The inspection results regarding lightning location error of KEPCO-LPATS and the calculated results on the lightning surge in the KEPCO power system

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***Abstract* – Due to the overhead transmission lines being exposed to the weather, the faults of the transmission lines are due to natural conditions. Among these faults, the outage rate by lightning is about 50%. Lightning causes damage to the power system equipment, a shutting down of electricity, and electromagnetic interference. For the optimal operation of the power system and basic research of the lightning parameters, LPATS-III(Lightning Position and Tracking System) has been in place since 1995 in Korea. This paper describes the inspection results regarding lightning location errors and the calculated results on the lightning surge in the KEPCO power system.**

Keywords – Lightning, Surge, LPATS(Lightning Position and Tracking System), EMTP(Electro-magnetic Transient Program), Power System

I. INTRODUCTION

Due to the overhead transmission lines being exposed to the weather, the faults of the transmission lines are due to natural conditions. Among these faults, lightning is responsible for 50% of the power outages in Korea. Lightning causes damage to the power system equipment, the shutting down of electricity, and electromagnetic interference. For the optimal operation of the power system and the basic research of the lightning parameters, LPATS has in operation since 1995 in Korea.

Last year, power failure caused by lightning was reported in two cases in the KEPCO 765 kV transmission line. Also, there were several failures due to lightning at other voltage levels such as 154 kV and 345 kV. We have investigated the lightning currents from LPATS, which caused a transmission line fault, and we calculated the lightning surges in the power system using EMTP. Depending upon the above data, the transmission line failure was classified as either a shielding failure or the back-flashover.

This paper describes the investigation results about the lightning location error and the results regarding the lightning surge in the KEPCO power system.

II. THE INSPECTION RESULTS ABOUT LIGHTNING DATA AND IT'S LOCATION ERROR

LPATS has been in operation since 1995 in KEPCO. For site accuracy of this system, remote receivers were installed at six sites based on the time of arrival methods. It receives not only lightning current data such as lightning position, time, number of strokes per flash and peak current, but also waveform data including peak times, time to half of a peak and waveform. This section describes the investigation results of lightning current amplitude and the location error by comparing the same lightning data on the Korean peninsula, which was simultaneously detected by LPATS of Korea and Japan.

A. The statistical distribution of lightning current

The ratio of negative lightning was about 80 % in the number of total strokes from 1996 to 2002, which is similar to that of foreign countries. The multi-stroke rate was about 7 % by the definition of a multi-stroke, which has a 10 km radius and is within a time interval of 500 milliseconds.

