Modeling of Modular Multilevel Converter

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Abstract — **This paper provides the simulation and analysis of single phase Modular Multilevel Converter using differential equations. The Modular Multilevel Converter is a new solution in the field of medium and high power electronics applications. It is a combination of cascaded multilevel converter and flying capacitor multilevel converter. The converter operation is based on the modular approach. By overcoming the drawbacks of multilevel converter modular multilevel converter is designed. In this project capacitor voltage balancing strategy using differential equations for three phase modular multilevel converter without output distortion also proposed. Besides balancing strategy has reduced the losses and improved the efficiency of anticipated modular multilevel converter.**

Keywords –Modular multilevel converter, capacitor voltage control.

I. INTRODUCTION

The current energy scenario is unavoidably changing. The dependence on fossil fuels and the progressive increase of its cost is leading to the investment of huge amounts of resources, economical and human, to develop new cheaper and cleaner energy resources not directly related to fossil fuels as well as to seek for the maximum efficiency in every energy conversion process. The MMC is a new and promising converter that can be used with high voltage and power levels. Among the different multilevel topologies; the modular-multilevel converter is designed for different voltage level. It is a new configuration of IGBT based VSC.

A. Advantages

Overcome the drawbacks of this multilevel converter, advantages over previous types of converters. Just one isolated DC supply is required. In other words, it is similar to a conventional converter in the sense of having a dc side and an AC side. Low switching frequency, high quality in the output waveform, reduced voltage steps in the switches. Modular realization, easily achieved just by using more cells than strictly needed. Faults cells can be easily by passed. The internal arm currents are not chopped, they flow continuously. The sub modules are two terminal devices. There is no need to supply the DC side capacitor with energy. This is true for real power or reactive power transmission of the converter in any direction or combination. Voltage balancing of the sub modules is not critical with respect to the timing of the pulses or the semiconductor switching times. In simple the MMC have low switching losses and there is no need of bulk DC capacitor.

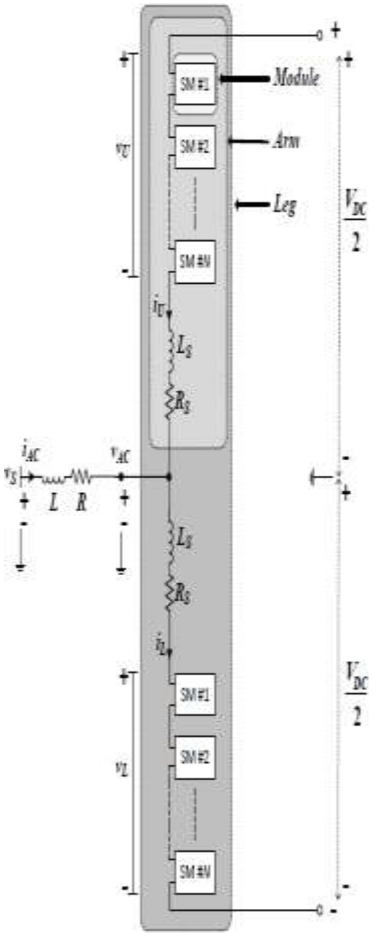
II. LITERATURE SURVEY

In [1], design and operation of Modular Multi Level converter is implemented. Here sub modules are connected in series, and form a single phase converter by expanding the single phase converter into three phase converter by adding more legs. Here study was done for known about the operation and principles of modular multi-level converter and intrinsic features about the Modular Multi Level Converter configuration. In [2], MMC family is based on multiple bidirectional chopper cells or single phase full bridge cells. MMC classified into four types from circuit configuration as follows: single star chopper cell (SSCC), single delta bridge cell (SDBC), double star chopper cell (DSCC), double star bridge cell (DSBC). Based on the applications double star chopper cell(DSCC)is used. In [3], performance of converter depends upon the pulse width modulation. Based upon the frequency, carrier and reference signal, modulation technique is used for control of converter. Several PWM techniques are used to analysis of MMC.

