Research on Voltage Sharing Optimal Control Strategy of Modular Multilevel Converter Based on Computer

Yusheng Fan¹, Shirong Wang¹, *, Jiaao Wu¹

¹Changchun University of Technology, Changchun, Ji Lin, China, 130012

*Corresponding author e-mail: wangshirong@ccut.edu.cn

Abstract. With the environmental protection requirements of smart grid in China, the power electronic technology has been developed rapidly, which greatly promotes the development of FACTS and HVDC. Based on the development requirements of facts and HVDC in China, modular multilevel converter (hereinafter referred to as MMC) has become the core component of high voltage converter, which has many advantages, such as modular design, high output waveform quality, active power troubleshooting control, high reliability, etc. MMC is a new type of voltage source converter, which is suitable for many occasions, such as new energy grid connection, island power supply, large city power supply, etc. With the continuous increase of voltage level in China, the requirements of MMC for power supply companies are gradually improved. At present, computer simulation analysis has been applied to the research of MMC, which can help designers to optimize the scheme better. Therefore, this paper analyzes the equalization control of MMC capacitor voltage (hereinafter referred to as CV). Through computer simulation and analysis of control parameters, the voltage sharing optimal control (hereinafter referred to as VSOC) of MMC is carried out, which solves the current flexible DC transmission system.

Keywords: Computer Simulation, Modular Multilevel Converter, Voltage Sharing Optimization, Control Strategy

1. Introduction

With the transition of MMC to highly modular structure, it will gradually avoid the direct series connection of switches and other components. Therefore, MMC can improve the output voltage waveform quality and effect, which has become an important direction of flexible DC transmission. According to the structure principle of MMC, the value of DC side mainly depends on the voltage provided by capacitor, which has become the main way to study and control voltage [1]. Therefore, the balance control of CV has become an important key to MMC security, which requires us to continuously optimize the control strategy. The traditional voltage balancing method is mainly through sorting algorithm, which is not suitable for large-scale transmission equipment. Therefore, this paper proposes a MMC voltage sharing optimization method suitable for large transmission equipment, which can be carried out better [2]. MMC has been able to use a variety of functions, such as wind power generation, solar power grid, asynchronous grid interconnection and so on. Through computer
simulation technology, we can carry out MMC physical simulation, which will be closer to the actual project. Therefore, MMC has an important application in engineering operation, which requires us to carry out topology structure and complex coordination control [3].

2. Topology and working principle of MMC

2.1. Topology of MMC
In 2003, Siemens proposed a new multilevel topology MMC. A phase unit of MMC is composed of two bridge arms, which is composed of N identical sub module (hereinafter referred to as SM) and a bridge arm reactor L in series [4]. The MMC topology is developed in this paper, as shown in Figure 1.

![Figure 1. MMC topology.](image)

2.2. MMC SM topology
The SM is the basic unit of MMC main circuit. There are three main topologies: HBSM-MMC, FBSM-MMC and CDSM-MMC, as shown in Figure 2. FBSM-MMC and CDSM-MMC retain all the advantages of HBSM-MMC, which has overcome the disadvantage that HBSM-MMC can’t effectively block the DC side bipolar short circuit. However, FBSM-MMC and CDSM – MMC will use a lot of power electronic devices, which has very poor economy [5].

![Figure 2. MMC SM topology.](image)

3. Research on VSOC strategy of MMC SM

3.1. Mechanism analysis of SM CV equalization control
According to the hierarchical control function division of MMC, the SM MMC control is mainly responsible for reasonably arranging the switching of SM capacitor, which can ensure that the CV is
controlled within the rated range. In this way, we can ensure the stable operation of the converter [6]. The operation mechanism of CV equalization control can be analyzed from the relationship between CV and current, as shown in Formula 1.

\[ U(t + t_m) = U(t) + \frac{1}{C} \int_{t}^{t + t_m} I_{arm}(t)dt \]  

(1)

Among them, \( I_{arm} \) is the bridge arm current, unit is A, \( t_m \) is the SM capacitance input time.

