LPATS를 이용한 한반도 뇌격파라메터의 통계분포에 관한 연구('96~'98)

論 文
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A Study on the Statistical Analysis of Lightning Parameters by Lpats in Korea ('96~'98)

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Abstract - To study the basic research of the lightning parameters for power system operation, LPATS(Lightning Positioning and Tracking System) has been introduced since 1995 in KEPCO(Korea Electric Power Corporation). We have developed the lightning parameters analysis program which can produce accumulative magnitude distribution of lightning current and IKL map by LPATS data. We obtained the various statistical distributions of lightning current parameters since 1996 by the lightning analysis program for the pertinent insulation design. In this paper, we describe the LPATS system in KEPCO, the statistical distribution of lightning current parameters and the IKL(Isokeraunic Level) map from 1996 to 1998. And the compared results between the calculated LFOR(lightning flashover rate) and the observed rate are also described.

Key Words : LPATS(Lightning Positioning and Tracking System), Lightning Parameters, IKL(Isokeraunic Level) map, LFOR(lightning flashover rate)

1. Introduction

Because the overhead transmission lines are exposed to the outdoor weather, the faults of the transmission lines are due to natural conditions, and among these faults, the outage rate by lightning is about 40 % or more.

The lightning causes the damage of power system equipments, the shut down of electricity and the electro-magnetic interference such as communication failure, mal-operation of relay and undergoing total destruction of electronic circuit board, etc.

Therefore, the pertinent insulation design is important, not only to decrease the damage of the facility itself but also to increase the reliability of electric power system.

For these reasons, we have to obtain and accumulate the lightning current parameters for the basic lightning research.

By the manually accumulated data from 1968 to 1992 in KEPCO, the average IKL was 12.19 and two third of lightning occurrence was concentrated in summer season, from June to August, of the year[1,2].

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This paper describes the LPATS system in KEPCO, the statistical distribution of lightning current parameters, the IKL map from 1996 to 1998 and the compared results between the calculated LFOR and the observed rate.

2. LPATS of KEPCO and its analysis program

LPATS has been operated since 1995 in KEPCO, which was developed by ARSI(Atmospheric Research System, Inc), U.S.A.[3]. For the site accuracy of this system, the remote receivers were installed at six sites based on the time of arrival methods. Each signal processed by an LPATS receiver is digitized to 8-bit resolution at a sample rate of 5 MHz. A total of 512 samples are taken, resulting in approximately 100 μsec of capture waveform discrimination. The receiver bandwidth is a bandpass characteristic with -3 dB limits of 2.5 kHz and 300 kHz. The waveform risetime is limited to approximately 1.0 μsec(minimum).

And the waveform buffers were installed at four sites and linked with KEPRI. It receives not only the lightning current data such as lightning position, time, number of strokes per flash and peak current, but also the waveform data including time to peak, time to half of peak and waveform. The measured lightning current data are transmitted to the central analyzer and the waveform data are transmitted to LWAS(Lightning Waveform Archive System).

