

## BrcLightning - Risk Analysis and Scaling for Protection against Atmospheric Discharge - Extender

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### ABSTRACT

*This manuscript intending to publicize the improvements incorporated in the BrcLightning application, including the Risk Analysis module with the help of a pop-up, which provides the result and assists in the identification of mitigating measures by the professional, which must be defined to reduce the calculated risks. Other points addressed in this extension are the improvements added to the database to meet the corporate demands of companies, referring to the Risk Analysis module. It also incorporates flexibilities to perform the sizing separately, in the design, evaluation and scaling modules of the LPS – Lightning Protection System that using rolling sphere method and Angle Method, incorporating, in some of the modules, the issue of opinions or alerts. These modules use the mathematical approach methodology. In addition to these improvements, this review included the reporting module of facilities in the filter system, which allows the use of the database more selectively for the emission of these documents. This filter has a structure for issuing corporate demands of reports. The results can be obtained quickly and easily, on-screen or printing several reports. The reliability and safety of the results can be assessed through the check with the examples of the standards that define the criteria and methodology, that must be followed to carry out for cases of Risk Analysis or through graphic drawings on AutoCad platform or similar for the sizing modules. Other improvements in this extension are the addition of topics for new modules for which we already have the equations modeled in Excel, although we have not yet coded in the programming language.*

## 1. Introduction

This article is an extension of the work originally presented at the Symposium SIPDA XV [1]. In the event, representatives of a large company attended our explanation and reported that the great difficulty they faced was to have the control and traceability of the various Risk Analyses that are performed for each building or structures of the various units of the company. So, considering that our system is structured in the form of a database, we evaluated that, by introducing structural changes in this database, it will be possible to meet this demand.

Concomitantly with this observation, we also identified that other improvements would be required, even to use the various modules of the system in isolation (before having to register a project), either in the database or through an app which may be via mobile phones. These improvements aim to meet specific demands, such as those to evaluate the effectiveness of the volume of protection of a given SPDA concerning the various structures or

equipment and facilities that, in principle, are or would be under protection against direct impacts of atmospheric discharges. In this case, the data is not embedded in the database but can be consolidated into a report, with options to be printed or archived.

Regarding the Reporting Module, this extension was less extensive, as it was composed by the improvements of the filters defined to facilitate the selective issuance of Database Reports, with limited coverage of the specificity of each module that make up the current system. However, because it is a database, we intended (in a new version) to provide tools in this module, to enable the data export specifically to the Excel environment, to allow better tools for analyzing historical data.

## 2. Definitions

- **Coverage radius (rc):** The distance between the point of the cover margin, of a determined envelopment of an LPS. This distance determines the size of the horizontal projection of the fictitious plane, given by equation (1):

$$rc = [h_1(2R - h_1)]^{1/2} - [h_2(2R - h_2)]^{1/2} \quad (1)$$

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where:

- rc horizontal protected distance
- h1 height of the higher mast
- R rolling sphere radius
- h2 height of the lower mast:

- **Cover margin height (hc):** The dimensions of the height of the nearest point on the envelope over the structure under the protection of the LPS;
- **Distance from the critical point (dl):** The distance between the critical point and one metallic element such as rods or wire air-terminations
- **Envelopment:** Geometric shape that limits the protected volume according to the rolling sphere method;
- **Coverage margin (cm):** The shortest distance between a point of the structure under the protection of the LPS and the envelopment of the protective volume. The dimension of the margin corresponds to the perpendicular tangent measurement of the envelopment to the nearest point of the structure under protection. The graphical representations of "cm" are as shown in Figure 1a, Figure 1b, and Figure 1c (all contained in Figure 1):

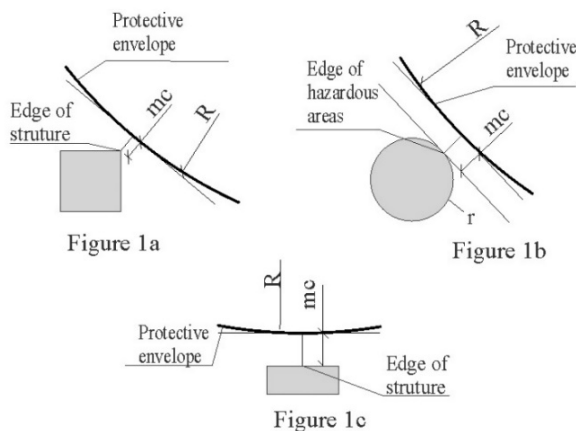


Figure 1: Examples of coverage margins

- **Fictitious plane (Fp):** Assumed horizontal plane that provides coverage of protection at a given height;
- **Hazardous areas:** Area surrounding storage facilities or transfer station of flammable liquids or gases, due to the possibility of containing flammable or explosive mixtures. They are defined in: Zone 0 (when the explosive/inflammable mixture is still there or will be for long periods); Zone 1 (likely to occur in normal operating conditions) and Zone 2 (it's unlikely – an abnormal condition of operation);
- **Sizing module marks:** The marks indicated in the graphs of the sizing and limit variation modules correspond to the extreme points of the structure that should be protected or evaluated on the effectiveness of the coverage by the SPDA protection wrap, as shown in figures 2 and 3 below:

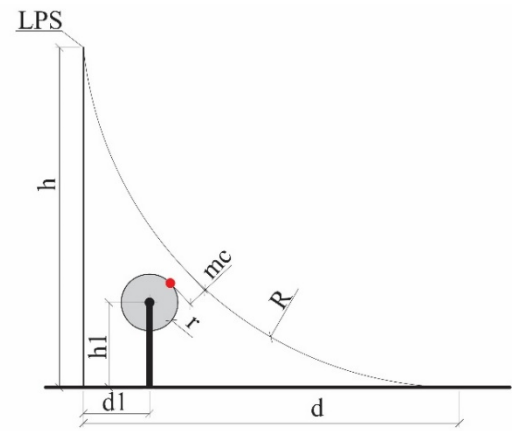


Figure 2: Hazardous areas limiting point figure (see Figure 1b)

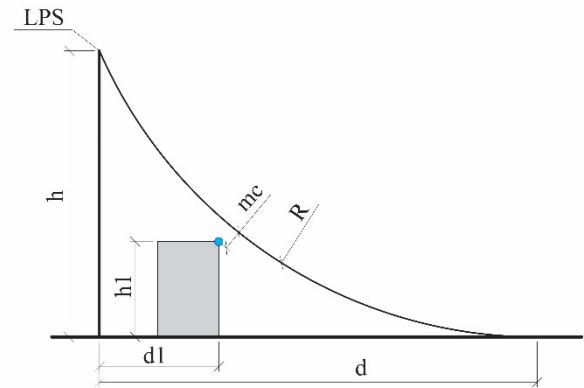


Figure 3: Structure limiting point figure (see Figure 1a)

### 3. Software Development

The application is developed in Access, in VBA language, to allow it to run on Windows and on the Internet. We had a project to carry out the migration to an Internet language; however, due to the Covid 19 pandemic, we had to cancel it. Nevertheless, we hope that, considering the problems due to the current situation, we can resume the project in the year 2021.

In this version, the system continues with the same configuration of modules and sections of the previous publication, from which this paper is an extension of (SIPDA XV [1]). Thus, we will focus on detailing the improvements that have been introduced, as described in sequence (items 4 to 7).

### 4. Risk Analysis Module

Risk Analysis consists of 5 sections: 1. Registration Module; 2. Zone Registration Module; 3. The configuration data of the connected lines and Zone.; 4. Risk Analysis Factors Module (typical loss value) and 5. Results Module.

#### 4.1. Registration Section

In this section, there are specific data related to design registration that can be common to all modules and all sections, but also, there are important data specific to the Risk Analysis Module. Due to this, we have identified that it will be more effective for these data input to be dismembered in two modules: one for general project registration and another for registration and

configuration of the Risk Analysis Module. However, this should only be performed in a new version.

The improvements that we introduced in this section included the fields of input to meet the demand to perform the registration of organizational structures, containing up to 5 levels: Level 1 - Hold Company; Level 2 - The Business Unit, which may or may not cover several other Operating Units; Level 3 - The Operational Unit; Level 4 - The Operational Sector and Level 5 - The

installation subject to risk analysis or the one containing Air Terminal. This improvement is only incorporated into the Registration Form of this Section. Therefore, in this version, it has not yet been possible to integrate this organizational structure registration with the other modules, including the Risk Analysis Module itself, regarding the reports. This requires numerous changes in the reports already formatted. The reported modifications are highlighted in green as shown in Figure: 4.

Figure 4: Main screen of data input

Figure 5: Screen for customizing structure and zones

#### 4.2. Zone registration module

The System was engineered to cover up to 5 Zones (NBR-5419-2 [2] and IEC 62305-2 [3] do not establish limits, but provide examples of up to 5 Zones), as we observe that this is a practice used and that already surpasses the examples provided by the standards cited. The number of Zones is selected as shown in Figure 4 (Zone in Study).

The System already makes several types of structures available, which were understood as necessary and sufficient to meet the range of facilities and buildings that must be studied and

related to each of them, the different types of Zones. However, the Designer can insert new structures and new zones, but he or she must proceed to register them. To do so, it will be necessary to customize them and make the association with the loss factors, as shown in Figure 5.

