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Large Installation Protection Summary

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1 Introduction

For over 40 years LEC has been installing DAS to prevent lightning related damage to sites varying in size from a single tower to an area close to 1.5 square kilometers.

This paper determines the area protected by a DAS and calculates the number of strikes that the protected area would have received had a DAS not been installed. This calculated number of strikes is compared with the reported number of strikes to provide an indication of the effectiveness of a DAS.

2 Analysis Method

To arrive at the expected strikes or flashes per year for the protected area, the following factors and formulas were used:

2.1 Lightning incidence to various objects

The vulnerability of a structure or object to lightning involves evaluation of the equivalent collection area of the structure or object and the flash density of the area in which the structure is located using equation 1 [1].

$$\mathbf{N_a = A_e N_g} \qquad \textbf{Equation 1}$$

Where:

- N_a: The downward lightning incidence to a flat area structure.
- A_e: Equivalent collection area
- N_g: Ground flash density in flashes per square kilometer per year from lightning flash density maps

2.1.1 Equivalent Collection Area

This is the equivalent ground area having the equivalent lightning flash vulnerability as the structure. It is an area that includes the effect of the height and location of the structure [2]. The equivalent collection area used by LEC is illustrated in the following figures.

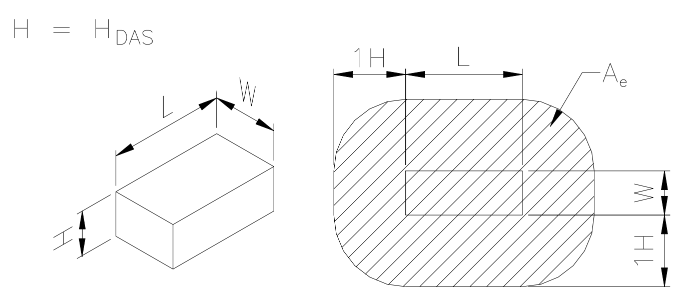
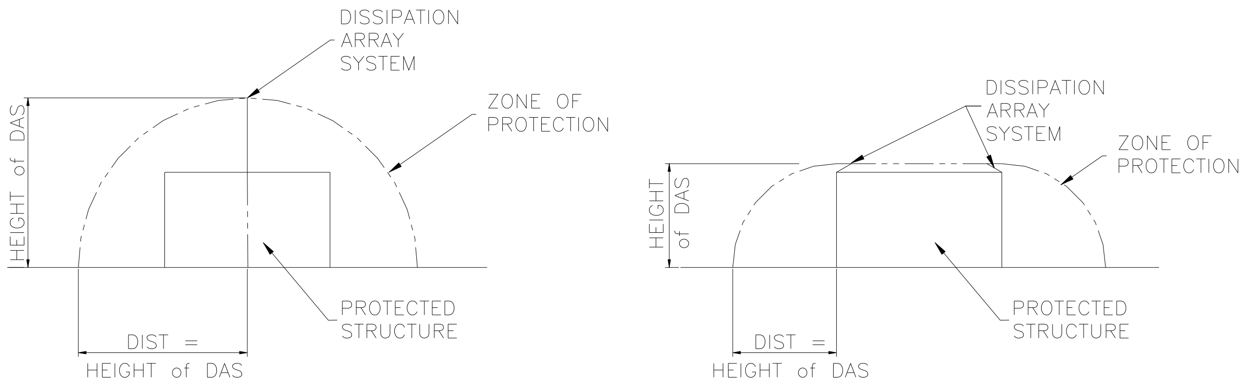


Figure 1: LEC Protection Area

The flat ground equivalent collection area used in this analysis is based on a collection area equal to the height of the structure as illustrated in figure 2: Flat Ground Equivalent Collection Area.



With Elevated DAS — With DAS on Roof

Figure 2: Flat Ground Equivalent Collection Area

Where there is a taller structure in the area, the protected area is determined as shown in figure 3: Influence of a Taller Structure.

