BARRIER OPTIMIZATION ALGORITHM APPLIED TO CALCULATION OF OPTIMAL LOADING OF DISSIMILAR CABLES IN ONE TRENCH

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ABSTRACT

This paper presents an optimization algorithm applied to the rating calculation of unequally loaded electric power cables. Whereas standards spell out the principles of rating calculations for single and identical equally loaded cables, the common situation where the cables in a trench are of different construction is given only a scant treatment. The paper does not introduce any new calculation method but addresses an issue of what is the best method of loading groups of cables in a common trench. To answer this question, an optimization algorithm utilizing barrier method is introduced and its application illustrated for a complex practical cable arrangement.

KEYWORDS

power cables, rating calculations, unequally loaded cables, barrier algorithm.

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INTRODUCTION

Information about the maximum current-carrying capacity which a cable can tolerate throughout its life without risking deterioration or damage is extremely important in power cable engineering and operation. Ampacity values are required for every new cable installation, as well as for cable systems in operation. With some underground transmission cable circuits approaching the end of their design life, the development of a systematic method for determining the feasibility of extending cable life and/or increasing current ratings is of paramount importance.

Current rating techniques of electric power cables have as long a history as the cable itself. Methods presented by Kennelly in 1893, [1] and Mie in 1905, [2], are still used in today's standards. Over the last hundred years many researchers and engineers have worked on various aspects of cable ratings and several international standards are in use today based on these works [3-6]. It would seam that not much new can be said about rating calculation methods. However, even today the work on refining cable ampacity computations is being continued. It proceeds in several directions: 1) experimental studies are being performed to fine-tune some of the computational formulas and adjust the value of constants, 2) numerical methods are being applied to overcome limitations inherent in the analytical approach, 3) computational methods are being developed for rating calculations for cables laid in non standard conditions (e.g., deep tunnels, ventilated troughs or ducts filled with water) and 4) real time rating algorithms are being developed. The developments presented in this paper fall into the first category above. They constitute an incremental improvement in the power cable ampacity calculation methods addressing an issue of loading of different cables types laid in the same trench.

Analysis of unequally loaded/dissimilar cables is given only a scant attention in the published literature. The method proposed in the IEC standard [3], whose mathematical basis is discussed in [7], outlines a procedure for calculation of the influence of the neighboring cables on the rating of the cable of interest. This procedure is a starting point for the developments presented in this paper and is summarized in Chapter II. The procedure is iterative in nature considering one cable at the time and adjusting its rating based on the loading of the remaining cables in the group. This way, a solution to the ampacity problem can be obtained, which although satisfactory, may not lead to the optimal cable utilization. In order to find an optimal solution for the problem of loading of dissimilar cables an optimization problem is formulated in Chapter III. Application of the algorithm is demonstrated in Chapter IV which contains also comparative studies of the proposed solution with that obtained using the method from the standards. A summary section closes the presentation.

RATING OF UNEQUALLY LOADED/DISSIMILAR CABLES

This section presents an overview and the method of rating calculations described in the IEC Standard 60287. It will be a starting point to the developments presented in the following chapters.

Cable rating equations

Steady-state rating computations involve solving the equation for the ladder network with the thermal capacitances neglected [7]. The unknown quantity is either the conductor current *I* (A) or its operating temperature θ_c (°C). In the first case, the maximum operating conductor temperature is given, and in the second case, the conductor current is specified. In this paper, our interest is in finding conductor current, hence the following rating equation will be used for the cable with *n* conductors [3].