THE SOCIALIST REPUBLIC OF VIETNAM

QCVN 32: 2011/BTTTT

National technical regulation

on lightning protection for telecommunication stations and outside cable network

(This translation is for reference only)

HANOI – 2011

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Foreword

QCVN 32:2011/BTTTT was prepared on basis of revision and transferring of TCN 68-153:2001 "Lightning protection for Telecomunication sites- Technical Requirements" with the enclosure of Decision No. 1061/2002/QD-TDBD dated December 21st, 2001 by the Director General of the General Post Offices (now as Ministry of Information and Communications).

Technical regulations and test methods of QCVN 32:2011/BTTTT are prepared on the basis of IEC 62305, part 1, 2, 3 (2006) and Recommendations K.39 (1996), K. 40(1996), K.25 (1999) and K.47 (2008) of ITU-T..

QCVN 32:2011/BTTTT was prepared by the Posts and Telecommunications Technology Institute, submitted by Department of Science and Technology and promulgated as an enclosure with the Circular No. 10/2011/TT-BTTTT dated April 14th, 2011 by the Minister of Information and Communications.

National Technical Regulation on lightning protection for telecommunication stations and outside cable network

1. General requirements

1.1. Scope

This national technical regulation regulates:

- Allowable risk of damage due to lightning for telecommunication stations and outside cable;

- Method of determination of frequency of damage due to lightning for telecommunication stations and outside cable;

- Lightning protection measures for telecommunication stations and outside cable.

This regulation is applicable for telecommunication plant with telecommunication stations, and outside cable for the purpose of reducing risk due to lightning, assuring safety for human life and capability of providing service of telecommunication works.

1.2. Normative reference

QCVN 09:2010/BTTTT, National technical regulation on earthing of telecommunication stations.

TCVN 8071:2009, Telecommunication plant. Code of practice for lightning protection and earthing.

1.3 Explanation of terms and abbreviated words

1.3.1. Risk area

Risk area is the risk of the zone surrounding telecommunication plant, when this area is lightened, the telecommunication plant is affected

1.3.2. Lightning impulse current

Lightning impulse current is electrical impulse current with low frequency, appearing without fixed cycles, increasing to the peak, then reducing to value 0. Its characteristics includes:

- The impulse peak value (amplitude), I ;

- The front side time reaching the peak value, T_1;

- The back side time reducing to the half of the peak value, T_2;

- Impulse current waveform, T_1/T_2;

Figure 1 gives the reference lightning waveform and determination of lightning current parameters.

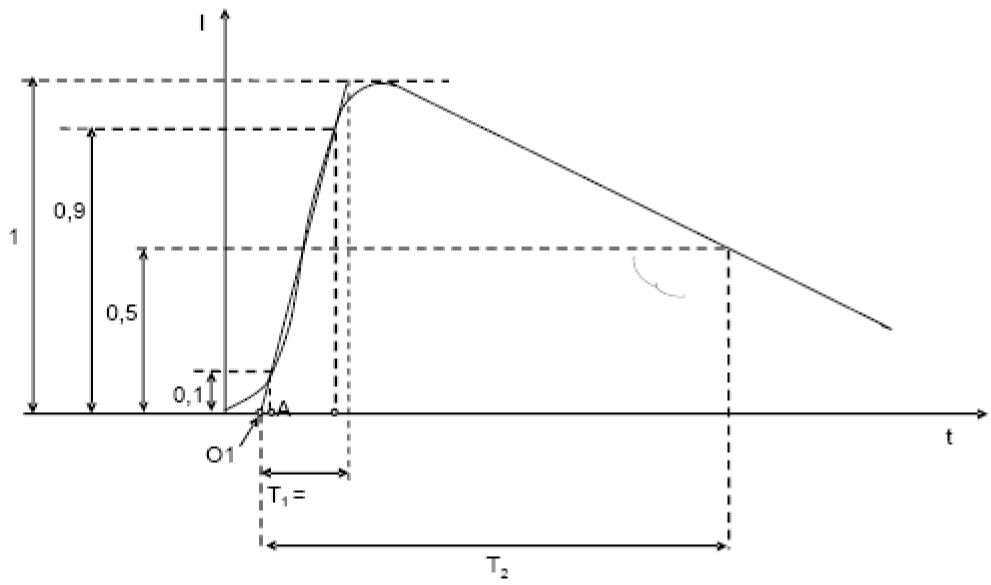


Figure 1 The reference lightning waveform

1.3.3. Impulse voltage

Impulse voltage includes characteristics as impulse current. Figure 2 gives the reference lightning voltage waveform and determination of impulse voltage parameters.

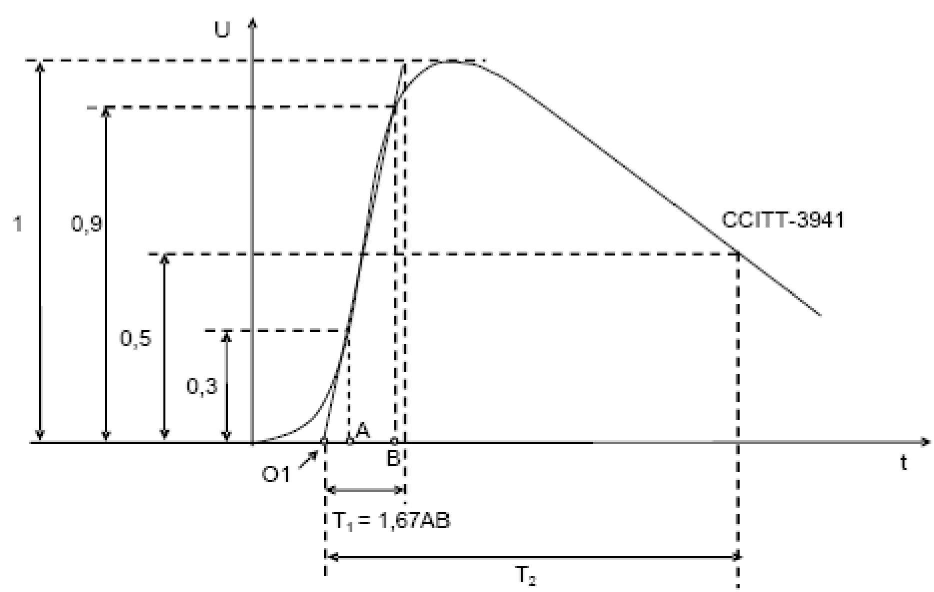


Figure 2- The reference lightning voltage waveform

1.3.4. Failure current

Failure current is minimum peak value of the lightning current which causes damage for telecommunication cable and has as consequence the interruption of service.

1.3.5. Sheath breakdown current

Sheath breakdown current is minimum current flowing in the metallic sheath which causes breakdown voltages between metallic elements inside the cable core and the metallic sheath, thus leading to primary failures.

1.3.6. Test current

Test current is the minimum current injected by arc in the cable metallic sheath that causes a primary failure due to thermal or mechanical effects.

1.3.7. Connection current

Connection current is the minimum current flowing in the interconnecting elements that causes a primary failure due to thermal or mechanical effects.

1.3.8. Breakdown voltage

Breakdown voltage is impulse breakdown voltage between metallic components in the core and the metallic sheath of the optical cable

1.3.9. Lightning density

Lightning density is the number of lightning flashes to the ground per square kilometre per year ($1km^2$).

1.3.10. Keraunic level

Keraunic level is the value of average thunder day per year, taking from the total thunder day in one working cycle of 12 years of the sun at one meteorological station

number of days per year in which thunder is heard in a given location.

1.3.11. Thunder day

Thunder day is the day in which thunder is heard

1.3.12. Lightning strike, flash

Lightning strike is electrical discharges on a massive scale between the atmosphere and an *earth-bound* object. They mostly originate in thunderclouds and *terminate* on the ground, called Cloud to Ground (CG) lightning. Telecommunication plants within the process of operation shall be affected by the lightning strike as follows:

- Due to direct lightning strike: is the effect of direct lightning strikes to telecommunication plant;

- Due to lightning strikes of discharging and induction: is the secondary effect of the lightning strikes due to static electricity, electromagnetic, galvanic…

1.3.13. Frequency of damage

Average annual number of service interruption on a telecommunication line cased by direct lightning discharges.

1.3.14. Surge Protective Device - SPD

Device that is intended to limit transient overvoltages and divert surge currents.

1.3.15. (Transfer coupling) impedance of metal cable sheath

Ratio of the peak values of the earth-termination voltage and the earth-termination current which, in general, do not occur simultaneously.

1.3.16. Lightning Protection Zone - LPZ

Zone where the lightning electromagnetic environment is defined.

1.3.17. Probability of damage

Probability of damage due to lightning flash is the probability of one time of lightning flash causing damage for telecommunication plant

1.3.18. Risk - R

Value of probable average annual loss (humans and goods) due to lightning, relative to the total value (humans and goods) of the object to be protected.

1.3.19. Tolerable risk - RT

Maximum value of risk which can be tolerated for the objects to be protected

1.3.20. Lightning Protection Level - LPL

Number related to a set of lightning current parameters values relevant to the associated maximum and minimum design values will not be exceeded in naturally occurring lightning.

1.3.21. Protection measures

Measures to be adopted in the object to be protected to reduce the risk.

1.3.22. Lightning Protection System - LPS.

Complete system used to reduce physical damage due to lightning flashes to a structure

1.3.23. External Lightning Protection System

Part of the LPS consisting of an air-termination system, a down -conductor and an earth-termination system.

1.3.24. Internal Lightning Protection System

Part of the LPS consisting of lightning equipotential bonding and/or electrical insulation of external LPS

1.3.25. Air-termination system

Part if an external LPS using metallic elements such as rods, mesh conductors or catenary wires intended to intercept lightning flashes.

1.3.26. Down-conductor system

Part of an external LPS intended to conduct lightning current from the air-termination system to the earth-termination system.

1.3.27. Earth-termination system

Part of an external LPS which is intended to conduct and disperse lightning current into the earth.

1.3.28. External conductive parts

Extended metal items entering or leaving the structure to be protected such as pipe works, cable metallic elements, metal ducts, etc. Which may carry a part of the lightning current.

1.3.29. Lightning equipotential bonding

Bonding to LPS of separated metallic parts, by direct conductive connections or via surge protective devices, to reduce potential differences caused by lightning current.

1.3.30. Shielding wire

Metallic wire sued to reduce physical damage due to lightning flashes to a service

1.3.31. LEMP Protection Measures System – LPMS

Complete system of protection measures for internal systems against LEMP

1.3.32. Telecommunication station

A area includes one or many stations which contain telecommunication equipment, antenna masts and its auxiliary equipments for providing telecommunication service. Telecommunication station do not include house and subscriber equipments.

1.3.33. Telecommunication plant

Telecommunication plant includes passive telecommunication technical infrastructure (house, station, column, sewer, tank) and network equipment which is fitted there.

1.3.34. Telecom building

Is the building where places telecommunication equipment system.

