Grid Voltage Regulation with MMC-HVDC System

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Abstract

This paper presents an operation of the modular multilevel converter-high voltage direct current (MMC-HVDC) system as a Statcom to support the grid voltage. The advantage of the MMC-HVDC system is that it can control the active and reactive powers independently. The proposed control scheme will be designed by combining this performance and the control method of the Statcom. The grid voltage is regulated by the control of the reactive power, meanwhile the active power is controlled according to its applications. The simulation results based on the PSCAD/EMTDC simulation program will evaluate the effectiveness of the control scheme.

Key words: Modular multilevel converter-high voltage direct current (MMC-HVDC), Static synchronous compensator (Statcom), Grid voltage.

1. Introduction

The MMC-HVDC system has emerged as a new topology of the HVDC system for medium and high voltage applications such as connecting offshore wind farm, supporting for the weak grid, or main supply source for island,... The operation of the MMC-HVDC system has been introduced in [1]. In a high power system, the voltage stability is a critical standard in operating the safeness and reliability of the system. However, the grid voltage is not often at nominal value because of the change of loads, power supply sources or the losses in the transmission lines and transformers. To solve this problem, the Statcom has been used for the power system [2]. It is a shunt device and is connected to the system at the point of common coupling (PCC). The Statcom regulates the grid voltage by exchanging the reactive power to the power system. However, the use of an extra device will cause the problem of cost. In the power system, which the MMC-HVDC system is connected to, the Statcom may be not required. Because the MMC-HVDC system has the ability of controlling the active and reactive powers independently, thus it can be employed to regulate the grid voltage via the reactive power. It means that the MMC-HVDC system will operate as a Statcom in this case. This paper presents an operation of the MMC-HVDC system as a Statcom to support for the grid voltage. The proposed control scheme will be designed by combining the control method of the conventional MMC-HVDC system and the Statcom.

2. Main subject

2.1 Structure of the MMC-HVDC system

A structure of the MMC-HVDC system is shown in Fig. 1. It consists of two MMC systems which are connected back-to-back together. Each MMC is created with six arms. Two arms in the same leg is called a phase unit. In this study, one arm comprises 20 sub-modules (SMs), that are connected in series, and a series inductance. A SM includes two IGBTs, two anti-parallel diodes, and a capacitor. Each MMC is connected to the grid via a delta-wye transformer.

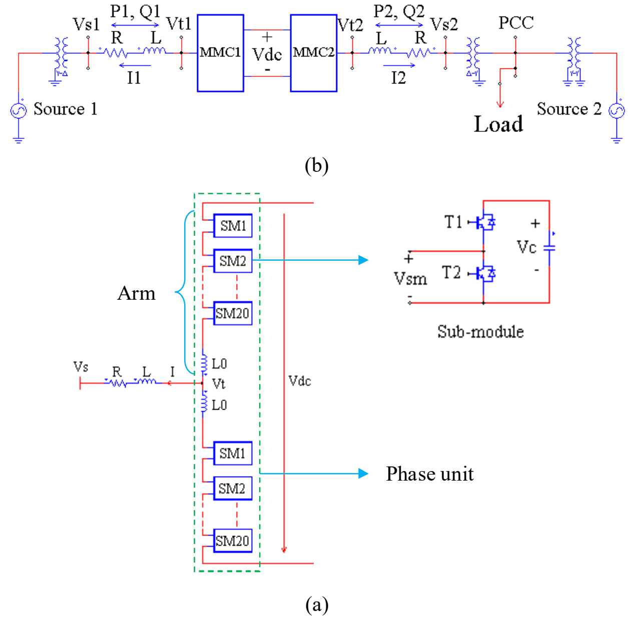

Fig. 1 Structure of the MMC-HVDC system.
(a) circuit configuration, (b) Single-phase diagram

2.2 Control theory

2.2.1 Conventional control of the MMC-HVDC system and Statcom

The MMC-HVDC control: one MMC is used to control the dc-link voltage and the reactive power, meanwhile other MMC is employed to control the active and reactive powers. Normally, the reactive powers are set to zero on both sides of the HVDC system.

The Statcom control: The Statcom, which is connected in parallel at the PCC, will regulate the grid voltage by controlling the reactive power to the power system, meanwhile the active power is almost zero.

2.2.2 Proposed control scheme

The proposed control scheme is a combination between the control method of the MMC-HVDC system and the Statcom. In this study, the MMC-1 controls the dc-link voltage and the reactive power ($Q_1 = 0$); the MMC-2 is responsible for controlling the active power and regulating the grid voltage at the PCC.

The current controllers of the MMC-HVDC system are the proportional-resonant (PR) controllers [3]. From Fig. 1(b), the terminal voltages can be calculated in the stationary reference frame (αβ-frame) as

$$v_{tn\_\alpha\beta} = -i_{n\_\alpha\beta}R - L\frac{di_{n\_\alpha\beta}}{dt} + v_{sn\_\alpha\beta} \quad (1)$$

where n means the MMC-1 and MMC-2, n = 1, 2. $v_{sn\_\alpha\beta}$, $v_{tn\_\alpha\beta}$, and $i_{n\_\alpha\beta}$ are the αβ-axis components of the three-phase voltages and currents of the MMC-n.

