# Influence of the Soil and Frequency Effects to Evaluate Atmospheric Overvoltages in Overhead Transmission Line - Part II: The Influence of the Soil in Atmospheric Overvoltages

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**ABSTRACT:** This paper presents the influence of soil in the overvoltage caused by lightning. To evaluate this influence, it was necessary to study the influence of soil and frequency in the electromagnetic parameters of the transmission lines. Then to introduce these influences on electromagnetics transients the well-known program ATP/EMTP was used. To compare the results, there are several curves in each one. There is the consideration of the electromagnetics parameters varying with the soil or not.

## INTRODUCTION

To avoid (or at least decrease) damage to electric power systems due to lightning, it is extremely recommended to model the system as precise as possible. Thus compute the electromagnetic parameters of soil must be included in this model to decrease the possibility of super or sub dimensioning the original project.

The influence of the soil is computed on the calculus of the characteristic impedance ($Z_c$) and on the propagation constant (γ). Both parameters are calculated using the longitudinal impedance and transversal admittance of transmission lines, presented in Part I of this document. As presented in Part I, there are several methodologies that compute σ and ε of the soil, e.g., J. R. Carson, M. Nagakawa, T. Noda and A. Deri.

Moreover, the soil is considered a dispersive environment and there are several methodologies that compute this characteristic. Although a dispersive medium suffers variation in its proprieties as a function of time, these methodologies correct ε and σ in the frequency domain because it is easier to implement computationally. In this paper the methodologies that correct these variations are the works proposed by: H. S. Scott, L. Longmire and K. Smith, R. S. Alípio, C. Portela and S. Visacro.

Therefore the influence of the soil in the electromagnetic surges caused by lightning strokes can be intense depending on the soil's characteristics. It is known that for soils with higher resistivity the electromagnetic parameters of the transmission lines suffer from more influence. This information subsidizes a more detailed study in this area to compare the traditional method and the new approach that is

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proposed.

**SIMULATED MODEL**

To evaluate the influence of the parameters presented in Part I of the paper, the situation shown in Figure 1 is simulated with the help of Alternative Transients Program (ATP), ATP (1987). According to I. 60060-1 (2010) and S. Kurokawa (2103) this model is adequate to study this phenomenon. The transmission line simulated in this paper is the same used in Part I (see Part I), with a span of 400 meters.

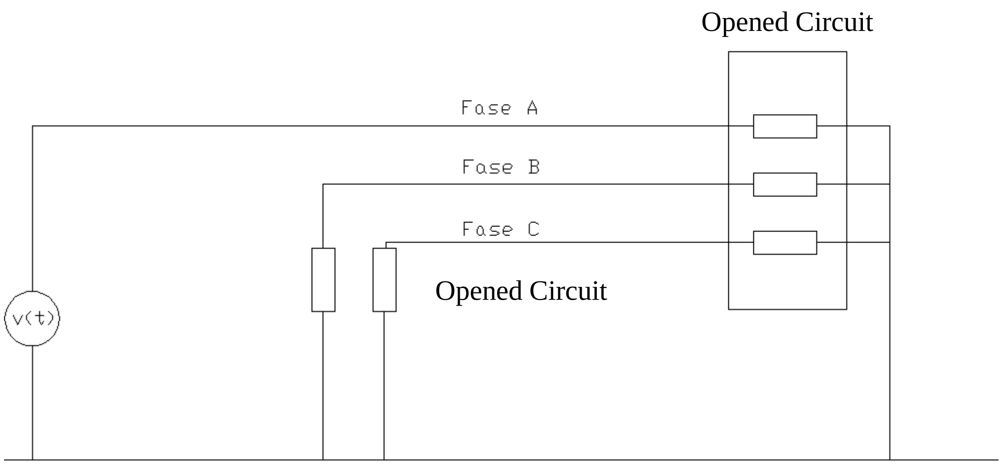


**Figure 1 – Transmission system model used to evaluate the overvoltage.**

Literature normally uses the typical frequency of the phenomenon in to simulate the transmission line. There are models on ATP that consider the influence of the soil (influence of the conductivity and permittivity), but do not consider the soil as a dispersive environment. This paper presents a new methodology to consider the transmission line, considering a new model of the transmission line for each frequency. To separate the signal (in this case the voltage wave) the Fast Fourier Transformation (FFT) is used on the signal. In this paper, it is considered 136 sin functions to recreate the signal, as presented in Figure 2. To model the voltage curve, a double-ramp (1.2/50 µs) is used. Then for each frequency a model of the transmission line is calculated and finally is simulated on the ATP. To compare the results in this paper, three different models are considered:

(i) J. Marti, existing on ATP - this model calculates the transmission line parameters continually distributed and considers the variation of the loss with the frequency.

(ii) Bergeron, existing on ATP - this model calculates the transmission line parameters for only a specific frequency (in this case, typical for lightning, 500 kHz).

