Analysis of pipe-type cable modelling for EMT-type simulations

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ABSTRACT

This paper studies different modelling procedures for the calculation of per-unit-length parameters for pipe-type cables. The characteristic admittance and propagation function of a cable are compared for the traditional Cable Constants routine and the Method-Of-Moments and surface Admittance Operator. Transient models obtained with the studied set of parameters are also computed and analyzed for different time-domain simulation scenarios.

KEYWORDS

Pipe-type cable; electromagnetic transients; wideband, frequency-dependent, EMTP.

INTRODUCTION

Electromagnetic transient (EMT) simulations are of great importance for the evaluation of power systems from a design stage up to a post failure analysis stage. Depending on the type of study, the level of detail required in terms of modeling may vary for the different components of power systems. When it comes to cables, different models can be used, such as a PI section, a Constant-Parameters, and or a Frequency-Dependent model [1]. The model selection depends on different factors, such as the frequency range of study, time-step required, among others [1]. In this paper, the focus is on accurate frequency dependent modeling for pipe-type cables.

A preliminary stage in the computation cable models for transient simulations is the calculation of per unit length (pul) parameters. The pul parameters consist of the series impedance (for longitudinal effects) and the shunt admittance (to represent transversal effects) matrices. Different approaches for the computation of pul parameters are available, such as the traditional Cable Constants (CC) [2], the Finite Element Method (FEM) [3], and the Method of Moments and Surface Operator (MoM-SO) [4] accompanied with analytical formulas [5], [6].

This paper presents a comparative study between the traditional CC method and the recently developed Line/Cable Data (LCD) method [7] applied to pipe-type cables. The LCD method is based on the MoM-SO technique and state-of-the-art formulas [5], [6]. An analysis in the frequency domain is presented for the pul parameters of a pipe-type cable. The characteristic admittance and propagation functions of the cable, which are required for the identification of transient models, are also compared. Moreover, different time-domain simulations are performed and the impact of the different modelling strategies on transient studies is discussed.

PER-UNIT-LENGTH PARAMETERS

Series impedance

The pul series impedance of a pipe-type cable can be expressed as

$$\mathbf{Z} = \mathbf{Z}_i + \mathbf{Z}_p + \mathbf{Z}_c + \mathbf{Z}_o \qquad (1)$$

where $\mathbf{Z}_i$ represents the magnetic field entering the conductors (loses), $\mathbf{Z}_p$ represents the pipe internal magnetic field, $\mathbf{Z}_c$ is a transfer matrix relating the pipe internal and external surfaces, and $\mathbf{Z}_o$ the field penetrating the ground [2], [8].

Shunt admittance

The pul shunt admittance of a pipe-type cable is given by

$$\mathbf{Y} = s\left(\mathbf{P}_i + \mathbf{P}_p + \mathbf{P}_c + \mathbf{P}_o\right)^{-1} \qquad (2)$$

where $\mathbf{P}_i$ denotes the internal potentials coefficients matrix, $\mathbf{P}_p$ denotes the pipe internal potentials matrix, $\mathbf{P}_c$ denotes the potentials coefficient matrix between the internal and external pipe surfaces, and $\mathbf{P}_o$ denotes the potentials coefficient of the air (only for aboveground cables) [2], [8].

The traditional CC technique is a popular approach for the computation of cable pul parameters. However, for today's needs it has certain limitations, for instance, it does not consider proximity effects and ground return expressions are based on approximations [5]. Also, combined underground and aerial line systems cannot be modeled, nor multilayer ground can be represented [4].

The FEM is an alternative method to overcome the limitations of the CC technique. However, FEM requires significantly larger CPU resources and a certain expertise is required, making it less practical. Therefore, this approach is beyond the scope of this paper.

The LCD technique is also available for the computation of pul parameters for pipe-type cables with similar accuracy to the FEM method but better efficiency [6], [7]. The MoM-SO approach brings major advantages such as proximity effect and multilayer earth representation. The analytical formulas applied on the computation of shunt admittance parameters allow considering ground return effects [5] leading to a more accurate modeling. The combined strategy is available in EMTP [9] and it is used in this paper for analysis.