The active and reactive powers of the MMC-n are described by

$$P_n = \frac{3}{2}\left(v_{sn\_d}.i_{n\_d} + v_{sn\_q}.i_{n\_q}\right) \quad (2)$$

$$Q_n = \frac{3}{2}\left(v_{sn\_d}.i_{n\_q} - v_{sn\_q}.i_{n\_d}\right) \quad (3)$$

where P_n and Q_n denote the active and reactive powers of the MMC-n.

Because the $v_{sn\_d} = 0$, the reference currents can be rewritten from (2) and (3):

$$i^*_{n\_q} = \frac{2}{3}\frac{1}{v_{sn\_q}}P^*_n \quad (4)$$

$$i^*_{n\_d} = -\frac{2}{3}\frac{1}{v_{sn\_q}}Q^*_n \quad (5)$$

where superscript * shows the reference value of the control signals.

The reference active power achieves from the demand of users. The reference reactive power is supplied from the grid voltage controller as follows.

$$Q^*_2 = -\left(K_p + \frac{K_i}{s}\right)\left(v^*_{pcc} - v_{pcc}\right) \quad (6)$$

Because the MMC-1 is employed to control the dc-link voltage, the q-axis current component can be computed by

$$i^*_{1\_q} = \left(K_p + \frac{K_i}{s}\right)\left(V^{*2}_{dc} - V^2_{dc}\right) \quad (7)$$

2.3 Simulation results

Simulation results are carried out by using PSCAD/EMTDC simulation program for a 200 MW MMC-HVDC system. The parameters of the MMC-HVDC system and load are given in TABLE I. Simulation are carried out in two cases.

First case: The operation of the MMC-HVDC system with constant active power as shown in Fig. 2(a). Because of the losses in the transmission lines and transformers, the grid voltage at the PCC will be dropped down. After the voltage controller is activated at 2 s, the grid voltage is regulated to the nominal value as shown in Fig. 2(b). In this case, the MMC-HVDC system operates as a Statcom. Fig. 2(c) expresses the active and reactive powers of loads.

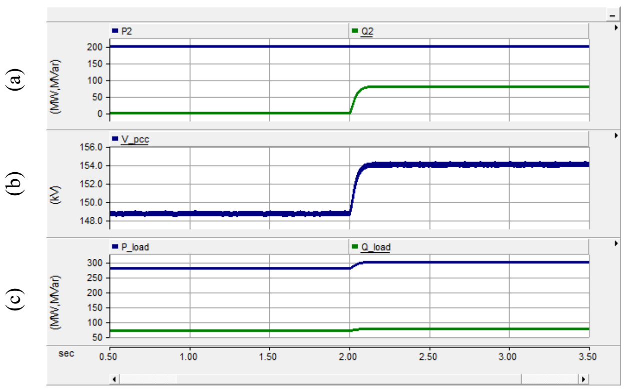

Fig. 2 The operation of the power system with constant active power.

Second case: The demand power of the MMC-HVDC system is variable as depicted in Fig. 3(a). This case is similar to the case of connecting offshore wind farms. The grid voltage is varied strongly according to the change of the active power. At t = 4 s, the voltage controller is applied. Because the MMC-HVDC system has the ability of controlling the active and reactive powers independently, the MMC-2 will supply the reactive power to the grid. Thus, the grid voltage is regulated to the nominal value as shown in Fig. 3(b). Fig. 3(c) presents the active and reactive powers of loads.

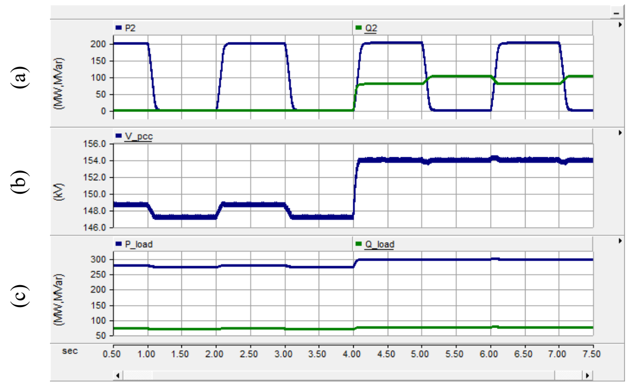

Fig. 3 The operation of the power system with variable active power.

3. Conclusion

This paper has presented an operation of the MMC-HVDC system as a Statcom to support the grid voltage. The active and reactive powers are controlled independently. The simulation results have demonstrated that the MMC-HVDC system not only transfer the active power, but also regulate the grid voltage as a function of the Statcom. This reduces the cost, meanwhile the system still operates stably.

TABLE I. SIMULATION PARAMETERS

Rated power	200 MW
AC system voltage	154 kV
Nominal frequency	60 Hz
Transformer ratio	154 kV/55 kV
Dc-link voltage	±50 kV
Number of SMs per arm	20
Load	300 MW
Power factor of the grid system	0.97

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