BrcLightning - Risk Analysis and Scaling for Protection against Atmospheric Discharge

Biagione Rangel de Araújo
BRC – Biagione Rangel Consultoria
Natal, Brasil
contato.brc@biagione.com.br

***Abstract*—This paper presents an application developed for the risk analysis in accordance with Brazilian NBR-5419-2 and the International IEC 62305-2, as well as it provides modules for designs, evaluation and scaling of LPS using the mathematical approach methodology to the methods of Rolling Sphere and Angle Method presented in the XIII SIPDA and XIV SIPDA.**

Keywords— risk management; lightning risks; angle method rolling sphere method; analysis LPS; APP

I. INTRODUCTION

The revision of NBR published in 2015 incorporated a specific part for the risk analysis NBR-5419-2 [1], in compliance with the International standard IEC 62305-2 [2]. It introduced an entirely new approach to the analysis and design of Lightning Protection System (LPS), since the analysis of the risks associated with atmospheric discharges (part 2 of the standard [1] and [2]), becomes the fundamental stage for the definition and design of lightning protection system (LPS), Part 3 of the standard NBR-5419-3 [3] and IEC 62305-3 [4] and surge protection measures (SPM), to reduce the risk of permanent damage to the internal structure due to electromagnetic impulses from atmospheric discharges (LEMP), in terms of the Part 4 of the Brazilian NBR-5419-4 [5] and International Standards IEC 62305-4 [6].

Whereas this new approach to the Brazilian Standard [1], already used by IEC [2], has entered a more comprehensive and complex analysis so that the risks are better identified, quantified and management, since there are many possible impacts, several points are the sources and the types of damage, resulting in various types of losses, with varying degrees of importance, from the loss of human lives to the loss of economic values. This universe of analysis involves the identification and quantification of multiple and different risks and risk component for each condition and situation, so that enables the definition and design of LPS and SPM that are the most effective possible, so that the impacts and losses can be eliminated or mitigated to tolerable values. This new approach requires the demand of qualified professionals and tools that can provide security, consistency and traceability of its analyses and design of LPS.

In order to meet this demand and these requirements BRC designed and developed BrcLightning in the form of a database, to enable the traceable historic, reporting of analyses performed and other features that are provided by a database, therefore it may provide information to the enhancement and improvement of the standard which deals with this theme. Whereas there is compatibility between the Brazilian standards [1] and [2], the application was developed in Portuguese and English versions, and the user can select the language to be used.

Taking advantage of this development was introduced some modules for analysis and design of LPS, using the mathematical approach, which were subjects of articles presented in the XIII SIPDA [7] and XIV SIPDA [8], extending this methodology for the American standard NFPA 780 [9]. The Standard [9] uses the Rolling Sphere Method for the dimensioning of LPS, but in 2 levels only: 100 ft and 150 ft, and recommends the use of the method of angle of the IEC [4] for the analysis of LPS Class IV for upper parts of tall structures where protection is provided on the top of the structure. Therefore, these modules are given the options of English and Portuguese language and the options to choose one of one the three standards [3]; [4] and [9]. These modules allow the formation of database and the graphical analysis.

II. DEFINITIONS

a) AD - Collection area for flashes to an isolated structure, expressed in square meter (m²) (see figure a. 5 the from Standards [1] and [2]);

b) AM - is the collection area of flashes striking near the structure (extends to a line located at a distance of 500 m from the perimeter of the structure, see Figure A.5 from standards [1] and [2]);

c) Coverage radius (rc): The distance between the point of the cover margin, of a determined envelopment of a LPS. This distance determines the size of horizontal projection of the fictitious plane, given by equation (2);

d) Cover margin height (hc): It is the dimensions of the height of the nearest point on the envelope over the structure under protection of the LPS;

e) Distance from the critical point (a): The distance between the critical point and one metallic element such as rods or catenary wires;

f) Envelopment: Geometric shape that limits the protected volume according to rolling sphere method;

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Company e-mail: contato.brc@biagione.com.br
Home: www.biagione.com.br

g) Coverage margin (cm): It's the shortest distance between a point of the structure under 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: Fig.1.a; Fig1.b and Fig.1c, contained in Fig.1.

