

Reduced Time Domain Behavioral Model of Three-Wire Shielded Power Cables

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Abstract—To quantify effectively the electromagnetic interference levels in a motor drive system, we have to build up a precise high frequency model of the power cable between the converter and the motor. In this context, this paper proposes a model of three conductors shielded power cables in time and frequency domain. This model takes into account all electromagnetic phenomena that occur in the cable when it is under a rapid variation of current and voltage. The rotational symmetry of the cable has been exploited to decouple its admittance matrix. Then, the frequency evolution of the admittance matrix eigenvalues has been approximated by using the vector-fitting tool. Thus, we obtain a behavioral model of the cable that is easy to convert to the time domain. Our approach has been validated by comparing the frequency and time responses of our model with those of a cascaded cell model, which is widely used in the literature.

Keywords—Time domain model, shielded power cables, per unit length parameters, admittance matrix, ANSYS Simplorer model.

I. INTRODUCTION

TO reduce the maintenance cost, increase safety and protect the environment, industrial systems have become increasingly more electric. This transition has been accompanied by the increased use of static converters. These last characterized by their high-performances, cost-effective can control the speed of electric motors. These converters are formed by electronic switches, which operate in commutation mode. The voltage and current variation due to the switching of these power transistors causes many EMC (Electromagnetic Compatibility) problems. The high-frequency interference generated from the converter propagates through the cable in differential and common mode and can cause significant damage [1]. Indeed, we will have a reflection of the electric field at the end of the cable because of the impedances mismatch. This reflection leads to an overvoltage at the load terminals [2]. In order to estimate these voltage peaks or to propose a filtering solution one must first have a model, which

represents the cable under these conditions of use. In addition, this model must be precise and convergent.

Several research works of modeling energy cables have been presented in the literature [3]-[4] and [5]. The conventional method is to subdivide the cable into several parts. Each part is formed by a RLGC elementary cell [5]. The techniques for calculating the cable per unit length (p.u.l) parameters have been extensively discussed in the literature. The simplest and fastest technique is the analytical formulation [6]. However, it is limited to regular geometries and does not take into account the proximity effect. On the other hand, numerical methods treat the general case and are more reliable to determine these parameters [7]. Furthermore, finite element methods have grown considerably in recent decades because of their precision [8]. To model the frequency dependence of the p.u.l parameters, ladder networks have been widely used. Another technique that achieves this goal is to approximate the longitudinal impedance of the cable's cell with the vector-fitting tool [9].

The accuracy of the cascaded cell model depends strongly on the number of cells chosen per meter, and the fineness of the p.u.l parameters' model. This model is incompatible with cables whose lengths exceed tens of meters. Indeed, the simulation time depends strongly on the number of nodes. Reference [10] proposes a solution based on the determination of the admittance matrix from the simulation of an equivalent cascaded cell model.

In this context, the aim of this article is to propose a simple and efficient method of reduced modeling of power cables in the time domain. The developed method must respect the requirements of stability, speed and precision.

Circuit type models are considered the most suitable for the study of conducted electromagnetic disturbances. To obtain a cable model of this type we have chosen the VHDL-AMS language. It allows to insert directly the differential equations and to manipulate quantities of different physical natures. In addition, it is a powerful means of modeling [11]. ANSYS Simplorer is the most suitable VHDL-AMS simulator.

The remainder of this article is organized as follows:

Section II presents the three wire shielded energy cable that is the subject of this study. The third section describes the adopted modeling method. While Section IV demonstrates the validity of our approach in both frequency and time domains. After that, Section V gives a simulation example of a motor drive system fed by the proposed cable model. A filtering solution has been used to mitigate the level of overvoltage spikes. Finally, we end with a conclusion.

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