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Series Connected Half Bridge Modular Multilevel Converter Motor Drive System

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Abstract- The Modular multilevel converter (MMC) possesses an expansion research concern in the field of motor drives and this topology is applicable to high-power/voltage applications. However, a challenge remains that the MMC suffers from large fluctuation of voltage ripple submodule capacitors particularly towards low level motor speed. Therefore, this paper presents a Back-to-Back (BTB) structure to control the capability of this large fluctuation to a constant with rated load, a MMC with series connected half bridge four level inverter is used. For, which can excellently reduce the voltage ripple of submodule capacitors. The motor stand MMC, connected to control the drive an AC motor through dclink with grid-tied. When dc- link current controls the constant fluctuation of capacitor, then the half bridge submodule with motor stand MMC can lower its dc-bus voltage at low frequencies, thus it's dissipated less power and can reduces the voltage ripple submodule capacitors. The operating principle and the corresponding control methods are confirmed by matlab/Simulink.

Index Terms: - *Back-to-Back system (BTB), capacitor voltage ripple, motor drive, modular multilevel converter (MMC), sub-module (SM).*

I INTRODUCTION

MMC's are newly advancement in the multilevel converters family in which it is primitively recommended for high voltage transmission lines (HVDC) and also gained attention in the field of motor drive applications for high power transmission [1], [2], because of its good quality of voltage waveforms, high efficiency, modular structure and its scalability [3], [4]. MMC medium-voltage AC machine drives have been successfully developed for commercial use [5].

But, being a floating submodule capacitor of MMC. The arm current flows, when the voltage capacitor fluctuates and it is confessed that the MMC is precisely comparable to the output amplitude current although contrarily comparable on output frequency [6]. Hence, the capacitor voltage ripple issue would become very harsh in the high voltage applications in which required high starting torque at low motor speeds. To overcome this issue, taken within an allowable range to limit the voltage ripple [6] – [9]. Hence, to reduce those ripples inject a high frequency flow current in order to each phase arms, especially in interface beyond a regular way voltage about similar frequency inflict by three phase AC terminals, confess more frequently submodule capacitor to gets charged and discharged. Therefore, extra flow current consequently raises the current rating so it may be huge as three times without the method of injection [10].

To reduce the injection current at the point value, further revised flowing current injection with square wave [10] – [12] rather using sinusoidal wave and formation the third-order harmonic [13]. Hence still the arm current is high compared to the rated speed, although the carriage current and insulator issue causes the high significance of unsafe common-way voltage are deliberately enclosed on top of the motor. Hence, reduces the period of the motor. Further many modifications have done on the capacitor voltage ripple problem [14]. Introduced a new circuit branch for upper and lower arms to connect into crosssection way so that leads an additional path to transferring the power. [15], To interchange power with SMs added a voltage supplementary clamping circuit into each SM's and enforced the capacitor voltage steady. The balanced supplementary circuit can also be fixed among the adjacent SMs in a paired MMC topology operate an open-end winding motor [16]. In [17], A series connection switch was attached in the dc-bus of MMC, thus the voltage ripple at low motor speeds runs twotimes the rate at the rated speed.

Moreover, [18], a front-end rectifier is operated as a back-toback MMC topology, which has possible for driving foursection motors with capacity of regenerative energy, like as the hydro pumped storage [19], [20]. [21], The advantage of control strategy can essentially keep the voltage ripple unchanged with absolute of the motor speed, but the grid stands MMC and motor stand MMC's are made up with full-bridge submodules (FBSMs). Compare to half bridge (HBSM's), the FBSM brings extra hardware cost and conduction losses, high switching frequencies. Further,[22], [23], the hybrid BTB MMC motor drive is introduced in that all SM's employed with HBSM about motor stand and FBSM about grid stand MMC, reduces the SM capacitor voltage ripple of the load-side MMC at very low motor speeds, and also it limits the conduction losses, semiconductor devices and higher switching frequency.

