IMPROVEMENT OF LIGHTNING-INDUCED RISK CALCULATION METHODS FOR TELECOMMUNICATION STATIONS

CẢI TIẾN PHƯƠNG PHÁP TÍNH TOÁN RỦI RO DO SÉT GÂY RA ĐỐI VỚI CÁC TRẠM VIỄN THÔNG

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Abstract:

In this paper, we first address the lightning-induced risk calculation method for telecommunication stations used in Vietnam and discuss its limitations when applied in real-world conditions. Subsequently, we propose an enhanced method to calculate the lightning-induced risks for telecommunication stations in a more comprehensive manner, aligning with international recommendations.

Keywords:

Telecommunication station, lightning and the risk of lightning-induced damage, calculating the risk of lightning-induced damage.

Tóm tắt:

Trong bài báo này, đầu tiên chúng tôi đề cập đến phương pháp tính toán rủi ro do sét gây ra với trạm viễn thông đang được áp dụng tại Việt Nam và thảo luận về những hạn chế của của chúng khi áp dụng trong điều kiện thực tế. Sau đó, chúng tôi đề xuất một phương pháp cải tiến nhằm tính toán rủi ro do sét gây ra với các trạm viễn thông toàn diện hơn, phù hợp với các khuyến nghị quốc tế.

Từ khóa:

Trạm viễn thông, sét và nguy cơ thiệt hại do sét gây ra, tính toán rủi ro do sét gây ra.

1. GENERAL INTRODUCTION

Lightning is the most common strong electromagnetic source occurring in nature. According to estimates, every second there are hundreds of lightning strikes to the ground. Lightning causes electrostatic, electromagnetic, thermal, and dynamic effects on surrounding objects, especially telecommunications stations. Therefore, calculating the risk caused by lightning to telecommunications stations, comparing it with the acceptable risk value, thereby proposing effective lightning protection solutions to minimize the risk caused by lightning to the telecommunications stations are very necessary, has scientific and practical significance. Lightning protection solutions must also be based on risk assessment - paying attention to

the cost and importance of telecommunications stations, lightning activity in the telecommunications station area, installation and maintenance costs of lightning protecting equipments and probability of damage caused by lightning.

In Vietnam, there are standards and regulations on lightning protection for telecommunications stations such as Vietnamese Regulations QCVN 32:2020/BTTTT, National Technical Regulations on lightning protection for telecommunications stations and telecommunication cable networks [1], National Standard, TCVN 8071:2009, Telecommunications works - Code of practice for lightning protection and grounding [2]. In these Standards and Regulations, there are detailed regulations on the method of calculating the risk caused by lightning for telecommunications stations. However, these regulations only consider the risks of human loss and service loss and do not mention the economic loss caused to telecommunications stations of service providers. Therefore, in this study, based on the study of ITU-T K39 [3] recommendations and IEC62305 [4] standards on building protection, specifically telecommunications stations, we propose a method to calculate additional risks to QCVN 32:2020/BTTTT, thereby minimizing the risk of damage to telecommunications stations caused by lightning.

The structure of the next part of the article includes: section 2 summarizes the method for calculating the risk caused by lightning to telecommunications stations according to current regulations, section 3 proposes an improved method to calculate the risk caused by lightning to telecommunications stations and section 4 is the conclusion of the article.

2. METHOD TO CALCULATE THE RISK CAUSED BY LIGHTNING TO TELECOMMUNICATION STATIONS

In this section, we will discuss the basic criteria for lightning protection, requirements for risks caused by lightning and methods for calculating risks caused by lightning to telecommunications stations according to current regulations of Vietnam as a basis for comparison and evaluation with recommendations and international standards in the next section.

2.1. Basic criteria for lightning protection

1) Lightning protection level: There are 4 different lightning protection levels (LPL - Lightning Protection Level). For each LPL, a set of lightning current parameters is assigned. The maximum value of the lightning current parameter corresponding to LPL I and LPL II will not be exceeded with a probability of 99% and 75%, while for LPL III and LPL IV, it will be 50%.

Table 1. Lightning current parameter values according to LPL

LPL	I	II	III	IV
Maximum peak current, kA	200	150	100	100
Minimum peak current, kA	3	5	10	16

The maximum and minimum values of lightning current parameters for different LPL levels are listed in Table 1 and used to design components of lightning protection systems, such as conductor cross-sections, the thickness of the metal shell, the current carrying capacity of the lightning protection device (SPD - Surge Protective Device), isolation distance to avoid dangerous ignition [1].

