CABLE MONITORING SOLUTION - PREDICT WITH CERTAINTY

Kuljit SINGH, MIEE (UK), B Sc Hon. (UK), kuljit.singh@sensornet.co.uk
Dan WATLEY, Ph. D, BA MEng (UK), CEng IEE, MIEEE, dan.watley@sensornet.co.uk

ABSTRACT

Existing thermal modelling and monitoring solutions cannot predict, detect and prevent hot spots caused by changes in the surrounding thermal environment for underground cables. Using Distributed Temperature Sensing (DTS) can provide you with a real time temperature profile of the underground cable. The benefits of this technology combined with real time Dynamic Cable Rating (DCR) systems, based on IEC 60287and IEC60583 [1] [2] allows you to optimise the power in the cables, to operate within rating limits whilst maximising the network lifetime.

KEYWORDS

Distributed Temperature Sensor (DTS), Dynamic Cable Rating (DCR), Fibre Optics Cable Monitoring System (CSM) and Temperature Monitoring.

INTRODUCTION

In the Transmission and Distribution power applications, the underground power cables can be critical assets in delivering power to commercial and residential population. There has been a growing trend of overhead transmission and distribution network immigration to underground power cables. Any outages will have tangible commercial implications and a high costs for repairs.

In the last 15 years, temperature monitoring based on fibre optic cable technologies have become common on high voltages above 132kV. A number of papers [3] [4], have already described successful and pioneering applications. This paper will provide an overview of the application of the technology and will describe examples and benefits of systems implemented to date.

UNDERGROUND CABLES ISSUES

At the time of cable layout designing stage, the cables are rated to thermal calculations based on (1) load on cable (2) thermodynamic properties of cable and (3) thermal Dissipation of Surrounding Environment

However, there are several factors which can lead to lower heat dissipation and cause cable overheating, such as unknown/changing soil thermal resistivity, dry weather conditions surface effects**,** shallow road crossings**,** microbes in soil (caused by decomposition) nearby cables & pipelines and faults in cables/connectors. If not managed, most of these issues can lead to cable failures due to hot spots.

SENSING TECHNOLOGY

Figure 1 shows a cross section of a typical HV power cable direct buried in a trefoil configuration where by the heat dissipation is related to the thermal properties around each of the conductor core.

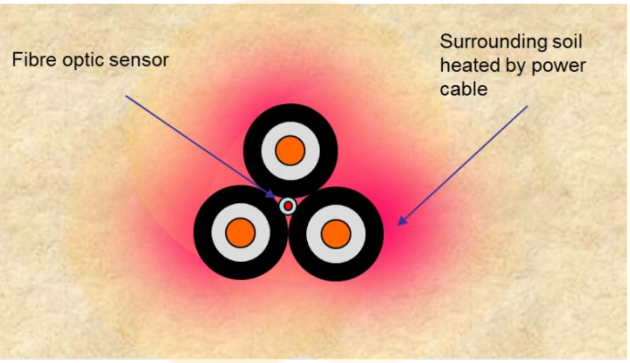

Figure 1: Power cable in trefoil configuration

DISTRIBUTED TEMPERATURE SENSING

As already mentioned, temperature sensing is well established at EHV voltages, for underground cables applications where there is a significant benefit. Due to the close location of the sensor, temperature accuracy is improved as the zone measured is in the T11-12 section rather than the more unpredictable section of IEC 60287. Much better correlation between calculations, models and measurements is thus possible. Figure 2 shows a Finite Element model demonstrating a 150A de-rating due to different soil resistivity.

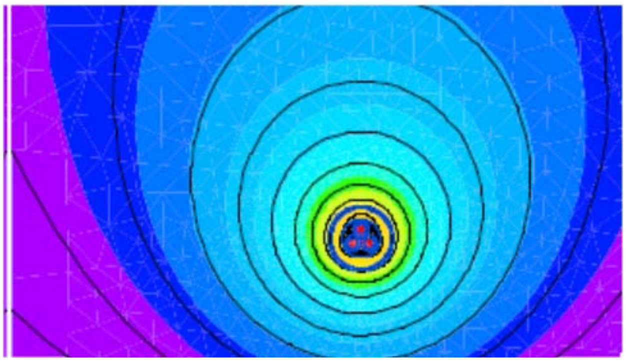

Figure 2: Power Cable Thermal Rating

Conductor temperature is the main driver in the cable ageing mechanism. If accurate thermal cable history is available, asset life can be extended if loads are lower than specified for cable type or the asset can be used closer to its full utilisation by increasing the load.