(iii) New Methodology proposed in this paper - this model calculates the transmission line parameters, according to Bergeron but for each frequency. To calculate the transmission line parameters, for each frequency, just follow the steps below:

1. Calculate the longitudinal impedance, in this case using J. R. Carson's equation to consider the soil's conductivity and permittivity;
2. Calculate the transversal admittance, in this case considering the soil with infinite conductivity;
3. Calculate the rest of the parameters: characteristic impedance, propagation constant and velocity propagation.

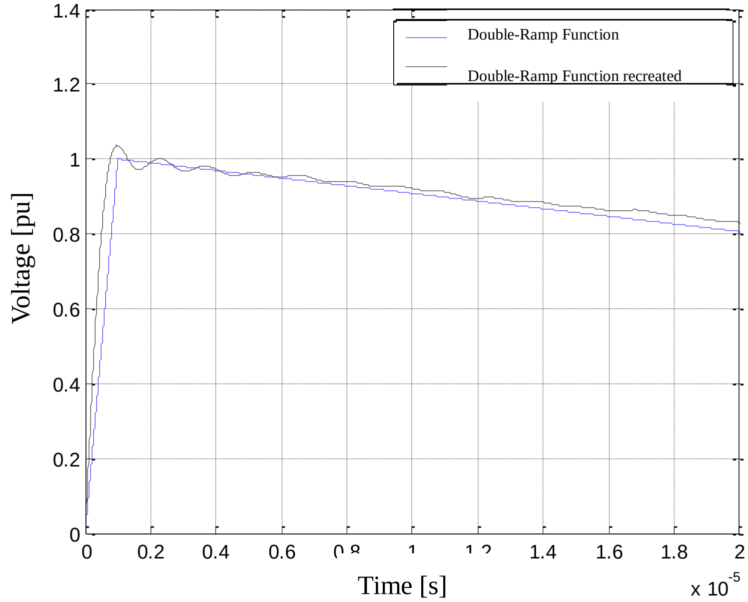


**Figure 2 – Entrance Voltage, v(t). Comparison between the double-ramp and the sum of several sin functions.**

To verify the sensibility of the exit signal considering the entrance signal, Figure 3 presents the overvoltage on phase A considering an entrance signal of double-ramp and a signal with a double-ramp recreated with 136 sin.

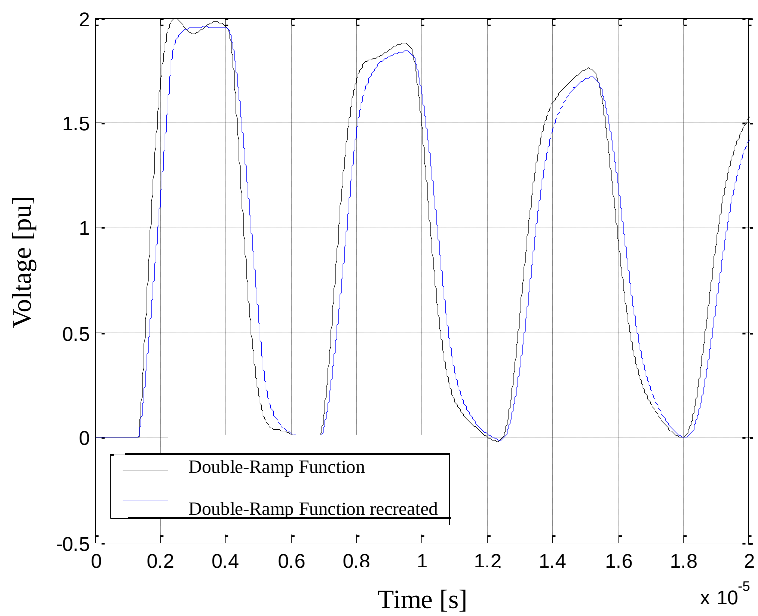


**Figure 3 – Out voltage. Comparison between the double-ramp and the sum of several sin functions. Soil with resistivity of 10,000 Ω.m. Soil modeled as a non-dispersive environment.**

Figure 3 uses the Bergeron for a frequency of 500 kHz. According to it, the values are close and from now on only the double-ramp function recreated is used. To include the dispersive characteristic only two methodologies are considered: S. Visacro and R. S. Alípio (2103) and C. Portela (1999). Part I of this work illustrates the reason that Visacro and Alípio´s methodology is most trusted and Portela's presents the most dissonant results of the methodologies used in this paper.

## RESULTS

Figures 4 and 5 are graphics of the voltage x time. On both Figures, the voltage measure is located on the phase A in the end of the transmission line, considering an input voltage on the same phase but in the beginning of the transmission line. The first one illustrates that soils with low resistivity do not suffer from much influence of each methodology. However, as it shows, the model proposed by Bergeron for a specific frequency has the most uncongenial values. The second illustrates that not only Bergeron's methodologies have numerical differences but the other ones too. Nevertheless, it is the one with more dissonant values.

As shown in Figure 5, the methodologies proposed in this paper and the methodology of J. Marti, already implemented on ATP, have close numerical values. In addition, J. Marti considers the frequency variation and when the methodology of this paper uses conductivity and permittivity constant with the frequency, the curves almost overlie. However, when the correction of σ and ε is considered, the values of the maximum overvoltage are lower than the non-consideration; it illustrates that (for the actual situation) considering the soil as a non-dispersive environment is a conservative analysis.

