ABSTRACT

The introduction of modular multi-level converter (MMC) has opened up the possibility of large scale expansion of high voltage direct current (HVDC) transmission systems. The modularity of the topology allows installations of much higher voltage levels without significant modifications in control. Full bridge (FB) sub modules (SM) are required for restricting dc side short circuit fault current, though it involves larger number of switches. The hybrid MMC, having a mix of half bridge (HB) and FB sub modules in each arm, has emerged as a suitable compromise. With proper choice of the proportion of FBSMs, the hybrid MMC can also provide reactive power support to the ac grid during dc side faults. However, suitable control scheme has to be adopted and coordination is to be established between the terminals for proper operation of the hybrid MMC in a HVDC transmission system with two or more terminals. Hence an investigation has been carried out in this work to identify suitability of control strategies for stable operation of the MMC based PTP-HVDC system. A small signal model of the PTP system is developed which is then used to assess the stability of the PTP system and to form a guideline for choosing the controller parameters. Few modifications in the control structure are proposed for making the controllers suitable to handle the fault conditions. On the basis of the modified control structure, the operational (*V-I*) characteristic of the hybrid MMCs forming the terminals of the PTP HVDC are defined. The *V-I* characteristics ensure fault ride through operation of the converters for dc and ac short circuit faults without requiring any fast communication between the terminals. Analysis is carried out to find the possible instability of the MMC (in the form of divergence of the leg voltages) in case of any imbalance arising in the ac system during a dc fault. An additional controller is proposed in this work to restrict this possible divergence through negative sequence current injection. A small signal model of the hybrid MMC is derived for analyzing this unbalanced condition, which is then used to show the effectiveness of the proposed controller. Next, an imbalance issue which may arise between HB and FB SM capacitor voltages during reduced dc voltage operation of hybrid MMC is presented. A method is proposed in which second harmonic circulating current (SHCC) is injected in each leg of the hybrid MMC for addressing this imbalance issue. Also, a method is devised through detailed analysis for computing the optimum amplitude and phase of the SHCC. The performance of the proposed method is tested through simulations as well as experimentation on a scaled down laboratory prototype.