Performance Optimization of Underground Power Cables using Real-Time Thermal Rating

Martin **OLSCHEWSKI**, Wieland **HILL;** LIOS Technology GmbH, Cologne, Germany, martin.olschewski@lios-tech.com, wieland.hill@lios-tech.com

ABSTRACT

Temperature monitoring is the key factor for the optimization of underground power transmission lines, because the ampacity of insulated power cables is limited by the maximum temperature of the conductor that does not affect the insulation material. Especially, the growing share of highly variable regenerative energy sources creates a demand for a reliable and accurate temperature monitoring of the power cables. Cable design, bonding, laying scheme, neighbouring cables, other heat sources, thermal resistivity of soil, ambient temperature and load history are the most significant factors that have important impact on the conductor temperature.
Distributed temperature sensing (DTS) is a powerful tool to monitor the temperature profile along the screen or the sheath of power cables. Depending on the load situation and surrounding parameters the temperature difference between screen or sheath temperature is not fixed. Real-Time Thermal Rating (RTTR) is the method of choice for the calculation of the conductor temperature and for ampacity predictions.

KEYWORDS

RTTR, real-time, thermal rating, underground cable, temperature monitoring, DTS, conductor temperature, prediction, distributed temperature sensing

INTRODUCTION

We have developed a fully integrated DTS/RTTR system with rating algorithms optimized for making full use of the DTS information and for fast real-time calculations. The RTTR engine uses the following main processes to evaluate the state and ampacity of a power cable:

- Calculation of conductor temperature profiles along the full length of the cable
- Identification of critical locations and triggering of (pre-) alarms based on conductor temperatures
- Fitting of soil and ambient parameters to match the temperature and load histories
- Prediction of ampacity, conductor temperature or time for different load scenarios
- Evaluation of the accuracy of the predictions

If the DTS fibre is embedded in the screen of or attached to the power cable, the conductor temperature can be calculated by using the DTS temperature and load histories as well as the cable design data. Influences outside the fiber position can be neglected in the thermal equivalent circuit (Fig. 1).
This makes the calculations fast enough to determine the conductor temperatures in real-time for all locations along the cable. It also enhances the accuracy of those calculations because they are not affected by less precisely known environmental parameters such as thermal resistivity of soil and ambient temperature.
Since future DTS readings are not known, full thermal models of the complete laying scheme have to be used in ampacity predictions. These models include environmental parameters such as soil thermal resistivity and ambient temperature that can vary considerably with the seasons. We determine the environmental parameters in real-time by fitting them to the DTS temperature and load histories of the cable. We also use a newly developed multilayer RC-ladder soil model [1] to avoid the approximations used in the IEC standards. We verify the accuracy of each model used in conductor temperature calculations and predictions by comparisons with finite element method (FEM) simulations.

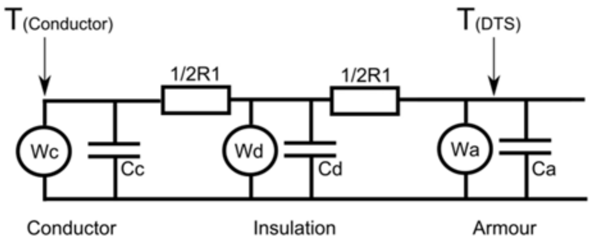

Fig. 1: Example of a thermal equivalent circuit for calculating conductor temperatures from DTS temperature and load histories.

The RTTR engine calculates predictions on ampacity, temperature and time for constant load and also for arbitrary load profiles. Finally, the accuracy of predictions is validated by comparing predictions from the past with conductor temperature calculations.
All DTS readings from multiple instruments, conductor temperature profiles and prediction results are stored together in a modern SQL database. Powerful visualization tools enable multiscreen visualization of temperature profiles and histories, current data as well as intuitive, custom visualization of all data on maps, pictures or drawings of the full power cable installation.

CONDUCTOR TEMPERATURE PROFILES

One may assume that it would be sufficient to calculate the conductor temperature only for locations with the highest DTS temperature. However, the locations of maximum DTS and conductor temperatures may not coincide because of:

- Noise of the DTS readings
- Different cable designs, installation schemes and sensor fibre positions
- Temporary external heating of the power cable by steam pipes, heated pipes, cable crossings, solar radiation or other heat sources

Proper thermal models and efficient algorithms of the RTTR engine enable the calculation of conductor temperature profiles along the full length of power cables (Fig. 2). Alarms can be triggered if the conductor temperature at any location exceeds the threshold. This enables a safe operation of the full cable length.