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A NEW REAL-TIME TOOL TO FAULT ANALYSIS BASED ON DATA PROVIDED BY LIGHTNING LOCATION SYSTEMS

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1. INTRODUCTION

Lightning is considered one of the major causes of faults in electric transmission systems in many countries. In order to minimize the effects of these occurrences, improving the ability of restoring the system, a large number of power electric utilities have used real time cloud-to-ground (CG) lightning data obtained from Lightning Location Systems (LLS) (Bernstein et al., 1996, Kappenman and Van House, 1996, Cummins et al., 1998b, Chen et al., 2004). Lightning real-time data can be very useful as an important decision tool in cases of reclosing a feeder breaker after a fault or locating a persistent damage in the system. Around the middle of 1990 decade, a large effort was made by several institutions in United States, captained by the EPRI institute, to develop a very sophisticated tool to fault analysis (Kappenman and Van House, 1996). The tool, called FALLS, was based on data provided by the National Lightning Detection Network (NLDN) (Cummins et al., 1998a). FALLS was projected to use very precise georeferenced data about the transmission lines and the GPS based information provided by NLDN. The random and systematic errors associated with the lightning location were also considered. Although very sophisticated, FALLS was projected to operate in the pos event period using historical archive data. Also, it did not take into account the serious limitation imposed by the low stroke detection efficiency of NLDN, at that time around 50-60% (Cummins et al., 1998a). Even though the stroke detection efficiency of NLDN has improved in the last years to 60-70% (Jerauld et al., 2004, Kehoe and Krider, 2004), after the recent upgrade (Cramer et al., 2004), a significant percentage of strokes are not detected yet. This limitation is still more evident in other LLS, which were not recently upgraded to more modern sensor technologies. More recently, Kosmac and Djurica (2000) developed a real-time power line outage to lightning location correlator, but still not considering the stroke detection efficiency related limitations of LLS.

In order to obtain a very high reliability in the fault analysis, it is necessary not only to consider in detail the intrinsic limitations of the LLS in terms of location accuracy, but also in terms of the stroke detection efficiency. The low detection efficiency of LLS is consequence of several aspects, including fail to record a stroke if the peak field is below the trigger threshold, which depends on the distance of the sensors, their characteristics and the noise level at the sensor locations, and fail to record a stroke in the waveform does not match the criteria of stroke selection in the central processor. The location accuracy, in turn, depends on the uncertainty associated with the times and angles recorded by the sensors.

In this paper, we present a new tool to use in fault analysis, called Real Time Extended FALLS, or RTE-FALLS. In the same manner of FALLS, it takes into account the errors associated with the lightning location provided by the LLS (ellipse error) but, differently of FALLS, it operates in real-time and also takes into account the strokes losses by the LLS in statistical terms. The RTE-FALLS takes advantage of the statistical knowledge about the number of strokes per flash, number of forked strokes per multiple strokes, time between successive strokes, duration of flashes, distance between different strike points on ground for strokes of the same flash, and distance of successive flashes in a same thunderstorm, to determine time and space probability distributions for “virtual strokes”, which are related to the real strokes detected by the LLS. The “virtual strokes” are assumed to approximately simulate the effect of the strokes lost by the LLS.

