2008
20th International Lightning Detection Conference
21-23 April • Tucson, Arizona, USA
2nd International Lightning Meteorology Conference
24-25 April • Tucson, Arizona, USA

A MULTIPLE POWER LINE CORRIDOR AND LIGHTNING ERROR-ELLIPSE SPATIAL PROCESSOR FOR REAL-TIME CORRELATOR

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1 INTRODUCTION

Real-time, historical and statistical information collected by LLS is well accepted by electric power utilities and its use is increasing in different areas. The use of lightning information for the automatic correlation process in which the line fault is correlated with the lightning location in a certain time and spatial window has been explained in papers [1,2,3]. Correlation may be understood as a value-added service that offers support to utility operators to improve the overall performance of the transmission and distribution networks. With such services LLSs prove to be more than systems which collect data about some natural phenomena; they are also useful and represent a basis for services that produce return of investment in LLS systems themselves.

Though the correlation service has been in Slovenia in operation for more than eight years, it has been lately discovered that there is still room to have it improved. In this paper we present an approach which in addition to providing a higher level of the correlation rate it also suggests that the lightning location accuracy that is usually presented as a fixed value has to be considered as a statistical value.

2 BACKGROUND OF THE MULTI-CORRIDOR PROCESSING

The term multi-corridor processing covers a processing technique that is implemented in the most recent correlator tool. Unlike the formerly used approach in which correlation was performed for a fixed width of the power line corridor, the improved technique is self adaptive in processing the line and error-ellipse spatial information and which in case that the spatial correlation in the first corridor is unsuccessful tries to meet requirements for spatial correlation for wider corridors. This is the main idea of this technique.

2.1 Time criterion

The correlation process may be divided in temporal and spatial correlation. Temporal correlation compares time stamps of two events: the lightning time stamp and the time the circuit-breaker operated.

Lightning events provided by modern LLS are time-stamped by GPS time stamps and their accuracy is well below a millisecond.

Time stamps provided by the SCADA systems exhibit accuracy that may be in range from some tens of milliseconds up to few seconds. The main reason is that Remote Terminal Units (RTU) that are the source of circuit-breaker events information are either poorly synchronized to the stable time reference or are not synchronized at all. It is true that the situation in control systems and the related RTU is constantly improving and that the share of GPS-synchronized RTU is increasing, but typically the difference between accuracies of lightning and circuit-breaker time stamps are in the best possible case at least 10 seconds.

The Slovenian experience in this field is that typical time differences for GPS-synchronized RTU is between 50-500 ms. This difference is related mainly to the protection relay settings. The protection of the line or the feeder is usually set to some “on set time”. This is the time at which the protection relay is requesting the fault to be present in the network before it trips the circuit breaker. The reason of the “on set time” is operational. Some short-duration faults are cleared in the time shorter than the “on set time” and switching off the self cleared fault would bring unneeded interruption in power supply.

Over the time of eight years of operation of the correlator used for the Slovenian transmission and distribution networks we have learned that the time difference of 500 ms is a strong excluding criterion. On the other side, this in turn means that all events that do match in time should be carefully checked for spatial locations.

