An Experiment on Pulse width-Modulated Modular Multilevel Converters

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Abstract - **Modular Multilevel Converters (MMCs) are distinguished by their modular nature that makes them suitable for wide range of high power and high voltage applications. However, they are vulnerable to internal faults because of the large number of series connected Sub-Modules. Additionally, it is highly recommended not to block the converter even if it is subjected to internal faults to secure the supply, to increase the reliability of the system and prevent unscheduled maintenance. This paper tells about the basic operation of modular multilevel converter and explain about the operation of each sub module. About the plus width modulation which is used to triggering the modular multilevel converter(MMC). by using the matlab the simulation process is done.**

***keywords* - sub modules**

I. INTRODUCTION

The ever increasing demand of industry for perfect stability, precise adjustability and great accuracy of control of power electronic system at very high voltages led to the development of relatively less total harmonic distortion. power electronic equipment that converts 'dc' power into 'ac' power at desired output voltage and frequency is called an "inverter". Inverters can be broadly classified into two types; voltage source inverters (VSIs) and current source inverters (CSIs). A voltage source inverter has stiff 'dc' voltage source at its input terminals and whereas current source inverter is fed from a stiff 'dc' current source. VSIs using transistors, like Bipolar Junction Transistor (BJTs), Metal Oxide Semiconductor Field Effect Transistor (MOSFETs), Insulated Gate Bipolar Junction Transistors (IGBTs) can be turned off by the control of their base/gate current. Switching-off of the devices with the help of their gate/base currents is called self-commutation. Self-commutated inverters using Gate Turn off Thyristors (GTOs), IGBTs and Transistors do not require additional commutation circuitry. This reduces the complexity and cost of the self-commutated inverter circuits and enhances the reliability of their operation. Inverters can be categorized into two ways such as single phase and three phase inverters. For providing adjustable frequency power to industrial applications, three phase inverters are more common than single-phase inverters. Presently, the use of IGBTs in single-phase and three-phase inverters is on the rise. The process of capacitor voltage balancing is mandatory for a stable operation of the MMC. If these voltages are left without control, the difference between them will lead to increasing the converter differential current

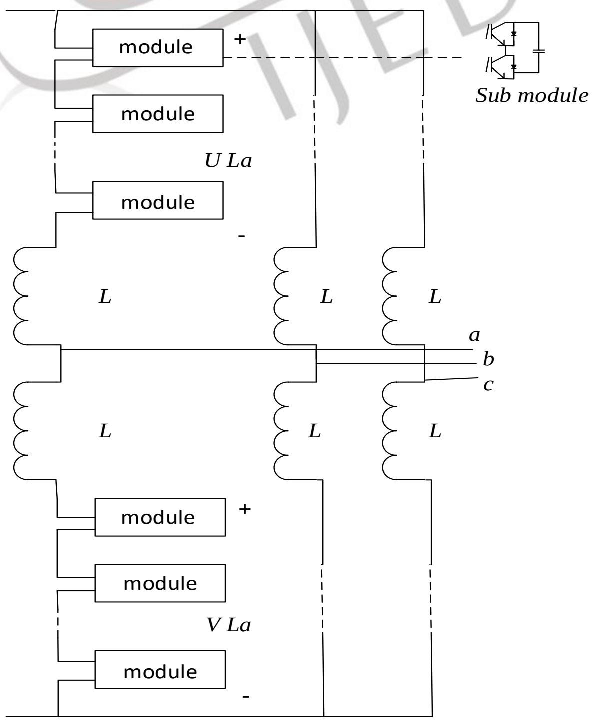

Fig:1

2.Basic operation of modular multilevel converter:

The basic generalized circuit of MMC is shown in figure. Five-level MMC along with its leg details is shown in the next figure. It is a three phase five level MMC having four sub modules (SMs) in upper limb/arm and four sub modules in lower limb/arm. The equivalent circuit is shown in figure. The basic circuit of each sub module is also shown in figure. This circuit mainly consists of inductors called 'arm inductors' having self-inductance L1 and L2 in upper and lower arm respectively. Each sub module consists of switches S1 and S2 with their anti-parallel diodes D1 and D2 respectively. The sub module switches are connected to a capacitor as shown in figure.