CABLE THERMAL MODELS

Typical thermal models used today are based on Electra 87 as recommended in IEC60287 & 60853. However, to understand the different environment close to the buried cables, real time cable surface temperature information will be required to provide better information to reflect the actual thermal stress experienced by the power cables. This can be achieved by placing the fibre optic cable as shown in Figure 1 to obtain the real time temperature along the entire power cable route.

DTS MEASUREMENT PRINCIPLES

Based on analysis of Raman backscatter light in an optical fibre, the DTS system uses a combination of variation in backscattered light intensity and Optical Time Domain Reflectometry (OTDR) to create temperature-against-distance profiles. The fibre acts as both sensing element and transmission medium. Many thousands of discrete measurement points can be achieved over distances up to 30km using a single fibre.

Referring to Figure 3, pulsed laser light is launched into the fibre. The interaction of the forward propagating light with the thermally excited molecules of the fibre causes the backscattering of two wavelength shifted Raman light (Anti-Stokes and Stokes). These light signals are passed through spectrum analyzer and the optical receiver conditions the signal prior to data acquisition and processing. The end result is a series of data points representing temperature, which can be displayed as a temperature versus distance profile of the temperature along the fibre.

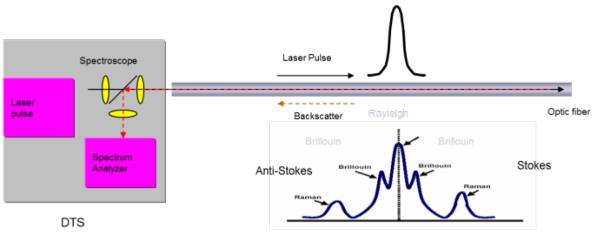

Figure 3: DTS technology principles

There are trade-off characteristics and performance of a DTS system, in general the longer the range of the DTS, the longer the time that is needed to resolve a given temperature. This is mainly due to the attenuation of the backscattered light signal and the fact that the sensing system processes very low level signals. A 20 km DTS system, using multimode fibre has the following typical performance:

- Range: 20 km
- Positional resolution: 1m
- Temperature resolution: < ±1°C
- Accuracy: < ±1°C
- Spatial resolution: 1m
- Measurement time for ±1°C resolution < 1 min

A typical profile of temperature versus distance is shown in Figure 4. From the data collected, it shows there were several hot spots positions due to the different soil environmental factors.

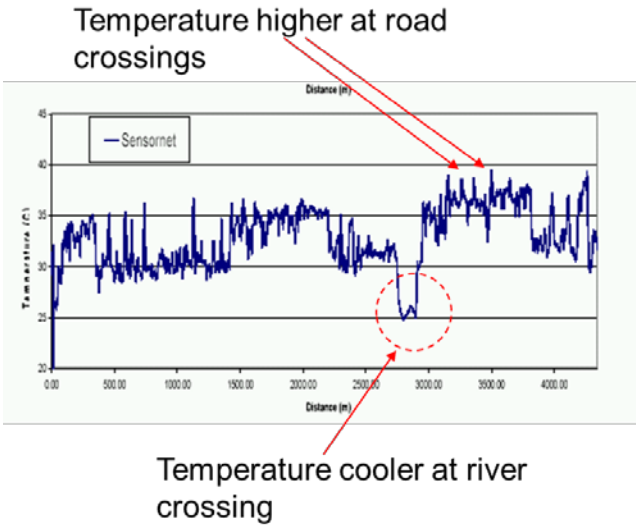

Figure 4: 24 hours Temperature profile

DYNAMIC CABLE RATING (DCR) TECHNOLOGY

DCR technology is a purpose built software tool for providing temperature and Ampacity data for power cable installations. This DCR solution is designed, in compliance with the relevant parts of internationally recognised standards IEC 60287 and IEC 60853, to provide both steady state and transient thermal analysis.