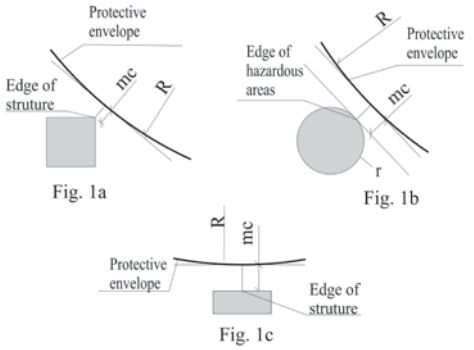

Fig. 1. Examples of coverage margins

h) Fictitious plane (Fp): Assumed horizontal plane that provides coverage of protection at a given height;

i) Hazardous areas: Area surrounding storage facilities or transfer station flammable liquids or gases, due to the possibility of containing flammable or explosive mixtures. They are defined in: Zone 0 (when the explosive mixture / inflammable is still there or for long periods); Zone 1 (likely to occur in normal operating conditions) and Zone 2 (it's unlikely - abnormal condition of operation);

j) LF: Loss in a structure due to physical damage;

k) LO: Loss in a structure due to failure of internal systems;

l) LT: Loss due to injury by electric shock;

m) L1: Loss of human life*;*

n) L2: Loss of service to the public;

o) L3: Loss of cultural heritage;

p) L4 : Loss of economic value;

q) Marks of the sizing module: the marking indicated in the graphs of scaling and checking modules, limits correspond to the extreme points of the structure to be protected or be evaluated on effectiveness of envelope coverage LPS protection, as shown in figures 2 and 3 below:

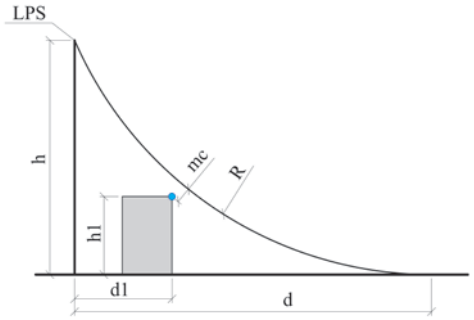

Fig. 2. Struture limiting point figure

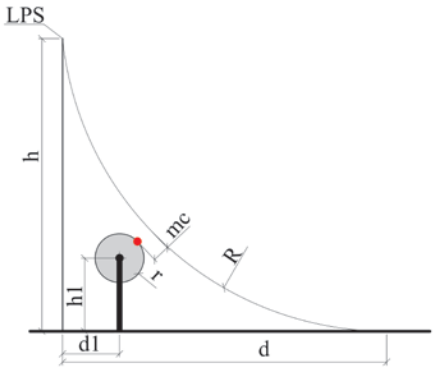

Fig. 3. Hazardous areas limiting point figure

r) NG - Lightning ground flash density (1/km2 × ano).

III. SOFTWARE DEVELOPMENT

The application was developed in ACCESS, using VBA language, with the goal of allowing run on Windows and on the Internet.

The system provides the options: risk analysis (the uses only this module); Calculation (the uses only calculation modules) and the Risk analysis and calculation (the user all modules of the application). In all cases the system writes the data in the form of database.

In this version the system provides 8 (eight) modules covering the risk analysis, composed of 5 (five) modules; Scaling by Method of the Rolling Sphere, composed of 1 (one) module with 4 (four) sections; Scaling by angle, composed of 1 (one) module with 3 (three) sections and Reports module. These modules are described in sequence:

A. Risk Analysis Module

On the risk analysis, the system incorporates Lightning ground flash density in Brazil (NG) associated with various Brazilian cities, based on the data provided by INPE-National Institute for space research (http://www.inpe.br/webelat/homepage/), but this data can be entered directly. Also, incorporates tables in different countries and a wide variety of structures and types of areas associated with these structures. The Professional may include new types of structures and associated areas of existing or new database that may be identified.

Still incorporates the various tables of factors set out in Brazilian standards [1] and international standards [2], as well as, the features and factors associated with structures and areas with the values set out in the standards, whose goal is to minimize possible flaws in the selection of factors. However, the professional responsible for the project may change this if factors have a different interpretation of what was considered in the system. The system offers this option.

The Risk Analysis of consists of 5 modules: A registration form (registration/Record). This Module also serves for the registration of the design of other options, mentioned previously, because this record is necessary for the database to integrate all modules. One to register the data of areas (Data/zones Zones-date); another for the technical data of the connected lines (Technical Data./Technical data); one for Risk

Analysis Factors (RA Factors) where it presents the relevant data of the factors to be considered in the different Zones, however, the designer can access them and if his/her was another understanding of subset, his/her can make modifications to understand as necessary. The new values will be registered, preserving from the system, in this way the professional can always use his/her data considerations for future analyses. And a module (results/Results). In this module are presented the calculation of various risks in the area, as well as, the percentage of risks, with emphasis on the dominant (by Total area) and highlight for those who exceed the tolerable values.

