SIMULTANEOUS MEASUREMENTS OF LIGHTNING INDUCED VOLTAGES IN THREE DIFFERENT POINTS OF AN ENERGIZED DISTRIBUTION LINE IN COLOMBIA

Horacio Torres **Javier Herrera** **Ernesto Pérez** **Camilo Younes**
Carlos Quintana **Daniel Rondón** **Milton Salgado** **Luis Gallego** **Johny Montaña** **Mauricio Vargas**

National University of Colombia
Research Program on Acquisition and Analysis of Signals – PAAS
www.paas.unal.edu.co

Abstract: **This paper presents simultaneous measurements of induced voltages due to nearby lightning strokes in three different points of an energized distribution line and its comparison with theoretical calculations obtained by mean of the inclusion of Rusck's Coupling Model into the ATP/EMTP.**

Keywords: Induced Voltages, lightning, measurements, ATP/EMTP.

1. INTRODUCTION

Colombia is located in tropical zone with a high electrical atmospheric activity [1]. The research program PAAS has been studying the spatial and temporal characterization of different electromagnetic interference phenomena associated with such activity as lightning since 1988.

Lightning is the major cause of electric service outages in Colombia. Induced voltages generated by indirect strikes cause more electrical faults than direct strikes on overhead distribution lines.

In order to deepen in the induced voltages knowledge due to nearby lightning strikes, simultaneous measurements in three different points of an energized experimental distribution line were carried out.

The calculation of lightning induced overvoltages were carried out by means of the ATP-MODELS routine using the algorithm proposed by Høidalen [2].

2. MEASUREMENT FEATURES

2.1 Location

The measurements were carried out in an Experimental Lightning Station, named Ilyapa, located in the highest Ground Flash Density Zone of the world, 40 flashes/km^2 – year [3]. The experimental Station contains a 30m-guyed lightning measurement tower and a 13.2 kV experimental three-phase distribution line.

2.2 Line Configuration

The overhead distribution line is about 3 km. long with three-phase and a neutral conductor arranged in a horizontal configuration of 13.2 kV rms phase-phase and 2/0 ASCR conductor, metallic pole, porcelain insulators and height of 10 m. The unifilar diagram is shown in Figure 1.

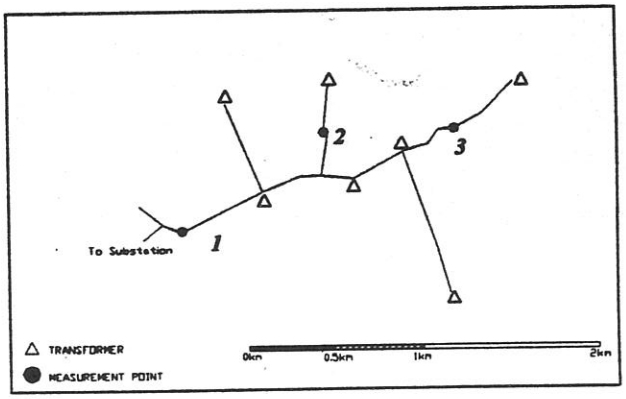

Figure 1. Unifilar Diagram of Distribution Line.

2.3 Measurement equipment and configuration

In order to register the signals, there was used a digital Fluke oscilloscope with 25Mhz bandwidth. An oil immersed Pearson capacitive divider (Model VD305A) of 300 kV maximum voltage range, 4975:1 ratio (factor obtained in laboratory), 100 ns risetime, 30 Hz to 4 MHz frequency range and a total capacitance of 18 pf; it was linked to the oscilloscope with a 10 m shielded RG58 coaxial cable grounded at the beginning as shown in Figure 2. Figure 3, shows a picture of the point of measurement on the line with the capacitive divider.