To evaluate the real influence of soil a more detailed model of the transmission line is necessary as well as the consideration of more elements (as grounding for instance) to conclude the real influence of soil. This paper is just a preliminary study on this topic.

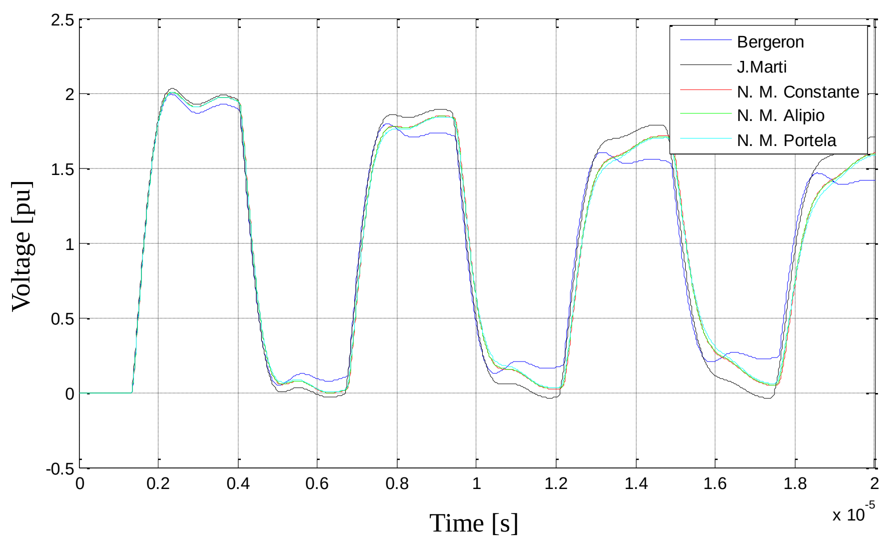


**Figure 4 – Out voltage. Comparison between Bergeron on a specific frequency (Bergeron Curve), J. Marti (J. Marti Curve), New Methodology considering the soil's parameters constants (N. M. Constant), New Methodology considering correction of σ and ε of the soil according Alípio (N. M. Alípio) and Portela (N. M. Portela). Soil with resistivity of 100 Ω.m.**

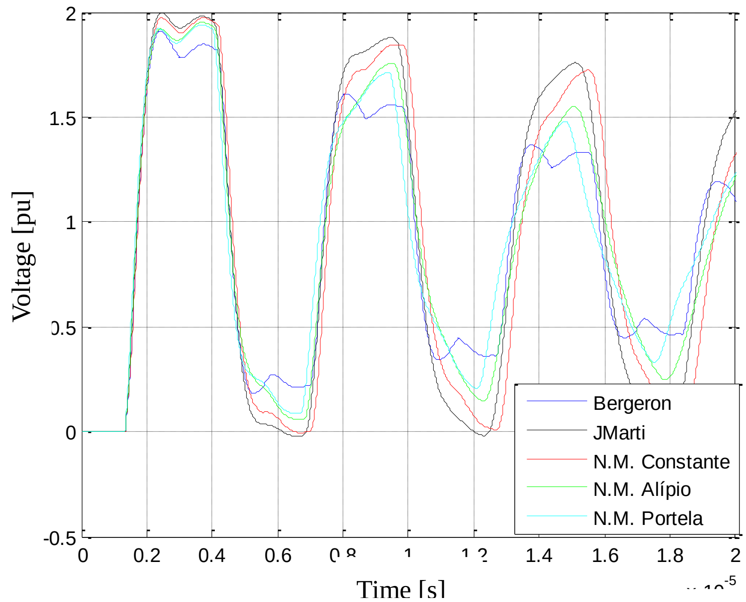


**Figure 5 - Out voltage. Comparison between Bergeron on a specific frequency, J. Marti, New Methodology considering the soil's parameters constants, New Methodology considering correction of σ and ε of the soil according Alípio and Portela . Soil with resistivity of 10,000 Ω.m.**

## CONCLUSION

The maximum values for the new methodology and J. Marti have close values; however, it holds off with the evolution of the time. For some studies, only the maximum overvoltage is interesting and since there are no discrepant numerical values for J. Marti and the new methodology proposed, it could subsidize using the J. Marti methodology proposed on ATP.

J. Marti methodology is widely used in literature and, according to this work, it presents consistent values and it has an advantage considering the new methodology, the computational effort. To obtain values for the new methodology it is necessary to follow some steps (basically): (i) Use FFT, (ii) recalculate the transmission line parameters for each frequency and simulate the final result. Following all these steps consumes lots of computational effort making the methodology proposed in this paper expensive from the point of view of computational waste.

According to the results, J. Marti methodology presents the maximum overvoltage even though the methodology proposed in this paper presents values close to it. For studies that do not want to study only the maximum overvoltage this new methodology is very interesting and further aspects must be studied.

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