INVESTIGATION INTO THE BENEFITS OF INSTALLING HIGH OPERATING TEMPERATURE CABLES IN TUNNELS

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ABSTRACT

Most of the transmission cables installed in cable tunnels in the UK are XLPE insulated, hence they are limited to a maximum operating temperature of 90℃. Next generation polymeric dielectrics may tolerate higher temperatures, giving increased current ratings. This paper investigates the potential benefits to both the continuous and emergency ratings from using such cable circuits in tunnels which contain both 400kV and 132kV circuits. Thermal issues surrounding joints in such circuits are also considered through the use of a 2D finite element model.

KEYWORDS

Current ratings; cable tunnels; finite element analysis; convective heat transfer

INTRODUCTION

Current ratings of high voltage cable circuits are generally limited by the maximum temperature of the dielectric material, typically 90℃ for XLPE (cross-linked polyethylene). In tunnels an additional restriction is often the tunnel air temperature, which for UK transmission tunnels is normally limited to 50℃. However recent research into new polymeric dielectrics with improved thermal performance suggests that the 90℃ limit could be raised [1]. Although such products are not yet commercially available, it is valuable to consider what operational benefits they might bring if deployed in cable tunnels.

This paper will consider the possible thermal impacts from installing high operating temperature cables (hereafter denoted HT cables) in a typical forced-ventilated cable tunnel. Despite the high capital costs of constructing cable tunnels, in urban areas such as London a number of tunnel projects are under construction or have recently been completed, such as the Elstree – St Johns Wood cable tunnel [2]. This is in part because cable tunnels can be constructed with a minimum of disruption at the ground surface, unlike direct burial of cable, which is a critical factor in busy metropolitan areas. In order to make the best use of the available space, it is becoming increasingly common to install cable of more than one voltage level into the same tunnel space.

To assess the potential ratings available from HT cables installed in tunnels, this paper uses an amended version of the Electra 143 [3] tunnel ratings method to model a co-located tunnel environment containing both 400kV and 132kV cable circuits. The amended model was presented in [4] and is better able to consider the independent operation of multiple different cable circuits. The possibility for elevated temperatures within cable joints is also accounted for through a 2D finite element analysis (FEA) technique which has previous been developed for buried cable joints [5].

RATING METHODOLOGY

A number of techniques exist for rating cables in tunnels, but the most widely used model is that of Electra 143 [3].

Electra 143

The Electra 143 model is based on a thermal-electrical analogue approach, using one dimensional slices through the tunnel to represent both the cables and their thermal environment. These slices are then linked along the tunnel length to form a complete model. Using a modern computer a full temperature profile can be obtained within seconds, however this comes at the expense of a number of limiting assumptions. For the purpose of this study, the most important assumption is that all of the cables installed in the tunnel are of the same operating voltage, construction and carry the same load. This arises due to the design of the one dimensional model, which makes it necessary to lump all of the heat generation in to one "equivalent cable". This is clearly not an acceptable assumption in this study given the use of multiple cable types and the different thermal capabilities of the cable circuits. No consideration is given to cable joints, for which a separate model is developed in this study.

Allowing independent cables

Using the amended modelling technique published in [4], it is straightforward to develop a model which is capable of representing individual cable circuits. The 5 node cable model used in [3] is retained, but instead of using it to represent all of the cables, one cable model is provided for each physical cable in the tunnel. Taking this approach offers a number of key advantages:

- A conductor temperature may be calculated for each individual physical cable, greatly improving the accuracy of emergency rating calculations
- Full temperature-variant ac resistance calculations (by the method of [6]) can be undertaken for each cable
- Different load cycles can be applied to different cable groups
- Different heat transfer coefficients can be specified at the surface of each cable

Making this change requires alterations to be made to the way in which the temperatures of the tunnel are calculated. The equations defining the tunnel air and wall temperatures are also amended to account for the need to sum the total heat transfer from each cable. Full details of the equations required and the appropriate solution procedure may be found in [4].