Paper

Development of Analysis Method for the Flashover Rate Due to Lightning on Power Distribution Lines in Consideration of Cost Performance

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ABSTRACT High reliability of electric power supply is requested by the rapid evolution of information-oriented and computerized society. On the other hand, it is important to consider the cost down on power distribution lines in power companies. From this point of view, the authors developed an analytical method that can calculate flashover rate caused by lightning considering both the reliability and cost performance. As the results of calculations, it is clear that the flashover rate is significantly influenced by various parameters such as the lightning current waveform and nearby buildings. Moreover it is clear that the flashover rates of power distribution lines for various lightning protection designs are much different even if the constructing costs of power distribution lines are the same.

Keywords: Lightning, Lightning protection, Lightning flashover rate, Cost performance, Power distribution lines

1. Introduction

High reliability of electric power supply is requested by the rapid evolution of information-oriented and computerized society. On the other hand, it is important to consider the cost down on power distribution lines in power companies

From these points of view, the authors developed an analytical method that can calculate the flashover rate caused by lightning considering both reliability and cost performance on power distribution lines. In this paper, following subjects such as (1) analytical method for calculating the flashover rate, (2) influence of the lightning current waveform and nearby building, (3) relation between the flashover rate and the constructing cost of power distribution lines, are described.

2. Simulation method

2.1 Summary of the method

Fig. 1 shows the flow chart of the calculation method. First, the construction cost of power distribution lines is calculated. Secondary a lightning stroke is determined whether or not it is direct lightning hit to power distribution lines. If the direct lightning hit occurs, phenomena are calculated by EMTP. If lightning stroke is not direct lightning hit, phenomena are calculated by calculation method for induced over-voltages developed by authors [1]. After analyzing the phenomena and calculating the flashover rate, next lightning stroke that is selected randomly is calculated. In order to converge the flashover rate, 1000 lightning strokes are calculated. Details of the calculation are

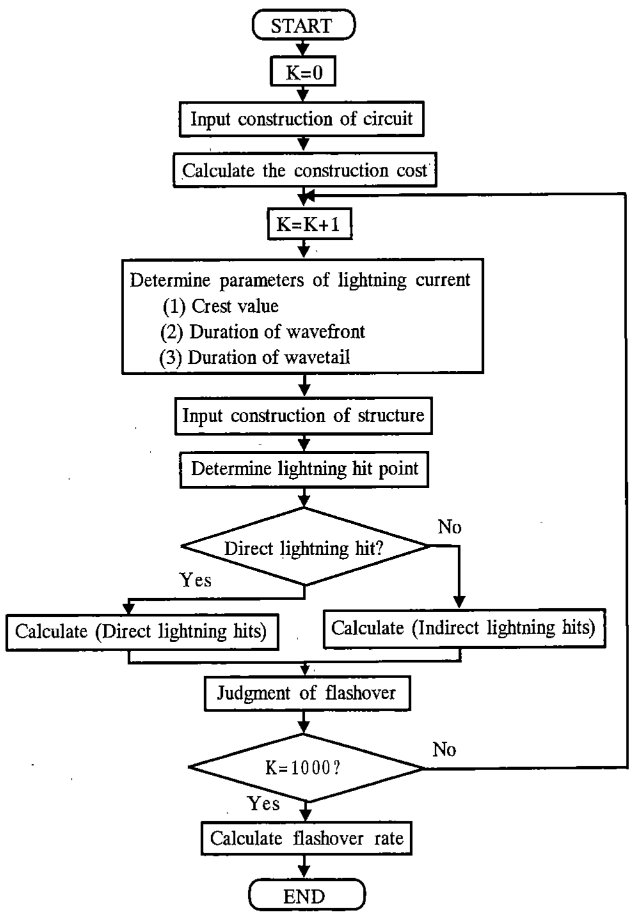

Fig.1. Flow chart of the simulation method.

