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Risk Assessment of Damage to Telecommunication Sites due to Lightning in Typical Areas in Vietnam by the Improved Method

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***Abstract*—Vietnam is in the lightning center of Asia, so damage caused by lightning is very large, especially in the telecommunications field. Telecommunication sites (TSs) are usually built in high positions, and have the antenna tower higher than surrounding structures thus the risk of direct lightning strikes is huge. Currently, the selection of lightning protection solutions for these TSs mainly based on experience and preliminary calculation, not based on the results of risk assessment of damage due to lightning. This paper calculates the risk of loss of service caused by lightning to typical TSs in areas in Vietnam by the improved method with greater detail than the previously suggested methods. Then, the useful lightning protection solutions to typical TSs would be suggested for risk protection of the damages due to lightning. The results show that the level of loss of services caused by lightning to TSs in areas in Vietnam much higher than the tolerable value. When the surge protective devices (SPDs) are installed on all the incoming service lines, the level of risk caused by lightning can decrease up to 100 times.**

Keywords—Telecommunication site; risk of damage due to lightning; lightning protection solution.

I. INTRODUCTION

Vietnam is in the lightning center of Asia, so the damage caused by lightning is very large, especially in the telecommunications field.

Along with national socio-economic growth rate, communication plays an important role, more and more telecommunication site have been continuously upgraded and built. To facilitate for the transmitting and receiving, TSs are usually built in higher positions and with adjacent antenna tower, the risk due to lightning is increasingly high. Annually, the damages caused by lightning to the telecommunications field in Vietnam are quite large. According to statistics from the Ministry of Information and Communications, in 2012 Vietnam Posts and Telecommunication Group had about 457 failures due to lightning, the damage was estimated at 16.7% in total damages caused by natural disasters [4].

Therefore, application of lightning protection solutions for telecommunication sites is always necessary. However, currently, designation and selection of lightning protection solutions is still based on experience and preliminary calculation, not based on results of risk assessment of the damage caused by lightning. The assessment of risk caused by lightning to TSs helps engineers designing the lightning protection system give the proper lightning protection solutions to reduce the risk to below the tolerable limit.

The level of risk of the damage caused by lightning to Telecommunication site (TS) depends on:

- The dimensions and characteristics of the TSs and the adjacent antenna tower.
- The dimensions and characteristics of the incoming lines.
- The environment around the TSs.
- The density of lightning strikes in the region where the TSs is located.

The following will analyze and calculate the risk of the damage of the services to typical TSs due to lightning in typical areas in Vietnam by the improved method with greater detail than the previously suggested methods. Then, the reasonable solutions for lightning protection of TSs would be proposed.

II. TYPICAL TELECOMMUNICATION SITE

According to [6], a typical TS consists of the telecommunication building by reinforced concrete and adjacent steel antenna tower.

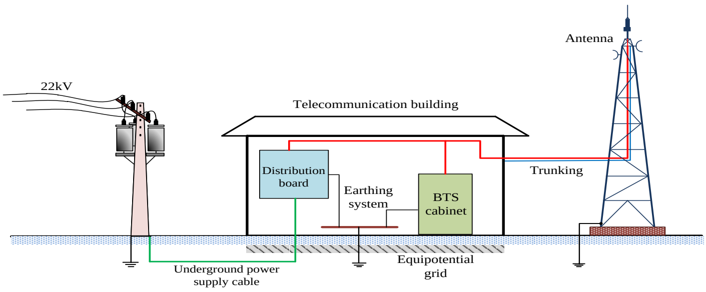


Fig. 1. Typical telecommunication site.

A 22kV overhead distribution line feeds a 22kV/380V delta-star primary winding of a transformer. The 380V supply is then fed via underground cable to distribution board. The output of the distribution board is then fed to lighting equipment, BTS cabinet, warning light…, with the power supply for the warning light, telecommunication cables for the antenna are put in the trunking. The surrounding of the TS is protected by metal fences.

