Modular Multilevel Converter Based HVDC for Grid Voltage Stability

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***Abstract*—This paper proposes a control method of the modular multilevel converter based high voltage direct current (MMC-HVDC) system for the grid voltage stability instead of using a static synchronous compensator (Statcom). The d-axis current component is used to control the grid voltage via the reactive power. Meanwhile, the q-axis current component is employed to control the active power according to its application. With this control method, the power system will operate stably with the maximum efficiency. Moreover, it can save the cost of installing Statcom. The simulation results are performed in the PSCAD/EMTDC software environment to confirm the effectiveness of the proposed control method.**

***Keywords*—MMC-HVDC, Statcom, Grid voltage stability**

I. INTRODUCTION

The increasing of electricity demand requires the development of the power systems with high quality, reliability and stability. However, the receiving voltage at the load side is often unstable at the nominal value because of losses in the transmission line and transformer or the random change of load. To solve this problem, the static synchronous compensator (Statcom) has been used [1], [2]. It is a shunt connected device at the point of common coupling (PCC) to stabilize the grid voltage. Nevertheless, the use of Statcom will increase cost. In the power system, which the modular multilevel converter based high voltage direct current (MMC-HVDC) system is connected to, the use of Statcom is not necessary. The function of voltage control will belong to the MMC-HVDC system. A MMC-HVDC system is a new type of voltage source converter for the medium or high voltage applications. Its operation under various conditions has been researched by many authors over the world [3]-[5]. It can control the active and reactive powers independently. The main function of the MMC-HVDC system is to transfer the active power between two power sources. In almost applications, the reactive power is set to zero. This wastes the ability of using the device because the MMC-HVDC system can absorb or generate the reactive power from or to the power system. Thus, this paper proposes a control method of the MMC-HVDC system for the grid voltage stability instead of using Statcom. With this control method, the device is used with the maximum efficiency, meanwhile the power system is operating stably. Moreover, it can save the cost of installing Statcom.

II. COMPENSATION TECHNIQUE OF STATCOM

Fig. 1 describes the single line and vector diagrams of the compensation technique of Statcom. The load requires the reactive power from the source. The load current, I_l, contains two components, the active and reactive currents. Without compensation, the source current, I_s, is high because of the reactive current as shown in Fig. 1(a). However, the source current will be decreased in case of compensation because the reactive current from the source is compensated by Statcom as

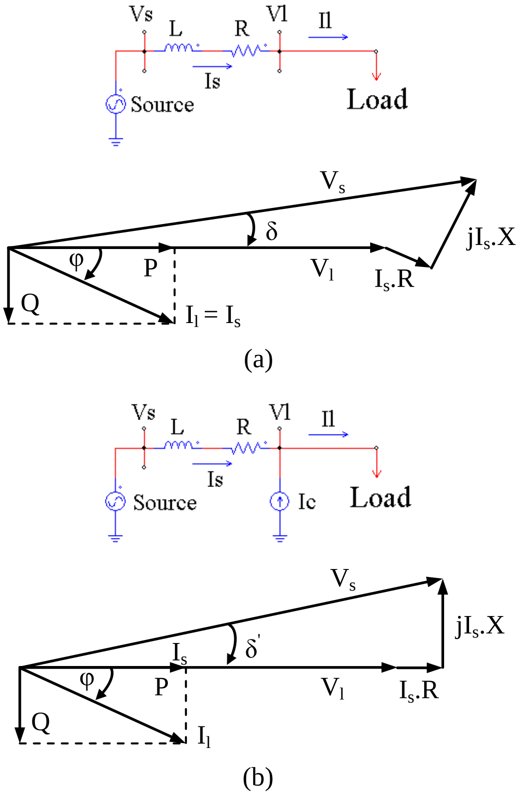


Fig. 1. Single line and vector diagrams of Statcom. (a) Without compensation, (b) With compensation.

expressed in Fig. 1(b). Thus, the losses will reduce significantly. As a result, the voltage received at the load side will be improved. If the Statcom is applied for regulating the grid voltage stability, the amount of the reactive power supplied from Statcom will depend on the reference value of the grid voltage.

III. PROPOSED CONTROL METHOD OF THE MMC-HVDC SYSTEM

The configuration of the MMC-HVDC system is shown in Fig. 2. The power system is created by the power generation source, transformer, transmission line and load. The source 2 will support for the power system via a MMC-HVDC system.

In this study, the controller of the MMC-HVDC system is designed by combining the compensation technique of Statcom and the conventional control method of MMC-HVDC system. The MMC-1 is employed to control the active power and the grid voltage. The MMC-2 is used to control the dc-link voltage and the reactive power ($Q_2 = 0$).

