Control of STATCOM Using Modular Multilevel Cascade Converters

Dr.K.Srinivas
Assistant Professor, Department of EEE
JNTUH College of Engineering Jagityal,
Jagityal, Telangana, India.
cnuiitm05@gmail.com

***Abstract*— The quality of output power generated from the utilities has the major focus of developed industries. The sensitive industry equipment's are damaged with the association of power quality problems like voltage interruption and harmonics problems. In the electrical grid the power quality will reduced by the power consumption of unsymmetrical currents created by heavy loads. The critical clearing time, voltage regulation and oscillations can be estimated by stimulating functions of Flexible AC transmission system. The main focus of this paper is to control reactive power and enhancement of power quality with the application of modular multilevel cascade converter based STATCOM. The PI control technique is used for controlling and simulations are carried by MATLAB software.**

Keywords-Modular multilevel converter(MMC), Static synchronous compensator(STATCOM),Flexible Ac transmission system(FACTS)

I. INTRODUCTION

In power system the fast acting devices are required for power quality problems which are happened in transient period. The different power electronics converters are required to compensate the both active and reactive power with FACTS technology. The voltage regulation, steady state power flow and damping frequency can be estimated by existing functions of FACTS technology. By introducing such custom devices in power system which will improve the voltage profile and transmission system reliability. The various facts controllers are exist in power system such as static synchronous compensator, static synchronous series compensator and unified power flow controller. To improve the transmission efficiency and voltage profile the STATCOM is a controller which supports the power system to compensate the harmonics at point of common coupling. To enhance the power quality the extended topology of STATCOM of modular multilevel converter based STATCOM is injected in power system for harmonic compensation.

The modular converter based STATCOM simulations in power system are performed in MATLAB software and for controlling PI controller will use. The PWM control technique is used in controller.

The modular multilevel cascaded converter can be classified in to different types such as single star bridge cells, single delta bridge cells, double star chopper cells, and double star bridge cells.

The single phase full bridge converter is same as the bridge cell and the chopper cell consists of a dc capacitor and two IGBT. The static compensator is same as double star bridge cells for eliminating harmonics. The multilevel converter has output waveform of stepped wave which have advantage of reduction in harmonics compared to square wave converter.

II. POWER QUALITY ISSUES

The power system may not stable with reduction in reactive power with slow changes in load parameters. The decrease in voltage at the bus with increasing power flow which results reduction of reactive power. The main problems in the power quality are voltage sag, voltage swell, Micro interruptions, Harmonics and transients. These problems are flickering lights and loosing data, failure operation of equipment. These problems can be avoided by using MMC based converter and also improving reactive power.

III. STATIC SYNCHNOOUS COMPENSATOR(STATCOM)

Static synchronous compensator consists of voltage source converter and a dc energy storage device. This STATCOM is capable of exchanging reactive power and it has small dc capacitor. By using this controller to exchange real and reactive power the small dc capacitor is replaced by dc storage battery or other dc sources. This controller can also extend operation for four quadrant operation. The model of the STATCOM is shown in figure 1.

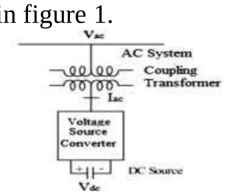

Fig.1 Basic operation of STATCOM

There is no ac current flow in converter and reactive power generation if the amplitude of ac system and converter output voltages are equal. The ac current magnitude can be calculated using the following equation

$$\mathrm{Iac} = \frac{\mathrm{Vout} - \mathrm{Vac}}{X}$$

From the converter to the ac system the ac current will flows and the reactive power exchange can be expressed as

$$Q = \frac{V2out - VoutVac\ cos\alpha}{X}$$

Between the voltage sourced converter and the ac system can be calculated as

$$P = \frac{Vac\, Vout\, sin\alpha}{X}$$

IV. MODULAR MULTILEVEL CONVERTER

The STATCOM can be connected to either load side or source side. The proposed MMC STATCOM topology consists of various blocks

A. Capacitor Voltage Balancing

In the MMC, in order to maintain capacitor voltages maintain constant the modules are constantly inserted and bypassed out of the system. The distortion in output voltage and damage of equipment is possible if module insertion failure. The selection is based on the direction of the current in the arm.

B. *Phase –Shifted Sinusoidal Pulse Width Modulation (PS-SPWM)*

In general SPWM methods the modulation signal compared with carrier wave with high frequency to get suitable gate pulses. In order to go for higher levels more number of carrier wave forms are compared with sinusoidal waveform with fundamental frequency but if the waveforms are phase shifted there is reduction in harmonics in output signals. The other advantage of MMC converter is the reduction in switching frequency of individual modules. Comparing with SPWM technique the harmonic content will decreases in PS-PWM technique .This will shows that if the number of modules increases which will reduce the harmonics and avoid the requirement of filters.

