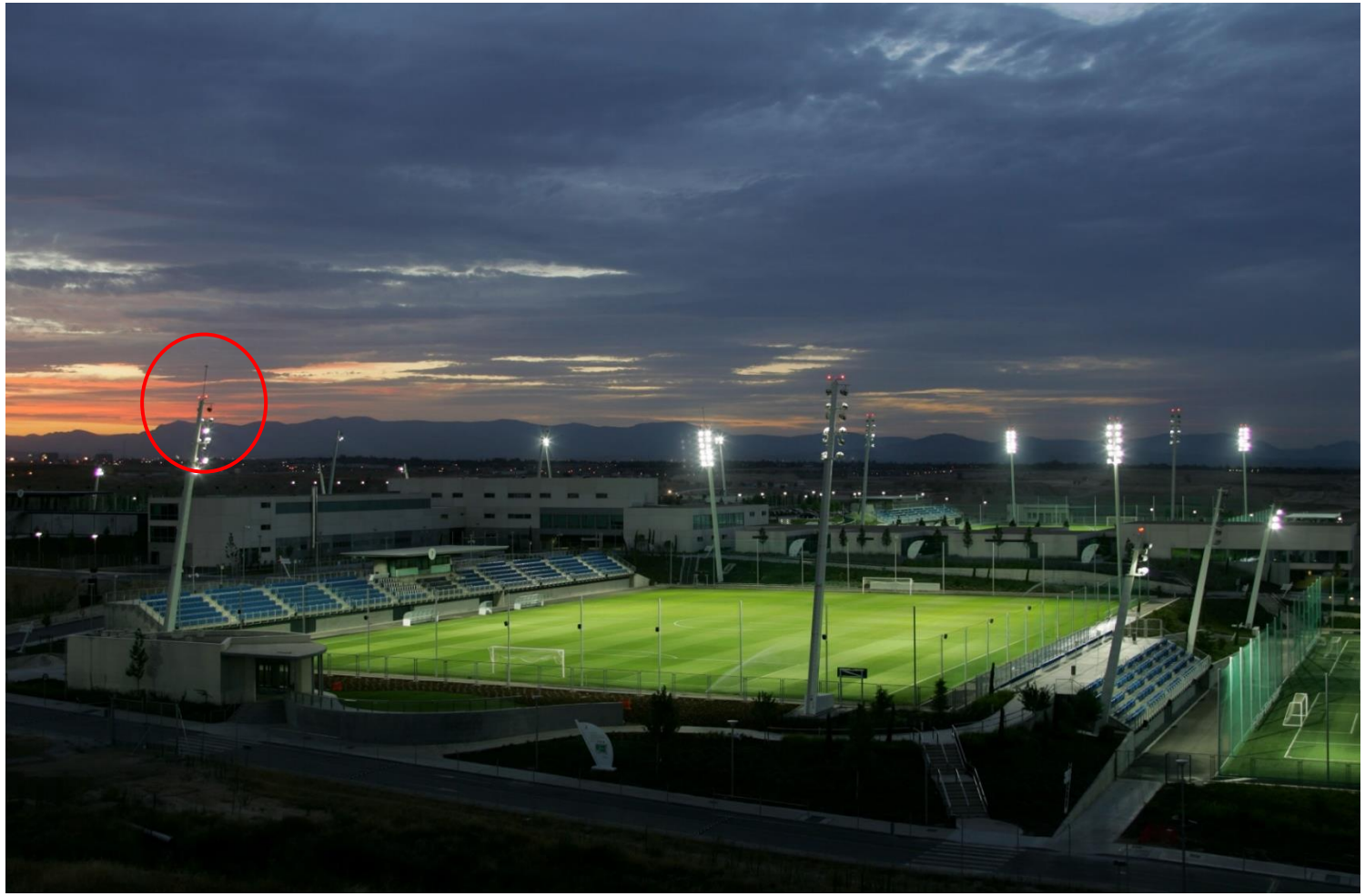


INGESCO
Multiple rod

INGESCO
Active rod

Installation examples
Sports fields





Real Madrid sports city – ESE in the light towers

Installation examples
Sports fields

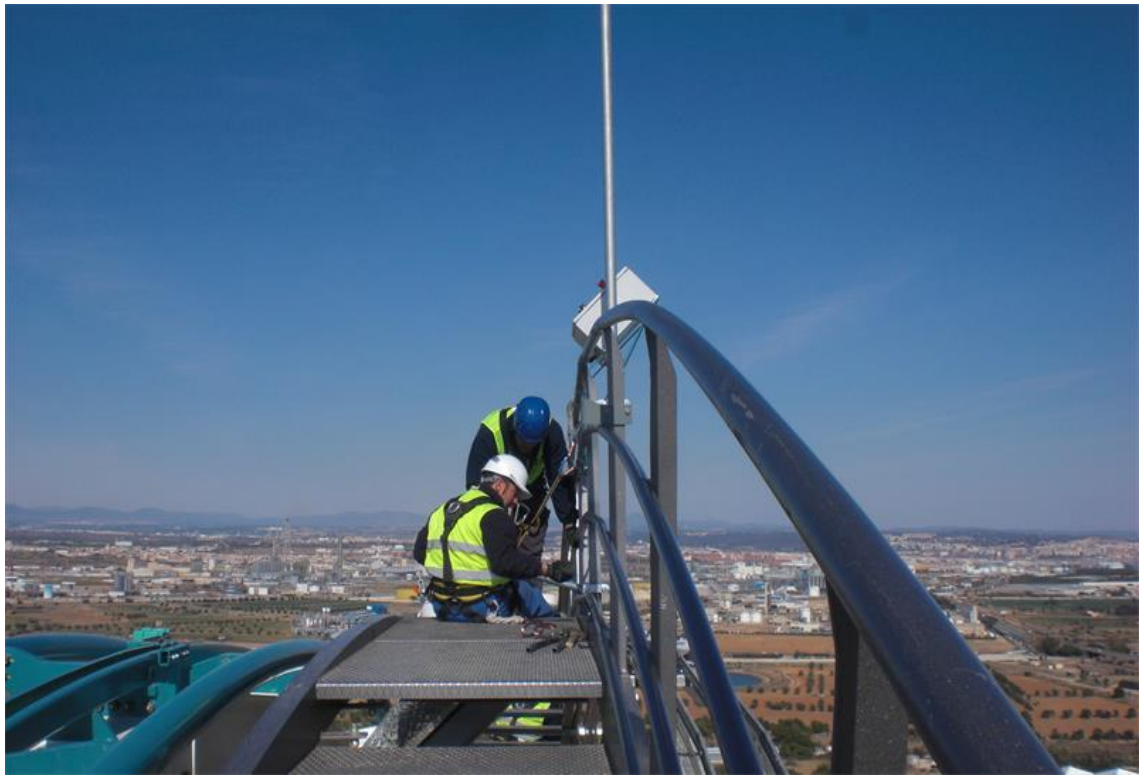
Football Club Barcelona stadium

Football Club Barcelona sports city

Installation examples
Light towers

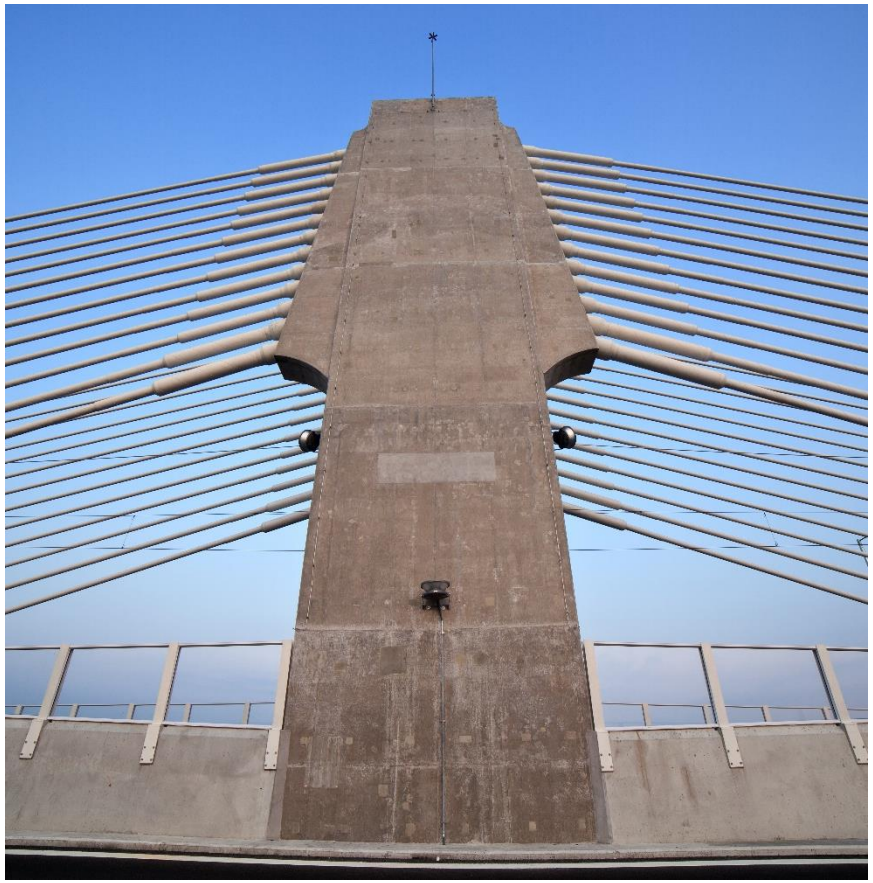
Tunis football stadium

Installation examples
Amusement parks



Amusement parks – Port Aventura (Tarragona)

Installation examples
Bridges – New Europe bridge



New Europe bridge over the Danube river between Vidin (Bulgari) and Calafat (Romania)

Earthing system – Low impedance (Z):

- Due to the high frequency of the lightning currents (up to 1 MHz), the installation of earthing systems with **resistive or capacitive behaviours are recommended**.

  - As earthing system measurements are usually made with low frequency, the result is obtained as a resistance.
  - The electrode behaviour (capacitive, inductive or resistive) depends on the electrode shape, soil resistivity.
  - **Capacitive behaviour** is typical for grounding systems with meshed electrodes branching out to cover an area.
  - In contrast, earthing systems with few electrodes and a very long length (e.g. deep electrodes) have an **inductive behaviour**.
  - Horizontal ground electrodes are less effective at power frequency in comparison to vertical rods, however they have better pulse efficiency.

