Ampacity derating factors for multiple circuits of low and medium voltage cable installations

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ABSTRACT

This paper develops ampacity derating factors for low and medium voltage cable installations with a large number of circuits. Finite element approach is used to obtain these values for a cable construction most often used in North America in industrial applications.The derating factors for Installations with up to 30 circuits in PVC ducts in various configurations are presented.

KEYWORDS

power cables, rating calculations, derating factors, LV and MV cables.

INTRODUCTION

Electrical engineers, who design commercial and industrial installations, often use current-carrying capacity tables provided by cable manufacturers or some standard organizations [3], [7]. This approach is usually sufficient; however, in certain conditions additional current-carrying capacity study needs to be conducted. The aforementioned conditions are applicable to installations where multiple circuits are laid close to each other (either parallel or crossing) which can be found in modern data centers and some industrial applications. Characteristic behavior of such circuits is a close-to-unity load factor and load close to the design value. Although the power loss of an individual cable selected on the basis of generic current-carrying capacity tables seems to be low, the impact of multiple tens of cables can be easily underestimated leading to overheating and, in effect, decreasing the reliability of such facility.

As previously mentioned, one of the solutions is to conduct ampacity study for each installation, which is usually considered impractical and not cost effective. Second approach is to develop coefficients for high number of cables (beyond 20) directly buried or installed in buried conduits. These tables or formulas, if implemented as a standard, will provide guidance for designing such installations.

In this paper the authors try to address the problem of assessing the de-rating factors for multiple-circuit installations.

DEFINITION OF THE PROBLEM

Problem of current-carrying capacity calculations of medium and high voltage cables has already been described in many ways in various publications [1], [2]. However, the commercial installations are usually low voltage (600V, 480V, 400V, 208V) and although currently available standards [2], [3] and [7] provide guidance allowing for computing ampacity of a single or multiple circuits and provide coefficients for many possible installations, the presented work goes beyond the tables provided in [3] and [7]. The work was inspired by a real case of overheating cables and following investigation; therefore, for the simulations similar type of installation was chosen, which involves cables in conduits. It needs to be mentioned that the ambient and installation conditions are based on actual installation, and therefore, cannot be directly compared to the aforementioned standards (the authors are planning to compare the results with [3] and [7] in the future).

The low voltage cables may be of single or multiple conductor design and various insulation types. Due to the variety of installation solutions and cable designs it is not possible to present all of them in this paper; hence, only one type of installation and one type of cable is considered. THHN/THWN cable type was chosen as it is popular in North America. This is an unshielded single core copper conductor (stranded or solid) cable, with thermoplastic insulation rated for 600V and protected by a nylon sheath [8]. The limit of the conductor temperature is up to 90°C in dry conditions.

The installations in modern data centers or in commercial buildings that require significant amount of power are designed to be laid in trays under the ceiling or in conduits/troughs under the floor. In this paper, only underground installations in conduits are considered. The conduits are made of PVC (standard electrical conduits). The size varies from 6” (ok. 152.4mm) to 8” (ok. 203.2mm), depending on cable size, and the wall thickness of approximately 6mm. Both horizontal and vertical distance between centers of two neighboring ducts is 165mm (6.5”). The depth of burial to the center of the top conduits is 635mm. Soil resistivity of the surrounding backfill is 1 K*m/W and due to the moisture barrier in the floor the backfill may be considered stable in terms of moisture content. No dry-out of the soil is considered. The soil ambient temperature (remote soil) is 20°C and the ambient air temperature (above ground) is 25°C.

Due to the fact that only 3-phase systems are considered in this paper as standard for industrial installations, it is assumed that there is no current flow in the 4th (neutral) cable due to the full symmetry of the supply and the load; hence, for the sake of simplicity and without the loss of