C. *Principle of Operation Of MMC*

The structure of module multilevel converter and as shown follows

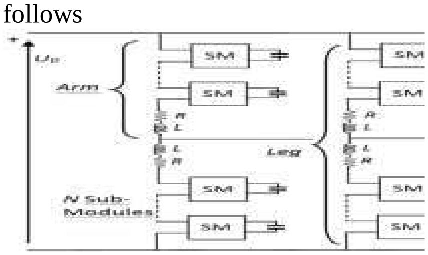

Fig.2 Three phase modular multilevel converter

Fig.2 shows the three phase modular multilevel converter which has various sub modules. If the switches are on and off at the same instant it makes short circuit across capacitor which will provide the different output voltages across the capacitor. The number steps involved in the output voltage depends on the number of series connected modular. By using two possible switching configurations the zero switching state can be obtain. The zero states must be existed alternatively to capacitor voltage balanced. The voltage generated waveform of three level inverter in Fig.3

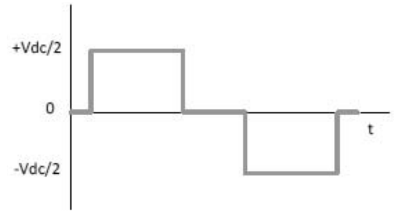

Fig.3 Voltage waveform of a Three level converter

The three level inverter operation can be extended to multilevel inverter by different number of switches and output of multilevel inverter will be stair case waveform which is approximated as sinusoidal waveform with less harmonic reduction.

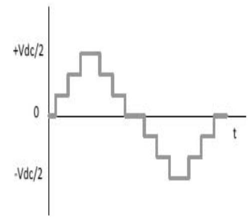

Fig.4 Voltage waveform of multilevel converter

V. SIMULATION OF MODULAR MULTILEVEL CASCADE CONVERTER BASED STATCOM

In this proposed system the Modular multilevel converter is used as STATCOM and it is connected parallel to the transmission line .This STATCOM can supplies reactive power to the transmission line. The switches of IGBT's can be used in Modular multilevel converter. The system is operated under steady state, sag and fault conditions.

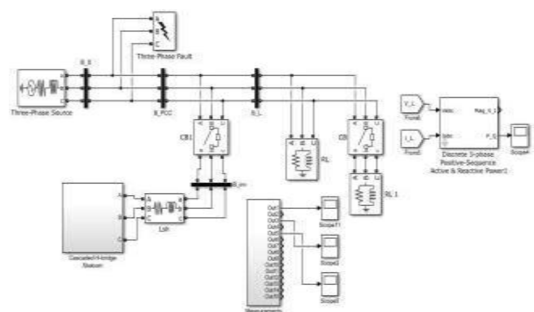

Fig.5 Simulation of Modular Multilevel Cascade Converter

The STATCOM Performance is studied at steady state conditions and voltages are well balanced and regulated. The passive filters not required because of good voltage waveform and STATCOM current at PCC.

VI. RESULTS

In the following figures which shows that source voltage magnitude and current without STATCOM under fault condition. The voltage magnitude reduced from 62.7 kv to 31.1 kV for sag condition from duration 0.2 sec and then decrease to 0 volt for transient fault for (0.3-0.4) sec transition period and the magnitude rises from 510A to 5027A for transient fault for (0.3-0.4) sec transition period .

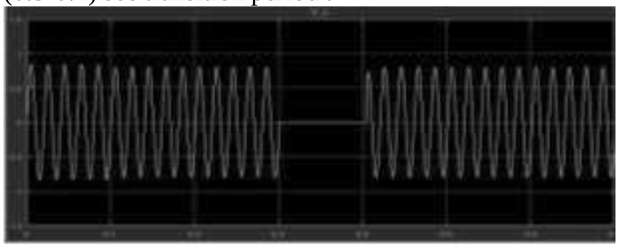

Fig.6 Source voltage in 3 phase fault condition without STATCOM

In order to restore voltage to normal condition the STATCOM injects reactive power of 82MVAR in system.