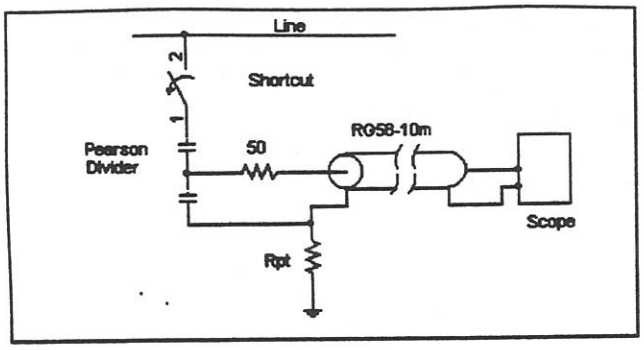

Figure 2. Schematics measurement system.

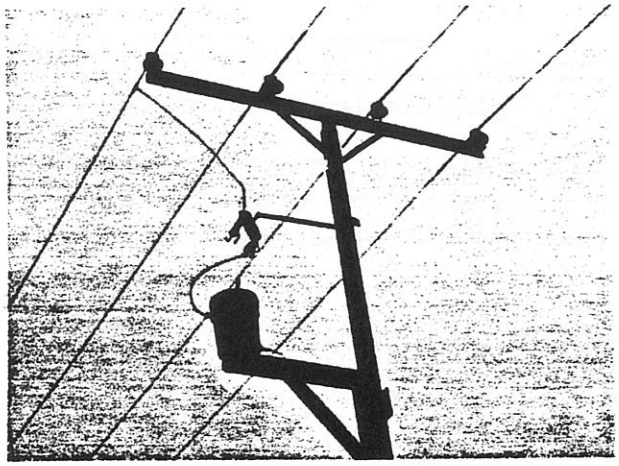

Figure 3. Measurement equipment.

3. MEASUREMENTS AND LLS CORRELATION

The induced voltages were registered in three points of the line as is shown in Figure 1. In order to correlate the measurements it was necessary to synchronize the signals at the same base time by mean of a GPS, with the Colombian Lightning Localization System (LLS) [4].

From the Colombian LLS, it was obtained the localization point of the stroke and Lightning Peak Current. Due to the high activity in the zone, data were restricted to a 2 km area around the experimental line in order to exclude unsuitable information.

3.2 Signals Characterization

In total, there were obtained 19 induced voltages signals from a few volts up to 40 kV and main frequency components among 20 kHz up to 100 kHz, the first peaks rise time were about 10 μs. Simultaneous induced voltages measurements samples are shown in Figures 4 to 8.

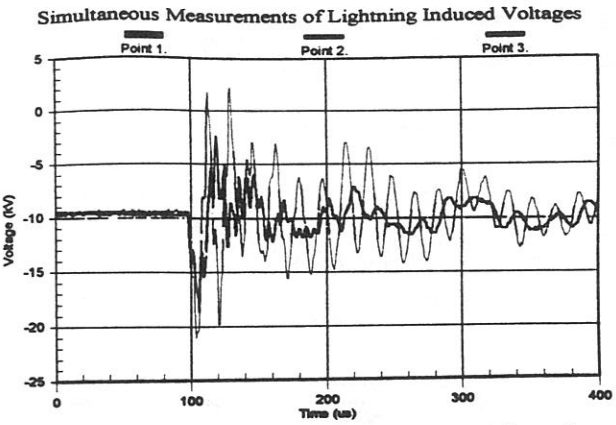

Figure 4. Simultaneous Measurement Sample.

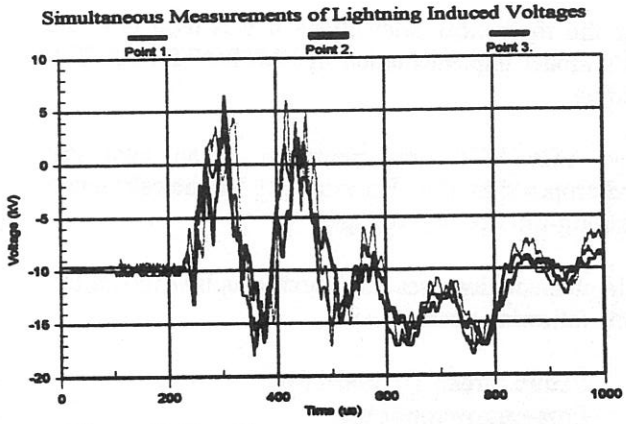

Figure 5. Simultaneous Measurement Sample.