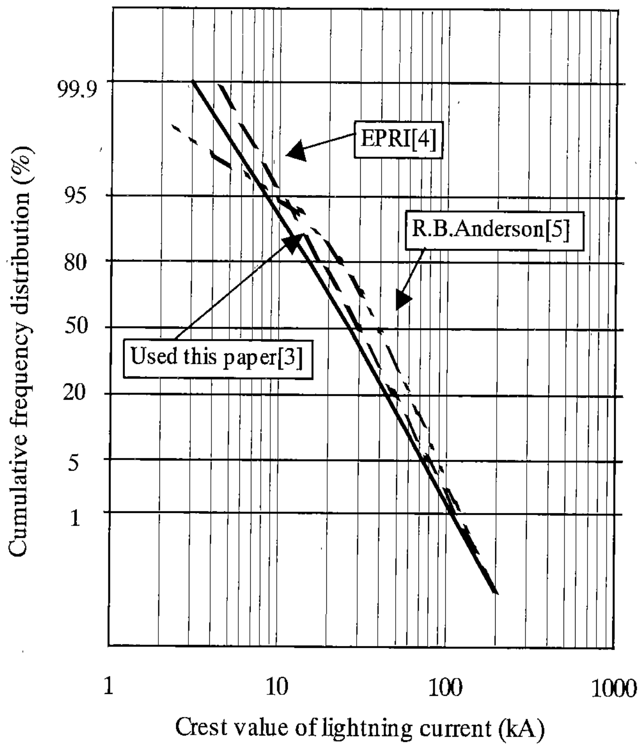

Fig.2. Cumulative frequency distribution of the crest value of the lightning current.

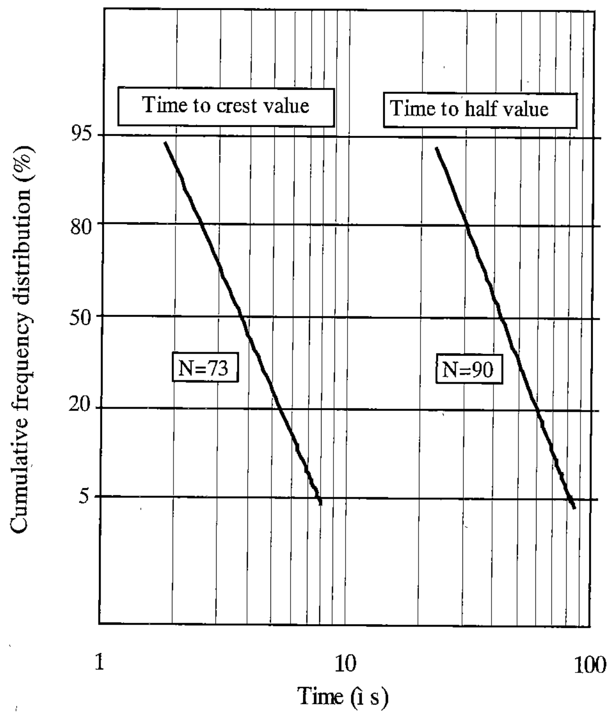

Fig.3. Cumulative frequency distribution of the lightning current waveform (By Ikeda et al. [6]).

described in reference [2]. New points in this paper are shown below.

(1) Correlation between the flashover rate and constructing cost of power distribution line can be made clear.

(2) This method can study the relation between the reliability and cost performance.

(3) Influence of statistics value of lightning current waveforms is considered.

(4) Influence of nearby buildings is considered.

2.2 Lightning current parameters

As the lightning current waveform, ramp waveform is used in this calculation. Lightning current parameters are shown below.

(a) Crest value

The crest value of lightning current is selected randomly by the Monte Carlo Simulation Method. Applied cumulative frequency distribution is shown in Fig. 2 [3]. The curve is the observed result in Japan.

(b) Times to crest and half value

Times to crest and half value of lightning currents are also selected randomly by the Monte Carlo Simulation Method. Applied statistical values of current parameters which were observed in Japan are shown in Fig. 3 [6].

