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Evaluation of the New LS7001 Network in the Chubu Region of Japan after Site-Error Corrections

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***Abstract*— Chubu Electric Power Co., Inc. (CEPCO) has constructed a Lightning Location System (LLS) consisting of ten LS7001 sensors in the Chubu Region of Japan. Lightning stroke information provided by the network is used in the maintenance of the company's transmission lines. The sensors were recently updated and relocated to improve the quality of the data. A Network Performance Evaluation Program (NPEP) was completed using lightning location data gathered from November 2011 to October 2012. The resulting site correction parameters were implemented in the LLS for the improvement of location accuracy. In this paper, we report the effects of the site-error corrections on location accuracy, which is quantitatively evaluated by comparing LLS data with data from transmission line faults caused by lightning.**

Keywords—LLS; LS7001t; Site-error Correction; Location accuracy

I. INTRODUCTION

Lightning Location Systems (LLS) detect the electromagnetic field signal caused by a lightning discharge with two or more sensors and estimate the lightning position and the peak current value. They are widely used all over the world (Cummins, 1998). In Japan, electric power companies began installing LLS networks more than 20 years ago. They have been using the real time lightning location data from those systems for a long time to make their electric power company equipment maintenance work more cost efficient (Suda, 1998) (Suzuki, 2006).

Until recently, Chubu Electric Power Company operated an LLS consisting of eight IMPACT sensors in the Chubu region of Japan. In order to utilize the LLS more effectively and to expand the range of lightning observation, Chubu Electric Power upgraded the eight IMPACT sensors to ten LS7001 sensors in 2010 and 2011, in cooperation with Sankosha Corporation. Thereby, the lightning detection performance of the LLS in the Chubu Region was improved and the number of lightning events detected by the system increased by 1.4 to 2.1 times (Momozawa, 2012).

A Network Performance Evaluation Program (NPEP) was completed using lightning location data gathered from November 2011 to October 2012. The resulting site correction parameters were implemented in the LLS for the improvement of location accuracy.

We evaluated the effectiveness of the site error corrections on lightning location accuracy by comparing LLS data with the data from transmission line faults caused by lightning that had occurred from November 2011 to October 2012. We also evaluated the location accuracy by analyzing the LLS located positions of subsequent strokes during lightning flashes where there were multiple strokes to the same point. In this paper, we report those results.

II. OUTLINE OF THE LLS REPLACEMENT

Chubu Electric Power Company is one of the ten electric power companies in Japan and provides electric power to Aichi Prefecture, Mie Prefecture, Gifu Prefecture, Nagano Prefecture, and a portion of Shizuoka Prefecture (See Figure 1).

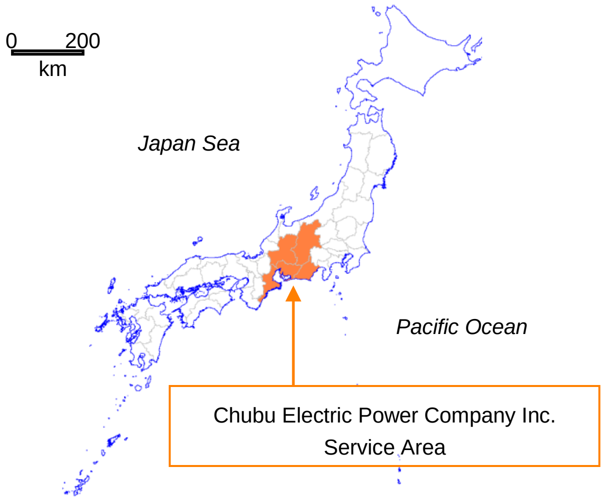

Fig. 1. Japan and the Chubu Electric Power Company Service Area

They built a new plant near the shore of the Japan Sea and a new transmission line running outside their electric power service area. Therefore, at the time the Chubu LLS was replaced, we expanded the range of lightning observations by rearranging the sensors and improved the lightning detection performance in this new area. Figure 2 shows the configuration of the LS7001 sensors. In order to detect lightning strikes to the new plant or the new transmission line more reliably, three sensors separated by about 100km have been located so that the plant and transmission line are surrounded. Figure 3 shows the lightning location accuracy projections before and after the upgrade of the Chubu LLS.