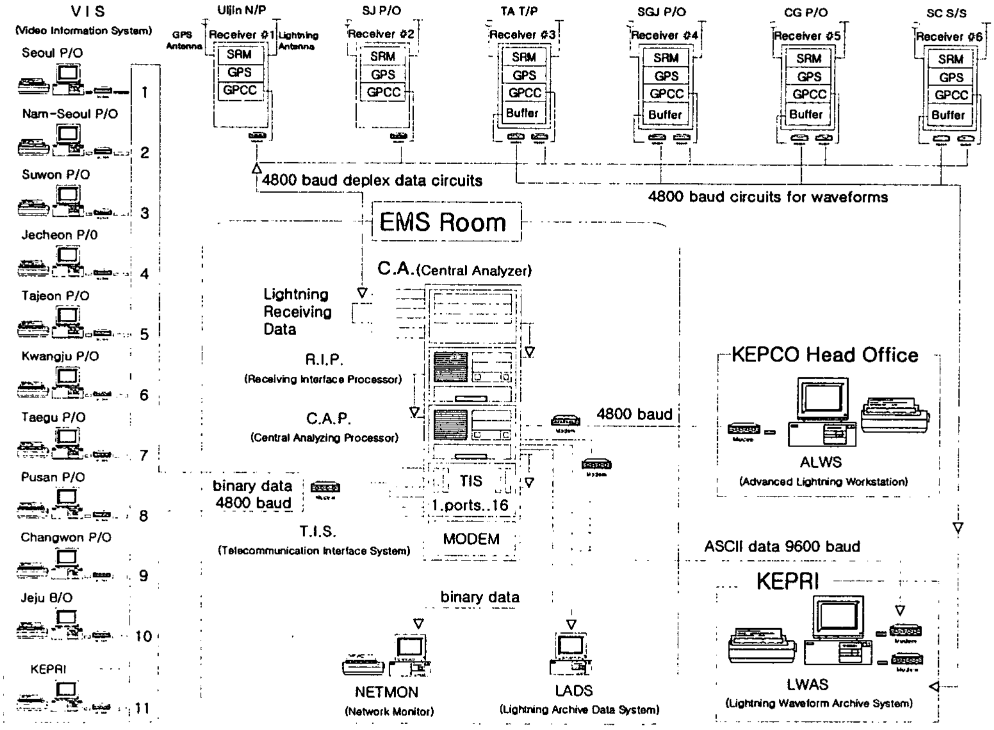

Fig. 1 Scheme of KEPCO LPATS system

We have developed the lightning analysis program, which can make the database of the lightning data, the lightning parameters analysis, the IKL maps and the comparison between the LFOR and the lightning current distribution.

3. Lightning Data Analysis Results

The rate of negative lightning was about 80 % in the total strokes from 1996 to 1998, which is similar to that of foreign countries. The rate of multi-stroke was about 7 % by the definition of multi-stroke, which has 10 km of radius and within 500 msec of time interval.

From the view point of season, the lightning was concentrated in the summer due to many heavy typhoons and thunderstorms.

The negative maximum of lightning current was 138.6 kA on 8th of August in 1998 located at latitude 37.1169 and longitude 126.9810(Chung-Nam, Non-San). And the positive one is 170.9 kA on 17th of April in 1998 located at latitude 35.0618 and longitude 126.9906(Jeon-Nam, Hwa-Soon). The average magnitude of lightning current was 22.34 kA during three years.

From the view point of the region of land, in the figure 2, the lightning was concentrated on Chung-Nam and Kyung-Kee province. Also, there are severest the stroke density number per square km in these regions.