2.3 Nearby building

Flashover rate is influenced by nearby buildings because the height of the building is usually the same as or higher than that of the concrete pole. Lightning striking area is shown in Fig. 4. In this figure, model (a) is the case that the building does not exist around the distribution lines, and (b) is the case that the only one building exists. In comparison of (a) and (b), it is clear that the lightning striking area to the distribution lines of (b) is smaller than that of (a) caused by the building existed. But generally plural buildings exist around distribution lines. Fig.4(c) shows that plural buildings exist around power distribution lines at the same interval. In comparison of (b) and (c), lightning striking area to the isolated building of (b) is larger than that to the nearest building of (c). So calculated flashover rate of (b) is bigger than that of (c) because of the increase of flashover due to induced over-voltages. Because many buildings generally exist around power distribution lines in Japan, (c) is recommended as the calculating model. But model (c) is very complicated. So the model of (d) which is simplified model of (c) is used

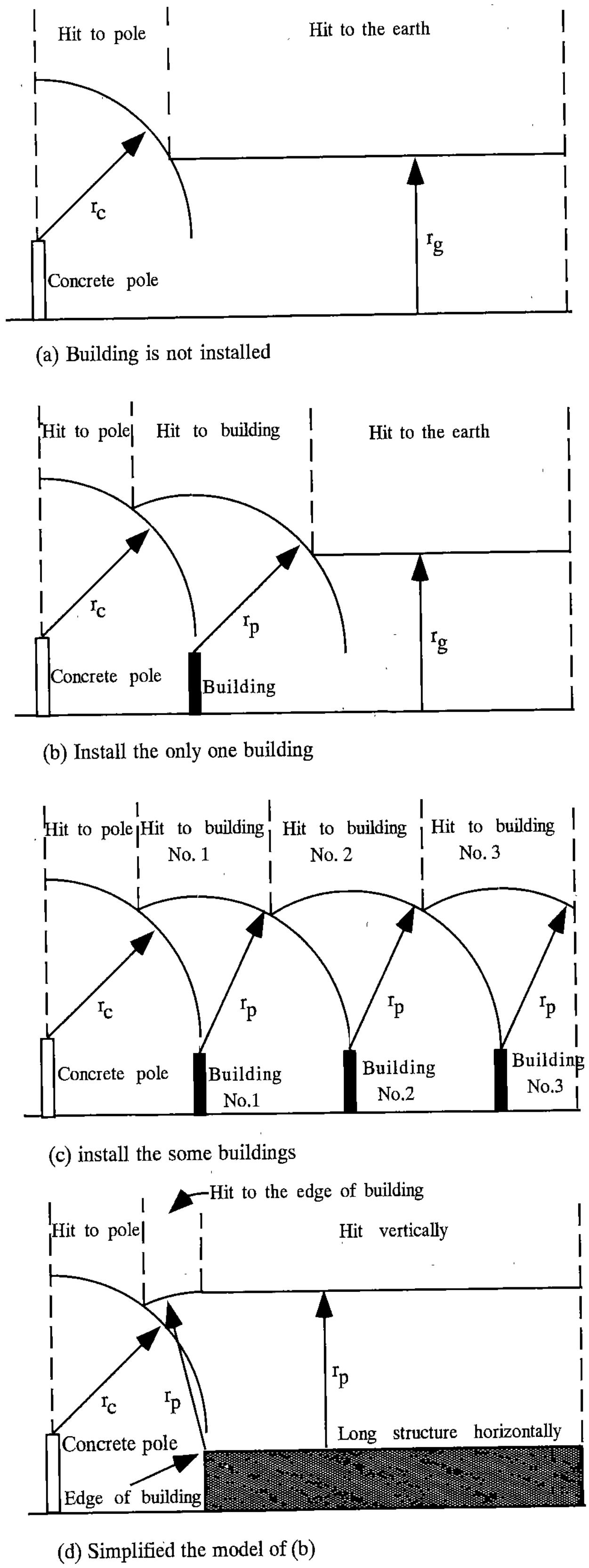

Fig.4. Lightning striking area according to the surrounding buildings.

