Space charge Evolution in XLPE HVDC cable with Thermal-Step-Method and Pulse-Electro-Acoustic

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ABSTRACT

This paper presents results from Alstom Grid's Cable Ageing facility of two complementary, state-of-the-art, on-line and simultaneous space-charge monitoring techniques that continuously assess the health of a full size HVDC cable. A 200kV cable made of pure XLPE grade is subjected to a VSC ageing programme according to CIGRE TB 496. The Cigre VSC prequalification programme is a 360 day test regime at ±1.45U_o which is considered to be equivalent of 40 years in service at three different thermal loading phases. On the same cable length two on-line space charge probes are installed that are capable of monitoring the space charge evolution throughout the duration of the ageing programme. One of the probes is the Thermal-Step-Method (TSM) and the other probe is the Pulse-Electro-Acoustic (PEA) technique. The space charge evolution during the first two Load Cycles is presented and discussed.

KEYWORDS

Space charge, VSC Ageing programme, HVDC cable, monitoring, Pulse-Electro-Acoustic, TSM, Cigre TB 496.

INTRODUCTION

Typical HVDC projects have a cost that ranges from hundreds to thousands of million GBP. These projects include HVDC generators, cables with cost up to 65% of total cost, and substations. 45% of on-shore projects awarded in 2014 use underground HVDC cables as planning permission for new power transmission lines is timely to obtain. Ensuring that the cable performance is maintained over the lifetime of service (40 years) is critical to successful schemes. In the case of land buried cables, eXtruded cross Linked PolyEthylene (XLPE) cables are the preferred type, due to their load capacities offered by operating temperatures of 70°C for pure XLPE cable, as compared to 55°C for the traditional Mass-Impregnated cables (MI). However, extruded HVDC power cables are prone to localised electrical charge accumulation that can lead to premature failure [1]. Many of the problems associated with HVDC electrical insulation are associated with the build-up of electrical charge. Such charge accumulation leads to significant distortion of electric field; so that much higher than average electric fields occur in, or on, certain parts of the insulating structures [2]. This can lead to premature ageing or even electrical breakdown and compromise the reliability of a HVDC link.

The development of Voltage Source Converters (VSC) and the ability to keep the transmission voltage in a single polarity has enabled the use of extruded cable technology in HVDC application. The rapid expansion of renewable power generation and subsequent drive for off-shore wind farm interconnections to the power grid generates 40 potential VSC projects to be awarded by 2019. The parallel development of low footprint HVDC converter technology enables HVDC links to be the preferred solution for off-shore applications. Areas with high wind speeds in Europe are often located 120-180km off-shore in the North Sea [3]. Thus, the increasing lengths of the cable used for off-shore wind farm HVDC links and the reduced costs associated with extruded cables in contrast with Mass Impregnated (MI) paper cables has led to the rapid development of HVDC extruded XLPE cables and increase in voltage and power ratings [4].

Although HV extruded cable insulation is the preferred and mature cable technology for AC system, under HVDC application the experience is limited at 200 kV (Transbay, USA), a number of ongoing projects at 320 kV scheduled to be in service in 2015, such as the France/Spain interconnection. Thus, the reliability of HVDC transmission link is more and more important as the power loading capabilities are increasing.

Despite the demand for XLPE cables in HVDC applications there is no standard procedure nor space charge limits universally agreed due to the limited field experience. The only pre-qualification guideline followed by cable manufacturers to date is the Cigre TB 496 recommendations for extruded cables up to 500kV [5]. A recommendation for space charge measurement protocol in full-size HVDC extruded cables has also been published recently [6].

Alstom Grid has built a HVDC cable ageing facility using 200 kV rated cables subjected to Cigre TB 496 VSC pre-qualification programme [7]. The facility is being used to evaluate the space charge dynamics and cable insulation ageing state during Cigre TB 496. Thus, the space charge data presented in this paper is obtained from an online Pulse-Electro-Acoustic (PEA) probe that monitors the space charge evolution throughout the 360 days ageing programme. Thermal Step Method current measurements are also performed at selected days under short circuit conditions. The online space charge monitoring with a PEA and TSM probes is not a CIGRE TB 496 requirement as the cable under test has to be stripped down to the outer semiconductor in an area to allow the implementation of the probe. The focus of this paper is to present the space charge evolution during the first two load cycles.