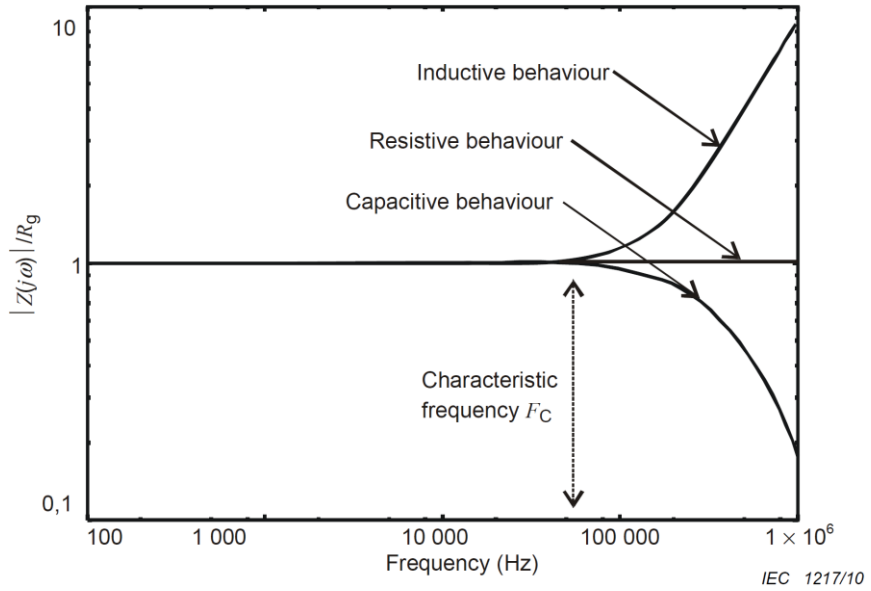


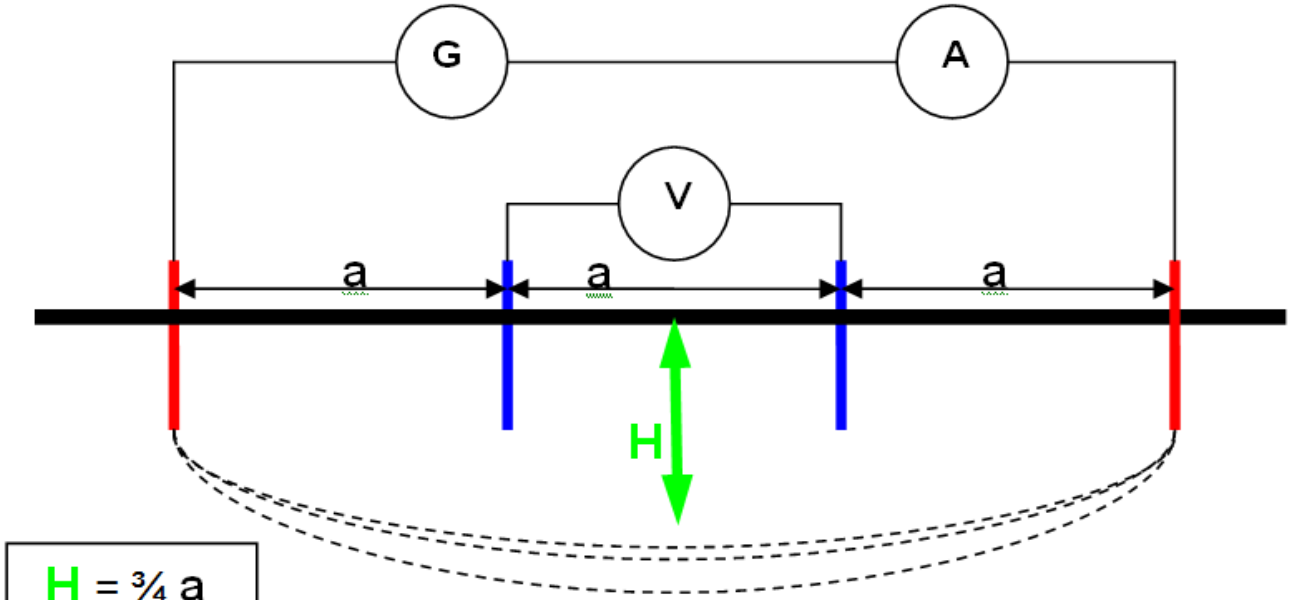
Figure I.2 – Frequency dependence on the impedance to earth (adapted from Cigré WG C.4.4.02 July 2005 [49])

(Source IEC 61400-24:2019)

Soil resistivity measure – Wenner method:

We need to drive 4 equally spaced test electrodes to a depth of not greater 5% of their spacing apart.

The separation distance "a" is used to obtain the soil resistivity value corresponding to a depth of H = 0,75 * a



$H = \frac{3}{4}\, a$

H = depth at which soil resistivity is measured

a = Separation between test electrodes

Soil resistivity measurement

- Using the Wenner Method, the soil resistivity is measured at different depths.
- With the help of a GPS in UTM coordinates we can position the values obtained on a drawing.

Two examples of soil resistivity (**ρ**) measurement, with a 4 terminal earth meter and with separations of **a=1m** ; and **a=10m**.

The results obtained were $\rho_{(1m)}$**= 631 Ω*m** and $\rho_{(10m)}$**=16,86 Ω*m** respectively.

Soil resistivity measurement

- Other example using the Wenner Method, the soil resistivity is measured at different depths and frequencies

Example: measurement of soil resistivity in rocky terrain at 4m depth , f=400 Hz ; **ρ= 1763 Ωm**

Earth rods installation

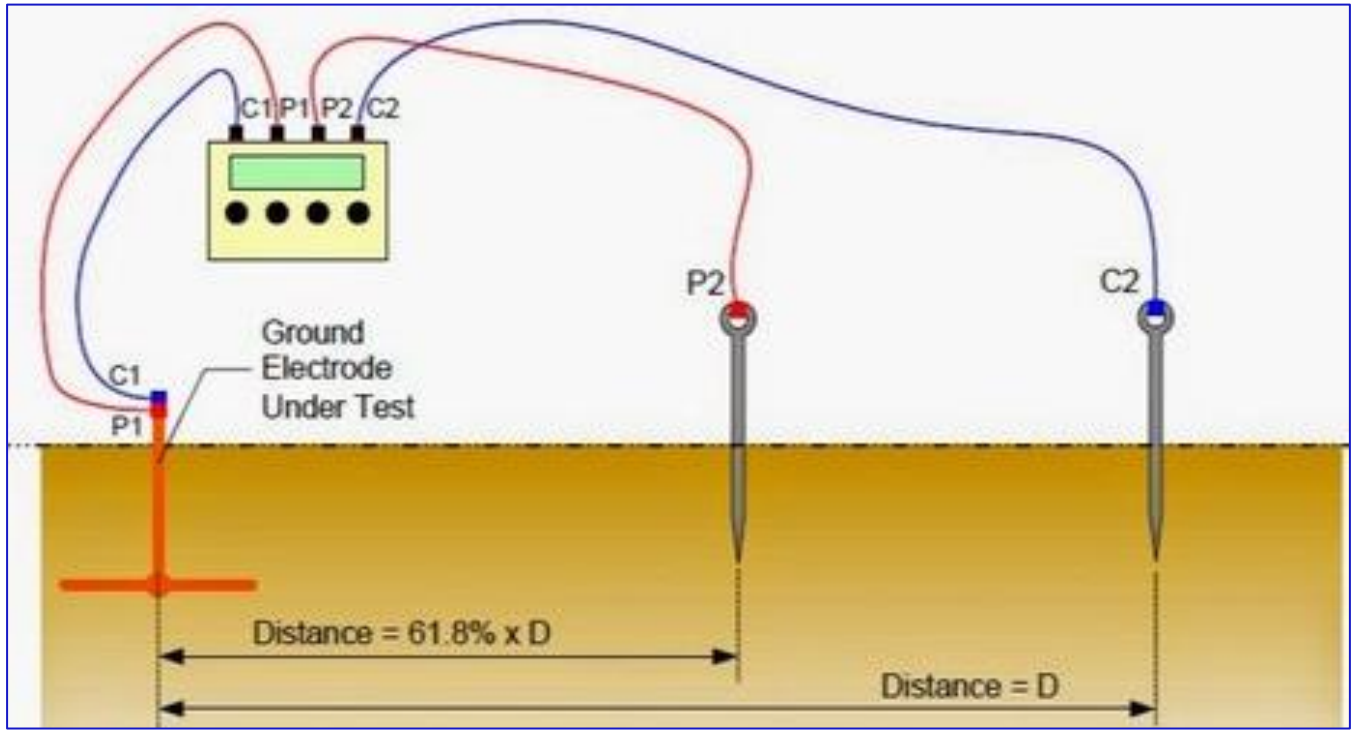
Electrode driving:

Low impedance earthing systems measured at high frequency

Installation of earth rods using an electric hammer

Measurement of earthing system resistance (R)

- **Resistance measurement by means of the fall-of-potential method**
  - This fall-of-potential method or 62% method is the most common:



Measurement of an earthing system with 2 references (62% method)

Measurement of earthing system resistance (R)

- **The recommended value of resistance is R ≤ 10Ω**

Measurement of an earthing system with 2 references

Resistance R= 6.6 Ω on x1 Ω scale

Most important points:

- The tip of the lightning rod must be located at least **two meters above** the area it protects (including antennas, cooling towers, etc.).
- The receiving antennas (TV, radio, telephone) must be connected by a **spark gap** to the down conductors of the lightning rod installation.
- The coaxial cable of the antenna must be protected with a **surge arrester**.
- The E.S.E lightning rod will be connected to the earthing system **using 2 down conductors** on opposite facades whenever possible.
- The path of the down conductor must be as straight as possible, following the shortest path, and **avoiding sharp bends** or upward sections.
- The radius of the cable bends shall **not be less than 20 cm**.
- The down conductor must be installed outside the building (whenever possible), avoiding the proximity of electrical or **telecommunication cables, or gas pipes**.

(Source NF C 17-102:2011)

Most important points:

- Each down conductor must be connected to an earthing system.
- Separation distances (s) must be respected.
- The inspection pit (or, in its absence, the down conductor cable) must be provided with a disconnecting system that allows the earthing to be disconnected in order to measure its resistance.
- The earthing resistance should be as low as possible (less than 10 ohms). This value will be measured on the earth connection isolated from all other conductive elements.
- It is advisable to bond the earthing of the lightning rod with the general earthing system of the building.

(Source NF C 17-102:2011)

Verification and maintenance :

The verification phases are carried out:

- ❑ Initially once the ESE System installation is completed;
- ❑ Periodically in accordance with following table 7;
- ❑ Whenever the protected structure is modified, repaired or **when the structure has been struck by lightning.**

Tabla 7 (Periodicity of inspection regarding the protection level)

Protection level	Visual inspection (year)	Complete inspection (year)	Critical systems complete inspection (year)
I and II	1	2	1
III and IV	2	4	1
NOTE: Lightning protection systems utilized in applications involving structures with a risk of explosion should be visually inspected every 6 months. Electrical testing of the installation should be performed once a year. An acceptable exception to the yearly test schedule would be perform the tests on a 14 to 15 month cycle where it is considered beneficial to conduct earth resistance testing over different times of the year to get an indication of seasonal variations.			

NOTE 1: for levels of protection 1 and 2, a complete inspection is carried out when the structure has been struck by lightning.

NOTE 2: Lightning flashes can be recorded by a lightning flash counter installed at one of the down-conductors.

NOTE 3: If national authorities or institutions require regular tests of the electrical system of a structure, it is recommended to test the lightning protection system with regard to the functioning of the Internal lightning protection measures including the lightning protection equipotential bonding with electric systems at the same time.