Furthermore, [24], Hybrid BTB MMC is improved for adjustable speed drives, the upper arm of the grid side employed with FBSM and lower arm with HBSM on the other hand all SM's of the motor side made up with HBSM so that can limit the capacitor voltage ripple of SM's towards low level motor speed. However, this paper further improved work of MMC with half bridge SM on the motor side only, in which represents with systematically approach and demonstrated with simulation results.

II CIRCUIT CONFIGURATION AND OPERATION PRINCIPLES

A proposed circuit configuration is shown in figure 1. MMC with half bridge motor drive system, one MMC is connected by the DC-link used to drive an AC motor, Each MMC connected three phase and each phase comprises of two arms, such as the superior arm and the bottom arms are connected over the motor MMC of two arm inductors (L_m), Each arm comprises of N-series connected. On the other hand, a front-end rectifier is employed.

The SM system of the motor stand MMC is made-up with HBSM, the term V_s, I_s represents the input AC voltage and current of the grid edge and V_m, I_m represents the AC output voltage of the load-side MMC. Correspondingly, the term Im is the arm current, in which superior and bottom arms of load-side MMC. Apart via I_{dc} (DC-link current) and V_{dc} (DC-link voltage).

The rectifier with DC-bus and inverter is also referred as an indirect link converter, in which these two converters are preferable for BTB system. A single-phase rectification with four diodes described D1, D2 and D3, D4 connected in "serial pair", when D1, D2 are in conduct then D3, D4 switch OFF, while D3, D4 are in conduction mode then D1, D2 will be OFF. The input current and voltage of the monitors the shape of the waveforms to be sinusoidal, total harmonic distortion may reduce up to 5 percent or less. The wye co connected load helps to wired a three-phase connection configuration, in which voltage source of these of these three-phase connected is directly connected to a load.

Voltage over the superior and bottom arms of the motor MMC can be expressed as

$$V_{um} = \tfrac{1}{2} V_{dc} - V_m \qquad V_{lm} = \tfrac{1}{2} V_{dc} + V_m \qquad (1)$$

The output current Im breaks uniformly into the superior and bottom arm of motor MMC. The $i_{cir\text{-}m}$ is the component of circulatory current, Currents over the two arms can be represented as

$$I_{um} = i_{cir\text{-}m} + \tfrac{1}{2} i_m \qquad I_{lm} = i_{cir\text{-}m} + \tfrac{1}{2} i_m \qquad (2)$$

The DC component considering ambient current with even order-harmonics can be expressed as

$$I_{amb\_m} = 1/3\ I_{dc} \qquad (3)$$

The output currents and voltages can be expressed as

$$V_m = V_m \cos(\omega_m t) \qquad I_m = I_m \cos(\omega_m t + \varphi_m) \qquad (4)$$

The output AC Voltage and current is Vm, Im and ωm, φm is the angular frequency and phase angle of the motor. While, I_m is constant according to constant load torque, and PWM generates the motor MMC, V_m can written as

$$V_m = \frac{M}{\_}\, V_{dc} \qquad (5)$$

Constant V_m/ω_m ratio in the motor drive application and M refers the modulation index.

The balanced power equation between the AC and DC motor side (i.e., $1/3V_{dc}\, I_{dc} = ½\, V_s I_s \cos\varphi_m$) and neglected the converter loss. When the motor operates at rated speed, Idc would be equal to rated value.

As a signification, with the advanced operation mode, modulation index M will be constant, when ωm varied, so this satisfied the relationship of (3) V_m/ω_m.

