Risk Assessment of Damages due to Lightning Discharges: A Case Study to a Telecommunication System in Singburi Province of Thailand.

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Abstract: - The paper describes a case study on risk assessment of damages to a telecommunication site with adjacent antenna mast. The site is located in the town centre of Singburi Province of Thailand. The risk analysis is based on an IEC standard [1, 2] and ITU–T recommendation [3, 4]. The aim of the risk analysis is to study the effect from the ac power supply lines on the annual number of expected damages due to lighting discharges. The analysis shows that by reducing the route length of power cables the frequency of damage can be decreased significantly. Also, the implementation of SPDs at the entrance of power cables into the telecommunication building contribute to a further decrement of damage.

Key-Words: - Risk assessment, Overvoltage, Number of damage, Surge protective device, Lightning discharges and Telecommunication Site

1 Introduction

Telecommunication networks are vulnerable to electrical damages from lightning or other surges. As the networks become more complex and the wide spread use of radio stations with high antenna mast for wireless communication has significantly increased the risk for damages.

Where the general public, subscriber or employees are concerned, safety from electrical shock and other hazard should be of prime consideration. Protection of plant and equipment is a secondary consideration. Various protection measures are available and the most appropriate protection measure to be provided can be determined by risk assessment procedure described in this paper.

2 Lightning disturbances affecting a telecommunication site

IEC 62305–2 [1] describes four different paths [Fig. 1] to which over voltages entering a network within a telecommunication building due to lightning strikes for the following sources:-

S1 : flashes to the building.
S2 : flashes near the building.
S3 : flashes to connected telephone service lines or power lines.
S4 : flashes near connected telephone service lines or power lines.

Flashes to the building or connected telephone service lines may cause physical damage and life hazards. Flashes near the building or near connected telephone service lines as well as flashes to the building or connected telephone service lines may cause failure of electrical or electronic systems due to overvoltages resulting from resistive and inductive coupling of these systems with the lightning current.

Moreover, failures caused by lightning overvoltages in subscribers' installations and in power supply lines may also generate switching type overvoltages in the installation.

The number of lightning flashes influencing the building and the telephone services depends on the dimensions and the characteristics of the telecommunication structure and of the connected telephone service lines, on the environment characteristics of the building and the connected telephone service lines, as well as on lightning ground flash density in the region where the building and the telephone service lines are located.

The probability of lightning damage depends on the building, the telephone service lines, and the lightning current characteristics;

as well as on the type and efficiency of applied protection measures.

The annual mean amount of the consequential loss depends on the extent of damage and the consequential effects which may occur as a result of a lightning flash.

The effect of protection measures results from the features of each protection measure and may reduce the damage probabilities or the amount of consequential loss.

The risks involved in failing to address the issue of lightning overvoltage protection can be summarized by the following:-

– Partial or complete loss of operations and system downtime resulting in lost revenue.
– Customer complaints in response to system downtime.
– Physical damage to equipment resulting in repair or replacement costs.
– Danger to staffs and other personnel from the effects of lightning discharges.

3 Risk Assessment

The risk assessment of possible damage due to lightning consists of the assessment of the following quantities related to the location of the network under consideration. Key parameters described by [2] include lightning flash density, earth resistivity, nature of the installation (buried, aerial, shielded or unshielded cable) and resistibility of equipment to be protected.

Completion of risk assessment will determine the extent to which protection measures need to be undertaken in order to satisfy the requirements of standards and performance targets of the network provider. The selection of the most appropriate protection measures will be based on the information gained from the risk assessment process as well as additional considerations given to the cost and benefit analysis. Installation costs of the protection components required are to be compared with the savings from greater reliability of the telecommunication services and lower maintenance and repair costs. Optimum choice must be based on balancing minimum costs against maximal operational efficiency of the network.

3.1 Risk Analysis

The risk, defined in [1] as the probable average annual loss in a building and in connected telephone service lines due to lightning flashes depend on :–

– The annual number of lightning flashes influencing the target building and the connected telephone service lines.
– The probability of damage by one of the influencing lightning flashes.
– The mean amount of consequential loss.

Lightning flashes influencing the building may be divided into

– Flashes terminating on the building.
– Flashes terminating near the building direct to connected telephone service lines or near the telephone lines.