(Source NF C 17-102:2011)

Installation video:

❑ STANDARDS:

- **НАРЕДБА № 4 от 22 декември 2010 г. за мълниезащитата на сгради, външни съоръжения и открити пространства**
- **NF C 17-102:2011 Protection against lightning - Early streamer emission systems**
- **IEC 62305-2:2010 Lightning protection - Risk assessment**
- **IEC 62561-2:2018 Lightning protection system components (LPSC) - Part 2: Requirements for conductors and earth electrodes**
- **IEC 62793:2020 Thunderstorm warning systems - Protection against lightning**

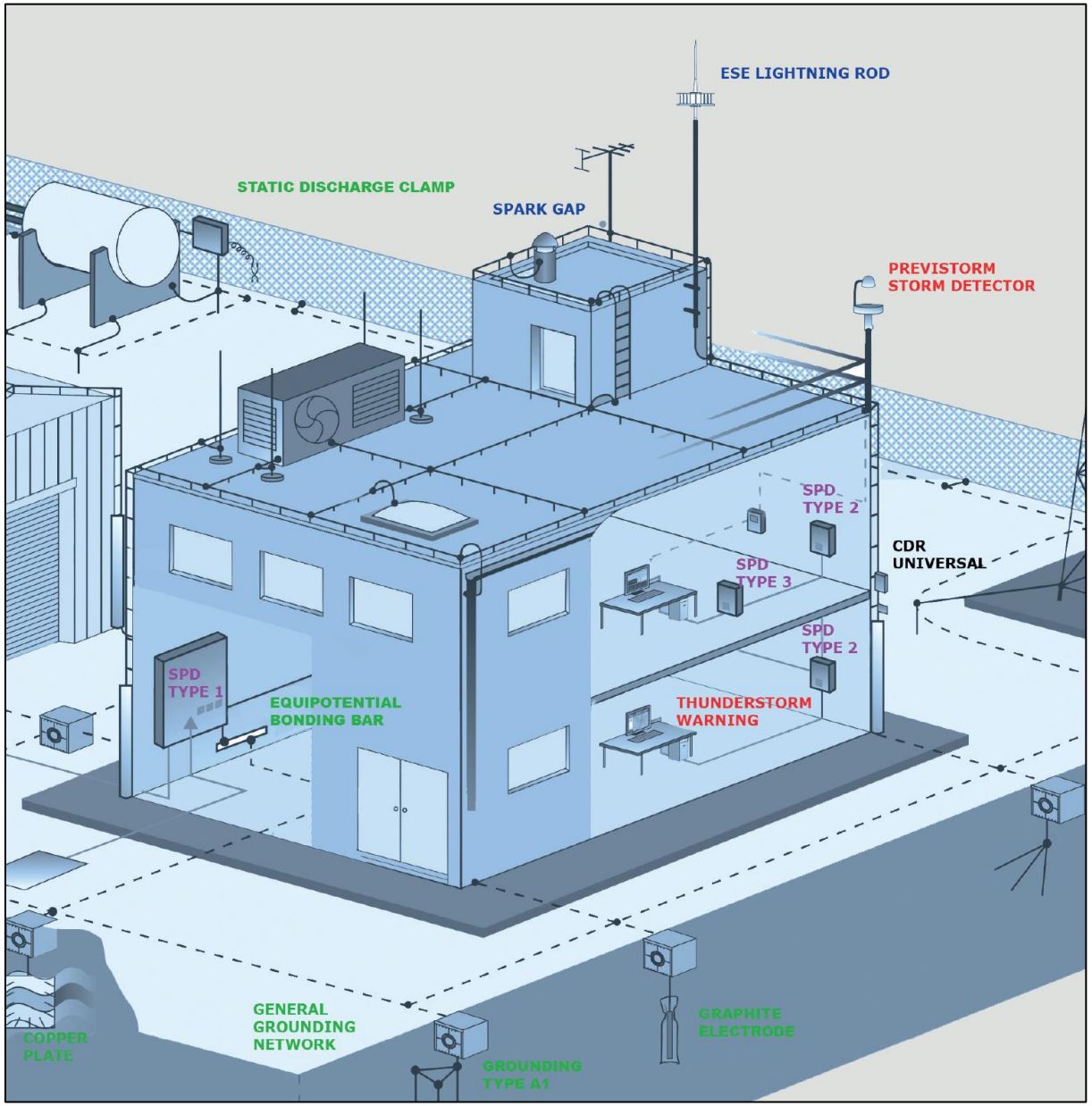
https://www.ingesco.com/en/noticias/lightning-protection-standards

3. Internal protection

Surge protection devices (SPDs)

INGESCO®
LIGHTNING SOLUTIONS

▸▸ SPD INSTALLATION - IEC 62305-4:2010



Surge protection devices SPD's:

Type 1: main electrical panel

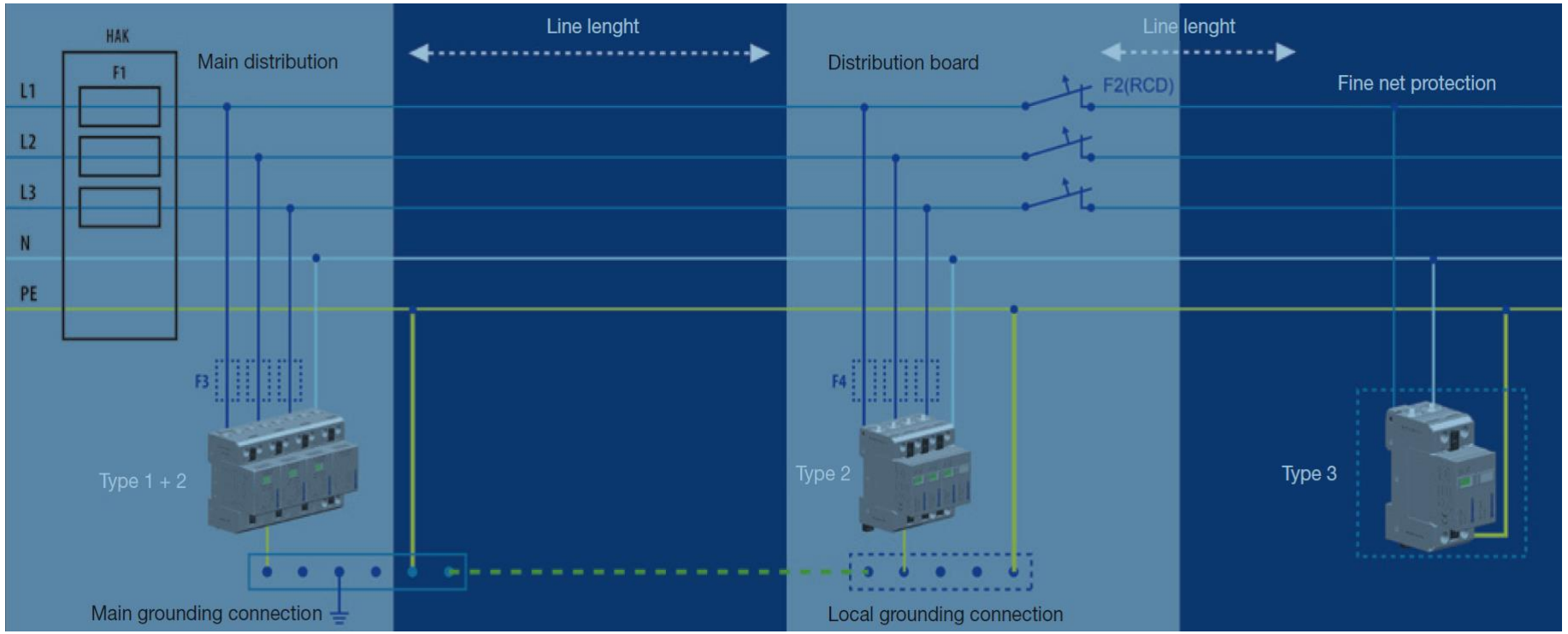
Type 2: secondary panel

Type 3: near de electronic equipment

SPD CLASIFICATION

Source: IEC 61643-12 - IEC 62305-1

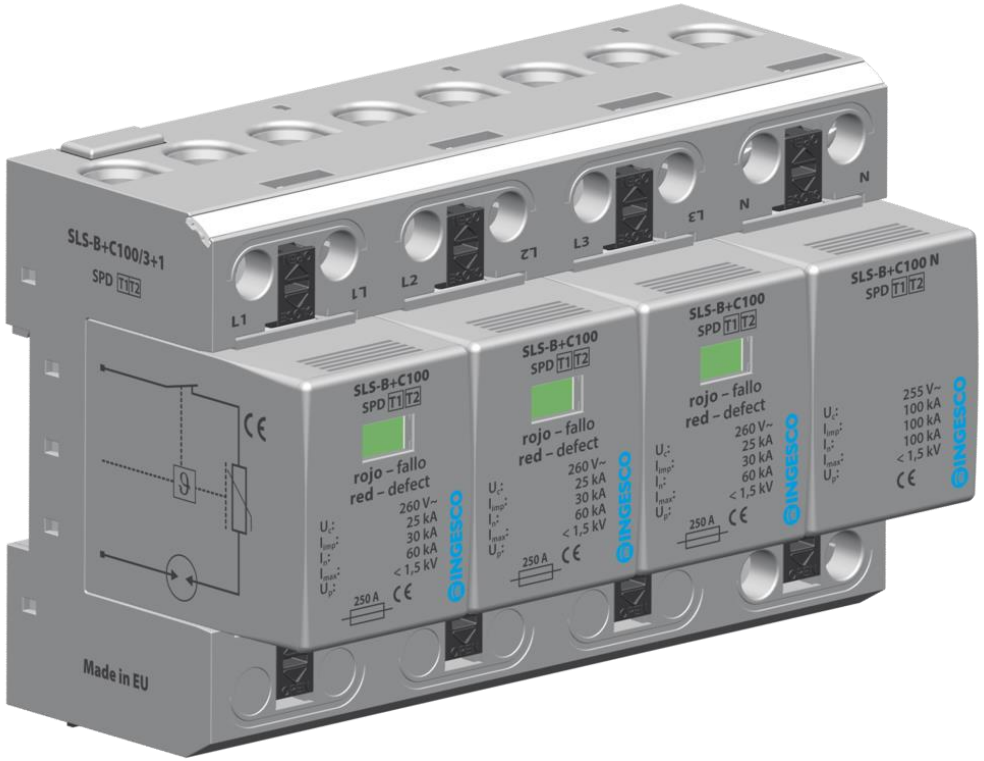
SPD Type 1 (B) : Lightning current arresters
SPD Type 2 (C) : Surge arresters
SPD Type 3 (D) : Surge protections



Type 1 and 2 SPD

SLS-B+C100/3+1

- For 3 phases **TT** or **TN-S**
  230/400 V AC
- Connection “3+1”
- I_{imp}
  25 kA (10/350) L-N,
  100 kA (10/350) N-PE

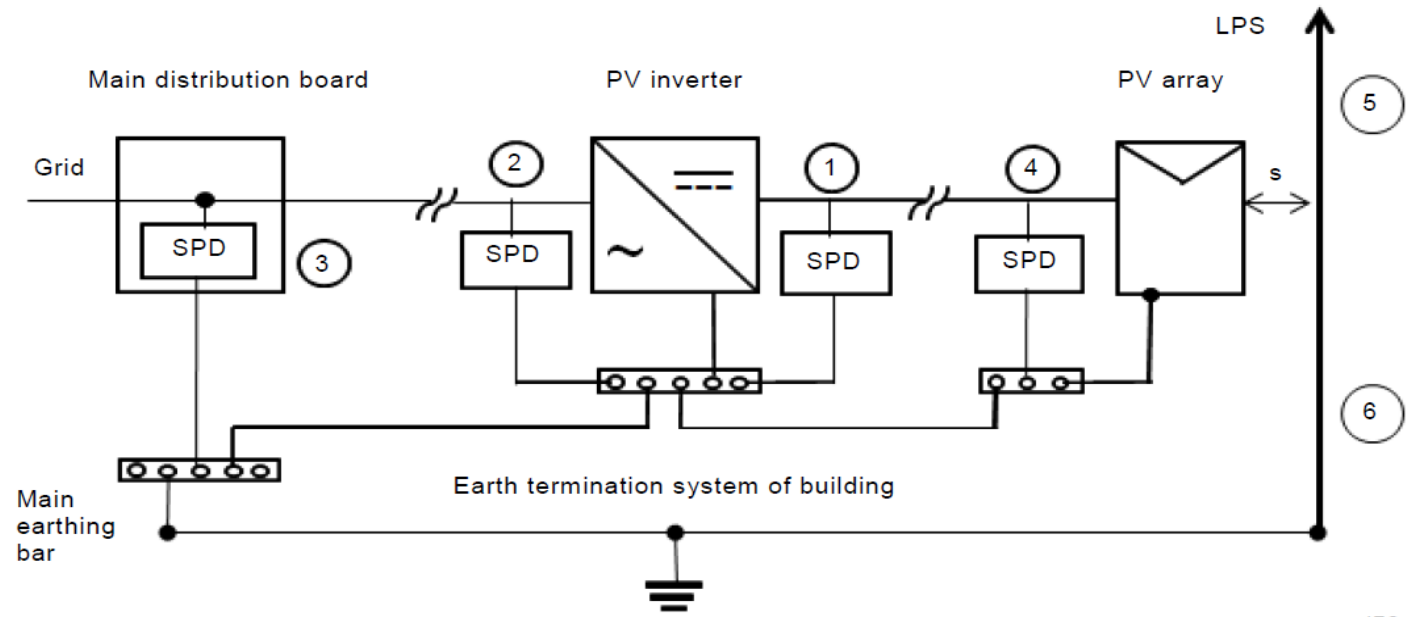


Type 2 SPD

SLS-C20/3+1

- For 3 phases TT
  230/400 V AC
- Connection “3+1”