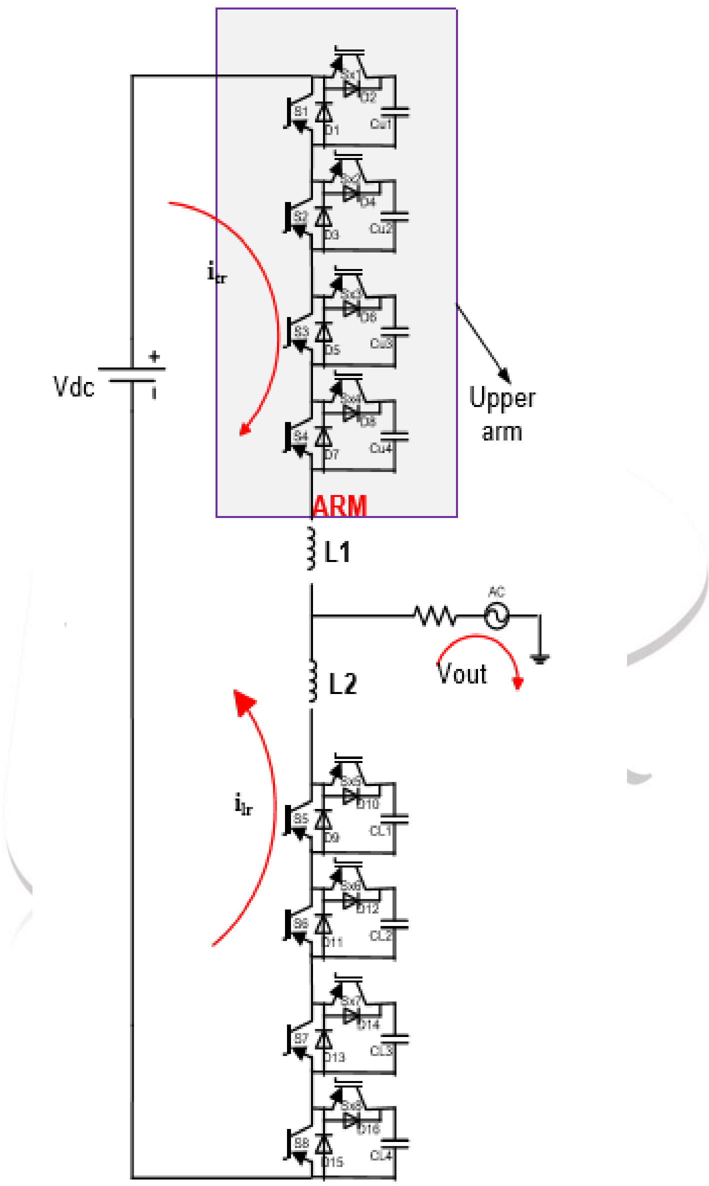

Fig:2.1

Basic Operation of Sub Module:

The basic sub module used in MMC is shown in fig.2.2, in which the output voltage across the SM is taken as 'Vsm', current passing through the two switches are taken as '$Is1$'and '$Is2$' respectively and voltage across the capacitor is taken as 'Vcu'.

