INFLUENCE RADIUS CALCULATION

CMCE TECHNOLOGY

Integrated Analysis IEC 62305 and Coulomb's Law

SERTEC SRL – Engineering Department

INDEX

CMCE PROTECTION AREA

THEORETICAL FRAMEWORK:

IEC 62305 is the most widely accepted international reference framework for the study of protection against atmospheric discharges. This body of regulations assumes as a guiding principle that protection is based on the direct interception of lightning by an air terminal (Franklin-type lightning rods or other sensors). Under this approach, lightning is modeled as a direct impact on a high conductive point, and protection systems are designed to capture, conduct, and disperse that current to the ground.

Although our CMCE deionizing technology is not based on the principle of "capture" but on the compensation and control of the electric field, it is essential to use IEC 62305 as a theoretical basis. From this framework we take especially:

Normalized lightning parameters: waveform 10/350 µs and 0.25/100 µs, current peak values, front slope (di/dt), transferred charge (Q) and specific energy (I^2t).

Electrogeometric models: correlation between the crest current and the radius of the fictitious sphere (r = 10· I^0.65), which allow for the establishment of geometric limits of protection.

Dielectric breakdown theory: conditions in which air or other media reach their dielectric strength and allow the formation of the ascending tracer, the physical basis for understanding how discharge begins.

Statistical distribution of currents and polarities: providing a probabilistic framework on the occurrence of positive and negative discharges and the associated current percentiles.

These elements, although originally formulated to justify protection by direct impact, are of great theoretical interest to us because they allow us to quantify the severity of the discharge, to understand the process of ionization and dielectric breakdown, and to have comparable parameters at an international level.

Consequently, the theoretical framework we adopt is based on IEC 62305, understanding that what is essential for our methodology **is the physical characterization of the lightning and not necessarily the principle of interception.** Deionization brings a paradigm shift, but it is sustained

in the same parameters that the international standard has established to model the most severe electrical phenomenon in the atmosphere. But with the concept of maintaining sufficient conditions so as not to reach the dielectric breaking point of the medium

Another of the principles that we will base the study on is Coulomb's law

Coulomb's law is one of the fundamental principles of electrostatics, establishing that the force between two point charges is proportional to the product of their magnitudes and inversely proportional to the square of the distance separating them:

$$F = k\frac{Q_1 Q_2}{r^2}, \qquad k = \frac{1}{4\pi\varepsilon_0}$$

From this relationship it follows that the **electric field** generated by a point charge at a point in space is:

$$E(r) = \frac{F}{q_{\text{prueba}}} = \frac{1}{4\pi\varepsilon_0}\frac{Q}{r^2}$$

This concept is the basis for understanding the interaction of the deionizing device with its environment. Although in practice the device is not a point charge but a system of electrodes, its external behavior can approximate that of an **electric dipole**. In that case, the dipole moment p=Q·d defines the external field, which decreases more rapidly with distance:

$$E_{\text{dip}}(r) = \frac{1}{2\pi\varepsilon_0}\frac{p}{r^3}$$

The direct consequence is that, at a certain RRR distance, the field generated by the device equals the ambient electric field present in the atmosphere during normal or storm conditions:

$$E_{\text{dip}}(R) = E_{\text{amb}}$$

From this equality the **radius of action** is obtained:

