Lightning Electromagnetic Fields Computation: An Approach to Reduce the Computational Effort

Daniele Mestriner[1], Massimo Brignone[1], Renato Procopio[1], Martino Nicora[1], Mansueto Rossi[1], Federico Delfino[1], Farhad Rachidi[2] and Marcos Rubinstein[3].

[1]University of Genoa – corresponding author: renato.procopio@unige.it
[2] Ecole Polytechnique Federale de Lausanne (EPFL)
[3] Haute Ecole d'Ingenierie et de Gestion du Canton de Vaud

Abstract—The computation of lightning electromagnetic fields computation usually requires a considerable computational effort if the Channel-Base Current (CBC) realistic waveform and the finite soil conductivity are taken into account. This work proposes a closed-form expression for the radial and vertical electric field and the azimuthal magnetic field generated by a lightning discharge. This is possible thanks to the representation of the CBC expression and of two other suitable functions as Prony series that allow to analytically solve the integrals appearing in the classical field formulas. Since the number of terms required for this approximation is limited, this results in a noteworthy CPU time saving.

Keywords-Lightning, Electromagnetic fields, Computational effort

I. INTRODUCTION

The numerical evaluation of lightning ElectroMagnetic Fields (EMF) using the general field expressions (e.g., [1]) involve numerical integrations, hence, requiring a high computational effort, which could be incompatible with cases where the EMF should be computed at different observation points (e.g., lightning-induced voltages and Lightning Performance (LP) evaluation [2]). This paper proposes an approach, based on the Prony series of some particular functions, that allows to significantly lower the computational effort. The method does not require any assumptions on the CBC and the attenuation function along the channel. The proposed approach has been validated by comparison with the numerical approach [1] and it guarantees an increase in the computational speed of up to 100 times.

II. GENERAL IDEA OF THE METHOD

The lightning magnetic field above an ideal ground expression can be found in [1]. In the proposed approach, we first compute the magnetic field according to the following steps (see [3] for further details). 1) For any model (except the TL one), the channel is discretized into *N* segments; along each segment the attenuation function is considered as constant. 2) After some mathematical manipulations, the magnetic field due to each segment can be expressed in terms of the convolution integral of the CBC and a function y_1 of the time t defined in [3]. 3) the CBC and $y_1(t)$ are expressed by means of their Prony series, which makes the convolution integrals analytically solvable. The radial and vertical components of the electric field can be then computed for a perfectly conducting ground by means of the Maxwell's equations applied to the channel geometry. This implies the discretization of a function $y_2 = ty_1$ by means of its Prony series. Once the radial term of the electric field is computed, the soil conductivity is taken into account by means of the Cooray-Rubinstein formula, suitably converted in the time domain.

III. VALIDATION AND COMPARISON

The proposed approach is compared with the results of a numerical code applied to the equations proposed in [1]. Fig.1 shows the EM fields computed considering an observation point located 200 m far from the lightning strike and placed 10 m above the ground. A typical first stroke is considered and the soil conductivity is 10 mS/m. The channel height is 8 km, while the propagation velocity is the half of the light speed. The MTLE is considered. As can be observed in Fig.1, the two approaches produce the same result. It is important to notice that, in terms of computational time, the proposed approach is more than 50 times faster than the numerical one.

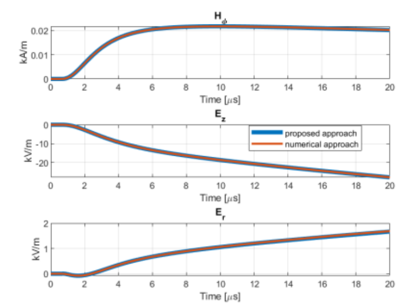

Fig. 1 Comparison between the proposed approach and the numerical one

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