IET Renewable Power Generation

Research Article

Zone partitioning protection strategy for DC systems incorporating offshore wind farm

ISSN 1752-1416
Received on 30th January 2017
Revised 9th June 2017
Accepted on 3rd July 2017
E-First on 28th July 2017
doi: 10.1049/iet-rpg.2017.0060
www.ietdl.org

Yue Zhao[1], *Libao Shi*[1] ✉, *Liangzhong Yao*[2], *Zheng Xu*[1], *Yixin Ni*[1]

[1]*National Key Laboratory of Power System in Shenzhen, Graduate School at Shenzhen, Tsinghua University, Shenzhen, People's Republic of China*

[2]*China Electric Power Research Institute, Beijing, People's Republic of China*

✉ *E-mail: shilb@sz.tsinghua.edu.cn*

Abstract: This study proposes a zone partitioning protection strategy for DC systems incorporating offshore wind farm. Regarding a DC system which consists of multiple local zones with radial topology, a multi-port DC hub is introduced to serve as firewall between different zones. By blocking the converter with DC fault blocking capability in the corresponding DC hub port, the fault can be prevented from spreading among zones. On the other hand, an inter-zone protection centre is designed and built in the DC hub to implement the continuous operation under the situation of any port outage. Furthermore, in every local zone, the hybrid DC circuit breaker is installed in each branch at the side near the star point in order to isolate the faulty branch quickly and selectively via installing the smoothing reactor at the other side to restrict the fault current. Especially, a zone protection centre is designed and built in the star point of each zone to implement the fault detection and fault isolation. A detailed model of the DC system with the proposed protection strategy is built under PSCAD/EMTDC^{TM} environment. Simulation results under different operating conditions demonstrate the feasibility and validity of the proposed strategy.

1 Introduction

Voltage source converter-based high-voltage direct current (VSC-HVDC) technology has gained much attention due to its numerous advantages [1–3]. The advent of modular multilevel converter (MMC) enables VSC-HVDC technology to be better used in the high-voltage large-capacity environments, and it provides a perfect choice for the transmission of offshore wind power [4–7]. Some offshore wind power projects adopting point to point VSC-HVDC technology have already been put into operation in Europe [4]. The VSC-HVDC system can be easily extended to multi-terminal HVDC (MTDC) systems if necessary for power transmissions from multiple offshore wind farms to multiple onshore zones [3], and the radial topology is widely used in the MTDC system since the corresponding development of protection system is relatively simple [8, 9].

During normal operation, local faults will cause widespread voltage collapse and large fault currents in the whole system with only a few milliseconds due to the small impedance of the DC system [10]. Appropriate protection strategies are imperative for the safe and reliable operation of the DC systems under severe faults. Numerous studies have been conducted on the protection methods for the VSC-HVDC systems.

The topology of the converter has a great influence on the design of protection method in general. Half-bridge sub-module (HBSM)-based MMC (HB MMC) is widely applied in most practical projects. Compared with the pole to ground short-circuit fault, pole to pole short-circuit faults at the DC side will cause severe overcurrent inside a HB MMC grounded by two equivalent resistors in parallel at the DC side [11]. The fault current will not be cut off by only blocking the MMC, and additional devices are necessary. AC circuit breaker (ACCB) can be used to interrupt the fault current; however, it will take more than 50 ms for the fault isolation, which is too slow and may cause the disruption of the whole MTDC system after fault [12]. Hybrid DC circuit breakers (DCCBs) provide a feasible choice for the fault currents interruption, but it brings huge challenges for the design of DCCBs. On the other hand, it will also increase the capital cost and coordination complexity if too many DCCBs are installed in a DC system [13, 14]. Li *et al*. [9] proposed an improved telecommunication-free protection method for a HB MMC-based three-terminal HVDC system by installing additional DC passive components and DCCBs on each branch at the side near the star point. It reduces the number of DCCBs and ensures the continuous operation of the healthy branches under a severe fault.

Studies on the MMCs with DC fault blocking capability are also popular in recent years because such technologies can overcome the disadvantages of the slow-acting ACCBs and the high-cost DCCBs. MMCs adopting sub-modules (SM) such as the full-bridge sub-module (FBSM) or the clamp double sub-module (CDSM) can interrupt the fault current by blocking themselves [15, 16]. In a MTDC system based on these MMCs, the local fault can be isolated from the system by blocking the corresponding MMCs [17]. Petino *et al*. [15] investigated the protection strategies pertinent to a FB MMC based MTDC system. DCCBs are not required in the system, but all the MMCs need to be blocked after the occurrence of a local fault, and the healthy MMCs need to be restarted after the fault clearance. It will take much time and may not be a proper choice for an actual DC grid.

Most studies mainly focus on the protection methods for a single VSC or a simple MTDC system. Some special protection strategies are indispensable with increasing topology complexity of the system. DC/DC converters are introduced into the complex MTDC system in which the system can be partitioned into multiple DC network zones after fault, and the severe fault can be prevented from spreading among zones [18, 19]. Jovcic *et al*. [10] recommended interconnecting multiple radial systems using DC/DC converters with each other to serve as firewall among different radial systems. In recent years, some researchers have proposed to reduce the topology complexity of large MTDC systems by adopting multi-port DC hubs [20, 21]. It takes advantage of the flexibility of power dispatch control, the reduction of investment and the efficient utilisation of the transmission lines. It is of great significance for offshore wind power transmission systems because it needs only one offshore platform to transmit powers from multiple offshore wind farms to multiple onshore zones. Accordingly, the development of protection strategy has to meet some significant technical challenges.

This paper proposes a zone partitioning protection strategy for a DC system incorporating offshore wind farm. The system is