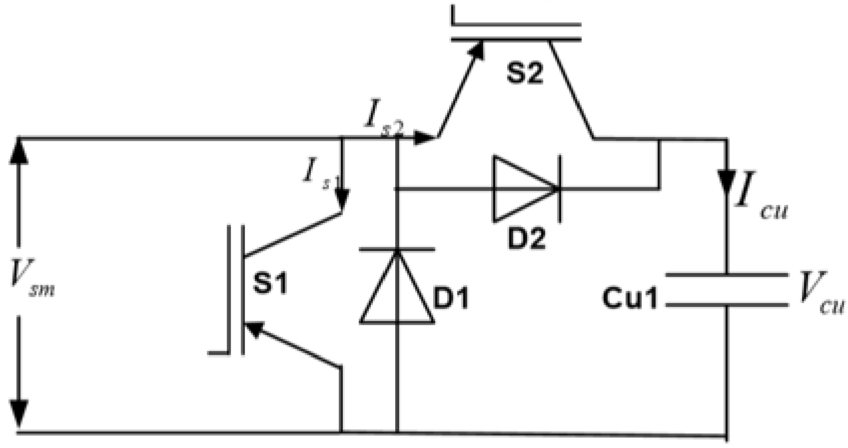

Fig:2.2 Sub module

The basic operation of MMC can be explained in four steps as follows:

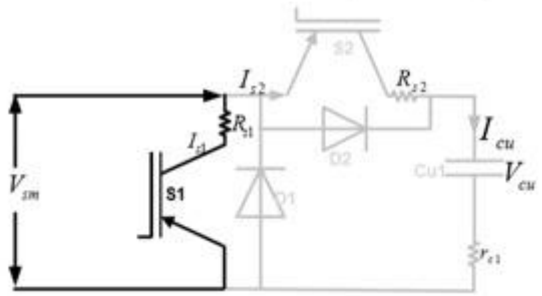

Fig:2.3 Sub Module used in MMC when S1 switch is in conduction state

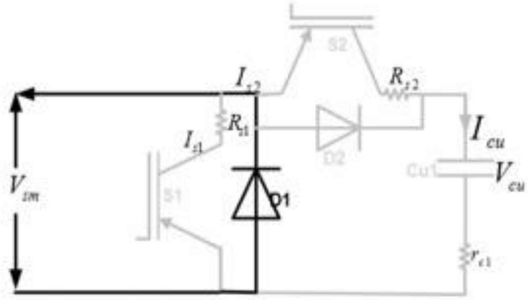

Fig:2.4 Sub Module used in MMC when D1 diode is in conduction state

1. When the switch 'S1' is in ON condition, if the input current is greater than sub module current, then current will flow through the switch 'S1'. At this instant, there is no influence of capacitor on the sub module. This state is called as bypassed capacitor state. As shown in figure 2.3

2. When both switches in SMs 'S1' and 'S2' are in OFF condition, if the sub module current is greater than input current, then current will flow through the diode 'D1'. At this instant, there is again no influence of capacitor on sub module. This state also belongs to bypassed capacitor state. This operation is shown in figure in 1.2

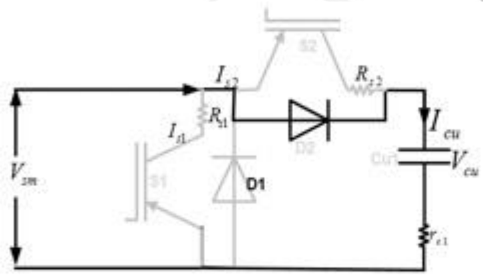

Fig:2.5 Sub Module used in MMC when D2 diode is in conduction state

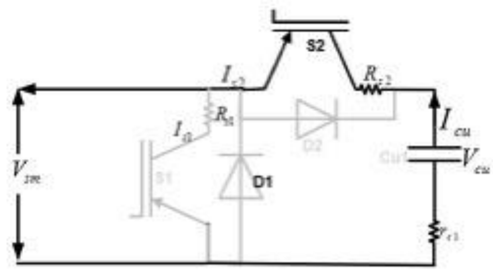

Fig:2.6 Sub Module used in MMC when S2 switch is in conduction state

1. When both switches in SMs 'S1' and 'S2' are in OFF condition, and if sub module current is less than input, then the current will flow through the diode 'D2'. At this instant, capacitor of sub module gets charged, this state can call be it as inserted capacitor state. This operation is shown in figure in 2.5

2. When the switch 'S2' is in ON condition, if the input current is less than sub module current, then current will flow through the switch 'S2' from the capacitor. At this instant capacitor in sub module is getting discharged. This state also belongs to inserted capacitor state. This operation is shown in figure in 2.6.

