Sequence impedance computation by means of multiconductor method

Roberto BENATO (1), Leandro CACIOLLI (2), Ernesto ZACCONE (3)
1 – Department of Electrical Engineering, Padova, Italy, roberto.benato@unipd.it
2 – TERNA S.p.A., Firenze, Italy, leandro.caciolli@terna.it
3 – Prysmian S.r.l, Milano, Italy, ernesto.zaccone.ex@prysmian.com

The computation of sequence impedances is a very important topic for cable lines chiefly in HV and EHV applications. In fact, a timely behavior of distance relays is strictly depending upon their suitable settings which are based on positive-negative and zero sequence impedances. Moreover in the planning phase of a new cable link power flow and short circuit studies are always based on the knowledge of sequence impedances. This highlights the importance of presenting reliable procedures in order to compute these impedances since, up to now, their computations are based on simplified formulae.

One of the authors has already presented a paper (see Jicable 2007 paper C.5.2.9) which allows analyzing the cable system by means of multiconductor cell method. 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, allows predicting the steady-state regime of any cable system. One of the major advantage of the multiconductor cell analysis is that it allows computing also the sequence impedances since it is possible to supply the asymmetric cable system with three sequence phasors i.e.:

Positive sequence → 1, α2, α
Zero sequence → 1, 1, 1

The injected currents in the phase conductors are so computed. The great advantage of this method is that it allows computing the stray current in the earth so that no hypothesis is needed to compute the zero sequence impedance. It is worth remembering that available formulae (e.g. IEC 60909-2) are based on the following hypotheses:

- all the current returning in the shields;
- all the current returning in the earth;
- half current returning in the shields and half in the earth.

Moreover some measurement campaigns have been performed on real cable installations and the results are compared with both available approximated formulas of IEC 60909-2 and multiconductor cell analysis. The good agreements of the different results demonstrate that the multiconductor cell analysis is a very powerful tool for power cable analysis.

Fig. 1 shows the multiconductor model of a double-circuit (in electrical parallel operation) cross-bonded cable link with phase transpositions supplied by zero sequence phasors.