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RISK OF LIGHTNING STRIKES ON TALL TRANSMISSION LINE TOWERS IN THE AMAZON REGION

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ABSTRACT — This work aimed to analyze the exposure to lightning strikes, of the transmission line system components (ground wires, phase cables and tower), all of them considered critical for the strategic planning and design of the protection systems for the transmission lines in the Amazon Region.

KEYWORDS — Amazonia. atmospheric discharges. striking distance. transmission line protection. non-conventional tall towers.

1. INTRODUCTION

The Brazilian part of the Amazon Region will be impacted by the construction of several hydroelectric energy generation and transmission systems, according to its Government "Energy Expansion Decennial Plan" – PDE 2020. The long distance transmission lines projects proposed, include the building of non-conventional high towers with heights reaching up to 300 m, in some cases. Under these circumstances and considering the high lightning density of occurrences in the region, the estimates of the transmission lines protection factor against atmospheric discharges, becomes critical for the expansion plans (Pinto et al., 2011).

The incidence of the atmospheric discharges on the transmission lines was made, based on an electro geometric model. Its fundamental input variable is the attraction distance between the leader pilot (of downward discharges) and the ground structure (origin of the upward directed channels). The model allows estimating the number of lightning direct incidences on the transmission lines. The lightning approaches are supposed to occur at a given angle with respect to the vertical, within a perpendicular plane to the transmission line.

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This plane may be divided in stripes, corresponding to individual conducting elements of the tower, subject to direct strikes by lightning. Moreover, other elements of the towers need to be analyzed, besides the shielding of the phase cables, since it is still unknown, the way that lightning may strike such exceptionally high structures in Amazonia. This problem has to be dealt with, if one expects to guarantee an acceptable operational performance of the electric systems in this region.

2. METHODOLOGICAL PROCEDURES

This work proposes a new method for the analysis of the tall towers elements (lightning rod cables, phase cables and the tower structure) exposure to atmospheric discharges, considering the peculiarities of the Brazilian National Interconnected System (SIN) of electric energy system expansion in the Amazon Region.

The exposure analysis is based on an electro geometric model which permits to evaluate the percentage of each incidence stripe and subsequently the estimated percentage of the lightning events likely to strike, each element of the tower. This estimate is made as a function of the lightning incidence angle, the stroke peak current, the height of the tower and the equation used to determine the striking distance of the atmospheric discharges (Sá, 2011).

The proposed methodology restricts the analysis to the tower elements contained on a plane perpendicular to the transmission line considered. Additionally, the lightning incidence angles are limited to the interval between 0º and 70º with relation to the zenith direction.

Within this exposure zone, it is then possible to determine approximately the lightning number fraction, likely to strike each component of the high tower system. In the following section, results will be presented from the application of such methodology.

3. RESULTS

The exposure analysis results of the transmission line elements are presented in two cases, according to the method described in Sá (2011). Both consist of an unconventional tall tower exposed to the lightning with the peak current of 45 kA, but differ in the propositions on the equation used for determining the striking distance (r_s). The first uses the traditional equation r_s=10$I_p^{0,65}$ (Love, 1973), while the second uses the alternative equation r_s=1,9$I_p^{0,90}$, proposed by Cooray, Rakov and Theethayi (2007).

3.1 *First Case (I_p = 45 kA and r_s = 10$I_p^{0,65}$)*

For the first analysis were used geometrical parameters listed in Table I.

TABLE I
GEOMETRICAL PARAMETERS OF NON-CONVENTIONAL TOWERS

Parameter	Value
Height of the lower phase cables FA and FC (y_A)	305.00 m
Height of the upper phase cable FB (y_B)	330.00 m
Height of ground wires G1 and G2 (y_1)	350.00 m
Distance between lower phase cables A and C	24.00 m
Distance between ground wires G1 and G2	12.00 m

Note: The upper phase cable FB is located in the tower axis.

Figure 1 shows that the percentage of the incidence stripe range on ground wires and the tower vary considerably depending of the lightning incidence angle.

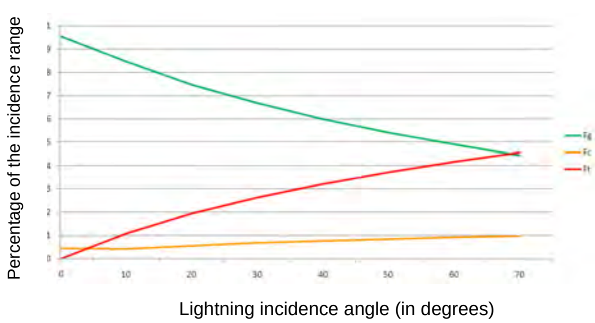

Fig. 1. Percentage of the incidence range (ground wires, phase cables and tower) to I_p=45 kA and r_s=10$I_p^{0,65}$.