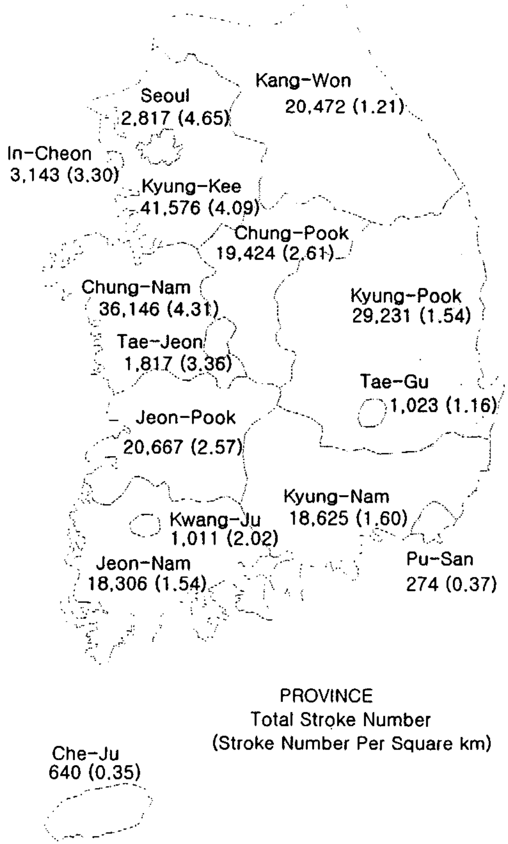

Fig. 2 Analysis result of lightning data

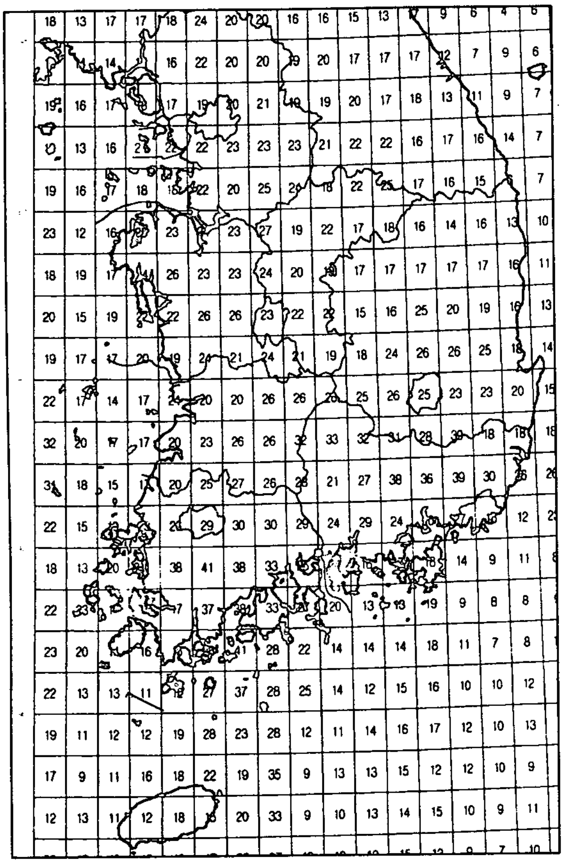

Fig. 3 Cumulative distribution of lightning current

The analysis program can draw the IKL map of mesh and contour type. Figure 3 is the IKL map of mesh type from the lightning data during three years. In this figure, we divided the meshes as a quarter of one degree longitudinally and latitudinally. The maximum value of IKL is 41 and the 90 % cumulative value is 30 for the insulation design of transmission line.

We had derived the equation of cumulative distribution of lightning current, following the same format of equation as Anderson-Erikson and Popolansky[4].

First, we used the Least Square Method, for making $f(I)$ from obtained lightning data. This equation is expressed by the Log-Normal Distribution. It has a positive skew and is defined from I=0 to I=∞. It has two parameter distribution ; the Median(M) and slope parameter(β).

The distribution function is ;

$$f(I)=\frac{1}{\sqrt{2\pi}\,\beta}\frac{1}{I}e^{-\frac{1}{2}\left[\frac{\ln I-\ln M}{\beta}\right]^2} \quad (1)$$

For, $0 < I < \infty$

The cumulative distribution function is ;

$$F(I)=\int_0^I\frac{1}{\sqrt{2\pi}\,\beta}\frac{1}{I}e^{-\frac{1}{2}\left[\frac{\ln I-\ln M}{\beta}\right]^2}dI \quad (2)$$

Now, Define the reduced variate, Z, as ;

$$Z=\frac{\ln I-\ln M}{\beta},\quad dZ=\frac{dI}{d\beta} \quad (3)$$

$$F(Z)=\int_{\infty}^{Z}\frac{1}{\sqrt{2\pi}}e^{-\frac{1}{2}Z^2}dZ \quad (4)$$

The possibility equation of cumulative distribution of lightning current is expressed as follows ;

$$P=1-F(I)=\frac{1}{1+(I/M)^k} \quad (5)$$

Anderson-Erikson $P=\frac{1}{1+(I/31)^{2.6}}$ (6)