2) Lightning protection zone: The distinction between lightning protection zones (LPZ - Lightning Protection Zone) is determined based on the significant difference in electrical impulses caused by lightning occurring in each protection zone. The LPZs defined include [1]:

- LPZ 0_A: is the area at risk of being directly struck by lightning and subject to the entire electromagnetic field due to lightning. Systems in this zone may be subject to all or part of the lightning surge current;
- LPZ 0_B: is an area that has been protected from direct lightning strikes but is still under the threat of the entire electromagnetic field due to lightning. Systems in this zone may be partially exposed to lightning surge current;
- LPZ 1: Is the zone in which the pulse current is limited due to current splitting and SPDs at the boundary location. Spatial shielding can attenuate the electromagnetic field caused by lightning;
- LPZ 2,…, n: are the zones in which the pulse current is further limited due to current splitting and additional SPDs at the boundary location. Additional spatial shielding can further attenuate the electromagnetic field due to lightning.

2.2. Requirements on risks caused by lightning

Telecommunications stations must be equipped with protective measures so that the risk value does not exceed the acceptable risk value as shown in Table 2.

Table 2: R_T - acceptable risk value for telecommunications stations [1], [3]

Type of loss	R_T
Risk of human loss R_{injury}	10^{-5}
Risk of service loss R_{loss}	10^{-3}

2.3. Method for calculating risk due to lightning

The risk caused by lightning to telecommunications stations is calculated according to the formula:

$$R_{injury} = L.p_{inj}.\sum F_i \quad (1)$$

$$R_{loss} = L.\sum F_i \quad (2)$$

where, F_i is the frequency of damage caused by lightning to the station due to lightning directly striking the station, lightning striking the antenna mast next to the station, lightning striking the ground near the station or lightning spreading through the lines going into the station. The value of F_i depends on inherent or additional protections; L is the loss weight, representing the level of loss in one lightning damage to the station. With the risk of human loss, $L = 1$, while with the risk of service loss $L = 2.74 \times 10^{-3}$; p_{inj} is the probability of minimizing damage to humans due to protective measures. Depending on the different protection measures used, the value of p_{inj} is also different, as given in [1], [3].

3. IMPROVED METHOD TO CALCULATE THE RISK CAUSED BY LIGHTNING TO TELECOMMUNICATION STATIONS

3.1. Basis for improvement

1) Based on recommendation ITU-T K39 (2019) [3]: The assessment of damage risk for telecommunications projects updates the need to take into account the risk of economic loss. According to this recommendation, the acceptable level of economic loss risk is determined by the telecommunications operator. However, deciding on the appropriate level of risk must be based on the cost of protective measures compared to the physical loss that may occur, calculated on an annual basis. The acceptable level of risk in relation to human loss must be assessed by national or international safety agencies. In addition, the acceptable risk related to service loss is recommended to be 10^{-4}, higher than QCVN 32:2020/BTTTT.

2) Based on IEC 62305 [4], [5], [6]: In addition to human loss (L1) and service loss (L2), this standard provides two other criteria to calculate risks: cultural heritage loss (L3) and economic loss (L4). Additionally, risk components and risk calculations are reviewed. Risk component groups used for calculation include:

- Risk components of structures struck by lightning:

R_A: involves injury to living beings due to electric shock due to contact voltages and step voltages inside and outside the structure in an area up to 3m around the electrical conductors. Losses of type L1 and L4 may arise.

R_B: involves physical damage due to the emission of dangerous sparks inside the structure causing fire, explosion and can also be dangerous to the environment. All types of losses (L1, L2, L3 and L4) can arise.

R_C: related to internal system error due to LEMP (Lightning electromagnetic pulse). Losses of type L2 and L4 can occur in all cases, while type L1 can occur in the case

of structures at risk of explosion and hospitals or other structures where failure of internal systems will cause damage immediate danger to human life.

- Risk components of a structure close to struck by lightning:

R_M: related to internal system errors caused by LEMP. Losses of type L2 and L4 can occur in all cases, while type L1 can occur in the case of structures at risk of explosion and hospitals or other structures where failure of internal systems will cause damage immediate danger to human life.

- Risk components of the structure due to lightning strikes on lines connected to the structure:

R_U: relates to injury to living beings due to electric shock due to contact voltage inside the structure. Type L1 losses and in the case of agricultural assets, type L4 losses may occur.

