Modular Multilevel Converter Based Statcom

[1]B.B. Thool, [2]S.P.Awate

[1]*Lecturer, Electrical, DMIETR,Sawangi Meghe Wardha, Maharashtra,India*

[2] *Lecturer , Electrical, DMIETR,Sawangi Meghe Wardha, Maharashtra,India*

ABSTRACT:- *This paper presents the transformer-less Static Shunt Compensator (STATCOM) based on Modular Multilevel Converter (MMC) topology. MMC based STATCOM have many feature over conventional Voltage source converter like transformer-less operation, Sub Modular structure, low expensive due to un-necessity of filters, redundancy , fault tolerant operation, standard components are used, low PWM carrier Frequency and quality of output waveforms. Due to the advantages of ModularMultilevel Converter over other converter topology it is used as Power Stages in STATCOM.__In this paper simulation result of Modula Multilevel converter based STATCOM under balanced linear load condition .*

KEYWORDS:- *Modular Multilevel converter, STATCOM, Voltage source Converter (VSC),Multilevel converter*

I . INTRODUCTION

Modular Multilevel Converter is used as a power stages in STATCOM.When number of level increases the voltage stresses can be reduced, capable of eliminating the coupling transformer and replacing it with cheap reactors to allow a power exchange with the power system. Due to this topology over convential converter topology.Modular Multilevel converter can synthesize a voltage waveform with a very low harmonics content [1]-[3]Compared with diode clamped multilevel converters or flying capacitor multilevel converters, the cascaded multilevel converters can be directly connected to a medium-voltage network without a bulky step up transformer, resulting in cost and weight reductions . However, they have some restrictions [7] when the fast compensation of large, fluctuating unbalanced loads, such as electric traction systems , is required . In addition, it can operate continuously under unbalanced conditions, it is capable of surviving symmetrical and asymmetrical faults without increasing the risk of system collapse and it has fault management capability.The focus of this paper is to realize a transformerless STATCOM, based on a MMC for the compensation of a unbalanced load in a medium-voltage level. For this purpose, a control strategy based on the instantaneous power theory is developed for extracting the compensating current signals. This technology, known as modular multilevel converters (MMCs) or cascaded two-level converters (CTLCs), generates voltages with very low harmonic content and presents loss levels much closer to those of "classic" thyristor line-commutated converters [1] [2] [3]. A MMC consists of multiple cascaded sub-modules (SM), the internal structure of which can be a half-bridge, a full bridge, or a clamp-double SM [8]. This work is dedicated to mathematical model which can be useful in the analysis and design of structures and control strategies of MMCs This paper studies the modular multilevel STATCOM using full-bridge SM. Due to its topology, MMC offers some advantages and unique features:

1. Its AC voltage and current have low harmonics. A passive filter becomes unnecessary.

2. MMC arm currents are continuous, and there is no longer a single bulky capacitor in a DC link.

3. The PWM carrier frequency is low, and consequently the losses are reduced.

4. Short-circuit of one sub-modules (SM) capacitor has little effect on others, and the system has fast recovery.

5. The modular structure provides redundancy to temporarily tolerate breakdown of some SM.

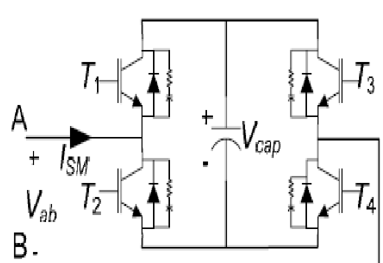

Fig.1 Structure of Modular Multilevel Converter

The SM terminal voltage is determined by the states of the four switches. For a SM, there are three operating modes, namely PWM mode, natural rectifying mode, and forbidden mode. In the PWM mode, four IGBT, T1 to T4 receive PWM gating signals. The pair of T1 and T2 has complementary signals, as well as the pair of T3 and T4. The SM terminal voltage is either equal to its capacitor voltage, or the negative of capacitor voltage, or zero. When there is at least one pair of IGBT being blocked, the SM is in the natural rectifying mode. The terminal voltage is determined by the current direction which forces certain antiparallel diodes to conduct. When there is no current, the SM has high impedance and the terminal voltage is determined by the external circuit. Two IGBT in one pair cannot have ON signals at same time. This mode will short circuit the capacitor and damage the device and therefore is forbidden..

