In Situ HVDC Cable Preparation Validation with Three-Dimensional Topography Scanning and Analyses

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ABSTRACT

On-site installation works of high voltage direct current (HVDC) cable accessories demands unique quality control (QC) methodologies. The techniques that form today's state-of-the-art are indirect, costly, and limited to short cable segments, hence alternative concepts are desperately needed. In this work, an innovative, in situ validation method has been developed that comprises both surface inspection and control algorithms. By scanning the three-dimensional (3D) topography of a prepared cable end, at very high accuracy and resolution levels, and performing an in situ mathematical analysis on the obtained point cloud, an instant quality evaluation can be made. This new approach provides direct feedback and geometric pin-pointing to the installer team, and allows dataset storage and accessibility for the full lifetime of the cable system.

KEYWORDS

HVDC cable; accessories; installation; surface preparation; 3D scanning; Algorithm; Big Data approach.

INTRODUCTION

Constructing highly reliable HVDC cable links demands the use of well-designed manufacturing processes, and efficient QC methods. The QC of on-site HVDC cable accessories installation is today a challenging subject.

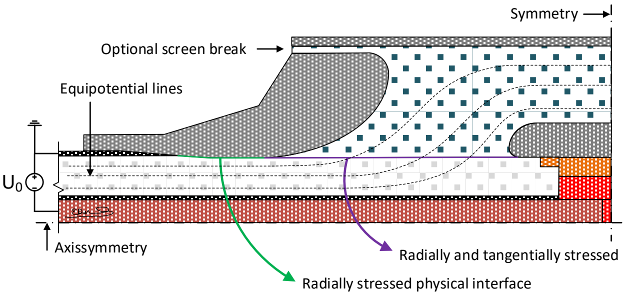

Fig. 1: Illustrative description of an HVDC joint comprising joint body and two cable ends.

HVDC joints, as illustrated in Fig. 1, GIS terminations, and outdoor terminations, comprise an accessory body, and one or two cables, all of which come electrically pre-screened for defects from the factory. Beyond such pre-tested components, an outer semiconductor removal process and further surface preparation are required to shape the cable ends and expose the insulation that mates with the accessory body. This on-site manufacturing step poses new challenges, for which QC methods may comprise after-installation tests (AIT), as described in Cigré TB 841 [1], such as DC tests, or ACPD measurements on short segments of the cable link. While such tests may provide some quality feedback, their capabilities are extremely limited whilst their scope, as mentioned in the TB [1], concerns the installation process only.

On-site ACPD measurements are not cost-efficient, feature a long quality feedback loop to installers, are limited by noise levels, and are unachievable for accessories that connect long HVDC circuits (offshore joints, landfall joints, platform joints, and joints connecting long, earlier tested link segments). Furthermore, the interfaces in the newly assembled joints may feature presence of dielectric sliding oil, which may suppress PD inception levels in any surface defects beyond the limited AC stress levels reached during the ACPD test. Also, while the AC waveform may successfully screen for air-filled cavities, it may not effectively screen for any protrusions nor surface defects causing field enhancement into the cable dielectric itself.

Given the enormous economic and societal impact an HVAC or HVDC cable system outage may have, there is a strong drive to reach new quality levels. An innovative, patented alternative, comprising highly accurate 3D scanning of accessories and cable end geometries, and an *in situ* computational verification has been developed. This work describes this alternative QC method, and presents results obtained on cable ends that have successfully passed different HV qualification tests.

METHOD

In order to shape a robust QC method, high accuracy is demanded from the 3D laser scanning process, which was achieved with a resolution 100 datapoints per mm^2. After scanning the cable end used in the cable accessory, the obtained point cloud is transformed to a 3D surface mesh, for which a mathematical computational algorithm has been tailor developed. The algorithm is designed to auto-detect and evaluate a series of acceptance criteria, being able to provide direct quality feedback on the jobsite. Localized finite element method (FEM) computations are also integrated into the algorithm, enabled by detecting troublesome regions and using a sectionalized approach.

Laser scanning backbone

A metrology-grade laser scanner, depicted in Fig. 2, was used to scan the cable end geometry. The handheld laser scanner uses real-time positioning, which allows obtaining a fully watertight point-cloud of the cable end's entirety, by means of performing subsequent sweeping motions from all possible directions and orientations. To increase the geometric accuracy and process stability further, an array of 3D markers is mounted on an external fixture around the cable end. The 3D marker array assists with the real-time positioning while it also allows for setting up an exclusion zone outside which no datapoints will be collected. During the 3D scanning, as shown in Fig. 3, a cross-hatched laser line pattern is projected, which's deformation allows a stereo-camera setup to deduce the surface coordinates. The laser projection is extremely important for scanning featureless objects, and allows creating a point cloud in which features can be assessed with up to 25 µm accuracy.