In this Section, the designer inserts the data for each zone that is defined for Risk Analysis, according to Section One of the Register, as shown in Figure 4. In this section, no improvement has been introduced, as show in Figure 6. For more details see SIPDA XV [1].

Figure 6: Screen of the setting module of the Zones (structure with all 3 Zones)

Figure 7: Setting screen of the connected lines and other zone data

#### 4.3. The setting data of the connected lines and Zone

This Section provides the space to enter information about power lines and telecommunications lines: how they connect to the site (building; installations; etc.). The designer can also enter protective measures due to touch and step voltage and other risk-mitigating measures, individually for each defined Zone. In this section, it was introduced improvements to the Help pop-up form with the result of the risk analysis, as shown in Figure 7. Thus, the designer can monitor the effectiveness of each mitigating measures

in real-time. This pop-up, once visible, can be viewed in all sections of the risk analysis module.

Also, there is a pop-up to help define line parameters and other alert parameters as shown in Figure 8.

#### 4.4. Risk Analysis Factors Module

This section presents the typical loss values for each zone (as shown in Figure 9), based on the definitions established in section one (as shown in Figure 4) and two (as shown in Figure 5).

The screenshot displays the BrcLightning software interface. The main window is titled "BrcLightning - Risk Analysis and Scaling for Protection against Atmospheric Discharge". It features a navigation bar with tabs: "Cadastro/Record", "Zonas - Dados/Zones - Data", "Dados Téc./Technical data", "Fatores da AR/RA Factors", "Resultados/Results", "Método ER/RS Method", "Mét. do Ângulo/Angle Method", and "Relatórios/Reports". The "Dados Téc./Technical data" tab is active, showing "Protective measures due to touch and step voltage and other mitigating measures in Zones". This section includes dropdown menus for "Additional measure (PTA)", "Protection measure (PTU/P)", "Protection measure (PTU/T)", "SPD (Pspd/P)", "SPD (Pspd/T)", and "Fire reduction factor (rp)". A pop-up window titled "Attribute of Connected Power Line" and "Attribute of Connected Telecom lines" is open, showing fields for "External line type", "Connection at entrance", "Additional description", "CLD", and "CLI". The pop-up also includes a warning message: "If there is equipment with different impulse withstand levels in an internal system, the lowest impulse withstand level should be selected."

Figure 8: The pop-up helps with line parameters and other information

The screenshot displays the BrcLightning software interface, specifically the "Loss Type Factors Module Screen". The main window is titled "BrcLightning - Risk Analysis and Scaling for Protection against Atmospheric Discharge". It features a navigation bar with tabs: "Cadastro/Record", "Zonas - Dados/Zones - Data", "Dados Téc./Technical data", "Fatores da AR/RA Factors", "Resultados/Results", "Método ER/RS Method", "Mét. do Ângulo/Angle Method", and "Relatórios/Reports". The "Resultados/Results" tab is active, showing a table with columns for "Z1 - External Area", "Z2 - Computer Center", and "Z3 - Offices". The table contains numerical values for "LT (L1/Z1)", "LF (L1/Z1)", and "LO (L1/Z1)" for each zone. The table also includes a section for "Considerations" with a text input field and a "Gravar / Record" button.

Figure 9: Loss Type Factors Module Screen



In the version presented in SIPDA XV [1], it was already possible for designers to change the typical loss value, if they had another interpretation regarding the one previously defined in the system (these factors defined in the system were based on the definitions established in NBR 5419 -2 [2] and IEC 62305-2 [3] for typical loss values). In this case, in the previous version, the designers had to standardize their basic values for each type of installation in advance. The improvement introduced allows that, in case they don't have a database parameterized with the values according to their interpretation criteria, they can do so by simply selecting the designer parameters (in the input field) and applying a double click on each factor that they want to parameterize. This way, a pop-up (as shown in Figure 10) form will appear for each factor and they will define it at their discretion. The new defined typical loss value, after being updated, will be highlighted in green

(as shown in Figure 10), but there are security restrictions and other requirements (see item 9.4).

#### 4.5. Results Module

In this section, the final result is as shown in Figure 11. Mitigating measures can also be inserted (the description of these measures), if the results indicate that this is necessary. Mitigation measures, as needed, can be included (these should be inserted descriptively). A technical note with the analysis design also can and should be inserted. Another improvement is the possibility of issuing, in a summarized format, the risk analysis report, as shown in Figures: 12 (a) and (b). This report contains the basic information of the risk analysis study and the result.

Figure 10: Loss Type Factors Module Screen with individualization pop-up

Figure 11: Result Module Screen and the button for printing the summarized report

### Risk Analysis Summary Report

(IE C 62305-2)

Design Nº: BRAAC2021FDA00001 - 0

Design Date: 16/02/2021

#### 1 - Registration data - Hospital

- Design name: STANDARD E.4 EXAMPLE HOSPITAL - Economic values: \$ 90.00 (10<sup>5</sup>)

- Address: 1000 Central Ave. NATAL, RN 59000000, Brazil

#### 2 - Physical and Environmental Characteristics

- Ground flash density (1/km<sup>2</sup>/year): NG 4,000000

- Structure dimensions (m): L=50; W=150; H=10 - Collection area (m<sup>2</sup>): AD 22.327

- Adjacent structure dimensions (m): L=20; W=30; H=5 - Collection area (m<sup>2</sup>): ADj 2.807

- Location factor of structure: Isolated structure: no other objects in the vicinity CD 1 (Table A.1)

- Location factor of Adj. struc: Isolated structure: no other objects in the vicinity CDj 1 (Table A.1)

#### 3 - Additional features

- Additional protection m: Structure not protected by LPS PB 1 (Table B.2)

- Total people in structure: 1000 - Time in hours per year: 8760 - Number of Zones: 4

#### 4 - Zone Customization Data

Z1 - External Area Z3 - Surgical Blocks/operating bloc

Z2 - Rooms Block Z4 - Intensive Care Unit

#### 4.1 - Specific characteristics of the Zones

	Z1	Z2	Z3	Z4
- Is the Zone considered in the Risk Analysis?	Yes	Yes	Yes	Yes
- Is it part of the main structure?	Yes	Yes	Yes	Yes
- Number of persons (nz):	10	950	35	5
- Time of presence in the Zone, in hours (tz):	8760	8760	8760	8760
- Reduction factor (type of surface)	"rt" (Table C.3)			
• Type of surface:	Concrete	Linoleum	Linoleum	Linoleum
• rt (Factor Value):	0.01	0.00001	0.00001	0.00001
- Reduction factor (risk of fire or explosion)	"rf" (Table C.5)			
• Risk	Explosion or fire	Fire	Fire	Fire
• Amount of risk	None	Ordinary	Low	Low
• rf (Factor Value):	0	0.01	0.001	0.001
- Is there a REI partitioning in the Zone?	Not	Not	Not	Not
- Increase factor in the amount of loss (presence of a special hazard)	"hz" (Table C.6)			
• Kind of special hazard	Difficulty of evacuation	Difficulty of evacuation	Difficulty of evacuation	Difficulty of evacuation
• hz (Factor Value):	5	5	5	5

#### 4.2 - Cost benefit analysis in the Zones

- No cost-benefit analysis (Risk R4) was performed

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### Risk Analysis Summary Report

(IE C 62305-2)

Design Nº: BRAAC2021FDA00001 - 0

Design Date: 16/02/2021

Location factor of adjacent structure: Isolated structure: no other objects in the vicinity CDj 1 Table A.1

Withstand voltage of internal system (kV): Uw 2,5

Resulting parameters	KS4	PLD	PLI	Value	Reference
	0.40	0.2	0.3		Eo. (B.7) Table B.8 Table B.9

#### 5.2 - Telecommunication

Input parameter	Comment	Symbol	Value	Reference	
Length (m)		LL	300		
Installation factor	Buried	CI	0.5	Table A.2	
Line type factor	Telecommunication or data line	CT	1.00	Table A.3	
Environmental factor	Suburban	CE	0.5	Table A.4	
Shield of line (W/km)		RS	19/km < RS ≤ 50/km	Table B.8	
Shielding, grounding, isolation	Shielded buried line (bonded)	CLD	1	Table B.4	
		CLI	0	Table B.4	
Adjacent structure (m)	Length, width, height (Li, Wi, Hi)		20 x 30 x 5		
Location factor of adjacent structure	Isolated structure: no other objects in the vicinity	CDj	1	Table A.1	
Withstand voltage of internal system (kV)		Uw	1,5		
Resulting parameters	KS4	PLD	PLI	0.67 0.8 0.5	Eo. (B.7) Table B.8 Table B.9

#### 6 - Risk R1 for the unprotected structure

Zone	%	R1 (10 <sup>-5</sup> )	RA	RB	RC	RM	RU	RV	RW	RZ
Z1	0.0%	0.009	0.009							
Z2	92.0%	64.368	0.001	42.422	8.484	2.414	0.000	9.206	1.841	0.000
Z3	7.0%	4.894	0.000	0.156	3.126	0.900	0.000	0.034	0.678	0.000
Z4	1.0%	0.699	0.000	0.022	0.447	0.128	0.000	0.005	0.097	0.000
Total R1	100.0%	69.970	0.010	42.600	12.057	3.442	0.000	9.245	2.616	0.000
% by risk component			0.0%	60.9%	17.2%	4.9%	0.0%	13.2%	3.7%	0.0%
D1 - Injury due to shock	0,010	0,0%								
D2 - Physical damage			51,845	74,1%						
D3 - Failure of internal			18,115							25,9%

#### Selection of protection measures

1) providing the whole building with an LPS Class I, included lightning equipotential bonding; 2) install coordinated SPD protection on internal power and telecom systems; 3) providing zone Z2 with automatic fire detection system; 4) install coordinated SPD protection on internal power and telecom systems in zones Z2, Z3, Z4.

