Localized Temperature Sensing (LTS) as new approach to HV cable system monitoring and uprating

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ABSTRACT

Even if distributed temperature sensing (DTS) has been accepted as the best way to manage undergrounded HV cable systems' exploitation, there are several inconveniences that have stopped its general usage and with it, the installation of fibre optics in cable screens.

The concept of Localized Temperature Sensing (LTS) tries to give an answer to utilities' needs of monitoring the real operation temperature of certain existing lines, in order to be able to optimize their exploitation regimes even if there is no fibre optics inside cable screens.

Accurate passive sensors operated at distance open a new field for dynamic cable rating.

KEYWORDS

Temperature, dynamic rating, LTS, DTS, Bragg.

INTRODUCTION

As power generation and consumption are having a shift in what was considered the status quo and international HV connections grow, changing the predefined power flows, some HV connections are being forced to reach its theoretical limits of power transmission capacity.

Most of these underground cable connections do not include fibre optic cables within their metallic sheaths, thus are not prepared for the conventional Distributed Temperature Sensing (DTS) methods of dynamic cable rating.

With this problem in mind, and by request of Union Fenosa Distribución (UFD), a new concept of temperature measurement in cables has been developed.

The initial requirements where temperature measurement accuracy of 1ºC or less, passive technology that would not interfere with the operating links and would require no power feeding, on line data availability and ad hoc sensor designs easy to install at any accessible point of the cable route.

LTS SENSORS

Bragg modified fibre optic sensors where chosen as the best solution to measure temperature with the required accuracy, time response and passivity.

These sensors act as mirrors at certain wave lengths, and this property is affected by temperature and strain, shifting the central wave length at which it reflects the light.

As it is know from other temperature measurement experiences with Brillouin, disassembling the strain effect from the temperature effect is not easy when the measurements are affected by both, so the approach was to design a sensor that would avoid any possible strain to the Bragg fibre.

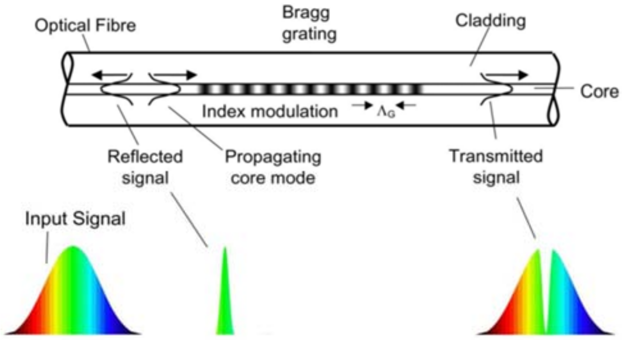

Fig 1: Bragg principle

The sensors, consisting of the modified Bragg fibre with the specially designed protection capsule, are intended to be installed on the cable outer sheaths with standard plastic clamps and are connected to each other by means of standard G652 single mode fibre optics that may or may not follow the cable route. This implies that different circuits can be monitored with one measuring unit, with the consequent economic saving.

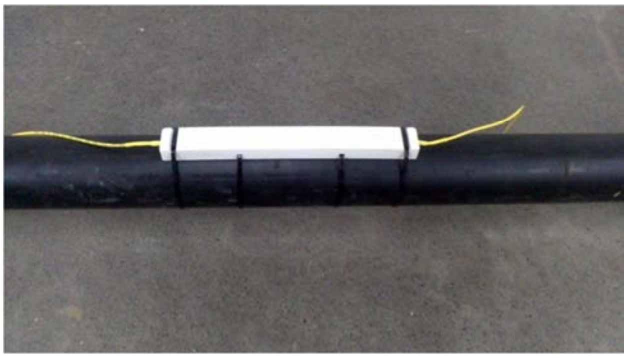

Fig 2: LTS sensor

The sensors are individually calibrated inside an oven, with controlled temperature conditions in order to define each unit's temperature – wave length (pm/ºC) ratio and the central wave length at 20ºC.

It is important to notice that this ratio does not change with the time (it does not suffer aging), but in order to assure the best accuracy and increase the confidence in the measurement, as well as having a method for the detection of any damage in the case that the sensors want to me moved from site to site, a simple on-site calibration is recommended.

MEASURING UNIT

Two measuring units have been developed, being the main difference the number of sensors that can be connected in series to them.

Depending on each site's necessities, the LTS 1500, with up to 15 sensors or the LTS 3000 when up to 30 sensors are required can be installed in the closest substation to any of the sensors.

The measuring unit, designed to be installed in a standard 19'' rack, can be customized to meet client's specifications about alarms, connection protocols, data saving capability, external connection, etc.

The measurements of each sensor are performed every second and displayed in a touch screen, saved in the internal memory and sent to the final user in defined time lapses.

By using a coherent light laser emitter working in the 1550 nm wave length range, standard single mode fibres can be used and attenuation issues are disregarded, allowing distances up to 10 km from the measuring unit to the sensors.

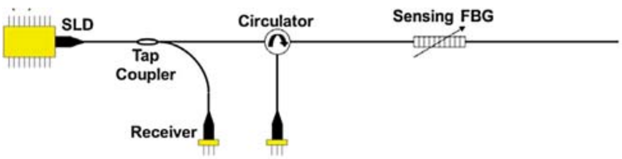

Fig 3: Measuring scheme

LTS MEASURING SYSTEM

The LTS 3000 measuring unit will handle up to 30 sensors with some meters or kilometers of fibre optic cable between them.

