An updated method for evaluating current sharing between parallel single-core cables: Case studies and correlation with field measurements

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ABSTRACT

The IEC 60287 standard provides methods for the calculation of the permissible current rating of cables in the conditions of steady-state operation. Part 1-3 focuses on the current sharing between parallel single-core cables and the calculation of circulating current losses [3].

The matrix algebra method has been improved and extended to wider configurations. Case studies illustrate the given refinements, and lead to recommendations for operation in the grid.

Then, the results of a bachelor thesis are reported, based on the study of circuits installed in a 110 kV substation, with calculations in good accordance with the measured values.

KEYWORDS

Cable impedances, current rating, parallel circuits, sheath bonding, cable losses, cable design.

INTRODUCTION

The current rating of a cable system (often referred to as “ampacity”) is the current which a cable can carry over a given time, such that the conductor attains – but not exceeds – the maximum rated temperature. For the steady-state operation, this is the value of the current when the maximum temperature is reached asymptotically over an infinite time.

The IEC 60287 standard is a series of documents providing analytical methods for the calculation of the permissible current rating of cable systems in the conditions of steady-state operation (continuous constant current – 100 % load). When the general assumptions are considered [1] [2], the currents are balanced in the parallel circuits, and the design is mainly based on thermal criteria.

The Part 1-3 of the standard series focuses on the current sharing between parallel single-core cables and the calculation of circulating current losses [3]. It provides a deeper electromagnetic approach to cable system design, taking into account the mutual induction effects with alternative currents:

- Circulating currents arise in the loops made by the metal screens or sheaths bonded at both ends.
- The load current may not share equally between the parallel cables, and the circulating currents in the sheaths differ as well.
- The currents are also affected by phase rotation.

DESCRIPTION OF THE METHOD

The method described by the International Electrotechnical Commission calculates the proportion of the phase current carried by each parallel conductor. It considers any number of cables per phase in parallel in any physical layout, and metal screen or sheaths grounded at both ends (solid bonding).

A square matrix with complex variables is built from the characteristics of metal components and mutual impedances, function of their relative positions and cable construction. The values of unknown currents in the parallel conductors and sheaths are solved from a system of simultaneous equations, and from the values of the three-phase currents injected into the grid. The calculation leads to a unique solution without iteration.

Once the proportion of the phase current carried by each parallel conductor and the circulating current in the sheath of each cable is calculated, the loss factor λ_1' in each sheath can be assessed.

Refinements to the IEC method

Several improvements have guided the present paper:

- Correction of several misprints identified in the IEC standard.
- Educational approach, including explanatory figures, to simplify in fewer pages the interpretation of the standardised calculation process.
- Consideration of circuits with single-point bonding and parallel-earthing-conductors, followed by the calculation of the standing voltage at open end.
- Possibility to mix three-phase and two-phase single-core cable circuits into the same vicinity.
- Consideration of parallel external electrical circuits, with cables of different design, connected or not to the same busbar. Each cable is studied in particular, with its own resistance and temperature.
- Coupling with a current rating calculation tool to take into account the variation of electrical resistivity with temperature of conductors and sheaths. [1] [2] [3] are then implemented in a very consistent way.
- Consideration of even a single 3-phase circuit, in order to cover any layout beyond the classical trefoil and flat formations, such as a triangle geometry in a duct bank.
- Calculation of the electromagnetic field mitigation effect of sheath currents.

From discussed typical configurations, guidelines are given about cases to be avoided.

CALCULATION PROCESS

The following items describe the main steps to achieve the calculation of the currents in the conductors and sheaths, before deducting the sheath loss factor values.

Figure 2 illustrates a case study similar to the example developed by the IEC standard ([3], Annex A) with two parallel three-phase circuits, to which two earthing-conductors have been added: $2\times3 = 6$ conductors,