1.3.35. Abbreviates

SPD Surge Protective Device

LEMP Lightning Electromagnetic Impulse

LPZ Lightning Protection Zone

LPL Lightning Protection Level

LPMS LEMP Protection measures system

1.4 Management procedure of risk of damage due to lightning flash

Preparation of lightning protection measures for the telecommunication plant shall be defined through the following risk management procedure:

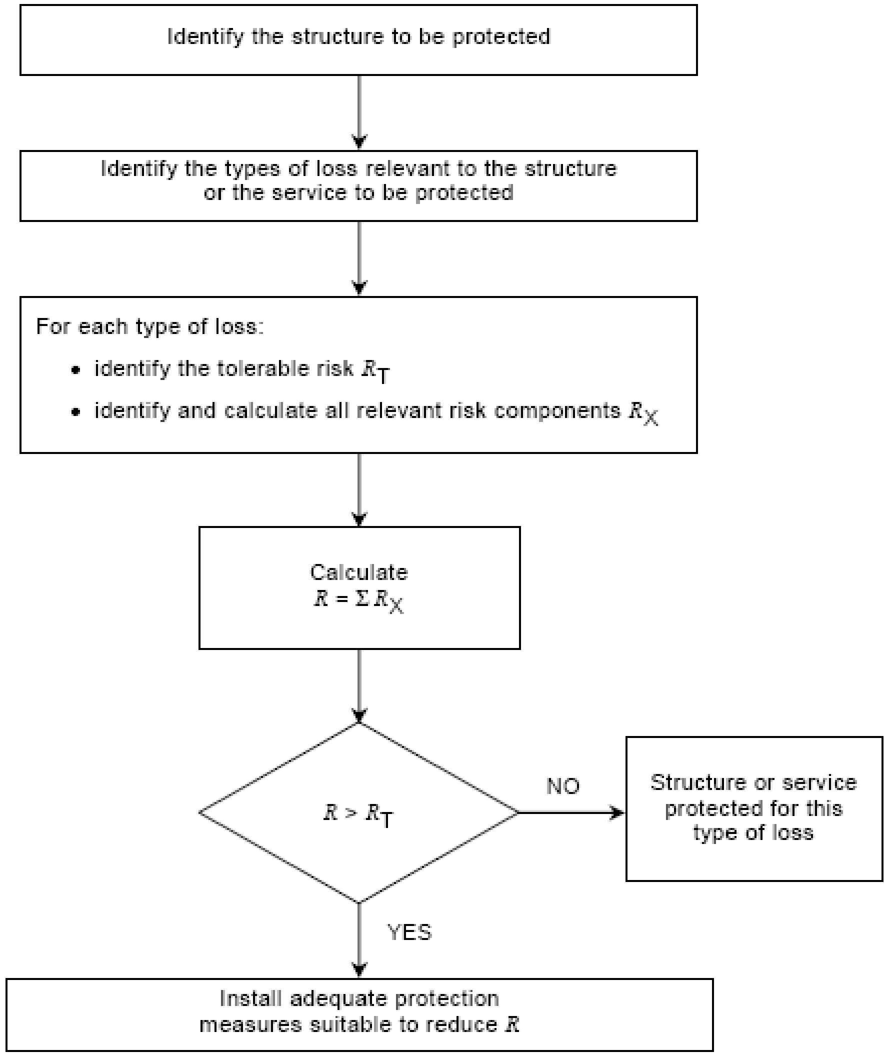


Figure 3 – Procedure for deciding the need of protection

1.5. Basic criteria for lightning protection

Protection measures, adopted in order to reduce the loss and damage, should be designed for a set of defined lightning current parameters, in which the protection is necessary to this strikes. (lightning protection level).

1.5.1. Lightning protection level

This national technical regulation regulates 4 levels of lightning protection. For each lightning protection level (LPL), a set of parameters is fixed.

The maximum values of lightning current parameters relevant to LPL 1 will not be exceeded, with a probability of 99%.

The maximum values of lightning current parameters relevant to LPL 1 are reduced to 75% for LPL II and to 50% for LPL III and IV.

Table 1- Values of lightning parameters corresponding to LPL

LPL	I	II	II	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 the different lightning protection levels are given in Table 1 and are used to design lightning protection components (e.g. cross-section of conductors, thickness of metal sheets, current capability of SPD, separation distance against dangerous sparkling).

The minimum values of lightning current amplitude for the different LPL are used to derive the rolling sphere radius in order to defined the lightning protection zone LPZ 0_B which can not be reached by direct strike (see 1.5.2 and Figure 4). The minimum values of lightning current parameters together with the rated rolling sphere radius are given in Table 2. They are used for positioning of the air-termination system and to define the lightning protection zones LPZ 0_B (see 1.5.2).

Table 2- The minimum values of lightning current and rolling sphere radius relevant to LPL

Criteria	LPL			
	I	II	III	IV
Minimum peak current, kA	3	5	10	16
Rolling sphere radius r, m	20	30	45	60

1.5.2. Lightning protection zone

Protection measures such as LPS, shielding wires, magnetic shields and SPD determine lightning protection zones (LPZ). LPZ downstream of the protection measure are characterized by significant reduction of LEMP than that upstream of the LPZ.

With respect to the threat of lightning, the following LPZs are defined:

LPZ 0_A- zone where the threat is due to the direct lightning flash and the full lightning electromagnetic field. The internal systems may be subjected to full or partial lightning surge current.

LPZ 0_B - zone protected against direct lightning flashes but where the threat is the full lightning electromagnetic field. The interval systems may be subjected to partial lightning surge current.

LPZ 1 - zone where the surge current is limited by current sharing and by SPDs at the boundary. Spatial shielding may attenuate the lightning electromagnetic field;

LPZ 2, …, n- zone where the surge current may be further limited by current sharing and by additional SPDs at the boundary. Additional spatial shielding may be used to further attenuate the lightning electromagnetic field.

Note 1: In general, the higher the number of an individual zone, the lower the electromagnetic environment parameters.

As a general rule for protection, the object to be protected shall be in a LPZ whose electromagnetic characteristics are compatible with the capability of the object to withstand stress causing the damage to be reduced (physical damage, failure of electrical and electronic systems due to overvoltages).

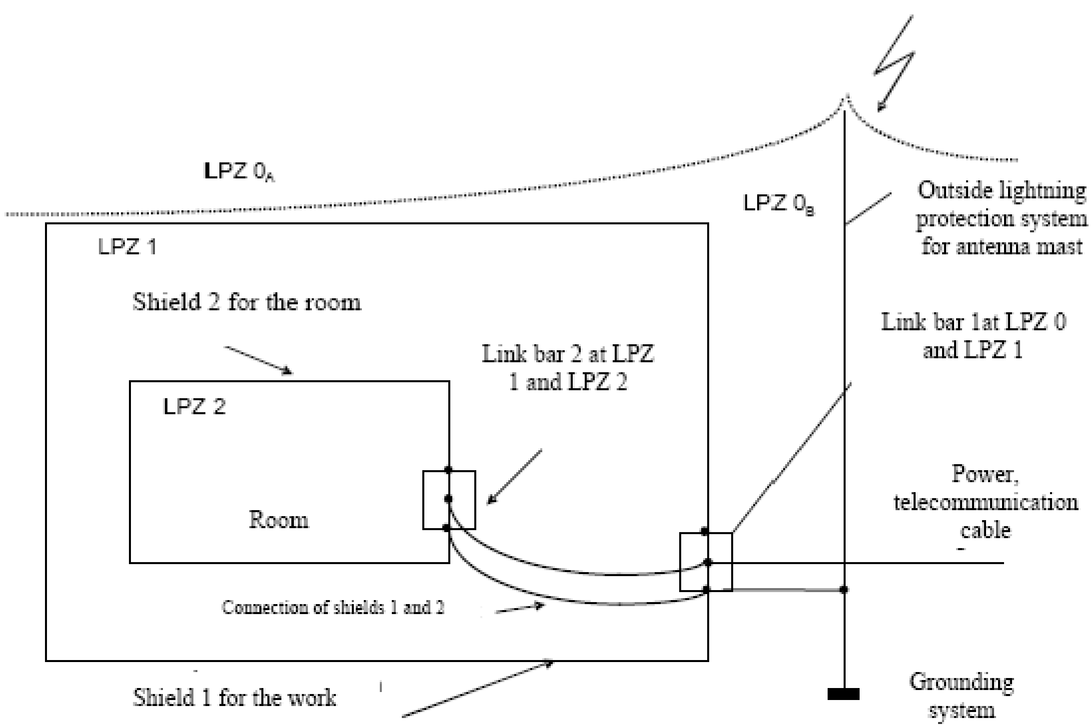


Figure 4- Illustration of LPZ at telecommunication station

2. Technical regulations

2.1. Requirement of risk due to lightning for telecommunication station

2.1.1 Requirement for telecommunication station

Telecommunication station shall be equipped with protection measures in such a way that the risk value should not exceed tolerable risk as follows:

Table 3- Values of tolerable risk for telecommunication station

Type of loss	**R_T (y^{-1})**
Loss of human life R_{injury}	10^{-5}
Loss of service R_{loss}	10^{-3}

2.1.2. Requirement for outside cable network

Outside cable network shall be equipped with protection measures in such a way that the risk value should not exceed tolerable risk as follows:

Table 4- Values of tolerable risk for outside cable network

Type of loss	**R_T (y^{-1})**
Loss of service R_{loss}	10^{-3}

Note: For outside cable network, loss of human life is not concerned.

Method of calculating risk due to lightning for telecommunication station and telecommunication lines is given in 2.2.

2.2 Method of calculating risk due to lightning

2.2.1 Calculation of risk due to lightning for telecommunication station

Risk due to lightning for telecommunication station shall be determined according to the following formula:

$$R_{injury} = L.p_{inj} \Sigma F_i \qquad (2.1)$$

$$R_{loss} = L \Sigma F_i \qquad (2.2)$$

Where:

- F_i- Frequency of damage due to lightning for telecommunication station because of direct lightning to the station, due to flash to adjacent antenna mast , to the ground near the structure, transmitting through lines to stations; defined as 2.2.1.1.

L: Weight of loss, expressing level of loss in a loss time due to due to lightning for telecommunication station.

- For loss risk of human life: L = 1;

- For loss risk of service: $L = 2.74 \times 10^{-3}$.

p_{inj} : probability reducing the loss of human life due to protection measures in Table 8 and Table 9.

2.2.1.1. Calculation of frequency of damage due to lightning for the areas near the telecommunication station

Frequency of damage (F) at a telecommunication station with lightning density of the area of this station (N_g) with concern of effectiveness of the existing and supplementary protection measures, defined as follows:

$$F = N_g (A_d.p_d + A_n.p_n + A_s.p_s + A_a.p_a) \quad (2.3)$$

Or

$$F = F_d + F_n + F_s + F_a \quad (2.4)$$

Where:

N_g - density of lightning at the area of the station, defined according to geographical regions, see D1, Annex D.

p: Different probability factors depending on the existing protection measures in order to reduce the frequency of damage (F), see 2.1.1.2.;

$F_d = N_g . A_d . p_d$ - frequency of damage due to direct lightning to the station (d);

$F_n = N_g . A_n . p_n$ - frequency of damage due to lightning to the ground nearby the station (n);

$F_s = N_g . A_s . p_s$ - frequency of damage due to lightning to cable or adjacent area of cable to the station (s);

$F_d = N_g . A_d . p_d$ - frequency of damage due to direct lightning to adjacent objects, e.g. antenna masts with metallic connection to the station (a).

A_d - Risk area due to direct lightning to the station:

$A_d = (9\pi h^2 + 6ah + 6bh + ab). 10^{-6}$, km^2 (2.5)

Where:

a: Width of telecommunication station, m;

b: Length of telecommunication station, m;

h: Height of telecommunication station, m.

In case of that area of risk due to direct lightning to the antenna masts which partially covers a part of area of risk due to direct lightning to the station, A_d is reduced by this cover.

A_n - Risk area due to lightning to ground nearby the station affecting the telecommunication centre. A_n is formed by a line at a distance d = 500 m from the building minus the risk area for direct impacts, A_d . Where adjacent objects like high structures (eg. antenna masts, high buildings) and incoming cables are present, the area A_n is further reduced by the area of these works, see Figure 5.

A_s - Risk area for direct strikes to the network (information, power). Generally, incoming cables are present including aerial and underground cables, the area of A_s is defined as follows:

$$A_s = 2.\sum_{i=1}^{n} l_i d_i \qquad (2.6)$$

Where:

l_i - length of each cable, m;

d_i - corresponding distance of each cable, m;

- For aerial cable, d_i = 1000m;

- For underground cable, d_i = 250m;

n: number of aerial and underground cables;

A_a : Risk area for direct strikes to an antenna mast with metallic connection to the centre.

- For antenna masts in tower shape, A_a is calculated as A_d

- For antenna masts being round pillar, rectangular pillar, quadrangular pillar with small dimension, A_a is defined as area of the round of radius 3h (h is height of antenna mast) $A_a = \pi\,(3h)^2$.

Risk areas due to lightning to telecommunication station are given in Figure 5.