IEC 61643-32: SPD's connected to the D.C. side of PV installations



Legend

1 Class II tested SPD according to IEC 61643-31

2 Class II tested SPD according to IEC 61643-11

3 Class I tested SPD according to IEC 61643-11

4 Class II tested SPD according to IEC 61643-31

5 LPS air termination system

6 LPS down conductor

Figure 2 – Installation of SPDs in the case of a PV installation with an external LPS where the separation distance (*s*) is maintained

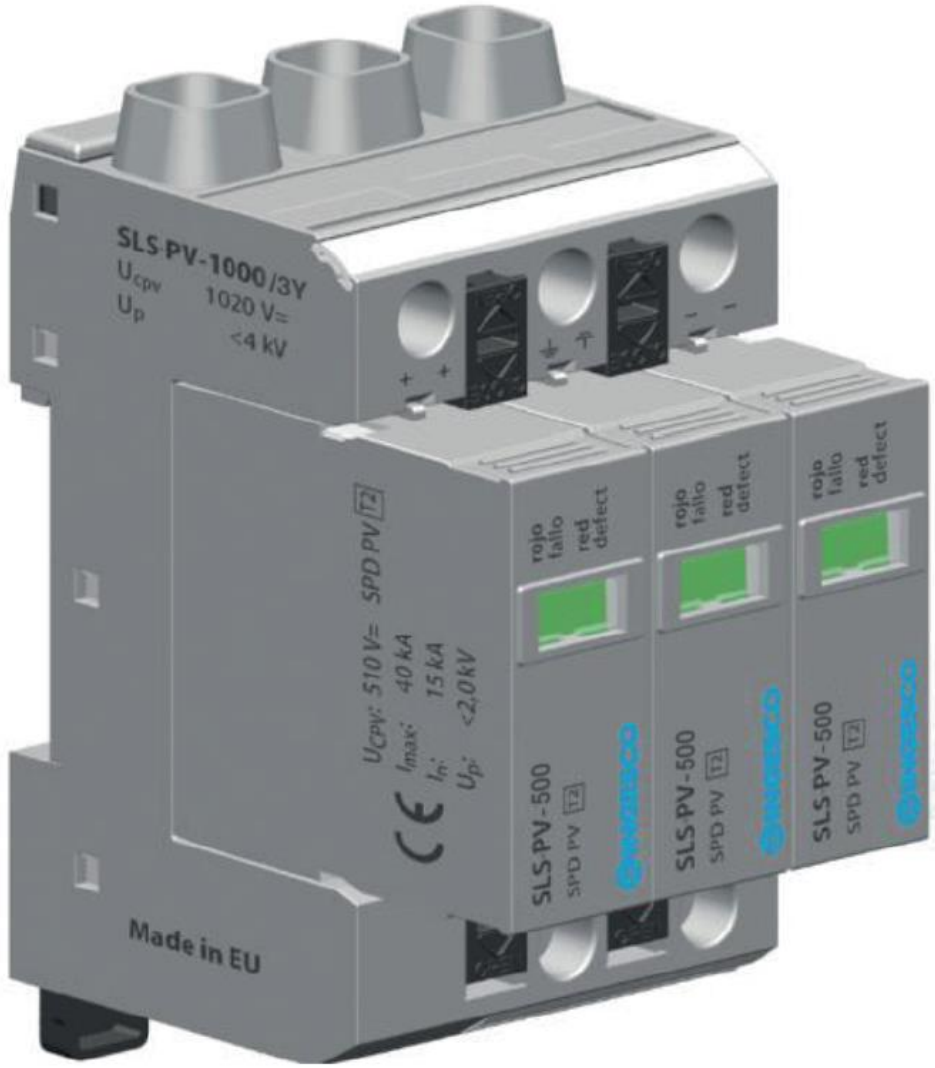
SPD for DC side: SLS-PV1000/3Y

Type 2 (T2)

1020 V DC

I_n 15 kA (8/20)

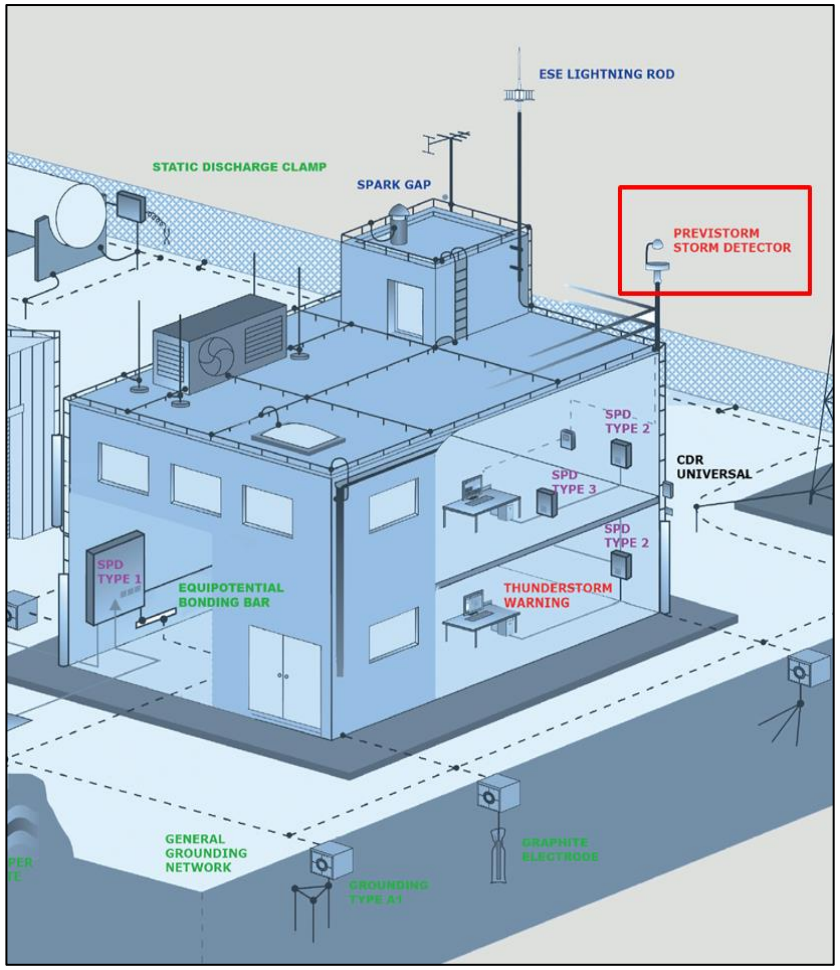
Imax 40 kA (8/20)



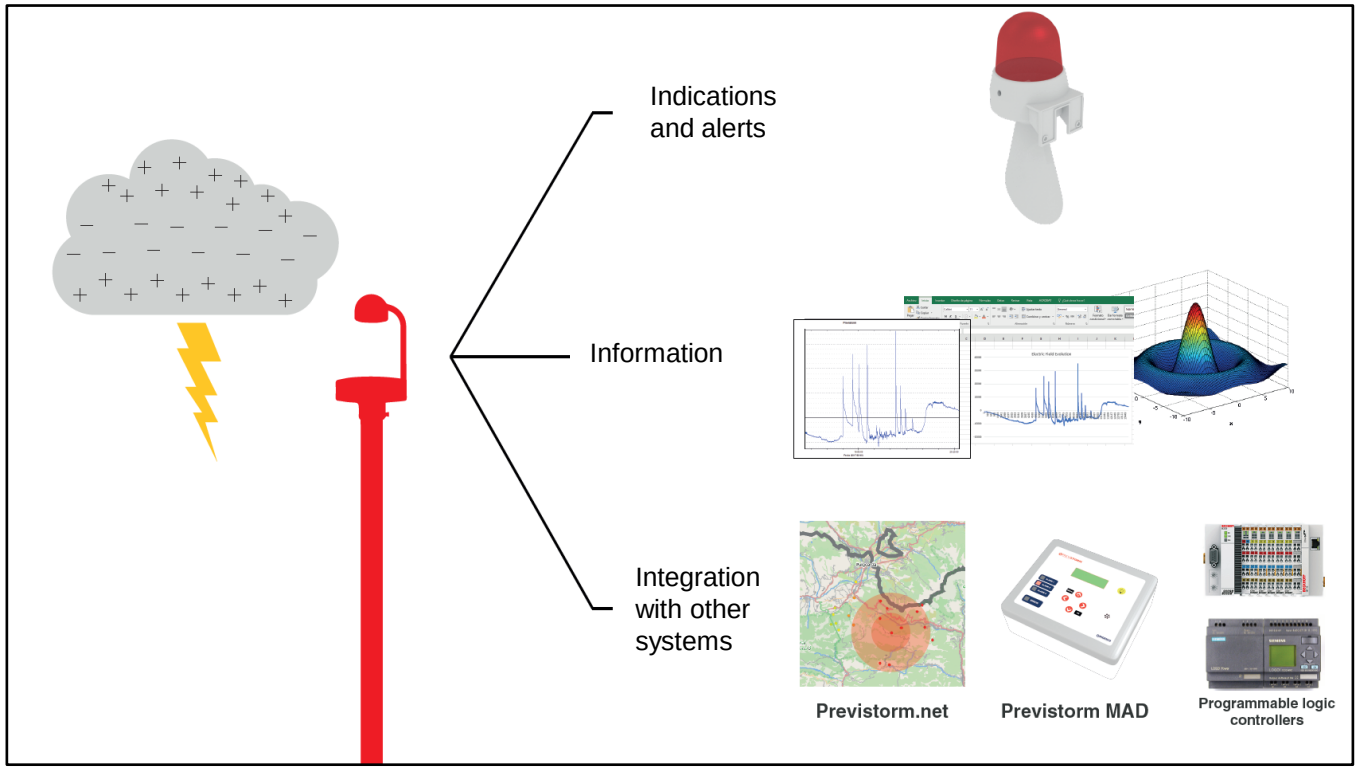
4. Preventive protection

Thunderstorm Warning Systems – (TWS)