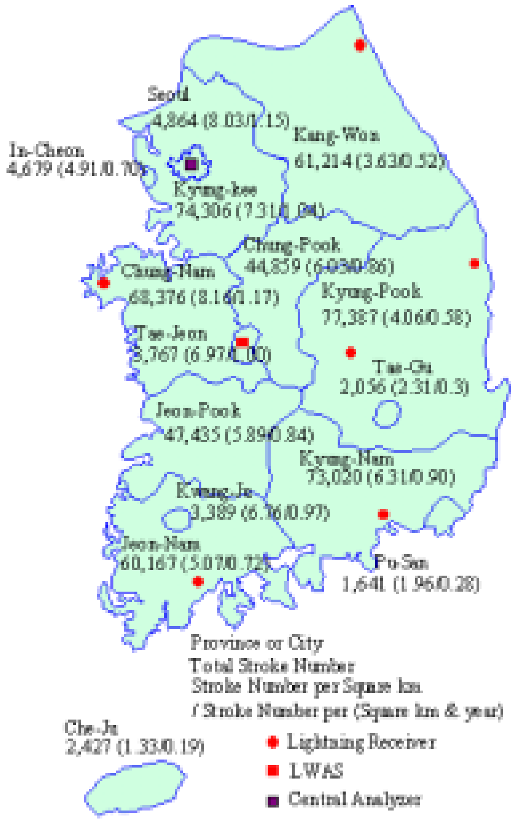

Fig. 1 The regional distribution of lightning data

From the viewpoint of seasons, lightning was concentrated in the summer due to many heavy typhoons and thunderstorms. Also, during the summer season, many power failures caused by lightning were reported. The negative maximum lightning current was –162.6 kA on the 19th of May 2000 located at a latitude of 37.59^{O} and a longitude of 126.96^{O} (Ul-Jeong 765 kV T/L). The positive one is 274.5 kA on the 28th of March 2000 located at a latitude 34.97^{O} and a longitude 128.44^{O} (KN Go-Seong). The average magnitude of a lightning current was 20.36 kA during a 7 year period. From the regional viewpoint in Fig. 1, lightning was concentrated in the Kyung-Kee and Chung-Nam provinces. Also, these areas had the height stroke density number per square km.

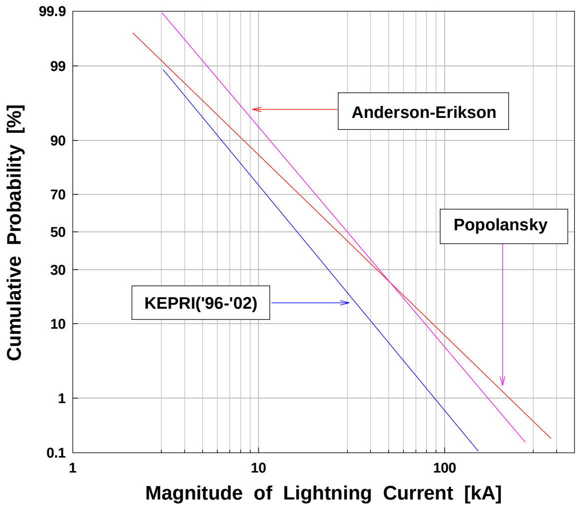

Fig. 2 The cumulative distribution of lightning magnitude

Fig. 2 shows the cumulative distribution of lightning current magnitude in Korea from 1996 to 2002[2, 3, 4]. For example, we can recommend the proper magnitude of a lightning current for insulation design as 40 kA, This means that 10 % of lightning strokes have a magnitude equal to or greater than 40 kA.

B. The estimated detection rate of LPATS data and the inspection results about the lightning location error

Fig. 3 shows the amplitude distribution of the lightning current which caused outages in the power system. The maximum amplitude is 200 kA and the minimum is 8 kA. The average amplitude of a lightning current is 40 kA. By Fig. 3, the estimated detection rate of LPATS data in comparison with real failures in the power system is about 60 %. The error was determined by comparing the measured data in LPATS-Korea with the data which was detected in Japan. Both were examined to confirm the accuracy of LPATS. The data that was examined within 12 hours on January 15 2002 were used.

First, we chose the data that was measured at same time(hour, min) with lightning data in Japan among the ones detected in Korea. And then we selected the data, which were included within 10-km range using latitude and longitude.

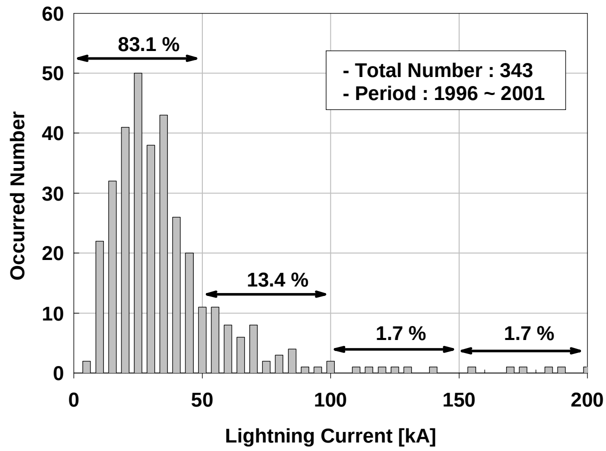

Fig. 3 The amplitude distribution of lightning current, which caused to the outages

