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Advanced topics in rating of power cables

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Abstract. *When cables cross external heat sources or cross the areas of high thermal resistivity, the conductor temperature will be higher than the values attained outside of the unfavourable area. In this paper, analytical solutions for the computation of the derating factors are quoted and sample computational results are presented. When the approximate methods cannot be applied, the heat conduction equations can be solved using numerical approaches. One such approach, particularly suitable for the analysis of underground cables, is the finite element method. The cases when the use of the finite element method is recommended are discussed in the paper.*

An alternative approach to address the issue of higher operating temperatures is to design and install dynamic feeder rating systems. This topic is also discussed in the paper.

Résumé. *Quand des cables souterrains s'approchent d'une source de chaleur externe ou sont dans des sols de haute résistivité thermique, la température de l'âme sera plus élevée qu'à l'extérieur de ces zones. Nous présontons dans ce rapport des solutions analytiques pour calculer les ampacités correspondantes, ainsi que des exemples spécifiques. Quand les formules approximatives ne peuvent être utilisées, les équations de chaleur peuvent être résolues de manière numérique. Une méthode particulièrement appropiée pour l'analyse des cables souterrains est la méthode des éléments finis. Les cas appropriés à l'utilisation de cette méthode sont décrits dans ce rapport.*

Une solution alternative pour appréhender le problème des températures anormalement élevées est un système de calcul en temps réel. L'application d'un tel système de calcul en temps réel est présenté dans ce rapport.

Introduction

Current rating calculations for power cables require a solution of the heat transfer equations that define a functional relationship between the conductor current and the temperature within the cable and its surroundings. The challenge in solving these equations analytically stems mostly from the difficulty of computing the temperature distribution in the soil surrounding the cable. An analytical solution can be obtained when a cable is represented as a line source placed in an infinite homogenous surrounding medium. Since this is not a practical assumption for cable installations, another assumption is often used; namely, that the earth surface is an isotherm. In practical cases, the depth of burial of the cables is in the order of ten times their external diameter, and for the usual temperature range reached by such cables, the assumption of an isothermal earth surface is a reasonable one. In cases where this hypothesis does not hold; namely, for large cable diameters and cables located close to the ground surface, a correction to the solution equation has to be used or numerical methods should be applied.

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. This is particularly so when cables cross unfavorable thermal environment, e.g., crossing other cables, steam pipes, parking lots, streets, and so on.

When power cables cross regions with unfavourable thermal conditions, temperatures higher than the design value can occur. If the region is wide enough, the rating of the cable will usually be based on the assumption that the entire route is characterized by the same conditions. In a majority of cases, the unfavourable thermal environment will be very short, usually a few meters (e.g., street crossing or perpendicular cable crossing). In these cases, the effect of the crossing is usually ignored. However, the conductor temperature in such cases may be much higher than in the remainder of the route and cable derating is required. Thermal analysis of cables crossing external heat sources or unfavourable soil conditions is discussed in the next section of the paper.

In most practical applications, approximate methods of solving the heat conduction equations are satisfactory. Such methods are described in the IEC standards 287 [1] and 853 [2]. When the approximate methods cannot be applied, the heat conduction equations can be solved using numerical approaches. One such approach, particularly suitable for the analysis of underground cables, is the finite element method. The cases when the use of the finite element method is recommended are discussed in this paper.