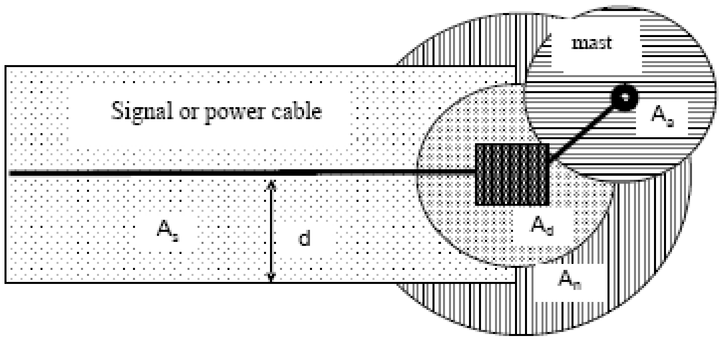


Figure 5- Description of risk area for lightning discharges to the telecommunication station

2.2.1.2 Estimation of probability factor p

Every factor p can be divided into one representing the natural protective characteristics of the installation (building material, aerial or underground network) and another depending on the specific protective measures provided at the building or cabinet interface and such installed in the internal and external network (surge protective devices, cable shields and isolation techniques…). In the design of lightning protection, where one measure is taken, damage probability due to corresponding strike can be reduced, expressing through the factor p.

Where several measures are taken, the effective probability factor may be given by the product of the particular values:

$p_{tt} = \Pi\, p_i$, $(p_i \leq 1)$.

Values of probability factors are given in Tables 5 to 9.

Table 5 – Values of p for different building materials

Building materials	p_d , p_a, p_n
Non-screening (wood, bricks, concrete without steel reinforcement)	1
Steel reinforced concrete with a standard mesh size	0.1
Metal container	0.01

Table 6 – Values of p for specific protective measures on the building

Specific external protective measures of the building	p_d, p_{inj}
No external or internal lightning protection	1
External lightning protection (according to 2.3.1.1)	0.1

Table 7 – Values of p for protective measures on incoming cables

Protective measures against conducted lightning transients	**p p**
Unshielded external cables without SPDs	1
Shielded external communication cables with maximum transfer impedance 20Ω/km (according to requirement of 2.3.1.2)	0.5
Shielded external communication cables with maximum transfer impedance 5Ω/km (according to requirement of 2.3.1.2)	0.1
Shielded external communication cables with maximum transfer impedance 1Ω/km (according to requirement of 2.3.1.2)	0.01
Isolation transformers at the low-voltage network interface, (breakdown voltage 20 kV) (according to requirement of 2.3.1.2)	0.1
Selected SPDs, good coordination with equipment resistibility, qualified installation technique(according to requirement of 2.3.1.2)	0.01
Metal-free opto cables (according to requirement of 2.3.1.2)	0

Table 8 – Values of p for specific protective measures inside the building

Separate protective measures internal to the building	p_d, p_a, p_n, p_{inj}
Implementation of ends and earthing configures according to TCN 68-141:1999 (according to part a) of 2.3.1.3)	0.5
Application of internal installation techniques (according to part b and c) of 2.3.1.3)	0.1

Table 9 – Values of p for different surface layers to mitigate step and touch voltages

Type of surface	p_{inj}
Wet concrete, humus	10^{-2}
Dry concrete	10^{-3}
Asphalt, wood	10^{-5}
Insulation layer with material of high breakdown voltage	10^{-6}

2.2.2. Calculation of risk due to lightning for outside cable network

Generally, cable network (metal cable or metal opto cable) includes aerial and underground sections. Risk of damage (R) need to be concerned is the annual risk of service loss due to direct lightning. Risk of damage is defined as follows:

$$R = F_{pa} \, . \, L_a + F_{pb} . \, L_b + F_{ps} . L_s \qquad (2.6)$$

Where:

F_{pa} is the frequency of damage for aerial cables;

F_{pb} is the frequency of damage for buried cables;

F_{ps} is the frequency of damage due to direct lightning discharges to structures that the cable enters;

L_a is the expected loss per damage due to direct lightning discharges to aerial cables;

L_b is the expected loss per damage due to direct lightning discharges to buried cables;

L_s is the expected loss per damage due to direct lightning discharges to structures that the cable enters.

- For metal cable network:

$L_a = 2 \times 10^{-3}$;

$L_b = 3 \times 10^{-3}$;

$L_s = 2 \times 10^{-3}$;

- For opto cable network:

$L_a = L_b = L_s = 10^{-3}$;

2.2.2.1. The frequency of damage for aerial and buried cables

The frequency of damage for aerial and buried cables can be calculated by the following equations:

$F_{pa} = 2 \times N_g \times k\,[L-3(H_a + H_b)] \times D \times p\,(l_a) \times C_d \times 10^{-6}$, (damages/year) (2.7)

$F_{pb} = 2 \times N_g \times k\,[L-3(H_a + H_b)] \times D \times p\,(l_a) \times C_d \times K_d \times 10^{-6}$, (damages/year) (2.8)

Where:

L is the line length (m);

H_a is the height of the structure connected at the end "a" of the line, (m);

H_b is the height of the structure connected at the end "b" of the line, (m);

$p(I_a)$ is the current probability factor, defined as follows:

$p(i) = 10^{-2}\, e^{(a-bi)}$ with $i \geq 0$

a = 4,605 and b = 0,0117 with $i \leq 20$ kA

a =5,063 and b = 0,0346 with $i > 20$ kA

C_d is the location factor;

C_d = 0.25 for an aerial line or structure surrounded by structures of same height structures greater height (power lines, trees, etc.);

C_d = 0.50 for aerial line or structure surrounded by smaller height structures;

C_d = 1,0 for isolated aerial line or structure (no other objects in the vicinity);

C_d = 2.0 for a line or structure on a hilltop or a knoll.

N_g is the lightning ground flash density [$km^{-2}.year^{-1}$] (see Annex D);

D is the striking distance (m);

- For buried cable:

$D = 0{,}482\ (\rho)^{1/2}$ for $\rho \leq 100\ \Omega.m$;

$D = 2{,}91 + 0{,}191\ (\rho)^{1/2}$ for $100\ \Omega.m < \rho \leq 1000\ \Omega.m$;

$D = 0{,}283\ (\rho)^{1/2}$ for $\rho > 1000\ \Omega.m$;

- For aerial cable:

D = 3 H, (m); H line height , which shall be between 4 m and 15 m;

I_a is the failure current, (kA) (see Annex B.1);

K_d is the damage correction factor

K_d = 2.5 for unshielded buried cable;

K_d = 1,0 for shielded buried cable;

2.2.2.2. Frequency of damage due to lightning for structures that the cable enters (F_{ps})

Frequency of damage due to lightning for structures that the cable enters shall be defined as follows:

$$F_{ps} = N_g \,.\, A_d.p(la).C_d \text{ (damages/year)} \qquad (2.9)$$

Where:

A_d is the collection area for direct lightning strikes to the structure, can be calculated by equation:

$A_d = (9\pi h^2 + 6ah + 6bh + ab)\ 10^{-6}$, ($km^2$);

Where:

a = length [m]

b = width [m]

c = height [m]

$p(l_a)$: the failure current probability

l_a - the failure current, see Annex B.2.

2.3 Lightning protection measures for the telecommunication works

2.3.1. Lightning protection measures for the telecommunication stations

To reduce the risk of damage to the tolerable level given in 2.2.1, some or all protection measures shall be applied:

2.3.1.1 External lightning protection system (protecting from direct lightning)

External lightning protection system (protecting from direct lightning) shall include the following main components:

- Air-termination system;

- Conductor system;

- Earthing system;

- Support system.

a) Air-termination system

- Air-terminations should be arranged, designed in such a way that it provides the zones of protection that the structure is entirely protected. The positioning is defined by the following methods:

+ the protection angle method; suitable for simple structures with limited height

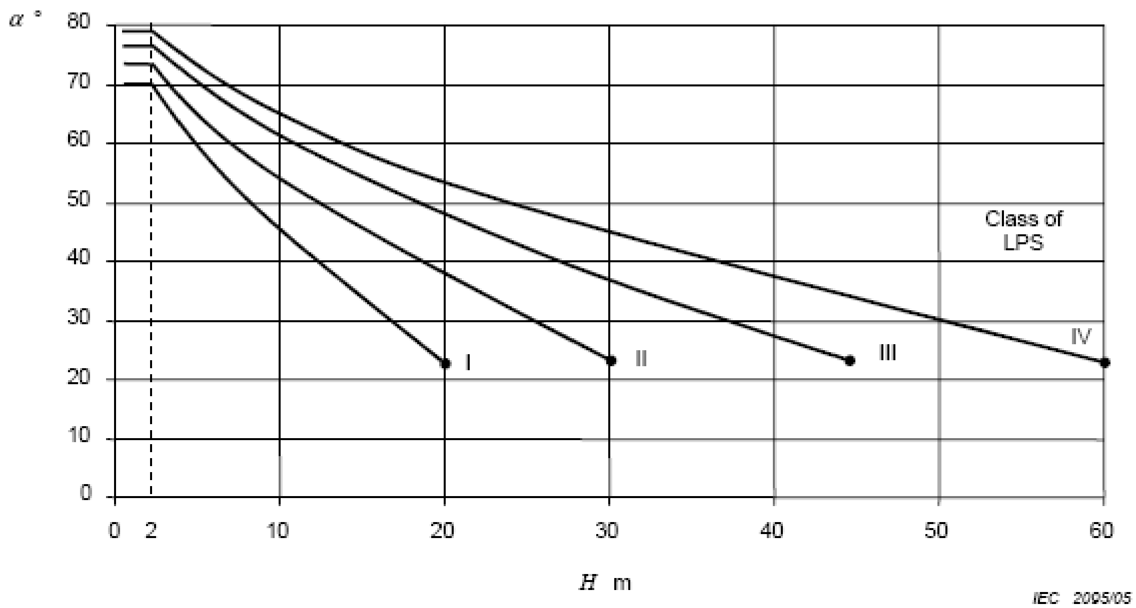
+ the rolling sphere method; suitable for all cases;

+ the mesh method, suitable for the protection of plane surfaces.

Details of these above methods are given in Annex A. Value of protection angle, radius of rolling sphere, mesh size for each class of LPS is given in Table 10.

Table 10- Maximum values of rolling sphere radius, mesh size and protection angle corresponding to the class of LPS

Class of LPS	Protection method		
	Rolling sphere radius r, m	Mesh size W, m	Protection angle α^o
I	20	5 x 5	See Figure 6
II	30	10 x 10	
III	45	15 x 15	
IV	60	20 x 20	



NOTE:

1- Not applicable beyond the values marked with •

2- H is the height of air-termination above the reference plane of the area to be protected.

3- The angle will not change for values of H below 2m.

Figure 6- Protection angle corresponding to the class of LPS

- Air-terminations can be composed of the following elements: rods, wire, mesh and its combination.

- Metallic components of the works such as metallic sheet for covering protected zones, metallic elements of roofs, pipes, metallic tanks can be used as "natural" air-terminations, provided that they satisfy the following conditions:

+ with sustainable and constant conductivity;

+ not covered by electrical insulating materials;

+ not causing dangerous cases when being pierced or hot-rolled due to lightning.

- Air-terminations can include support structure which itself is the objects to be protected; If using column support structure, it should be made by a material that assures mechanical durability, suitable for climate conditions.

b) Conductor system

- The lightning conductors must be distributed around the perimeter of the protected construction so that distance between two conductors do not exceed 30 m. In all cases, at least two down conductors

- The lightning conductors must be connected to the earth - termination system.

- The lightning conductors must be installed vertically so that the ground path is the shortest and straightest and doesn’t create loop circuit. Don’t allow to install the lightning conductors in the dangerous place for humans.

c) Grounding System

- Grounding system including the electrodes, wires and earth cables

- Design of grounding system and earthing resistance value in accordance with regulation in QCVN 9:2010/BTTTT, National technical regulation on earthing of telecommunication stations

- Form of earth – termination and layout diagram of electrodes must be selected to match actual terrain where equipped grounding

- Earth –termination system must be linked with the other grounding systems (if any) according to regulation in QCVN 9:2010/BTTTT, National technical regulation on earthing of telecommunication stations

d) Material

Material and its size that selected to make the direct lighting protection system must ensure so that the system is not damaged because of electromagnetic and electric effect of the lighting current and effects of erosion and other mechanical forces.

e) The air terminations, the lighting conductors must be fixed and linked together certainly, not broken, loose due to the electromotive force or the other mechanical forces. The joints must be secured by welding methods, screw, bolt and their amount must be as small as possible.