II. CONTROL METHOD

A. Mathematical Models of STATCOM

According to the main circuit in Fig I, in stationary coordinate frame, by using Kirchhoff's voltage law, we can get the relationship between voltage and current. The mathematical model of star-configuration STATCOM can be represented

$$L\frac{d}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \begin{bmatrix} v_{sa} \\ v_{sb} \\ v_{sc} \end{bmatrix} - \begin{bmatrix} v_{ca} \\ v_{cb} \\ v_{sc} \end{bmatrix} \quad [1]$$

ia, ib and ic are the current of STATCOM. Vsa, Vsb and Vsc are the voltage of the grid. Vca, Vcb and Vce are the voltage of STATCOM. The model under dq coordinate system can be required

$$\frac{d}{dt}\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \frac{d}{dt}\left(T_{abc-dq}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}\right) = T_{abc-dq}\frac{d}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{dT_{abc-dq}}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$
$$= T_{abc-dq}\frac{d}{dt}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \omega\begin{bmatrix} i_d \\ -i_q \end{bmatrix} = \begin{bmatrix} \omega i_q \\ -\omega i_d \end{bmatrix} + \frac{1}{L}\begin{bmatrix} v_{sd} - v_{cd} \\ v_{dq} - v_{cq} \end{bmatrix} \quad [2]$$

Where

$$T_{abc-dq} = \sqrt{\frac{2}{3}}\begin{pmatrix} \sin\omega t & \sin\left(\omega t - \frac{2\pi}{3}\right) & \sin\left(\omega t + \frac{2\pi}{3}\right) \\ \cos\omega t & \cos\left(\omega t - \frac{2\pi}{3}\right) & \cos\left(\omega t + \frac{2\pi}{3}\right) \end{pmatrix}$$

$$\begin{bmatrix} v_{cd} \\ v_{cq} \end{bmatrix} = \begin{bmatrix} v_{sd} \\ v_{sq} \end{bmatrix} + \begin{bmatrix} \omega L i_q \\ -\omega L i_d \end{bmatrix} - \begin{bmatrix} K_1(i_d^* - i_d) + \frac{K_1}{T_1}\int(i_d^* - i_d)dt \\ K_2(i_q^* - i_q) + \frac{K_2}{T_2}\int(i_q^* - i_q)dt \end{bmatrix} \quad [3]$$

Combining equation [3] with [2]

$$L\frac{d}{dt}\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} K_1(i_d^* - i_d) + \frac{K_1}{T_1}\int(i_d^* - i_d)dt \\ K_2(i_q^* - i_q) + \frac{K_2}{T_2}\int(i_q^* - i_q)dt \end{bmatrix} \quad [4]$$

III.CONTROL ALGORITHM

Voltage and current closed loop controller is used in this system, which is shown in Fig 4. The output of the DC voltage regulator is used as the reference of active current Ipref; and the reference of reactive current lqref is achieved by PI regulation of the reactive current of grid. Dq transformation of STATCOM output current is used as feedback of current inner loop PI controller, ωL is the parameter of connection reactor. According to equation (4), we can get the output voltage of STATCOM Uiqref and Uidref. Three-phase modulation wave is achieved by the application of dq-inverse transformation, then we can compare modulation wave and carrier to get PWM signals to control the voltage of STATCOM.

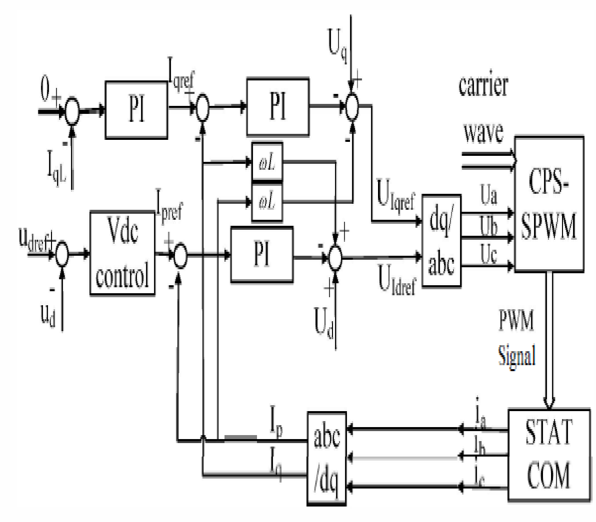

Fig.2 Control Scheme

IV. MATLAB MODELING AND SIMULATION RESULTS

Here simulation is carried out with Balanced and linear Load condition.