A. Half-bride submodule system.

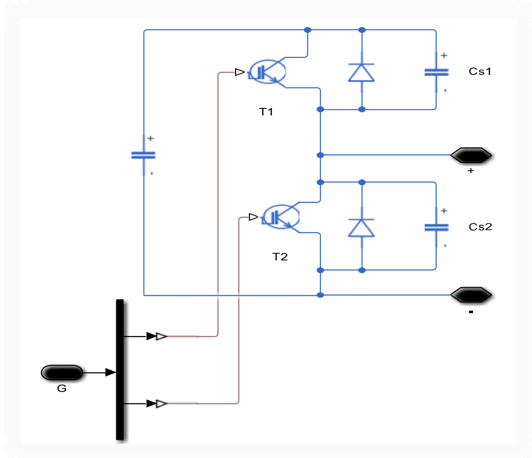

Fig. 2. Half bridge Circuit.

The half-bridge, where it is used to proposed an AC output waveform from DC-link by using the two power switches (S1, S2), The feedback diodes, in which diodes are connected in parallel with power switches, used IGBT as a semiconductor switch.

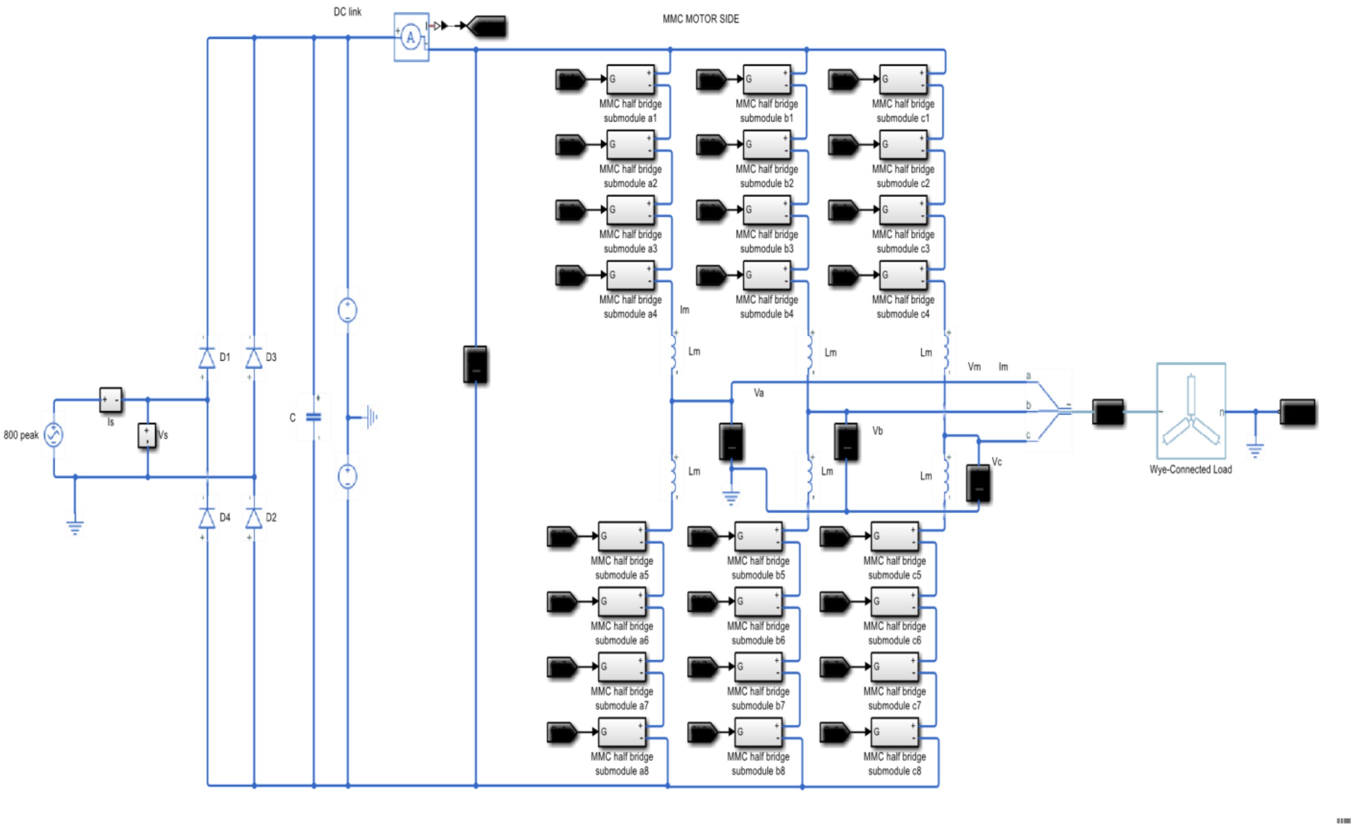

Fig. 1 Circuit configuration of series connected half-bridge modular multilevel converter of motor drive system

III SUBMODULE CAPACITOR VOLTAGE RIPPLE ANALYSIS

In this section to confess the merits of advanced motor drive system at low motor speeds, The submodule capacitor voltage ripple is analysed in the motor side

Based on (1) (5) the motor side MMC of the upper and lower arms can be written as

$$P_{vm} = V_{um} I_{um} = \frac{Vdc}{2} (1 - M\cos \omega_m t) \left[\frac{Idc}{3} + \frac{Im}{2} \cos (\omega_m t + \varphi_m) \right] \quad (6)$$

$$P_{lm} = V_{lm} I_{um} = \frac{Vdc}{2} (1 + M\cos \omega_m t) \left[\frac{Idc}{3} - \frac{Im}{2} \cos (\omega_m t + \varphi_m) \right]$$

The spontaneous energy engaged by the arms, hence the P_{um}, P_{lm} integral can be expressed as

$$\omega_{UM} = \frac{Vdc}{2Wm} \left[\frac{Im}{2} \sin (\omega_m t + \varphi_m) - \frac{MIdc}{3} \sin(\omega_m t) - \frac{MIm}{8} \sin (2w_m t + \varphi_m) \right] \quad (7)$$

$$\omega_{IM} = \frac{Vdc}{2Wm} \left[\frac{Im}{2} \sin (\omega_m t + \varphi_m) - \frac{MIdc}{3} \sin(\omega_m t) - \frac{MIm}{8} \sin (2w_m t + \varphi_m) \right]$$

The expression $(1 - M\cos \omega_m t)$ is constantly higher than zero, thus the equation can be verified as

$$t_{um} = -\varphi_m + \arccos \left(-\frac{2Idc}{3Im}\right) \quad (8)$$