in this calculation. Final striking distances of power distribution lines, buildings, and the earth are supposed to be equal as shown in equation (1) [7] because these flashover characteristics are not clear at present.

$$Rc = Rg = Rp = 8\,I^{0.65} \qquad (1)$$

Where,

I : Peak value of lightning current [kA]
Rc: Final striking distance of distribution lines [m]
Rg: Final striking distance of the earth [m]
Rp: Final striking distance of buildings [m]

Fig.5 shows an example of the relation between the ratio of direct lightning hits and the distance from a concrete pole to the building. In this figure, it is clear that the ratio of direct lightning hits decreases by existence of the nearby building, and that ratio becomes smaller when the height of the building is higher.

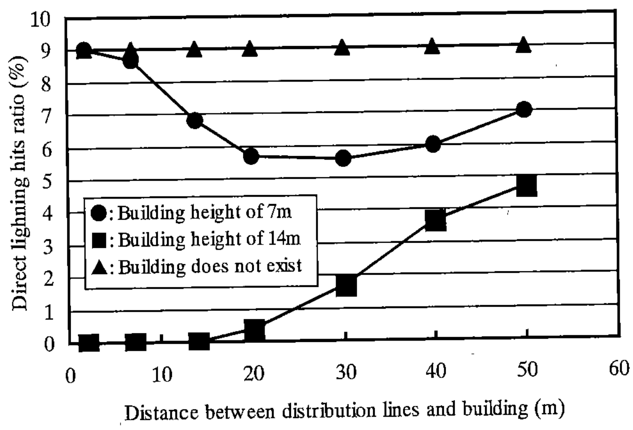

Fig.5. Ratio of direct lightning hits on power distribution lines in consideration of nearby buildings.

2.4 Calculation of the flashover rate

Flashover rate calculated from a number of calculations is shown in equation (2).

$$P = (K / N) * (IKL / 10) \qquad (2)$$

Where,

P: Flashover rate [Number/km·year]
N: Number of calculation
K: Number of flashover
IKL: Iso-Keraunic Level [days / year]

Here density of ground flash [flash / km ^{2}·year] is supposed one tenth of IKL [4].

Fig. 6 shows the comparison of the effect of each factor to the flashover rate. In this figure, consideration of statistics value of current waveforms or nearby buildings decreases the flashover rate. And consideration of these two parameters further more decreases the flashover rate.

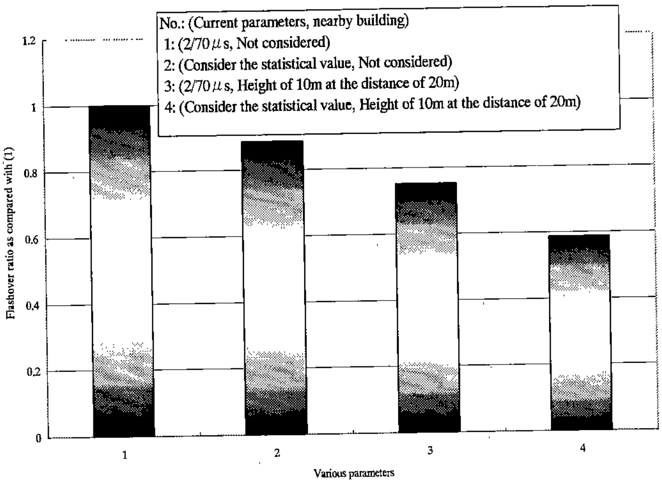

Fig.6. Comparison of flashover rate applied various parameters.

Table.3. Comparison of total cost constructing the power distribution lines.

Grounding interval of ground wire	Installing interval of surge arresters: 50m	100m	200m	400m	Not installed
50m	127%	120%	116%	115%	113%
100m	127%	117%	114%	112%	110%
200m	127%	117%	112%	110%	109%
400m	127%	117%	112%	110%	108%
Not installed	120%	110%	105%	102%	100%

3.2 Relation between reliability and cost performance

Table.3 shows the construction cost ratio of power distribution lines installing grounding wire or surge arresters. When the protection equipment is surge arrester only, the shorter interval of surge arrester is, the higher construction cost ratio is. On the other hand, when the protection equipment is grounding wire only, the construction cost ratio increases with the installation of the grounding wire, but it does not increase very much with the interval of grounding wire. Cost ratio installing surge arresters at every pole increases 20 % of the value of that without lightning protection equipment. When grounding wire is grounded at every pole, the ratio is 13 %, for these combinations it is 27 %.