2.3.1.2 Lighting Protection from outside the building

The electronic devices inside the telecommunication building can be damaged by the lightning and induction via the communication lines, metallic power line into the building. To limit the influences, it is necessary to apply the following measures:

a) Protection measures for communication lines into the station

- Selecting telecommunications cables into and out of the building with the sheath with low transfer impedance or optical cable without metallic components, the cable sheath must be the lightning equipotential bonding according to regulation in QCVN 9:2010/BTTTT, National technical regulation on earthing of telecommunication stations

- The surge protective devices (SPD) are installed on the communication line at interface of wire – machine according to regulation in TCVN 8071:2009, Telecommunication plant – Code of practice for lightning protection and earthing

b) Protection measures for power line into the station

- The surge protective devices are installed on the power line where transmission line into the station according to regulation in TCVN 8071:2009, Telecommunication plant – Code of practice for lightning protection and earthing

- Using separate low voltage transformer to provide power to the building.

2.3.1.3. Interior LPS system (Lighting protection and induction inside the building

a) Lightning equipotential bonding

Making the lightning equipotential bonding at the boundary between the lightning protection zones (LPZ) for the parts and metallic systems (metallic conductors, cable racks, equipment racks)

b) Implementing shielding measures inside the building

- Linking the metallic components of the buildings to each other and the direct lightning protection system, for example roofs, metallic surfaces, reinforcement and metallic frames of the buildings.

- Using the metallic cable sheath or conducting cable in metal ducts with low impedance.

Sheath or metal ducts must be the lightning equipotential bonding at both ends and at the boundary between lightning protection zones (LPZ). Cable conductors must be divided into two sections by metallic partitions, one part contains the communications cable, one part contains the power cable and bonding wire.

c) Making connection configuration and grounding in the telecommunication building

It is necessary to make the regulation on connection configuration and grounding inside the telecommunication station according to QCVN 9:2010/BTTTT, National technical regulation on earthing of telecommunication stations.

2.3.2. Lightning protection measures for outside cable network

2.3.2.1. General principles

The metallic components of the cable must be continuous throughout the length of the cable, which means they must be connected through all sleeves, regenerators ... The metallic components must be connected (directly or via SPD) with the lightning equipotential bonding bar at cable top.

Application of protection measures of telecommunications lines will reduce the frequency of damage due to the lighting, is expressed by protective factor (K_p) as follows:

$$F'_d = F_d . K_p \qquad (2.10)$$

In which:

F'_d is the frequency of damage after applying the protection measure

F_d is the frequency of damage before applying the protection measure.

Many protection measures will reduce the frequency of damage by increasing the failure current. In this case, the protective factor is calculated by the formula:

$$K_p = \exp [b_1 (I_a - I_a ')] \quad \text{with } I_a \text{ and } I_a' \leq 20 \text{ kA} \qquad (2.11)$$

$$K_p = \exp [b_2 (I_a - I_a ')] \quad \text{with } I_a \text{ and } I_a' > 20 \text{ kA}$$

$$K_p = \exp [(a_2 - a_1) + (b_1 I_a - b_2 I_a ') \quad \text{with } I_a \leq 20 \text{ kA and } I_a' > 20 \text{ kA}$$

In which:

I_a is the failure current before applying the protection measure;

I_a ' is the failure current after applying of the protection measure

$a_1 = 4.605$

$a_2 = 5.063$

$b_1 = 0.0117$

$b_2 = 0.0346$.

2.3.2.2 Direct lighting protection measures on cable

a) For buried cables, it should be applied the following protection measures:

- Using shielding wire, often be galvanized wire;

- Using steel pipe, often be galvanized steel pipe

b) For hanger cable, it should be applied the following protection measures:

- Using support wire as shielding wire (see section a), Section 2.3.2.3);

- Replace with buried cable route and applying the protection measures under a).

c) For both the hanger cable and the buried cable, it should be applied the following measures:

- Replace with optical cable without metallic components or radio transmission line (see part a), Section 2.3.2.3);

- Using cable with big sheath breakdown current (see section b), Section 2.3.2.3);

- Using cable with big sheath breakdown voltage (see section c), Section 2.3.2.3).

2.3.2.3 Cable selection

a) Optical fiber cable without metallic components

Optical cable without metallic components will not be directly stroked by lightning, so using the optical cable with non-metallic then $K_p = 0$.

b) Cable with big sheath breakdown current

If the failure current (I_a) is determined by the sheath breakdown current (I_s), cable with bigger sheath breakdown current can selected as follows:

- Increasing the sheath breakdown voltage by selecting plastic insulating material instead of paper or increasing the insulation in the joints;

- Reducing the resistance of sheath by using thicker metallic sheath

Protective factor achieved by increasing the failure current is calculated according to the formula 2.11.

c) Cable with big breakdown voltage

If the failure current is determined by the test current (I_t), cable with higher test current is selected as follows:

- Using sheath with high mechanical strength (eg iron);

- Using thicker metal sheath

Protective factor achieved by increasing the failure current is calculated according to the formula 2.11.

2.3.2.4 Using surge protective devices SPD

SPD can be installed at the point which can be stroked directly by lightning in the line into the building, to reduce the frequency of damage due to lightning strike into buildings (F_{ps}). SPD must be connected between the fibers of the cable to the lightning equipotential bonding bar of the building

The installation of SPD will increase the breakdown current of cable sheath I_s (see Appendix B.3)

Protective factor achieved by increasing the failure current is calculated according to the formula 2.11 and B.4 (Appendix B).

2.3.2.5. Equipping the underground lightning conductor for buried cables

To reduce the lighting current strike on the buried cables, using metallic underground lightning conductor buried above, along the cable to attract a part of lightning current. Thus, the underground lightning conductor will increase the failure current (I_a) and reduce the frequency of damage. The underground lighting conductor must be arranged along the entire length of the protected cable and extended for a section Y, Y is calculated according to formula:

$Y \geq 2.5\ (\rho)^{1/2}$, (m) (2.12)

In which:

ρ = Soil resistivity, Ω.m

New failure current value (I'_a) is calculated according to formula:

$I'_a = I_a / \eta$, (kA) (2.13)

In which, η is the screen factor, see Annex C.

3. MANAGEMENT REGULATIONS

The telecommunication station and outside cable network of business which set up telecommunication network infrastructure should comply with the requirements specified in this regulation.

4. RESPONSIBILITIES OF ORGANIZATIONS, INDIVIDUALS

4.1. Businesses set up telecommunication network infrastructure with the telecommunications station and outside cable network in shall ensure that the communication station and outside cable network in accordance with the regulation on design, installation, operation and maintenance.

4.2. Businesses set up telecommunication infrastructure with the telecommunications building and outside cable network shall be published regulation conformity the according to the regulations and guidance of the Ministry of Information and Communications, and it is necessary to inspect regularly and irregularly by state management under the current regulations.

5. IMPLEMENTATION ORGANIZATION

5.1. Quality Management Department of Information Technology and communication and Department of Information and communication have responsibility for instruction, organization management of telecommunication station and outside cable network in accordance with this Regulation

5.2. This Regulation is replaced for Standard TCN 68-135:2001, "Lightning protection of telecommunication buildings – Technical requirements”

5.3. In case there are any modifications, supplementations or replacements for regulation shown in this Regulation, the regulation in new version shall be applied.

Annex A

(Normative)

Positioning the air-termination system

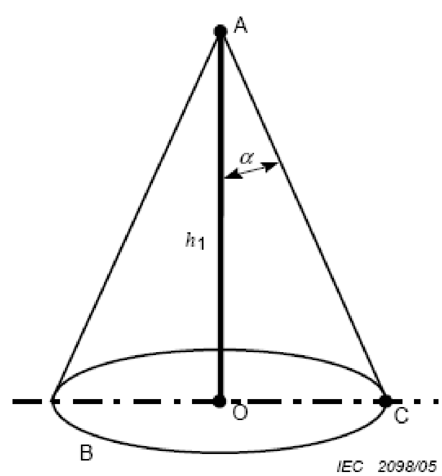
A.1. Positioning the air-termination system when utilizing the protective angle method

The position of the air-termination system is considered to be adequate if the structure to be protected is fully situated within the protected volume provided by the air-termination system.

For the determination of the volume protected only the real physical dimensions of the metal air-termination systems shall be considered.

A.1.1 Volume protected by a vertical rod air-termination system.

The volume protected by a vertical rod is assumed to have the shape pf a right circular cone with the vertex placed on the air-termination axis, semi-apex angle α, depending on the class of LPS, and on the height of the air-termination system as given in Table 10. Examples of the protected volume are given in Figures A.1 and A.2.



Key

A tip of an air-termination rod

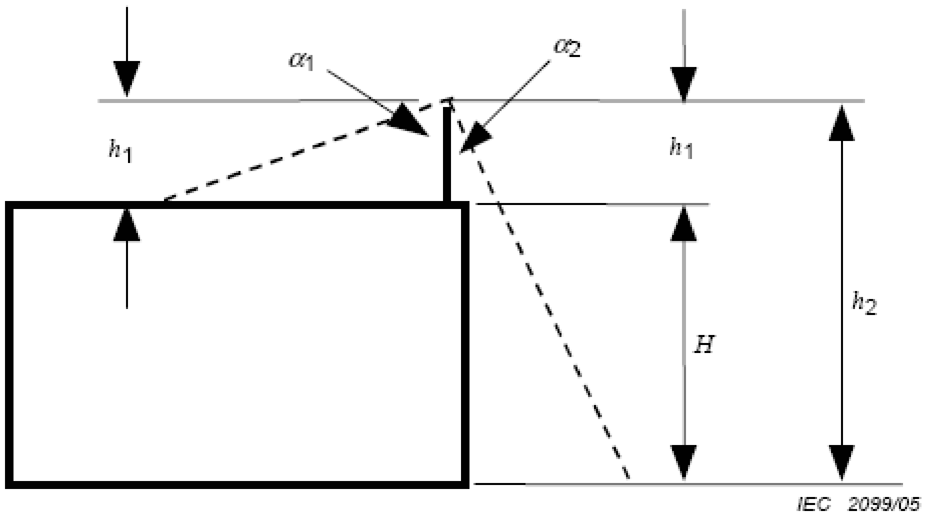
B reference plane

OC radius of protected area

h_1 height of an air-termination rod above the reference plane of the area to be protected

α protective angle according to Table 10

Figure A.1 – Volume protected by a vertical air-termination rod

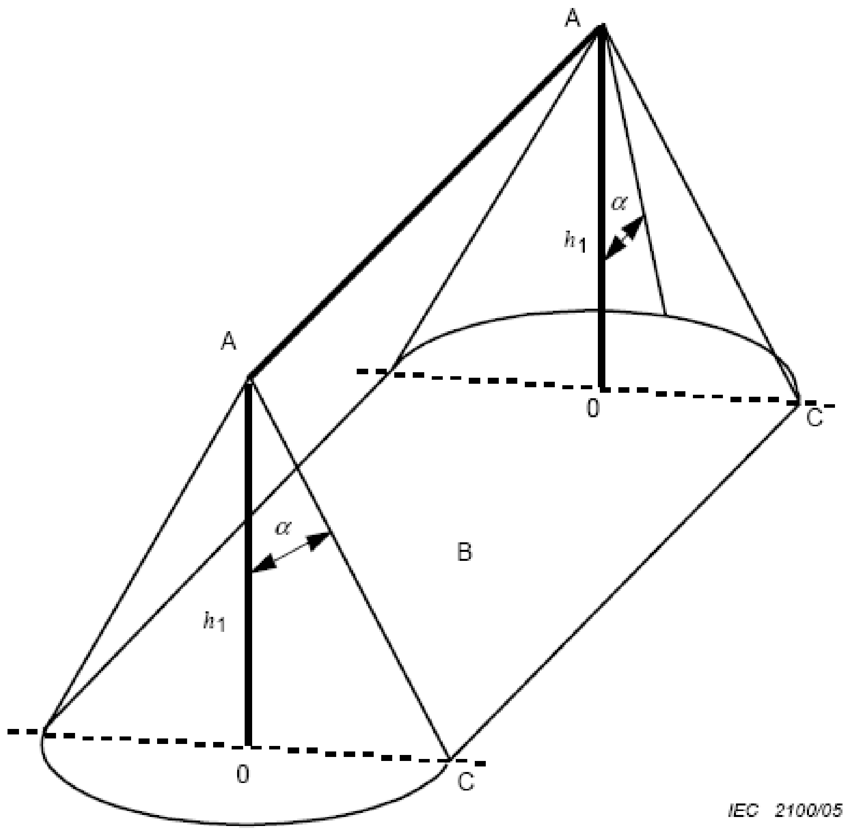


Note: Protective angle α_1 corresponds to the air-termination height h_1, being the height above the roof surface to be protected; protective angle α_2 corresponds to the height $h_2 = h_1 + H$, the ground being the reference plane.