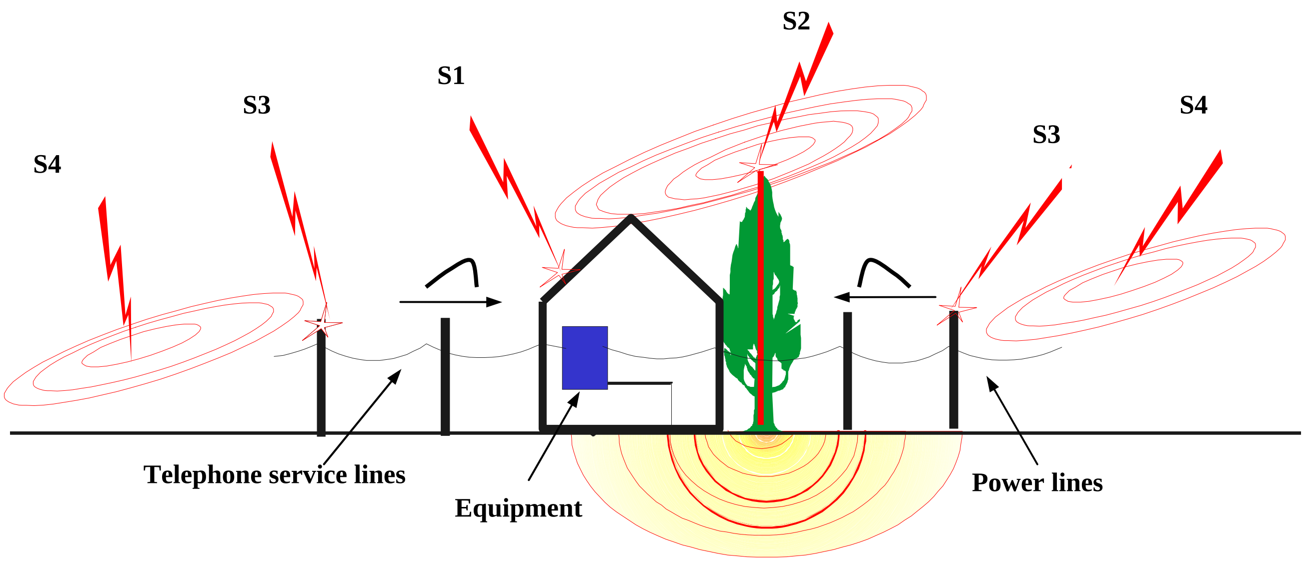


Fig. 1 Different sources of disturbances such as lightning discharge that influences on telecommunication system.

Lightning influencing the telephone service lines may be divided into.

- Flashes terminating on the telephone service lines.
- Flashes terminating near the service or direct to a structure connected to the service.

The purpose of risk analysis as described by [1] is to reduce the expected risk of damage (R_p) due to lightning to a value which is equal to or lower than the tolerable risk of damage (R_a).

3.2 Configuration of the telecommunication site and networks under investigation.

A site located in Singburi province, Thailand, is selected for the risk assessment of damages due to lightning discharges. The site composed of a center building with physical connection via telephone service lines to subscribers' installations and with physical connection via ac power lines to the Utility in Singburi Province, Thailand is given in Fig. 2.

3.3 Sources of Damage under Consideration

Sources of damage due to lightning discharges to a site under investigation can be divided to four main contributing factors which include:–

1. Direct strikes to the site.
2. Nearby strikes to ground.
3. Lightning discharges to or in the vicinity of incoming telephone and ac power supply cables.
4. Direct discharges to adjacent antenna masts with metallic connection to the site.

3.4 Calculation of Frequency of damage (F)

Risk areas for the telecommunication System under investigation shown in table 1 and may be defined as the areas shown in Fig.3. Lightning discharges confined to these areas are assumed to damage building itself or at least the installed electronic equipment inside.

A_1 = Equivalent risk area for direct strikes the building.

A_2 = Risk area for discharges to ground nearby the building effect the network by resistive and inductive coupling.

A_3 = Risk area for direct strikes to adjacent antenna masts, with metallic connection to the network

A_4 = Risk area for incoming telephone service lines.

A_5 = Risk area for incoming power lines.

The sum of the areas gives the total risk area for the site and corresponds to the average number of damages every year, F, at a normalized lightning intensity N_g of 1 flash to ground per km^2 and year.

Regarding the local lightning flash density, the number of yearly prospective number of damages, F, is expressed by formula (1)

$$F \approx N_g\,(A_1p_1+A_2p_2+A_3p_3+A_4p_4+A_5p_5) \qquad (1)$$

where the different values of probability factor p depend on the existing or planned protective measure, which decrease the probability of damages.

