Large Scale Monitoring of Extruded Cables – Review of TSO's Needs and Options

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ABSTRACT

This paper is a review giving an overview of the different techniques available on the market for online monitoring of extruded transmission cables. The purpose is to present the cost and benefits of the different monitoring techniques, as seen from a Transmission System Operator's (TSO's) point of view, and in this way to start a discussion in the cable community about defining standardised approach for detecting when condition-based maintenance is needed. This leads to the definition of the 3Wishes to monitoring solutions: 1. Warn when components need maintenance 2. Calculate the cable rating online 3. Evaluate the remaining lifetime.

KEYWORDS

Condition based maintenance, remaining lifetime, partial Discharge (PD), point temperature (PT100), Distributed Temperature Sensing (DTS), Distributed Acoustic Sensing (DAS), Distributed Vibration Sensing (DVS), screen current, tanδ, traveling wave, Time Domain Reflectometry (TDR), wide band impedance spectroscopy, Sheath Voltage Limiter (SVL) integrity, manhole monitoring, pressure in terminations

INTRODUCTION

Over the last 30-40 years, new cables in transmission systems, in most of the world, have been with solid insulation, primarily XLPE. For environmental reasons, as well as costs, this transition is good, however the transition from pressurised oil-filled paper cables to solid insulation cables led to the problem that simple monitoring of the cable integrity is not inherent. In oil-filled cables the pressure can be easily monitored. By applying a single measurement at the end of each oil-pressurised cable-section, it is possible to alarm about leaks that indicate a problem with the cable integrity, such as excavation damages, fatigue, degradation, etc. Such a simple monitoring solution, where the integrity of the entire cable system can be monitored has until now not been available on the market for solid insulation cables.

On this background, the following sections will discuss the monitoring possibilities for solid insulation cables which are commercially available on the market and evaluate the value of the different solutions seen from a Transmission System Operator's (TSO's) point of view.

This paper is therefore to be seen as an effort to start a discussion in the cable community about how to establish a standardised approach to cable integrity monitoring.

THE MONITORING REQUIREMENTS AND WISHES FROM THE TSO

TSOs have the mission to ensure reliable transmission of electrical power both in the specific moment and in the future as discussed in the following.

To ensure a reliable transmission system in the moment, it is required that proper maintenance is done of the transmission assets (including the cables), such that outages to the furthest extent can be prevented. However, when e.g. a cable failure is experienced, it also means that the fault shall be quickly repaired.

To ensure a reliable transmission system in the future, it is required that the grid is dimensioned, and possibly expanded with new and/or bigger lines, to cope with the future energy demand. However, until now transmission cables have been dimensioned according to a static set of parameters which most often have been set conservatively, which means that most cable assets will be able to transmit more power than their name plate rating. Furthermore, the grid planning is done based on expected lifetimes of existing assets. For example, a solid insulation cable is typically expected to have a lifetime of 40 years, so the grid planner must, before the 40 years are over, plan for exchanging the ageing cable. However, if being able to follow the remaining lifetime expectations on each specific cable, a better, and timelier, planning of new cables can be done.

Condensing the above, TSOs basically have three wishes to monitoring services which could optimise their investments and operational costs (CAPEX and OPEX). These three wishes (denoted 3Wishes) are:

1. A monitoring system that can warn when parts of the cable system soon needs maintenance
2. A monitoring system that can analyse how much power can be transferred through the cables, given each cable's specific conditions
3. A monitoring system that can predict how much lifetime is left in each specific cable system

By having these three monitoring systems in place, the TSO would have a much better overview of the assets, and thereby be able to utilize the assets better in the moment and make grid planning "just-in-time" instead of based on static ratings and static remaining lifetime estimations.

Monitoring system for cable maintenance

A system that is able to monitor and evaluate the need for maintenance of a cable system will increase the availability of the cable system as it is possible to increase the Mean Time Between Failure (MTBF) by performing preventative maintenance which:

- Can be done at times where there is lesser need for the specific cable system
- Typically, is quicker to perform as the damage is less severe than a full-blown cable fault (corrective maintenance)

For overhead lines (OHLs), it is relatively easy to monitor the condition of the OHL system to evaluate the need for maintenance. This can e.g. be done by making a complete overfly of the line in a helicopter, or with drones, to make photo documentation of the condition of the complete