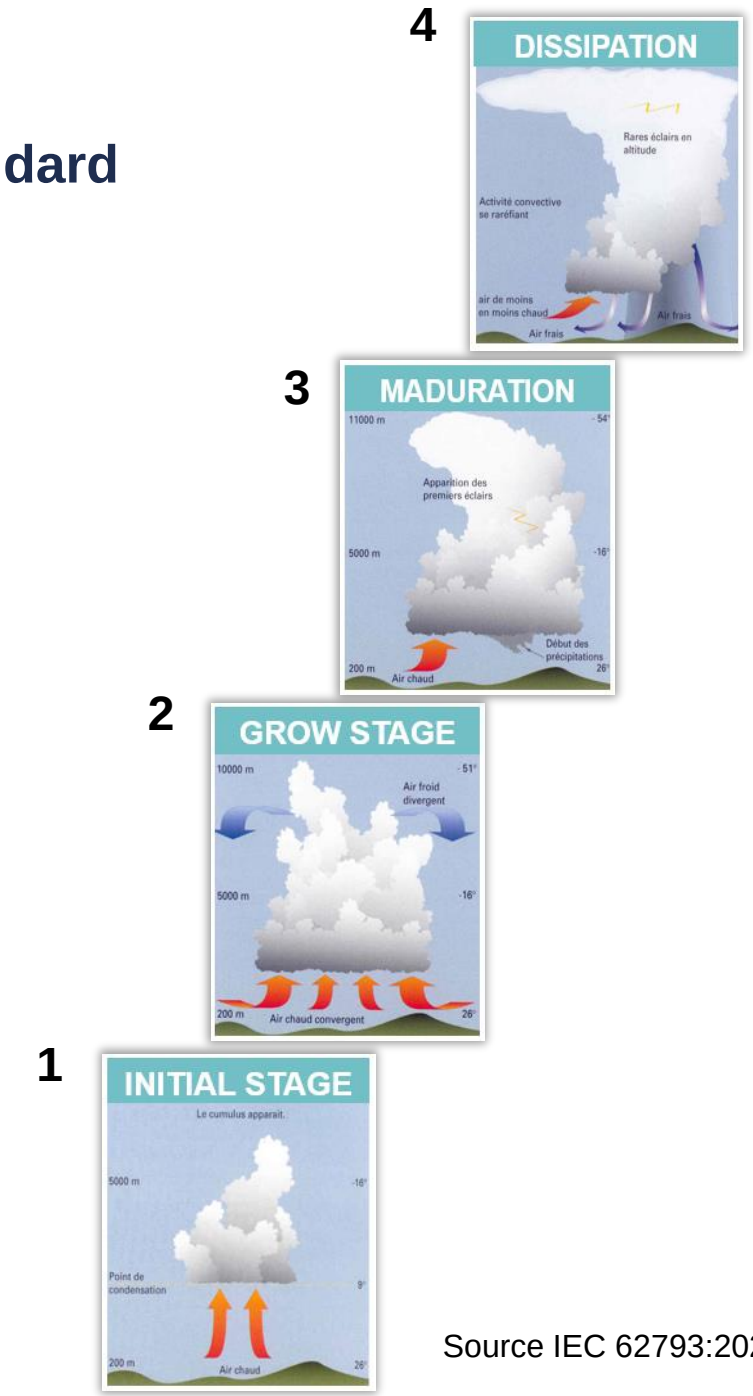
Introduction



- Electrostatic field detector
- Software
- Alarm and warning system



Standard



Source IEC 62793:2020

Thunderstorm Warning System Technologies

- **Electrostatic sensor**
  Detects a thunderstorm in the vicinity of the sensor, like electric field meters based on the electric field mill operating principle.
  Provides warnings before the first IC/CG lightning (all phases).

- **Electromagnetic sensor**
  Detects the occurrence of lightning.
  Provides information “after” lightning is already occurring (phases 2 to 4).

- **Lightning location system**
  Network of sensors that allow tracking already active thunderstorms. Provides information about lightning impact locations (phases 2 to 4).

Standard

SCOPE:

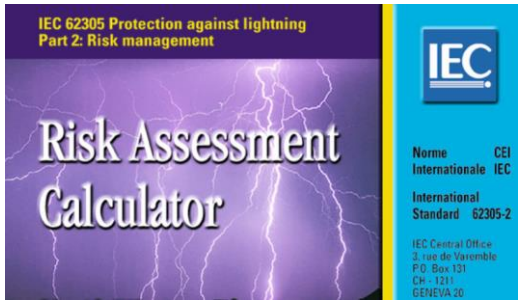
The IEC 62793:2020 standard applies to the use of information from thunderstorm warning systems on atmospheric electric activity in order to monitor preventive measures.

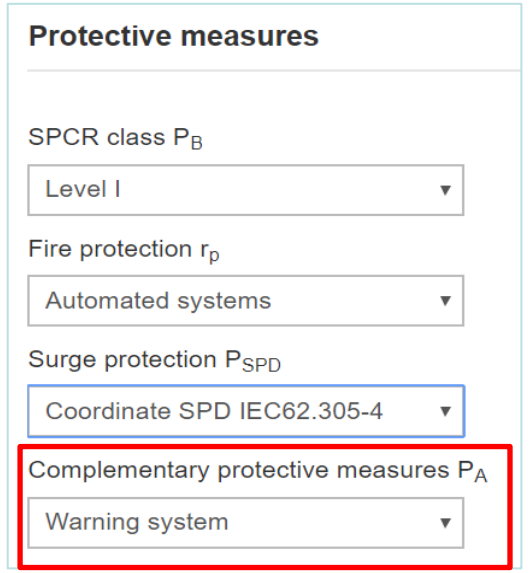
RISK REDUCTION:

When we evaluate the risk calculation of a building or structure according to IEC 62305-2: 2010, there are 4 possible lightning protection measures to reduce it:

Class of LPS (lightning protection systems)
Fire protection
Surge protection
Supplementary protection measures

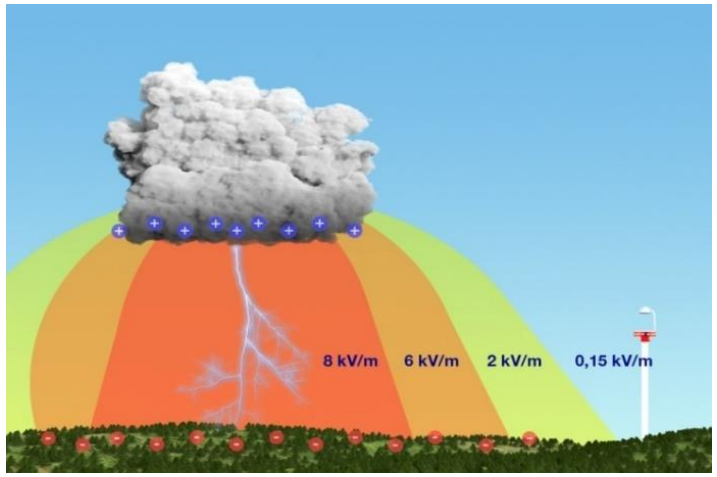
One of these complementary protection measures are the warning systems. That is why the detection systems are highly recommended and will help us along with the other protection measures to reduce the risks of damage.





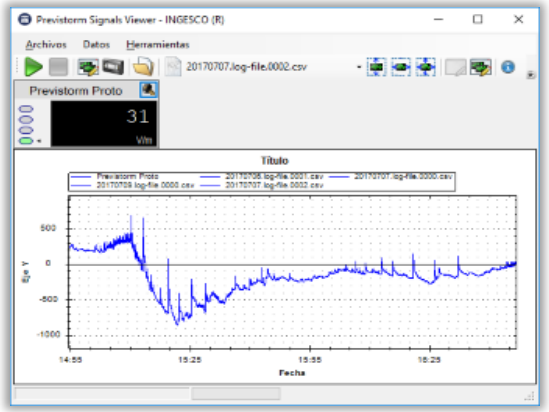
Source IEC 62793:2020

Flow chart



Continuous electric field evolution monitoring

PREVISTORM® E-Field Sensor



PREVISTORM® Viewer

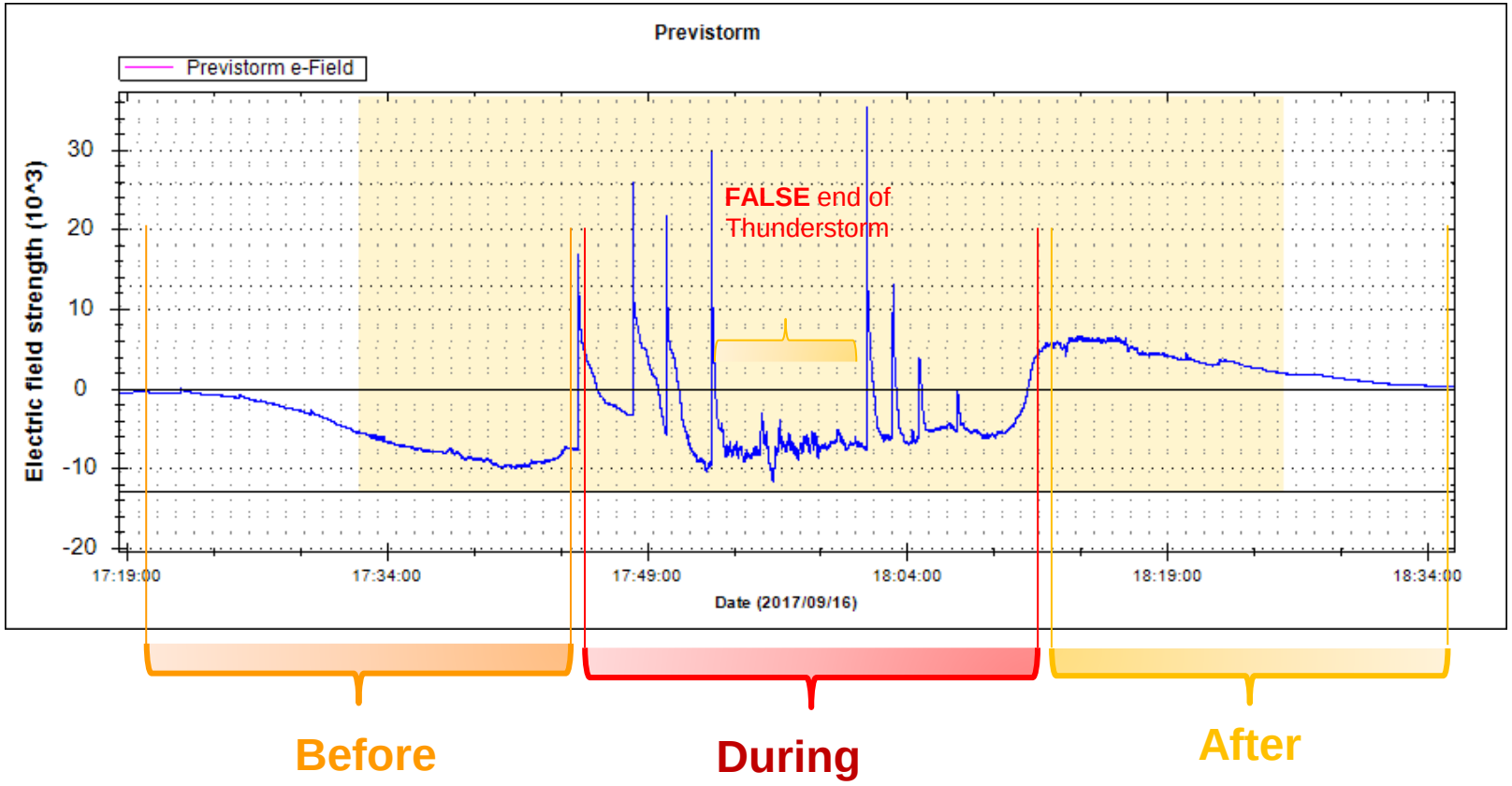
Preventive Actions

Alerting devices activation

Automation systems

Previstorm® Viewer

- ✓ Example of electric field strength evolution during a thunderstorm with lightning impacts close to the site.
- ✓ Shadowed area corresponds to Alarm Active state.
- ✓ Notice how other systems based exclusively on lightning detection could fail to detect the start of the storm and the real end of the storm.