1. Registration Module.

The registration module includes the address of the structure under analysis, of physical and environmental characteristics, the NG of the city where it is located, the professional responsible, dimensions, economic value (optional) and amount of zones that will be analyzed, among others. The input and data are evaluated for consistency and / or absence of consistency. In this module, can also be used a helper module for calculation of AD (Area) of more complex structure as well, it makes consistency of existence of adjacent structures. The screen of this module is presented in Fig. 4.

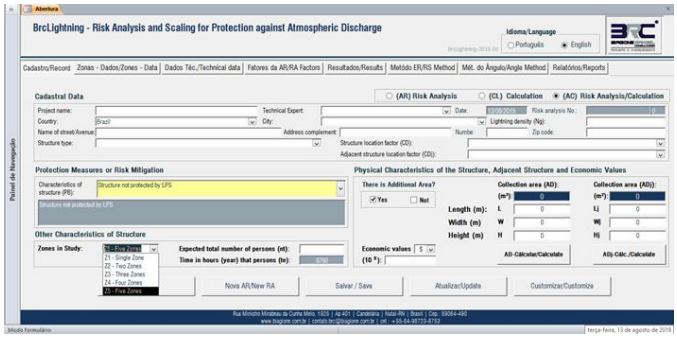

Fig. 4. Main screen of data input

2. Zones Registration Module.

This module qualifies and set of the characteristics e factors available by system, for each zone of the structure to be analyzed. The system considers up to 5 Zones for structure, and will only be available to fill the number compatible with what was defined in the record. Therefore, setting for 5 will appear the fields of 5 Zones, if 2, just for two, Zones so on. The types of available areas to fill, are associated with which the system and thus facilitates the user to the register. To avoid duplicity of Zones, there is a consistency check. In this module all the features of the area are available for setting, including whether it should be or not be an integral part of the risk analysis, as well as consistency of the amount of people distributed in the Zones and the total structure, the same way for consistency as the economic values, will be considered in the calculation of economic losses. Fig. 5 shows the module.

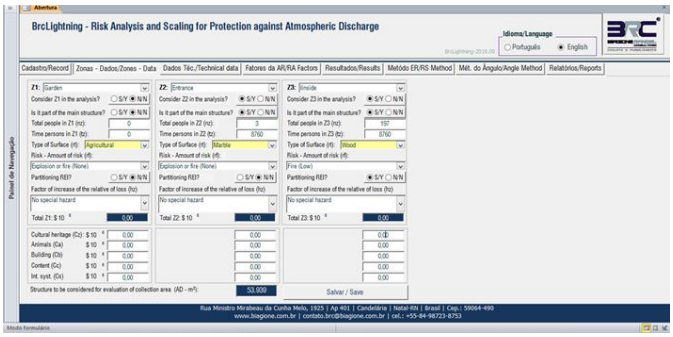

Fig. 5. Screen of the seting module of the Zones (structure with 3 Zones)

This module also provides additional fields where are calculation or input valor for extended area (AM), in cases when hazardous areas or other conditions are present and require consider this kind situation (see Figure A.5 the standard [1] and [2]). Also, offers help to define the area of the structure that will be in the consideranda analysis, in terms of what sets the standards [1] and [2] due to the existence of fire-resistant separation (REI), as shown in Figure A.4 standards mentioned. The Fig. 6 shows this screen. As can be seen, the system calculates, to complex structures the AD Area and ADj Area.

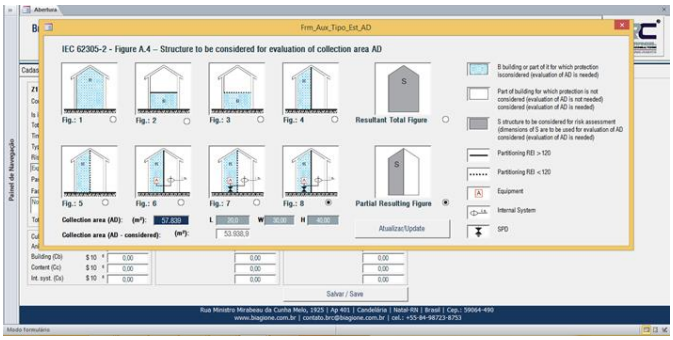

Fig. 6. Screen for the definition of the structure considered for AD

3. The setting data of the connected lines and Zone.

In this module the connected lines: electrical and signal are being configured and data is evaluated for consistency and avoid errors of data information in the database. For example, if the connected line is not shielded, the shielding resistance factor (RS), the availability of the option will be only the of unprotected or not connected.

