Engineering Analysis with Boundary Elements 35 (2011) 1101–1108

Contents lists available at ScienceDirect

Engineering Analysis with Boundary Elements

journal homepage: www.elsevier.com/locate/enganabound

Wire antenna versus modified transmission line approach to the transient analysis of grounding grid

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ARTICLE INFO

Article history:
Received 1 October 2010
Accepted 13 April 2011
Available online 7 June 2011

ABSTRACT

The paper deals with transient analysis of grounding grids using two different approaches, wire antenna theory and modified transmission line model. The Pocklington integro-differential equations, in frequency domain, arising from the wire antenna theory are numerically handled via the Galerkin–Bubnov variant of indirect Boundary Element Method (GB-IBEM), while the transient response was obtained using inverse Fourier transform. The modified transmission line equations are treated using the finite difference time domain (FDTD) method. Some illustrative numerical results are presented and discussed in the paper.

1. Introduction

Transient analysis of grounding systems is of great importance in lightning protection systems (LPS) design. One of the most important parameters arising from the transient analysis is the transient impedance of the grounding electrode. Grounding systems can be modeled using simple electric circuit methods [1,2], the transmission line based model (TLM) [3–5] or antenna (full-wave) model (AM) [6–9]. While the circuit methods can be considered to be rather oversimplified, the TLM methods have advantage of simplicity and relatively low computational cost. On the other hand, though valid for long horizontal conductors, simplified TL approach is not convenient for vertical and interconnected conductors. Also, the influence of earth–air interface is usually neglected [10]. Within the framework of the TL method, the effect of mutual coupling between different conductors of the grounding system is neglected. In general, TLM based solutions are limited to a certain upper frequency, depending on the electrical properties of the ground and configuration of particular grounding system.

On other hand, the rigorous electromagnetic models based on antenna theory are the most accurate. The AM approach is based on solution of the Pocklington's integro-differential equation for the half space problems. The earth–air interface effect is usually taken into account by the Sommerfeld integrals [11], or certain approximate approaches like modified image theory (MIT) [10,12], or reflection coefficient approximation (RC) [6,7]. The main drawback of the Sommerfeld integral formulation is rather long computational time, especially for the evaluation of broadband frequency spectrum. On the other hand, MIT approach accounts only for the electrical properties of the soil, but not the burial depth, while RC approximation produces error within 10% comparing to the rigorous Sommerfeld integral approach [11].

In this work, an assessment of the transient behavior of different grounding grid configurations using both the antenna and modified transmission line approaches has been carried out. This paper can be considered as a sequel of already published papers dealing with comparison of these two methods. In [13] the comparison of direct time domain approach based on antenna theory and TL model is presented for buried cables, while trade-off between the direct TLM approach and indirect frequency domain approach based on antenna theory model for transient analysis of grounding electrodes has been discussed in [14]. Furthermore, comparison of wire antenna and MTL approach to the assessment frequency response of horizontal grounding electrodes has been presented in [15]. It is worth mentioning that research presented in [13–15] is limited to a rather simple geometry of a single grounding electrode, while the research presented in this paper is extended to a complex grounding grid configuration, where mutual coupling between wires has to be taken into account along with the wire junctions effects.

The approach presented in this paper, which can be considered as an extension of the work published in [15], within AM is based on the integro-differential equation of Pocklington type, with ground-air interface effects being taken into account trough exact Sommerfeld integral formulation. Contrary to the usual approach featuring the Moment Method [9], in this work the current distribution along the grounding grid is obtained by solving Pocklington integro-differential equation in the frequency domain

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doi:10.1016/j.enganabound.2011.05.002