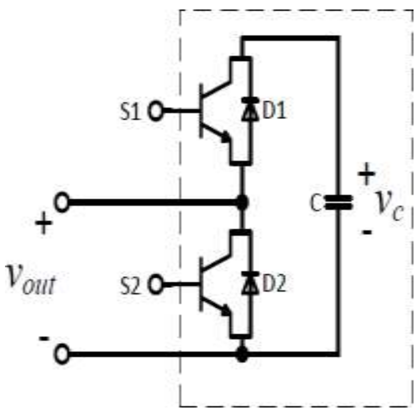
Using the sinusoidal pulse width modulation and types of its method depends upon phase shifting among carrier wave forms, and classified as phase disposition (PD) technique, phase opposition disposition (POD), alternate phase opposition disposition (APOD). Due to the advantage of alternate phase opposition disposition technique, it will be used for the analysis. In [4], describing the structure and operation of a single module, which will then be included in a single-phase model and finally in a three-phase model and the switching operations of the converter. Using the sinusoidal pulse width modulation, the control of MMC and harmonics reduction in current and voltage was performed by simulation. In [5], describing the modeling of the modular multilevel converter based on differential equations. By using two cascaded control loops a multilevel voltage and capacitor voltage balancing was obtained. The simulation was done by using the detailed modeling equations, which is suitable for n number of sub modules. In [6], authors proposed two types of pulse width-modulated modular multilevel converters (PWMMMCs) with focus on their circuit configurations and voltage balancing control. Combination of averaging and balancing controls enables the PWM-MMCs to achieve voltage balancing without any external circuit. The viability of the PWM-MMCs, as well as the effectiveness of the voltage-balancing control, is confirmed by simulation and experiment. In [7], authors proposed an improved phase disposition pulse width modulation (PDPWM) for a modular multilevel inverter which is used for Photovoltaic grid connection.

This modulation method is based on selective virtual loop mapping, to achieve dynamic capacitor voltage balance without the help of an extra compensation signal.

A. Structure of MMC



B. Structure of submodule



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C. Equations

Five level mmc mathematical equation

$$V_{AO} = V_{PO} - \sum_{i=1}^{n/2} V_{ci} \cdot (1 - S_i)$$

$$V_{BO} = -V_{ON} + \sum_{i=n/2+1}^{n} V_{ci} \cdot S_i$$

$$V_{AB} = V_{AO} - V_{BO} = V_{PO} + V_{ON} - \sum_{i=1}^{n/2} V_{ci} \cdot (1 - S_i) - \sum_{i=n/2+1}^{n} V_{ci} \cdot S_i$$

D. Capacitor voltage control

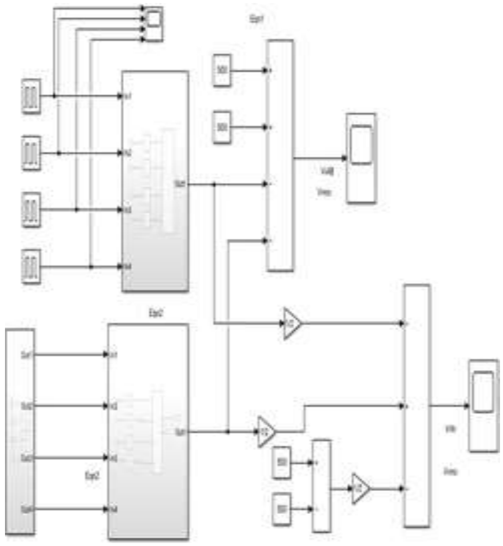
A control method and the operating performances of Modular Multilevel Converter (MMC) for high-voltage motor drive. The magnitude of capacitor voltage ripples increases when operating frequency decreases. To deal with the significant voltage fluctuation under low frequency conditions, theoretical analysis is presented in this paper, and a new capacitor voltage balancing control strategy is proposed, which is based on carrier phase-shifted sinusoidal pulse width modulation (CPS-SPWM). The simulation results show that MMC works well and capacitor voltages are balanced with the control strategy at low frequency.

High-voltage AC-AC power converters have been widely used in industry, because of the wide speed range, quick response and good performances. In the field of high-voltage AC-AC power conversion, traditional “high-low-high” two-level AC-AC converters with introduction of transformers have the disadvantages of large volume, high cost and low efficiency, and high-voltage AC-AC converters based on power electronic devices in series are hard to achieve. Contrast to the drawbacks of traditional AC-AC converters mentioned above, the multilevel converter technology has the advantages of low harmonic component, small *dV/dt*, high power factor, and it has developed rapidly in the last few years. Modular Multilevel Converters (MMCs) are made up of many sub modules (SMs)connected in series. In order to avoid semiconductor over- voltages, SM capacitors should be kept within strict voltage limits.