Figure A.2- Volume protected by a vertical air-termination rod

A.1.2 Volume protected by a wire air-termination system

The volume protected by a wire is defined by the composition of the volume protected by virtual vertical rods having vertexes on the wire. Examples of the protected volume are given in Figure A.3.



NOTE See Figure A.1 for key.

Figure A.3- Volume protected by a wire air-termination system

A.1.3. Volume protected by wires combined in a mesh

The volume protected by wires combines in a mesh is defined by a combination of the protected volume determined by the single conductors forming the mesh.

Examples of the volume protected by wires combines in a mesh is given in Figures A.4 and A.5.

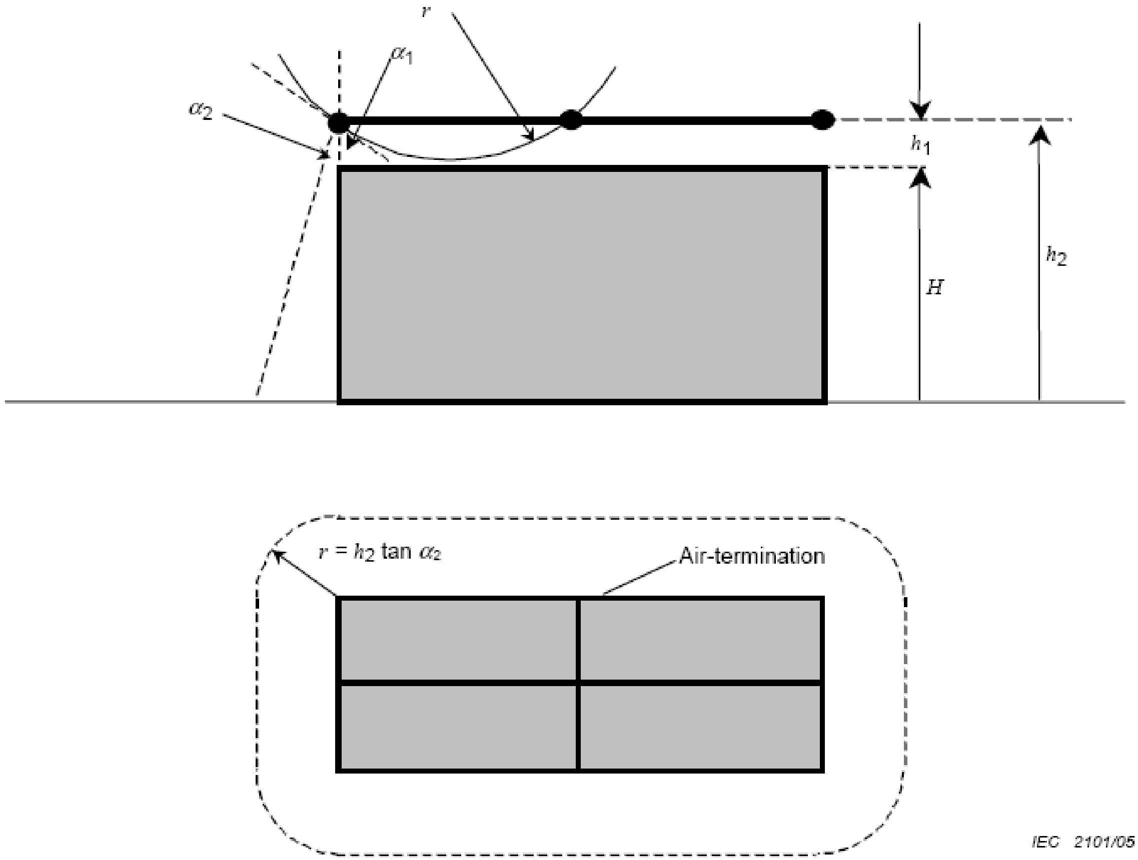
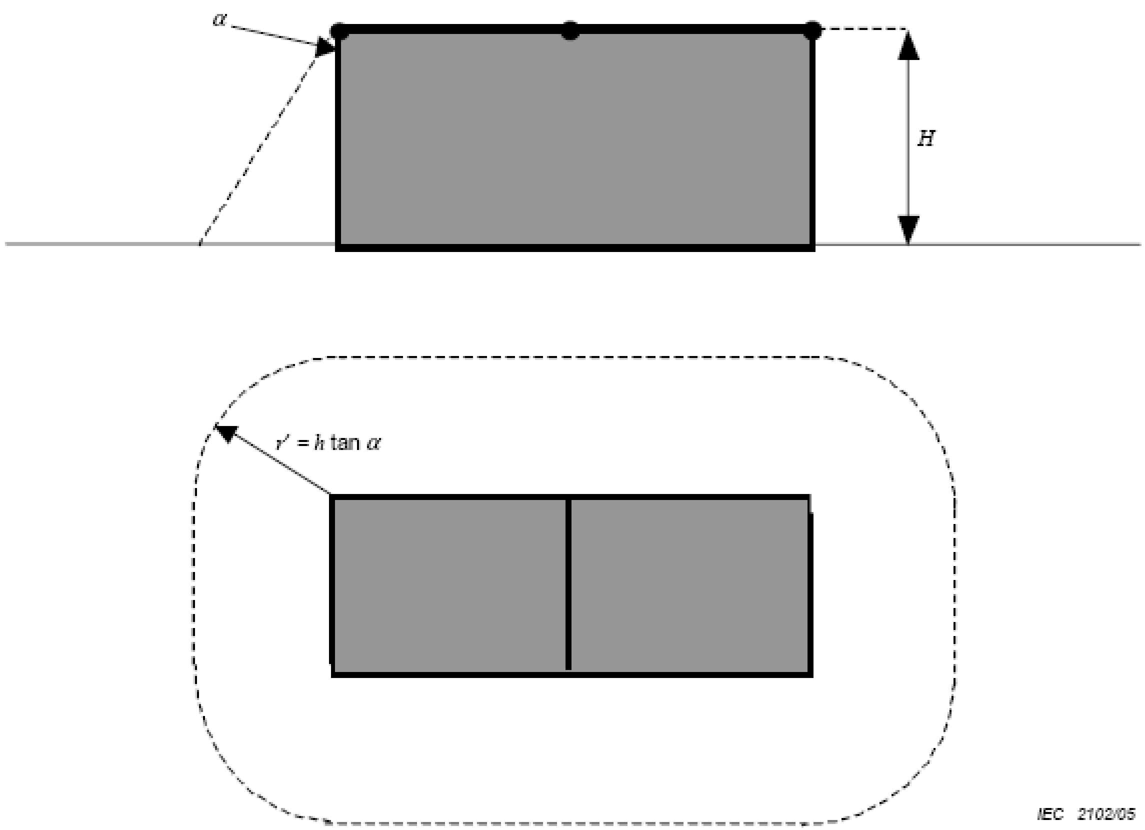


Figure A.4 – Volume protected by isolated wires combined in a mesh according to the protective angle method and rolling sphere method

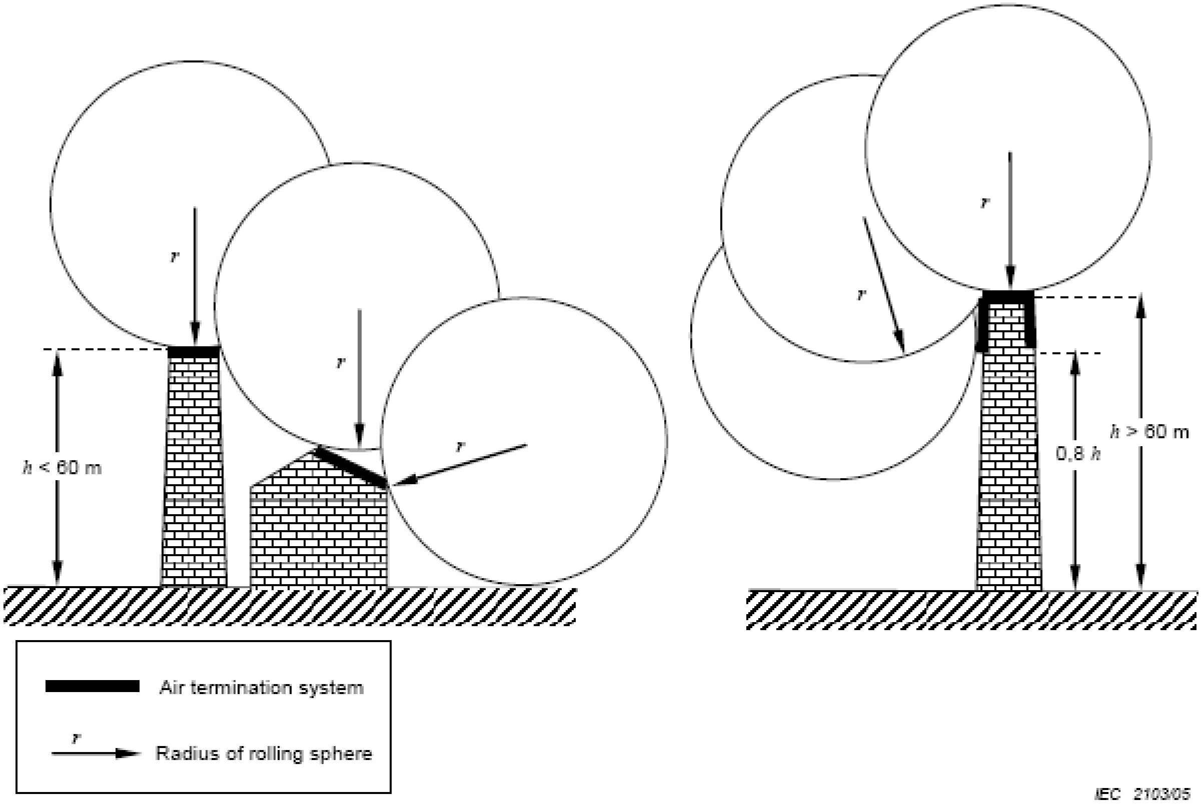


NOTE $H = h$.

Figure A.5 – Volume protected by non-isolated wires combined in a mesh according to the mesh method and the protective angle method

A.2 Positioning of the air-termination system utilizing the rolling sphere

Applying this method, the positioning of the air-termination system is adequate if no point of the structure to be protected comes into contact with a sphere with radius, r, depending on the class of LPS (see Table 10), rolling around and on the top of the structure in all possible directions. In this way, the sphere only touches the air-termination system (See figure A.6).



NOTE 1 The rolling sphere radius r should comply with the selected class of LPS (see Table 2).

NOTE 2 $H = h$.

Figure A.6 – Design of an air-termination system according to the rolling sphere method

On all structures higher than the rolling sphere radius r, flashes to the side of structure may occur. Each lateral point of the structure touched by the rolling sphere is a possible point of strike. However, the probability for flashes to the sides is generally negligible for structures lower than 60 m.

For taller structures, the major part of all flashes will hit the top, horizontal leading edges and corners of the structure. Only a few percent of all flashes will be to the side of the structure.

Moreover, observation data show that the probability of flashes to the sides decreases rapidly as the height of the point of strike on tall structures when measured from the ground. Therefore consideration should be given to install a lateral air-termination system on the upper part of tall structures (typically the top 20% of the height of the structure). In this case the rolling sphere method will be applied only to the positioning of the air-termination system of the upper part of the structure.

A.3. Positioning of the air-termination system utilizing the mesh method

For the purpose of protecting flat surfaces, a mesh method is considered to protect the whole surface, dependent upon all of the following conditions being fulfilled:

a) Air-termination conductors are positioned:

- on roof edge lines;

- on roof overhangs;

- on roof ridge lines, if the slope of the roof exceeds 1/10.

Note:

- The mesh method is suitable for horizontal and inclined roofs with no curvature.

- The mesh method is suitable for flat lateral surfaces to protect against side flashes.

