Multilevel based STATCOM for PQ Enhancement

Abdul Kalam Sk[1], G V Prasanna Anjaneyulu [2]

[1,2] *EEE Department, TIRUMALA ENGINEERING COLLEGE*
Narasaraopet, Guntur, Andhra Pradesh, India

[1]kalam.sk@gmail.com

[2]gvp.anjaneyulu@gmail.com

***Abstract*— A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure and misoperation of end user equipment's and loads. Industrial loads and critical commercial operations suffer from various types of outages and service interruptions which can cost significant financial losses and wasting of time. This dissertation is dedicated to a comprehensive study of static synchronous compensator (STATCOM) systems utilizing cascaded-multilevel converters (CMCs). Among flexible AC transmission system (FACTS) controllers, the STATCOM has shown feasibility in terms of cost effectiveness in a wide range of problem- solving abilities from transmission to distribution levels. Finally, simulations are shown the 3-level & 5-level MLI based STATCOM operation for sag mitigation.**

***Keywords*— T.H.D, Flexible AC Transmission devices, Multilevel inverters, STATCOM**

I. INTRODUCTION

Power Quality and Voltage instability problems are attracting more and more attention in the areas of power system operation, planning, automation, transmission distribution and control. These problems are becoming a more serious concern with the ever-increasing utilization and higher loading of existing transmission systems, particularly with increasing energy demands, and competitive generation and supply requirements. Under the heavy load conditions, a significant voltage drop may occur in the system. Voltage sags can occur at any instant of time, with amplitudes ranging from 10 – 90% and a duration lasting for half a cycle to one minute [1]**.** Voltage swells are not as important as voltage sags because they are less common in distribution systems. Voltage dips are one of the most occurring power quality problems.

There are no. Of ways to mitigate Power quality issues, voltage dips, swell and interruptions in transmission and distribution systems. At present, a wide range of very flexible controllers, which capitalize on newly available power electronics components, are emerging for custom power applications [3,4]. Amongthese, the distribution static compensator and the dynamic voltage restorer are most effective devices, both of them based on the VSC principle.

The multilevel voltage source inverter is recently applied in many industrial applications such as ac power supplies, static VAR compensators, drive systems, etc. One of the significant advantages of multilevel configuration is the harmonic reduction in the output waveform without increasing switching frequency or decreasing the inverter power output [5-11]. The output voltage waveform of a multilevel inverter is composed of the number of levels of voltages, typically obtained from capacitor voltage sources. The so-called multilevel starts from three levels. As the number of levels reach infinity, the output THD approaches zero.

A STATCOM, which is schematically depicted in Fig.1, consists of a three-level VSC, a dc energy storage device, a coupling transformer connected in shunt to the DS. The VSC converts the dc voltage across the storage device into a set of three-phase ac output voltages.

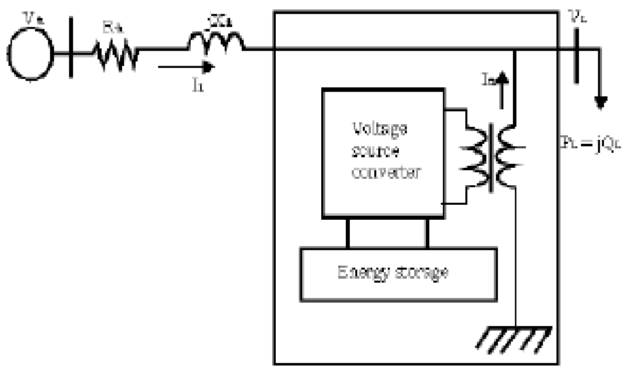

Fig. 1 Basic Representation of a STATCOM

These voltages are in phase and coupled with the ac system through the reactance of the coupling transformer. Suitable adjustment of the phase and magnitude of the STATCOM output voltages allows effective control of active and reactive power exchanges between the STATCOM and the ac system. Such configuration allows the device to absorb or generate controllable active.

II. MODE OF OPERATION

A new approach has been proposed to control currentwith Peak Current mode control (PCM) without any instability. PCM is instable for duty cycles more than half. This approach adopts PCM for duty ratios smaller than half, but it changes the control strategy for duty ratios larger than half. In traditional PCM method, the circuit current is controlled in such a way that it does not become larger than the reference. When the current in each cycle crosses the reference, the control method will change the switch status to decrease current. However, this algorithm will cause instability to the current for duty ratios greater than half. The new method will control circuit current in duty ratios larger than half in such a way that it does not become smaller than the reference.