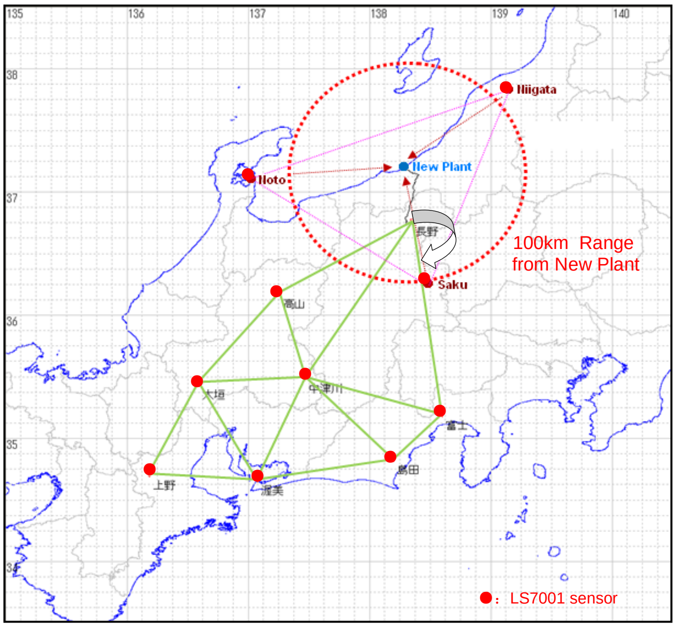

Fig. 2. Ten Sensor LS7001 Network Configuration (The green lines show the previous IMPACT sensor network configuration. The "Nagano" IMPACT sensor was decommissioned and replaced by an LS7001 Sensor at the "Saku" location.)

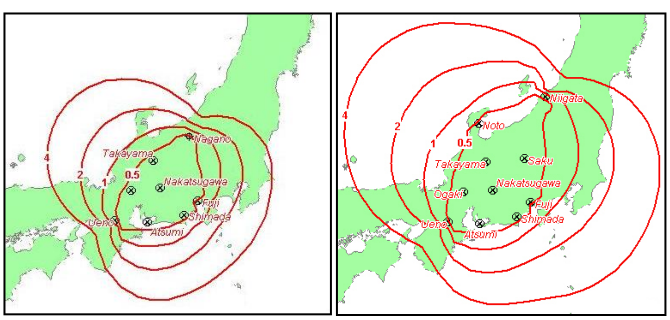

Fig. 3. Location Accuracy Projections for the IMPACT network (left) and the LS7001 Network (right) showing location accuracy range contours of 0 to 0.5km, 0.5 to 1km, 1 to 2km and 2 to 4km)

III. Location Accuracy Evaluation Using Transmission Line Fault Data

In Japan, transmission line fault data is accumulated over many years, and location accuracy evaluations comparing transmission line fault positions with LLS lightning locations are performed widely. In this evaluation method, the features and performance of an LLS can be confirmed by analyzing the transmission line fault data of over a large area. We calculated the site-error corrections using lightning data collected for about one year, applied those corrections and reprocessed the data. We then performed an accuracy evaluation of the location positions on the basis of the reported transmission line fault positions.

A. The method of analysis

There were lightning data from 566 transmission line faults in the period from November 2011 to October 2012, and we chose and used 120 of those data in our study. The selection criterion for lightning data was based on these two factors.

- The fault point is distinct (For example, a position for which arcing horn action has been confirmed).
- There is no bias in the fault location.

We assumed that the position of the selected transmission line fault point was actually struck by lightning, and considered the difference between that location and the lightning location system position to be the location error. The selection criterion of the lightning strike location position was based on the following conditions.