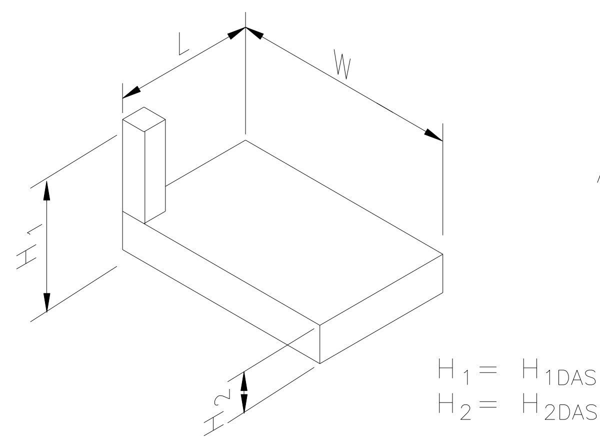


Figure 3: Influence of a Taller Structure.

The protection area for an entire site is represented in figure 4: Example of a Site Protection Area. This is the effective area used in the LEC calculations for an entire site

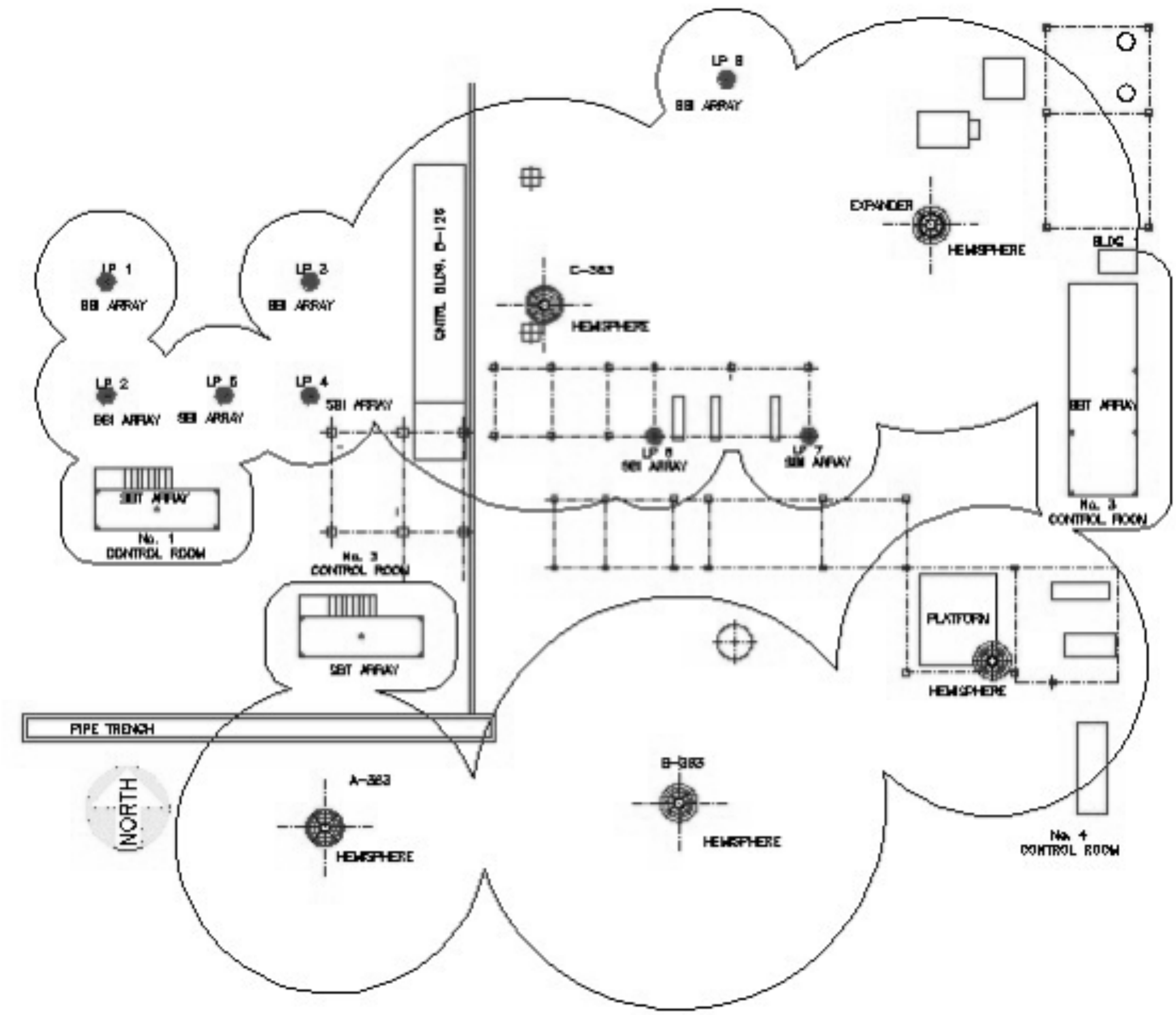


Figure 4: Example of a Site Protection Area

The LEC equivalent collection area determined by one of two factors is multiplied by the flash density to determine the number of strikes per year to the site.

2.1.1.1 Flat ground area

The first factor is based on the flat ground area shown in figure 4: Example of a Site Protection Area.

2.1.1.2 Tall Structures

The second factor involves structures significantly higher than the surrounding area. Tall structures are subject to both upward and downward lightning flashes and may pose a greater risk to collection due to their height. Most of the sites under consideration have a structure taller than the surrounding structures so each site has a separate analysis of the tallest structure on site to compare with the flashes per year to the lower ground based objects.

This second factor analysis uses the following method concerning only the tallest structure on the site and its attractive radius determined by equation 2[1].

$$N = 24 \times 10^{-6} H_s^{2.05} N_g \qquad \textbf{Equation 2}$$

Where:

N = number of flashes per year
H_s : Height of the object in meters
N_g : Ground flash density in flashes/square kilometer/year

The greater number of these two factors is used to state the number of strikes per year that the protected area is expected to receive.

2.1.1.3 Sites with a single installation year

To determine how many strokes the site would have received since the initial installation of the DAS, the calculated yearly strikes are multiplied by the number of years the DAS has been installed to give the number of strikes that have been expected to the site since the DAS installation. The reported number of strikes to the site have been tabulated and compared to the expected number of strikes to demonstrate the effectiveness of the DAS in preventing strikes to a vulnerable site.

2.1.1.4 Sites with multiple installation years