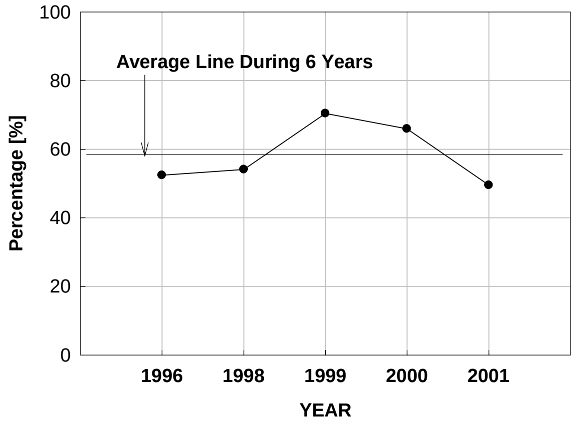

Fig. 4 The detection rate of LPATS by the comparison with real failures in the power system

Table 1. Compared results for accuracy

		Before		After	
		Japan	Korea	Japan	Korea
Total Number		856	830	259	259
Average [kA]		-46.8	-17.8	-47.3	-14.34
Lightning Number	Negative	629 73.5 %	476 57.3 %	193 74.5 %	195 75.3 %
	Positive	227 26.5 %	354 42.7 %	66 25.5 %	64 24.7 %

Table 1 shows the total data and the average current before and after they were selected on the conditions proposed. The data was only selected if it satisfied the conditions proposed in comparison with the lightning data from Japan. As a result of the comparison, 30.3% of the total data from Japan and 31.2% of the Korea data decreased. Regarding the average current, there was an increase of 3.51kA in the Korean data. On the other hand, there was a decrease of 0.45kA in the Japanese data.

For the data from Japan, the share of negative polarity increased 1% from 73.5% to 74.5% and the share of positive polarity decreased 1% from 26.5% to 25.5%. For the Korean data, the share of negative polarity changed from 57.3% to 75.3% and positive polarity changed from 42.7%

to 24.7%. Fig. 5 shows the total data of lightning according to time distribution. As a result, a large number of lightning patterns occurred mostly around 8 o'clock.

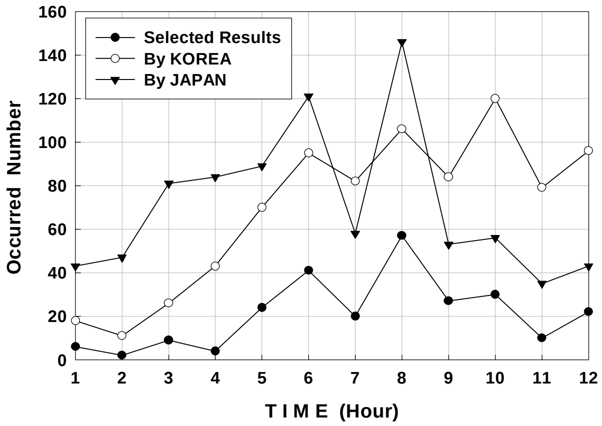

Fig. 5 The time distribution of comparison results

The current difference, time difference and distance difference were calculated with 259 data. UTM was used for the distance difference instead of latitude and longitude coordinates. As a result, the total average of current difference was 32.96kA, the time difference was 12 seconds and distance difference was 30.5541m.

As for location and time accuracy, LPATS is satisfactory, but we need the calibration of lightning current amplitude of LPATS by direct measurement results about the lightning current or the other detection methods.

C. Calibration of LPATS System

We checked the LPATS of KEPCO in 2002 in order to increase detection efficiency and to adjust the lightning current amplitude. First, we substituted the stroke antenna for each receiver site and calibrated the threshold level and gain of antenna.

During the calibration of sensitivity of each receiver, we used the remote lightning data recorded 500 km to 1,500 km off the cost of the Korean peninsula. Each receiver site should detect a similar amplitude for the same distance lightning stroke if the stroke distance is much longer than each receiver's base line.