$$t_{lm} = -\varphi_m + \arccos \left(-\frac{2Idc}{3Im}\right)$$

Each arms absorbed the energy into peak-to-peak value, (7) into (8)

$$\Delta\omega_{um} = \Delta\omega_{lm} = \frac{2Vdc\, Idc}{3\omega m\, M\cos\varphi m} \left(1 - \left(\frac{M \cos \varphi m}{4}\right)\right) \quad (9)$$

N- series capacitor in each arm and energy variation is expresses as

$$\Delta\omega_{um} = \Delta\omega_{lm} = N (½\, CV2\ max - ½\, CV2\ min) = NCVc\Delta Vcpp \quad (10)$$

The voltage ripple of SM capacitor is ΔV_{cpp} and this equivalent to max and min of the voltage capacitor V_{max} and V_{min}, hence, the verified result of the motor side MMC capacitor voltage ripple is

$$\Delta V_{cpp} = \frac{2Vdc\, Idc}{3\omega m\, MNCVc\, Cos\varphi m} \left(1 - \left(\frac{M \cos \varphi m}{4}\right)\right) \quad (11)$$

In conventional MMC, when the motor speed reduce the modulation index M might have smaller, I_{dc}/w_m is constant and Vdc is changeless hence leads remarkable at low motor speed because of higher capacitor voltage ripple. By contrast, the advanced operation mode, V_{dc}/w_m is constant and M, Idc are changeless. Therefore, the capacitor voltage ripple constant within the range of speed

IV CONTROL BLOCK DIAGRAM

Control strategy of the MMC is shown in fig.3., firstly, to analysis for three phase connection, a reference frame theory is used to modelling and simplify the circuit of the power converter and also easy to design. The simulation of proposed digital scheme, which means the abc axes are static in space for three phase variables. Pulse width modulation (PWM) is utilized to monitor and control the AC output voltage of the converter and also used to lower the harmonic distortion, raises the magnitude in the output voltage.