$$R = \left(\frac{1}{2\pi\varepsilon_0}\frac{p}{E_{\text{amb}}}\right)^{1/3}$$

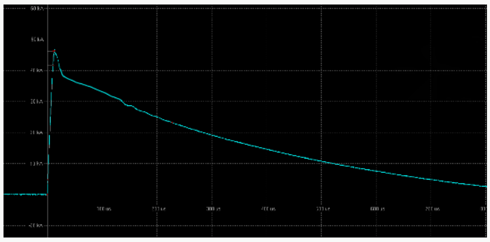
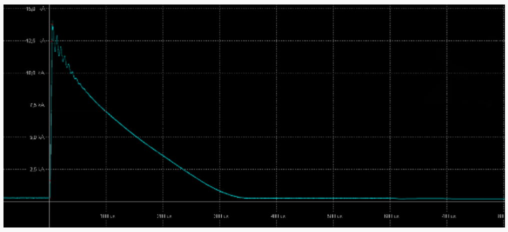
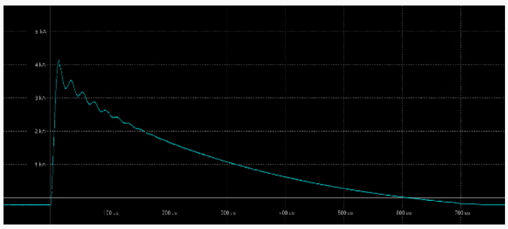
This radius represents the extent to which the device exerts an effective influence on the electrical environment, modulating the local field gradient and reducing the probability of formation of ascending tracers that favor the impact of lightning.

In conclusion, the use of **Coulomb's law** and its extensions to the dipole model allow the translation of internal parameters of the device (accumulated charge, effective electrode separation, maximum operating voltage) into a **quantifiable external radius of action**, which constitutes the practical measure of its effectiveness as a deionizing protection technology.

ANALYSIS OF THE CMCE SYSTEM IN CASE OF FAILURE 1%– IEC 62305 WAVEFORM

For this part, we took the resource that from the failure of the CMCE system, in this case a short circuit, the limits based on this condition are estimated and values are obtained for the curve of 10/350 µs.

The three main land models and the three marine models are subjected to these impulses and discharge currents are used, the values of the peak current greater by similar size will be taken as a reference in order to increase the safety coefficient, after derivation to Earth according to the following table:

MODELS	FAIL CURRENTS MARINE MODELS	FAIL CURRENTS LAND MODELS	**GRAPH**
CMCE 120/CMCE DIAMOND	44 KA	47.5 KA	
CMCE55/ CMCE PLATINUM	13.5KA	13.78 KA	
CMCE 25/ CMCE GOLD	3.9KA	4.1KA	

Part I – IEC 62305 (10/350 µs Waveform) and Sphere Radius

Lightning current model (IEC 62305, first stroke 10/350 µs)

IEC 62305 defines the first stroke 10/350 µs waveform by:

$$i(t) = \frac{I}{k} \frac{(t/\tau_1)^{10}}{1 + (t/\tau_1)^{10}} \cdot e^{-t/\tau_2}$$

with (I) the crest current, (τ_1) the front parameter, (τ_2) the tail parameter, and k a normalization factor. For the 10/350 waveform:

(τ_1 = 19,µs)

(τ_2 = 485,µs)

Normalization: (k ≈ 0.93118).

Example with CMCE 55: CMCE Platinum/CMCE 55 Fail in failure, the current through the protection device is **I = 13.78 kA** (minimum design current).

1.1 Parameters for I = 13.78 kA/CMCE PLATINUM

Crest current: **13.78 kA**

Time to crest: **31.4 µs**

Front time (10–90%): **8.0 µs**

Tail to half-value: **339 µs**

Charge transfer: **Q ≈ 6.78 C**

Specific energy: **I^2t ≈ 4.86×10^4 $A^2 \cdot s$**

Sphere radius

Analyzing the radius of protection in relation to the fault

IEC/IEEE correlation:

$R = 10 * I^{0.65}$

For **I = 13.78 kA → R = 55 m**

Design note: This is the minimum radius to ensure interception of strokes ≥ 13.78 kA.

R = 120 m → I ≈ 45.7 kA

Q ≈ 22.5 C, I^2t ≈ 5.42×10^5 $A^2 \cdot s$

R = 25 m → I ≈ 4.1 kA

$Q \approx 2.0$ C, $I^2t \approx 4.28\times10^3$ $A^2\cdot s$

Time-related parameters remain stable (31.4 µs to peak, 8 µs front, 339 µs tail), while energy and charge scale with current magnitude.