III. PROPOSED METHOD

The Conventional method is shown in Fig. 2. The output voltage of the inverter used as a single phase STATCOM shall be in phase with the grid voltage. At the same time, the duty cycle shall be controlled according to the new current control approach. In order to adopt this approach, the duty cycles shall be id entified whether it is greater or smaller than half. In order to define the duty cycle for different voltage conditions, the inductor current should be calculated according to the inductor voltage drop. If the inductor voltage drop during current increase in a switching period is larger than the one for current decrease instance, the duty cycle will be less than half. It is because it takes le ss time for the current to rise to its final value than the time for it to decrease to its bottom value.

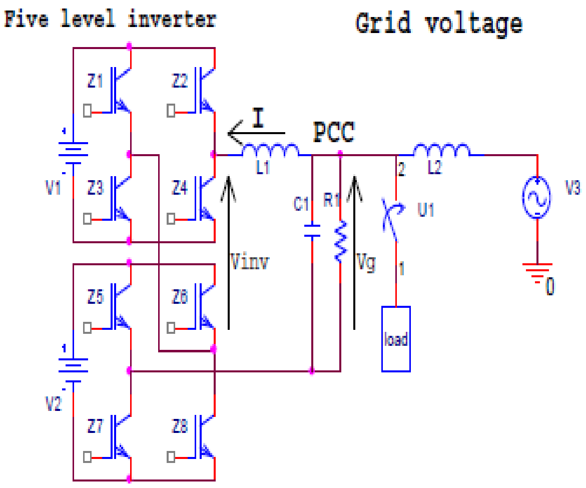

Fig. 2: Single Phase Grid and the STATCOM Compensator

$$V_{L1} = L_1 \frac{\Delta I}{\Delta t} \quad (1)$$

$$V_g - V_{inv} = L_1 \frac{\Delta I}{\Delta t} \quad (2)$$

$$I_{sh} = I_L - I_S = I_L - (Vth - V_L) / Z_{th} \quad (3)$$

$$I_{sh} \angle \eta = I_L \angle -\theta \quad (4)$$

According to Equation (2) the different voltage conditions and its related duty cycle is calculated and shown in Table I. For example if the grid voltage is below half unit of the DC voltage supply, the voltage that is generated in the output of the converter is zero or one unit of the DC voltage. In order to increase the current, zero will be assigned to the output of the converter. On the other hand, to decrease STATCOM current one u nit of the DC voltage supply will be assigned to output of the converter. In this case the inductor voltage drop when current increasing is equal to the grid voltage and the inductor voltage drop when current decreasing is the difference between grid volta ge and one DC voltage supply. Since it was assumed that the grid voltage is lower than half of the DC voltage supply, the inductor voltage drop during current increase is lower than the voltage drop during current decrease. This means that it takes a longer time for the current to increase than for it to decrease as in Fig. 4 which leads to the duty cycle larger than half as in Table I.

Table .1: Duty cycle for different circuit Conditions depending on the required voltage and current polarity

Grid Voltage amplitude (V) compared to DC voltage supplies (V_{DC})	Duty cycle (D) status
$V<0.5\ V_{DC}$	$D>0.5$
$0.5\ V_{DC} < V < V_{DC}$	$D<0.5$
$V_{DC} < V < 1.5\ V_{DC}$	$D>0.5$

In order to manipulate the control method on the multilevel inverter, the conditions that affect the circuit current should also be identified. There should be a table to define the true voltage that should be imposed to the inverter output voltage terminals. There are some measures to select the appropriate output voltage. One of the criteria is that the grid voltage should be always between the nearest available DC-voltage magnitude that can be generated by the inverter as shown in Table II.

Table .2: Switch arrangements for required inverter output

Required output voltage	Switches to be ON
$-2V_{dc}$	Z5,Z8,Z1,Z4
$-V_{dc}$	Z5,Z8,Z3,Z4
0	Z7,Z8,Z3,Z4
V_{dc}	Z7,Z8,Z3,Z2
$2V_{dc}$	Z7,Z6,Z3,Z2

Table II will be used to implement the controller utilizing a DSP. According to the tables above and measuring the instantaneous current and voltage, the DSP decides the status of switches. The block diagram of the controller in DSP according to the tables above is in Fig. 3 According to Fig. 3, the grid voltage (Vg) and inverter current (I) are measured and fed into the DSP. The DSP controls the switches according to the network parameters and tables mentioned above.