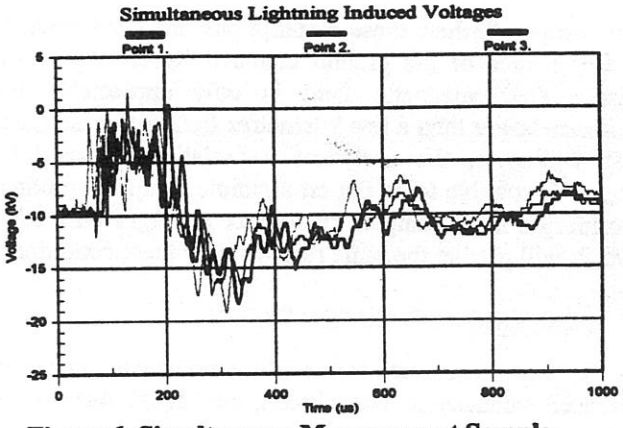

Figure 6. Simultaneous Measurement Sample.

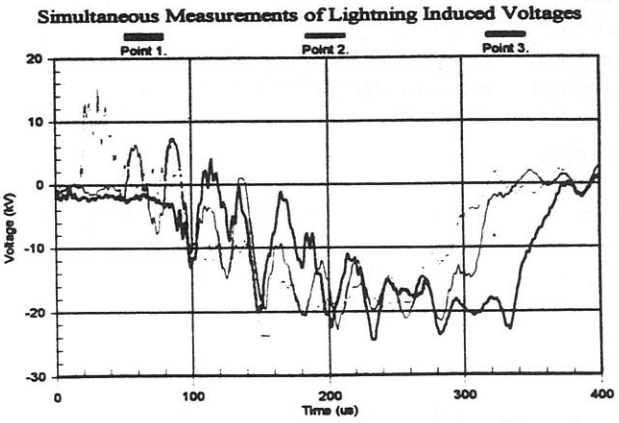

Figure 7. Simultaneous Measurement Sample.

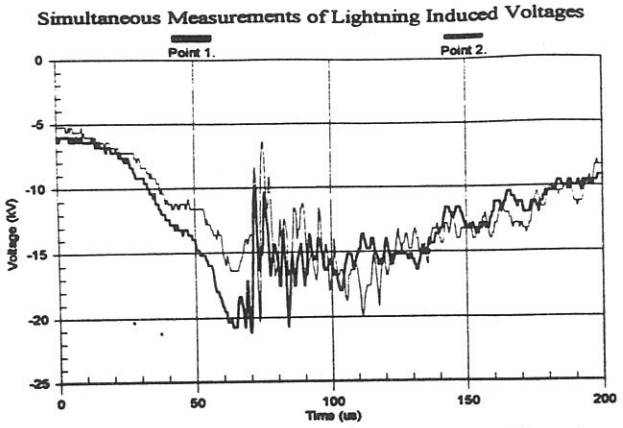

Figure 8. Simultaneous Measurement Sample.

For the theoretical calculations it was used only the Rusck's model implementation in EMTP/ATP MODELS subroutine.

The ATP/EMTP implementation is an analytical method proposed by H.K. Høidalen [2], for the calculation of lightning-induced overvoltages.

This implementation uses the Rusck coupling model [5], with the following assumptions:

- Return Stroke TL Model [6].
- Loss-less overhead line.
- The ground conductivity is infinite.

For nearby flashes, these assumptions are valid because the influence of the ground conductivity on the return stroke electromagnetic field is only appreciable for distance larger than a few kilometres from the strike point [6]. Moreover, the analytical formulation proposed by Rusck is suitable to be put on a simple computer routine, avoiding a more complex routine for the Agrawal model, which will predict the same results under these conditions.

4. ANALYSIS AND COMPARISON

In order to compare the coupling model with measured induced voltages it was chosen the signal due to the nearest lightning strike to the distribution line, because the Rusck model approximation used in ATP/EMTP simulation, has adecuate response for close lightning strike points than for distant ones as seen before. For this simulation the measurement point 3 signal was not taked into account because it was not registered by the osciloscope.