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(a) Figure 12 (a): Summary of risk analysis report (first page) (b): Summary of risk analysis report (last but one page)

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Idioma/Language: ☐ Português ☒ English

BrcLightning-2020.00

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Cadastro/Record

Zonas - Dados/Zones - Data

Dados Téc./Technical data

Fatores da AR/RA Factors

Resultados/Results

Método ER/RS Method

Mét. do Ângulo/Angle Method

Relatórios/Reports

Cálculo d x h/Calculate d x h

Cálculo Spda Isolado/Calculate Isolated LPS

Cálculo Planos Cobertura/Calculation of Plans Coverage

Verificação de limites/Limit check

☐ NBR 5419-3 ☒ IEC 62305-3 ☐ NFPA 780

Is the calculation 'h' or 'd'? ☒ h ☐ d Data Base: ☐ Separate ☒

Technical Expert: Fulano dos Anzois Pereira

Design name/Rev:

No. LPS: 1 LPS for parking protection

LPS Design Class: Class IV

Rolling sphere radius (m): 60

Horizontal protected distance - d (m): 30,0

Height of LPS (calculated) - h (m): 8,04

Height of LPS (Design) - hp (m): 10,0

Horizontal protected distance (Design) - d (m): 33,2

New

Height protected h (m) of LPS for Horizontal protected distance d (m) - Class IV

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Figure 13: Example of calculation of h x d for Class IV

**BrcLightning - Risk Analysis and Scaling for Protection against Atmospheric Discharge**

Idioma/Language: ☐ Português ☒ English

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Cadastro/Record Zonas - Dados/Zones - Data Dados Téc./Technical data Fatores da AR/RA Factors Resultados/Results Mét. do ER/RS Method Mét. do Ângulo/Angle Method Relatórios/Reports

Cálculo d x h/Calculate d x h Cálculo Spda Isolado/Calculate Isolated LPS Cálculo Planos Cobertura/Calculation of Plans Coverage Verificação de limites/Limit check

☒ NBR 5419-3 ☐ IEC 62305-3 ☐ NFPA 780

Are there any hazardous areas? ☒ N ☐ Y Data Base: ☐ Separate: ☒

Technical Expert:

Design name/Rev:

No. LPS:  1 ☐ LPS for parking protection

LPS Design Class:  Class IV

Rolling sphere radius (m):  60

Height 'h1' of the structure to be protected (m):  2,5

Horizontal distance 'd1' of the structure to be protected (m):  15,0

Coverage margin 'mc' for the design of the LPS (m):  0,5

Height 'hc' calculated for the structure protection LPS (m):  10,44

Design height 'hp' for the LPS of protection structure (m):  12,00

Horizontal protection distance 'dp', of design, provided by the LPS (m):  36,00

Margin of coverage 'mcp', of project, provided by the LPS (m):  1,21

Design limits

Limit for height 'h1', keeping the distance 'd1' from the LPS (m):  3,26

Limit for the distance 'd1', keeping the height 'h1' of the LPS (m):  17,19

Maintaining the coverage margin values (mc) and the project height (hp) of the LPS.

Height protected h (m) of LPS for Horizontal protected distance d (m) - Class IV

If all or some of the chart legend markers aren't visible, it is because there is an overlap due to the similarity of values: h1≈h11 and / or d1≈d11.

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Figure 14: Sizing of the Isolated LPS, without hazardous area

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Idioma/Language: ☐ Português ☒ English

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Cadastro/Record Zonas - Dados/Zones - Data Dados Téc./Technical data Fatores da AR/RA Factors Resultados/Results Mét. do ER/RS Method Mét. do Ângulo/Angle Method Relatórios/Reports

Cálculo d x h/Calculate d x h Cálculo Spda Isolado/Calculate Isolated LPS Cálculo Planos Cobertura/Calculation of Plans Coverage Verificação de limites/Limit check

☒ NBR 5419-3 ☐ IEC 62305-3 ☐ NFPA 780

Are there any hazardous areas? ☒ N ☐ Y Data Base: ☐ Separate: ☒

Technical Expert:

Design name/Rev:

No. LPS:  1 ☐ LPS for parking protection

LPS Design Class:  Class IV

Rolling sphere radius (m):  60

Height 'h1' of the structure to be protected (m):  2,5

Horizontal distance 'd1' of the structure to be protected (m):  15,0

Coverage margin 'mc' for the design of the LPS (m):  0,5

Height 'hc' calculated for the structure protection LPS (m):  10,44

Design height 'hp' for the LPS of protection structure (m):  12,00

Horizontal protection distance 'dp', of design, provided by the LPS (m):  36,00

Margin of coverage 'mcp', of project, provided by the LPS (m):  1,21

Design limits

Limit for height 'h1', keeping the distance 'd1' from the LPS (m):  3,26

Limit for the distance 'd1', keeping the height 'h1' of the LPS (m):  17,19

Maintaining the coverage margin values (mc) and the project height (hp) of the LPS.

Height protected h (m) of LPS for Horizontal protected distance d (m) - Class IV

If all or some of the chart legend markers aren't visible, it is because there is an overlap due to the similarity of values: h1≈h11 and / or d1≈d11.

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**Complementary Design Data**

Design name:  LPS for parking protection

City:  Natal

Technical Report:  The option for an isolated LPS with a mast of 12m (1.56m in addition to the calculated) was to allow adjustment in the installation.

Technical Expert:  Dantas, Sicrano B. No Identification:  Crea 99999-0

OK!

Figure 15: Pop-up for supplementary data

## 5. Rolling sphere module

This Module maintains the 4 Sections of the original version presented in SIPDA XV [1] and is in accordance with NBR 5419-3 [4]; IEC 62035-3 [5] and NFPA 780 [6]. However, the possibility of performing the sizing separately and the printing of the report of this dimensioning was introduced in all four sections. This can be seen in the sequence. Other improvements have been introduced and are detailed in each of the sections.

### 5.1. Section for sizing 'h' or 'd'

In the version presented in SIPDA XV [1], the system included one graph related to the calculation of the protected horizontal distance at ground level or on a reference surface when the height of the LPS is known and another for the calculation of the height, required to provide protection of a horizontal distance at ground level or a reference surface. Now, these graphs have been integrated into one (as shown in Figure 13). When calculating the height, it is a non-standard commercial value, this version provided



an input field to adjust the calculated height. In addition, it was added the option for issuing the report of this dimensioning.

In this section, the height of the insulated LPS is scaled (mast or air termination system of the insulated (only one) overhead wire to protect a specific structure) based on the required LPS Class and the determined coverage margin, including the characterization of a structure with or without hazardous area, as shown in Figure 14. Improvements were also incorporated to print the report of the sizing (the button with the printer icon) and the option to scale the LPS of a database design or a separate design for the issuance of

the report, it is necessary to provide additional data, as shown in Figure 15 (in the case of a separate project). The pop-up appears when the print button is pressed. The issued report is shown in Figure 16. Separated projects are not saved in the database.

When the design definitions of the structure to be protected ('h1' and 'd1', besides 'mc') do not allow the sizing of the LPS to the defined protection Class, the System issues an alert of the impossibility of sizing and indicates the limit of the maximum distance and height the structure can be protected by LPS, as shown in Figure 17.