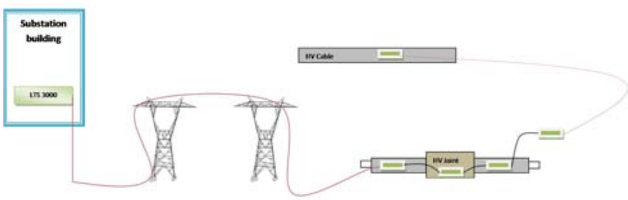

Fig 4: LTS installation scheme

Each sensor is clearly identified by the distance to the measuring unit, which is easily calculated by the required time to detect the reflection, and the answer wavelengths.

The central wavelength of each sensor is selected in such a way that they are unique per sensor and they don't superpose within the defined temperature variations.

For this reason, each system has to be tailored in order to meet user's requirements, defining temperature measuring ranges, alarms and number of sensors to be connected in series.

DEVELOPMENT MILESTONES

The connection of any new equipment to electrical assets and its installation inside a substation requires a maximum of reliability and previous tests.

In order to meet UFD's standards, a development sequence was defined as follows:

- Laboratory temperature accuracy measurement test.
- Laboratory temperature accuracy measurement test on cable samples.
- Laboratory temperature accuracy measurement test on a cable sample with a 132kV joint with cyclic loading and 4 sensors connected in series.
- EMC type testing.
- Pilot installation in a HV connection in Madrid.

The first two milestones served to show how the system works and how easily it meets the required accuracy and time response requirements.

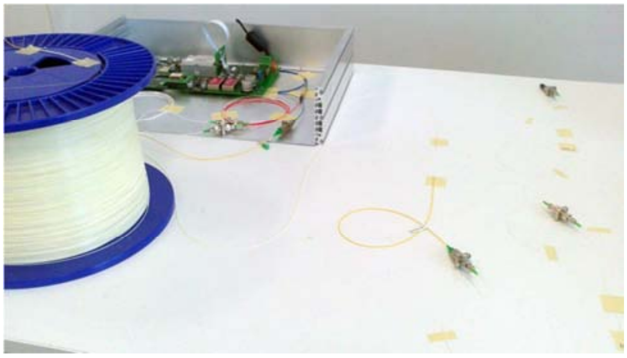

Fig 5: Initial laboratory test

This was a very important milestone for a development that is dealing with the edge of the innovation and a solution that has been never used before with this application.

Thermo cycling testing

A high voltage cable with a 132kV joint was installed in General Cable's HV R&D laboratories in Spain trying to simulate what would be the behavior of joint in a gallery.

3 thermo cycles according to IEC were performed while temperature in the conductor and the outer sheath were controlled by means of standard calibrated temperature sensors following IEC 60840, while 4 LTS sensors were installed in series over the outer sheath, the joint and on the laboratory floor, measuring ambient temperature. 1 kilometer of fibre optics was added between them and the measuring system.

The objective of the test was to prove that:

- The measuring equipment worked properly after the transportation from the development laboratory.
- The LTS sensors followed accurately the variations in temperature.
- The accuracy of the measurements during all the cycles was comparable to standard sensors' accuracy.
- The equipment distinguished between several

sensors connected in series with short fibre optic links while measuring at certain distance from the substation.

Fig 6: Laboratory set up

Fig 7: LTS sensor installed on a joint

Once the measurements were added up in the same plot it was very difficult to distinguish the readings of each technology as can be seen in figure 8..

It is possible to see that LTS' curves are smoother because of the amount of data registered (every 10 seconds against every 10 minutes), and its sensitiveness; a slight increment in the temperature before the second heating cycle was due to the switching on of some equipment's air heater close to the test loop.

The 4 main curves reflect conductor temperature, cable outer sheath temperature, joint outer sheath temperature and ambient temperature.

The thermal inertia of each component is found on each curve's maximum's shift on time.

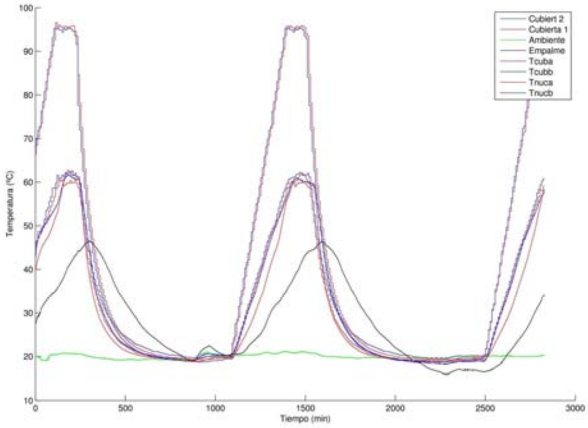

Fig 8: Measurement comparison

Next milestones

EMC type testing is scheduled for Q2 2015 as a basic requirement before the pilot installation is performed during 2015.

Once the final installation is performed, the system will have to be integrated in a more complex environment by

- Thermal model verification
- Dynamic rating
- High temperature alarm testing (by changing alarm criteria on line)
- Accuracy verifications

The authors will share these results in future articles.

Acknowledgments

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GLOSSARY

DTS: Distributed Temperature Sensing
LTS: Localized Temperature Sensing