Performance optimization of underground power cables using real-time-thermal-rating

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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. Cable design, bonding, laying scheme, neighboring cables, other heat sources, thermal resistivity of soil, ambient temperature, load history are the most significant factors that have important impact on the conductor temperature. The calculation of the conductor temperature even under cyclic load conditions demands for efficient algorithms and still remains a current research topic.

Distributed temperature sensing (DTS) is a powerful tool to monitor the temperature of the screen or at the sheath along the power cable. 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 the capacity prediction.

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 the power cable:

- Calculation of conductor temperatures 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 in the screen or attached to the power cable, the conductor temperature can be calculated by using the DTS temperature readings, the current history and the cable design data. Everything outside the fiber can be neglected. This makes the calculations fast enough to determine the conductor temperatures for all points along the cable in real-time. 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. We verify the accuracy of each model used in conductor temperature calculations by comparisons with finite element method (FEM) simulations.

Since future DTS readings are not known, full thermal models of the complete laying scheme have to be used in ampacity predictions. Those 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 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.

Predictions for ampacity, temperature and time can be calculated for constant load and also for custom load profiles. Finally, the accuracy of predictions can be 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.

[1] M. Diaz-Aguilo, F. de León, S. Jazebi, and M. Terracciano, IEEE Trans. Power Deliv, 2014

Key words

Real-Time-Thermal-Rating, Distributed-Temperature-Sensing, power cable monitoring, integrated DTS/RTTR system