Sheath circulating currents calculation in asymmetrical installation schemes for power frequency models

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ABSTRACT

Sheath losses are an important factor in the determination of the ampacity of a cross bonded cable system. Existing standards provide analytical formulation to calculate the sheath losses however; these are based on assumptions that are often not applicable in real world cases. In this paper Complex Impedance Matrix method is applied to calculate the sheath losses in cases where the assumptions of the standards do not apply, i.e. asymmetrical installation schemes. The effect of non – uniform installation methodology and joint pit location in a major section are evaluated for a single and double circuit configuration demonstrating that the ampacity is overestimated in most cases.

KEYWORDS

Complex Impedance Matrix (CIM), cross bonding, unequal minor sections, sheath losses.

INTRODUCTION

In order to avoid large circulating current losses, the sheaths of high voltage power cables are usually cross-bonded. Typically, the cables are installed in either trefoil or flat formation. Calculation of circulating currents and voltage drops along the sheaths are well described in several publications. In particular, CIGRE Technical Brochure 283 [1], and the IEEE Standard 575 [2], contain equations for the calculation of sheath induced voltages for various practical cable configurations. When the sheath currents are known, the sheath loss factors can be obtained as a ratio of the losses in the sheath to the losses in the conductor of the same cable. Calculation of the sheath loss factor for cross-bonded systems is also summarized in the IEC Standard 60287-1-1, [3]. These factors are in turn, used in cable ampacity calculations.

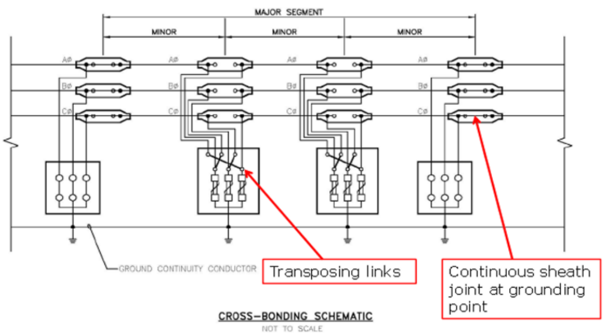

Figure 1 Indicative Cross-bonding schematic

The equations given in the existing standards pertain to the cases with all minor sections of a single cross bonded cable system circuit have uniform parameters along the route i.e., they have been laid at the same depth and in the same configuration, either triangular or flat with or without cable transposition. However, it is not always possible to locate three minor sections satisfying these conditions. Double circuit configurations with different laying conditions characterizing each minor section are encountered in practice. In real world cases, often there is a need to change the laying conditions because of a road or river crossing for a part of a particular minor section. In addition, cables systems are often installed close to existing ones, which affect them electromagnetically. Such variations introduce asymmetries, which result in calculations of the sheaths losses that are more complex.

The aim of this paper is to present the development of the formulae, which were recently implemented by the authors for the calculation of the sheath loss factors for cable arrangements where the IEC standard assumptions are not fulfilled and subsequently, to demonstrate that neglecting those asymmetries may cause cable overheating. The methodology proposed in this paper is an extension of a general approach described by Dorison [4] and an illustration of the methodology introduced by the authors of this paper in [5]. The main extension features include arbitrary cable locations and a consideration of multiple circuit installations with mixed phase arrangements in any minor section. The developments will be illustrated by numerical examples for power frequency situations involving asymmetrical installation schemes as those described above.

EXAMINED CASES

In order to present the significance of the existence of asymmetries, the sheath losses will be evaluated for a cable system in real world scenarios where the following asymmetries are included.

- Unequal minor sections
- Non uniform installation methodology

The examined underground cable system, have copper conductor, aluminium sheath of nominal voltage 220 kV 2000 mm^2 conductor cross-sectional area. The cable follows the design of Fig. 2, where the various layers are indicated. Their properties, including the surrounding media, are given in Tables A.I-A.II of Appendix A.