CMCE System Analysis Capacitances and Coulomb

Analyzing the CMCE as a high-efficiency capacitor. In this context, CMCE (Electrostatic Field Compensator) technology acts as a deionizing system, whose operating principle is assimilated to that of a "dynamic capacitor". The device continuously stabilizes and drains the electrical charge to the ground, preventing sufficient potential gradients from building up to initiate an upward tracer. Unlike traditional systems, which assume the impact of lightning on an air terminal, the CMCE seeks to alter the conditions of ionization and dielectric breakdown, reducing the probability of lightning formation on the protected structure.

Calculation Memory – CMCE Device Influence Radii

(with V_{max} = 1.10 MV)

Context of the problem

The device was tested in the laboratory and it was found that it withstands **330 kV at 0.30 m**,

which extrapolated to 1 m is equivalent to a breaking dialectric of **Emax ≈ 1.10 MV/m**.

This is the operating limit that is adopted as the **maximum permissible working voltage before flashover**, based on the laboratory

The aim is to calculate, for radii of influence, the equivalent capacitance obtained and the charge of the devices in which the electric field generated by the device is capable of imposing itself on the **ambient field**:

- **Good weather:** $\boldsymbol{E}_{amp\beta}$ = 100 V/m
- **Storm:** $\boldsymbol{E}_{amp\beta}$ = 1000 V/m

Physical model

The device consists **of two modules that after an integral one is equivalent to the upper and lower distances**, separated by polyacetal:

1. Superior: $d_1 = 9.2\ cm = 0.092\ m$.

2. Bottom: $d_2 = 5.4\ cm = 0.054\ m$.

Both contribute to the **total dipole moment**:

$$p_{\mathrm{eq}} = C_1 V_{\max} d_1 + C_2 V_{\max} d_2$$

Since the rod connects in parallel, we can express the sum with a **weighted average of dielectric distance**:

$$p_{\text{eq}} = V_{\max}\, C_{\text{eq}}\, d_{\text{eq}}$$

with

$$d_{\text{eq}} = \frac{C_1 d_1 + C_2 d_2}{C_1 + C_2}$$

and

$$C_{\text{eq}} = C_1 + C_2.$$

Definition of the radius of influence

The radius of influence **R** is defined as the distance where the device's eigenfield equals the ambient field:

$$E_{dip}(R)=E_{amb}$$

which leads to:

$$\boxed{C_{\text{req}} = \frac{2\pi\varepsilon_0\, E_{\text{amb}}\, R^3}{V_{\max}\, d_{\text{eq}}}}$$

which leads to:

$$\boxed{Q_{\text{suf}} = C_{\text{req}}\, V_{\max} = \frac{2\pi\varepsilon_0\, E_{\text{amb}}\, R^3}{d_{\text{eq}}}}$$

Choice of the effective parameter $d_e q$

The values C_1, C_2, are adopted are similar therefore:

$$C_1 \approx C_2 \quad \Longrightarrow \quad d_{\text{eq}} = \frac{d_1 + d_2}{2} = \frac{0.092 + 0.054}{2} = 0.073\ \text{m}.$$

This puts $d_e q$ within the range [0.054 m, 0.092 m]. The sensitivity will be ±20–35% around the face value.

Numerical substitutions

Constant:

- $\varepsilon_0 = 8.854 \times 10^{-12}\ \mathrm{F/m}$
- $V_{\max} = 1.10 \times 10^{6}\ \mathrm{V}$
- $d_{\mathrm{eq}} = 0.073\ \mathrm{m}$

Caso A: R= 120m

1. Storm (1000 V/m):

$$C_{\mathrm{req}} = 1.197 \times 10^{-6}\ \mathrm{F} = 1.197\ \mu\mathrm{F}, \qquad Q_{\mathrm{suf}} = 1.317\ \mathrm{C}$$

The capacitance of the CMCE 120 and CMCE Diamond exceed 2.5 and 2.1 µF Respectively, this capacitance is related to the internal design and patented with Sertec as part of its intellectual property of the capacitances obtained.