- If the slope of the roof exceeds 1/10, parallel air-termination conductors, instead of as mesh, may be used provided the distance between the wires is not greater than the required mesh width.

b) The mesh dimensions of the air-termination network are not greater than the values given in Table 10.

c) The network of the air-termination system is constructed in such a way that the lightning current will always encounter at least two distinct metal routes to each termination.

d) No metal installation protrudes outside the volume protected by air-termination systems.

e) The air-termination conductors follow, as far as possible, the shortest and most direct route.

Annex B
(Normative)

Determination of breakdown current for metal cable and optical fibre cable with metal components

B.1 Determination of breakdown current for buried and aerial cable due to direct lightning

B.1.1 Breakdown current for metal cable

Breakdown current for metal cable, I_a shall be determined as follows:

$$I_a = \begin{cases} I_t \text{ if } I_t < 2I_s \\ 2\,I_s \text{ if } I_t > 2I_s \end{cases} \quad \text{(B.1)}$$

Where:

I_t : test current;

I_s : sheath breakdown current (see Annex B.3);

B.1.2. Breakdown current for optical fibre cable with metal components

Breakdown current for optical fibre cable with metal components, I_a shall be determined as follows:

$$l_a = \begin{cases} l_t \text{ if } l_t < 2l_c \, and l_t < 2l_s \\ 2\,l_c \text{ if } 2l_c < l_t and 2l_c < 2l_s \\ 2l_s \text{ if } 2l_s < l_t and 2l_s < 2l_c \end{cases} \quad \text{(B.2)}$$

Where:

$l_{t:}$ test current;

l_c : joint current

l_s : sheath breakdown current (optical fibre cable where metal is present in the sheath and in the core (see Annex B.3).

Note:

The value I_s is concerned in optical fibre cable where metal is present in the sheath and in the core.

The value l_t, l_c is defined at the laboratories and may be provided by the producer.

B.2. Determination of breakdown current, l_a for cable entering into structures being lightened

When the lightning directly strikes the structure where the cable enters, causing damage for cable, breakdown current, l_a is defined with the following assumptions:

- 50% lightning current strikes earthing system of the works;

- the rest ratio shall be divided among n service lines entering into the works (telecommunication lines, power line, water conductor);

- The total lightning current through telecommunication lines shall flow into the shielded sheath of the cable or shall be divided among m fibres of cable without sheath.

For the lightning striking to the works where the telecommunication line enters, breakdown current can be defined as follows:

- For shielded cable:

$l_a = 2.n.l_s$ (B.3)

- For unshielded metal cable:

$l_a = 2.n.m.l_c$ (B.4)

Where:

l_s is sheath breakdown current, defined in accordance with B.3;

l_c is the current flowing into each fibre:

+ For unshielded cable, without SPD, $l_c = 0$

+ For unshielded cable, with SPD, $l_c = 8.S_c$; (KA)

Where, S_c is the horizontal section of the conductor, by mm^2.

- For optical fibre cable

$$l_a = \begin{cases} 2.n.l_s \text{ if } l_s < l_c \\ 2.n.l_c \text{ if } l_c < l_s \end{cases} \qquad (B.5)$$

Where:

n - Number of conductor and metal cable entering into the structure (telecommunication, power, water…);

B.3. Determination of sheath breakdown current, l_s

Formula for sheath breakdown current in this annex is applied to cable with one metal layer. For common telecommunication cables, the following breakdown voltage values are considered:

- Cable with paper insulation layer: U_b = 1,5 kV
- Cable with plastic insulation layer: U_b = 5 kV

B.3.1. Sheath breakdown current of buried cable

The sheath breakdown current of buried cable or optical fibre cable with metal elements in the sheath and in the core may be estimated from the following equation:

$I_s = U_b/(K.R.\rho^{1/2})$, kA; (B.4)

Where:

K= 8 is the waveshape factor for lightning current (10/350 μs waveform), $(m/\Omega)^{1/2}$;

R: is the sheath resistance per unit length, Ω/km;

U_b : is the breakdown voltage of the cable, V;

ρ: is the soil resistivity, Ω.m;

B.3.2. Sheath breakdown current of aerial cable

Sheath breakdown current of aerial cable or optical fibre cable with earth connections of the metal sheath may be estimated from the following equation:

$l_s = U_b/(K.R.\rho e^{1/2})$, kA ; (B.5)

Where:

ρe: is the effective earth resistivity, Ω.m, which is defined as:

$\rho e = \pi.D.R_g/\ln(2.H/a)$; (B.6)

Where:

D- is the spacing between earthing points, in metres;

H- is the height of the cables, in metres;

a: is the radius of the cables, in metres;

R_g : is the resistance of the earthing points in Ω.m;

Annex C
(Normative)

Calculation of shielding factor of shield wire for protecting buried cable

Shielding effects of shield wire depend on location of placing shield wire and defined by shielding factor η.

Shielding factor η is defined by ratio of current on cable cover with (l'sh) and without (lsh) shield wire as follows:

η = l'sh/ lsh

C.1 Shielding factor for one shield wire

When there is only one shield wire, the shielding factor is given by:

$\eta = \ln (x/s) / \ln (x^2/s\, r)$ (C.1)

where [see Figure C.1 (a)]:

r radius of the sheath

s radius of the shield wire

x distance between the axes of the cable and the shield wire

Tables C.1 and C.2 give values of shielding factor for different sizes of conductors and spacing.

Table C.1 – Shielding factor for r = 10 mm

x(m)	s = 2 mm	s = 3 mm	s = 5 mm	s = 8 mm	s = 12 mm
0.15	0.61	0.59	0.56	0.52	0.48
0.25	0.60	0.58	0.55	0.52	0.49
0.50	0.59	0.57	0.54	0.51	0.49
1.00	0.57	0.56	0.53	0.51	0.49

Table C.2 – Shielding factor for r = 20 mm

x(m)	s = 2 mm	s = 3 mm	s = 5 mm	s = 8 mm	s = 12 mm
0.15	0.68	0.65	0.62	0.59	0.55
0.25	0.65	0.63	0.60	0.57	0.54
0.50	0.63	0.61	0.59	0.56	0.54
1.00	0.61	0.60	0.58	0.55	0.53

C.2 Shielding factor for multiple shield wires disposed in a circle around the cable

C.2.1 For two shield wires

See Figure C.1b.

Table C.3 – Shielding factor for two wires

x(m)	g = 30°	g = 45°	g = 60°	g = 90°
0.15	0.38	0.36	0.34	0.33
0.25	0.38	0.35	0.34	0.33
0.50	0.37	0.35	0.34	0.33
1.00	0.37	0.35	0.34	0.33

C.2.2. For three shield wires, with x = 0.25 m

See Figure C.1c.

Table C.4 – Shielding factor for three wires (x = 0.25 m)

g = 30°	g = 60°	g = 90°	g = 120°
0.33	0.26	0.23	0.22

C.2.3 For n wires symmetrically disposed in a circle around the cable with x = 0.25 m

See Figure C.1d, C.1e, C.1f

Table C.5– Shielding factor for n wires symmetrically disposed in a circle around the cable (with x = 0.25 m)

n = 4	n = 6	n = 8
0.16	0.09	0.06

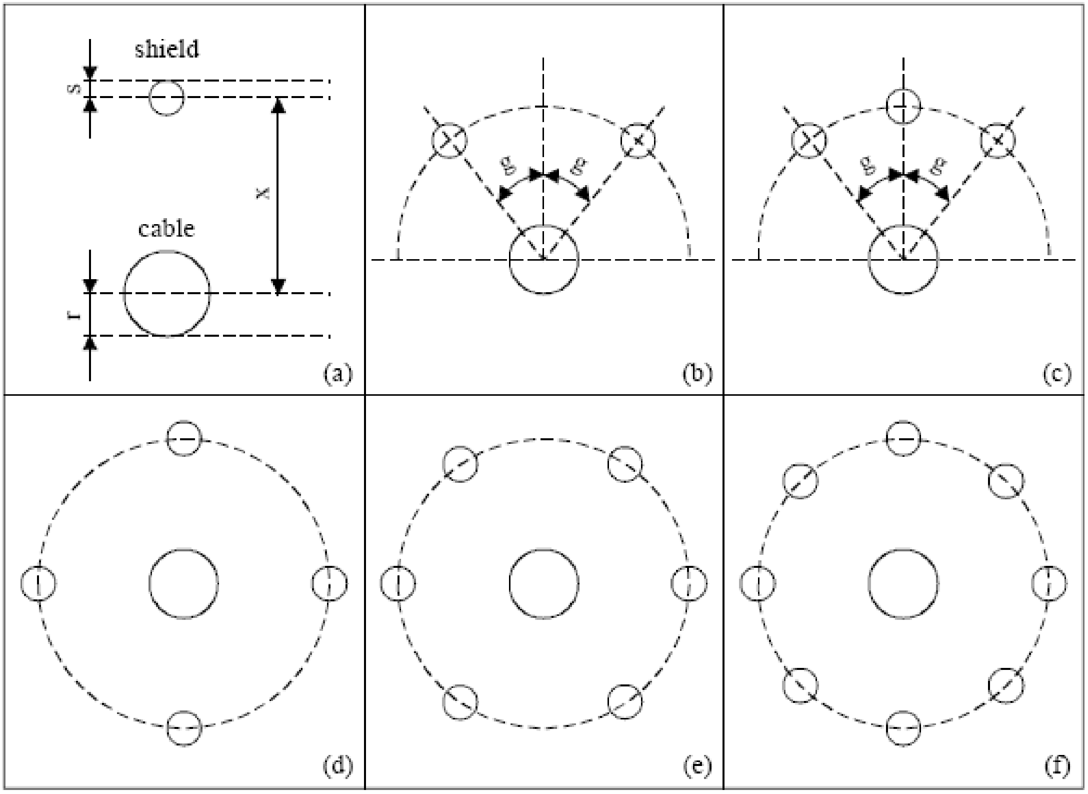


Figure C.1- Configuration of shield wire

Annex D

(Informative)

Characteristics of lightning in Vietnam

Table D.1- Lightning density at provinces, cities of Vietnam

No.	Provinces, cities	District	Lightning density (time number/km^2/year)
1	An Giang	Long Xuyen City, Chau Doc Town, An Phu, Chau Phu, Chau Thanh, Cho Moi, Phu Tan, Tan Chau, Tinh Bien, Thoai Son, Tri Ton	13,7
2	Ba Ria Vung Tau	Vung Tau City, Ba Ria Town, Chau Duc, Con Dao, Long Diem, Dat Do, Xuyen Moc	8,2
		Tan Thanh, Chau Duc	10,9
3	Bac Can	Bac Can Town, Bac Thong, Cho Don, Cho Moi, Na Ri, Ngan Son, Pac Nam	8,2
		Cho Don	10,9
4	Bac Giang	Bac Giang Town, Hiep Hoa, Lang Giang, Luc Nam, Luc Ngan, Son Dong, Tan Yen, Viet Yen, Yen Dung, Yen The	8,2
5	Bac Ninh	Bac Ninh Town, Gia Binh, Luong Tai, Que Vo, Yen Phong	8,2
		Tu Son, Tien Du, Thuan Thanh	10,9
6	Bac Lieu	Bac Lieu Town	10,9
		Gia Tao, Dong Hai, Hong Dan, Phuoc Long, Vinh Loi	13,7
7	Ben Tre	Ben Tre Town, Chau Thanh, Cho Lach, Giong Trom, Mo Cay	13,7
		Thanh Phu, Ba Tri, Binh Dai	10,9
8	Binh Dinh	Quy Nhon City, Tuy Phuoc	5,7
		An Lao, An Nhon, Hoai An, Hoai Nhon, Phu Cat, Phu My, Tay Son, Van Canh, Vinh Thanh	8,2
9	Binh Duong	Thu Dau Mot Town, Di An, Tan Uyen, Thuan An	13,7
		Ben Cat, Dau Tieng, Phu Giao	14,9
10	Binh Phuoc	Dong Xoai Town, Binh Long, Chon Thanh, Dong Phu	14,9