Installation diagram

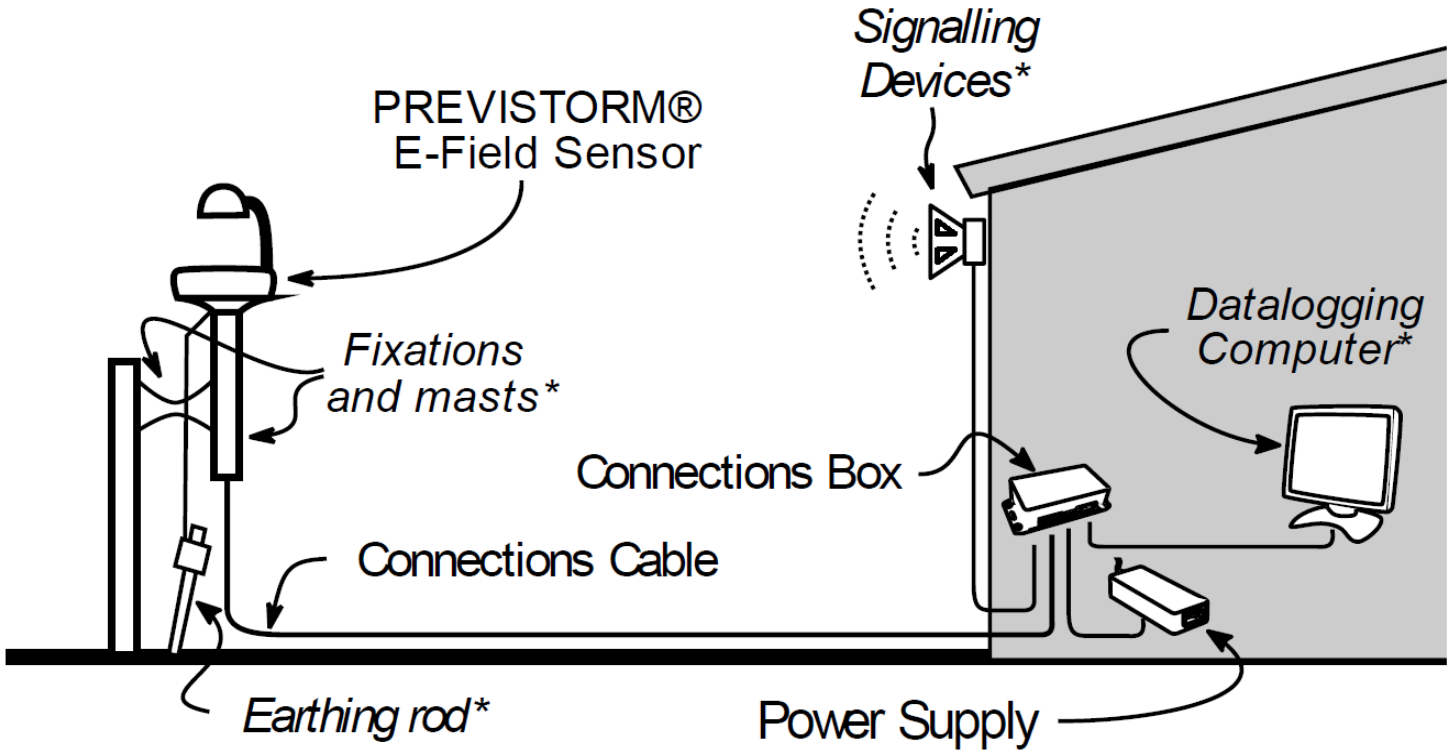
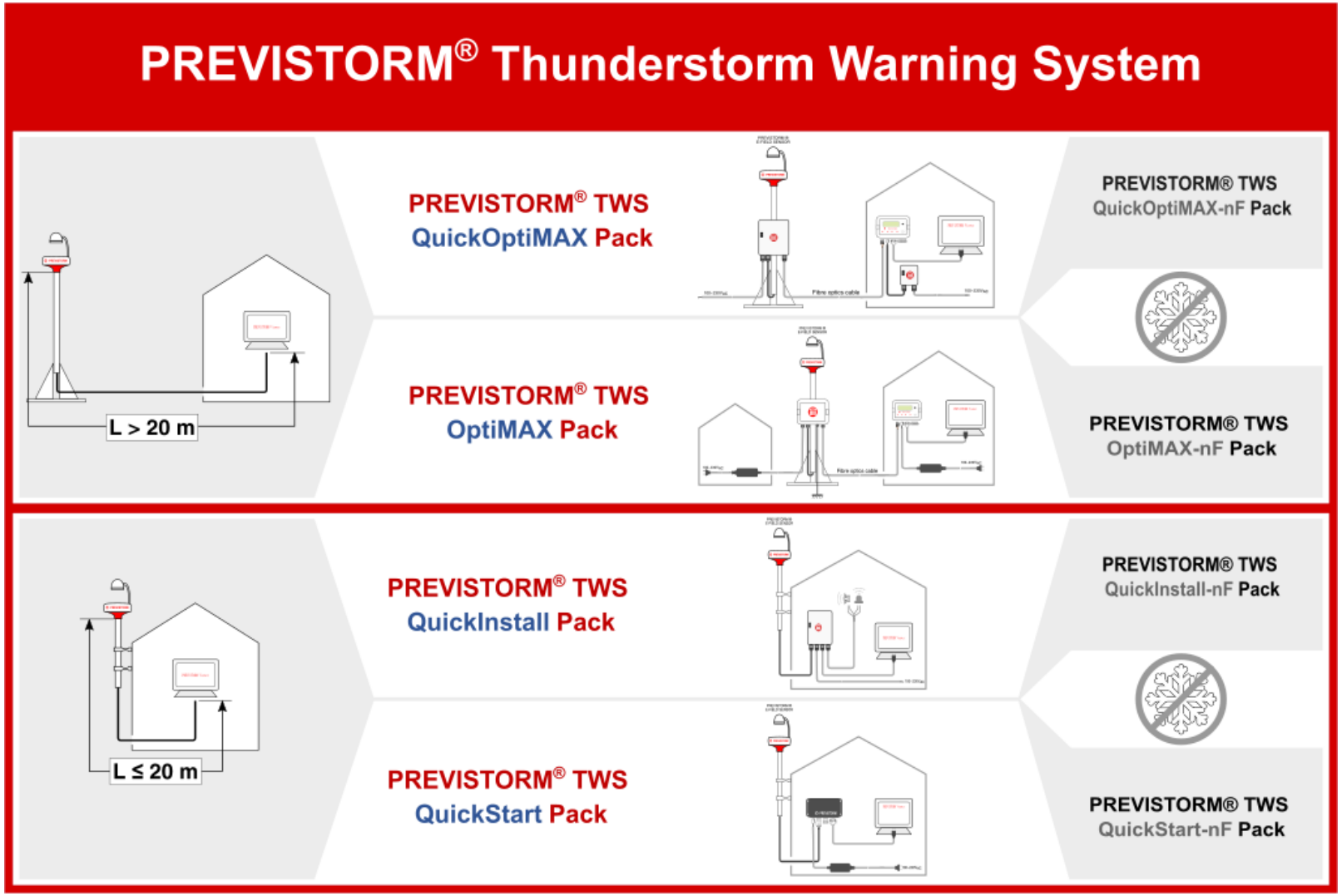
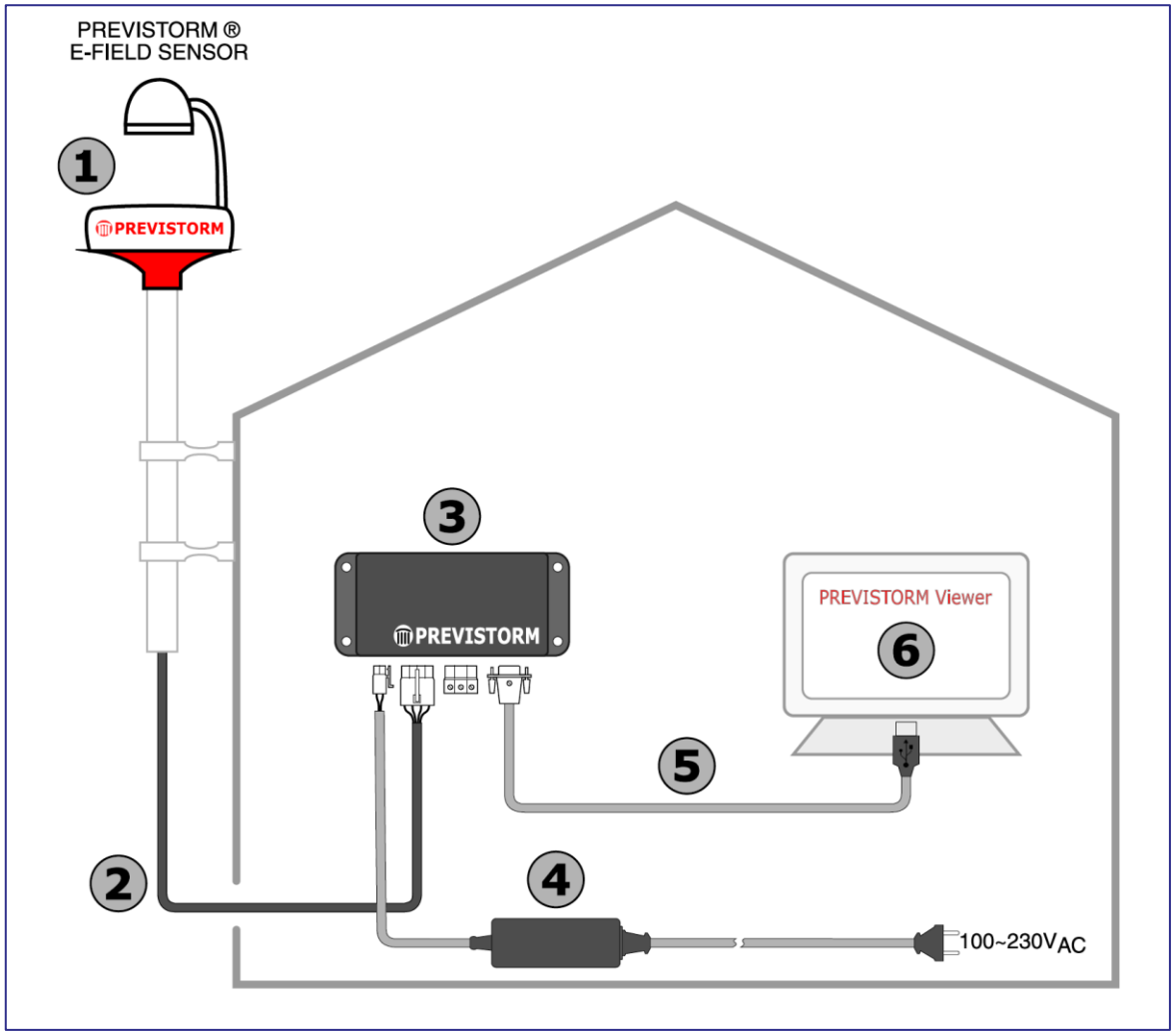


Figure 5. Previstorm® Thunderstorm Warning System, main components.

Packs


PREVISTORM® Thunderstorm Warning System
L > 20 m
PREVISTORM® TWS
QuickOptiMAX Pack
PREVISTORM® TWS
QuickOptiMAX-nF Pack
PREVISTORM® TWS
OptiMAX Pack
PREVISTORM® TWS
OptiMAX-nF Pack
L ≤ 20 m
PREVISTORM® TWS
QuickInstall Pack
PREVISTORM® TWS
QuickInstall-nF Pack
PREVISTORM® TWS
QuickStart Pack
PREVISTORM® TWS
QuickStart-nF Pack