The parameters and characteristics of the typical TS located at Ho Chi Minh City and of the service lines connected to the station are shown in TABLE I, II and III as follows:

TABLE I. ENVIRONMENT AND TELECOMMUNICATION SITE CHARACTERISTICS

Parameters	Comment	Symbol[a]	Value
Ground flash density (*flashes/km²/year*)		N_g	12
Structure dimension (*m*)		$L\times W\times H$	5×4×3
Antenna tower height (*m*)		H_{anten}	45
Location factor	isolated	C_D	1
Probability of a dangerous discharge based on structure type	reinforced concrete	P_s	0.2
Type of floor	ceramic	r_t	10^{-2}
Risk of fire	low	r_f	10^{-3}
Fire protection	extinguishers	r_p	0.5
Shield at external structure boundary	none	K_{S1}	1
Shield at internal structure boundary	none	K_{S2}	1
Protection measures	no LPS	P_B	1
Coordinated SPDs	none	P_{EB}	1
Protection measures	equipotential grid	P_{TA}	10^{-2}
Protection against touch voltages	none	P_{TU}	1
Hazard	no special hazard	H_Z	1
Loss	by electric shock	L_F	10^{-2}
	by physical damage	L_O	10^{-3}
Probability of a dangerous discharge based on structure type	unscreened	p_i	1

a. For more information about symbols and values adopted refer to standard IEC 62305-2, AS/ANZ 1768

TABLE II. CHARACTERISTICS OF THE POWER LINE

Parameters	Comment	Symbol[b]	Value
Length (m)		L_P	600
Line installation factor		$C_{I/P}$	1
HV/LV transformer		$C_{T/P}$	1
Line shield	$U_{W/P}$=2.5	$P_{LD/P}$	1
		$P_{LI/P}$	0.3
		$C_{LD/P}$	1
		$C_{LI/P}$	1
		$K_{S4/P}$	0.4
Reduction factor for surge protective device on input of equipment	no SPD	k_3	1
Reduction factor for surge protective device on input of service line	no SPD	k_5	1
Coordinated SPDs	no SPD	$P_{SPD/P}$	1

b. For more information about symbols and values adopted refer to standard IEC 62305-2, AS/ANZ 1768

TABLE III. CHARACTERISTICS OF THE TELECOM LINE

Parameters	Comment	Symbol[a]	Value
Length (m)		L_T	1000
Line installation factor		$C_{I/T}$	0.5
HV/LV transformer		$C_{T/T}$	1
Line shield	$U_{W/T}$=1.5	$P_{LD/T}$	1
		$P_{LI/T}$	0.5
		$C_{LD/T}$	1
		$C_{LI/T}$	1
		$K_{S4/T}$	0.6
Reduction factor for surge protective device on input of equipment	no SPD	k_3	1
Reduction factor for surge protective device on input of service line	no SPD	k_5	1
Coordinated SPDs	no SPD	$P_{SPD/T}$	1

c. For more information about symbols and values adopted refer to standard IEC 62305-2, AS/ANZ 1768

III. RISK ASSESSMENT OF DAMAGE DUE TO LIGHTNING BY THE IMPROVED METHOD

The improved method of risk assessment of damage caused by lightning is built on calculation method recommended by IEC 62305-2 standard [1], but the level of detail of the parameters such as: the probability of dangerous discharge based on structure construction materials; the probability of dangerous discharge based on internal wiring type; the number of service lines and shielding factor along the distribution line is considered added based on references from [2] and [3].

This method has been presented in detail in [5], the procedure of risk assessment has been shown in Fig. 2. According to [1], the components of the risk R_2 are expressed by:

$$R_2 = R_B + R_C + R_M + R_V + R_W + R_Z \quad (1)$$

Where:

$$R_B = N_D\times P_B\times r_p\times r_f\times L_F\times n_z/n_t \quad (2)$$

$$R_C = N_D\times P_C\times L_O\times n_z/n_t \quad (3)$$

$$R_M = N_M\times P_M\times L_O\times n_z/n_t \quad (4)$$

$$R_V = N_L\times P_V\times r_p\times r_f\times L_F\times n_z/n_t \quad (5)$$

$$R_W = N_L\times P_W\times L_O\times n_z/n_t \quad (6)$$

$$R_Z = N_I\times P_Z\times L_O\times n_z/n_t \quad (7)$$

(Refer to [1] for the meaning of symbols)