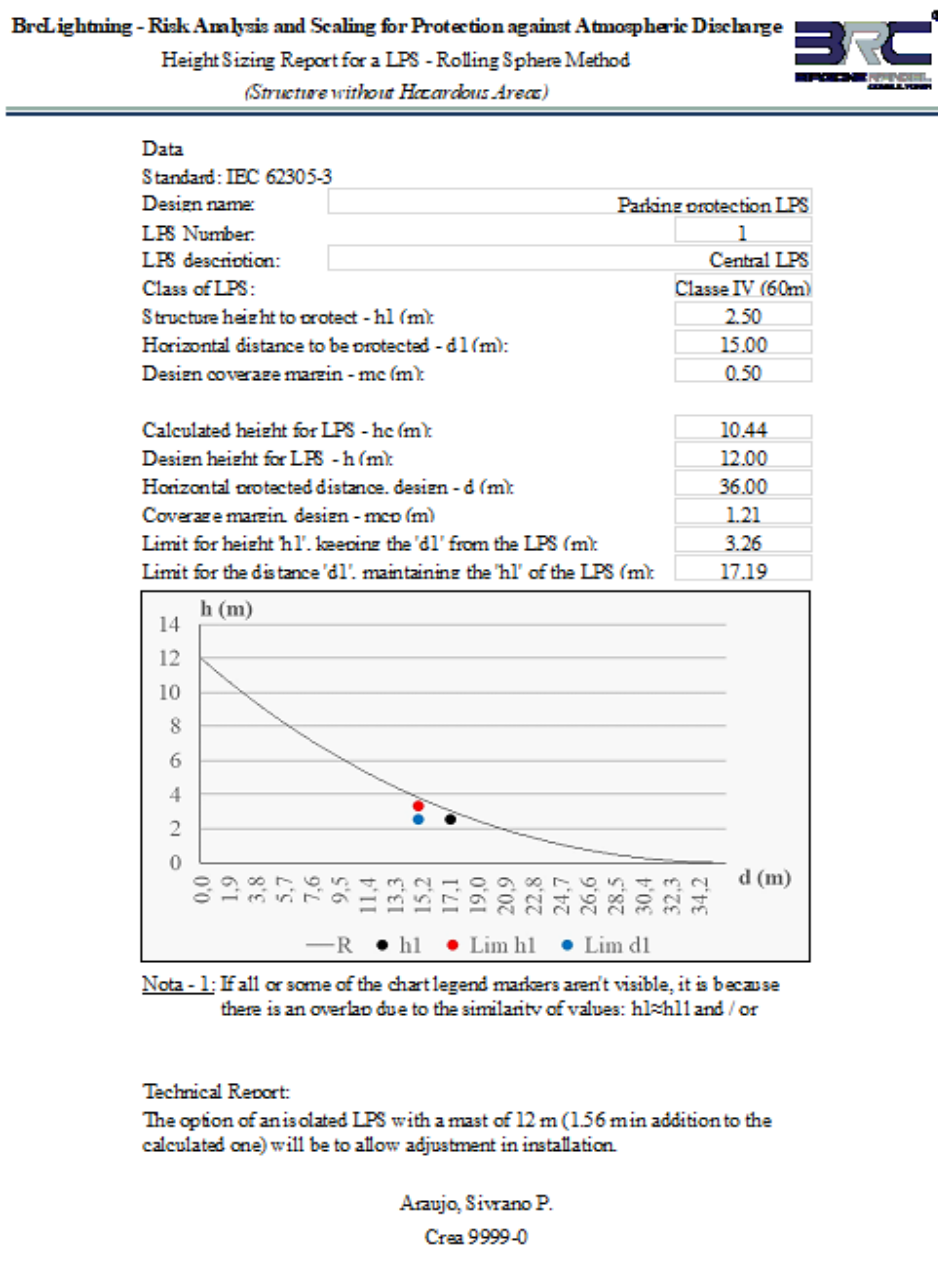


Figure 16: Example report of sizing the isolated LPS

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Idioma/Language: ☐ Português ☒ English

BrcLightning-2020.00

Cadastro/Record | Zonas - Dados/Zones - Data | Dados Téc./Technical data | Fatores da AR/RA Factors | Resultados/Results | Método ER/RS Method | Mét. do Ângulo/Angle Method | Relatórios/Reports

Cálculo d x h/Calculate d x h | Cálculo Spda Isolado/Calculate Isolated LPS | Cálculo Planos Cobertura/Calculation of Plans Coverage | Verificação de limites/Limit check

☒ NBR 5419-3 ☐ IEC 62305-3 ☐ NFPA 780

Are there any hazardous areas? ☒ N ☐ Y Data Base: ☐ Separate: ☒

Technical Expert:

Design name/Rev:

No. LPS:  1 Central LPS

LPS Design Class:  Class II

Rolling sphere radius (m):

Height 'h1' of the structure to be protected (m):  2,5

Horizontal distance 'd1' of the structure to be protected (m):  20,0

Coverage margin 'mc' for the design of the LPS (m):  0,5

Design limits

Limit for height 'h1', keeping the distance 'd1' from the LPS (m):  0,00

Limit for the distance 'd1', keeping the height 'h1' of the LPS (m):  0,00

Maintaining the coverage margin values (mc) and the project height (hp) of the LPS.

Height 'hc' calculated for the structure protection LPS (m):

Design height 'hp' for the LPS of protection structure (m):

Horizontal protection distance 'dp', of design, provided by the LPS (m):

Margin of coverage 'mcp', of project, provided by the LPS (m):

**d1 Máx/Max:** 16,81

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It isn't possible to protect the structure with 1 (ONE) LPS for the Selected Class and the reported data.

OK

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Figure 17: Alert for impossibility of isolated LPS sizing

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Cálculo d x h/Calculate d x h | Cálculo Spda Isolado/Calculate Isolated LPS | Cálculo Planos Cobertura/Calculation of Plans Coverage | Verificação de limites/Limit check

☐ NBR 5419-3 ☒ IEC 62305-3 ☐ NFPA 780

Is there an hazardous areas? ☐ N ☒ Y Data Base: ☐ Separate: ☒

Technical Expert:  Fulano dos Anzois Pereira

Design name/Rev:

No. LPS:  1

LPS Design Class:

LPS height - h (m):

Height of the fictional coverage plane h(pFc) (m):

Radius of the fictional (rFp) coverage plane (m):

Coverage margin 'mc' for calculating the limit distance of the structure (m):

Radius 'r' of the hazardous area (m):  0,0

Struture height limit - h1 (Lim) (m):

Horizontal distance limit for structure - d1(Lim) (m):

Height Limit of structure with hazardous areas - h1(ha) (m):

Distance Limit of structure with hazardous areas - d1 (Ae) (m):

**LPS Type**

☒ Vertical rod air-termination system

☐ Multiple vertical rod air-termination system

☐ Isolated wire air-termination system

☐ Multiple wire air-termination system

OK!

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Figure 18: Screen with pop-up to define the LPS type

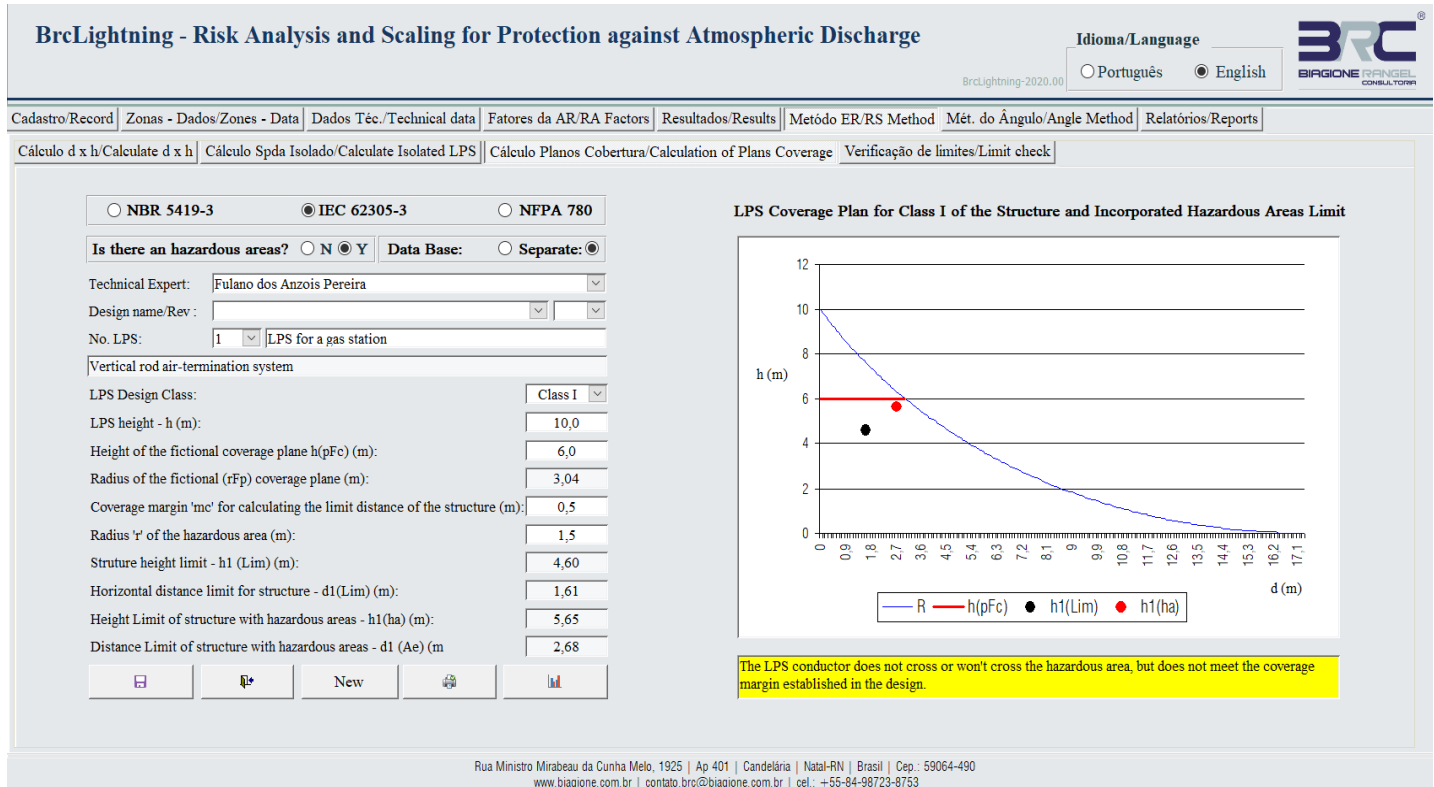


Figure 19: Calculation of the Fictional Coverage Plan with alert

### 5.2. Evaluation section of the limits of an installed LPS

This last section of the Rolling Sphere Module is intended to assess the protection that a specific LPS can provide, considering

all the Classes of Protection established by NBR-5419-3 [4]; IEC 62305-3 [5] and NFPA 780 [6]. Improvements have been made to the definition of the LPS type and alert with a technical note, as shown in Figure 20.