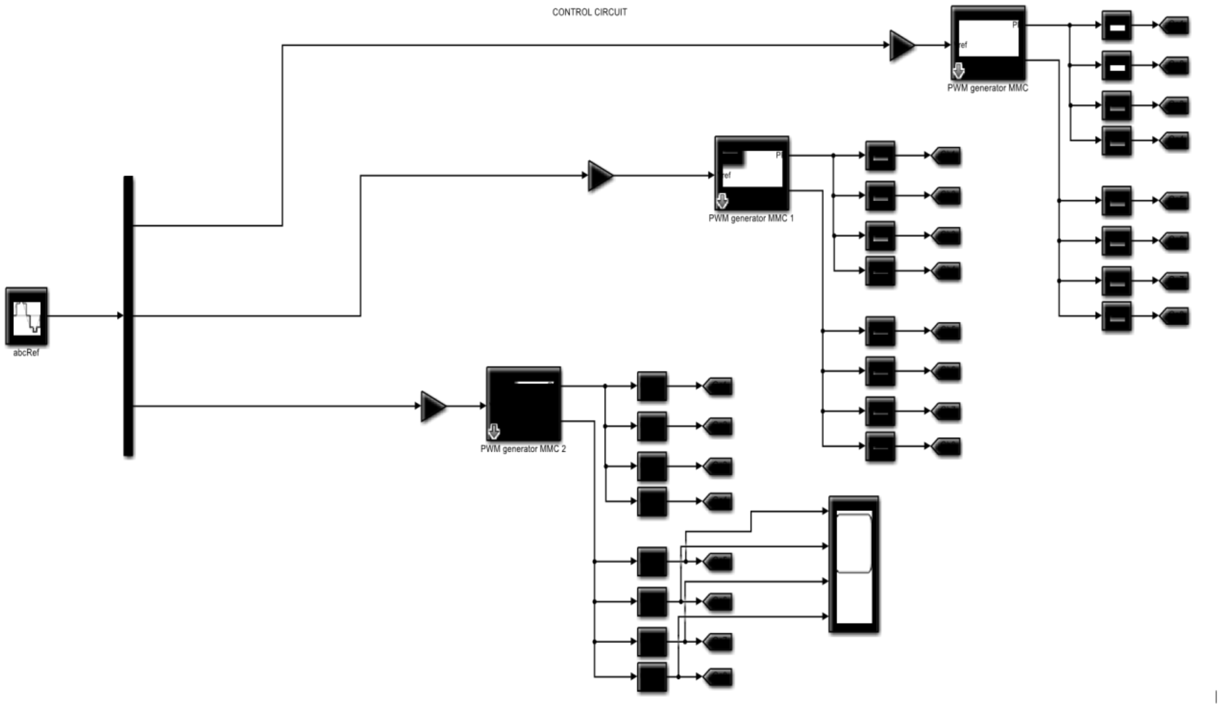

Fig. 3 Control block diagram.