A. *Assessment of dangerous events due to lightning in the risk components*

- The number of dangerous events due to flashes to structure is determined by the equation:

$$N_D = N_G\times C_D\times A_D\times 10^{-6} \quad (8)$$

- While N_L (9), N_I (10) are the number of dangerous events due to flashes to and near the service lines, are determined by the equations:

$$N_L = N_G\times C_I\times C_E\times C_T\times A_L\times 10^{-6} \quad (9)$$

$$N_I = N_G\times C_I\times C_E\times C_T\times A_I\times 10^{-6} \quad (10)$$

In (9) and (10), the coefficients such as: installation factor C_I, environmental factor C_E and line type factor C_T are mentioned.

However, environmental factor C_E in (9) and (10) without reference to the terrain where the service lines go through as: the pole height h, the horizontal distance between the outer wires b and shielding factor S_f of the object height H, the distance to the service line x (Fig. 2), and in this case, the number of lightning strikes directly to line service follow [3] is determined by equation:

$$N_L = N_G \times C_f \times 10^{-6} \quad (11)$$

Where:

$$C_f = (b + 28 \times h^{0.6}) \times 10^{-1}(1 - S_f) \quad (12)$$

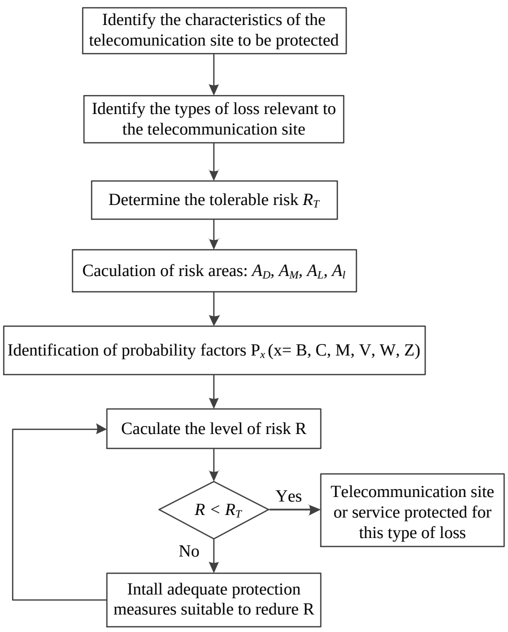
To improve accuracy when calculating the number of lightning strikes directly and indirectly on the overhead service lines, coefficient C_E in (9) and (10) should be replaced by the coefficient C_f defined in (12). The number of lightning strikes to and near overhead service lines is defined by the following equations:

$$N_L = N_G \times A_L \times C_I \times C_f \times C_T \times 10^{-6} \quad (13)$$

$$N_I = N_G \times A_I \times C_I \times C_f \times C_T \times 10^{-6} \quad (14)$$

- Number of dangerous events due to flashes near a structure, is equal to:

$$N_M = N_G \times A_M \times 10^{-6} \quad (15)$$



(Refer to [1] for the meaning of symbols)

Fig. 2. Procedure for risk assessment for telecommunication site.

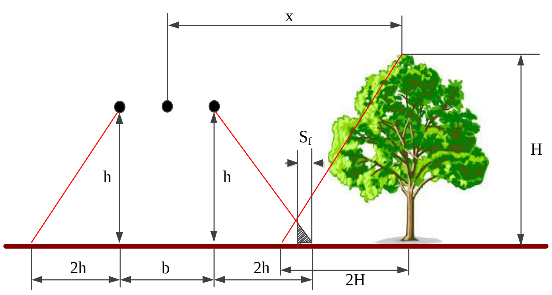


Fig. 3. Shielding power line by nearby object.

B. Assessment of the P_x in the risk components

1) Probability of physical damage to a structure P_B :

According to [1], when calculating risk component R_B related to physical damages due to flashes to the structure, the value of the probability P_B is determined only depending on the lightning protection level designed [1].