In order to calibrate the lightning current amplitude of LPATS without any signal transmitter, we assumed that the median value of lightning current cumulative distribution is identical everywhere an Earth.

This method also needs lot of measured data at each receiver site. Unfortunately, we did not have such data in the past. We will accumulate the lightning current amplitude from each receiver site for the calibration of lightning currents starting from this year.

III. LIGHTNING SURGE MODELING BY EMTP

Last year, there were two reported cases of power failure due to lightning in the KEPCO 765 kV transmission line. Also, there were several failures caused by lightning at other voltage levels such as 154 kV and 345 kV.

We have investigated lightning currents from LPATS which caused transmission line fault and calculated lightning surges in the power system by EMTP. Depending upon the above data, the transmission line failure was classified as a shielding failure or a back-flashover[3, 4, 6].

A. Lightning Data by LPATS

Table 2. LPATS lightning data (2002.06.05)

Min	Sec	Lat			Lon.			I [kA]
19	10.251	37	34	55	127	46	41	-15.08
19	31.640	37	31	34	127	47	30	-9.14
19	42.148	37	31	3	127	44	2	-10.7
19	42.234	37	31	3	127	43	45	-16.22
19	42.395	37	30	57	127	45	31	-8.7
20	0.899	37	43	17	127	50	39	-15.96
20	1.079	37	36	13	127	49	9	-21.02
20	46.513	37	32	8	127	44	26	-6.17
21	1.542	37	44	36	127	51	28	-13.81
21	6.781	37	38	14	127	51	24	-8.94
21	39.853	37	44	31	127	51	37	-10.77
21	45.793	37	32	55	127	48	5	-11.39
21	47.767	37	42	21	127	46	7	-17.68
21	53.827	37	45	17	127	48	13	-14.16

During the failure caused by lightning at the 765 kV transmission line on June 5^{th}, LPATS had detected 14 strokes(shown in Table 2). The closest lightning to the transmission line was 14 kA and 21 kA at the same time. The second one (22 kA) was exactly in the same position as the tower location on the GIS map(Geographic Information System map).

B. Transmission line modeling

The 765 kV transmission line consists of two overhead ground wires and a six-phase power lines of six bundle conductors. For the EMTP modeling, we used the K.C.Lee model because the surge frequency is very high in lightning phenomena, and the calculated result is identical to that of the frequency model[5]. The height of the transmission towers are about 90 meters. The transmission towers are arranged in groups of up to 10 towers including the fault tower. The rest of the towers are modeled as a matching resistance matrix to prevent the reflection of the travelling wave. Also, the four-section tower model with a distributed line parameter is used for high accuracy. The tower footing resistances have a level of 10, 15, 20, 30, 40 and 50 ohms for the modeling.

The tower model directly affects the wave shapes of lightning surges which appear on the arcing horn gap. For the arcing horn gap model, we used the linear inductance model. If the generated voltage between the arcing horn gap exceeds the withstand voltage of the voltage time curve of arcing horn gap, the TACS controlled switch is automatically closed, which can simulate a flashover. We used the CIGRE volt-time characteristics for the flashover of line insulator’s arcing horn[4, 6].

We assumed that the lightning stroke is in the middle of the towers. The lightning surges would travel to the other towers if the back flashover occurs in that tower. The assumed lightning currents are between 0 and 200 kA of peak, with a 2 msec wave front and a 70 msec wave tail[2]. Also, we considered the shielding failure case where it was assumed that the lightning stroke is on the lower phase.

C. Modeling Results

We calculated the critical lightning current that causes the back-flashover at the arcing horn. We assumed that lightning was induced at the top of tower. The lengths of the arcing horn were 4.8 m (the suspension type) and 4.6 m (the tension type). At a level of 15 ohm for tower footing resistance, the lightning current should be about 124 kA for an occurring back-flashover at the arcing horn. Table 3 shows the calculated results and Fig. 6 shows the results of arcing horn flashover by 118 kA (TFR=15 ohms).