Since these sites are large and have been expanded as the owner increased the area size, the DAS protection has also grown. The protected area analysis is based on the area of the latest significant DAS installation, not on the original DAS protection. The year used in the calculation to determine the length of time without a strike is the year of the latest significant installation.

This continual adding of the DAS is an indication that the customer understands that the DAS reduces or eliminates the cost of lightning related expenses.

2.1.2 Lightning flash density

The lightning flash density (flash density) is defined as the yearly number of flashes to ground per square kilometer[2]. A lightning flash to earth is defined as an electrical discharge of atmospheric origin between cloud and earth consisting of one or more strokes[3].

The flash density number for protected areas in the United States is determined from the NFPA 2014, Figure L.2, 1997-2010 Average U.S. Lightning Flash Density Map (flashes per square kilometer per year). For protected areas outside the U.S., the map "Lightning flashes per square kilometer per year, from April 1995 to February 2003. The data is from the combined observations of the NASA Optical Transient Detector (4/95-3/00) and Land Information System (1/98-2/03) instruments was used.

Some sites are in an area where there is a range of yearly strikes to a square kilometer; such as 8 – 10 strikes per square kilometer per year. For analysis purposes, the greater number in the range was used as the flash density.

3 Site Comments

The calculations of the protected area are based on a well maintained and inspected DAS. Where there have been reported strokes to the protection area, this paper provides comments on the particular site as well as the condition of the DAS or unusual circumstances that led to a degradation of the ability of the DAS to function as originally designed.

Facilities with multiple installation years analyzed for this paper are:

3.1 Federal Express, Memphis, TN

This site was originally protected in 1985 and has been modified numerous times as the Federal Express hub footprint has grown in size. As the hub has grown, the location of some of the airplane gates have changed with Federal Express moving them as required. Usually LEC is notified about these gate changes when they happen. LEC has always been advised to the addition of new buildings.