Due to LLS data as amplitude, location and waveform are parameters obtained indirectly it was necessary to make sensibility analysis for these data and use the best ones in the simulations.

The simulation with the ATP/EMTP implementation adopts the TL model with a return stroke velocity of $1.9 \cdot 10^8$ m/s, for the channel base current the Heidler funtion was adopted [8], with front-time 2 μs and decay time 50 μs, the maximum current peak was 30 kA. Those values are assumed on the basis of the studies carried out by several authors [6]. The implemeted line was a trhee-phase one with 10 m height. The ligthning strike point is shown in figure 9.

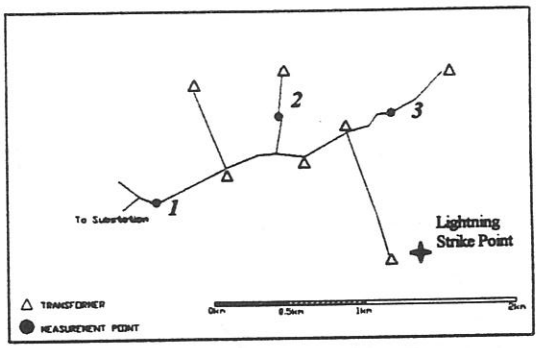

Figure 9. Lightning Location for Signal .

The results obtained in ATP/EMPT show that the induced voltages have the same polarity of the channel base current and it doesn't change along the distribution line.

As is shown in Figure 10 and 11 the simulation results are in agreement with the measurements, but only for the first microseconds. This is probably due to the Lightning discharge model used, and because the Rusck's analytical aproximation does not include the lossy ground effect.

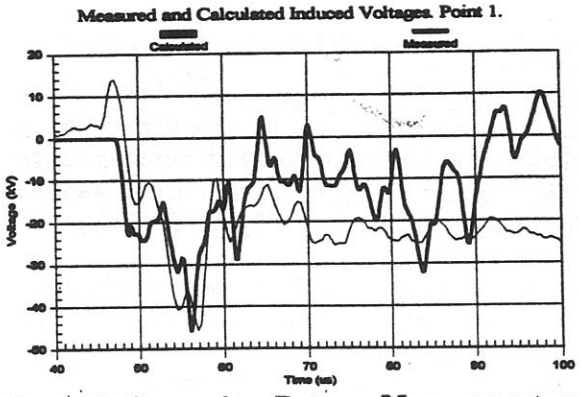

Figure 10. Comparison Between Measurement and ATP/EMTP

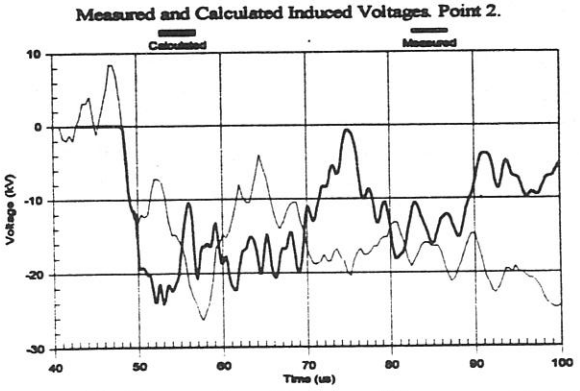

Figure 11. Comparison Between Measurement and ATP/EMTP

CONCLUSIONS

We have presented the analysis and comparison of measured and calculated induced voltages using the Rusck's analitical aproximation.

The Høidalen implemented model in EMTP/ATP, shows aceptable results for the first microseconds, but it doesn't represent well the complete waveform of the induced Voltages.

Due to the analyitcal aproxiamtion limitations of Rusck's model, it is necessary to develop on the basis of MODELS routine, the induced voltage calculation including the ground conuctivity using the Agrawal's Model [9].

In future works we will carry out measurements of the electric field, in order to model in ATP/EMTP the actual source of the lightning signal.

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