Caso B: R=55 mR = 55 \, mR=55m

- **Storm (1000 V/m):**

$$C_{\mathrm{req}} = 1.154 \times 10^{-7}\ \mathrm{F} = 115.0\ \mathrm{nF}, \qquad Q_{\mathrm{suf}} = 0.127\ \mathrm{C}$$

La capacitancia del CMCE 55 y CMCE Platinum superan los 317.51 nF y 259.13 nF Respectivamente, esa capacitancia esta relacionado con el diseño interno y patentada con Sertec como parte de su propiedad intelectual de capacitancias obtenidas.

Caso C: R=25 mR = 25 \, mR=25m

1. Storm (1000 V/m):

$$C_{\mathrm{req}} = 1.082 \times 10^{-8}\ \mathrm{F} = 10.82\ \mathrm{nF}, \qquad Q_{\mathrm{suf}} = 0.0119\ \mathrm{C}$$

The capacitance of CMCE 25 and CMCE Gold exceed 43nF and 38 nF Respectively, this capacitance is related to the internal design and patented with Sertec as part of its intellectual property of the capacitances obtained.

Summary:

For **R = 120 m** , ≈120 nF (0.132 C) in good weather, or ≈1.2 µF (1.32 C) in storm, are required. **Sertec's Capacitance systems (CMCE 120 and CMCE DIAMOND) exceed 2.1 µF**

For **R = 55 m** , ≈115 nF (0.127 C) is sufficient in stormy weather. **Sertec's Capacitance systems (CMCE 55 and CMCE PLATINUM) exceed 250 nF**

For **R = 25 m**, ≈10.82 nF (0.0119 C) in stormtime. **Sertec's Capacitance systems (CMCE 25 and CMCE GOLD) exceed 38 nF**

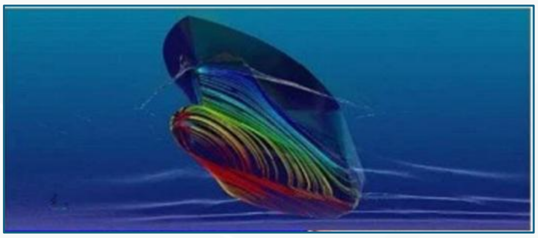
MARINE APPLICATION IN SCOPE OF PROTECTION

Importance of the land system and hull in marine applications

Although the previously calculated radius of protection is a fundamental parameter to define the protected area, in marine applications it cannot be considered in isolation. The ground system and the nature of the hull – whether it is a driver or a non-driver – play an equally decisive role.

In boats with a metal hull, the submerged surface itself acts as a large electrode, facilitating the natural dissipation of charges into the water. On the other hand, in insulating hulls (fiber, wood, composites), it is essential to incorporate submerged plates or anodes that provide a low-impedance path to the sea. In this way, the theoretical protection radius is complemented by the actual ability of the system to discharge induced electrostatic charges, ensuring that the electric field is kept below the dielectric breakdown threshold.

Hull Material	Resistivity ρ (Ω·m)	Conductivity σ (S/m)	Practical note for grounding / CMCE
Bare Aluminum (5xxx/6xxx alloys)	$(2.8–4.0)\times10^{-8}$	$25–36\times10^{6}$	Excellent conductor: the hull itself can act as a natural electrode if in direct contact with water.
Painted or Anodized Aluminum	$10^{10}–10^{14}$ (surface layer)	$10^{-10}–10^{-14}$	Paint/anodizing are insulators: the hull must be treated as non-conductive → requires grounding plates or exposed anodes.
Bare Carbon Steel (naval grade)	$(1.0–1.6)\times10^{-7}$	$6–10\times10^{6}$	Very good conductor; if uncoated, the hull itself can provide dissipation.
Painted Steel / Stainless Steel with coating	$10^{8}–10^{12}$ (surface layer)	$10^{-8}–10^{-12}$	Paint/oxides create insulation → requires submerged plates or exposed metallic contact points.
Fiberglass (GRP)	$10^{12}–10^{14}$	$10^{-12}–10^{-14}$	Fully insulating → always requires grounding plates/anodes.
Wood (dry → wet)	$10^{8}–10^{14}$ (dry) · $10^{2}–10^{6}$ (wet)	$10^{-8}–10^{-14}$ · $10^{-2}–10^{-6}$	Highly variable; recommended to be treated as non-conductive.
Carbon Fiber (anisotropic)	$\sim10^{-5}$ (longitudinal) · $\geq10^{-2}$ (transversal)	$\sim10^{5}$ · $\leq10^{2}$	Directional conductor: requires bonding bridges and connection to plates/anodes.