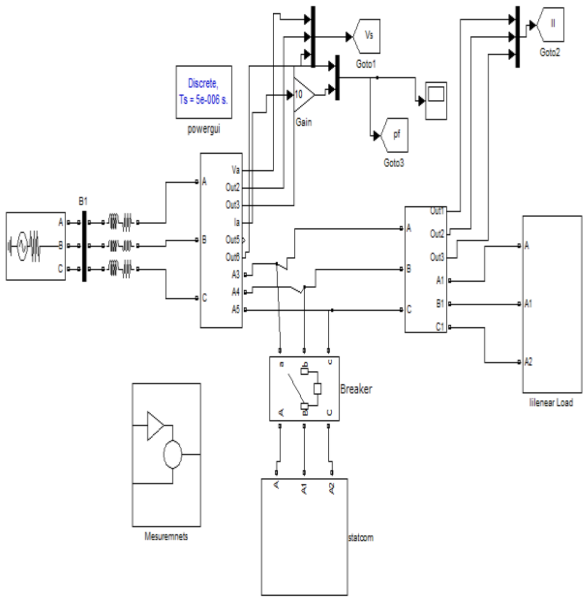

Fig.3. Matlab/Simulink Model of Proposed 11 Level Cascaded Multilevel Based STATCOM with linear load

Fig. 3 shows the Matlab/Simulink power circuit model of STATCOM with balanced linear load. It consists of five blocks named as source block, linear load block, control block, STATCOM block and measurements block. The system parameters for simulation study are source voltage of 415v, 50 Hz AC supply, DC bus capacitance 1500e-6 F, Inverter series inductance 10 mH, Source resistance of 0.1 ohm and inductance of 0.9 mH. Load resistance and inductance are chosen as 60mH and 50 ohms respectively.

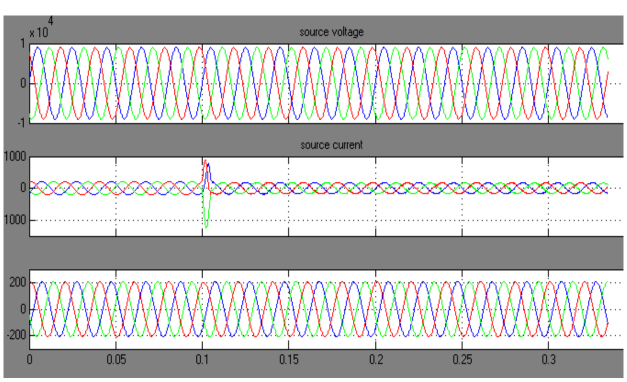

Fig. 4 Source Voltage, Source Current, Load Current

Fig-4 shows the three phase source voltages, three phase source currents and load currents respectively with STATCOM having balanced linear load. It is clear that the source current and load current are sinusoidal.

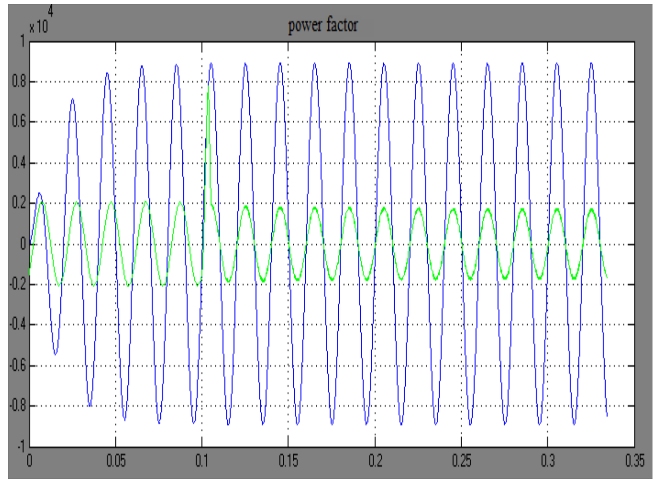

Fig.5 Source Power Factor

Fig. 5 shows the source side power factor, is unity condition due to linear load, source current somewhat distorts, before compensator is at on condition