Popolansky $P=\frac{1}{1+(I/25)^{2.0}}$ (7)

KEPRI 96-98 $P=\frac{1}{1+(I/19)^{3.5}}$ (8)

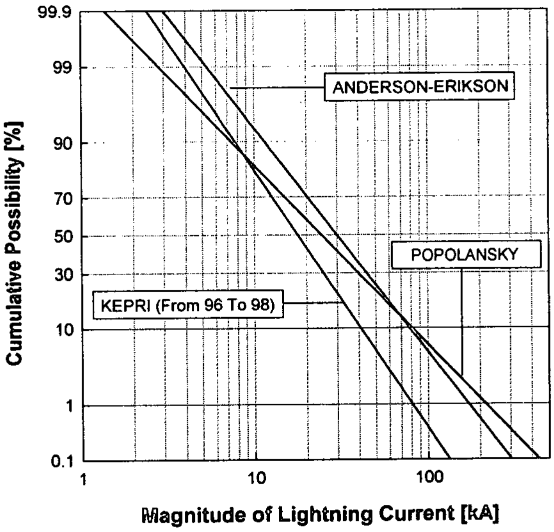

Fig. 4 Cumulative distribution of lightning current

Table 1 The analysis results of the waveform data

Contents	Author	95 %	50 %	5 %
Time to peak [sec]	KEPRI	0.44	1.90	12.8
	JAPAN	1.80	5.50	8.0
	Berger	1.80	5.50	18.0
Time to half of peak [sec]	KEPRI	3.00	8.80	38.0
	JAPAN	22.00	40.00	85.0
	Berger	30.00	75.00	200.0
Rising time [kA/sec]	KEPRI	0.50	2.04	5.0
	JAPAN	1.30	5.00	22.0
	Berger	5.50	12.00	32.0

These equations ((6)~(8)) show the comparison result with that of Anderson-Eriksson and Popolansky, and figure 4 shows the analysis result.

For an example, we can recommend the magnitude of lightning current for the insulation design as 40 kA, that is 10 % of lightning strokes have magnitudes equal to or greater than 40 kA.

For the application of lightning data at insulation design, the basic parameters are the waveform data including time to peak, time to half of peak and waveform.

Table 1 describes the analysis results of the waveform data during past 3 years. The average value of time to peak is 2.53 sec, that of time to half of peak is 10 sec, that of rising time is 2.71 kA/sec.

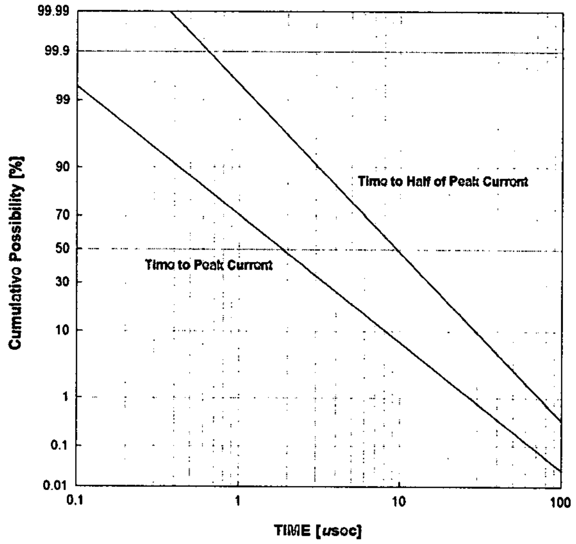

Fig. 5 Cumulative distribution of parameter

By table 1 and figure 5, the KEPRI result was quite difference with the foreign results. We guessed that the difference was caused by the regional difference and the performance of the lightning detecting equipment.

Generally, for the certification of the LPATS detection efficiency, the lightning data were compared with the outages of transmission line[5].