The five terms represent damages caused by

1. direct strike to the building
2. nearby strikes to ground
3. direct discharges to antenna tower with metallic connection to building and
4. lightning discharges to or in the vicinity of incoming telephone service lines.
5. lightning discharges to or in the vicinity of incoming power lines.

The value of lightning ground flash density is calculated by using the following approximate formula [2]

$$N_g = 0.04\,T_d^{1.25} \quad \text{per km}^2 \text{ and year} \qquad (2)$$

where Td = 70 is the average number of thunderstorm registered per year.

3.5 Risk of damage, R

The risk R that a site will suffer serious damages can be estimated to

$$R = (1 - e^{-F \cdot T}) \cdot \delta \qquad (3)$$

which is simplified to

$$R = F \cdot \delta = \Sigma\, F_i \cdot \delta_i \qquad (4)$$

For t = 1 year and F << 1

The factor δ is determined with respect to the prospective consequent damages in relation to the full hardware value of the equipment and to the effects of a total loss of service.

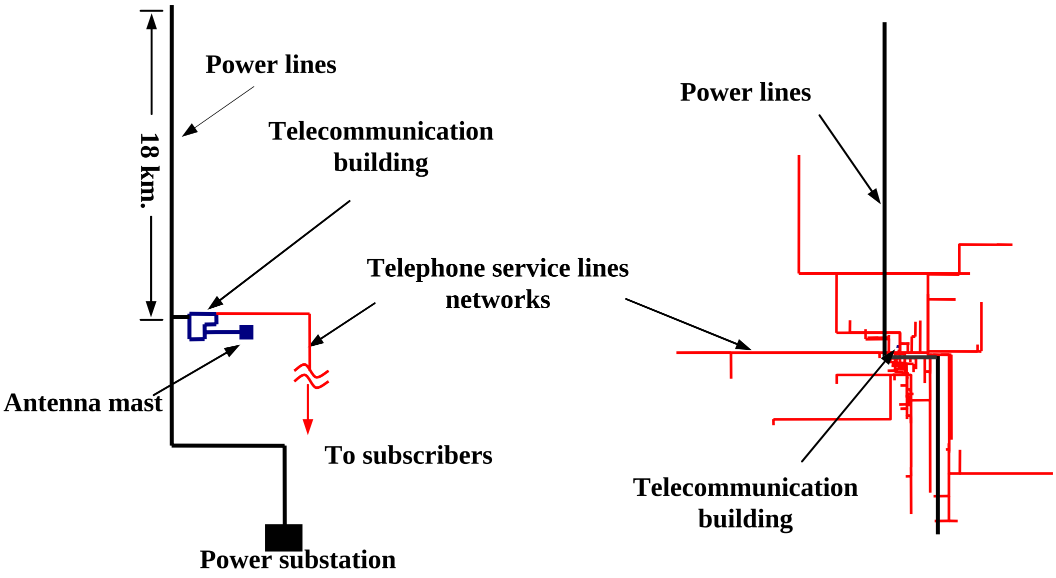


Fig. 2 Configuration of a telecommunication building and networks under investigation.

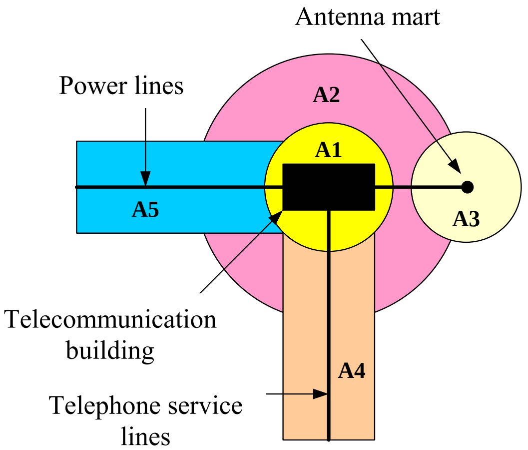


Fig. 3 Risk areas for lightning discharges

3.6 Probability Factor p

The probability factor p according to [3] can be divided into two parts. The first part associated with the natural protective characteristic of the installation (building material, aerial or underground network). The second part associated with 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).

The values of probability factors p_1, p_2, p_3, p_4 and p_5 are extracted from [3] corresponding to the network under investigation are 0.1, 0.1, 0.01, 0.01 and 0.01 respectively.