As shown in Table.3 cost ratios of following three cases are almost equal.

(1) Grounding wire is grounded at the interval of 100m, and surge arresters are not installed.

(2) Surge arresters are installed at the interval of 100 m, and grounding wire is not installed.

(3) Combination both a grounding wire and surge arresters at the interval of 400 m.

Calculated results of above three cases in consideration with the statistics value of current waveform and nearby buildings are shown in Table.4 and Fig.7.

In this figure flashover rate for the case of surge arresters only is the smallest, and second is the case of combination and third is the case of grounding wire only. It is clear that flashover rates for various protection designs are much different in spite of the same construction cost.

4 CONCLUSIONS

The authors developed an analytical method for the flashover rate due to lightning on power distribution lines in consideration of both reliability of power supply

Table.4. Comparison of the flashover rate as the same constructing cost of power distribution lines.

IKL=30

Protection design		Ground wire only (100m)			Ground wire and surge arresters (400m)			Suege arresters only (100m)		
Coase of flashover		Undirect hit	Direct hit	Sub total	Undirect hit	Direct hit	Sub total	Undirect hit	Direct hit	Sub total
Flashover rate	1 phse only	0.027	0	0.027	0	0	0	0	0.036	0.036
	2 phases over	0.024	0.09	0.114	0.006	0.084	0.09	0.003	0.033	0.036
	Total	0.051	0.09	0.141	0.006	0.084	0.09	0.003	0.069	0.072

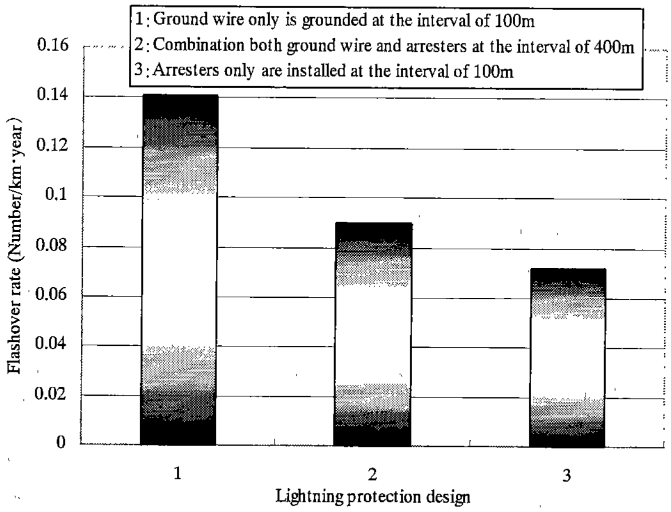

Fig.7. Comparison of flashover rate for various protection design as the same construction cost.

and cost performance. This method can show the lightning protection effect for various protection designs including direct lightning hits and lightning induced over-voltages. Consequently it is clear that flashover rate considering various parameters such as lightning current waveform and nearby building is smaller than that considering none of them. Moreover flashover rates for various protection designs such as grounding wire only, surge arresters only, and these combination are much different each other in spite of the same construction cost for power distribution lines.

Acknowledgment

The authors are very grateful to Dr. Shindo for his suggestions, and Mr. Sugimoto for his help of this study.

(Manuscript received December 25, 2000; revised June 11, 2001)

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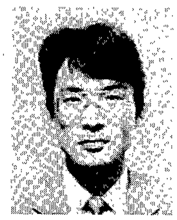

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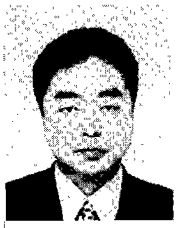

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