3.simulation results:

modulating sinusoidal signal of ma = 0.9, at frequency 50HzIn the phase disposition (PD) pulse width modulation scheme where all carrier wave are in same phase, sine wave generates the . Whereas triangular wave generates the two carrier waves for each arm, Carrier wave amplitude varies from -1 to -0.5,-0.5 to 0, 0 to 0.5 and 0.5 to 1 for 5-level MMC. Sine wave and the four carrier waves are compared using the relational operator block in MATLAB and the output signal of the relational operator blocks are used to trigger switches S1, S2, S3 and S4 of fig 3.8. When these signals are passed through NOT logical operator then compliment signals are generated and are used to trigger S9, S10, S11 and S12 switches.

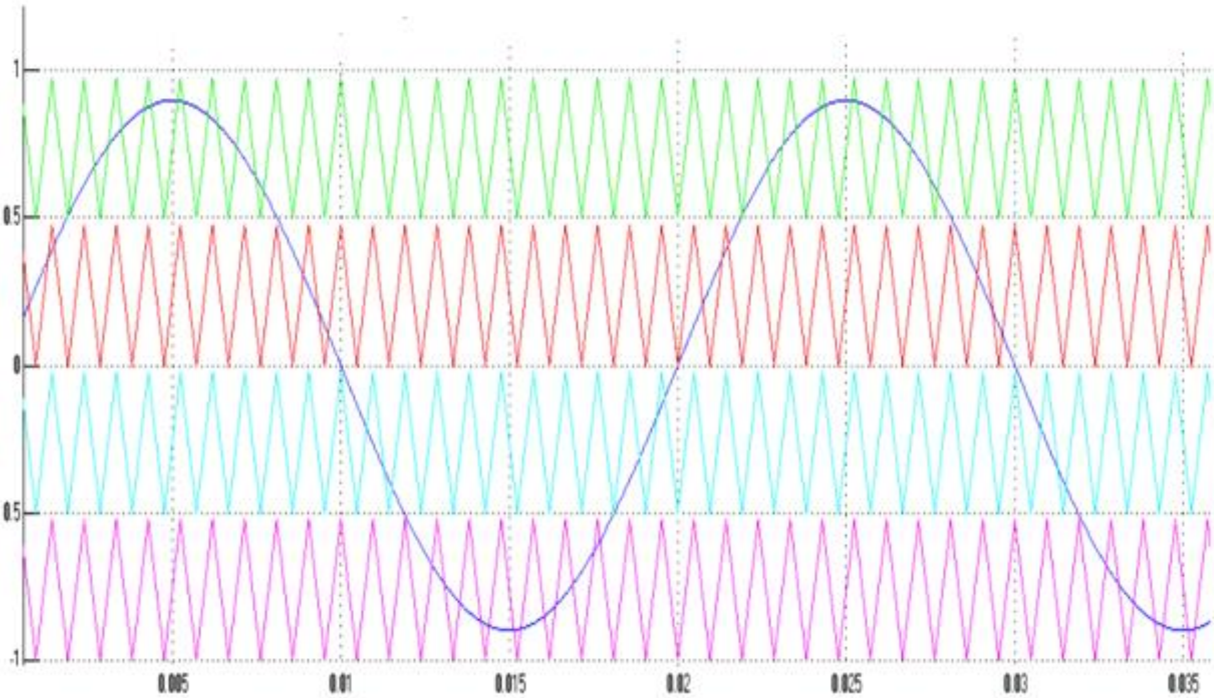

Fig:3

shows the firing pulses to trigger the positive/upper half and negative/lower half switches of each arm of the inverter. Similarly -120° and +120° out of phase firing pulses can be generated to trigger the rest two arm switches.