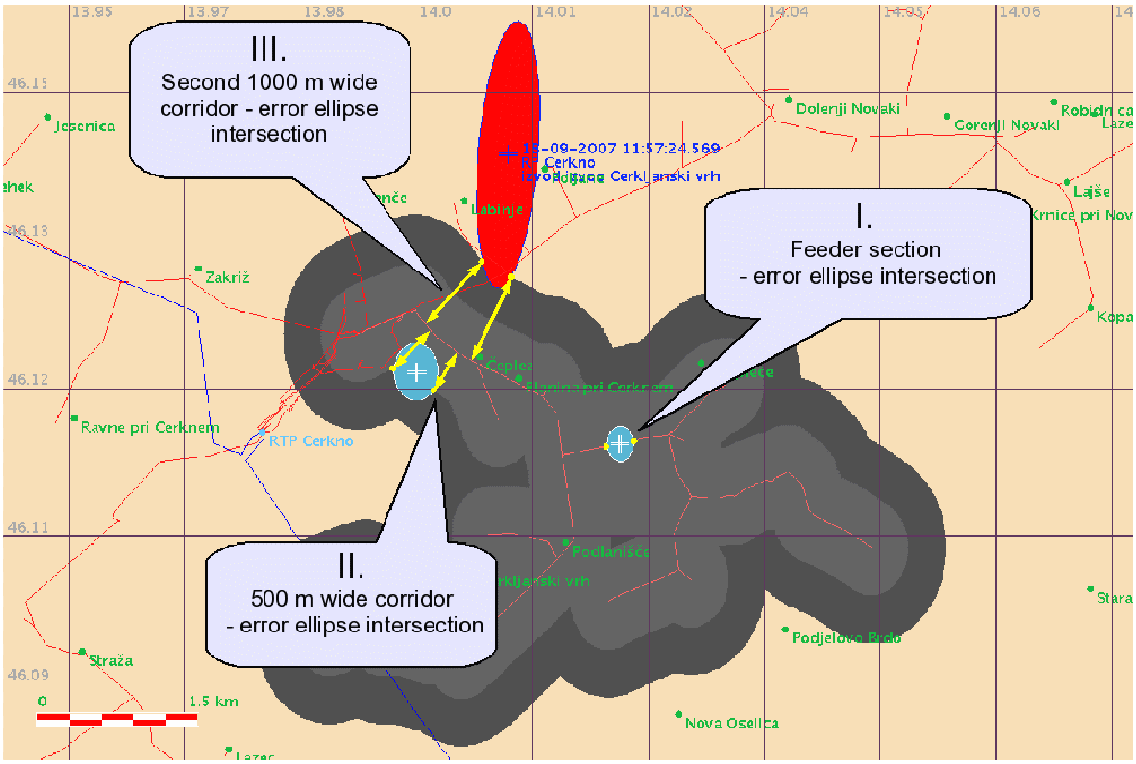

Figure 1: Geographical object that are subject to spatial correlation

2.2 Spatial criteria

From the very beginning of our correlation project, we approached the spatial correlation criteria issues most seriously. First, when dealing with spatial correlation, the relation between two spatial objects has to be defined. The first object that surrounds the distribution or transmission power line is the error ellipse and the second is the polygon.

The algorithm calculates possible intersection points between the power line or feeder sections and error ellipse. If there is an intersection, the algorithm stops.

However, if there is no intersection between the ellipse and the line, the spatial correlation between the ellipse and the corridor should be processed.

This requires that - based on the power line or feeder section - the corridor around the line is calculated. Determining the width of this corridor is the key issue. If it is too narrow, only a few correlations are obtained and the tool is inefficient. On the other hand, a too wide corridor will result in inexact correlations.

In 2000, when our project started this value was set to 500 m for being declared as an LLS accuracy. During operation of the correlator, we have learned that there have been some manual correlations made by our customers thus meaning that the 500 m wide corridor is too narrow.

Following the above, a decision was taken to introduce multi-layer corridors processing. The width of each corridor was increased by the factor of 2. The first corridor is now still 500 m wide, whereas the width of the second and third has been increased to 1000 m and 2000 m, respectively.

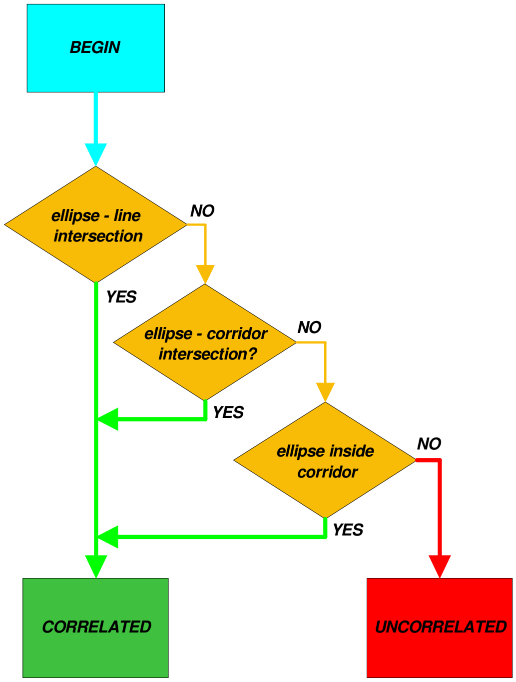

Figure 2: Possible spatial correlation cases at the line outage

3 STATISTICAL EVALUATION

The simplest way to illustrate performance of the multi-corridor correlator processing is through statistical evaluation. Figure 3 shows correlations in the second half of 2007. Events taking place in the western area of Slovenia - which is more exposed to the lightning activity than its other areas - are more correlated. In 2007, the utility responsible for the central area took no part in the correlation process. The multi-corridor processor began operating in 2007 just before the beginning of the main lightning season in Slovenia.

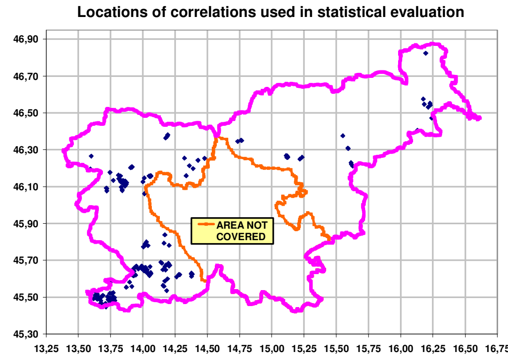

Figure 3: Observed correlations in Slovenia used in statistical evaluation.

The first results indicated a 10 to 35 percent increase in the number of successful automated correlations produced by MCP (Figure 4).