Decision Rule by A_{water} (insulating hulls)

Model	Nominal radius (m)	A_{Water} range (m²)	Reference vessel	Notes
CMCE Gold	25	≤ 50	Small sailboat / recreational boat	Use if DF,DP,DH < 25 m; upgrade in high lightning zones
CMCE Platinum	55	50–200	Medium catamaran / cruising sailboat	Use if 25–55 m dimensions; good for larger insulating hulls
CMCE Diamond	120	>200	Large yacht / passenger ship	Use if 55–120 m dimensions; prefer in high electrostatic demand

Integration with DF, DP, DH

- <25 m → Gold
- 25–55 m → Platinum
- 55–120 m → Diamond
- If A_{agua} suggests higher model, the higher model prevails.

Adjustment Factors

- High lightning density zones
- Multiple masts/superstructures
- Critical equipment continuity
- High average speed or long voyages
- Wind wings and other technologies that increase the electric field around the vessel and mast
- Oil Rigs and others

APPROACH APPLIED TO SUCCESS STORIES

The effectiveness of a lightning protection system cannot be evaluated in the laboratory alone. For this reason, the methodology applied by Sertec includes **field validation**, in real scenarios with high storm density with strong data in geographical points where lightning discharge is the norm and not the exception. The analysis of **local ceramic levels** and their evolution after the installation of the CMCE allows documenting the improvement in operational continuity and the reduction of failures, consolidating the technology as a practical alternative to traditional systems.

VALIDATION IN THE FIELD:

AES – PANAMA

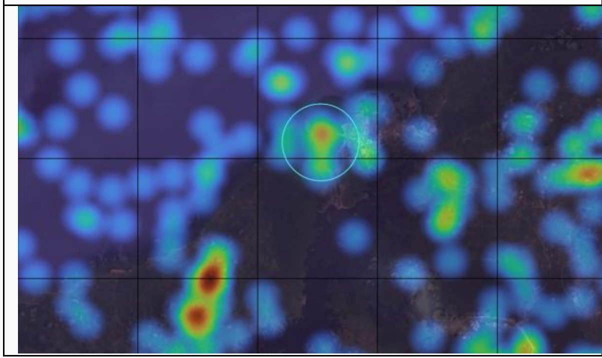
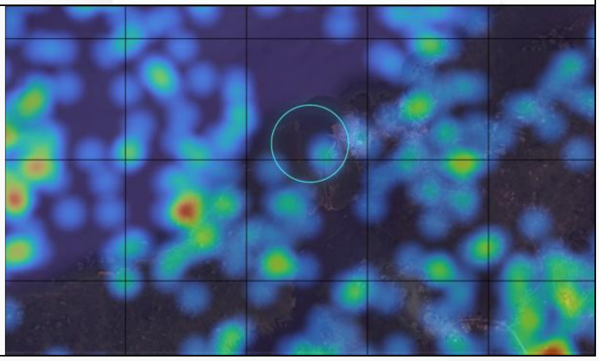
AES – COLÓN is the Natural Gas Power Plant that uses combined cycle technology for its efficiency and contribution to the environment. It reuses the heat from the exhaust gases of the gas turbines to obtain steam, to then be used by the steam turbines and save on fuel consumption in the production of electricity.

It is the first Liquefied Natural Gas plant in Panama and the Central American region, and it also has a 180,000 m^3 LNG storage tank.