By integrating real time circuit load data and distributed temperature data, within a software based model of the cable installation, we provide the ultimate cable management solution.

Designed to operate over and above Distributed Temperature Sensing (DTS) technology, the DCR solution is able to deduce the cable core temperature from the temperature monitored on the outer surface of phase of the underground power cables. The solution enables the utility to determine cable core conductor temperature along its entire length, and enable the operator to use this data to maximum effect. It provides four key parameters:-

•Accurate real-time conductor temperature data extrapolated from DTS temperature data

•Location and trending data for power circuit bottle-necks and hot spots

•Enables circuit specific emergency rating calculations to enable the operator to cope with future planned and emergency circuit loads (e.g. maximum load cable can sustain for a defined period of time – 24 hours, 6 hours, 20 minutes)

•Seamless system integration (e.g. SCADA, Ventilation, Relay)

CIRCUIT REQUIREMENTS

Based on a typical circuit specification as shown in Figure 5, the DCR system will configurable software solution which enables a multitude of cable installation practises to be accurately modeled. By offering the operator a database of historical data for the specific cable asset, the solution enables the effective decision making regarding how the cable asset is managed.

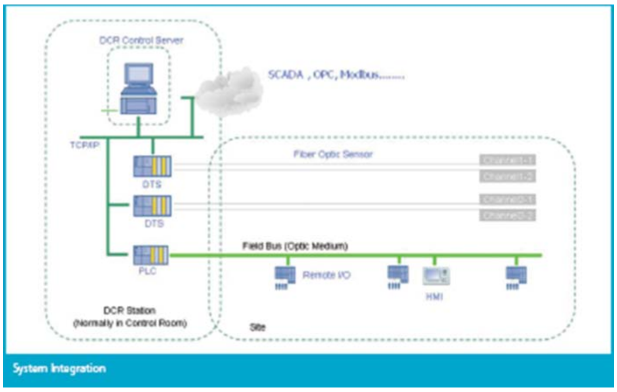

Figure. 5: Typical DCR and DTS circuit layout

RESULTS

The DCR provides an overview plan for the DTS being used to monitor electric cables. It provides two core functions: Trouble Detection & Load Monitoring. The former, unique from conventional DTS detection methods, provide distributed temperature in three time-scales – real-time, hourly, and daily. This helps to locate potential/early trouble that might be visible only in statistical. Example of a real time monitoring as shown in the following figure 6.

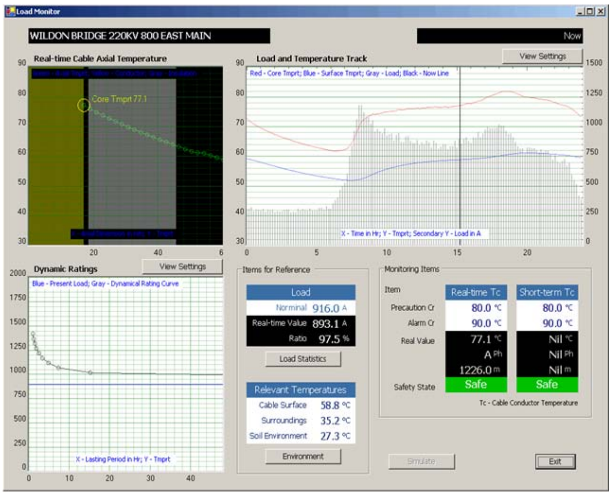

Figure 6: Real time Power Cable monitoring

<u>CONCLUSION</u>

The use of DTS and DCR allows the operator the ability to monitor the power cables in real time. With the effective use of DTS – it provides a fast real time temperature values and changes of the underground power cables.

Using these real time temperature changes with the DCR software, it can be effectively interpret the thermal stress experienced by the cable and providing the thermal model for the cable.

There has been a number of successful implementation using DTS and DCR for the use on real time monitoring of power cables.

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