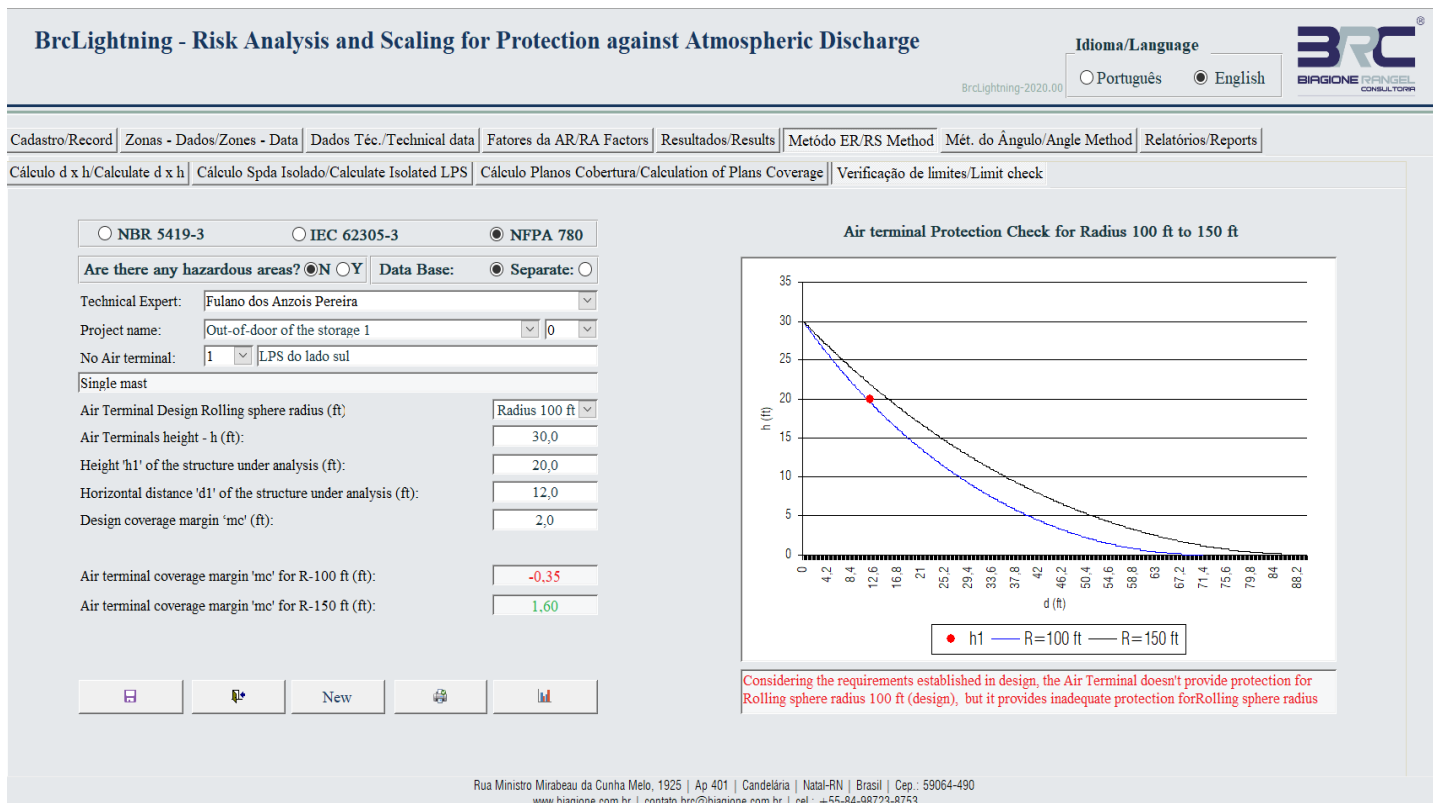


Figure 20: Limits evaluation module screen

## 6. Angle Method Module

This module maintains the three Sections of the original version presented in SIPDA XV [1] and in accordance with NBR 5419-3 [4]; IEC 62035-3 [5]. However, it was introduced in all of them the possibility to carry out the sizing separately and printing the report of this. Considering that this method is not widely used, only an improvement was introduced, in addition to those reported above, in Section 1, as detailed below.

### 6.1. Height or Distance Sizing (Angle Method)

This Section calculates the horizontal distance protected at ground level or from a reference surface when the height of the LPS is known. It also allows you to calculate the height required for an LPS when you know the horizontal distance that needs to be protected, as shown in Figure 21.