To increase the accuracy of the probability P_B for risk component R_B in IEC 62305-2, should be added the probability that external wiring carries a surge from structure that causes physical damage (P_{ewd}) and the probability of dangerous discharge based on structure construction materials (p_s) according to standard [2], as follows:

$$P_B = k_1 \times p_s + P_{ewd} \quad (16)$$

2) Probability of failure of internal systems P_C:

When calculating the probability P_C for risk components R_C, the coefficients are taken into account such as: the coordinated SPD system is installed P_{SPD} and the depending on shielding, grounding and isolation conditions C_{LD}.

While in [2], when calculating this probability, the factors are considered such as: the probability of dangerous discharge based on structure construction materials (p_s); the probability of dangerous discharge based on internal wiring type (p_i); reduction factor for surge protective device on input of equipment (k_3); correction factor for impulse level of equipment (k_w) and probability that external wiring carries a surge from structure that causes a damaging overvoltage to internal equipment (P_{wedo}).

When calculating the probability P_C, the coefficients as calculated probability P_w in [2] should be added as follows:

$$P_C = 1 - (1 - k_1 \times p_s \times p_i \times k_2 \times k_3 \times k_w)(1 - P_{wedo}) \quad (17)$$

3) Additional the number of service line number when calculating the probability of lightning flashes to and near the service line:

If there are many service lines connected to the structure in the separate rout, the probability of flashes to the service line will increase along with the number of service lines. Therefore, to increase the accuracy when calculating probability P_U, P_V, P_W and P_Z, the number of service lines should be added. The equations for calculating P_U, P_V, P_W and P_Z for overhead lines are defined as follows:

$$P_{V/oh} = P_{EB} \times P_{LD} \times C_{LD} \times n_{oh} \quad (18)$$

$$P_{W/oh} = P_{SPD} \times P_{LD} \times C_{LD} \times n_{oh} \quad (19)$$

$$P_{z/oh} = P_{SPD} \times P_{LI} \times C_{LI} \times n_{oh} \quad (20)$$

And the equations for calculating P_U, P_V, P_W and P_Z for underground lines are defined as follows:

$$P_{V/ug} = P_{EB} \times P_{LD} \times C_{LD} \times n_{ug} \quad (21)$$

$$P_{W/ug} = P_{SPD} \times P_{LD} \times C_{LD} \times n_{ug} \quad (22)$$

$$P_{z/ug} = P_{SPD} \times P_{LI} \times C_{LI} \times n_{ug} \quad (23)$$

(Refer to [1] for the meaning of symbols)

IV. CALCULATION OF THE RISK FOR TYPICAL TELECOMMUNICATION SITE

Applying the improved method as in Section 3, calculate the value of risk of service due to lightning to typical TS using the values of TABLE I, II and III. (The rate between the number of people in zone (n_z) and the total number of people in the structure (n_t) has been chosen as equal to 1). It is possible to obtain the value for risk R_2=0.01636. This result is greater than the tolerable risk for loss of service is equal to 0.001 [1].

Similar calculation for the case of typical telecommunication site is located in different areas in Vietnam with ground flash density change from 1÷17 (*flashes/km²/year*) and the height of antenna tower change from 20÷80 (*m*). The results of risk calculation are shown in TABLE IV and the results are compared with tolerable risk values in Fig. 4.

The level of risk of loss of services caused by lightning to telecommunication sites in typical areas in Vietnam is much greater than the tolerable value for the loss of services. The level of risk depends mainly on the ground flash density at the region where the telecommunication site is located; the characteristics of the incoming cable and existing protection measures against lightning for the telecommunication site; the higher antenna tower is the more level of the risk increases.

Recalculating for typical TS above with installed SPD on all telecommunication and the low-voltage power line, the risk of loss of service caused by lightning will decrease up to 100 times. The results of risk calculation are shown in TABLE V and the results are compared with tolerable risk values in Fig.5.

Results in TABLE V and Fig.5 indicate that installation of protective measures against lightning for the telecommunication site is needed. Surge reduction filter, SPDs on power lines, telecommunication cables and equipment inside should be installed. Besides, determining the location for installation of lightning protection devices and coordinating protection measures in order to achieve maximum efficiency is also important tasks should be taken into account.