- Within ±1 minute of the transmission line fault occurrence time (a).
- When there were two or more corresponding lightning data, the nearest data was selected (b).
- Lightning data with a current value of 10kA or less were not used (c).
- When the distance of the corresponding lightning data was 10km or more from the transmission line fault point, we concluded that the LLS was not able to detect the lightning strike which caused the fault. (d).

Only one data corresponded to selection condition (d) in all the location error data. We presumed that that this lightning was not able to be located by the LLS, and we removed it for this analysis.

B. Analysis result

Figure 4 shows the distribution of location error variances before and after the site error corrections, and Figure 5 shows the location error cumulative frequency distribution before and after site error corrections. Although there is data where the location error has increased after applying the site error corrections, the average error of all the data was reduced by 0.025km. The 50% value of the cumulative frequency distribution decreased by 0.006km from 0.374km to 0.368km, and the 95% value decreased by 0.12km from 1.870km to 1.750km. Since the location error was reduced after applying the corrections, we have concluded that the site error corrections contributed to the improvement in lightning location accuracy.

These values along with the results of a similar evaluation before the upgrade of the LLS (Shimizu 2000) are shown in Table 1. We were able to confirm that the location accuracy of the LLS after site error corrections has improved greatly when compared with network prior to the upgrade.

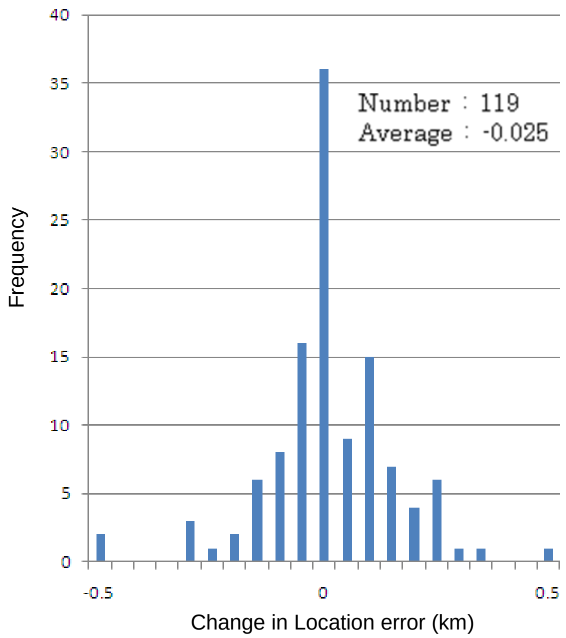

Fig. 4. Change in Location Error before and after Site Error Corrections

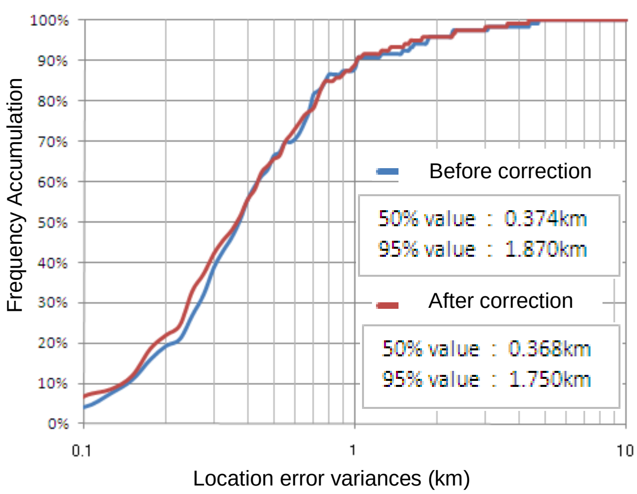

Fig. 5. The Location Error Cumulative Frequency Distribution before and after Site Error Corrections

TABLE I. CHUBU LLS LIGHTNING STROKE LOCATION ACCURACY COMPARISON USING TRANSMISSION LINE LIGHTNING DATA

	50% value of lightning location accuracy	*95% value of lightning location accuracy*
2005/4 – 2008/9 (IMPACT)	0.56 km	3.83 km
2010/11 –2011/10 (LS7001)	0.378 km	1.750 km

