Ampacity Calculation of Multi-System Cable Crossings at 40 MVA Frequency Converter Station Mendrisio

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ABSTRACT

The planning of a new 40 MVA frequency converter station and substation for the Swiss federal railway and the local electric utility in Mendrisio, Switzerland, needed to consider multiple cable crossings for up to twenty cable systems at various voltage levels between 11 and 150 kV, including five 15 kV systems with 16.7 Hz for the supply of the railway system. In order to reach this goal, an iterative method was developed to analytically calculate the derating factors for all cables in case of multiple systems crossing multiple other systems.

KEYWORDS

Ampacity, Cable Rating, Cable Crossing, Derating Factor.

INTRODUCTION

It is common to find multiple medium- and high-voltage cables crossing each other in the vicinity of substations, even ductbanks containing multiple systems crossing other ductbanks. In these cases, the permissible current-carrying capacity of the cables should be reduced to avoid overheating. This is a three-dimensional problem because the temperature rise decreases with the distance from the crossing. The resulting longitudinal heat flux in the conductor reduces the temperature rise at the crossing. Therefore, calculating the mutual heating using formulae valid for parallel routes would overestimate the influence of the crossing cables.

The IEC standard 60287-3-3 "Calculation of Power Ratings – Cables Crossing External Heat Sources" [1] provides a general simplified method to estimate the reduction of the current rating of a cable crossed by heat sources. The standard states that by applying a superposition principle the method can be generalized for several heat sources crossing the rated cable horizontally, plus it contains an iterative example calculation of a three-core cable crossing three single core cables in a 90° angle. However, the standard gives no advice on multiple systems crossing multiple other systems.

Only one commercially available software tool was found capable to compute the cable rating for cables crossing external heat sources, but again for only two systems crossing each other.

As finite element calculation was not feasible for the planning at hand, an analytical method, based on IEC 60287-3-3, but extended for crossing of multiple systems, was implemented and integrated into an existing cable rating software [5].

IEC 60287-3-3 Method

Capabilities

The IEC 60287-3-3 describes a method for calculating the continuous current rating factor for cables of all voltages where crossings of external heat sources are involved. The standard was published in 2007 and the method is based on the description and illustrations given in [3]. The method was presented in 1999 in two publications [2]. The method is applicable to any type of cable and assumes that the entire region surrounding the cable(s) has uniform thermal characteristics and that, consequently, the principle of superposition applies. The crossing heat source can be located either above or below the rated cable(s) with the crossing angle ranging from parallel to perpendicular.

The conductor temperature rise along the route of the rated cable, caused by the influence of the crossing heat source, may be calculated using Kennelly's principle. The temperature rise is maximum at the crossing point and decreases with the distance z from it. As a consequence of the varying temperature rise along the cable length, a longitudinal heat flux is generated in the conductor, which leads to a reduction in the conductor temperature rise at the crossing, compared to the case when this longitudinal flux is ignored.

The maximum permissible current in the cable to be rated, taking into account the presence of a crossing heat source, is obtained by multiplying the steady-state rating of the cable, without the crossing heat source, by a derating factor (DF) related to the influence of the heat source.

Limitations

The method has some limitations and is not applicable without further considerations when

- crossing cables are touching
- cables are installed in ducts
- the soil is not uniform
- drying-out of soil is considered
- the rating is dynamic

Extended Method

After implementing cable rating calculations for two crossing systems as described in IEC 60287-3-3, the method was extended to multiple systems crossing multiple other systems, as well as cables installed in unfilled ducts, and backfilling.

Multiple Crossings

The IEC standard states that the DF can be generalized for several heat sources crossing the rated cable by applying a superposition principle. In order to make this generalization, it is assumed that the point $z = 0$ is the position where the temperature of the rated cable is at its