The control diagram of the MMC-1 for regulating the grid voltage is shown in Fig. 3. Because the MMC-HVDC system is a type of the voltage source converter, thus the d-axis and q-axis current components are controlled independently. The grid voltage is adjusted by using the d-axis current component via the reactive power control. The controller of grid voltage is the proportional-integral (PI) controller. The output signal of the grid voltage controller is the reference reactive power for the MMC-1. The active power is controlled by using the q-axis current component. The output signals of the current control loop are the reference voltages for the pulse-width modulation (PWM) method. Then, the gating signals of the IGBT will be generated from the capacitor voltage balancing method.

IV. SIMULATION RESULTS

The 250 MW MMC-HVDC system and the power system in Fig. 2 are modeled by using the PSCAD/EMTDC simulation program. The grid voltage is 154 kV. The parameter of the power system is shown in Table 1. The simulation results are set up in two cases.

A. *Independent control between the active and reactive powers*

The simulation results are shown in Fig. 4. The initial conditions are $P_1^* = 100$ MW, $V_{dc} = 100\,\text{kV}$, $Q_1^* = Q_2^* = 0$. At t = 3 s, the active power is ramped up to 250 MW. Then, the reactive power will be ramped up from 0 to 100 MVar at t = 5 s. Fig. 4(a) is the dq-axis current components of the MMC-1. The active and reactive powers of the MMC-1 are shown in Fig. 4(b). It can be seen that the active and reactive powers do not depend on each other while one of them is changed. The dc-link voltage is always kept at its reference value as depicted in Fig. 4(c). Besides, the reactive power of the MMC-2 is controlled to zero in this case as illustrated in Fig. 4(d). The capacitor voltages of the MMC-1 and MMC-2 are also shown in Fig. 4(e), (f). It is controlled around its nominal value when the active and reactive powers of the MMC-1 are changed.

B. *Grid Voltage Stability with the MMC-HVDC system*

Fig. 5 shows the operation of the MMC-HVDC system with the proposed control method. Because of losses on transmission lines and the transformers, the grid voltage at the PCC will be dropped below the nominal value. Moreover, the source 2 is an offshore wind farm in this study. Thus, the active power which is transferred by the MMC-HVDC system

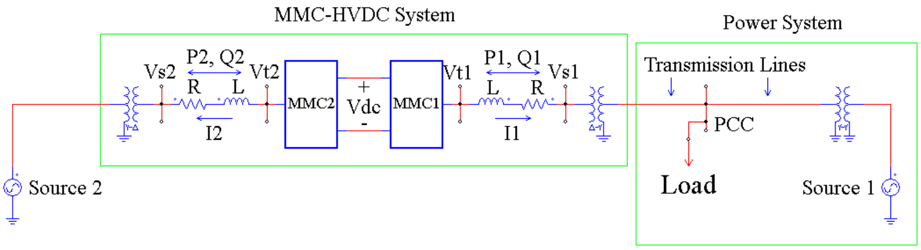


Fig. 2. The configuration of the MMC-HVDC system in the power system

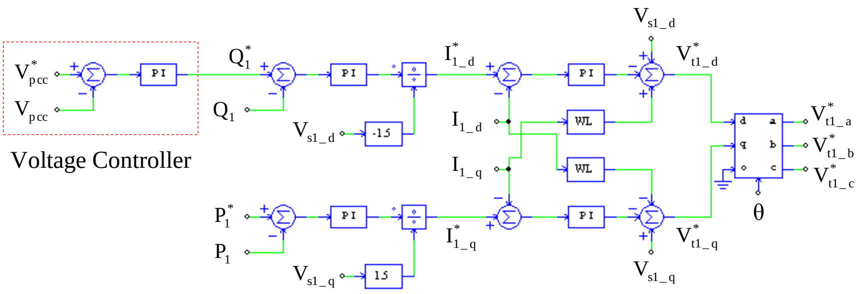
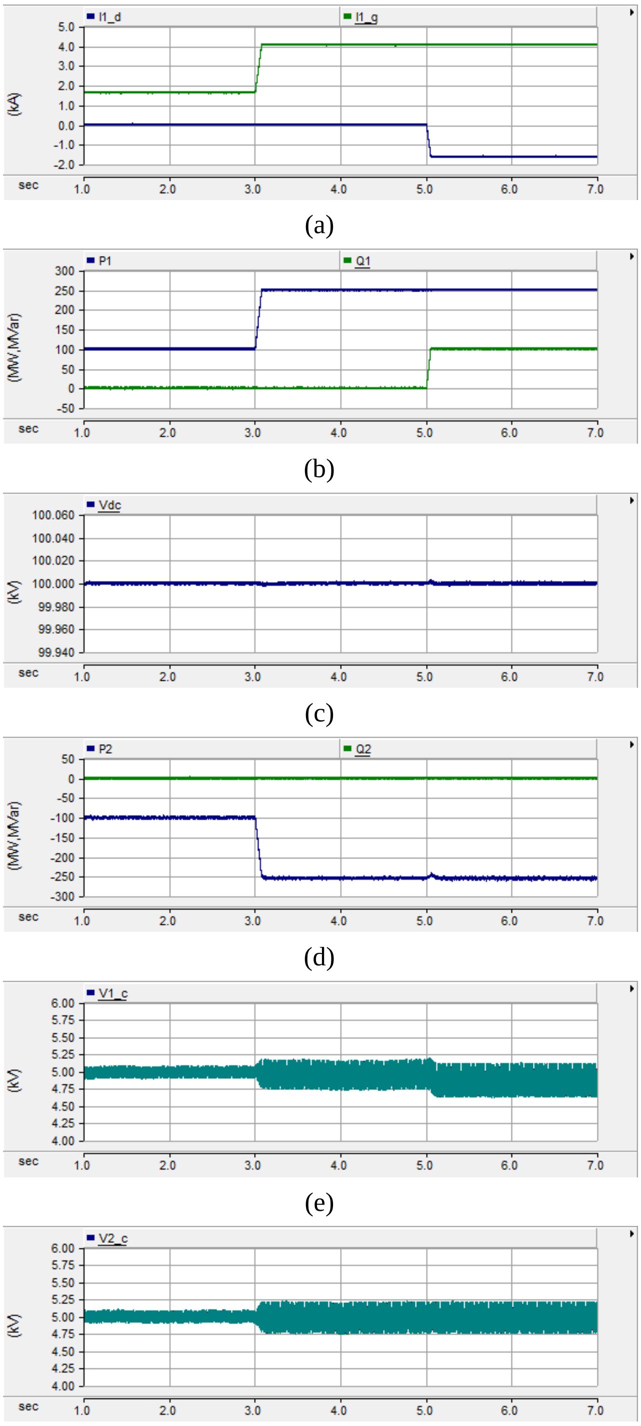