IV. LOCATION ACCURACY EVALUATION USING MULTIPLE STROKE DATA

We described the accuracy evaluation of the LS7001 network performed by comparing transmission line fault data with the lightning data from the LLS in the previous section. There was no fault data during the term of this analysis in the area of the new plant where the lightning detection range was extended. Therefore, in this section, we will describe the accuracy evaluation of the LS7001 network before and after the site error corrections performed using multiple stroke data in this region.

A. The method of analysis

We gathered the multiple stroke data used for this accuracy evaluation using the following requirements. These conditions are the same as those used in conventional analysis (Honma 2011).

- The stroke occurred within 1 second after the first stroke
- The stroke occurred within 10km of the position of the first stroke

We selected flashes with ten or more multiple strokes from the obtained data and we assumed that the difference in the location position of each stroke was the location error. In addition, in order to eliminate the strokes that might have struck other points from being included in the same flash, we selected only strokes from the 5th stroke on.

We evaluated the location accuracy before and after implementing the site error corrections in the area including the new plant where we expanded the lightning observation range and in the central area of the LLS network, using this method.

B. The analysis results in the central area of the LLS network

The results of the accuracy evaluation of the LLS network's central area which used multiple stroke data in the area (see Figure 6) of 34.5-36.5 (longitude) / 136.5-138.5 (latitude) on August 18, 2012 is shown below. 582 multiple strokes were used.

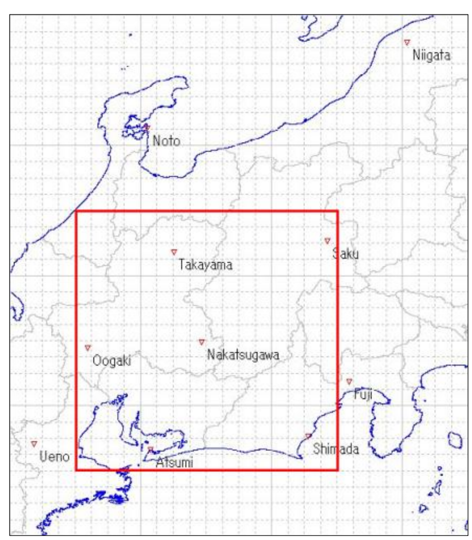

Fig. 6. LLS network central area (34.5-36.5 / 136.5-138.5)

Figure 7 shows the cumulative frequency distribution of location error. After applying site error corrections, although the average location error has increased slightly from 1.474km to 1.476km, the 50% value has decreased from 0.696km to 0.562km. And, the cumulative frequency graph (Figure 8) shows that the frequency after implementing the corrections is higher in the 0.5km or less region. This shows that the lightning location accuracy was improved by adopting the site error corrections.

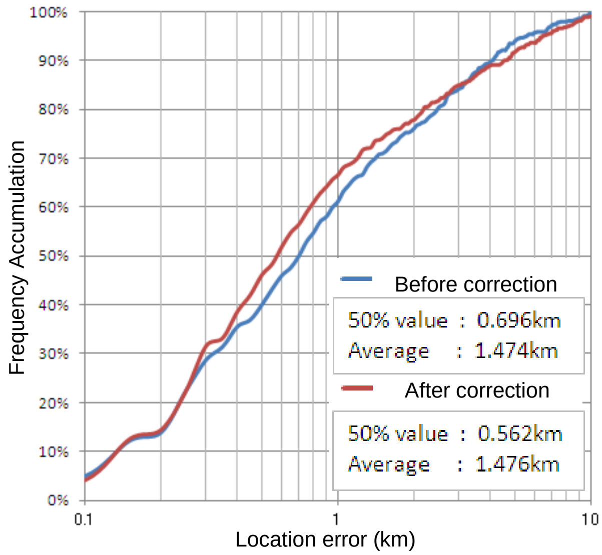

Fig. 7. The Cumulative Frequency Distribution of Location Errors in the LLS Network Central Area