Also, in this module are set other protective measures due to touch and step voltage and other mitigating measures for each Zone. The screen of this module, also offers some help for filling in the fields, as well as, provides boxes POP UP alerts and information. Fig. 7 shows the screen that module.

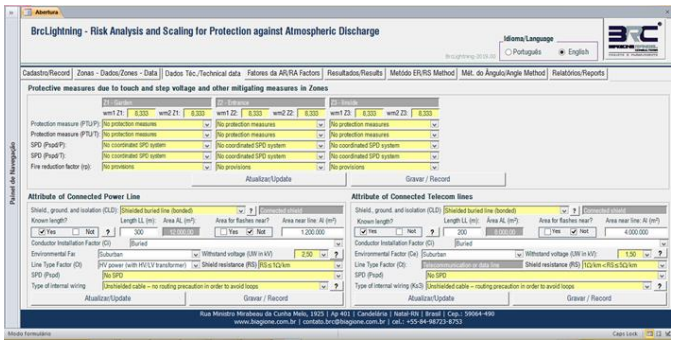

Fig. 7. Setting screen of the connected lines and other zone data

4. *Risk Analysis Factors Module*

This module has the purpose of providing the values of the typical loss factors: LT; LF and LO, which were considered in the system, for evaluation by the designer. These factors are available for each Zone, associated with Loss Types: L1; L2; L3 and L4. In order to block the selection of parameters unsuitable for the type of structure and Zone, as well as, evaluation of losses not required for them. Fig. 8 shows the screen of this module.

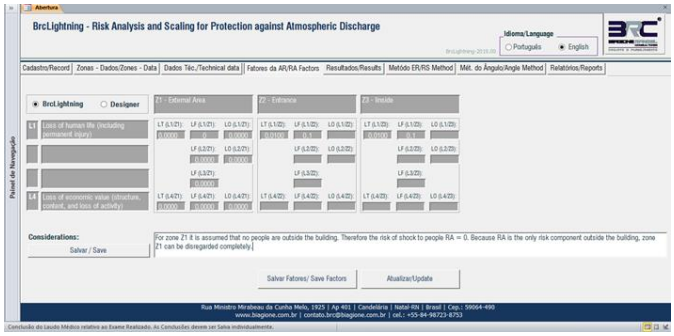

Fig. 8. Loss Type Factors Module Screen

5. *Results Module*

Here are presented in this module the results of the various Risks, by Zone, with visual indication of those values that do not meet the tolerable risks established in Standard [1] and [2], as well as the indication of which components of the risks of Total Risk of each category, thus indicating the dominant origins for the result. This information aims at guiding the designer about which areas can act more effectively to improve the protection or mitigation of risks, in such a way that they are eliminated or within tolerable values, as established in standards [1] and [2]. The fields that are likely to act to mitigate risks are those highlighted in yellow in the various modules. Fig 9 shows the display of this module.

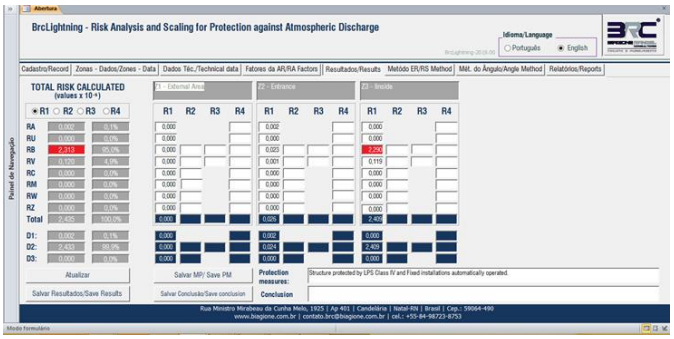

Fig. 9. Result Module Screen (structure with 3 Zones)

B. *Rolling Sphere Module*

In this version of BrcLightning is being available in 1 Module, with 4 Sections that use the methodology of the paper presented at the XIII SIPDA [7] and are composed of: Calcular d x h/Calculate d x h; LPS Calcular um SPDA Isolado/Insulated LPS Scaling; Calcular o Plano de Cobertura/Scaling Coverage Plans and Avaliar limites/Check limits. In all these Sections are available options for calculating in the 3 standards: Brazilian [3]; International [4] and the Americans [9], as well as in Portuguese or English language versions. The American [7] is available only in the English version and, for this standard, the unit of measurement foot/feet (ft).