No.	Provinces, cities	District	Lightning density (time number/km^2/year)
		Bu Dop, Bu Dang, Loc Ninh, Phuoc Long	13,7
11	Binh Thuan	Phan Thiet City, Ham Tan, Ham Thuan Bac, Ham Thuan Nam, Tanh Linh	8,2
		Duc Linh	10,9
		Phu Quy	7,0
		Bac Binh	5,7
		Tuy Phong	3,4
12	Ca Mau	Ca Mau Town, U Minh, Thoi Binh, Tran Van Thoi, Cai Nuoc, Dam Doi, Phu Tan, Nam Can, Ngoc Hien	13,7
13	Cao Bang	Cao Bang Town, Bao Lac, Bao Lam, Ha Quang, Ha Lang, Ha An, Nguyen Binh, Phuc Hoa, Quang Uyen, Thach An, Thong Nong, Tra Linh, Trung Khanh	9,2
14	Can Tho	Binh Thuy Dist., Cai Rang Dist., Ninh Kieu Dist., O Mon Dist., Co Do, Phong Dien, Thot Not, Vinh Thach	13,7
15	Da Nang	Hai Chau Dist., Lien Chieu Dist., Ngu Hanh Son Dist., Son Tra Dist., Thanh Khe, Hoa Vang	8,2
		Hoan Sa	7,0
16	Dac Lak	Buon Ma Thuan City, Buon Don, Ea Sup, Cu M'Gar, Ea H'Leo, Krong Buk, Krong Nang	13,7
		Krong Pak, Krong Ana, Lak, Krong Bong, Ea Kar	10,9
		M'Dak	8,2
17	Dien Bien	Dien Bien Phu City, Dien Bien, Dien Bien Dong	8,2
		Muong Lay Town, Muong Cha, Muong Nhe, Tua Chua, Tuan Giao	10,9
18	Dac Nong	Dak Nong, Krong No	10,9
		Dak Mil, Dak R'Lap, Dak Song	13,7
19	Dong Nai	Bien Hoa City, Long Thanh, Nhon Trach, Vinh Cuu, Trang Bom	13,7
		Long Khanh Town, Tan Phu, Dinh Quan, Thong Nhat	10,9
		Xuan Loc, Cam My	8,2

No.	Provinces, cities	District	Lightning density (time number/km^2/year)
20	Dong Thap	Cao Lanh Town, Lap Vo, Sa Dec, Tan Hong, Tam Nong, Thap Muoi, Hong Ngu, Cao Lanh, Thanh Binh, Lai Vung, Chau Thanh	13,7
21	Gia Lai	An Khe Town, Chu Pah, La Grai, Mang Yang, Dac Doa, Dac Po	8,2
		Pleiku City, K'Bang, La Pa, Duc Co, Krong Pa	10,9
		Chu Prong, Chu Se, A Yun Pa	13,7
22	Ha Giang	Ha Giang Town, Bac Me, Bac Quang, Meo Vac, Quang Ba, Vi Xuyen	10,9
		Hoang Su Phi, Quang Binh, Xin Man, Dong Van, Meo Vac, Yen Minh	8,2
23	Ha Nam	Phu Ly Town, Kim Bang, Thanh Liem, Duy Tien	10,9
		Binh Luc, Ly Nhanh	8,2
24	Ha Noi	Ba Dinh Dist., Cau Giay Dist., Dong Da Dist., Hai Ba Trung Dist., Hoang Mai Dist., Hoan Kiem Dist.,Long Bien Dist., Tay Ho Dist., Thanh Xuan Dist., Gia Lam, Thanh Tri, Tu Liem, Dong Anh	10,9
		Soc Son	8,2
		Ha Dong Dist., Son Tay Town, Ba Vi, Chuong My, Dan Phuong, Hoai Duc, My Duc, Phu Xuyen, Phuc Tho, Quoc Oai, Thach That, Thanh Oai, Thuong Tin, Ung Hoa	10,9
		Phuc Tho, Dan Phuong, Thach That, Quoc Oai, Hoai Duc	8,2
25	Ha Tinh	Ha Tinh Town, Cam Xuyen, Can Loc, Duc Tho, Huong Son, Ky Anh, Nghi Xuan, Thach Ha, Vu Quang	8,2
		Huong Khe	10,9
26	Hau Giang	Chau Thanh, Phuc Hiep	10,9
		Vi Thanh Town, Vi Thuy, Long My, Chau Thanh A	13,7
27	Hai Duong	Hai Duong City, Binh Giang, Cam Giang, Chi Linh, Gia Loc, Nam Sach, Ninh Giang, Thanh Mien	8,2

No.	Provinces, cities	District	Lightning density (time number/km^2/year)
		Kinh Mon, Kim Thanh, Thanh Ha, Tu Ky	10,9
28	Hai Phong	Hong Bang Dist., Kien An Dist., Le Chan Dist., Ngo Quyen Dist., An Duong, An Lao, Kien An, Bach Long Vi, Thuy Nguyen	10,9
		Hai An Dist., Do Son Town, Tien Lang, Vinh Bao, Kien Thuy, Cat Hai	8,2
29	Hoa Binh	Hoa Binh Town, Da Bac, Kim Boi, Ky Son, Lac Thuy, Luong Son, Mai Chau	10,9
		Cao Phong, Tan Lac, Lac Son, Yen Thuy	13,7
30	Hung Yen	Hung Yen Town, Phu Cu, Tien Lu	8,2
		An Thi, Khoai Chau, Kim Dong, Ky Hao, Van Giang, Van Lam, Yen My	10,9
31	Khanh Hoa	Nha Trang City	3,4
		Cam Ranh Town, Dien Khanh, Van Ninh, Ninh Hoa	5,7
		Khanh Son, Khanh Vinh	8,2
		Truong Sa	7,0
32	Kien Giang	Rach Gia Town, Ha Tien Town, An Bien, An Minh, Chau Thanh, Giong Rieng, Go Quao, Hon Dat, Kien Hai, Kien Luong, Tan Hiep, Vinh Thuan	13,7
		Phu Quoc	7,0
33	Kon Tum	Kom tum Town, Kon Plong, Kon Ray, Dak Glei, Dak Ha, Sa Thay	8,2
		Dak To, Ngoc Hoi	5,7
34	Lam Dong	Tp. Da Lat, Dam Rong, Don Duong, Duc Trong, Lam Ha	10,9
		Bao Loc Town, Bao Lam, Cat Tien, Di Linh, Da Huoai, Da Teh	5,7
		Lac Duong	13,7
35	Lao Cai	Lao Cai City, Sa Pa, Bac Ha, Bat Xat, Muong Khuong, Si Ma Cai	8,2
		Bao Thang, Bao Yen, Van Ban	10,9
36	Lang Son	Lang Son City, Bac Son, Binh Gia, Cao Loc, Chi Lang, Dinh Lap, Huu Lung, Loc binh, Trang Dinh, Van Lang, Van Quan	8,2

No.	Provinces, cities	District	Lightning density (time number/km^2/year)
	Lai Chau	Lai Chau Town, Muong Te, Phong Tho, Sin Ho, Tam Duong, Than Uyen	8,2
37	Long An	Tan An Town, Ben Luc, Can Duoc, Can Guoc, Chau Thanh, Duc Hoa, Tan Tru, Tan Hung, Tan Thanh, Thu Thua	13,7
		Duc Hue, Moc Hoa, Thanh Hoa, Vinh Hung	14,9
38	Nam Dinh	Nam Dinh City, Giao Thuy, Hai Hau, My Loc, Nam Truc, Nghia Hung, Truc Ninh, Vu Ban, Xuan Truong, Y Yen	8,2
39	Nghe An	Vinh City, Cua Lo Town, Hung Nguyen, Nam Dan, Thanh Chuong, Do Luong, Yen Thanh, Quynh Luu, Dien Chau	8,2
		Anh Son, Con Cuong, Nghia Dan, Tan Ky, Tuong Duong, Ky Son, Que Phong	10,9
		Quy Chau, Quy Hop	13,7
40	Ninh Binh	Ninh Binh Town, Tam Diep Town, Hoa Lu, Kim Son, Yen Khanh, Yen Mo	8,2
		Gia Vien, Nho Quan	10,9
41	Ninh Thuan	Phan Rang Town, Ninh Phuoc	1,4
		Bac Ai, Ninh Son	5,7
		Ninh Hai	3,4
42	Phu Tho	Viet Tri City, Phu Tho Town, Doan Hung, Ha Hoa, Lam Thao, Phu Ninh, Cam Khe, Tam Nong, Thanh Ba, Thanh Son, Thanh Thuy, Yen Lap	10,9
43	Phu Yen	Tuy Hoa Town	3,4
		Dong Xuan, Song Hinh, Son Hoa	8,2
		Phu Hoa, Song Cau, Tuy An, Tuy Hoa	5,7
44	Quang Binh	Dong Hoi Town, Bo Trach, Le Thuy, Minh Hoa, Quang Ninh, Quang Trach	8,2
		Tuyen Hoa	10,9
45	Quang Nam	Tam Ky Town, Hoi An Town, Bac Tra My, Duy Xuyen, Dai Loc, Dien Ban, Nam Tra My, Phu Ninh, Nui Thanh, Que Son, Thang Binh, Tien Phuoc, Hiep Duc	8,2
		Dong Giang, Nam Giang, Phuoc Son, Tay Giang, Nam Tra My	10,9

No.	Provinces, cities	District	Lightning density (time number/km^2/year)
46	Quang Ngai	Quang Ngai Town, Binh Son, Duc Pho, Ly Son, Mo Duc, Nghia Hanh, Tu Nghia, Son Tinh	8,2
		Ba To, Minh Long, Son Ha, Son Tay, Tay Tra, Tra Bong	10,9
47	Quang Ninh	Ha Long City, Uong Bi Town, Dong Trieu, Yeu Hung, Hoanh Bo, Binh Lieu	8,2
		Mong Cai Town, Ba Che, Co To, Dam Ha, Hai Ha, Hoanh Bo, Tien Yen, Van Do, Cam Pha	10,9
48	Quang Tri	Dong Ha Town, Cam Lo, Con Co, Da Krong, Gio Linh, Hai Lang, Huong Hoa, Vinh Linh	8,2
		Quang Tri Town, Da Krong, Hai Lang, Trieu Phong	10,9
49	Son La	Son La Town, Bac Yen, Mai Son, Moc Chau, Muong La, Phu Yen, Quynh Nhai, Song Ma, Sop Cop, Thuan Chau, Yen Chau	10,9
50	Soc Trang	Soc Trang Town, Cu Lao Dung, Ke Sach, Long Phu, My Xuyen, Vinh Chau	10,9
		My Tu, Nga Nam, Thanh Tri	13,7
51	Tay Ninh	Tay Ninh Town, Chau Thanh, Hoa Thanh, Tan Bien, Tan Chau	13,7
		Go Dau, Trang Bang, Ben Cau, Duong Minh Chau	14,9
52	Thai Binh	Thai Binh Town, Dong Hung, Hung Ha, Kien Xuong, Quynh Phu, Thai Thuy, Tien Hai, Vu Thu	8,2
53	Thai Nguyen	Thai Nguyen City, Dinh Hoa, Dong Hy, Pho Yen, Phu Binh, Phu Luong, Vo Nhai, Song Cong Town, Dai Tu	8,2
54	Thanh Hoa	Thanh Hoa City, Bim Son Town, Sam Son Town, Dong Son, Ha Trung, Hau Loc, Hoang Hoa, Nhu Thanh, Nhu Xuan, Nong Cong, Nga Son, Thieu Hoa, Tho Xuan, Quang Xuong, Tinh Gia, Trieu Son, Vinh Loc, Yen Dinh	8,2
		Ba Thuoc, Thach Thanh, Cam Thuy	13,7
		Lang Chanh, Muong Lat, Quan Hoa, Quan Son, Thuong Xuan, Ngoc Lac, Cam Thuy	10,9
55	Thua Thien Hue	Hue City, Phong Dien, Phu Loc, Phu Vang, Quang Dien	10,9