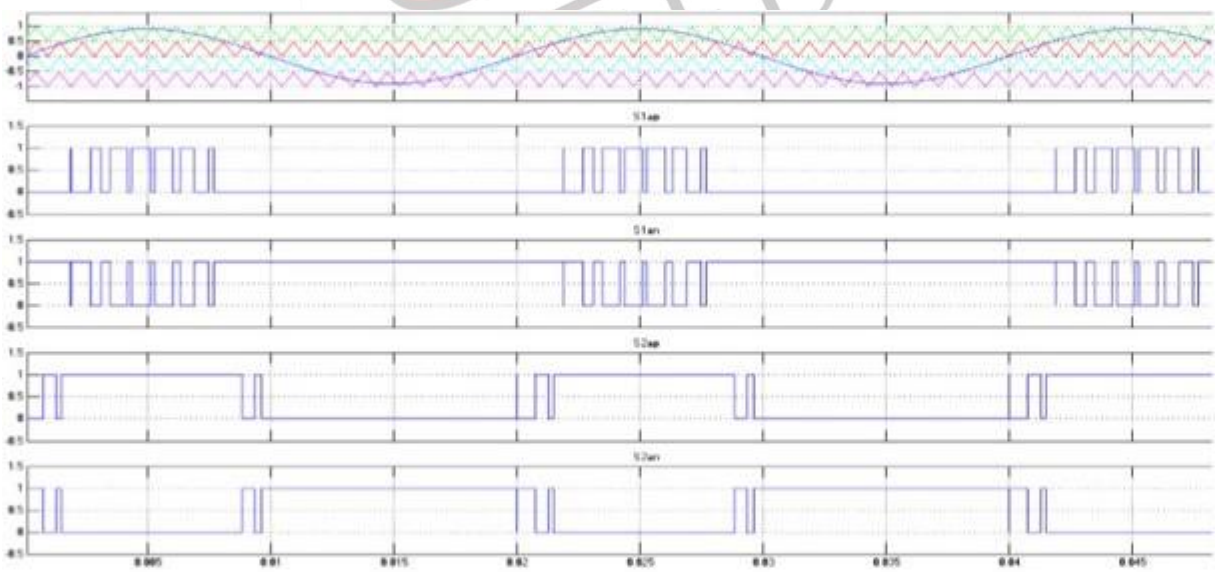

Fig:3.2 Pluses for upper arm

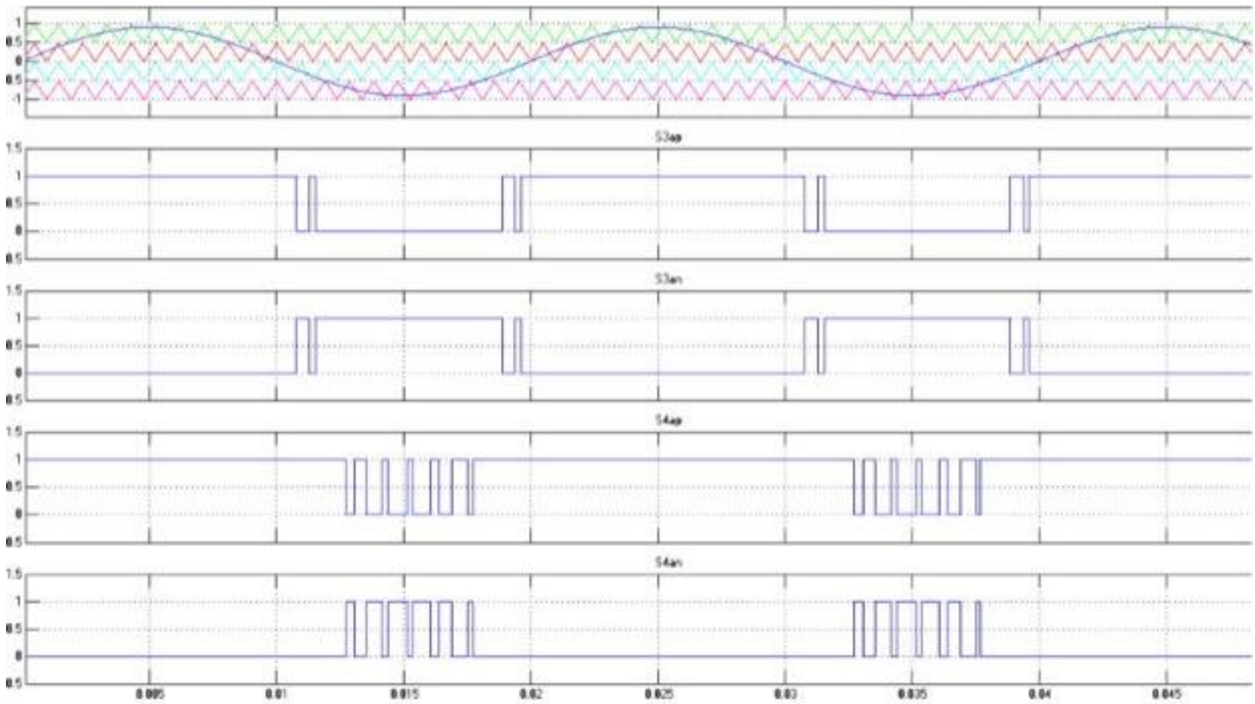

Fig:3.3 Pluses for lower arm

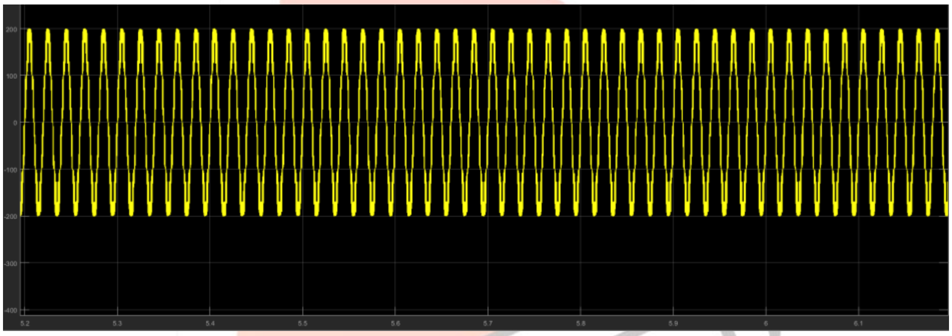

Fig:3.4 simulation resulta f=50*HZ*

To demonstrate the accuracy of the analytical MMC model, a set of simulation studies have been conducted on a fifive-level converter in MATLAB-SIMULINK environment. The dc side of the converter is supplied by a constant dc source and, the