2. METHODOLOGY

When correlating outages of transmission lines with lightning strokes one must consider correlation in space and time domain. In the space domain, the methodology is described in Figures 1 and 2, assuming that the location of the transmission line is GPS georeferenced.
Figures 1 illustrates the methodology used to calculate the integral probability for one stroke detected by LLS to cause a fault in terms of the boundaries of individual probability distributions for the detected stroke (ellipse error) and the virtual forked and single related strokes, and their intersections with the corridor around the transmission line, which is defined by the attraction distance of the line, calculated assuming the peak current of the detected stroke. The dependence of the attraction distance on the relative altitude of the terrain around the line can also be implemented.
Figure 2 illustrates, in a 2D representation, the relative contribution of the individual probability distributions to the integral probability. In a real case, such distributions are defined in terms of the statistical probabilities for: number of strokes per flash, number of forked strokes per multiple strokes, time between successive strokes, duration of flashes, distance between different strike points on ground for strokes of the same flash and, finally, distance of successive flashes in a same thunderstorm.
After the probability distributions for all (real and virtual) strokes are determined, the integrated probability is computed for “all” strokes for a corridor defined by the striking distance of the line, considering the peak current of the real stroke, and for a given time interval, which is defined by the precision of time stamp of a fault, considering also the time uncertainty associated with the virtual strokes.
Finally, once the integral probability is computed, it can be related to the real probability by comparing both for a statistical significant sample of “well defined” faults caused by lightning.

3. FIRST RESULTS AND CONCLUSIONS

The simplified version of the algorithm described above is being implemented to generate a new real-time tool to fault analysis in the transmission system of the Furnas Centrais Elétricas in Brazil. Besides to provide support in real time to decisions by the Furnas operation center, the tool has shown in the first evaluations more realistic correlation of outages with lightning location data than the normal procedure, based on correlate faults with strokes inside an arbitrary corridor around the transmission line, used in most power electric companies around the world.
After implemented, the tool will provide reliable data to calculate more realistically the outage rate of the transmission lines given additional support to lightning protection analysis based on lightning location data.

4. REFERENCES

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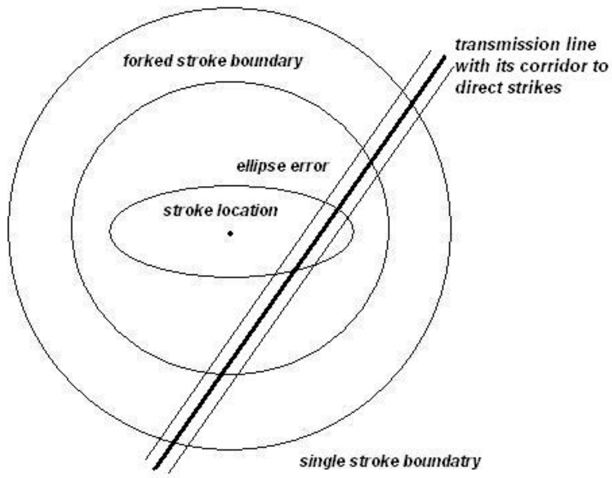

Figure 1. Methodology used to calculate the integral probability for one stroke.

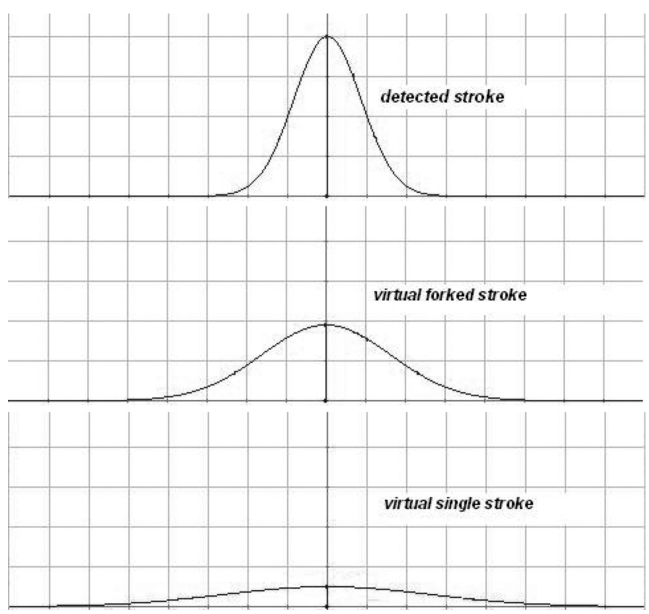

Figure 2. 2D representation, the relative contribution of the individual probability distributions to the integral probability