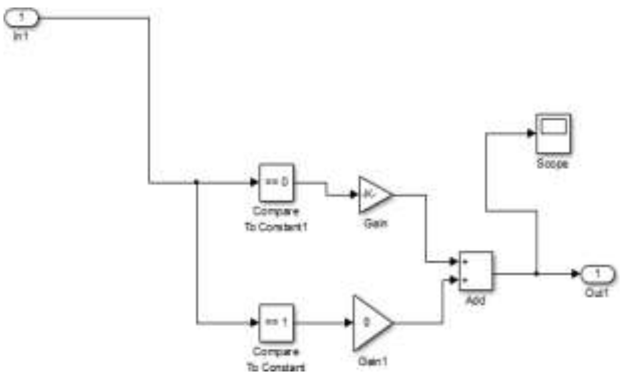
The Capacitor Balancing Controller (CBC) is used to sort SM capacitor voltages prior to modulation. As a generation of high-capacity Voltage Source Converter (VSC), Modular Multilevel Converter (MMC) is a potential topology of VSC based High Voltage Direct Current Transmission System(VSC-HVDC).Focuses on the voltage balancing control of floating dc capacitors based on CPS-PWM. The imbalance mechanics of capacitor voltage between and within arms are theoretically revealed. A new balancing control strategy called Capacitor Voltage Balancing Control Loop (CVBC Loop) is proposed, which can directly and accurately regulate the active power injected into the MMC module to guarantee dc voltage balance of capacitors within the same arm. The experiment

Results verify the validity of the proposed control strategy under both steady and dynamic state.

III. MATHEMATICAL MODELING OF AN MMC



A. Basic diagram of submodule in simulation



B. Considerations

- No of level=N=5
- No of cells per arm=N-1
  =5-1=4
- No of switches per cell=2
- Topcellswitchis1;bottomcellswitchis2
- No of gate pulse pattern needed=N-1
- In the first half of upper arm, the switch 2 connected to direct pulse switch 1 connected to inverter pulse
- In the second half of upper arm, the switch 1 connected to direct pulse switch 2 connected to inverted pulse
- No of arms per leg(phase)=2
- No of sources needed=2
- Same voltage level, connected in series and center point is connected to ground.

C. Pulse generator

The Pulse Generator block generates square wave pulses at regular intervals. The block's waveform parameters are Amplitude, Pulse Width, Period, and Phase delay, determine the shape of the output waveform. The pulse type for this block is time-based or sample-based. The default is time- based. The pulse amplitude default is 1. Time specifies whether to use simulation time or an external signal as the source of values for the output pulse's time variable. In this Use simulation time, the block generates an output pulse where the time variable equals the simulation time. The duty cycle specified as the percentage of the pulse period that the signal is on if time-based. The period is mentioned in milli seconds. The value of frequency is 50HZ.

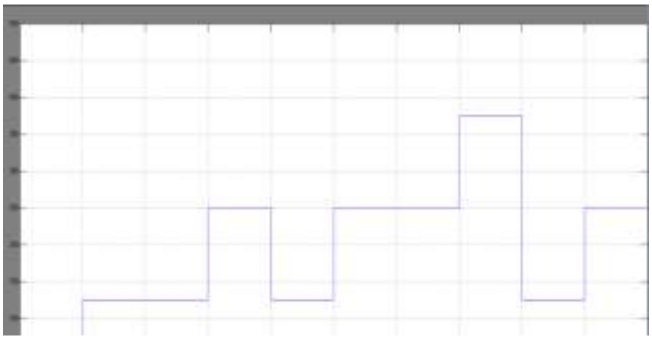
D. Not gate

This is a logic operator which performs inverse operation. If the input is true, output is false. If the input is false, output is false.

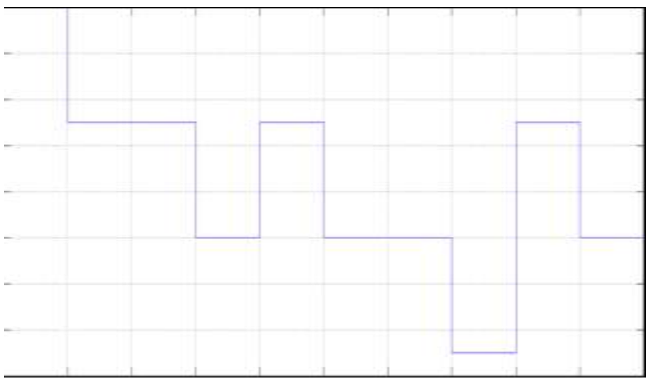
Not gate pulse for submodules	
T112	T111
T122	T121
T131	T132
T141	T142

IV. SIMULATION RESULTS

A. Lower arm output voltage



B. Upper arm output voltage



C. Five level MMC output voltage

V. Conclusion

The new and promising type of Modular Multi Level Converter is proposed. Its performance can be analyzed by differential equations. The analysis was based on the use of a simplified circuit, constituted by a single leg of the converter, where all the modules in each arm were represented by a single voltage source. From single phase converter it was extended to three phase converter and the analysis was performed. To make the analysis valid using the Sinusoidal Pulse Width Modulation. Due to the differential get smooth output waveform with different voltage level. Capacitor voltage balancing strategy using differential equations for three phase modular multilevel converter without output distortion also proposed. Besides balancing strategy was reduced the losses and improved the efficiency of anticipated modular multilevel converter.

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