No.	Provinces, cities	District	Lightning density (time number/km²/year)
		A Luoi, Huong Tra, Huong Thuy, Nam Dong	13,7
56	Tien Giang	My Tho Town, Go Cong Town, Cai Be, Cai Lay, Chau Thanh, Tan Phuoc, Cho Gao, Go Cong Dong, Go Cong Tay	13,7
57	Tp. Ho Chi Minh	Dist. 1, Dist. 2, Dist. 4, Dist.5, Dist.6, Dist.7 Dist.8, Dist.9, Dist.10, Dist.11, Tan Phu Dist Binh Tan Dist., Binh Thanh Dist., Go Vap Dist Phu Nhuan Dist., Tan Binh Dist., Thu Duc Dist Binh Chanh, Nha Be, Hoc Mon	13,7
		Can Gio	10,9
		Cu Chi	14,9
58	Tra Vinh	Tra Vinh Town, Cang Long	13,7
		Cau Ke, Cau Ngang, Chau Thanh, Duyen Hai, Tieu Can, Tra Cu.	10,9
59	Tuyen Quang	Tuyen Quang Town, Chiem Hoa, Ham Yen, Na Hang, Son Duong	10,9
		Son Duong	8,2
60	Vinh Long	Vinh Long Town, Long Ho, Mang Thit	13,7
		Tam Binh, Tra On, Ving Liem, Binh Minh	10,9
61	Vinh Phuc	Vinh Yen Town, Phuc Yen Town, Binh Xuyen, Lap Thach, Tam Duong, Vinh Tuong, Yen Lac	10,9
		Tam Dao, Me Linh	8,2
62	Yen Bai	Yen Bai City, Nghia Lo Town, Luc Yen, Mu Cang Chai, Tram Tau, Tran Yen, Van Chan, Van Yen, Yen Binh	10,9

Table D.2 - Distribution of main characteristics of surface lightning

No.	Lightning characteristics	Percentage of the characteristics value can be higher than the following values							Unit
		99	90	75	50	25	10	1	
1	Repeated lightning number	1	1	2	3	5	7	12	
2	Interval among strikes	10	25	35	55	90	150	400	ms
3	First lightning current, I_{max}	5	12	20	30	50	80	130	kA
4	Next lightning current amplitude	3	6	10	15	20	30	40	kA
5	First lightning slope, (dI/dt)	6	10	15	25	30	40	70	GA/s
6	Next lightning slope, (dI/dt)	6	15	25	45	80	100	200	GA/s

Annex E
(Informative)

Calculation of risk of failure for one typical telecommunication stations

Calculation of risk of damage due to lightening for one telecommunication stations at Tuy Hoa City, Phu Yen Province, with the following data:

- Dimension and material of the station: (5 x 3 x 3) m; reinforced concrete;

- Height of aerial and distance from the aerial to station: 80m, 4m apart ;

- Characteristics and height of cables to stations:

+ Power cable with height of 60m, without cover, underground;

+ Telecommunication cable with height of 1000m, without cover, suspended;

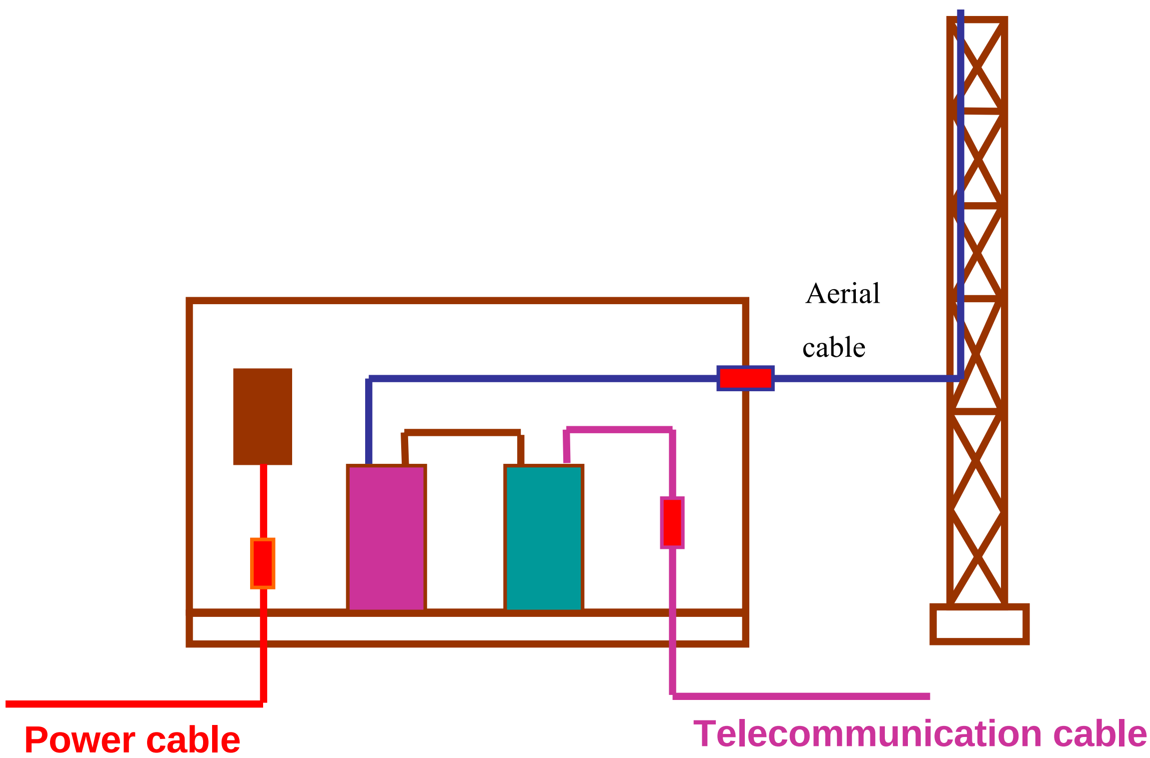


Figure E.1- Model of telecommunication stations with adjacent aerial high mast

E.1. Calculation of risk areas, A

- The risk area for direct lightning strikes to a structure, $A_d = 0$ (because the station is covered with risk area of antenna mast);

- The risk area for direct lightning strikes to antenna mast:

$A_a = \Pi\ (3h)^2 = \Pi.\ (3.80)^2 = 1800956\ (m^2) = 0,2\ (km^2)$;

- The risk area for direct lightning strikes to telecommunication cable:

$A_{stele} = 2.d_{1tele}.L_{tele} - A_a/2 = 2.1000.\ 1000 - 90000 = 1,91.\ 10^{-6}\ (m^2) = 1,9\ (km^2)$ – (risk area due to lightning strikes to cables which is reduced due to cover by risk area for lightning strikes to aerial column);

- The risk area for direct lightning strikes to power cable:

$A_{spower} = 2.\ d_{1power}.L_{power} - A_a/2 = 2\ .\ 250.\ 600 - 90000 = 0,21.\ 10^{-6}\ (m^2) = 0,2\ (km^2)$

- The risk area for direct lightning strikes to adjacent stations, , the area A_n is further reduced due to the due to cover by risk area for lightning strikes to antenna mast and risk area for lightning strikes to lines, specifically as follows:

- Covered with telecommunication cable:

$A_{n(tele)} = \Pi\ d^2/2 - A_a/2 = 0,3\ (km^2)$;

- Covered with power cable:

$A_{n(power)} = \Pi\ d^2/2 - Aa/2 + (\Pi\ d^2/3 - 2\ d1.\ d1\ \sqrt{3}/2) = 0,5\ (km^2)$ – (components in blanket which demonstrates area of circle piece when $d = 2\ d_1$)

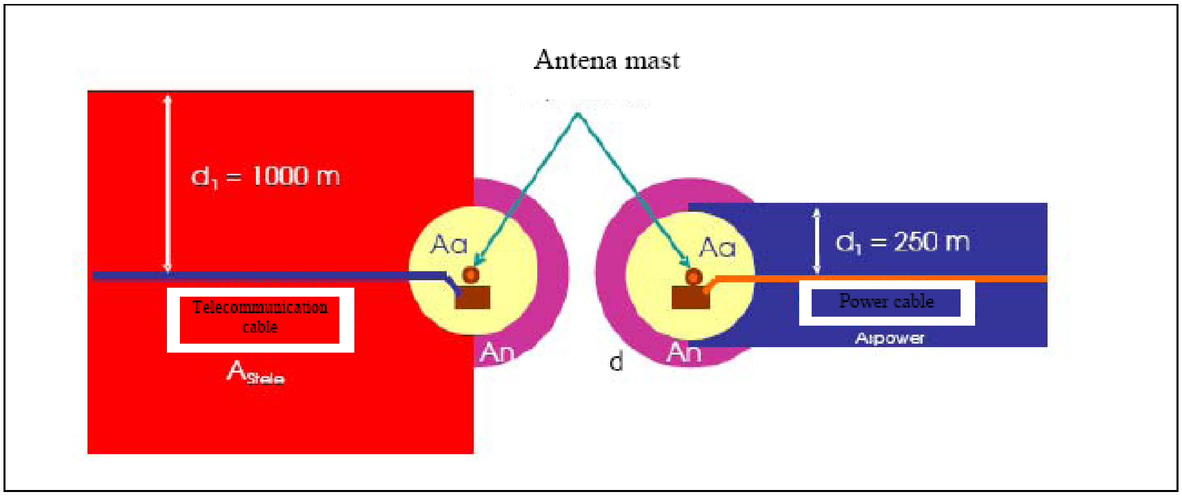


Figure E.2 – Risk areas

E. 2 Calculation of frequency of damage

Lightning density of the area of placing telecommunication stations at Tuy Hoa City, Phu Yen Province, according to Table D.1, Annex D, N_g = 3,7 times/ km^2/ year.

Frequency of damage F depends on N_g, the above risk areas and loss probability factors corresponding to protective measures, taken as in Table 5 to Table 9.

When without protective measures, the shield of the station and shield connection of the aerial cable to the station, frequency of damage shall be:

- frequency of damage due to direct lightning strike to the station:

$F_d = N_g.A_d.\ pd = 0$ (do $A_d = 0$)

- frequency of damage due to lightning strike to the ground adjacent to station area:

$F_n = N_g.\ A_n.p_n = N_g.(A_{n(tele)} + A_{n(power)}).pn$

with p_n = 0,1 due to the station with reinforced concrete structure (Table 5).

Fn = 3,7. (0,3 + 0,5). 0,1 = 0,296 (time/ year);

- frequency of damage due to lightning strike to the cable or adjacent area of cable:

$F_s = N_g.\ (A_{s(tele)} + A_{s(power)}).\ p_s$

with p_s = 1 due to without protective measures on cable (according to Table 7):

Fs = 3,7. (1,9 + 0,2).1 = 7,7 (time/year)

- frequency of damage due to direct lightning strike to antenna mast:

$F_a = N_g.\ A_a.\ p_a$

with pa = 0,01 due to the station with reinforced concrete structure (Table 5) and with the suppositions that cable is well grounded to reinforced concrete of the station:

F_a = 3,7.0,2 . 0,01 = 0,0047 (time/year);

E.3. Calculation of risk of injury

- Risk of injury for humans inside the telecommunication stations shall be defined according to formula 2.1, with the supposition that the surface layer is made by dry concrete ($p_{injury} = 10^{-3}$ according to table 9);

$R_{injury} = L.p_{injury}.\ \Sigma Fi = 1.10^{-3}.\ (0,296 + 7,7 + 0,0047) = 8.10^{-3}$

The above risks are too high in comparison with requirement of allowable risk (10^{-5}), so it is necessary to have more protective measures.

- Risk of loss is defined as 2.2:

$R_{loss} = L.\Sigma Fi = 2,47.10^{-3}.8 = 19,76.10^{-3}$

The above risks are too high in comparison with requirement of allowable risk (10^{-3}), so it is necessary to have more protective measures.

From the above calculations, it is noted that the biggest source of damage frequency due to the lightning is from information lines and power lines (F_s = 7,7 times/ year), so, it is necessary to fit with protective equipment on these lines. If the construction method is good, F_n and F_s will be reduced to p = 0,01. Then, the frequency of damage is:

$\Sigma F = 3,7.[0,8.10^{-1}.10^{-2} + 2,1.10^{-2} + 0,2.10^{-2}] = 8,51.10^{-2}$ (time/ year)

- Risk of injury for humans can be reduced by setting lightning protection system in the outside (p_{injury} = 0,1 according to table 6) and surface of working area is covered with asphalt material or wood $p_{injury} = 10^{-5}$), Risk of injury for humans is:

$R_{injury} = 8,51.10^{-2}.10^{-1}.10^{-5} = 8,51.10^{-8}$

This value is suitable with allowed standard. So, the above equipment for humans is enough.

- Risk of loss:

$R_{loss} = 8,51.10^{-2}. 2,74.10^{-3} = 23,3.10^{-5} = 0,233.10^{-3}$

This value is suitable with allowed standard. So, the above equipment for humans is enough.

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