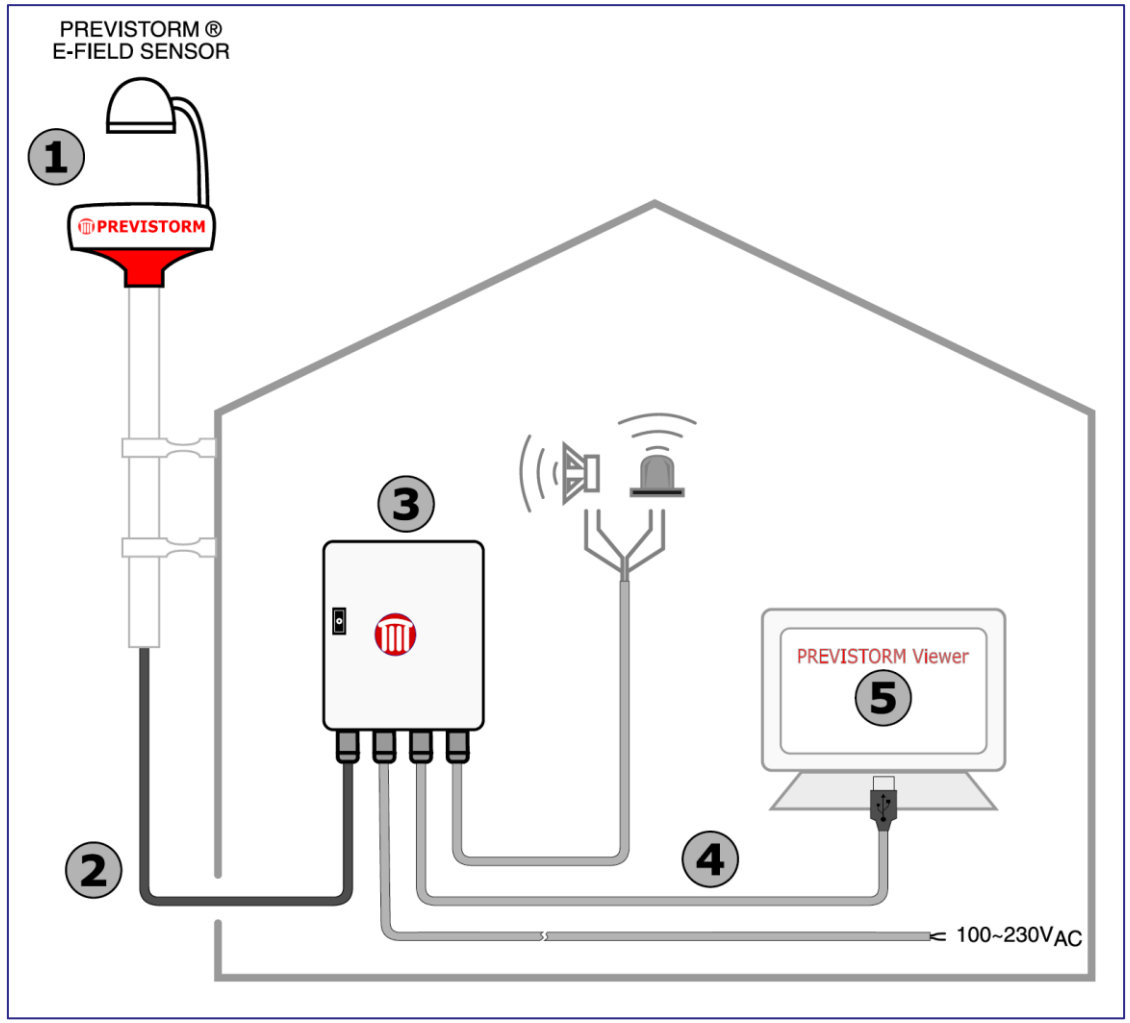
Basic KIT



PREVISTORM® TWS QuickStart Pack

1. PREVISTORM® E-Field Sensor.
2. 20m Connections cable.
3. Indoor connections box.
4. Industrial desktop power supply.
5. Serial communications interface.
6. PREVISTORM® Viewer Software.

Easy installation KIT

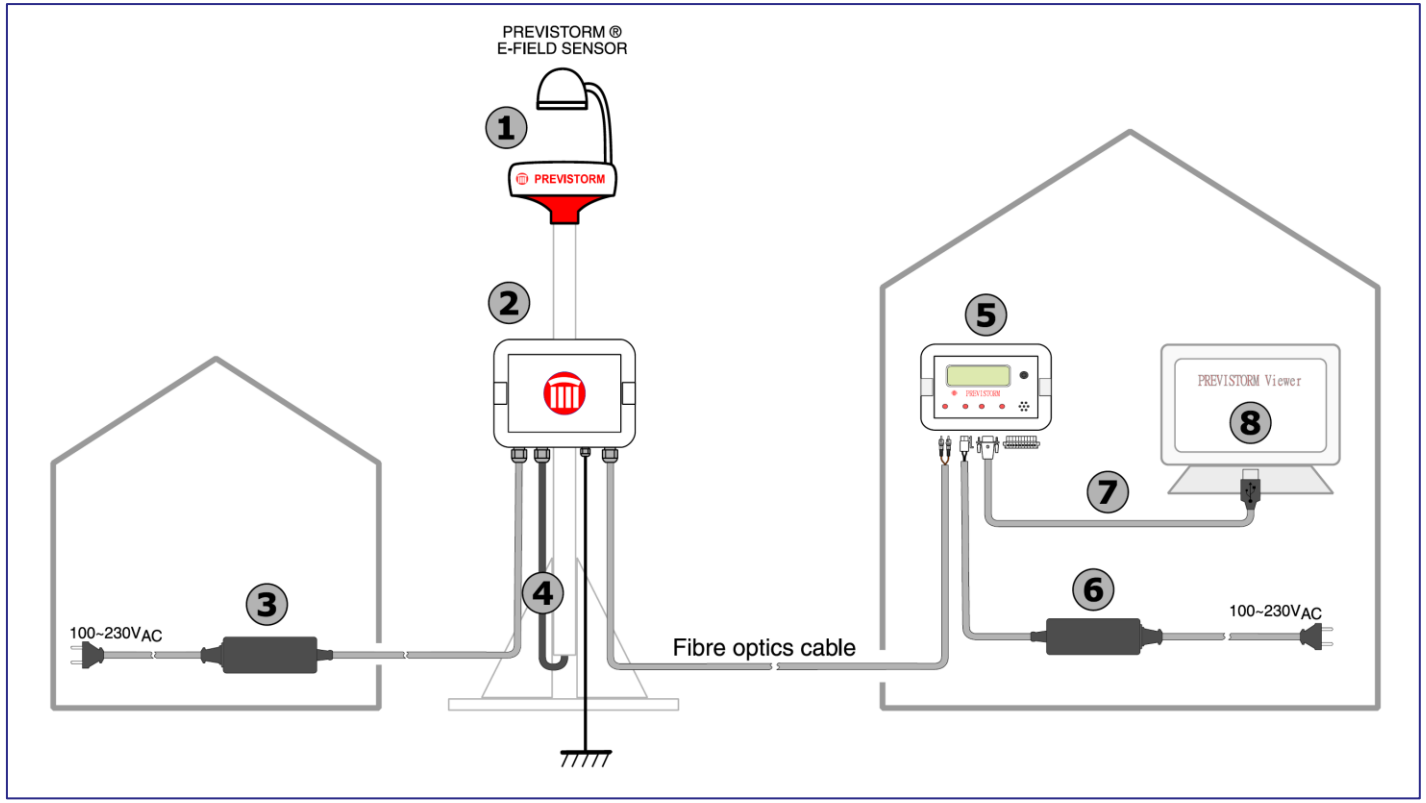


PREVISTORM® TWS QuickInstall Pack

1. PREVISTORM® E-Field Sensor.
2. 20m Connections cable.
3. Sensor Interface cabinet (1).
4. Serial communications interface.
5. PREVISTORM® Viewer Software.

(1) The sensor interface cabinet includes the power supply for the sensor, the connections box and two isolated auxiliary relays for controlling external devices like sirens, lights, etc.

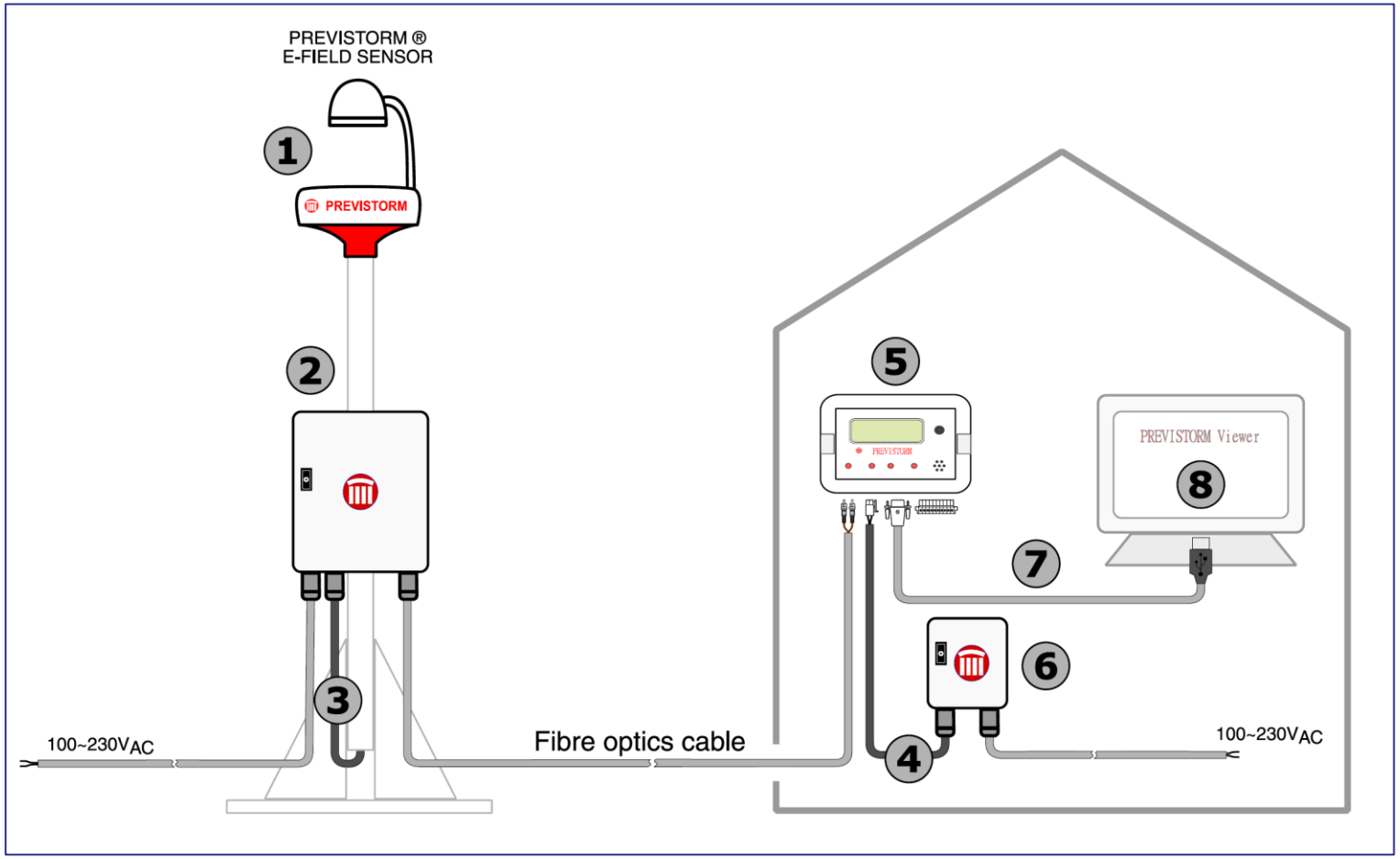
Optical fiber KIT



PREVISTORM® TWS OptiMAX Pack

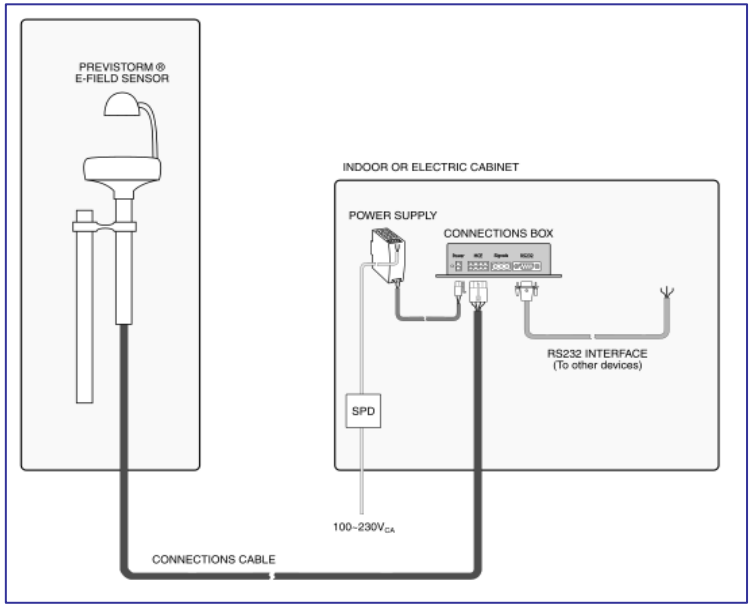
1. PREVISTORM® E-Field Sensor.
2. Cable to fibre optics converter.
3. AC -to- DC Power supply.
4. 2.5m Connections cable.
5. PREVISTORM® Console.
6. AC -to- DC Power supply.
7. Serial communications interface.
8. PREVISTORM® Viewer Software.

