Ampacity Calculation of Multiple Independent Cable Systems in Ventilated Tunnels

Damian **AEGERTER**, Braavos GmbH, Stetten (Switzerland), damian.aegerter@cableizer.com
Stephan **MEIER**, Emetor AB, Västerås (Sweden), stephan.meier@cableizer.com

ABSTRACT

In 2017, the standard IEC 60287-2-3 for the calculation of the current rating of cables installed in ventilated tunnels was published, however, the method is not suited for applications with multiple independent cable circuits. A new and extended analytical method was developed to allow for the calculation of multiple different cable systems or other heat sources in ventilated tunnels. The numerical method consists of a thermal network representing axially connected slices of the tunnel cross sections.

KEYWORDS

Ampacity, Cable Rating, Cables in Tunnel.

INTRODUCTION

In 2017, the International Electrotechnical Commission (IEC) published the new standard IEC 60287-2-3 for the calculation of the current rating of cables installed in ventilated tunnels [1]. The method is not suited for applications with multiple different cable circuits.

Only one commercially available software tool was found capable to compute the cable rating for cables in ventilated tunnels, but with the limitation that only one cable system can be used. The planning of new energy tunnels often needs to consider two or more different cable systems. Sometimes, even 50 Hz three-phase systems and 16.7 Hz two-phase railway systems are combined in energy tunnels.

An analytical method capable to calculate multiple different cable systems of any type or other heat sources such as gas insulated lines (GIL) or heat and cooling pipes installed in ventilated tunnels was developed and integrated into an existing cable rating software [6]. The software also allows for calculation according to the IEC method which is limited to four identical cables systems.

CALCULATION OF CABLES IN TUNNELS

IEC 60287-2-3 Method

Capabilities

The IEC 60287-2-3 describes a method for calculating the continuous current rating for cables of all voltages installed in ventilated tunnels. The standard was published in 2017. The main features of the calculation method are based on the report of a CIGRE working group published in Electra n°143 and 144 [2].

The air flow in the tunnel removes heat from the cables and transports it along the tunnel axis, thus gradually increasing the air temperature. Therefore, calculating the rating for cables in ventilated tunnels must consider longitudinal temperature gradients.

The numerical method consists of a thermal network representing slices of the tunnel cross sections. One slice is axially connected with the next by the longitudinal heat transfer of the air flow along the tunnel. For every slice, a delta-star transformation is applied in order to derive a thermal network with one thermal resistance each between the star point and the cable surface, the tunnel wall, and the ventilating air respectively. This allows the definition of a fictitious increase of the ambient temperature to account for the ventilation. The equivalent thermal resistance of the cable surrounding is used similar to the classical formula in order to determine the permissible current rating.

The provided iterative method is fast and easy but based on several simplifications:

- The thermal resistances, computed using temperatures at the tunnel outlet, are assumed to be constant along the tunnel route.
- The longitudinal heat transfer within the cables and the surroundings of the tunnel is assumed to be negligible.
- All cables are assumed to be identical within the tunnel and it is assumed that the tunnel cross-section does not change with distance along the tunnel.
- Only steady-state conditions are considered

Limitations

The method is applicable to any type of cable but it has an important limitation that where multiple circuits are involved, their characteristics are assumed to be identical. This means that multiple systems in a tunnel can be calculated, but all systems are identical and equally loaded.

Extended Method

General Idea

The general idea of the newly developed extended method is based on the previous work by J. A. Pilgrim et al published in [3], [4], and [5].

A thermal network was designed such that each cable is modeled explicitly for slices of 1 m length along the tunnel. Using multi-level iterations and weighting of the data from previous iterations, the tunnel air temperature and the temperature of the inner tunnel wall can be calculated for each slice. The axial thermal resistance due to the movement of air through the tunnel is used to consider the longitudinal temperature gradients.

Tunnel Equations

First, the conditions at the beginning of the tunnel are set as follows:

The tunnel air temperature of previous slice $\theta_{at(z-1)}$ and the tunnel air temperature of the current slice $\theta_{at(z)}$ are initially