Fig. 3. Control diagram of MMC-1 for regulating the grid voltage

is variable as described in Fig. 5(a). This can cause an oscillation on the grid voltage. At t = 8 s, the voltage controller is activated. The MMC-1 will supply the reactive power to the grid. Therefore, the grid voltage is regulated to the nominal value of 154 kV as expressed in Fig. 5(b). Finally, Fig. 5(c) shows the active and reactive powers of loads.



(a)

(b)

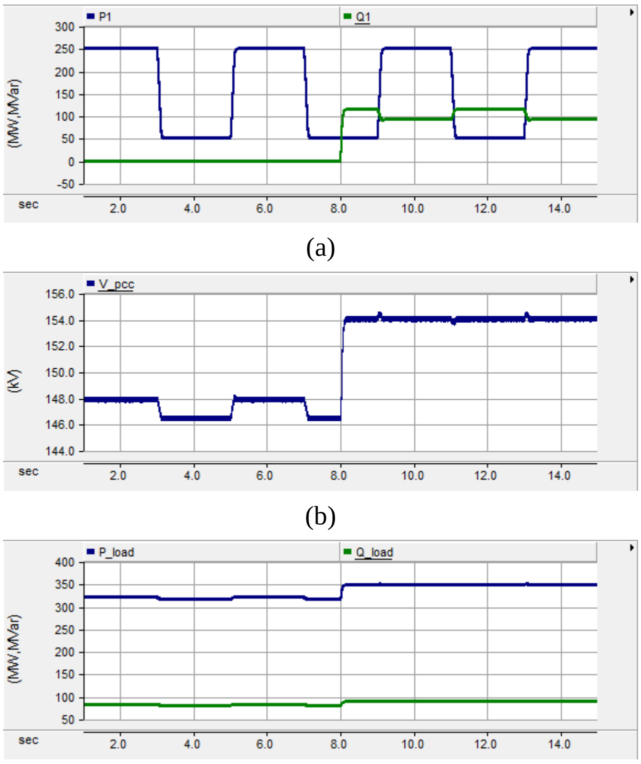
(c)

(d)

(e)

(f)

Fig. 4 Independent control



(a)

(b)

(c)

Fig. 5. Grid voltage stability

TABLE I. SIMULATION PARAMETER

		Value
MMC-HVDC system	Active power	250 MW
	Ac voltage	154 kV
	Nominal frequency	60 Hz
	Transformer ratio	154 kV/ 50 kV
	Dc-link voltage	100 kV
	Sub-module capacitor	9700 µF
Grid	Load	350 MW
	Power factor of power sytem	0.97

V. CONCLUSION

This paper has proposed a control method of the MMC-HVDC system for the grid voltage stability instead of using Statcom. The simulation results have demonstrated that the MMC-HVDC system can control the active and reactive powers independently. Moreover, the grid voltage is almost stable at the nominal value without depending on the losses and the power variation from the source. With the proposed control method, the using efficiency of the MMC-HVDC system is maximum and the use of Statcom is not necessary. Thus, it can save the cost.

ACKNOWLEDGMENT

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