Modelling of the Thermal Behaviour of AC EHV Cables in Cable Duct Banks Using a Best-Fit Approach for Geometric Factors

Felix **KORFF**, Siyuan **LI**, Simon **MASSAT**, Jutta **HANSON;** Technical University of Darmstadt, (Germany), felix.korff@e5.tu-darmstadt.de, siyuan.li@e5.tu-darmstadt.de, simon.massat@tu-darmstadt.de, jutta.hanson@e5.tu-darmstadt.de

Constantin **BALZER;** Hitachi Energy PowerConsulting (Germany), constantin.balzer@hitachienergy.com

ABSTRACT

High voltage (HV) and extra high voltage (EHV) cables are usually laid in duct banks to ensure a better heat dissipation. One way of modelling the thermal behaviour of duct banks is to consider the construction dimensions based on geometric factors. In this work a methodology is presented for determining geometric factors of EHV duct banks using a best-fit approach. For this purpose, the results of a finite element method (FEM) model and an analytical model based on IEC 60287 are compared and the geometric factor that provides the best approximation is selected. While using the FEM-Model as a reference, it is shown that the presented approach provides a better solution in the steady-state calculation as well as in the transient temperature calculation for analytical modelling than previous literature models.

KEYWORDS

Ampacity Rating, Duct Banks, Thermal Modelling, Geometric Factors, Transient behaviour, Emergency Rating

I. INTRODUCTION

The thermal behaviour of cable systems is significantly influenced by the thermal resistance of the environment surrounding the cable. HV and EHV cables are therefore often laid in duct banks that have a high thermal conductivity and a better heat dissipation to the environment than normal soil [1].

However, in thermal cable modelling, the presence of the duct bank leads to the need to consider this additional thermal layer. The behaviour of duct banks was first explored in 1923 by Simmons, who assumed that the duct bank can be modelled by an equivalent isothermal circuit [2]. This methodology was further developed by Neher and McGrath, who emulate the thermal behaviour of cables and the cable environment by an equivalent thermal network [3, 4]. The methodology of the equivalent thermal network is also used in the IEC 60287 standard for the calculation of the cable ampacity rating. The ampacity rating indicates the maximum steady-state continuous current that a cable can carry without exceeding the permissible temperature limit. In IEC 60287 it is assumed that the rectangular duct bank can be replicated via an isothermal circle with an equivalent radius r_b. However, the procedure of IEC 60287 is only applicable for aspect ratios of the duct bank between 0.33 and 3 [5]. Especially in the case of HV and EHV duct banks, the aspect ratios can exceed the value of 3. Therefore, other approaches need to be examined.

[6] builds up on the methodology of IEC 60287 and develops an approach how the equivalent radius can also be calculated for larger aspect ratios. The authors use a FEM approach, assuming that the cable environment is an isothermal boundary layer. They calculate the equivalent radius on basis of a geometric factor G_b [6]. This geometric factor depends on two ratios: The ratio L_G/h of the duct bank laying depth L_G and the duct bank height h. The second ratio which influences the geometric factor according to [6] is the h/w-ratio of the duct bank width w and the duct bank height h.

In a later publication [7], the authors state that the assumption of an isothermal boundary layer is not correct, as the heating below the duct bank always exceeds the heating above the duct bank. Subsequently, the geometric factors not just depend on the duct banks aspect ratios but also on the shape and design of the duct bank and how the cables are laid inside. The authors give the geometric factors for different construction forms of duct banks and show that the geometric factors deviate from the values in [6]. The presented duct bank construction forms in [7] are mainly usable for low voltage and medium voltage cables. This paper investigates HV and EHV cables, therefore it is necessary to develop the approach of [6] and [7] further and to develop a methodology to estimate geometric factors for HV and EHV duct bank geometries.

First, Section II explains the calculation of the ampacity rating using the methodology from IEC 60287-2 and shows the results using the original geometric factors according to [6]. Section III explains the calculation of the geometric factors by the developed best-fit approach and shows the results of the ampacity rating calculated by the newly determined geometric factors. In Section IV, the transient thermal behaviour is investigated and the time dependent results of the newly determined geometric factors and the geometric factors according to [6] are compared with a FEM model.

II. CALCULATION OF THE AMPACITY RATING

In this paper, a 380-kV-cable trench is investigated. The cable trench consists of two duct banks with two cable systems each and three cables per system. The cable type used is N2XS(FL)2Y with a cross-section of 2500 mm². The conductor material is copper. The cables are laid in ducts. The construction of the cable trench is shown in Figure 1.

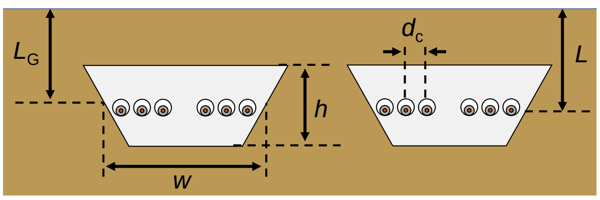

Figure 1: Investigated cable trench