Numerical Model Parameter Study for Dynamic Thermal Rating Calculations Based on the Wiener Netze 400 kV Dataset

Florian **AINHIRN**, Wiener Netze GmbH, Austria, florian.ainhirn@wienernetze.at
Joachim **NIEMANN-LARSEN**, Energinet Eltransmission A/S, Denmark, jal@energinet.dk

ABSTRACT

This publication describes the step-by-step construction and validation of a calculation model for the thermal rating calculation of a 400 kV cable system based on the finite element method. For this purpose, different implementation approaches were pursued, and the results obtained were continuously compared with measured data from the Wiener Netze 400 kV dataset. The aim is not so much to present a final modelling solution, but to show the implementation and validation of some practices and to encourage further investigations and refinements of the model and discussion on the implementation.

KEYWORDS

High Voltage Cable Systems, Thermal Rating, Finite Element Analysis, Modelling Validation

INTRODUCTION

The established analytical method for thermal rating calculations of power cables is given by IEC standards [1 - 3]. These methods have served cable engineers well for many years, as power cables are mostly operated as black boxes and there are practically no failures due to overheating. One of the reasons for this is the safety margin that underlies the analytical method.

In order to utilize the transmission capacity of power cables, real time thermal rating (RTTR) systems were introduced in the 1990s, which, with the help of distributed temperature sensing (DTS) systems, enabled not only a real-time calculation of the cable temperature but also forecasts for the ampacity over several time horizons. However, due to the relatively high initial costs and because cables tended to be operated "cold" in the past, RTTR systems were sparsely used at the beginning, although they were already relatively advanced when they were introduced.

Due to the energy transition and the accompanying massive expansion of the electrical grid, cable operators are increasingly striving to use their assets more efficiently and to tap transmission potentials, which is illustrated by the trend towards an increased use of DTS systems for high voltage cable monitoring.

However, due to the large number of models required for a single cable system and the need for quasi-real-time capability, RTTR systems have been based mainly on analytical models. With the energy transition, however, new power cable designs, e.g., armored three-core submarine cables, and laying arrangements, such as crossings, are appearing in which the analytical methods reach its limits.

Here, finite element analysis (FEA) offers an alternative, as it can solve arbitrarily complex geometries and multi-physical problems by approximation methods. However, FEA offers many parameters and so-called adjusting screws that can significantly influence the result. This makes FEA anything but straight forward, which also makes it difficult to standardize this method. With [4], a technical report has been available since 2003, which outlines the method, but does not offer comprehensive guidance in its application, which is why this topic is also currently subject of CIGRE WG B1.87.

In the present work, therefore, using known best practice an attempt was made to create numerical models based on FEA, which would achieve high agreement with the measured temperature data of a 400 kV high voltage cable system. As a starting point, numerical models for the steady-state calculation were created and verified using a study case from [5]. These models were then used, their results compared with the measured data and parameter adaptations carried out to achieve good agreement to the measured results. Furthermore, it was investigated to what extent the models, which achieve a good agreement with stationary loads, are also suitable for dynamic loads and which additional adaptations may be required. The basis for this work is the Wiener Netze 400 kV dataset [6], which contains currently about 2 years of stationary load tests with various variables such as currents, cable temperatures and environmental parameters.

BASIC ASSUMPTIONS AND DECISION BEFORE NUMERICAL MODELLING

Before starting with the different implementations and realizations of the modeling, a set of basic assumptions and decisions was formulated. These looked as follows:

- Use of IEC values for all material properties where possible / available.
- Use of a thermal resistance of the soil based on IEC instead of implementing a moisture migration model (PDE) because no drying-out of the soil occurred during the measurement period.
- Use of an isothermal approach for the temperature boundary condition, as the cable is laid relatively deep, but with time-varying values according to a soil temperature function.
- The Milliken conductor design should not be implemented in the geometry but rather in the material parameters of the conductor.
- Dielectric losses are not implemented as the cable system was operated without voltage excitation.
- Global radiation can be neglected as it has little influence on the cable laid at depth of 2.7 m.
- Transient simulations only.
- Limit the investigation to the "steady-state" loads.
- Use solvers with default settings as much as possible.
- Frequency dependent electromagnetic field with coupled heat transfer in solids.
- IEC-oriented approach with heat transfer in solids only.

Table 1 gives a list of the material parameters used.