FACTORS AFFECTING THE OPTIMAL CABLE PLACEMENT IN DUCT BANKS OR CASINGS FOR BEST AMPACITY OR POWER

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ABSTRACT

This paper presents a method for determining the best placement of cables inside a duct bank or steel casing for maximizing the total ampacity. The method implements a genetic algorithm for searching a portion of the total solution space, and is compared with a brute-force approach of exploring all possible cable configurations. The results show the proposed method requires a significantly shorter computation time for obtaining the optimal solution than the brute-force approach. The paper also presents general guidelines for allocating cables inside duct banks or casings. Finally, the paper proposes using total power, rather than ampacity, as the objective function in loading different-voltage circuits, since it would lead to cooler cable operation.

KEYWORDS

Cable ampacity, combinatorial optimization, VIS algorithm, convex optimization, barrier method, optimal configuration, duct bank, casing.

INTRODUCTION

Installing and maintaining underground cable systems is relatively costly. It is important to design them efficiently, such as to provide maximum possible ampacity. A design factor that greatly affects the ampacity value is cable configuration. The cable placement has a significant effect on the eddy and circulating current losses and mutual heating of the cables, and subsequently on their operating temperature. If the installation involves placement of the cables in a large steel casing, the eddy current and hysteresis losses in the steel pipe need to be considered as well. Therefore, knowledge of the best cable configuration is important.

The optimal cable placement depends on the type of installation and its parameters. In this paper, two underground installations are studied, namely: 1) cables inside a duct bank as illustrated in Fig. 1, and 2) cables inside a large magnetic steel casing as shown in Fig. 2. The former is widely used in the urban areas where the available installation space is at a premium, while the latter can be used when crossing railways or rivers. The paper presents a method for determining the best cable configuration, from the total ampacity or transmitted power point of view, for the aforementioned two installations.

The optimal cable configuration is obtained by using a genetic algorithm, namely the Vector Immune System (VIS). The algorithm searches for the best configuration that provides the largest (or lowest) ampacity, or power. The accuracy of the algorithm is assessed by applying it

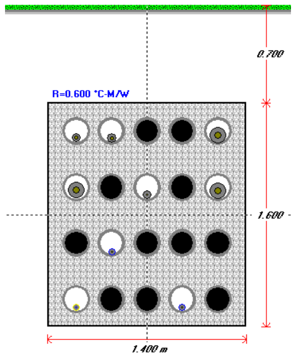

Fig. 1: Duct bank installation

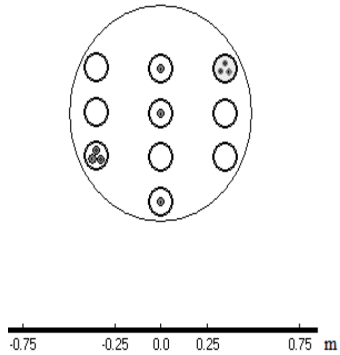

Fig. 2: Casing installation

to a relatively simple duct bank installation, where a brute force search can be implemented in a reasonably short time. The results of this method are used to generate guidelines for placing cables inside duct bank or large casing installations.

So far in the literature, rating computations of underground cables have aimed at maximizing the total ampacity while ensuring that no cable overheats. In this paper, it is shown that for installations containing different-voltage circuits, maximizing the total power rather than the ampacity can lead to a larger total transmitted power *and a cooler cable operation*. Since the main objective of a cable system is to transmit maximum power rather than the current, the comparison indicates that using power as an objective function should be a consideration for future work in cable ratings.

METHODOLOGY

This section describes the methods for computing the ampacity of cables in a duct bank, or steel casing, and for determining the optimal cable placement. Computing the ampacity involves using a convex optimization procedure whereas determining the optimal cable placement implements a genetic algorithm.

Ampacity Computation

Duct Bank Installation

The standard IEC 20687 [1] rating equation for computing the ampacity of cables in a duct bank installation is used and is shown below for convenience.

$$I = \left[\frac{\Delta\theta_{\max} - W_d(0.5T_1 + n(T_2 + T_3 + T_4)) - \Delta\theta_{\text{int}}}{RT_1 + nR(1+\lambda_1)T_2 + nR(1+\lambda_1+\lambda_2)(T_3+T_4)} \right]^{0.5} \quad (1)$$

Where the notation is the same as in the standard and $\Delta\theta_{\text{int}}$ represents the temperature interference of the neighbouring cables. The application of this equation to