Table 3. The calculated results (BFOR) [kA]

TFR [ohms]	10	15	20	30	40	50
79 m tower	136	124	120	112	104	96
90 m tower	120	118	116	110	104	96

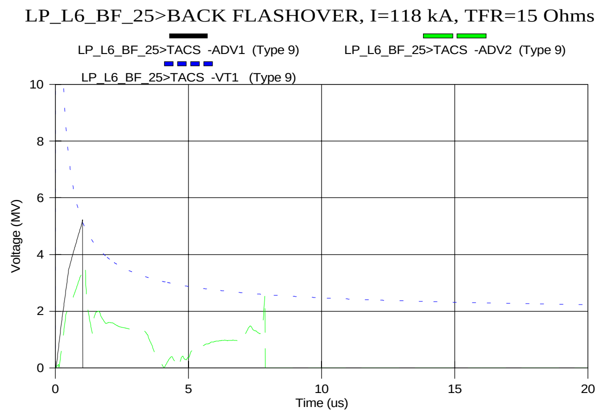

Fig. 6 The calculated results (BFOR)

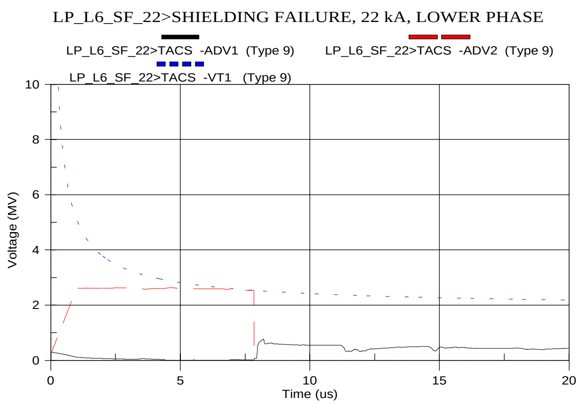

Fig. 7 The calculated results (SFFOR)

Also, we considered the shielding failure case, where it was assumed that the lightning stroke is on the lower phase. When the lightning current was about 22 kA, there was a flashover at the arcing horn. Fig. 7 shows the results of the arcing horn gap flashover by 22 kA of lightning current (TFR=15 ohms).

Fig. 8 shows the tower configuration and hill side angle of faulted 765 kV Line. We concluded that this failure was the shielding failure from LPATS data and the calculated results.

By the same procedure, we concluded that about 70 % of the total outages by lightning was caused by shielding failure in the another voltage level (154 kV and 345 kV).

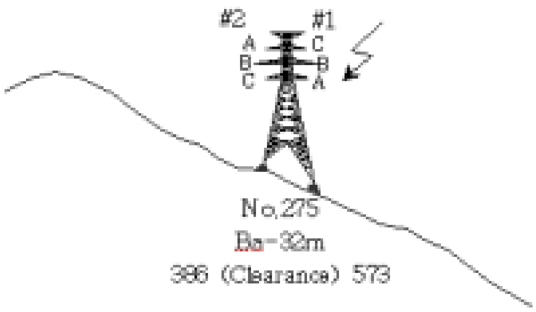

Fig. 8 The tower configuration and the SFFOR concept in 765 kV line

VI. CONCLUSION

We described the investigation results about lightning location error and the calculated results on the lightning surge in the KEPCO power system in this paper.

- The ratio of negative lightning was about 80 % of the total strokes from 1996 to 2002.
- By comparison of the failure records in the power system and detected lightning from LPATS, the estimated detection efficiency of LPATS is about 60 %.
- As for the location and time accuracy, LPATS is satisfactory. We, However, need the calibration of lighting current amplitude of LPATS by direct measurement of the lightning current or by indirect detection methods.
- Judging from the calculated results, we concluded that the tripping of the 765 kV transmission line was due to a shielding failure.

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