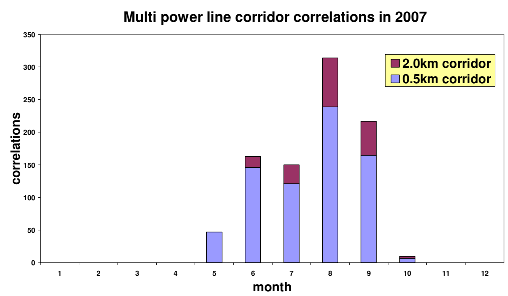

Figure 4: Lightning location distance distribution comparison between a 0.5 km and 2.0 km power line corridor.

A detailed analysis also revealed an increase in the median distance value and greater distance dispersion between the 0.5 km and 2.0 km corridor width processing. The median value increased form 254 m to 1187 m and the dispersion value from 402 m to 434 m (Figure 5). An additional systematic error that was observed is explained below. The increase in both parameters is presumably mostly due to the lightning impact on the power line or could be attributed to the LLS accuracy which is not as low as it has been expected. The impact of lightning on the power line due to the distance between lightning location and power line drastically decreases with the distance. The distances above 1.0 km hardly produce any over-voltages that would be high enough to trigger the power line protection (see [4]). Whenever this is not a case, the LLS accuracy should be validated.

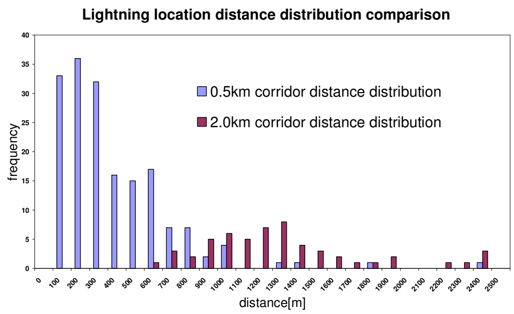

Figure 5: Lightning location distance distribution comparison between a 0.5 km and 2.0 km power line corridor.

4 LLS ACCURACY

Improvements obtained from single- to multi-corridor processing made us extend the statistical approach on to the LLS accuracy. Prior to validation, we made some basic agreement on the data set. As the lightning location is represented by a single point and the correlated power line by a polyline, their common relationship must be defined. The so called reference point is defined as being the nearest single point between the power line and the lightning location (Figure 6).

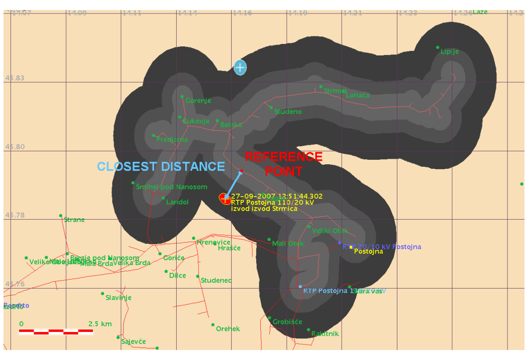

Figure 6: Reference point as the nearest point on the power line to the lightning location.

The reference point calculation is made in the multi-corridor processor requiring no additional effort. Since the exact lightning location and the exact lightning impact on power line are not known, we can conclude that the reference point is the closest approximation of the actual lightning location. The statistical data used in LLS accuracy validation covered over 200 multi-corridor correlations on an area of four Slovenian power distribution utilities. The results are shown in Figure 7 together with some similarities from previous LLS accuracy validations. The LLS accuracy dispersion increases with the widening of the corridor and systematic shift appears almost in the same direction as in RLDN validation of the LLS accuracy published in 2006 and in the High-Resolution Flash-Density Map validation in 2004.

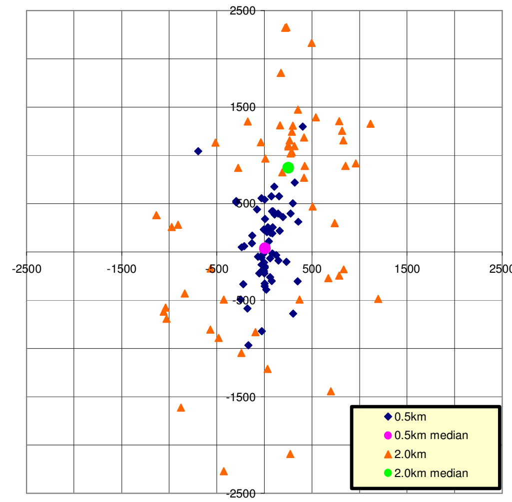

Figure 7: LLS accuracy validation using a 0.5 km and 2.0 km power line corridor.

5 CONCLUSIONS

Multi-corridor processing has evolved from single corridor processing as a result of experiences with the automatic fault correlator accumulated during eight years of operation in the Slovenian power transmission and distribution utilities. The time criterion of 500 ms being of a rather excluding character, the spatial algorithm was improved with multi-corridor processing. Multi-corridor processing foresees that accuracy of the LLS may only be correctly represented by statistical distribution.

The multi-power line corridor processing proved to be a very promising LLS accuracy validation tool. By connecting the fifth Slovenian power distribution utility to the real-time correlation process in 2008, the correlation area will be extended to the whole area of Slovenia providing the basis for the LLS accuracy validation map to be made more precisely. Further results are still to be presented.

6 REFERENCES

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