PROBLEM

The plant faced the problem that as a result of the constant electrical discharges, the gas leak sensor failed and gave false alarms, which generated plant shutdown, representing millions of dollars in loss of profit, apart from the material and structural damage that this phenomenon generated. Due to the high frequency of discharges, their implanted solutions of air terminals were not enough, since they received many induced voltages and transient voltages, this was because the plant was located on the Atlantic coast with an important metallic wingspan as a whole as a plant and they were the first reference in electrical discharges since the storm fronts moved in the area and there is a confrontation in precipitation and collisions of Atlantic and Pacific wind, see the image on the left represented by a map of sunspots according to atmospheric electrical activity.

BEFORE & AFTER

BEFORE	AFTER
	

After implementing Sertec technology in a large part of the plant, an apparent reduction in atmospheric electrical activity in the area indicated on the map can be detailed after 5 years, this great change can be noticed because the plant is of great size, therefore it can be perceived in a satellite view

The single isocera analysis shows a significant reduction in the density of atmospheric discharges in the protected area, showing a safer and more controlled environment.

This confirms the effectiveness of CMCE-SERTEC technology in **mitigating electrical risk**, guaranteeing the protection of facilities, operational continuity and personnel safety.

TATA POWER – INDIA

TATA POWER is one of the leading power generation companies in India, with a strong commitment to the implementation of innovative technologies for the safety and efficiency of its facilities. Within the framework of its operation, a study of the incidence of atmospheric discharges in the region between 2018 and 2022 was carried out. The results show a high level of electrical activity, especially in the delimited area (marked on the red diamond), which is exposed to a large number of lightning strikes.

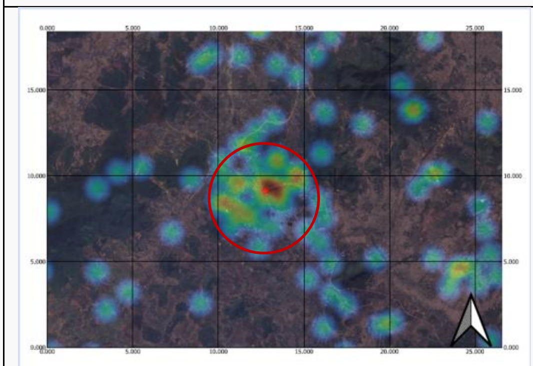
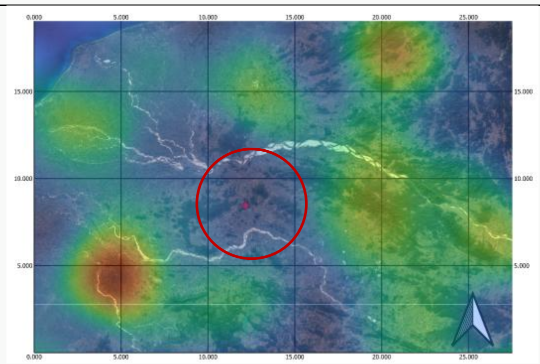
This analysis reinforces the need to adopt advanced protection systems that guarantee the safety of the infrastructure and the continuity of the electrical service.

PROBLEM

The discharge study showed that conventional technologies were not sufficient to ensure effective protection in the high-risk area of TATA POWER. Faced with this situation, the need to update the existing protection system and opt for a comprehensive solution that can neutralize and deionize the charges present in the atmosphere was raised, thus reducing the probability of direct lightning strikes on critical facilities.

This scenario opened the way for the incorporation of **CMCE-SERTEC Electro-Atmospheric Protectors**, based on results proven in other generation plants and in conditions of high incidence of discharges.

BEFORE & AFTER

BEFORE	AFTER
	

The ceraunique map of the TATA POWER area clearly shows the positive impact of the installation of **CMCE-SERTEC Electro-Atmospheric Protectors**. In the *BEFORE* section, a strong concentration of electrical discharges is observed in the critical area, with high density in red and yellow colors, which represented a constant risk to the infrastructure. In the *AFTER* section, after the implementation of the CMCE technology, there is evidence of a dispersion of electrical activity, significantly reducing the concentration of lightning in the plant facilities.

This result confirms that the CMCE-SERTEC system manages **to neutralize C-G (Cloud to Ground) type discharges in the protection radius**, reducing the probability of direct impacts and ensuring greater protection for TATA POWER's equipment and operations.

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