DC cable modelling and High Voltage Direct Current grid grounding system

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ABSTRACT

This paper describes the influence of grounding on voltage and current transients during DC-link fault in a High Voltage Direct Current (HVDC) cable system. After presenting the topology and the modelling of the HVDC system, the paper focuses on cable parameters calculation and on propagation behaviour of travelling waves during fault conditions. DC short-circuit fault is then simulated for different cable screens as well as converter station neutral points grounding impedances. The results presented in the paper provide a preliminary insight for HVDC grid protection system design.

KEYWORDS

DC cable – HVDC cable systems – MMC-VSC – cable grounding – HVDC grounding system.

1. INTRODUCTION

The use of HVDC system for bulk power transmission instead of Alternative Current system has shown its worth regarding the amount of transmissible power and the transmission efficiency [1]. Today, most of the existing HVDC systems are limited to point-to-point connections. The opportunity to build multi-terminal Direct Current (MTDC) grids appears thanks to large flexibility provided by the Modular Multilevel Converters (MMC) [2].

One of the main challenges for the development of future MTDC grids is related to the protection system design including sensors, switchgears, relays and algorithms. In a HVDC cable system, low value of resistance and surge impedance of cables lead to a fast propagation of the fault along the system and a sharp fault current rising. The protection system has to operate in few ms to ensure the safety of the DC grid and the stability of the connected AC grids [3]. While designing such a protection system, the grounding impedances of converter stations and cable screens are relevant elements impacting transient waves propagating into the grid during fault conditions. Modelling of grid components, in particular cables must be accurate enough when studying transient behaviours.

The paper is divided as follows: section 2 describes the topology of the bipolar HVDC point-to-point connection test system. Characteristics and models of the components of the system are then presented for implementation in EMTP-RV 3.0. Section 3 gives an overview of high voltage cable modelling and its accuracy for DC application. Finally section 4 focuses on contributions to DC short-circuit fault current and analyses influences on it of grounding impedances of cable screens and converter stations neutral point.

2. HVDC SYSTEM TOPOLOGY AND MODELLING

This section describes the HVDC system topology and components modelled in the simulation.

2.1. HVDC system topology

The point-to-point HVDC cable system under study is in a bipolar configuration rated at $\pm 320\ kV$, $1.5 kA$ and connected with two AC grids according to Figure 1.

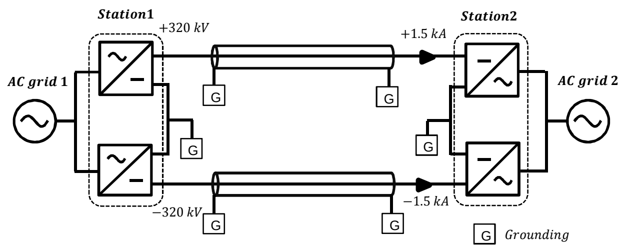

Figure 1:Point-to-Point HVDC cable system

2.2. AC/DC Converter stations

Converter stations in bipolar configuration consist of two AC/DC converters connected respectively to the positive and the negative pole of the HVDC system. In normal operation, station1 feeds station2 through the positive pole and current returns through the negative pole.

The neutral point of the converter station is connected to the earth in order to provide a ground reference to the converters in addition to protecting the equipment. For simulation purposes, the grounding of the station is made either effectively or through a station grounding resistance $R_{station}$.

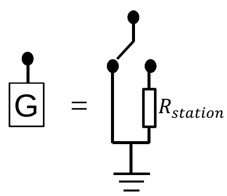

Figure 2: Grouding options of stations

The converter used in the simulations is the Modular Multilevel Converter (MMC) which is well adapted to the requirements of advanced HVDC transmissions systems [2]. The model of MMC used in the simulations is the average model "*model 3*" described in [4] based on switching function concept of half-bridge converters and available in EMTP-RV. This model allows blocking capability of the converter IGBTs in case of overcurrent. Thus, as soon as DC current reaches two times the nominal current, converter IGBTs are blocked and the converter behaves like an uncontrolled rectifier.

Station 1 controls the active power exchanged in the system to a given reference and station 2 controls the DC