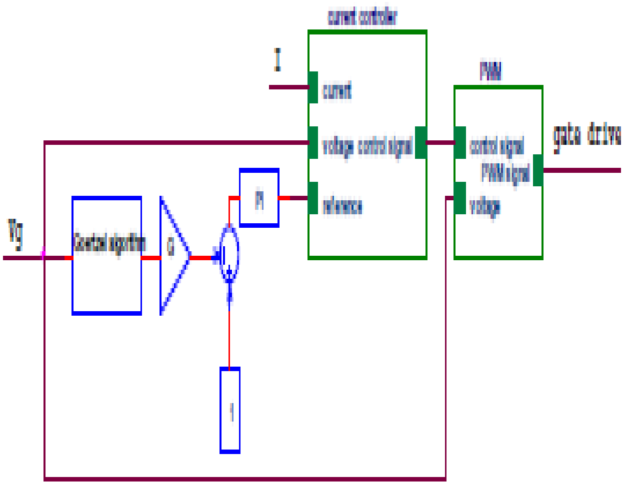

Fig .3 Block Diagram Representation in current control mode of peration

IV. IMPLEMENTATION AND SIMULATION RESULTS

The proposed scheme is implemented and simulation is carried out and shown Fig. 4 in two topologies, three level STATCOM, 5-level multilevel converter STATCOM. compensating the voltage sags & swells for improvement of power quality.

Fig.5 shows the grid current when 3 level inverter is connected to single phase circuit. Fig.6 shows the output waveforms of the unity power factor. It is clear that voltage and current are in phase and there is unity power factor because 3level based STATCOM is used.

Fig .8 shows the Simulink Circuit of Single phase circuit with 5-level multilevel STATCOM.

