Ampacity Calculation of Multiple Cables with Different Crossing Angles

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ABSTRACT

This paper solves the ampacity calculation problem of an arbitrary number of cable systems with different crossing angles. Each cable conductor is treated as a distinct source calculating its thermal impact at any point along the route of the rated cable. By applying the superposition theorem, the temperature rise from each source is added up, resulting in the derating factor for the examined cable. The proposed method is demonstrated to problems of multiple cable circuits with different crossing angles, while its results are in good agreement with the corresponding of Finite Element Method and of other approaches, if the latter are applicable.

KEYWORDS

Ampacity calculation, cable crossing, crossing angle, derating factor, power cables.

INTRODUCTION

In the design phase of a new project it is common to find cable systems crossing other heat sources, such as electrical links or steam pipes. In such cases, the ampacity calculation shall include the thermal impact of the adjacent heat sources considering the crossing angle. Compared to parallel sources, the contribution of longitudinal heat dissipation in the cable must be additionally considered when sources cross each other. An algorithm considering the heat flux along the cable based on analytical formulae has been proposed in [1], [2]. To simplify the formulation, it is assumed that the heat flux propagates only along the conductor. Other enhancements such as the inclusion of cycling loading [3], soil drying-out [3], [4] and heat transfer along the metallic sheath [4], [5] have been also proposed.

The IEC Standard 60287-3-3 [6] describes a simplified yet accurate method for calculating the continuous current rating factor for cables crossing other external heat sources. The method, based on the previous algorithm and the principle of superposition, is applicable to any type of cable and assumes that the surrounding region is uniform. The maximum permissible current in the rated cable is obtained by multiplying the continuous rating of the cable, as though this was isolated, by a derating factor related to the influence of the crossing heat source. In the case of multiple heat sources crossing the rated cable, the IEC standard states that the derating factor can be generalised when the hottest point along the cable is determined. This, however, may be a tedious task requiring repetitive calculations at several points to ensure that the hottest point is found. Recently, an iterative scheme based on an approximated weighted location has been proposed in [7] to determine the hottest point. This method, however, does not support the crossing of multiple cables with different crossing angles.

This paper presents the methodology and the mathematical background for the ampacity calculation problem of multiple cables with different crossing angles. Each cable conductor is treated as a linear source calculating the temperature rise from this source at any point along the route of the rated cable. By applying the superposition theorem, the temperature rise from each source is added up, determining the hottest point, and resulting in an overall derating factor for the examined cable. The proposed method is executed in an iterative manner for all cables considering all other adjacent sources being parallel, perpendicular or oblique. Results are in good agreement with finite element models (FEM), validating the proposed method and demonstrating its ease of use. Significant margin for design optimisation can be exploited by employing the proposed method, leading to a more cost-efficient cable solution.

PROPOSED METHOD

The proposed method is best described via the conceptual example of Figs. 1 and 2. In these figures, the sectional and plan view of three cable circuits buried at various depths are shown, respectively. Each circuit crosses the other two at a different intersection point and with different crossing angle. Without any loss of generality, circuits 1 and 2 consist of a three-core cable each, while circuit 3 includes three single-core cables in a flat formation.

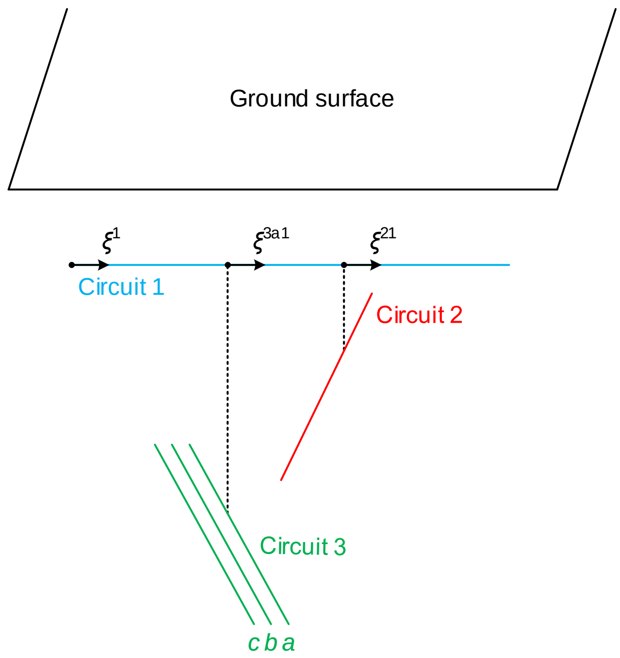

Fig. 1: Example of multiple circuits with different crossing angles. Sectional view

First, the derating factor of circuit 1 is calculated, assuming that circuits 2 and 3 carry their maximum permissible currents as if they were isolated. The temperature rise $\Delta\theta^{21}(\xi^{21})$ due to the thermal impact of circuit 2 on circuit 1 at any point along its route is derived via [1] by setting $i = 2$ and $j = 1$