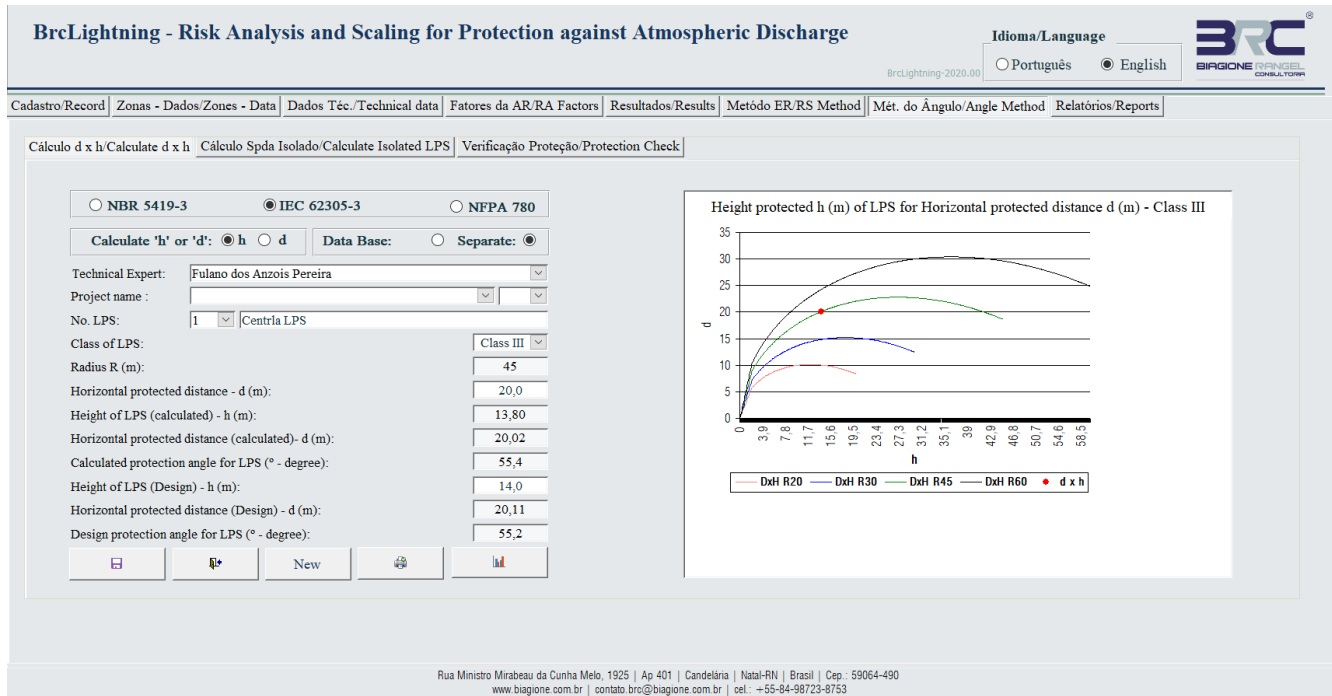


Figure 21: Calculation of the height x distance

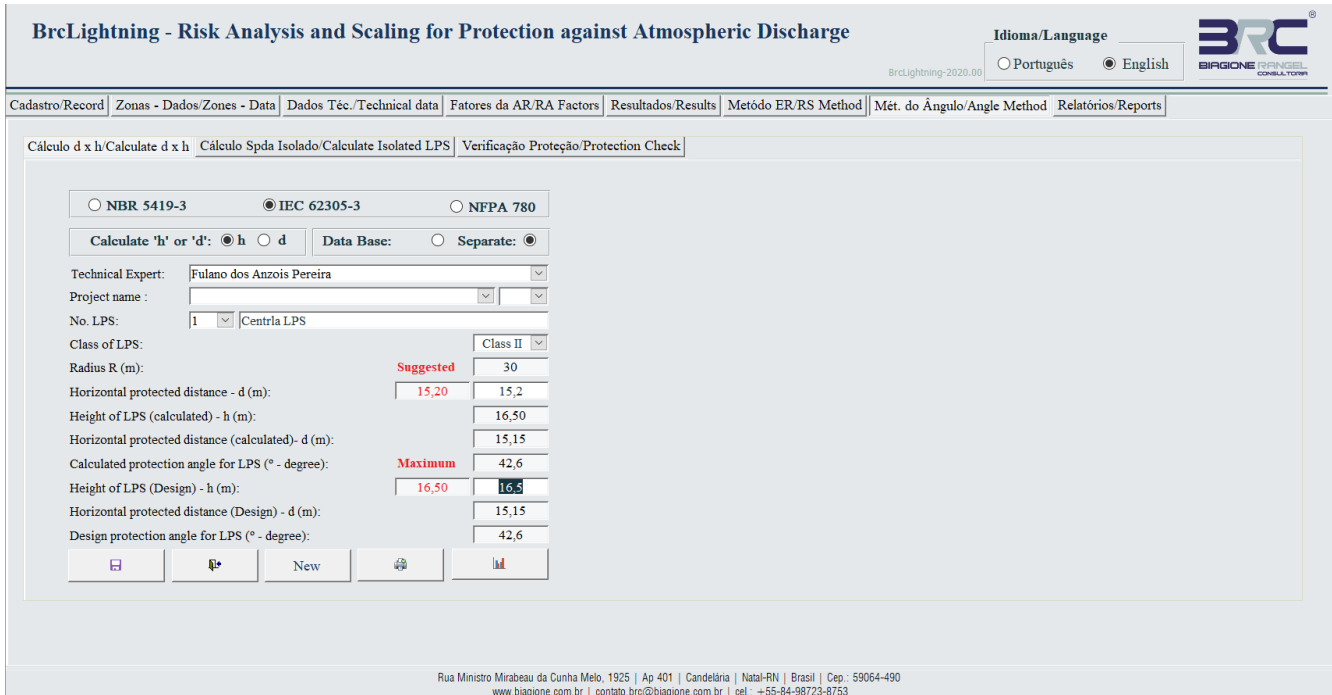


Figure 22: Calculation of the height x distance - Alert

Figure 23: Calculation of the height x distance with alert

In order to comply with NFPA 780 [6], the improvement for converting units of measure in meters was introduced, as shown in Figure 23.

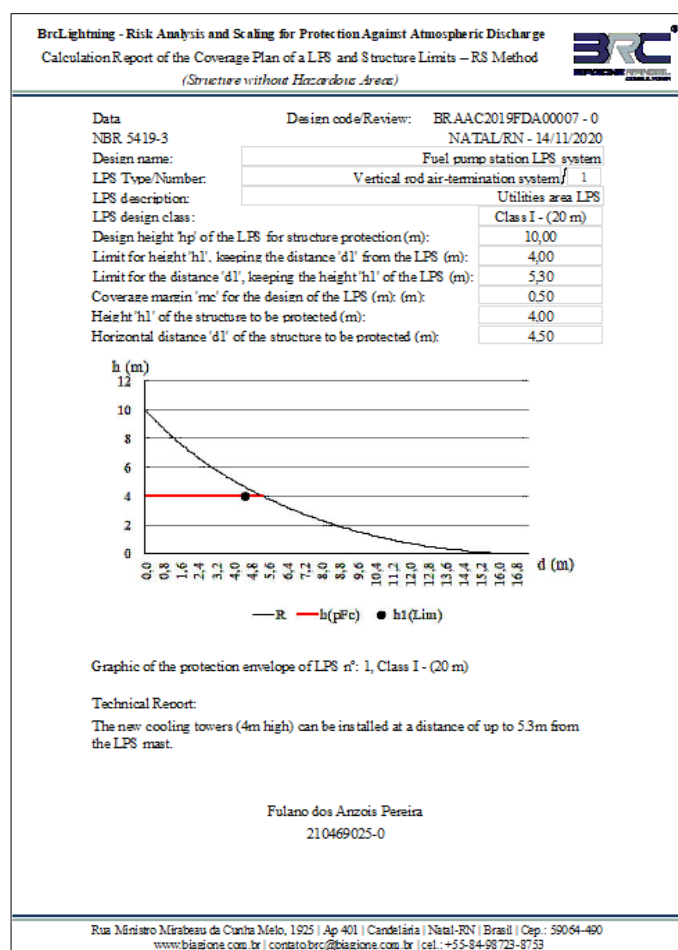
The system for this calculation only allows input in meters, thus, with this improvement, it becomes possible to insert the values in feet unit. To do so, two clicks are applied in the input field and one pop-up appears (as shown in Figure 23), providing an input field with the unit in feet. After this, when the pop-up is closed, the unit of measurement in meters. In case of exceeding the suggested limit, an alert will be issued.

## 7. Report Module

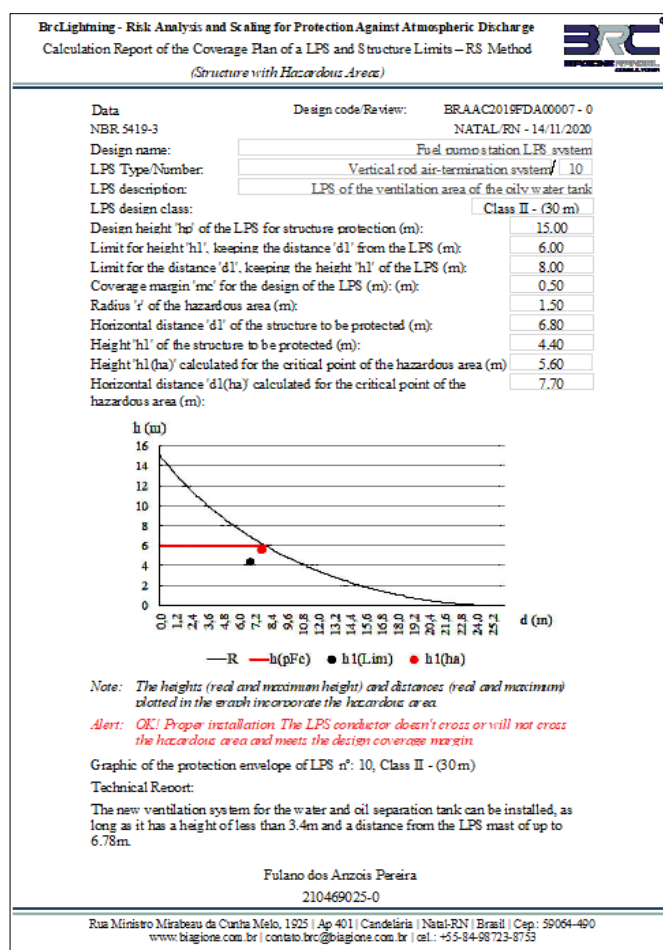
This Module includes options for the various preformat of reports that the system, currently, can provide: Risk Analysis Report; LPS project report by Rolling Sphere Method; Module Report using angle method, etc. The system screen where these options are available is shown in Figure 24 and several report templates are shown in Figure 25a Figure 25b. The improvements introduced in this module were composed by the increase in filter options to allow for more appropriate selectivity and the inclusion of the project revision number, as shown in Figure 24.

Figure 24: Screen of the reporting module





(a)



(b)

Figure 25 (a): System report templates formatted without hazardous areas (b): System report templates formatted with hazardous area

## 8. Improvements already identified for future insertion

### 8.1. Module for sizing the surge protective device

Considering that one of the most important mitigating measures identified in the Risk Analysis is the installation of Surge Protective Devices - DPS, it was understood that the inclusion of a module to meet this need is extremely important and, as the methodology and formulas already exist and are supported by NBR-5419-4 [7] and IEC 62305-4 [8], the insertion of a module with this function was included in the planning of future improvements.

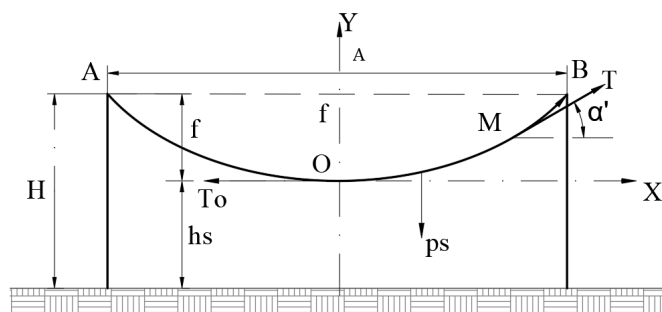


Figure 26: Efforts in wire air termination with supports of the same height

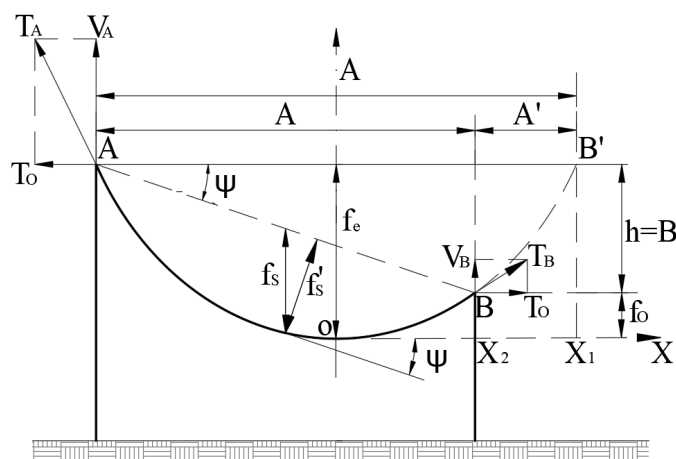


Figure 27: Efforts in wire air termination with supports of different heights

## 8.2. Module for sizing wire air-termination support structures

Considering that many of the SPDA systems are composed of wire air-termination, it was identified that it is convenient to have a tool to scale the efforts requested from supports of this kind of captor, especially when there is variation in room temperature. Considering, also, that the guarantee of the volume of protection derives from a projection of the height of a captor element and that the control of this lowest point is critical. So, equations were

developed to calculate these efforts from the catenary arrow that is required for the wire air-termination. Therefore, it was reversed the practice of calculating this type of sizing, where the effort is calculated and after that, the arrow of a catenary of the cable is calculated. The developed equations include both for supports for the same height and different heights, as shown in Figure 26 and Figure 27. However, these equations are not yet coded in a programming language.