1. *Section for dimensioning h or d*

In this section, the designer can calculate the protected horizontal distance, at ground level or on a reference surface, when the height of the LPS is known or can calculate the height of the LPS to protect a certain horizontal distance. In this way, this section has direct application in the LPS project of protection of structures. This calculation can be performed for several points of the same LPS or of several LPS and all are integrated in the same project in the database. Fig. 10 and Fig. 11 show for both options, respectively, based on one of the selected patterns and protection class:

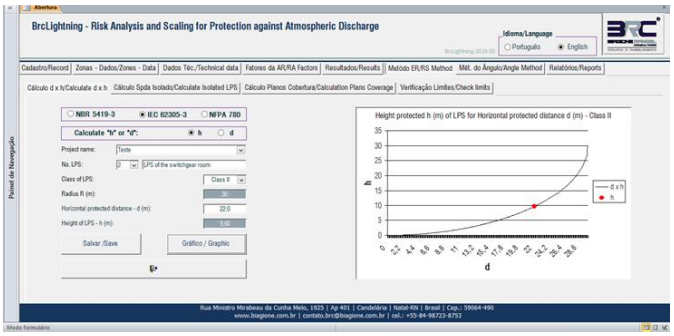

Fig. 10. Example of calculation of h for Class II, for [4]

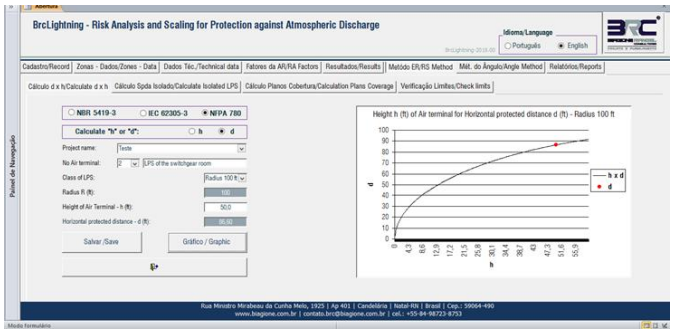

Fig. 11. Example of Distance Calculation for Class 100, for [9]

2. Section for Scaling the Isolated LPS

In this section the height of the isolated LPS is scaled (the mast is isolated from the structure to be protected), based on the required LPS Class, the desired coverage margin. The designer has the discretion to define this margin. However, the system sets in 1.0 m for the Standard [3] and [4] and 3ft for Standard [9]. In this module, in addition to the Standards options, the option is also given for structures with classified areas and, in this case, the coverage margin is above the critical point of the classified area, as shown in Fig 3 of this article. Fig 12 and Fig 13 show the screens of this design.

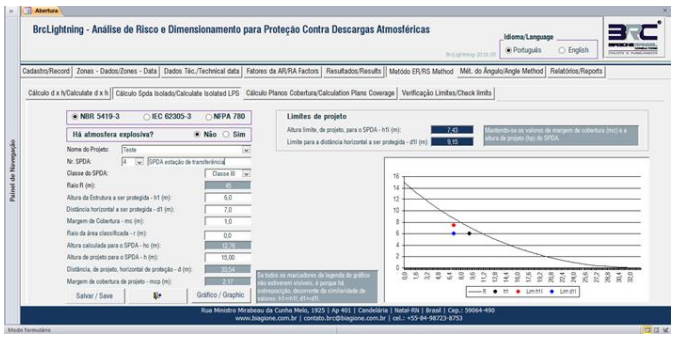

Fig. 12. Scaling of one isolated LPS by standard [3], indicating the limits

Whereas the system presents a sizing of the height and the designer can set a higher mast, the system calculates the bounds of this project, for two situations: one is the height of the structure to be protected. Then the system calculates what the maximum distance that the LPS can be away from the face farther from the structure and the second if the horizontal distance of the project to be protected is maintained, so that is the maximum height that the structure might have so that the calculated protection is maintained considering the conditions of the project coverage. Given these limits, the designer can specify others limits, which can vary between them. To do so, the designer can use the data on the screen and modify the heights and distances and after use the chart, because data will be presented on the screen.

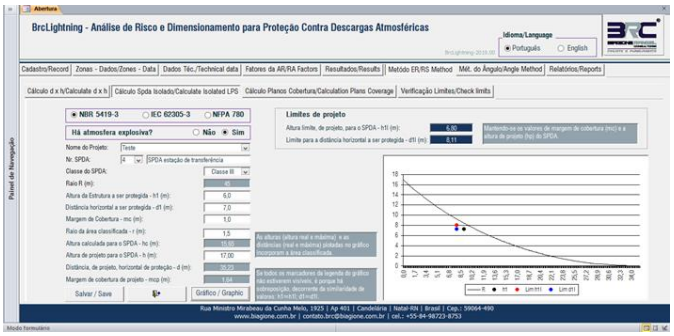

Fig. 13. Sizing of the Isolated LPS, with hazardous area by [3]

For structures with classified areas, the calculation is the same, but incorporates the area classified, so the limits and the height, enter the radius of the hazardous area. The procedures for evaluation of the limits are the same as those projects that do not have classified area.

