Thermal analyses and dynamic rating of power cables

Power cables are vital parts of most power systems and their uninterrupted operation is key for system stability and capacity. Some power cables are radial connections between two parts of a power system, for example between a wind farm and the grid, between the grid and an offshore oil or gas facility, or between two otherwise disconnected grids. In the former two radial cases, cable operation is critical for the operation of the wind farm or offshore facility. In the latter radial case, the cable may be a merchant transmission and in that case cable operation is critical for the owner.

Power cables may be AC or DC transmissions and the types of cables may be Mass Impregnated Non-Draining (MIND), oil insulated, or extruded insulation. Regardless of technology, conductor temperature and the temperature drop across the insulation must be kept within specified limits to avoid accelerated aging or failure of the insulation.

Depending on the length of the cable, the cable's surface temperature can be measured using a Distributed Temperature Sensing (DTS) system. Such systems require a fibre optic cable to be strapped to the power cable's surface or be an integral part of the cable, and analyses of the reflection of light in the optical fibre can be used to sense its temperature along the cable. Such sensing systems cannot, however, measure the power conductor temperature or the temperature drop across the power cable's insulation.

The conductor temperature and the temperature drop across the insulation can, however, be calculated. IEC 60287 provides formulae to calculate steady state temperatures for cables with non-varying load, although IEC 60287 is known to have limited accuracy for three-core AC cables. For (single-core) cables with varying load, IEC 60853 provides formulae for the resulting time varying temperatures.

Both IEC 60287 and IEC 60853 have shortcomings with respect to calculation of losses, lack of generality, and the thermal model. For some situations the standards are adequate, but for others they may overestimate or underestimate the temperature significantly due to inaccurate estimation of losses and/or limitations in the thermal model.

In Cigré working group B1-64 — with Ronny Stølan as convenor and Marius Hatlo as Norwegian representative, both are Unitech Power Systems employees — a new and accurate methodology for calculation of cable losses in three-core AC cables has been developed.

In-depth knowledge about the physics, extensive 3D Finite Element modelling, and measurements on several different cable designs, has enabled the development of an analytical model that most likely will replace the loss calculations in IEC 60287 for three-core cables in a future update of the standard.

By combining the knowledge and experience about cable losses and thermal modelling, Unitech Power Systems has developed a general method for calculation of the cable temperature suitable for Real-Time Thermal Rating (RTTR) applications for AC and DC cables. The method has been verified against measurements, and results were published [1] at the Cigré Centennial Session and named Best Paper for Insulated Cables.

As DTS systems cannot measure the power cable's conductor temperature or its insulation temperature drop directly, RTTR systems — also known as Cable Loading Prediction Systems (CLPS) — are recommended for critical power cables. Such systems continuously calculate the critical power cable temperatures and provide operational limiting signals to supervisory control systems and to Operator Workstations (OWS). RTTR systems may provide cable operators with the opportunity for dynamically overloading the cable when that is desired for power system operational reasons or to maximise profits.

Unitech Power Systems' personnel have expertise in the field of thermal analyses of cables. Services offered include:

- Thermal analyses of cables to be installed, to verify design and check operational limits
- Thermal analyses of existing cables given either operational scenarios or historical operational data, for example to calculate historical temperature extremes
- Development and delivery of RTTR systems for power cables with or without DTS systems

Contact us for more information and to discuss how we can serve your needs.

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[1] Olsen, Brynem, Hatlo: "Dynamic Current Rating—Thermal Transient Response", CSE 023, December 2021