Space charge evolution in composite XLPE HVDC cable insulation during VSC pre-qualification programme

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ABSTRACT

This paper presents results from Alstom Grid's cable ageing facility recorded by an on-line space charge monitoring technique. A 200kV cable with HVDC composite XLPE insulation is subject to a VSC ageing programme according to CIGRE TB 496. The Cigre VSC prequalification programme is a 360 day test regime at ±1.45 U_o that is equivalent of 40 years of service life (at three different thermal loading phases). A bespoke on-line Pulse-Electro-Acoustic (PEA) measurement system is installed on the cable under test which is capable of monitoring the space charge evolution throughout the duration of the ageing programme. The space charge evolution recorded by PEA during the first two positive and negative Load Cycles is presented and discussed.

KEYWORDS

Space charge, VSC Ageing programme, 200kV, HVDC cable, Composite XLPE, Cable monitoring, Pulse-Electro-Acoustic.

INTRODUCTION

Typical High Voltage Direct Current (HVDC) projects cost hundreds of millions of pounds sterling. Projects can require a transmission cable which consumes up to 65% of the scheme expense. 45% of on-shore projects awarded in 2014 use underground HVDC cables as planning permission for new power transmission lines is difficult and timely to obtain. Ensuring that the cable performance is maintained over the 40 year service 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 up to 90°C; ease of installation which allows XLPE cable to be utilised in existing tunnels unlike MI cable. However, XLPE 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 a significant distortion of the electric field; so that higher than average rated 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 [1].

The development of Voltage Source Converters (VSC) and the ability to maintain the transmission voltage polarity regardless of the power flow direction 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 stimulates a potential of 40 VSC projects to be awarded between 2015 and 2019. Areas with the highest capacity factor and shallow sea bed in Europe are located 80km to 180km off-shore in the North Sea (Dogger Bank) [3]. Thus, the increasing lengths of the cable used for off-shore wind farm HVDC links and the reduced cost of extruded cables in contrast with Mass Impregnated (MI) paper cables has led to the rapid development of HVDC XLPE cables and demand for production and voltage [4].

Although HV extruded cable insulation is the preferred and mature technology for AC application. The field experience in HVDC application is limited at 200kV (Transbay, USA) with a number of ongoing projects at 320kV scheduled to be in service in 2015, such as the France/Spain interconnection. Thus, the reliability of HVDC transmission links is uncertain and the severity of space charge accumulation on the cable lifetime is unknown.

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 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 200kV rated cables and then 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 on-line Pulse-Electro-Acoustic (PEA) probe that monitors the space charge evolution throughout the 360 days ageing programme. The cable under test was stripped down to the outer semiconductor in an area to allow the implementation of the probe. VISCAS has reported space charge data following the completion of the 360 days ageing programme. The focus of this paper is to present the space charge evolution during the first two load cycles under positive and negative voltage stress.

VSC PRE-QUALIFICATION PROGRAMME

The CIGRE TB 496 VSC pre-qualification ageing programme is followed for the VISCAS cable loop. The recommendations are based on the following technical criteria:

- Minimum duration is 360 days ageing programme at ±1.45U_0 equivalent to 40 years of design life.