Modeling of DC cables for transient studies

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The electrical modeling of AC underground single-core cables is a topic that has been quite well addressed. Accurate models are available and suitable for steady-state as well as transients studies.

The development of DC systems goes along with an increasing demand for electromagnetic transient simulations involving DC cables. These are generally represented by simple models or AC cable models. As a result, physical phenomena proper to DC cables are omitted, which may be detrimental to calculations accuracy.

In AC cables, dipoles generation and orientation phenomena occur with time constants much shorter than one power frequency period; space charges migration are only of secondary importance. Therefore, the electric field inside the insulation can easily be calculated, assuming that the charge density is nil.

On the other hand, in DC cables, these phenomena cannot be ignored, for they lead to a non-zero charge density inside the insulation. It is then considered that the insulation conductivity varies with temperature and electric field. This makes the computation of the latter much more difficult.

To model a transmission line is to derive the telegrapher's equations, which govern voltages and currents in conductors, from Maxwell's equations, which describe the propagation of the electromagnetic field. This is what is behind the models commonly used in EMTP-like programs. Can these models be used to represent DC cables?

In this paper, the impact of a temperature and field dependent conductivity on the telegrapher's equations is studied, starting from Maxwell's equations. It is shown that in this case, the telegrapher's equations cannot be solved as they currently are in EMTP. However, it seems still acceptable to use the existing models for transient studies, if the following changes are carried out:

- Adding a voltage source to the model to represent the electric field due to space charges;
- Modification of the admittance matrix to reflect the inhomogeneity of the conductivity.

This approach contributes to enhance the accuracy of DC cable modeling, without requiring deep changes in the EMTP code.