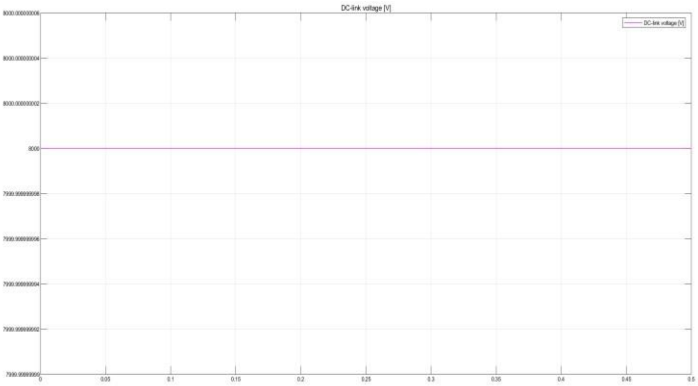

Fig. 4 Output Dc-link voltage

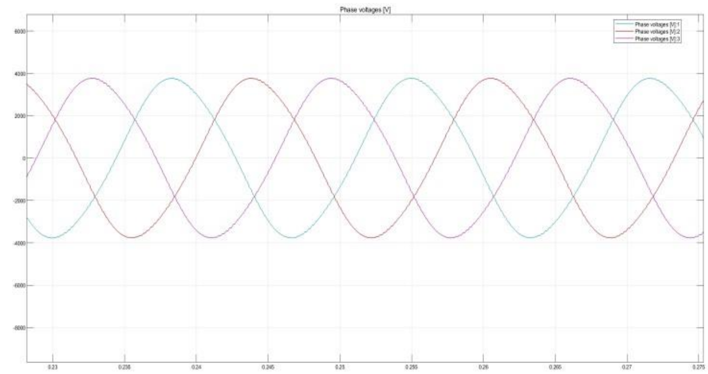

Fig. 5 Output waveforms of phase voltages.

Table I Simulation Parameters

Number of SMs per arm	N=4
SM capacitor voltage	V_c=800V
Rated DC-link voltage	V_{dc}=8000V
Arm inductance	L_m=1MH
Rated ac output current amplitude	I= 1.25kA
Rated power	2.1MW
SM capacitance	C= 4mF
output voltage	3.54kV
Rated dc-link current	164A

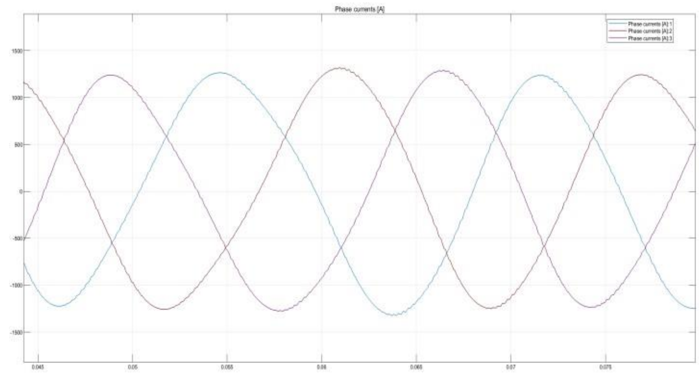

Fig.6 Output waveforms of phase currents.

V SIMULATION RESULTS

To verify the valid results of the proposed series connected half-bridge MMC motor drive system and its control strategies, a 2.1MW is simulated depend upon the matlab/Simulink. Where, (I=164A) connected a constant load torque for a motor side MMC. The rated AC input voltage is set as 800v and DClink voltage is 8000v, delivered by 4 SMs in each arm of the load side and frequency was rated at 60Hz the simulation parameters are detailed in table 1.

Fig. 4. shows the constant average SM capacitor voltage is 800V. In fig. 5. Shows the phase output voltages regulated at 3.2kv. The voltage ripples of capacitor were primarily kept constant. fig. 6. represents the rated frequency was at 60HZ. The dc-link voltage was 8000V, a 1.5kA of the output regulated amplitude current.

CONCLUSION

This paper presents a series connected half-bridge MMC motor drive system. With only HBSM, a constant DC current provides to the motor-stand MMC and the corresponding control strategies are used to reduce the large voltage ripples at very low-level motor speeds. Compared to earlier, one MMC with half-bridge were employed, therefore BTB system always that integrity that voltage ripple problems and also reduced the semiconductor devices and its losses. Thus, the corresponding control strategy and operating principle for this series connected half-bridge MMC were discussed and valid result were obtained by simulation.

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