ac-side current is provided by a single-phase current source. The switching frequency is *fsw* =4 kHz.

4.EXPERIMENTAL RESULTS:

System Configuration Used for Experiment:

Below figure shows a half-bridge circuit based on the MMC, where the stack number of chopper cells was selected as four per leg to confirm the basic operating principle

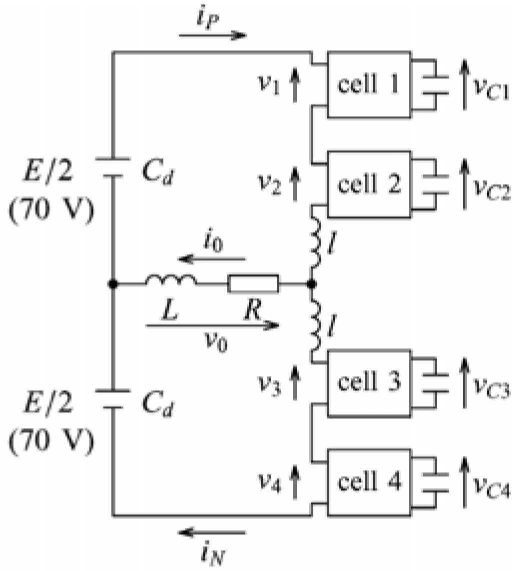

Fig:Half-bridge circuit

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