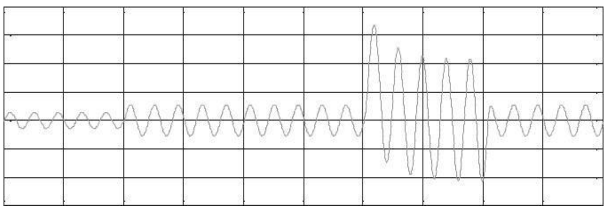

Fig. 7 Source current in fault condition without STATCOM

For the following figures shows that under different types of fault conditions the voltage waveforms analyzed .The faults like LL faults, LLG faults.

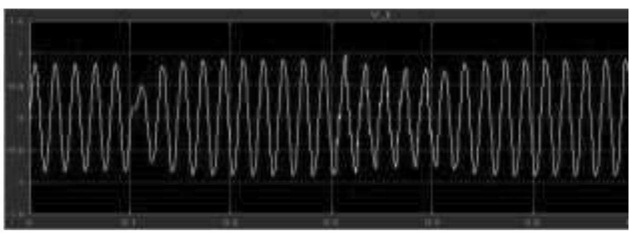

Fig.8 Source voltage in LL fault condition with STATCOM

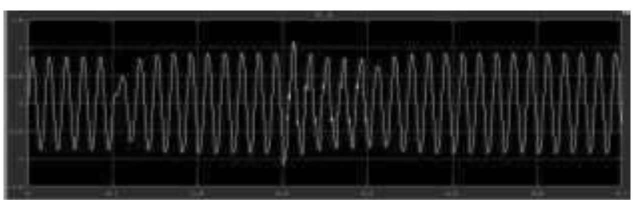

Fig.9 Source voltage in LLG fault condition with STATCOM

The following figure shows that the voltage and current waveforms with and without STATCOM for during three phase fault at PCC.

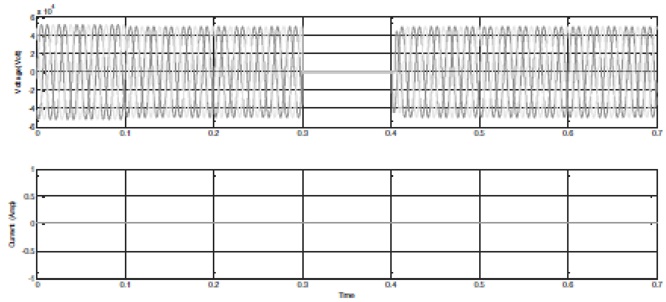

Fig.10 Voltage and current at PCC during three phase fault without STATCOM

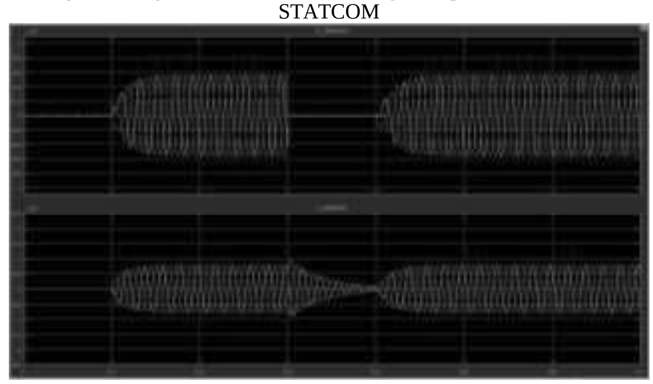

Fig.11 Voltage and current at PCC during three phase fault with STATCOM

The following figures shows that load active and reactive power for three phase fault with and without STATCOM

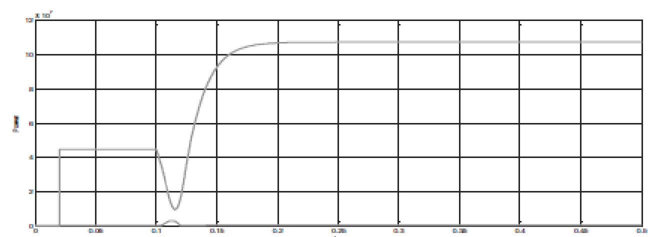

Fig.12 Load Active Power & Reactive Power under Fault Condition without STATCOM

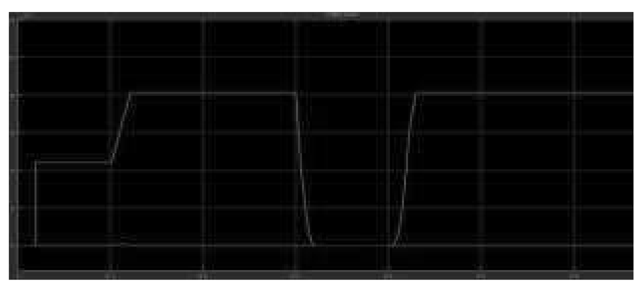

Fig.13 Load Active Power & Reactive Power under Fault Condition with STATCOM

VII. CONCLUSION

The proposed system in this paper is MMC converter is simulated in MATLAB with PS-PWM scheme. In this system, the two control loops are using to balance the series Module capacitor voltages .One control loop is used to equalize the capacitor voltage and other one used to balances the capacitor voltage within each arm. These control methods has quick response and reduce effect of voltage and current harmonics. The Multilevel Modular converter STATCOM are tested and analyzed with Steady state, voltage sag, different fault conditions and the results by using this controller shows more effective. The STATCOM has fast recovery after ac or dc faults and also has quick response to voltage without any protection circuits.