It can be seen from Formula 1. The voltage of the SM capacitor is mainly determined by the voltage value before the SM capacitor is put into operation, the bridge arm current value and the input time. Therefore, we can control from these three factors, which can ensure that the SM CV is controlled within the rated range. First, according to the voltage before the capacitor is put into operation, whether the capacitor needs charging and discharging is arranged. Secondly, according to the direction and time of the bridge arm current, the charging or discharging of the capacitor is controlled reasonably. In the traditional control method, when the bridge arm current is greater than 0, the SM with high CV is preferred. When the bridge arm current is less than 0, the SM with low CV is preferentially put into operation.

3.2. Traditional equalizing method

At present, the traditional voltage sharing method is widely used in engineering, which is a kind of selection by sorting CV and conducting according to the direction of bridge arm current. The main principle of the traditional voltage sharing method is: when the SM needs to be turned on and operates in the full voltage state, the operation state of the SM capacitor depends on the current direction of the bridge arm. When the bridge arm current flows out of SM, the SM discharges and the SM voltage decreases. When the bridge arm current flows into SM, the SM charges and the SM voltage increases. According to the operation state of SM, we can select the appropriate SM, which can adjust the CV. In this way, we finally achieve voltage equalization. Therefore, the principle of traditional equalizing method is very simple. When the current flows out of SM, we choose the SM with higher turn-on CV to discharge, which can reduce the corresponding SM CV. When the current flows to SM, we choose the SM with lower CV to charge, which can make the voltage of the selected SM capacitor rise.

3.3. Optimized equalizing method

In this paper, the double hold factor sequential voltage sharing method is selected, which can effectively reduce the switching frequency and reduce the loss. The method can reduce the amount of sorting operation, which can improve the sorting speed. Therefore, the combination of the two can reduce the loss and improve the sorting speed. Figure 3 is the schematic diagram of the optimized equalizing method.

![Figure 3. The schematic diagram of the optimized equalizing method.](image-url)
The optimal voltage sharing method is to add double retention factors to the grouping and sorting method. When the current flows to SM, we multiply the capacitance voltage of the SM in the charging state by a holding factor HF1 less than 1. When the current flows out of the SM, that is, when the SM is discharged, the capacitance voltage of the SM in the group in the on discharge state is multiplied by a holding factor HF2 greater than 1. Then through normal sequencing, we can select the SM switching, which can keep the original state of the input SM as much as possible in the next trigger control. In this way, we can effectively reduce the frequency.

4. Simulation analysis

4.1. Model of 21 level single ended MMC HVDC transmission system
In PSCAD / EMTDC environment, this paper establishes a 21 level single ended MMC HVDC system model, as shown in Figure 4. The specific parameters are as follows: the effective value of AC side line voltage is 24.4kv, the phase angle is 0°, the frequency is 50 Hz, and the internal reactance is 1.850 Ω; in the DC system, the bridge arm reactance is 0.004h, the SM capacitance value is 17mf, and the DC voltage is 40kV.

![Figure 4. Model of 21 level single ended MMC HVDC transmission system.](image)

4.2. CV of traditional VSOC
Through the traditional VSOC method, the CV of each SM is simulated. The curves with different colors represent the capacitance voltage of different SMs, as shown in Figure 5. The CV of the SM is charged and discharged around 1.5% of its rated value, and the capacitance voltage sharing effect between SMs is better.

![Figure 5. The CV of traditional VSOC method.](image)
4.3. Hierarchical VSOC of CV
When the number of layers is 2, 3 and 4, the capacitance voltage of each SM is obtained as shown in Figure 6. The smaller the number of layers m, the smaller the time complexity of the algorithm is, but the fluctuation of CV increases obviously.

![Control CV by layer voltage sharing](image)

**Figure 6.** Control CV by layer voltage sharing.

5. Conclusion
The VSOC method in this paper causes the fluctuation of CV to a certain extent. In the actual operation, we can consider the allowable deviation of SM CV. Within the allowable deviation range, we choose the number of voltage layers, which can ensure the performance and safety of the converter.

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