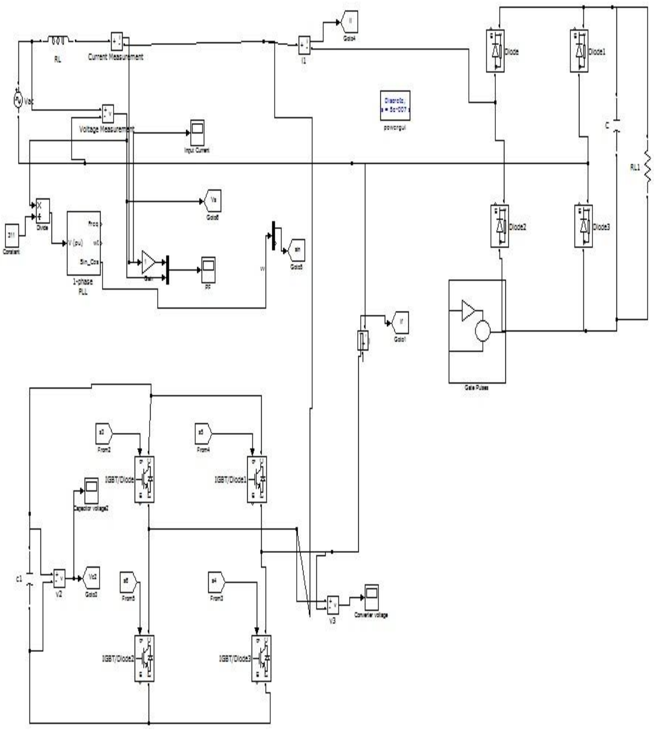

Fig .4 MATLAB/Simulink Model of Single Phase Circuit with 3-level STATCOM

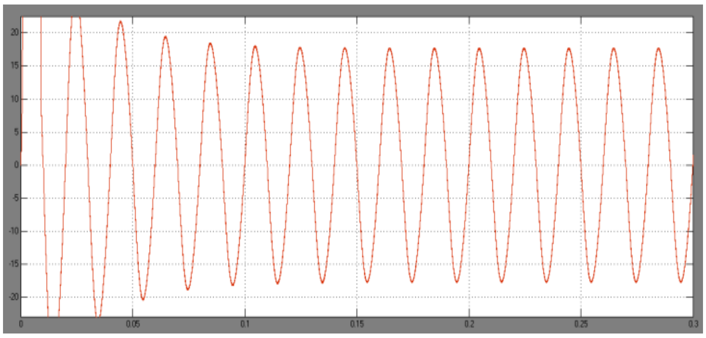

Fig .5 Grid Current Wave forms

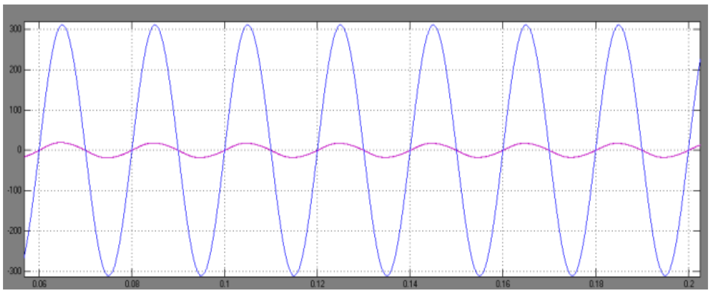

Fig .6 Wave forms showing Power Factor

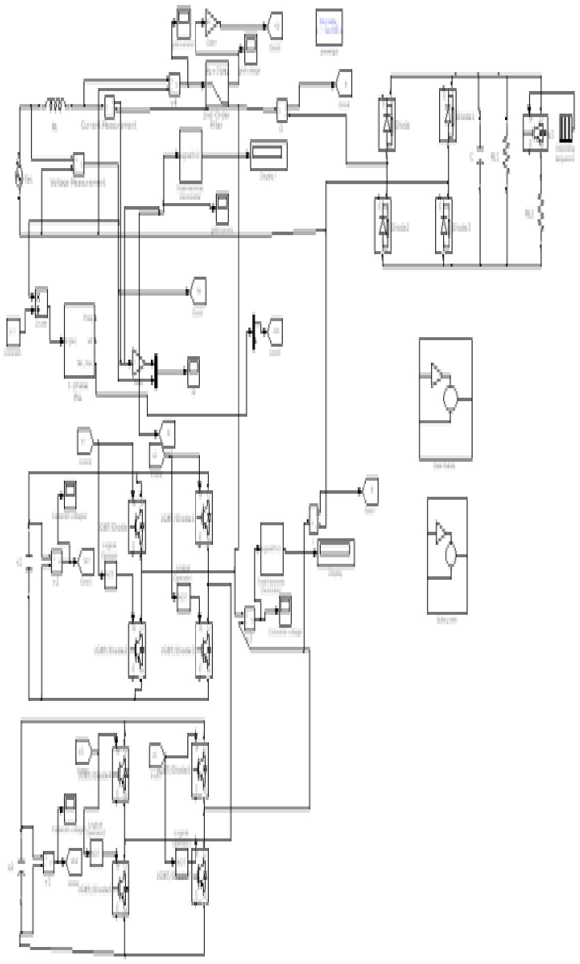

Fig.8: MATLAB/Simulink Model of 5 level circuit with STATCOM

Fig .9 shows the Grid voltage of the STATCOM circuit. Fig 10 shows the output waveforms of the unity power factor. It is clear that voltage and current are in phase and there is unity power factor because STATCOM is used.

