SENSITIVITY ASSESSMENT FOR FIELD PD MEASUREMENTS FOR HV AND EHV CABLE ACCESSORIES VIA LABORATORY TESTS

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ABSTRACT

For the past decade and a half HV and EHV cable systems have been subject to after-laying commissioning withstand and partial discharge commissioning tests. As jointed cable systems constitute a large, distributed capacitance, the apparent charge of a partial discharge pulse is extremely small, and the high-frequency propagating transient is neither related to the apparent charge, nor conserved in propagation. To achieve sufficient sensitivity, a distributed PD measurement, sensitive to the HF (> 1 MHz) propagating transient, must be performed. The relationship between the actual PD current, and therefore charge, and that of the detected PD current is not trivial and depends highly on the exact location of the discharge. Therefore, two primary problems exist with respect developing an acceptance level (sensitivity threshold) for field PD measurements: (A) Partial discharge magnitudes are not diagnostic. (B) Injection of known pulses with high-frequency content into HV and EHV accessories is not a trivial matter. A simple calibration constant between apparent charge and the magnitude of the detected transient cannot be established, nor is it necessary. This paper suggests a sensitivity assessment methodology for high-frequency field PD measurements which relies on characterization of the transfer function of individual HV & EHV cable accessories via laboratory tests (following successful type testing) and proposes how the results can be applied to PD field tests on similar accessories

KEYWORDS

Partial Discharge field measurement, calibration, sensitivity assessment methodology

INTRODUCTION

Partial discharges occur in the bulk of high voltage insulation materials where local electrical field conditions are sufficiently high to sustain PD activity. In the case of extruded cables (EPR or XLPE cables) partial discharges typically occur in cavities at the conductor shield, cavities in the insulation due to shrinkage or gas-formation, near defects in the insulation shield, near loosely bound solid particles in the insulation, at protrusions, at splinters or fibers or near contaminants in the insulation shield. In cable joints or terminations, partial discharges typically occur along dielectric interfaces, along stress interfaces, in cavities near the conductor or insulation shield due to, for instance, misalignment during installation or thermal movement as a result of normal operation. Finally, partial discharges may also occur within the cable insulation itself around mechanically degraded spots or impurities resulting in the formation of electrical trees.

For PD measurements performed in the laboratory, the magnitude of PD detected is evaluated in pC of apparent charge as per IEC 60270. The magnitudes associated with this measurement method are highly frequency dependent, and, comparisons between one test and another are only possible because the measuring circuit is strictly defined. In field tests, where a variety of bandwidths of couplers and instruments are used, the IEC 60270 calibration is not applicable, and cannot be used to compare the sensitivity of different measuring systems. Furthermore, where laboratory PD tests typically involve terminal measurements only, field PD tests on long lengths of cable have additional sensors at joints. These sensors may be embedded in the accessories or inductively coupled to bonded leads.

THE MEASUREMENT OF APPARENT CHARGE AS PER IEC 60270

Partial discharges consist of two distinct but related signals – an overall charge redistribution in the bulk capacitance, and a very fast, local, electromagnetic field disturbance due the motion of charge. IEC 60270 attempts to measure the small system voltage drop due to overall charge redistribution once the discharge is complete. In systems with large capacitance, this signal is tiny, and may not be detectable. The fast transient, however, takes on an electromagnetic field shape that propagates well in a coaxial system, and this transient is more easily captured by broadband detection methods. The shape and magnitude of this transient is related to the quantity of charge transferred, but also very strongly shaped by the geometry of dielectric and conductive structures around the discharge site, and the physical direction of the discharge. For example, the shape and magnitude are strongly influenced by the radial proximity of the partial discharge location relative to the cable conductor, i.e. the closer to the cable conductor, the higher the induced current on the conductor [2, 3]. The relationship between the induced charge on the high voltage electrode and the *actual* discharge itself may be evaluated by the λ- function [2, 3].

As the induced PD currents propagate through the cable towards the cable ends, they are subjected to attenuation and, to a lesser extent, dispersion [10]. In addition part of the propagating signal is reflected and lost as a result of impedance mismatches due to joints and cross bonding.

It is well understood that IEC 60270 applies to a narrow-band, low frequency partial discharge measurement performed on a HV component acting as a pure, lumped capacitance [10]. Voltage signals may be injected via a coupling capacitor to provide a relationship between actual, detected pulse magnitude as measured in mV (the overall system voltage drop due to charge redistribution) and apparent charge in pC.