Abstract

Line commutated converter (LCC)-based HVDC network has been a popular technology in HVDC terminals for decades. After the foray of voltage-source converters (VSC) into high voltage dc (HVDC), the multi-terminal HVDC system has emerged as a well-known concept in the present scenario. This research work puts forward an effective inter-connecting scheme, called hybrid interconnection, to interface the existing bipolar LCC and recently installed bipolar VSC-based HVDC network. It is a fact that an LCC-based HVDC network achieves power reversal by reversing the voltage polarity of the dc bus, whereas a VSC-based HVDC network achieves so by reversing the direction of the dc-link current. Therefore, the direct interconnection between such networks cannot provide bidirectional power exchange. In this thesis, a modular multilevel converter (MMC)-based dc-dc converter is proposed, facilitating bidirectional power flow between them and functioning symmetrically at all quadrants of operation on the LCC side. This converter is also presented as a potential solution for a multi-terminal HVDC network while having a hybrid interconnection. In addition to that, suitable philosophy is proposed when an LCC or VSC-based HVDC link is converted into an asymmetric monopolar dc link, and the operation of the system is demonstrated for the same multi-terminal HVDC network model with similar transitions of power flow as in bipolar operation. The number of semiconductor devices is minimized by introducing a hybrid arm composed of full-bridge (FBSM) and half-bridge submodules (HBSM). Unlike HBSM, FBSM can represent negative voltage but involves twice the number of devices as in HBSM. Based on this fact, the proportion of FBSM is calculated so that the converter can represent negative voltage resulting from a short-circuit fault in the VSC bus and ride through this fault condition. The philosophies are validated by simulation on the Matlab/Simulink platform for a three-terminal (LCC1, LCC2, and VSC) HVDC network with a power throughput of 1400 MW. The operations are experimentally verified in a down-scaled laboratory prototype of a two-terminal (LCC and VSC) system of power rating 300 W. This work further discusses the impact of short-circuit fault at a dc bus on the proposed system, and effective fault mitigation strategies are proposed to restore the system to regular operation. The restoration strategy ensures de-energizing only the faulty pole before isolating it while the other part of the converter remains operational with reduced power. Thereafter, the system is restored after re-energizing the bypass path of the faulty pole. Henceforth, the converter continues to operate with an asymmetric monopole at the faulty side. These fault restoration strategies are validated on Matlab/Simulink for the same simulation model as used in other operations.

Keywords: High voltage dc (HVDC), line commutated converter (LCC), modular multilevel dc-dc converter, multi-terminal HVDC network, voltage source converter (VSC).