During 1998, the outage rate of transmission line by lightning was 73 % of the total outages, according to the annual report of transmission line outage from the KEPCO head office.

And among the total outage by lightning, the 85 event was detected by LPATS, which detection rate is 53 % approximately. Judging by the events which correspond to LPATS, the outage by lightning was concentrated on July and August, the summer season of KOREA.

Figure 6 shows the amplitude distribution of lightning current, which caused to the outages. The maximum amplitude is 170 kA and the minimum is 4.4 kA. The average amplitude of lightning current is 32 kA.

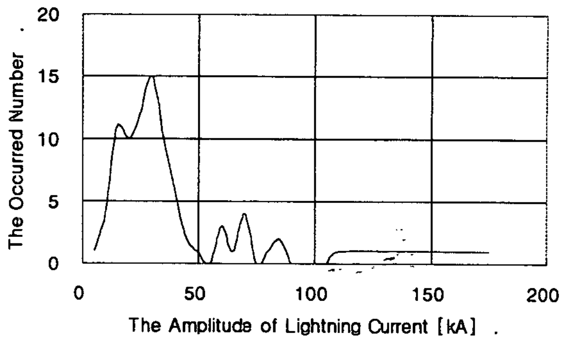

Fig. 6 The amplitude of lightning current, which caused to the outages

We can estimate the LFOR of the transmission line using several equation suggested by EPRI of USA or CRIEPI of Japan, and the LFOR is divided by the SFFOR(Sheilding Failure Flashover Rate) and the BFOR(Back Flashover Rate). According to the equations listed above, the LFOR is proportional to the ground flash density(Nd), the IKL, the amplitude of lightning current and the trespass angle of lightning[6].

$$n = N\int_{I_{0MIN}}^{I_{0MAX}} P(I_0)\, r_{SS} \cdot \int_{\theta_2}^{\theta_1} \frac{\sin(\theta - \alpha)}{\cos\alpha} \cdot f(\alpha)\cdot d\alpha \cdot d\theta \cdot dI_0 \qquad (9)$$

n : *SFFOR (Sheilding Failure Flashover Rate)*
N : *Ground Stroke Density [strokes/ km^2/year]*
$P(I_0)$: *Cumulative Possibility of Lightning Current*
r_{SS} : *Striking Distance [m]*
α : *Stroke Angle*
θ : *Vertical Angle by exposure arc*
$f(\alpha)$: *Possibility Distribution of Stroke Angle*
I_0 : *Lightning Current [kA]*

$$P(n) = \frac{N}{10}\int_0^{\infty}\int_{\theta_{m}}^{\theta_{M}} P(I_0)\cdot \delta P(I_0)\cdot P(\theta, m) dI_0 \cdot d\theta \qquad (10)$$

$P(n)$: *BFOR (Back Flashover Rate)*
N : *Ground Stroke Density [strokes/ km^2/year]*
$P(I_0)$: *Cumulative Possibility of Lightning Current*
$P(\theta, m) = K_m \cos^m \theta$
θ : *Vertical Angle by exposure arc*

Table 2 The lightning flashover rate

[No./100km.year]

LFOR	154 kV	345 kV
Calculation	1.42	0.90
Observation	0.79	0.40

Table 2 shows the difference between the calculated LFOR of transmission line and the observed outage rate. The reason of big difference should be analyzed in the near further.

4. Conclusion

In this paper, we described the analysis results of the lightning data by LPATS in Korea since 1996.

The rate of negative lightning was about 80 %, which was similar to that of foreign countries.

We obtained the equations of cumulative distribution probability of lightning current magnitude, the time to peak, the time to half of peak and the rising time of lightning current waveform.

During 1998, the outage rate of transmission line by lightning was 73 % of the total outages. And among the total outage by lightning, the 85 event was detected by LPATS, whose detection rate is 53 % approximately.

To raise the detection efficiency of LPATS, we are going to install the direct lightning current measuring system in the near future.

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