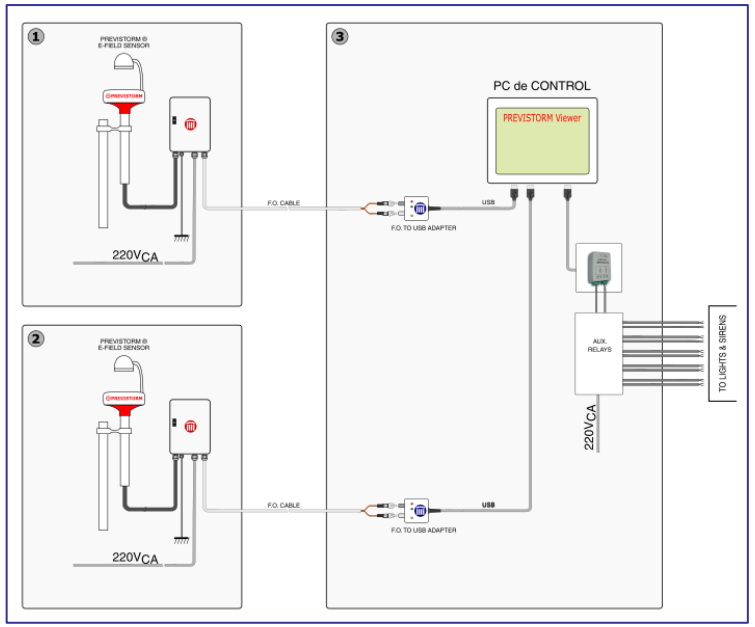
Optical fiber easy installation KIT



PREVISTORM® TWS QuickOptiMAX Pack

1. PREVISTORM® E-Field Sensor.
2. Sensor Interface cabinet.
3. 2.5m Connections cable.
4. 1m DC Power cable.
5. PREVISTORM® Console.
6. Power supply cabinet.
7. Serial communications interface.
8. PREVISTORM® Viewer Software.

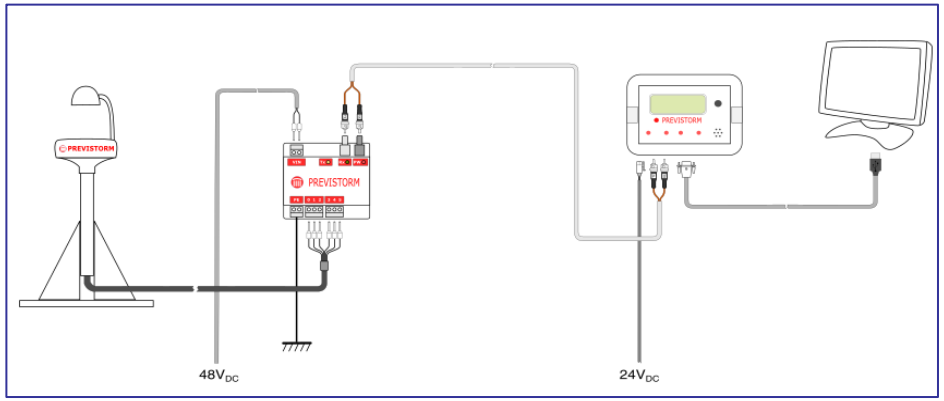


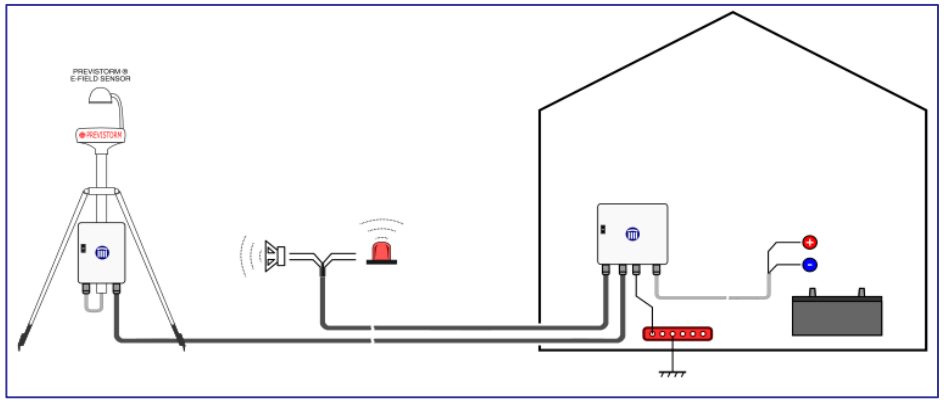


Source IEC 62793:2020

Highly configurable system

The **PREVISTORM® TWS** can be adapted to satisfy from simplest to most demanding sets of requirements.

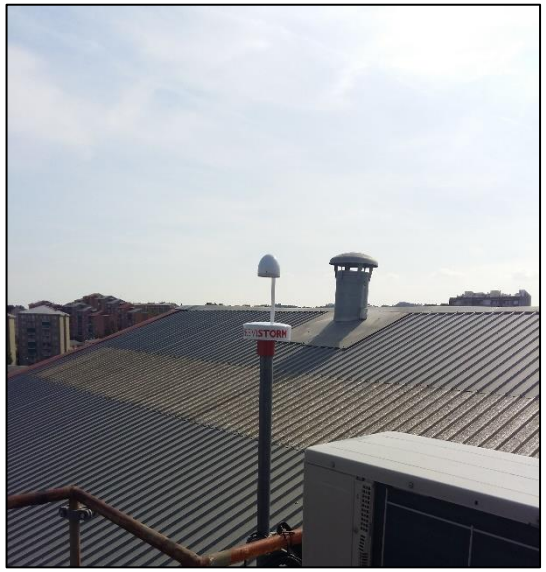


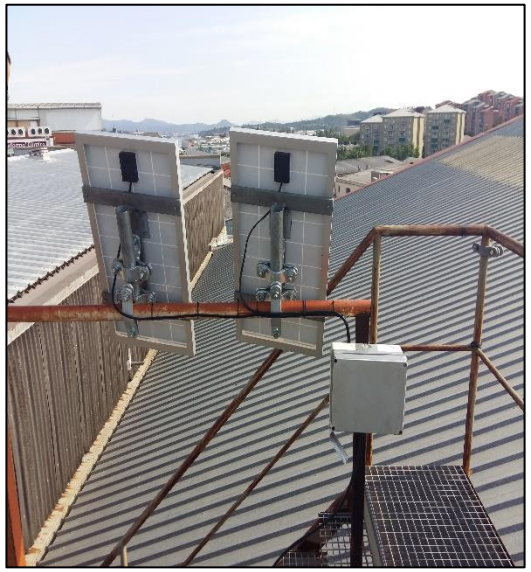


INGESCO LIGHTNING SOLUTIONS

PREVISTORM THUNDERSTORM WARNING SYSTEM

Installation example





Installation example

Installation example

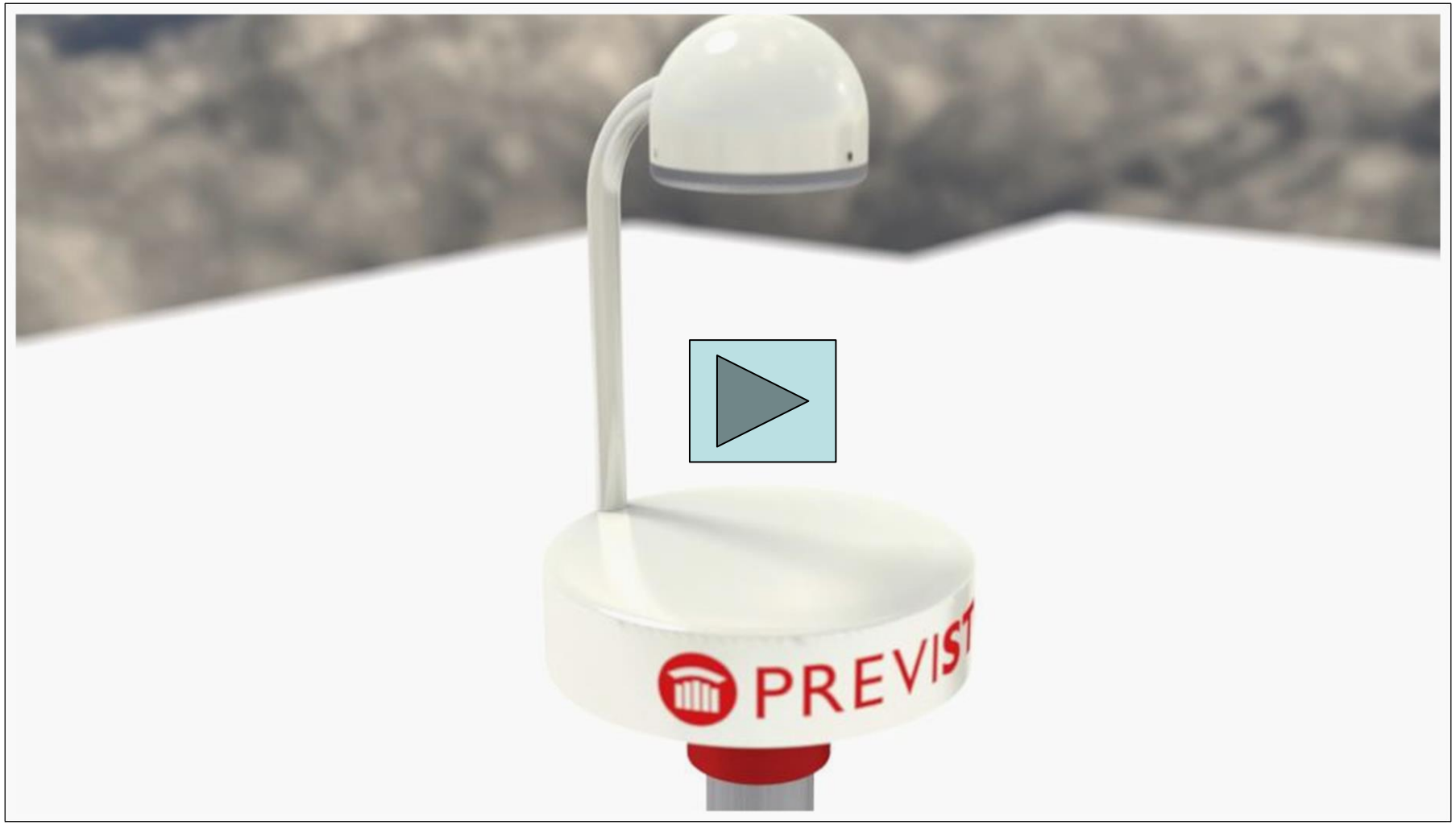
Installation example

Market Applications

▸▸ Thunderstorm warning system

- ❑ Mining.
- ❑ Amusement and theme parks, fairs and shows.
- ❑ Telecommunications towers and transmission centres.
- ❑ Nuclear plants, power plants in general.
- ❑ Hotels,resorts and schools.
- ❑ Oil and gas industries.
- ❑ Airports and harbours.
- ❑ Open sport areas.
- ❑ Scientific investigation centres.
- ❑ Renewable energy

Installation video



THANKS FOR YOUR ATTENTION

PARADISE ELECTRIC GROUP

INGESCO® LIGHTNING SOLUTIONS

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