3.7 Results of the risk analysis

The aim of the risk analysis in this paper is to study the effect from the power supply lines on the number of expected damages due to lightning discharges. The existing site is physically connected to ac power supply originating from a substation. However, the medium voltage distribution lines also supply other loads on the same route in the vicinity of the site. This extends the line to a further length of 18 kilometers contributing to a very significant additional risk area. With the information on parameters of the above system the risk for loss of service R_{loss} and the risk for physical damages to site R_{damage} are estimated and the results are shown in table 2.

The calculated risk level is comparatively higher than the tolerable risk of damage as recommended by ITU-T K.39 [3]. By reducing the power cables route redundancy by a decrement of 3 kilometers interval starting from 18 km. length the resultant total number of damages per year and the number of damages due to lightning discharges in the vicinity of power cables (F_{power}) are found to vary as shown in Fig. 4(a). the frequency of damages due to the power cables in proportion to the total number of damages per year are found to reduce considerably as shown in table 3 and Fig. 4(b).

4 Conclusions

Assessment of the risk of damages to a site presented in this paper is calculated based on condition that the site is not provided with any particular protective measures. Inherent natural protective parts of the construction of the building or in the outside cable plant can offer some possible reduction in the penetrating fields and currents. The likelihood that damage should occur is expected to be significantly lower than in the theoretical case. The analysis shows that route length reduction and implementation of SPDs at the interface of the power supply cables and the entrance of the existing site can significantly reduce the total number of damages per year.

Table 1. Risk areas for the telecommunication System under investigation

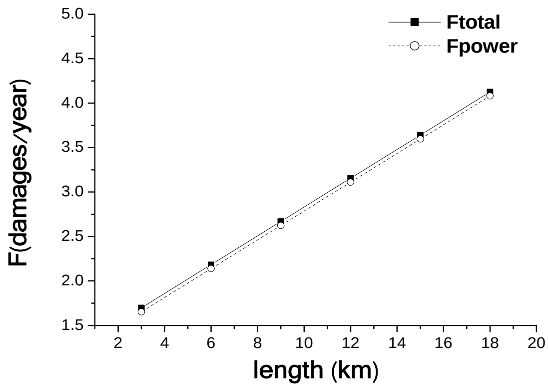
Risk areas	km^2
A_1	≈ 0 (cover by A_2)
A_2	0.108686
A_3	0.21029
A_4	45.097205
A_5	48.296089

Table 2. Risk for loss of service and risk for physical damages to equipment in the existing telecommunication in Singburi Province, Thailand.

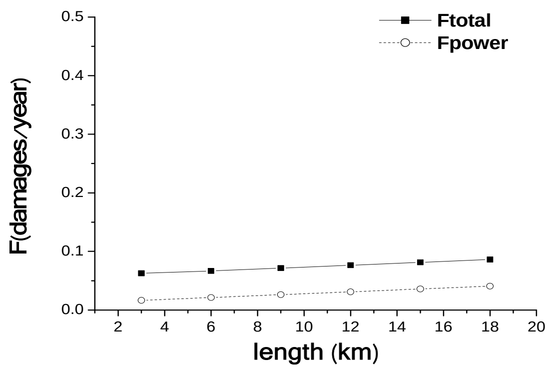
R_{damage}	0.8307
R_{loss}	0.0113

Table 3. Number of damages due to the power line proportion to the total number of damages.

Length of power line (km)	3	6	9	12	15	18
F_{total}	1.69	2.18	2.66	3.15	3.64	4.12
F_{power}	1.65	2.13	2.62	3.10	3.59	4.08
$\frac{F_{power}}{F_{total}}.100\%$	97.2	97.9	98.3	98.5	98.7	98.9



(a)



(b)

Fig. 4 Variation of number of damages per year (a) without SPDs (b) with SPDs at the incoming lines of low-voltage power of telecommunication building

References:

[1] IEC 62305–2, "*Protection against lightning - Part 2: Risk management*"

[2] IEC 61643-22, "*Low-voltage surge protective devices – Part 22: Surge protective devices connected to telecommunications and signalling networks –Selection and application principles*", Reference number CEI/IEC 61643-22:2004.

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[6] ITU-T Recommendation K.20, "*Resistibility of telecommunication switching equipment to overvoltages and overcurrents*".

[7] ITU-T Recommendation K.40, "*Protection against LEMP in telecommunications centres*".