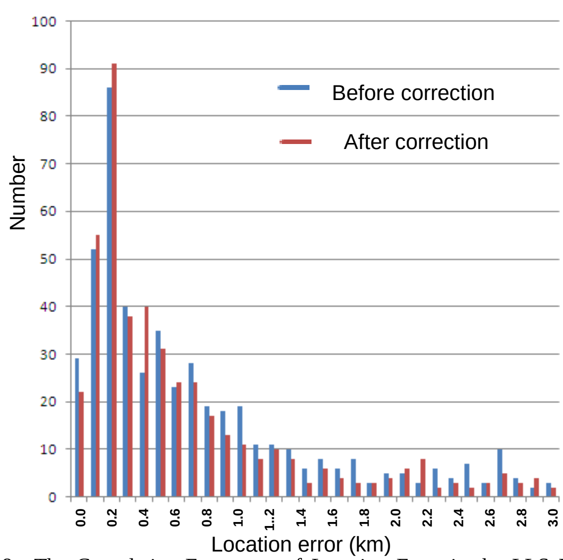

Fig. 8. The Cumulative Frequency of Location Error in the LLS Network Central Area

C. The analysis results in the area including the new plant

The results of the accuracy evaluation of the area including the new plant (see Figure 10) of 36.5-37.5 (longitude) / 137.5-138.5 (latitude) on August 22, 2012 are shown below. 390 multiple strokes were used.

Figure 10 shows the cumulative frequency distribution of location error. After applying site error corrections, it was confirmed that the average location error had decreased from 1.648km to 1.362km, and that the 50% value had decreased from 0.691km to 0.565km. The cumulative frequency graph (Figure 11) shows that the frequency after applying the corrections is higher in the 0.5km or less region. This is evidence that the lightning location accuracy was also improved in the area including the new plant by implementing the site error corrections.

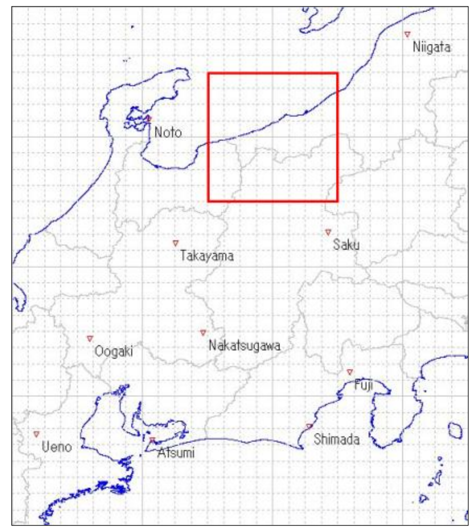

Fig. 9. New Plant Are (36.5-37.5 / 137.5-138.5)

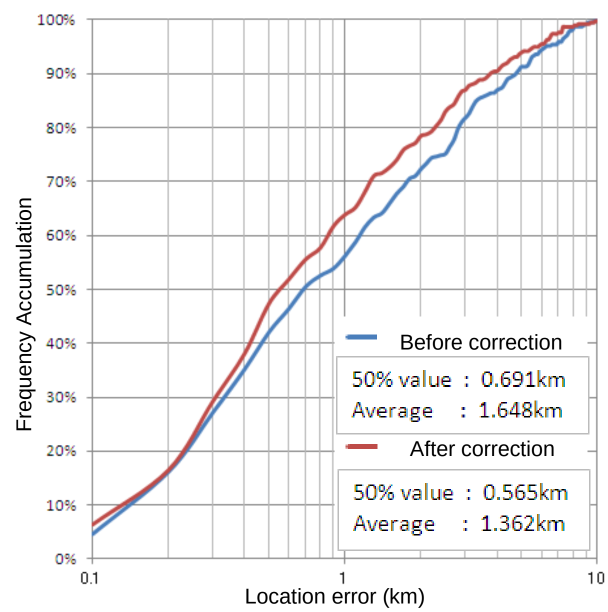

Fig. 10. The Cumulative Frequency Distribution of Location Error in the New Plant Area

