PD commission test of 400kV XLPE cables over 22km in length

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ABSTRACT

This paper describes Partial Discharge (PD) commissioning on-site testing of three (3) parallel 3-phase 400kV XLPE cable systems, each over 22km end-to-end. Each cable system consists of 33 cross-linked joints and 6 end terminations and was energized with a resonant test set to 330kV for a period of 60 minutes. Using HFCTs and mobile PD test equipment, PD measurements by three teams are performed simultaneously at the cable joints, often times referred to as "joint-hopping". Selecting proper measurement frequencies and verifying sufficient sensitivity is explained in the paper. The results are discussed and different attenuation of PD signals along the cable are visualized.

KEYWORDS

Partial Discharge Measurement, commissioning test, HFCT, joint-hopping

INTRODUCTION

High Voltage (HV) cable systems are vital for energy networks around the globe. Purchasing HV cables is costly, however the installation and required civil works can be even more expensive. Full turn key projects for long lengths of HV or EHV cable, installation, civil works, substations and associated needed infrastructure can exceed $ 1 Billion. Once installed and energized, HV cables are an important and vital asset for energy grid, that should not fail during service.

To assure proper production, installation and ideally life cycle management of such assets, IEC, IEEE and CIGRE have issued multiple guides, suggestions and standards, demanding proper testing of HV cables. Before HV cables leave the factory, multiple tests shall be carried out, assuring that cables meet contractual specification. These contractual specifications very often are taken out of the abovementioned standards and guides.

High Voltage testing with voltages exceeding the future operating voltage (U_0) combined with Partial Discharge measurement are the most widely used tests, that HV cable systems should undergo and pass before leaving the factory. Next to others, these tests shall assure, that no life limiting production related damages or impurities in the cable system are present. Successful testing in the factory require trained personnel and adherence to cable factory testing standards.

To assure proper installation of HV cables and before cable systems are handed over from the installers to the future owner, usually commissioning tests in the field are carried out. Such tests are designed to detect possible damages of the cables that might have been inflicted during the transportation or laying process. Special focus lies on the accessories, that were often installed in the field in conditions that are far from clean, shielded room conditions of factory setups. The primary purpose of on-site testing is to detect possible issues in the cable system resulting in limiting life [1].

According to studies from CIGRE based on a population of 26,494 km of HV and EHV cable, tested with AC (20 Hz – 300 Hz) only 0.01% of the cables systems showed non-passing issues in the cable sections itself, while the non-pass rate for terminations and joints are 2.8% and 0.75% respectively [2].

For on-site testing, usually overvoltage tests above nominal voltage phase to ground (U_0) in combination with PD testing is state of the art nowadays. For such tests the IEC and CIGRE state requirements concerning voltage levels and setup of PD measurement equipment. These requirements are rigorous to assure proper testing of HV cable systems. Often the parties carrying out the on-site tests follow all requirements, especially concerning voltage levels and durations of the tests.

To energize the HV cables, often Resonant Test Systems (RTS) are used. RTS usually have a fixed inductance. Together with the capacitance of the cable system, a resonance circuit is established and by means tuning the frequency, the resonance frequency between 20Hz and 300Hz is being established as per Clause 16.3 of IEC 60840 and IEC 62067. The longer the cable system at a certain voltage class, the bigger the capacitance and resistive losses in a cable system under test.

For long cable systems, such as the 22 km cable system described here, multiple RTS need to be used in series and parallel to drive the needed current and therefore voltage for the overvoltage tests.

IEC and CIGRE state clear requirements concerning the PD measurement, the needed sensitivity, maximum allowable PD from a cable system and thus the maximum background noise [3,4]. These requirements are justified and are important to be achieved. Unfortunately, for long cable systems seldom they can be met, especially the demands for the background noise. Even with state-of-the-art PD test systems, obtaining a background noise of less than 5pC can often be challenging to impossible, based on the surroundings of the test area.

For the time being, the only way to conduct PD measurements is by trying to reduce background noise and varying the PD measurement frequencies (center frequency) by assuring, proper sensitivity.

CABLE SYSTEM

The cable under test is a 230/400 kV cable with U_0 = 220 kV and U_{max} = 420 kV with a length of 22 km and a copper conductor with a minimum of 2500 mm². Each phase of the 3 phase cable is separated in 34 sections, with