REFERENCES

[1] *H. Akagi, "Classification, terminology, and application of the modular multilevel cascade converter (MMCC)," IEEE Trans. Power Electronics, vol. 26, no. 11, pp. 3119–3130, Nov. 2011.*

[2] *J. S. Lai and F. Z. Peng , "Multilevel converters-A new breed of power converters," IEEE Trans. Ind. Appl., vol. 32, no. 3, pp. 509–517, May/Jun. 1996.*

[3] *F. Z. Peng and J. S. Lai, "Dynamic performance and control of a static var generator using multilevel inverters," IEEE Trans. Ind. Appl., vol. 33, no. 3, pp. 748–755, May/Jun. 1998.*

[4] *Y. Liang and C. O. Nwankpa, "A new type of STATCOM based on cascading voltage-source inverters with phase-shifted unipolar SPWM", IEEE Trans. Ind. Appl, vol. 35, no. 5, pp. 1118–1123, Sep./Oct. 1999.*

[5] *S. Sirisukprasert, A.Q. Huang ,"Modeling analysis and control of cascaded-multilevel converter-based STATCOM," in Proc. Power Eng. Soc. Gen. Meeting, 2003, pp. 13–17.*

[6] *C.K. Lee, J. S. K. Leung, S. Y. R. Hui, and H. S. H. Chung, "Circuit-level comparison of STATCOM technologies," IEEE Trans. Power Electron., vol. 18, no. 4, pp. 1084–1092, Jul. 2003.*

[7] *F. Z. Peng and J. Wang, "A universal STATCOM with delta connected Cascade multilevel inverter," in Conf. Rec. IEEE PESC, 2004, pp. 3529–3533.*

[8] *H. MohammadiPirouzy and M. TavakoliBina "Modular Multilevel Converter Based STATCOM Topology Suitable for Medium-Voltage Unbalanced Systems", Journal of Power Electronics, September 2010,Vol. 10, No. 5, pp. 1534 – 1545.*

[9] *Wei Li, L.-A. and J. Bélanger, "Modeling and Control of a Full-Bridge Modular Multilevel STATCOM", Power and Energy Society General Meeting, 2012 IEEE 22-26 July , 2012,pp.1 – 7.*

[10] *T. Yuvaraja, S.Mazumder, "Performance and Analysis of Modular Multilevel Converter"; American Journal of Engineering Research (AJER) 2014 e-ISSN : 2320-0847 p-ISSN : 2320-0936 Volume-03, Issue-01, pp. 01-08.*

[11] *R. Naderi, A. Rahmati "Phase-shifted carrier PWM technique for general cascaded inverters", IEEE Trans. Power Electron., vol. 23, no. 3,pp. 1257–1269, May 2008.*

[12] *S. Madichetty, A. Dasgupta, "Modular Multilevel Converters Part-I: A Review on Topologies, Modulation, Modeling and Control Schemes", International Journal of Power Electronics and Drive System (IJPEDS) Vol. 4, No. 1, March 2014 pp. 36-50.*

[13] *K. Atal, R. K. Sandhu, "An Implemented Approach of Fuzzy Logic Based Controlled STATCOM", International Journal of Advance Engineering and Research Development, Volume 2, Issue 3, March2015, PP.487-496.*

BIOGRAPHIES

Dr K.Srinivas received the B.E. degree in Electrical and Electronics Engineering from Chithanya Bharathi Institutue of Technology and Science, Hyderabad, Osmania University, Hyderabad, India, in 2002, M.Tech. Degree in power systems and Power Electronics from Indian Institute of Technology, Madras, Chennai, in 2005, Ph.D from Jawaharlal Nehru Technological University Hyderabad. Currently working as an Assistant Professor and Head Department of Electrical and Electronics Engineering, Jawaharlal Nehru Technological University Hyderabad College of Engineering Jagitiala. His fields of interest include power quality and power-electronics control in power systems.