The mathematical approach to dimension the efforts in the wire air-termination was developed in a spreadsheet and the results are in tables such as the Table 1. Other temperature ranges are possible. This is for information only.

### 8.3. Module to consolidate the list of materials of a project

The insertion of the LPS type in the sizing sections already allows to insert in the database the list of materials. Thus, it will be possible from commercially standardized systems to associate the spare parts list required for that dimensioning, when applicable. This module should have a restricted section to address the material list of grounding systems. There is no prediction to perform the calculation of grounding systems because several software are already dedicated to this purpose. Hence, the module includes only the integration of materials to the LPS design.

### 8.4. Module for sizing parallel wire air-termination system

We already have several mathematical models responsible for sizing this kind of LPS by parallel wire air-termination in several configurations for this type of systems, as shown in Figure 28 and Figure 29 (other details can be found in the XIII SIPDA [9]). However, we do not yet have the conversion of equations into

programming codes, but this is not the biggest problem for insertion. The understanding is that the greatest difficulty is to develop the graphic formulation because it is more complex and I still do not have training in this area, and the addition of this qualification will require planning.

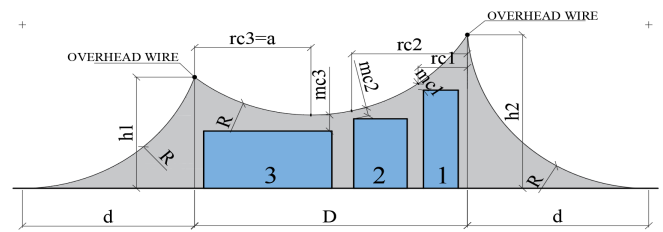


Figure 28: Representation for different levels of parallel wire air termination

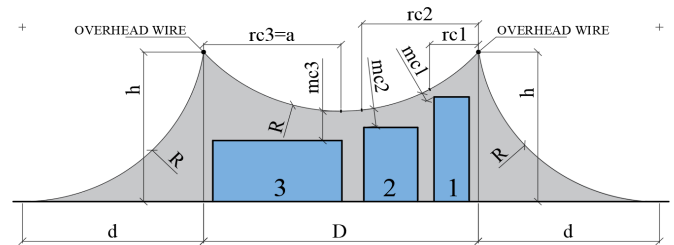


Figure 29: Representation for equal levels of parallel wire air termination

The mathematical approach to determine the limits of a parallel wire air-termination design, considering a possible unevenness of the terrain – at the time of the project implementation or spacing between the wire air-termination or both – produces a table as the one presented in Table 2. This is only an example.

Table 1: Calculated forces for the wire air-termination

Span: 20,30 (m)			Arrow of a catenary: 0,20 (m)		Length: 20,30 (m)		Reference temperature: 26°C
Item	Temp.: (°C)	Length: A (m)	f (m)	To (kgf)	T (kgf)	p <sub>s</sub> (kgf)	Transverse force (kgf)
01	16	20,303	0,153	137,63	137,63	4,151	2,85
02	20	20,304	0,175	120,55	120,55	4,151	2,85
03	26	20,305	0,203	103,78	103,79	4,151	2,85
04	30	20,306	0,220	95,84	95,85	4,151	2,85
05	36	20,308	0,243	86,75	86,75	4,151	2,85
06	40	20,309	0,257	81,95	81,95	4,151	2,85
07	45	20,310	0,274	76,94	76,95	4,151	2,85
08	22	20,304	0,185	138,38	138,38	4,151	2,85
09	36/16	20,301	0,075	280,12	280,12	4,151	2,85
10	36/22	20,302	0,128	200,00	200,01	4,151	2,85

Note: Reference temperature: 26°C

Table 2: Calculations of the LPS Limits for Figure 28

Designation		Distance between LPS)					
		30.0 (m)		30.5 (m)		31.0 (m)	
Reduce level	Height of the lower LPS	a	hpc	a	hpc	a	hpc
-	16.00	13.23	10.50	13.55	10.21	13.87	9.92

0.50	15.50	13.03	10.18	13.35	9.89	13.68	9.60
1.00	15.00	12.83	9.85	13.16	9.56	13.49	9.27
1.50	14.50	12.63	9.51				

### 8.5. Development of tools to integrate with software graph

Another important tool is the integration with design software, such as Autocad. Therefore, the future idea is to develop tools to migrate the sizing data of the various Modules and Sections to enable the plotting of drawings with the horizontal coverage planes for the various Covering projection for the various classes of protection of 15 meters high LPS over structures with a height of 3.5 m. These tools should incorporate the generation of 3D plants, which the resources necessary to rotate and promote cuts of the protected volume.

## 9. Software security requirements

This software is intended to be a tool used by professionals who design systems to protect against atmospheric discharges – either by direct or nearby impacts – and these might cause harmful effects with high probability of causing losses either by  $L_1$  - losses of human life (including permanent injury);  $L_2$  - losses of services to the public;  $L_3$  - losses of cultural heritage and  $L_4$  - losses of economic value. Thus, it is necessary for these professionals to carry out a very detailed and safe risk analysis. Therefore, safety requirements were established, with the goal of blocking errors or deviations from the requirements established by the standards on which this application was based. These requirements are as follows:

### 9.1. Controle na determinação das Zonas

The System alerts and blocks Zones from being repeated in the Risk Analysis, as shown in Figure 31.

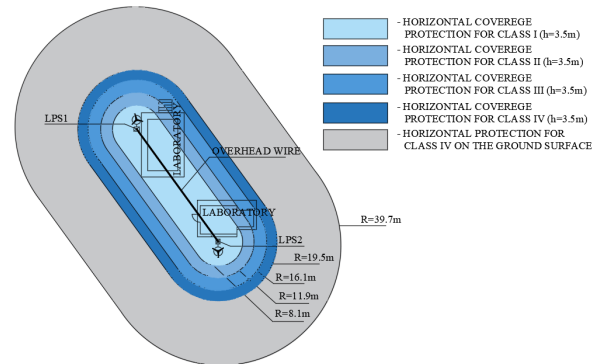


Figure 30: Horizontal projection screen of an LPS project (only for guidance)

### 9.2. Control of the total number of people in the Zones

When the number of people distributed in all Zones is inserted, the System verifies consistency. So, in case of divergence with the total number reported in the Registry (Figure 4), it issues an alert and blocks for further correction, either for more (Figure 32) or for less (Figure 33):

Figure 31: Zone alert already selected

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**Z1: Entrance**  
 Is it considered for analysis? ☐ Y ☐ N  
 Is it part of the main structure? ☐ Y ☐ N  
 Total people in Z1 (nz): 0  
 Time persons in Z1 (tz): 8760  
 Type of Surface (rt): Agricultural  
 Risk - Amount of risk (rf):  
 Explosion or fire (None)  
 Partitioning REI? ☐ Y ☐ N  
 Factor of increase of the relative of loss (hz)  
 No special hazard  
 Total Z1: \$ 10<sup>6</sup> 0,00  
 Cultural heritage (Cz): \$ 10<sup>6</sup>  
 Animals (Ca): \$ 10<sup>6</sup>  
 Building (Cb): \$ 10<sup>6</sup>  
 Content (Cc): \$ 10<sup>6</sup>  
 Internal systems (Cs): \$ 10<sup>6</sup>

**Z2: Offices**  
 Is it considered for analysis? ☒ Y ☐ N  
 Is it part of the main structure? ☒ Y ☐ N  
 Total people in Z2 (nz): 145  
 Time persons in Z2 (tz): 8760  
 Type of Surface (rt): Ceramic  
 Risk - Amount of risk (rf):  
 Fire (Low)  
 Partitioning REI? ☐ Y ☒ N  
 Factor of increase of the relative of loss  
 Average level of panic (e.g. Structure for cultural/sporting events for 100 to  
 Total Z2: \$ 10<sup>6</sup> 0,00

**Z3: Waiting Room**  
 Is it considered for analysis? ☒ Y ☐ N  
 Is it part of the main structure? ☒ Y ☐ N  
 Total people in Z3 (nz): 6  
 Time persons in Z3 (tz): 8760  
 Type of Surface (rt):  
 Risk - Amount of risk (rf):  
 Explosion or fire (None)  
 Partitioning REI? ☐ Y ☐ N  
 Factor of increase of the relative of loss  
 Average level of panic (e.g. Structure for cultural/sporting events for 100 to  
 Total Z3: \$ 10<sup>6</sup> 0,00