3. Coverage Rays Sizing Section of LPS

This Section aims to provide a tool to the designer, to allow calculate the coverage provided by the plan existing LPS isolated (for non-isolated LPS evaluation, use Section 1) or designed for a particular time that is the object of evaluation or an equipment or a structure within of the one installation. This calculation is done for each of the standards and to the level of protection that is selected. The screen of this module is shown in Fig. 14.

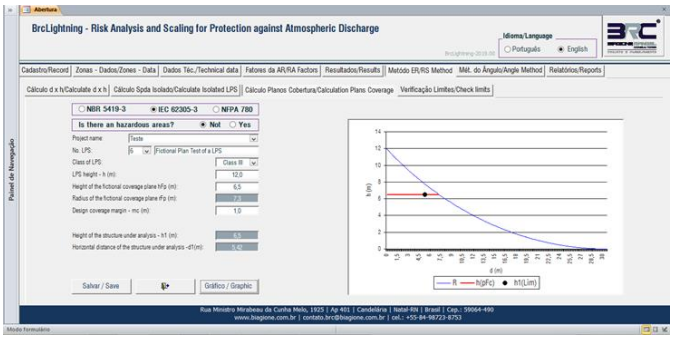

Fig. 14. Calculation of the Fictional Coverage Plan

The data coverage plan calculated for one LPS or the various LPSs under analysis allows the designer to draw, in top view, the horizontal protected area that the LPS can provide for the installation, considering various dimensions of height as shown in Fig. 15. With In this tool, the designer can easily identify unprotected areas and act to mitigate this failure or confirm the effectiveness of the project. In addition, it indicates to designer, which height limit for a structure is under LPS protection. Fig. 15 shows an example of the application of this tool.

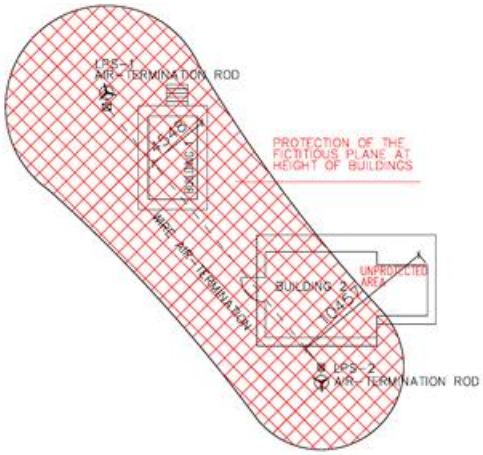

Fig. 15. Projection of horizontal coverage for the LPS

4. Section of evaluating the Limits of an Installed LPS

This Section aims to provide a tool to the designer, to access whether a particular LPS provide the correct protection of points of the analysis, as well as installations, access whether its coverage envelopment interacts with other structures in the neighborhood. This tool can be used in addition to the previously described.

The Section has two options: one for the situation where classified or dangerous areas are missing and another when these areas are present. In all cases the system offers the calculation for the four levels of protection, however, when the standard selected is the Brazilian [3] or IEC [4] and two levels, when American standard [9]. In this option the system shows the calculated values highlighted in colors: green when meets the conditions set out in the project, in yellow for the cases in which provide coverage, but not provided coverage margin established and in red where the coverage is not effective. These calculations are also presented in chart form. The Fig. 16 represents this module, be with the chart presentation of the result.

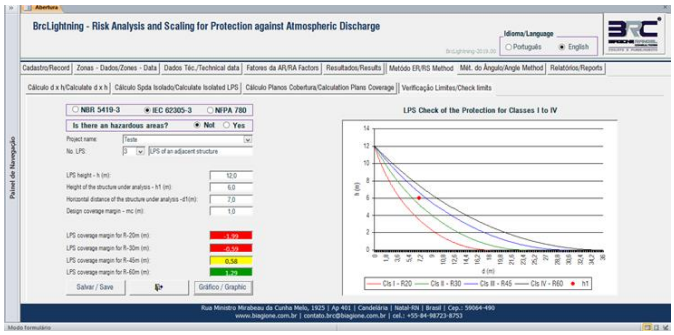

Fig. 16. Limits evaluation module screen - Option 1

When the structure contains classified or dangerous area, due to chart visual precision the option was change the 4 levels of protection of the Brazilian Standard [3] and [4] and the 2 American levels, for a chart with only one level of protection. However, in this situation the representation in chart for the selected class. The visual indication of effective color cover uses the same pattern of colors already mentioned, but the data enter area classified or dangerous. However, the chart representation shows the critical point of the structure and of the hazardous area. Fig. 17 shows that for an example, considering the level of protection, there is no adequate coverage, because it considers the hazardous area, however, the chart shows that the structure is protected and the hazardous area not. The objective of this module is to provide this information to the designer, and that way assists his or her identify the cause of the failure or effectiveness of the project.

