Nonlinear Shielded Multipair Twisted Railway Cable Modeling with COMSOL Multiphysics®

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Abstract

Signaling and telecommunication cables are shielded multipair twisted cables that lie along the railway and transfer railway information at low frequency (some kilohertz). Due to the electromagnetic disturbance of the railway environment, coming from high voltage conductors such as the overhead line and the electric energy transmission lines parallel to the railway those cables can be subjected to high induced longitudinal electromotive force. This can lead to the transmission of wrong information and a risk of electrocution of the staff doing its maintenance. In order to avoid hazardous situations it is necessary to study the behavior of those shielded cables in different situations in order to design appropriate electromagnetic protections.

Nowadays the shielding factor (reduction factor) is calculated by integrating measurement data from a test measuring bench by the evaluation of voltage and current of a cable submitted to an external magnetic field. However, those results are limited in intensity and frequency exposition. The railway cables' shielding factors in stronger electric and magnetic fields and their nonlinear behavior resulting from their material's magnetic property are still unknown.

In this paper, we present a COMSOL Multiphysics® study of the electromagnetic behavior of the shielded multipair cables in a real railway electromagnetic environment. The main objective is the simulation of the nonlinear magnetic behavior of the steel shield under different intensities and frequencies of external electromagnetic disturbing sources. We are also interested in the reduction effect brought by the coupling of the different pairs composing the cable core. Furthermore, we also take into account the performance of different cable structure and composition.

The model was built using the AC/DC Module in 2D. A one-pair twisted shielded cable is disturbed by the magnetic field produced by an external interference current in a defined frequency. An infinite element domain is used at the extremities of the geometry. The induced current is computed with and without the shielding, in order to calculate the reduction factor brought by the shielding.

The nonlinearity of the cable's behavior is a result of the ferromagnetic material magnetization saturation, therefore it is inevitable to import the nonlinear HB curve for the shielding material of the cable. Afterwards, Maxwell's equations and Ampere's law are used to calculate the induced voltage over the pairs.

A parametric analysis of different types of shields has been done in order to see the influence of different materials on the shielding efficiency. Hence, by varying the external interference current and the frequency, we could observe the nonlinear behaviors of the cable, meaning a nonlinear curve of the shielding factor. Once the nonlinear curves in terms of different parameters are identified from modeling, we compare the modeled curves with those from measurements.

Figures used in the abstract

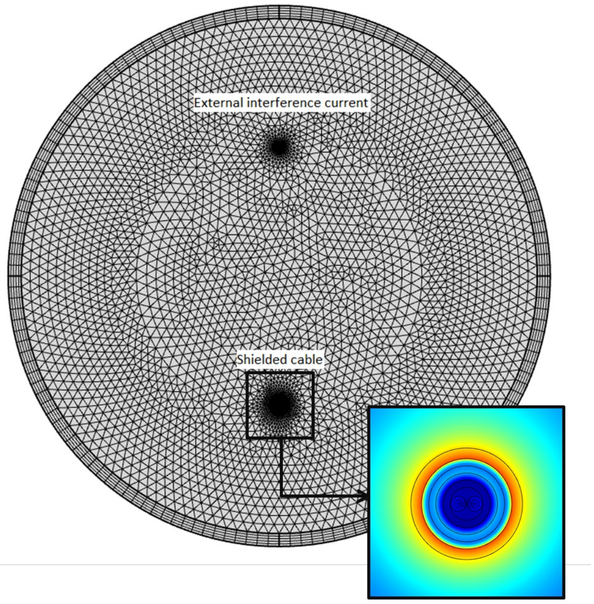

Figure 1: 2D COMSOL® model of a one-pair twisted shielded cable disturbed by an external interference current.