TABLE IV. THE VALUE OF RISK OF LOSS OF SERVICE – R_2

Ng (*flashes/km²/year*) / H_{anten} (*m*)	The value of risk of loss of service – R_2								
	1	3	5	7	9	11	13	15	17
20	0.00135	0.00404	0.00674	0.00944	0.01213	0.01483	0.01753	0.02022	0.02292
40	0.00136	0.00408	0.00679	0.00951	0.01224	0.01495	0.01767	0.02040	0.02311
60	0.00138	0.00414	0.00689	0.00965	0.01241	0.01516	0.01792	0.02068	0.02343
80	0.00140	0.00421	0.00702	0.00983	0.01264	0.01545	0.01826	0.02107	0.02388

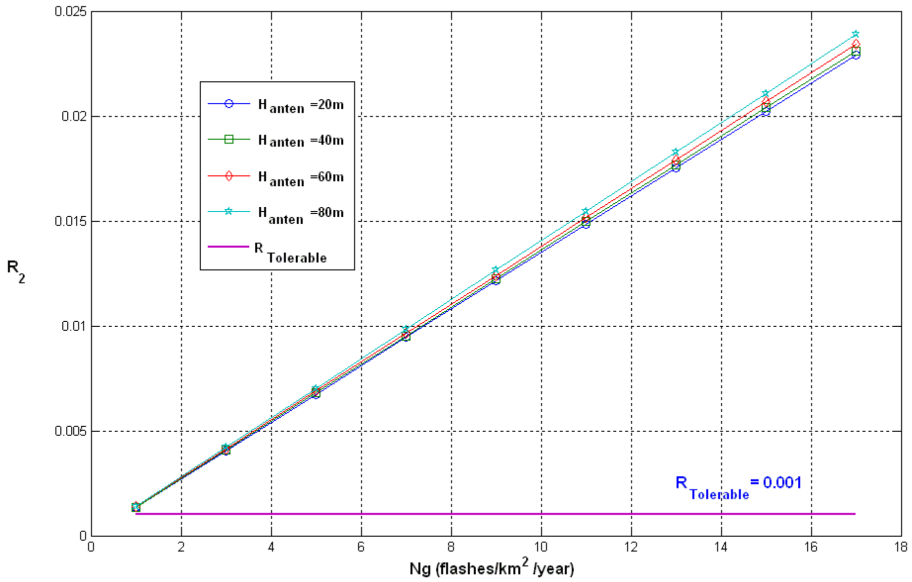
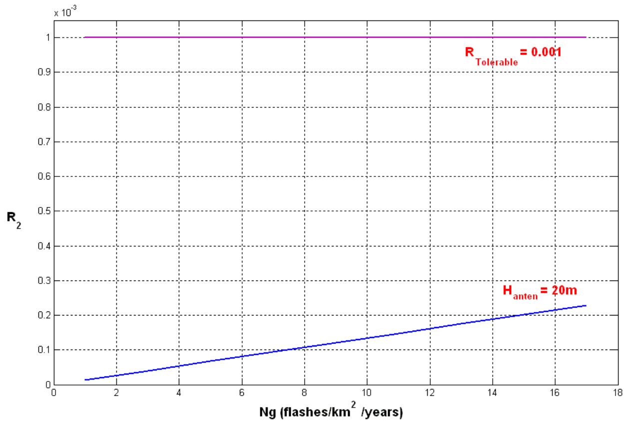


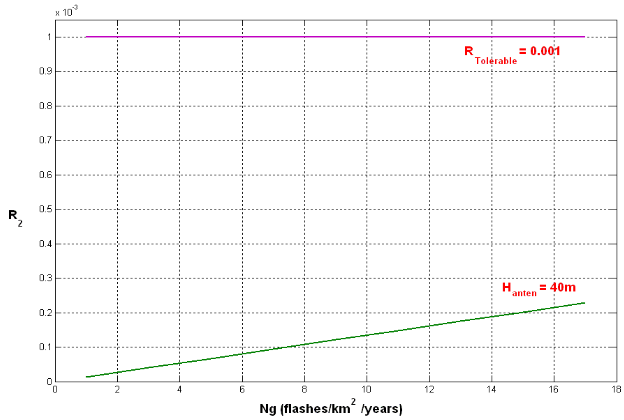
Fig. 4. The values of risk – R_2 compare with tolerable risk values R_T.