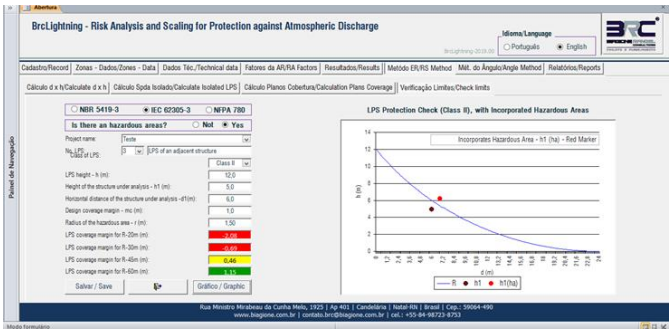

Fig. 17. Limits evaluation module screen - Option 2

C. Angle Method Module

This module replaces part of the methodology developed and presented at the XIV SIPDA [8] and consists of 3 (three sections): A calculation of the height or distance required to provide protection to a protected area at ground level (d x h/Calculation Calculate d x h) , another that scales the height of the LPS, to provide coverage of a structure (SPDA Isolated/Calculation Calculate Isolated LPS) and the third that evaluates the effectiveness of a given LPS (Verificação da Proteção/Protection Check).

1. Sizing of height or distance

This section show us calculation of distance or height required by an LPS to cover at ground level or from a reference surface, like the top of a building. Also, allows, that given a LPS, one point if you can calculate the horizontal distance that the same offers. In both cases the data are calculated for a class of selected LPS and the chart representation shows the height x distance on the curve radius of protection, when considered the method of angle, as shown in Fig. 18.

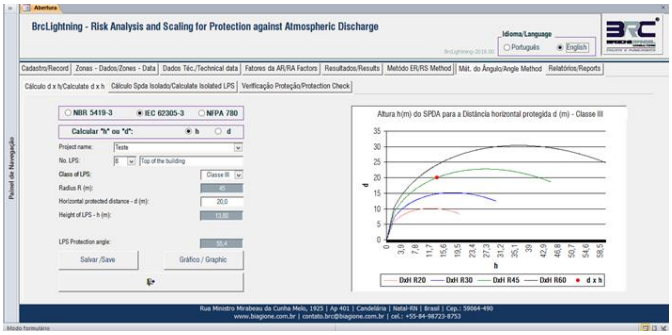

Fig. 18. Calculation of the height x distance

This Section also offers what the angle of protection of LPS in accordance with Figure 1, item 5.2.2 of the rules [3] and [4] or Figure a. 4.7.3.2.3 of the standard [9].

2. Sizing of Isolated LPS (Angle Method)

In this section we calculate a LPS isolated by the Angles Method, for a certain level of protection. However, because of this method to define an angle for each LPS height (after the height of 2 m) the solution requires a solution of equations by complex methods, interactively, as the Newton-Raphson Method or another. Then, to overcome this situation, the system provides the option of interactive resolution, with visual orientation (Fig. 20), suggesting the first approximation. If the calculated values for the coverage margin and the angle α1 (see Fig. 19) are highlighted in the blue color for the coverage margin and yellow for the angle, the suggested height in this first approximation is high, so a height is indicated (by system). If the color of the coverage margin is red and the angle is yellow, the suggested LPS height is lower than required, so a new value should be indicated (input). If the two colors: coverage range and angle are yellow the height is lower than required. New indication must be made and if the colors are green the indicated height value is the one recommended for the LPS. If the angle color is green and the blue coverage margin, the height is higher than required, however, the structure will be well protected, but the designer may indicate a smaller height if the coverage margin is yellow, the recommendation is to return to the value of h, above.

