RECENT EXPERIENCES WITH AC HIPOT & PD COMMISSIONING TESTING OF XLPE CABLE SYSTEMS RATED 69KV AND ABOVE

Mark **FENGER**, Kinectrics Inc., Canada, mark.fenger@kinectrics.com

ABSTRACT

Over the last decade and a half, thousands of kilometres of installed XLPE HV and EHV cable systems have been subjected to after-laying commissioning testing prior to energization. The commissioning test usually consists of a combination of AC HiPot & Partial Discharge testing. Partial discharge testing, in particular, gained acceptance as a valid diagnostic tool for condition assessment of cable insulation. It is well known and understood that the results obtained from a partial discharge test depend not only on the conditions under which the test was performed but also on the test equipment itself including the type of sensor used and its location. The issues related to actual discharge, induced charge and measured apparent charge are also well understood. Yet, for commissioning testing of solid dielectric, test specifications often reference magnitude levels in pC of apparent charge as the only pass/fail acceptance criterion. The practice is based on factory acceptance testing of individual cable components. This paper outlines the difference between PD testing performed on individual components in the factory and PD testing performed on installed systems in the field with respect to magnitude calibration of PD pulses. The paper also proposes how PD tests can be applied as a valuable tool for commissioning tests despite issues related to non diagnostic nature of PD magnitudes. The paper further provides statistical summary of tests performed on more than 2000km of HV and EHV cable systems including failure rates of accessories and PD occurrence rates. The paper also provides several case studies of PD detected in cable accessories during AC HiPot commissioning testing.

KEYWORDS

Partial Discharges, Pulse Propagation, Calibration, Sensitivity Assessment.

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 and or impurities resulting in the formation of electrical trees.

ACTUAL, INDUCED AND APPARENT CHARGE

Partial discharges are a high frequency phenomenon. Fundamentally, whenever a partial discharge occurs internal to a cable section or a cable joint, a charge – and consequently a high frequency current - is induced on the cable conductor (high voltage electrode) and the cable shield (grounded electrode). The magnitude of a measured partial discharge signal depends partly on the magnitude of the partial discharge current itself, i.e. the higher the actual partial discharge current the higher the induced currents, and partly on 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 it self may be evaluated by the λ- function [2, 3]. The rise-time of the induced partial discharge current is similar to the frequency of the actual partial discharge current itself whereas the fall time of the induced current is dependent on the impedance of the measuring system itself [2]. In this case, the impedance of the cable system is defined not just by the series impedance of a PD sensor and monitor but also in the impedance of the part of the cable system a given PD pulse must travel through prior to being detected. The rise-time of the partial discharge current itself depends on path and velocity of the partial discharge (avalanche) and, consequently, the frequency depends primarily on (1) the strength of the electrical field in the void (the higher the strength of the electrical field the higher the velocity of the avalanche itself, the faster the rise time of the PD current and the higher the frequency of the PD current) and (2) the size of the void relative to the direction of the electrical field (the longer the void, the longer the duration of the PD pulse, the longer the rise time of the PD current and the lower the frequency of the PD current). Also, local conditions in the void such as gas pressure, temperature, void surface conductivity has an impact on the partial discharge behavior.

In addition, as the induced PD currents propagate through the cable towards the cable ends, they are subjected to primarily attenuation and, to a lesser extent, dispersion [10]. In addition, it should be noted that the magnitude of high frequency currents propagating along the coaxial cable line further deteriorates as a result of impedance mismatch due to joints and cross bonding.

It can thus be intuitively seen that for shorter cable runs induced currents as a result of partial discharge activity may be readily detected via a terminal measurement, i.e. via a capacitive or inductive sensors connected to the conductor or shield at the end of a cable. For longer cable runs, attenuation will prevent the measurement of inducted currents related to PD activity occurring from the opposite cable and thus a distributed PD measurement