TABLE V. THE VALUE OF RISK OF LOSS OF SERVICE – R_2, AFTER INSTALLING PROTECTIVE DEVICES.

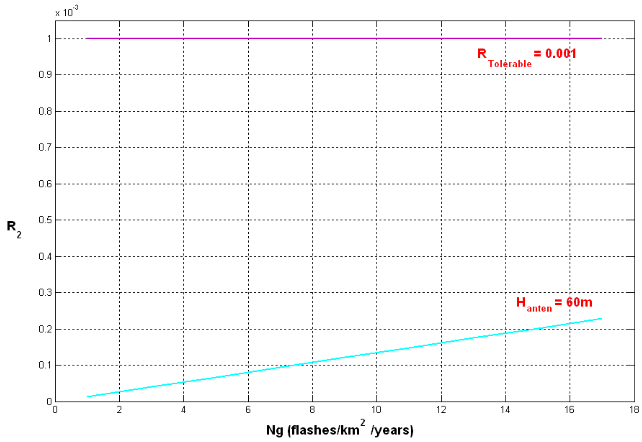
H_{anten} (*m*) \ Ng (*flashes/km²/year*)	The value of risk of loss of service $R_2 \times 10^{-5}$								
	1	3	5	7	9	11	13	15	17
20	1.3444	4.0332	6.7220	9.4108	12.0996	14.7884	17.4772	20.1660	22.8549
40	1.3446	4.0339	6.7232	9.4125	12.1018	14.7910	17.4803	20.1696	22.8589
60	1.3450	4.0351	6.7252	9.4153	12.1053	14.7954	17.4855	20.1755	22.8656
80	1.3456	4.0368	6.7280	9.4191	12.1103	14.8015	17.4927	20.1839	22.8750



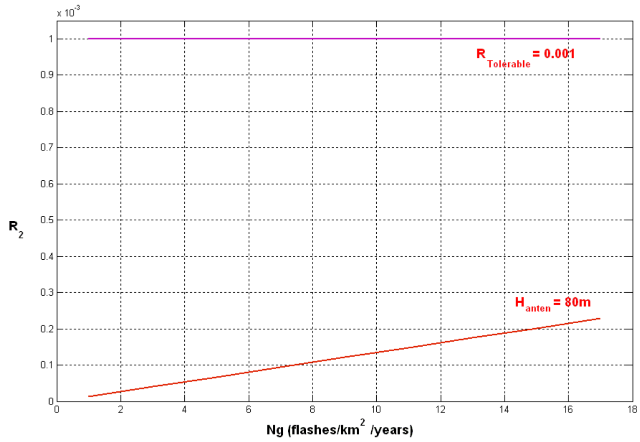
a) H_{anten} =20 m



b) H_{anten} =40 m



c) H_{anten} =60 m



d) H_{anten} =80 m

Fig. 5. The value of risk R_2 compare with tolerable risk values R_T, after installing protective devices.

V. CONCLUSION

This paper analyzed and calculated the risk of loss of service to typical TSs due to lightning in typical areas in Viet Nam by the improved method. The level of risk of loss of service caused by lightning for typical TS in areas in Viet Nam is shown with ground flash density change from 1÷17(*flashes/km²/year*) and the height of antenna tower changes from 20÷80 (*m)*. The results of calculation indicated that the level of risk greater than the tolerable value. The level of risk increases and depends mainly on density of lightning strikes.

Therefore, designation and installation of lightning protection measures to minimize the risk of the damages of the services caused by lightning for TS in areas in Vietnam is necessary. When the SPDs are installed on all the power lines and telecommunication cables, the level of risk caused by lightning can decrease up to 100 times.

Risk assessment of the damages due to lightning at TSs helps forecast the damages of the services, which supports the engineers designing the lightning protection system give proper lightning protection solutions to reduce the risk to below the tolerable limit.

ACKNOWLEDGMENTS

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