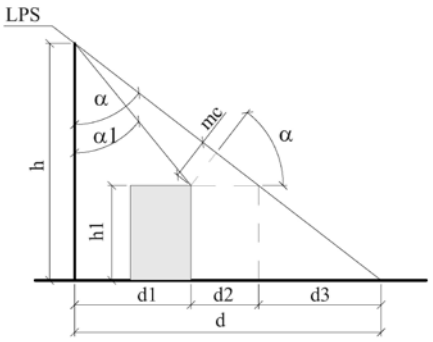

Fig. 19. Calculation of LPS Isolated by Angle Method

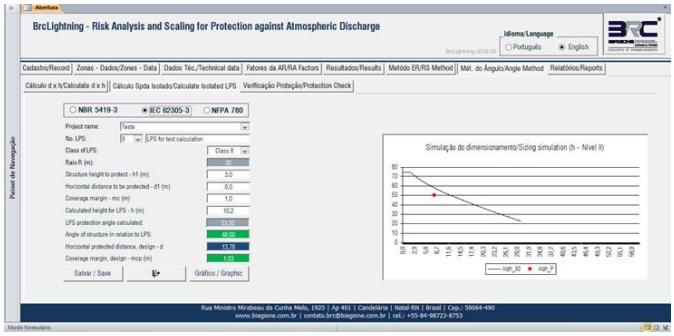

Fig. 20. Calculation and graphical representation of an isolated LPS

3. Verificação Proteção de LPS

Considering the mathematical approach to the Angle Method [8], the system offers in this section to verify the effective protection of the LPS designed or installed by checking the angle α1 (see Fig. 21) in relation to all levels of protection that a LPS provides, i.e. If the angle α1 (see Fig. 19) is greater than the angle α of LPS for the level established, the LPS don't provides protection and the system highlights in red; if less than α, like Fig. 19, but the coverage margin is less than set by designer/system analyst highlights in yellow; in the case of angle α1 less than α and will be coverage margin greater than equal to that the set by the designer, the system highlights in green. Fig. 21 shows the graphical representation on screen.

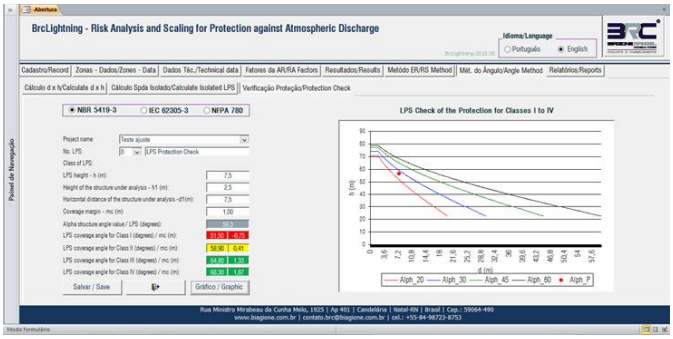

Fig. 21. Evaluation of protection effectiveness

This check can be performed to various points of the system. The option to record in the database and can later be issued reports of these checks are present in this module.

D. Reporting Module

This Module includes the options for the various version reports that the system can available: Risk Analysis Report; Report on the design of LPS by the Rolling Sphere method; Module Report using the Angle Method, etc. The screen of the system where these options are available is shown in Fig 22.

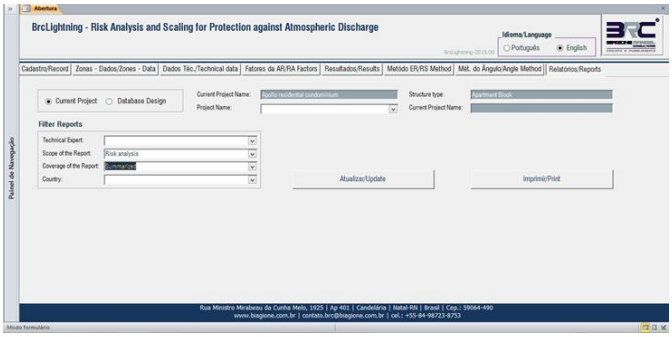

Fig. 22. Screen of the reporting module

IV. CONCLUSION

This is the initial version of BRCLighting, but it already incorporates several tools that provide designers with the facilities and security, accordance with the Brazilian, International and American standards, for the development of Risk Analysis and Scaling for protection against atmospheric discharges.

The subject is broad and complex, so it wasn't possible to address it in its entirety in this release, but the next goal is to incorporate new improvements into the tools already incorporated and to include enhancements and conditions that the standards already set or will establish, as well as, other recommendations defined by CIGRE and other institutions that study the theme. Also, it is objective include new resources to

make available to LPS designers the means more efficient and security for project development. In this way, we hope to be contributing to a better understanding of the standards and to the development of safer and more effective projects of the protect against atmospheric discharges.

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