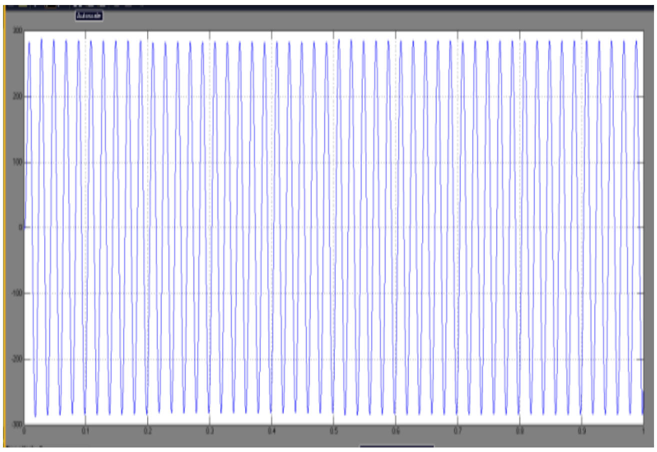

Fig.9: Grid Voltage

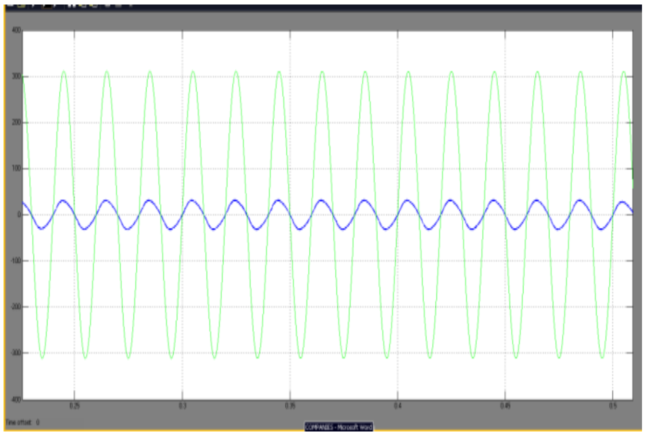

Fig.10: Waveforms Showing Unity Power Factor Representation

V. CONCLUSIONS

The simulations show that 3level &5level STATCOM can effectively work to mitigate voltage sag and maintain voltage in safe limits.A Power quality problem is an occurrence manifested as a nonstandard voltage, current or frequency that results in a failure and misoperation of end user equipment’s and loads. Industrial loads and critical commercial operations suffer from various types of outages and service interruptions which can cost significant financial losses and wasting of time. A new 3 Level & 5-Level Based Multilevel STATCOM controller on Goertzel sag detection and a new current control mode is proposed and simulated. The sag detection method is suitable for DSP implementation. It does not require extensive calculations such as in FFT nor is it prone to noise interference. The proposed current control method has also great superiority over conventional voltage control methods in terms of simplicity and harmonic spectrum. It is a fixed frequency approach and does not have the filtering and EMI problems as in the hysteresis method. The control method is also applied on a cascade multilevel inverter to make a multilevel STATCOM. Both the controllers are in single phase controller and can handle all single phase voltage sag disturbances. The simulations show that 3level &5level STATCOM can effectively work to mitigate voltage sag and maintain voltage in safe limits.

RFERENCES

[1] Naidoo. R, Pillay. P, “A New Method of Voltage Sag and Swell Detection” , IEEE Transactions on Power Delivery ,Volume 22, Issue 2, Page(s):1056 – 1063, April 2007.

[2] Chien-Hung Liu; Yuan-Yih Hsu; , "Design of a Self-Tuning PI Controller for a STATCOM Using Particle Swa Optimization," IEEE Transactions on Industrial Electronics, vol.57, no.2, pp.702- 715, Feb. 2010

[3] An Luo; Ci Tang; ZhikangShuai; Jie Tang; Xian Yong Xu; Dong Chen; , "Fuzzy-PI-Based Direct-Output-Voltage Control Strategy for the STATCOM Used in Utility Distribution Systems," IEEE

Transactions on Industrial Electronics, , vol.56, no.7, pp.2401- 2411, July 2009

[4] Ben-Sheng Chen; Yuan-Yih Hsu; , "A Minimal Harmonic Controlle for a STATCOM," IEEE Transactions on Industrial Electronics, vol.55, no.2, pp.655-664, Feb. 2008

[5]. L. H. Hansen, L. Helle, F. Blaabjerg, E. Ritchie, S. Munk-Nielsen, H. Binder, P.Srensen and B. Bak - Jensen "Conceptual Survey of Generators and Power Electronics for Wind Turbines ", Ris0 National Laboratory, Roskilde, Denmark, December 200l.

[6]. Z.Saad-Saoud, M.1.Lisboa, 1.B.Ekanayake, N. Jenkins & G.Strbac, Application of ST A TCOMs to wind farms, Proc. TEE Generation, Transmission & Distribution, Vo1.I45, No. 5, 1998, 511-516.

[10]. Leszek S. Czamecki:lnstantaneous Reactive Power p-q Theory and Power Properties of Three-Phase Systems' IEEE Trans on power delivery', vol. 21, no. I, Jan 2006.

[11]. K. Derradji Belloum, and A. Moussi, 'A Fixed Band Hysteresis Current Controller for Voltage Source AC Chopper' World Academy of Science, Engineering and Technology 45 2008.

[12]. Dalessandro, U. Drofenik, S. D. Round and 1. W. Kolar, 'A Novel Hysteresis Current Control for Three-Phase Three-Level PWM Rectifiers', Swiss Federal Institute of Technology (ETH) Zurich, Power Electronic Systems Laboratory.

[13]. D. Dragomir, N. Golovanov, P. Postolache, C. Toader, 'The connection to the grid of wind turbines.