As a result of this lag in installation of gates and construction of new buildings there have been a few reported lightning events at the site. Each report has been investigated and found that there was no direct lightning strike to the area. The ensuing investigation found that the system had not been fully functional due to bonding, grounding or maintenance issues. The satisfaction of Federal Express with the LEC designed lightning protection system is evident by their continued use of the system as the Federal Express package delivery system expands.

3.2 PDVSA

The Amuay refinery tank farm in Venezuela was originally protected in 1990 with the remainder of the tank farm protected in 1991.

Since the tank farm (133 tanks) is all that is protected, the protected area is the sum of the area protected for each tank. None of the tanks are over 20 m high so the tower analysis limit of 20 m applies and there is no tall structure analysis for any of the tanks.

In 2012, the Amuay refinery (PDVSA) had a fire which killed several people. This fire was not the result of a lightning strike, but a gas line explosion.

3.3 PPG, Lake Charles, LA

This site was originally protected in 1991 and has been modified numerous times as new or different areas at PPG required lightning protection.

There was a strike reported to the Membrane area in 2009. This is one of the older parts of the plant, built in the late 1940s. LEC investigated the event and determined that the plant below grade grounding system, to which the DAS was connected, was not adequate and therefore required significant upgrading. LEC provided additional DAS protection to prevent additional problems until the grounding is improved.

3.4 BASF, Port Arthur

There have been no reported direct lightning strikes to the protected area since 2005.

4 Summary

Using the analysis method described above, the attached table is of the largest sites LEC has protected from direct lightning strikes since 1985.

DAS Success of Large Installations								
Site Name, Location	Flash Density (strikes/sq km/year)	Protected Area (sq km)	Before DAS Installa-tion	After DAS Installation				
			Expected Flashes per year	First Year or last significant installation	Expected Stikes to Protected Area since	Reported Flashes to protected area	Stikes per year since installation	Percent Success
Conoco, Lake Charles, LA	8 - 10	0.054	1.000	1994	21.000	0	0.000	100.00%
Covanta, Oxford, NJ	0.5 - 1.0	0.031	0.100	2006	0.900	0	0.000	100.00%
Turner; Campbellton Road, GA	5 - 6	0.010	0.050	2012	0.150	0	0.000	100.00%
Turner; Techwood, without uplink dishes	5 - 6	0.078	0.390	2012	1.170	0	0.000	100.00%
Huntsman, Port Neches, TX	8 - 10	0.030	0.851	2002	11.063	0	0.000	100.00%
Grand Bahama Power	15	0.084	1.260	2006	11.340	0	0.000	100.00%
Mission Energy, Gordonsville, VA	3 - 4	0.028	0.112	1994	2.352	0	0.000	100.00%
SCE&G, Eastover, SC	8 - 10	0.063	2.510	2008	17.570	0	0.000	100.00%
BASF, Port Arthur, TX	8 - 10	0.184	1.840	2004	20.240	1	0.091	95.06%
UPS, Louisville, KY	5 - 6	0.543	3.258	2009	19.548	0	0.000	100.00%
Fed-X, Memphis, TN	6 - 8	1.470	11.760	1985	352.800	2	0.067	99.43%
PPG, Lake Charles, LA	8 - 10	0.180	1.800	1994	37.800	0	0.000	100.00%
Int'l Paper, Pensacola (Cantonment), FL	10 - 14	0.036	1.590	2014	1.590	0	0.000	100.00%
Fidelity National, Jacksonville, FL	10 - 14	0.056	0.631	2005	6.310	0	0.000	100.00%
Borco Oil, Bahamas	15	0.190	2.850	2006	2.322	0	0.000	100.00%
Exxon, Baytown, TX, FCC #3	8 - 10	0.037	0.910	1997	16.380	0	0.000	100.00%
PDVSA, Amuay, Judibana, VZ	10	0.430	4.300	1992	98.900	0	0.000	100.00%
		Total Expected Strikes :			621.435			

5 References

1) "Lightning, Physics and Effects", Cambridge University Press, 2003; Rakov & Uman
2) NFPA-Installation of LP Systems-780-2014
3) IEC 62305-1 Protection against lightning - Part 1; General Principles, Edition 2.0