For this configuration there is an intersection point around 70° indicating that for discharge at angles greater than this value, the exposure range of the tower becomes higher than the exposure range of the ground wires, which infers in an higher incidence probability on the tower.

3.2 *Second Case (I_p = 45 kA and r_s = 1,9$I_p^{0,90}$)*

For this case, the same geometrical parameters listed in Table I were used, but a different equation was then considered for the determination of the striking distance (Cooray, Rakov and Theethayi, 2007).

Figure 2 shows that in this configuration the intersection point, where the percentage of the exposure range of the tower becomes greater than the percentage of the exposure range of the cable guard, would be at approximately 30º. The end result was a considerable percentage increase of lightning strikes on the tower, as shown in Figure 3.

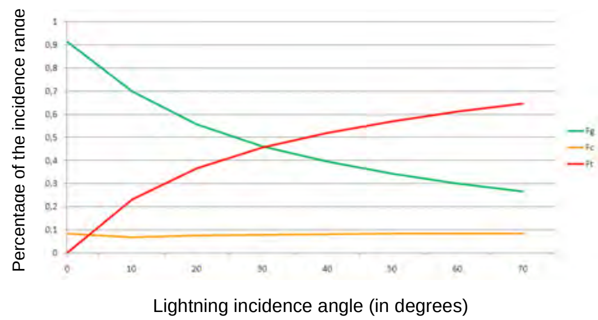

Fig. 2. Percentage of the incidence range (ground wires, phase cables and tower) to I_p=45 kA and r_s=1,9$I_p^{0,90}$.

3.3 *Estimated Lightning Strikes Percentages*

Figure 3 shows the estimated lightning percentage of peak current with 45 kA incident on the elements analyzed.

For the first case, the estimated numbers per element corresponding to each exposure zone was: 70.88% incidence for the ground wires, 6.17% for the phase conductors and 20.95% for the tower itself. It was estimated that 2% of the lightning may occur with inclinations over 70°, but these were not considered in the methodology.

For the second case, the estimated quantities, indicated a considerable increase of incidence in relation to the tower. The exposure areas percentages were: 54.69% for impact on ground wires, 7.74% for the phase cables and 35.57% for the tower.

Note that the configuration most unfavorable for the protection of the transmission line tower was that which uses the equation r_s=1.9 $I_p^{0.90}$ in determining the striking distance. In this proposition the estimated amount of lightning incident on the tower is high, accounting for approximately 36% of the total number of strikes on the system, which leads to a compromising of the shielding efficiency of the transmission line.

This expected number of strikes on the tower can produce undesirable effects such as the back flashover phenomenon due to the overvoltage phase, earth generated (Araújo and Neves, 2005).

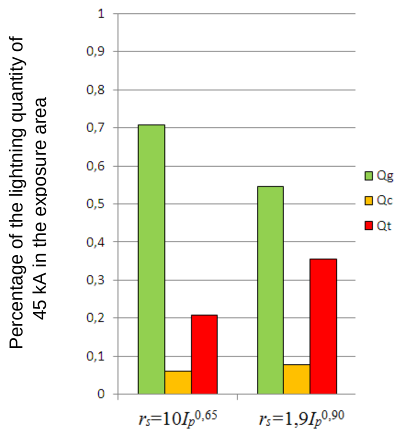

Fig. 3. Lightning estimated quantities on the ground wires, cables phase and tower per configuration analyzed.

4. CONCLUSION

This work presented a new approach for the analysis of the exposure to lightning, of the elements of non conventional transmission line high towers, projected to be built in the Amazon Region.

It was proposed the concept of incidence stripe ranges per constituting element of the tower system, for which a strike probability was calculated as a function of the discharge incidence zenithal angle.

The lightning strike percentage on each element of the transmission line elements were determined for two cases of the striking distance (one traditional and another alternative equation proposed).

The results have demonstrated the usefulness of the proposed methodology, by revealing that for either one of the equations used, the percentage of estimated strikes on the tower structure elements is very high. It is in fact, nearly equal to the estimated percentage of lightning incident on the guard cables, when the alternative equation for the attraction distance was applied. This fact poses serious questioning regarding the efficiency of conventional shielding for these unusually tall electric energy transmission line structures.

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