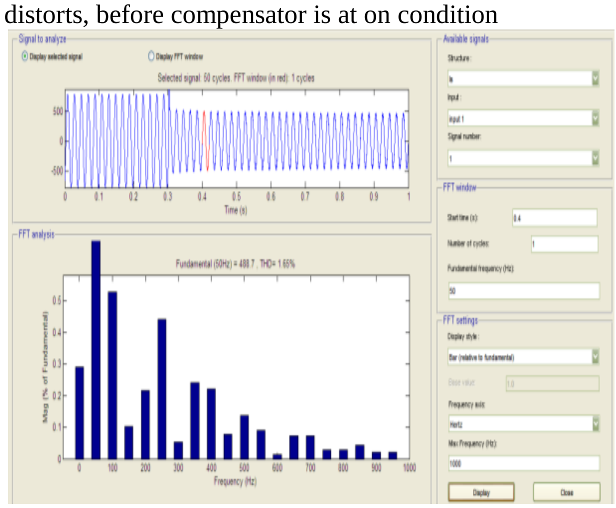

Fig.6 FFT Analysis of Phase A Source Current with Balanced Linear Load Condition.

Fig.6 shows the FFT Analysis of Phase A Source Current with Balanced Linear Load Condition, we get THD 1.165%

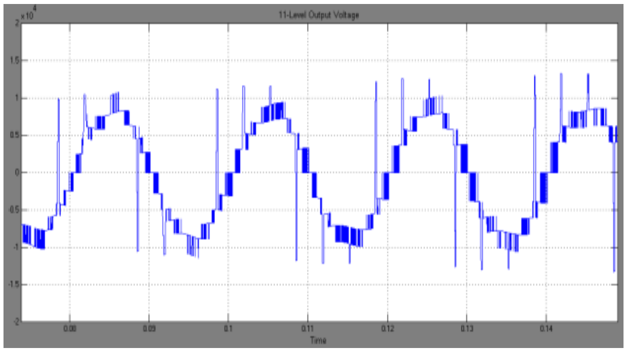

Fig.7 shows 11 Level Output Voltage

Fig.7 shows 11 Level Output Voltage of CMC Based Multilevel Inverter with Balanced Linear Load Condition.

V. CONCLUSION

Multilevel inverter has the advantages of simple structure and little harmonic content. In this paper, a 11 Level multilevel cascaded converters has been proposed with balanced linear load conditions, levels increases we get better response as well as better THD values with respect to IEEE standards. This approach requires no extra sensors and only one additional bypass by pass switch per module per phase. The approach has been validated on a system with a STATCOM compensating an electric arc furnace load. Which result in reduce output harmonic, which can solve the problems in high-power converters. Simulation results verify the compensation function and dynamic response of STATCOM based on the control strategy with balanced load conditions are introduced in this paper, which indicates from prospect of the device in high-power applications

VI.REFERENCES

[1] C. K. Lee, J.S K. Leung, S.Y R. Hui, H.S.H. Chung, “Circuit-level comparison of STATCOM technologies,” IEEE Transactions on Power Electronics, Vol. 18, No. 4, pp. 1084-1092, Jul. 2003.

[2] N.G.Hingorani, L. Gyugyi, “Understanding FACTS, Concepts and Technology of Flexible AC Transmission systems”, IEEE Press 2000.

[3] K.R.Padiyar, “FACTS Controllers in power Transmission and distribution”. New age international publishers, first edition 2007

[4] “MULTILEVEL INVERTER BASED STATCOM USING REACTIVE POWER THEORY FOR DIFFERENT LOAD CONDITIONS’’R.KEERTHI G.NAVEEN M.KONDALU International Journal of Emerging Trends in Technology Science & Engineering (IJETTSE) ISSN (Online) Volume-2, Issue-1, 2013

[5] M Ozaki, Y. Adachi, Y. Iwahori, and N. Ishii, Application of fuzzy theory to writer recognition of Chinese characters, *International Journal of Modelling and Simulation, 18(2),* 1998, 112-116. (8)

[6] S. S. Gjerde and T. M. Undeland, “The best suitable multilevel converters for offshore wind power generators without transformers,” in *Proc. Int. Power Electron. Conf.*, 2010, pp. 2398–2404.

[7] G. P. Adam, O. Anaya-Lara, and G. Burt, “Multi-terminal DC transmission system based on modular multilevel converter,” in *Proc. 44th Int.Universities Power Eng. Conf.*, 2009, pp. 1–5.

[8] S. Allebrod, R. Hamerski, and R. Marquardt, “New transformerless, scalable modular multilevel converters for HVDC-transmission,” in *Proc. IEEE Power Electron. Spec. Conf.*, 2008, pp. 174–1