MULTICONDUCTOR CELL ANALYSIS OF SHUNT COMPENSATED CABLE LINES

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ABSTRACT

The author has already presented some papers [1, 2] which allow studying cable systems by means of the multiconductor cell analysis (MCA). This method considers the cable system in its real asymmetry without simplified and approximated hypotheses. The multiconductor matrix procedure based on the use of admittance matrices, which account for the line cells (with earth return currents), different types of shield bonding, possible multiple circuits (single and double circuits or more), allows predicting the steady-state regime of any cable system. In previous papers, these matrix algorithms had been presented with reference to a short extra-high voltage (EHV) double-circuit cross-bonded (CB) underground cable (UGC) system. Since the cable link was short, the shunt reactive compensation was not used and consequently not considered. In this paper the procedure is generalized in order to take into account three single-phase (or also one three-phase) reactors installed at the cable ends or also at intermediate locations.

KEYWORDS

Insulated cables, Multiconductor Cell Analysis, Extra High Voltage, Shunt reactive compensation.

INTRODUCTION

Insulated cables constitute complex cases of multiconductor systems which cannot be studied in detail by means of a simplified single-phase equivalent circuit. In the electrical system research, the multiconductor theory is used in several situations e.g. analysis of electromagnetic interferences between systems of different kind. Obviously, the modelling used for the abovementioned electromagnetic compatibility studies cannot be applied to the multiconductor analysis inside a unique power system where besides the overhead lines there are also UGCs with their metallic shields. Hence it is easy to understand how, considering the physical reality of the power networks, it can be questionable to assume purely three-phase configurations and perfectly symmetrical ones, so to use the three sequence modelling; in many cases, the multiconductor analysis becomes necessary, since it allows one to achieve great precision results so offering a powerful tool in order to validate approximated and simplified computation methods.

BRIEF RECALLS TO THE MULTICONDUCTOR CELL ANALYSIS

The whole exposition of the general procedure can be found in [1, 2] or, with a more didactical approach, in the book [3]. In the following only a brief synopsis is provided. Let us consider three single-core cables (*3 phases and 3 shields* for a total of 6 conductors parallel to themselves and to the ground surface where earth return current flows) with total length *d* (see Fig. 1) and a stretch of length Δ_ℓ between the two sections *S* and *R* composed of *6* conductors; if $d \gg \Delta_\ell$, the border effects can be neglected. In such a case, the treatment (given by Carson [4], Pollaczek [5]), shows (if the transversal couplings due to the phase-to-shield and shield-to-earth conductive-capacitive susceptances are treated separately) how the longitudinal ohmic-inductive self impedances $\underline{z}_{i,i}$ and mutual impedances $\underline{z}_{i,j}$ of *n* conductors (*n=6* in the present case) can be computed, considering also the electromagnetic field inside the earth; once $\underline{z}_{i,i}$ and $\underline{z}_{i,j}$ have been computed, it is possible to form the matrix $\underline{\mathbf{Z}}_L$ (6×6) and to characterize, by means of the relation (1), the steady state regime of longitudinal block *L* of Fig. 2 (where the voltage column vectors $\underline{\mathbf{u}}_S$, $\underline{\mathbf{u}}_R$ and the current column vectors $\underline{\mathbf{i}}_S$, $\underline{\mathbf{i}}_{SL}$, $\underline{\mathbf{i}}_{ST}$, $\underline{\mathbf{i}}_R$, $\underline{\mathbf{i}}_{RL}$, $\underline{\mathbf{i}}_{RT}$ are shown):

$$\underline{\mathbf{u}}_S - \underline{\mathbf{u}}_R = \underline{\mathbf{Z}}_L \, \underline{\mathbf{i}}_{SL} \quad , \tag{1}$$

and by considering the obvious relation (2)

$$\underline{\mathbf{i}}_{RL} \equiv -\underline{\mathbf{i}}_{SL} \tag{2}$$

it yields, (being $\underline{\mathbf{Z}}_L$ not singular)

$$\underline{\mathbf{Z}}_L^{-1}\mathbf{u}_S - \underline{\mathbf{Z}}_L^{-1}\mathbf{u}_R = \mathbf{i}_{SL} \tag{3}$$

$$-\underline{\mathbf{Z}}_L^{-1}\mathbf{u}_S + \underline{\mathbf{Z}}_L^{-1}\mathbf{u}_R = \mathbf{i}_{RL} \quad . \tag{4}$$

Hence the following matrix relation (5), where $\underline{\mathbf{Y}}_{L\Delta}$ (*12×12*) regards the block *L* circuit formed by the 6 longitudinal links, can be written:

$$\underbrace{\begin{bmatrix} \underline{\mathbf{i}}_{SL} \\ \underline{\mathbf{i}}_{RL} \end{bmatrix}}_{\underline{\mathbf{i}}_{L\Delta}\ (12\times1)} = \underbrace{\begin{bmatrix} \underline{\mathbf{Z}}_L^{-1} & -\underline{\mathbf{Z}}_L^{-1} \\ -\underline{\mathbf{Z}}_L^{-1} & \underline{\mathbf{Z}}_L^{-1} \end{bmatrix}}_{\underline{\mathbf{Y}}_{L\Delta}\ (12\times12)} \underbrace{\begin{bmatrix} \underline{\mathbf{u}}_S \\ \underline{\mathbf{u}}_R \end{bmatrix}}_{\underline{\mathbf{u}}_{\Delta}\ (12\times1)} \quad . \tag{5}$$

In particular, it is important to mark the directions of the currents in correspondence to *S* and *R* (both towards the circuital block) since the study will be developed by means of models identified by nodal admittance matrices.

Being Δ_ℓ sufficiently small, it is possible to lump the uniformly distributed shunt admittances at both ends of the cell (transverse blocks T_S and T_R whose pertaining matrices are shown in [1-3]) and to consider separately the longitudinal elements in the block *L*.

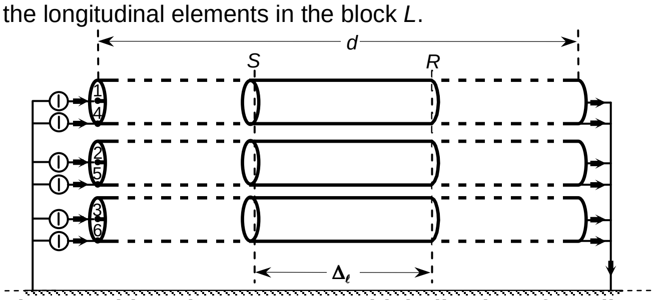

Fig. 1: Multiconductor system with indication of a cell