Transients on DC cables connected to VSC converters

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ABSTRACT

This paper presents some examples of typical events that lead to voltage fluctuation on cables connected to VSC converters. DC faults or internal faults in converters can result in significant over-voltages at the DC cables which persist even after the system has been disconnected from the AC networks. Cables discharging and travelling waves propagation generated by faults or grounding switches operation impose stresses on cables insulation that are not well described in literature and usually not covered by cables specifications.

These transients are described, compared against the standard tests for lightning and switching impulses. Technical solutions to limit stresses on cables are proposed and discussed.

KEYWORDS

XLPE cables, VSC converters, EMT simulation.

INTRODUCTION

Oil-impregnated insulation cables, such as mass impregnated (MI) cable and oil-filled (OF) cable, have been applied to DC power transmission. Since then, they have been the mainstream of DC power transmission cables. The oil-impregnated insulation cable technology has developed in response to demand for higher voltage and larger capacity. On the other hand, extruded insulation cables, in which such material as XLPE is extruded on the conductor, were first applied in Gotland to an 80 kV DC line in 1999. The main advantages of XLPE cables compared with MI and OF cables are their cost and their environment impact. Nevertheless they are more sensitive to voltage transients and especially polarity reversal.

Application of voltage source converters (VSCs) in power systems is rapidly growing due to advantages such as absence of commutation failures, ability of independently controlling the active and reactive power, and fast dynamic response. Insulated Gate Bipolar Transistor (IGBT) is the power electronic switch used in VSC applications.

VSC technology does not require the inversion of the voltage polarity when reversing the direction of power flow. This has made the use of extruded insulation cables easier for DC applications. Since then, the number of extruded insulation cables, used in combination with VSCs, has increased for HVDC power transmission applications.

Even if VSC does not require the inversion of the voltage polarity, many events can generate transients on cables that are not covered by standard tests.

The work presented in this paper has been done in the context of the INELFE interconnection.

The VSC based HVDC link between France and Spain (INELFE project: France-Spain ELectrical INterconnection) will be the most powerful HVDC-VSC link by 2015. This 2,000 MW interconnection is composed of 2 parallel HVDC-VSC links including 4 XLPE cables are used to transmit power between the 2 converter stations.

In order to present analysis and results without revealing any confidential information on the project, generic data for cables and converters are used in the paper.

THE INELFE INTERCONNECTION

Context

The new HVDC electrical interconnection line between Spain and France has a length of 64.5 km with 2,000 MW capacity. It connects the towns of Baixàs, in the Roussillon region (France), and Santa Llogaia, in Alto Ampordá (Spain). Converter stations are designed and built by SIEMENS. Prysmian Cables & Systems has been awarded the contract for the installation of cables. More information on this project is available in [1].

This new HVDC interconnection will be the first VSC installation operated and maintained by the French (RTE) and the Spanish (REE) Transmission System Operators (TSO). RTE decided to acquire competences in modeling and simulation of HVDC-VSC link equipments (converters and cables). Competences in this field were required for the INELFE project but, above all, were mandatory for the numerous HVDC and FACTS projects that are planned in a near future in the French grid. Some converter models for EMT studies have been developed in this context and are described in [2].

Main parameters

The interconnection is composed of 2 HVDC-VSC links. Each link has two Modular Multilevel Converters (MMC) stations with a rated transmission capacity of 1,000 MW and a DC voltage of ±320 kV. A simplified single line diagram is presented in Figure 1. Each link is composed of 2 symmetrical monopole converters, 2 step down transformers and 2 underground cables. VSC-HVDC technology, using the modular multilevel converter (MMC) topology, has been selected for this project due to the dynamic performance, power flow control requirements and the low AC short-circuit ratio of the France-Spain system. More details on the converters topology and data are available in [3].