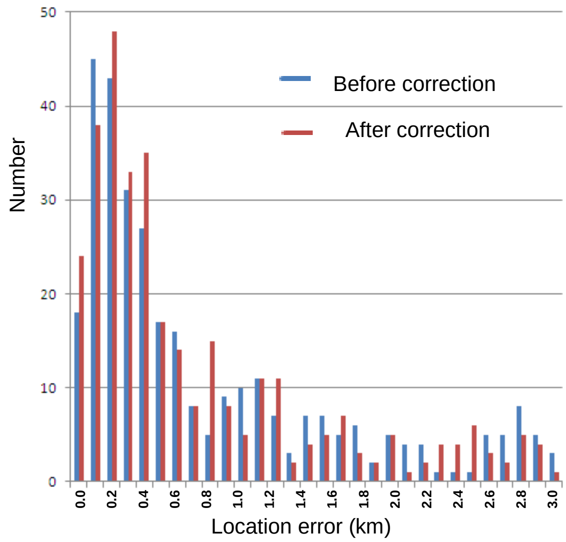

Fig. 11. The Cumulative Frequency Distribution of Location Error in the New Plant Area

D. Comparison of the analysis results

Table 2 shows the analysis results using multiple stroke data from the central area and from the new plant area. This analysis was performed using transmission line fault data. Our analysis confirmed that the location accuracy in the area including the new plant where we expanded the lightning observation range by rearranging the sensors was almost equivalent to the network's central area. This was exactly the main purpose of the LLS upgrade.

TABLE II. LIGHTNING STROKE LOCATION ACCURACY COMPARSION OF USING DIFFERENT METHODS

	50% value of lightning location accuracy
Location accuracy evaluation using multiple stroke data (The LLS network's central area)	0.562 km
Location accuracy evaluation using multiple stroke data (The area around the new plant)	0.565 km
Location accuracy evaluation using transmission line lightning data	0.368 km

In this result, the reasons why the location accuracy appears to be better in the transmission line fault data analysis when compared with the location accuracy in the multiple stroke lightning analysis are explained below.

- In the transmission line fault data analysis, only the nearest lightning strokes that were detected ±1 minute or less from time of the transmission line fault were used. This caused the error to be underestimated.
- In the multiple stroke analysis, strokes that actually struck other points may have been grouped in the same flash causing the error to be overestimated.

V. SUMMARY

Chubu Electric Power Company built a plant and a transmission line outside of their electric power supply area, and they constructed their LS7001 network in 2010 and 2011 so that the lightning observation range could be expanded to the Japan Sea coast area where the plant is located. We confirmed an improvement in lightning detection efficiency in our analysis after construction.

After implementing the site error corrections created after an analysis covering one year of LLS data, we evaluated the location accuracy of the LLS on the basis of a transmission line fault positions. It was confirmed that site error corrections had reduced the average, the 50% value, and the 95% value of location error. And, in comparison to the location accuracy in a similar evaluation of the LLS before upgrading, the 50% value has improved from 0.56km to 0.38km.

In order to evaluate the location accuracy in the extended lightning observation area, we used multiple stroke data. This showed that the location accuracy in the extended area was equivalent to the accuracy in the network's central area, and that the 50% values were 0.562km. The lightning location accuracy in the multiple stroke analysis is worse when compared with the 0.368km result using transmission line fault data. It is presumed to be because strokes whose actual positions were different may have been included in the data set for this analysis. Therefore, the true 50% value of the lightning location accuracy of this LS7001 network may be estimated at 0.4km - 0.5km.

In the future, we will continue to evaluate the LS7001 network after getting more transmission line fault data in the area around the new plant.

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