R_V: involves physical damage (fire or explosion due to dangerous sparking between the external installation and general metal parts at the point of entry of the line into the building) due to lightning current transmitted through or along the incoming line. All types of losses (L1, L2, L3 and L4) are possible.

R_W: related to damage to internal systems due to overvoltage caused on lines entering and transmitting to the structure. Type L2 and L4 losses can occur in all cases, along with type L1 in the case of structures at risk of explosion, and hospitals or other structures where damage to internal systems immediately causes damage to human life.

- Risk components for the structure due to lightning strikes near the lines connected to the structure:

R_Z: related to damage to internal systems due to overvoltage caused on lines entering and transmitting to the structure. Type L2 and L4 losses can occur in all cases, along with type L1 in the case of structures at risk of explosion, and hospitals or other structures where damage to internal systems immediately causes damage to human life.

The risk components that need to be considered for each type of loss in the project are determined as follows [5]:

- Risk of human loss:

$$R_1 = R_{A1} + R_{B1} + R_{C1} + R_{M1} + R_{U1} + R_{V1} + R_{W1} + R_{Z1} \quad (3)$$

- Risk of loss of public services:

$$R_2 = R_{B2} + R_{C2} + R_{M2} + R_{V2} + R_{W2} + R_{Z2} \quad (4)$$

- Risk of loss of cultural heritage:

$$R_3 = R_{B3} + R_{V3} \quad (5)$$

- Risk of loss of economic value:

$$R_4 = R_{A4} + R_{B4} + R_{C4} + R_{M4} + R_{U4} + R_{V4} + R_{W4} + R_{Z4} \quad (6)$$

Acceptable risk values for reference of loss levels for structures hit by lightning according to IEC 62305-2 standard are given in Table 3 [5].

Table 3. RT acceptable risk value

Type of loss	R_T
Human loss	10^{-5}
Loss of public services	10^{-3}
Loss of cultural heritage	10^{-4}
Loss of economic value	10^{-3}

According to IEC 62305-2, risks R_1, R_2, R_3 should be considered when assessing the need for lightning protection. Specifically, if $R_x \geq R_T$, it is necessary to implement lightning protection measures for the building to minimize the risk of $R_x \leq R_T$ for all risks of loss [4], [5], [6].

3.2. Method for calculating the risk caused by lightning with improved telecommunications stations

Based on the study of ITU-T K39 recommendations [3] and IEC62305 standards [4], [5], [6] on building protection, specifically telecommunications stations, we propose a method to calculate additional risks to QCVN 32:2020/ BTTTT, thereby minimizing the risk of damage to telecommunications stations caused by lightning.

Specifically, in addition to the risk components due to human loss and service loss, the risk calculation must take into account the risk of economic loss caused to telecommunications stations of service providers service. This is an important parameter that recommendation ITU-T K39 has proposed and standard IEC 62305 gives specific calculation instructions.

The risk of loss of economic value is calculated based on the Eq.(6). Combined with QCVN 32:2020/BTTTT [1], ITU-T recommendation K39 [3] and IEC62305 standards [4], [5], [6], we propose an acceptable risk value R_T as shown in Table 4.

In addition to adding loss of economic value, this proposal retains the acceptable value-at-risk requirement for human loss risk while increased demands at the expense of Information and Communications Technology service (ICT) services.

Table 4. Acceptable risk value proposed by R_T

Type of loss	R_T
Human loss	10^{-5}
Loss of ICT services	10^{-4}
Loss of economic value	10^{-3}

4. CONCLUSION

calculating the risk caused by lightning to telecommunications stations according to Vietnam's current regulations and researched international standards and recommendations on lightning protection for buildings. On that basis, the paper advances an improvement to the methodology for assessing lightning-induced risks pertinent to telecommunication stations. This The article discussed the method of enhancement involves the integration of economic loss parameters and elevating criteria for acceptable risk thresholds for the loss of public services. Importantly, this proposition aligns entirely with prevailing international standards and recommendations.

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Biography:

Duy Phong Pham received the B.E. degree in telecommunications engineering from the University of Communications and Transport, Hanoi, Vietnam, in 2000, the master's degree in electronics and telecommunications from the Hanoi University of Technology, Hanoi, in 2007, and the Ph.D. degree in telecommunications engineering from the Vietnam Research Institute of Electronics, Informatics and Automation, Hanoi, in 2013. He was a Researcher with the Posts and Telecommunications Institute of Technology, from 2000 to 2005. He is currently the Dean of the Faculty of Electronics and Telecommunications, Electric Power University, Hanoi.

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