Salvar / Save

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Figure 32: Alert of more people in the Zones than the registered total

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**Z1: Entrance**  
 Is it considered for analysis? ☐ Y ☐ N  
 Is it part of the main structure? ☐ Y ☐ N  
 Total people in Z1 (nz): 0  
 Time persons in Z1 (tz): 8760  
 Type of Surface (rt): Agricultural  
 Risk - Amount of risk (rf):  
 Explosion or fire (None)  
 Partitioning REI? ☐ Y ☐ N  
 Factor of increase of the relative of loss (hz)  
 No special hazard  
 Total Z1: \$ 10<sup>6</sup> 0,00  
 Cultural heritage (Cz): \$ 10<sup>6</sup>  
 Animals (Ca): \$ 10<sup>6</sup>  
 Building (Cb): \$ 10<sup>6</sup>  
 Content (Cc): \$ 10<sup>6</sup>  
 Internal systems (Cs): \$ 10<sup>6</sup>

**Z2: Offices**  
 Is it considered for analysis? ☒ Y ☐ N  
 Is it part of the main structure? ☒ Y ☐ N  
 Total people in Z2 (nz): 145  
 Time persons in Z2 (tz): 8760  
 Type of Surface (rt): Ceramic  
 Risk - Amount of risk (rf):  
 Fire (Low)  
 Partitioning REI? ☐ Y ☒ N  
 Factor of increase of the relative of loss  
 Average level of panic (e.g. Structure for cultural/sporting events for 100 to  
 Total Z2: \$ 10<sup>6</sup> 0,00

**Z3: Waiting Room**  
 Is it considered for analysis? ☒ Y ☐ N  
 Is it part of the main structure? ☒ Y ☐ N  
 Total people in Z3 (nz): 3  
 Time persons in Z3 (tz): 8760  
 Type of Surface (rt):  
 Risk - Amount of risk (rf):  
 Explosion or fire (None)  
 Partitioning REI? ☐ Y ☐ N  
 Factor of increase of the relative of loss  
 Average level of panic (e.g. Structure for cultural/sporting events for 100 to  
 Total Z3: \$ 10<sup>6</sup> 0,00

Salvar / Save

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Figure 33: Alert of fewer people in the Zones than the total registered

### 9.3. Consistencies of line parameters

The System filters the options of values of the probability PLD depending on the resistance RS of the cable screen and the impulse

withstand voltage UW of the equipment, based on the line type, routing, shielding, and bonding conditions, as can be seen in Figure 34. Power line is not bonded to the same bonding bar as equipment and telecom is bonded to the same bonding bar as equipment.

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**Protective measures due to touch and step voltage and other mitigating measures in Zones**

	Z1 - Entrance	Z2 - Accommodation	Z3 - Endangers Human Life Unit
Additional measure (PTA):	wm1 Z1: 8,333 wm2 Z1: 8,333	wm1 Z2: 8,333 wm2 Z2: 8,333	wm1 Z3: 8,333 wm2 Z3: 8,333
Protection measure (PTU/P):	No protection measures	No protection measures	No protection measures
Protection measure (PTU/T):	No protection measures	No protection measures	No protection measures
SPD (Pspd/P):	No coordinated SPD system	No coordinated SPD system	No coordinated SPD system
SPD (Pspd/T):	No coordinated SPD system	No coordinated SPD system	No coordinated SPD system
Fire reduction factor (rp):	No provisions	No provisions	No provisions

Atualizar/Update | Ajuda/Help | Gravar / Record

**Attribute of Connected Power Line**

Shield, ground, and isolation (CLD/CLI): ☐ Shielded buried line (bonded) ☒ ? ☐ Connected shield

Known length? ☐ Yes ☒ Not ☐ ? Length LL (m): 1.000 Área AL (m²): 40.000 Área for flashes near? ☐ Yes ☒ Not Área near line: Al (m²): 4.000.000

Conductor Installation Factor (Ci): Buried

Environmental Factor (Ce): Suburban Withstand voltage (UW in kV)-PLI: 2,50 ?

Line Type Factor (Ct): LV power Shield resistance (RS):

SPD (PEB): No SPD RS ≤ 1Ω/km 0,20 1Ω/km < RS ≤ 5Ω/km 0,60 5Ω/km < RS ≤ 20Ω/km 0,95

Type of internal wiring (Ks3): Unshielded cable – routing precaution in order to avoid large loops

Atualizar/Update | Gravar / Record

**Attribute of Connected Telecom lines**

Shield, ground, and isolation (CLD/CLI): ☐ Shielded aerial line (not bonded) ☒ ? ☐ Shield not connected

Known length? ☐ Yes ☒ Not ☐ ? Length LL (m): 1.000 Área AL (m²): 40.000 Área for flashes near? ☐ Yes ☒ Not Área near line: Al (m²): 4.000.000

Conductor Installation Factor (Ci): Aerial

Environmental Factor (Ce): Suburban Withstand voltage (UW in kV) - PLI: 1,50 ?

Line Type Factor (Ct): Telecommunication or data line Shield resistance (RS): Unshielded or not bonded

SPD (PEB): No SPD

Type of internal wiring (Ks3): Unshielded cable – routing precaution in order to avoid large loops

Atualizar/Update | Gravar / Record

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Figure 34: Filters for line parameters

#### 9.4. Restrictions for changing typical loss values

When it comes to loss of human life (L1), the typical LT loss values (loss due to injuries from electric shock) cannot be changed (the system freezes). The same applies to the typical LF loss value (loss in a structure due to physical damage) when it is indicated that there is a risk of explosion in the Zone or when it is indicated that the place is a hospital, hotel, school or civic building.

In addition, changes in typical LO loss values (loss in a structure due to failure of internal systems) are blocked when it comes to areas that are part of the hospital or life support structure. When dealing with L2 and L3 losses, the values of LF and LO are also blocked for changes. For losses of type L4, permissions similar to L1 losses are applied. Blocking alerts are via a pop-up message, as shown in Figure 35.

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☒ BrcLightning ☐ Designer

	Z1 - Entrance	Z2 - Accommodation	Z3 - Endangers Human Life Unit
<b>L1</b> Loss of human life (including permanent injury)	LT (L1/Z1): 0,0100 LF (L1/Z1): 0,1 LO (L1/Z1):	LT (L1/Z2): 0,0100 LF (L1/Z2): 0,01 LO (L1/Z2):	LT (L1/Z3): 0,0100 LF (L1/Z3): 0,1 LO (L1/Z3):
	LF (L2/Z1): LO (L2/Z1):	LF (L2/Z2): LO (L2/Z2):	LF (L2/Z3): LO (L2/Z3):
	LF (L3/Z1):	LF (L3/Z2):	LF (L3/Z3):
<b>L4</b> Loss of economic value (structure, content, and loss of activity)	LT (L4/Z1): LF (L4/Z1): 0,2000 LO (L4/Z1): 0,0100	LT (L4/Z2): LF (L4/Z2): 0,2000 LO (L4/Z2): 0,0100	LT (L4/Z3): LF (L4/Z3): 0,5000 LO (L4/Z3): 0,0100

Considerations:

OK

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Figure 35: Blocking alert screen for changing typical loss value



### 9.5. Permission to modify data and customize

It is important to emphasize that to perform any customization and or modify parameters predefined in the System, there is a need for the professional to make, in advance, his or her registration in the system and, after that, he or she will have to define on the initial screen (Figure 4) the designer responsible for the project. This way, the system will save the modifications in an associated way with the person responsible for performing them.

## 10. Acknowledgment

This is a work that I have been developing alone, from the need I had to carry out the evaluation of projects of Protection Against Atmospheric Discrimination. Therefore, to be certain about my work, I developed the methodology and then the migration to the programming codes of this system, having paid every expense with my own resources, including all the development so far and the costs regarding my participation in all the previous symposia and the development of the papers.

## 11. Conclusion

This paper is in line with the conclusion of the work originally presented at the SIPDA XV symposium [1], as it incorporates new resources to provide LPS designers with more efficient and safe tools and means for project development, in accordance with Brazilian, International and American standards.

In this context, the BrCLightning application continues, also, with the objective of consolidating itself as an integrated software, having as a support, for some of its modules, the dimensioning of LPS based on the mathematical approach, which was developed and presented at the SIPDA XIII [9] and SIPDA XIV [10] symposia. Thereby, we hope to be contributing to a better understanding of the standards and to the development of safer and more effective projects for protection against lightning strikes.

Also, its modulated design and the format of a database allows the development of applications to be used on the internet, online, and by app systems used on cell phones or other mobile devices.

## References

- [1] Araújo, R. Biagione, “BrCLightning - Risk Analysis and Scaling for Protection against Atmospheric Discharge,” International Symposium on Lightning Protection (XV SIPDA), 1(0), 8-17, 2019.
- [2] ABNT, “NBR-5419-2. Lightning protection Part 2: Risk management,” ABNTCatálogo, p. 116, 2015.
- [3] IEC, “IEC 62305-2. Protection against lightning - Part 2: Risk management,” IEC, 2012.
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