

Effect of Temporary VSC-HVDC converter blocking on Multiterminal HVDC and offshore windfarm performance

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Applications of voltage source converters (VSC) in high voltage direct current (HVDC) systems are becoming more and more significant for a variety of reasons, including controllability of both active and reactive power [1]. VSC HVDC systems have been successfully applied for integration of renewable energy sources (RES) such as offshore windfarms. The key advantage of using VSC-HVDC in RES integration is its ability to decouple large-scale high-power wind turbine generators from the AC grid, thereby preventing undesirable interactions. Compared with AC transmission connection, VSC HVDC offers desirable functions such as supporting AC grid with reactive power control in a wide range, in addition to lower cost and higher efficiency compared to AC transmission systems [2]. It is also well established that connecting multiple DC transmissions on the DC side to form Multiterminal HVDC (MTDC) system offers proven advantages such as operational flexibility, redundancy, and economic advantages. Through the facilitation of power exchange among several geographical locations, this approach will mitigate the intermittent character of renewable energy supplies and enable a more sustainable power supply [3]-[4].

Due to the inherently low impedance of DC systems, DC fault currents rise rapidly; therefore, prompt fault current limitation and/or interruption is essential to maintain safe and secured operation of the remaining healthy sections of the network. The valve semiconductors (IGBTs/ BIGTs) have limited overcurrent capability. To prevent the damages to the valve, the arm overcurrent protection blocks them when the current exceeds a specific level. To completely prevent blocking there are three options: a) a fast DC circuit breaker (DCCB) that isolates the fault before the current reaches the blocking level b) using a large current limiting reactor (CLR) which limits the current rate of rise (di/dt) and thereby keeps the current below the block level until DCCB isolates the fault c) increase the current rating of IGBTs. The first option may necessitate the use of DCCB with fast operating time (e.g., a pure semiconductor DCCB) which may not be economical both in terms of cost and losses. The downside of the second option is that a large CLR may have severe impact on the DC dynamics [5]-[6] while it also increases system losses, cost and footprint. The third option is also not economical and may necessitate changing the current MMC valve design (e.g. parallelling IGBTs). Thus, to have an economical design and optimum performance of an MTDC, a complete prevention of the IGBTs/BIGTs block may not be realistic, and hence it can be inevitable. Instead, short time temporary block of a valve could achieve that.

The concerns regarding temporary block (TB) and its impacts on MTDC (or DC grid) and offshore wind farms (connected to some MTDC terminals) have recently gained significant interest [5], [7]. Currently, wind turbine generators (WTGs) predominantly operate in grid-following (GFL) mode and Maximum Power Point Tracking (MPPT). The offshore HVDC converter operates in grid forming (GFM) control, namely Voltage and Frequency (V/f) control and it establishes the AC

voltage the WTGs synchronize to. The main concerns raised are 1) during TB the V/f control will be lost, therefore there is no well-defined AC voltage that GFL WTGs can synchronize to, and thus WTGs may not be able to ride through the event, resulting in a loss of significant wind power and this in turn that may severely impair the onshore grid's stability 2) possible need for a proper synchronization logic of HVDC converter when deblocking again to limit the transients.

The goal of this paper is to demonstrate the benefits of the TB functionality, which has been in use in point-point HVDC for more than a decade; as well as to address the concerns above. The paper will provide simulation results which prove that the above-mentioned concerns are not valid if the TB is properly designed.

Keywords

Temporary block, MTDC, Offshore wind farms

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