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SPWM Switching Strategy for Compensation of Unbalanced and Non Linear Load Effects in Three Phase Four Wire System Using D-Statcom

S. Srinivasa Rao* and Ch. Sai Babu**

Abstract : This paper deals with synchronous reference frame(SRF) theory based on sinusoidal-PWM (SPWM) switching control strategy for two level neutral clamped VSI, used in static compensator for distribution (D-STATCOM) for compensating the effects of unbalanced and nonlinear loads. Further, it introduces the filter currents and reactive power to non linear loads and making the source currents are purely sinusoidal with power factor of unity. In this paper validation of load compensation with dq0 current controller for the Proportional-Integral (PI) controller and PI plus harmonic component (HC) regulator is carried out using MATLAB/SIMULINK environment. Prominent reduction in Total harmonic distortion (THD) in source currents is obtained for (PI plus HC regulators)SPWM control strategy compared to PI regulator alone

Keywords : Distribution static compensator, SRF theory, voltage source inverter, Sinusoidal pulse width modulation control, PI regulator, HC regulator.

1. INTRODUCTION

The power quality problems are contemporarily dominant because of large usage of power electronic devices in distribution systems such as uninterrupted power supplies, adjustable speed drives etc. Flicker, harmonics, and voltage fluctuations are the most regular power quality requirement situations. Therefore for improvement of power quality, custom power devices are being used. Hingorani [1] in 1955 was the first one to explain the concept of custom power. To make source currents balanced ,sinusoidal, and in phase with the load voltages by injection of reactive and harmonic components of load component of load currents, one of the custom power devices used is Distribution static compensator(DSTATCOM) [2]-[5]. By using synchronous reference frame theory [2], for controlling algorithms used for the extraction of reference current components and generating gating pulses for switches, are key aspects which are to be banked on for DSTATCOM performance. Here, due of less complexity and more reliability in control and efficient compensation of neutral wire current [3], a neutral clamped three phase four wire voltage source Inverter configuration is selected as DSTATCOM. In order to realize constant switching frequency, for a three level power factor rectifier application, a proposition of hysteresis band modulation is exhibited, having input voltage and output dc voltage as a function of band amplitudes. In order to acquire constant switching frequency of operation, similar variable hysteresis band controller is to be bulletined [4]. On the other hand with this method, predetermined frequency switching is feasible, but extracting an exact constant frequency is left unaccomplished. Therefore, for producing inverter switching pulses at a constant

* Assistant Professor, Dept. of Electrical & Electronics Engg, GIT,GITAM University, Visakhapatnam, AP, India., Srinu722@gmail.com

** Professor, Dept. of Electrical & Electronics Eng., Jawaharlal Nehru Technological University Kakinada, Kakinada, AP, India, chs_eee@yahoo.co.in

frequency, SPWM switching strategy is proposed which in turn leads to the reduction of stress on VSI switches and also for making the design of inverter output filter easier.

In this paper, a three phase four wire neutral clamped VSI based DSTATCOM compensation performance is compared with DQ0 current controller (using Proportional plus Integral and Harmonic compensation regulators) along with sinusoidal pulse width modulation (SPWM) switching[5]. MATLAB/ SIMULINK is used for simulation of compensator and performance is analyzed. The measures of performance are source current total harmonic distortion is presented and the corresponding results are presented.

2. SYSTEM MODEL AND SYNCHRONOUS REFERENCE (*dq*0) FRAME CURRENT CONTROLLER

In this current work, in order to produce signals (u_d, u_q, u_0), the realization of current controller in synchronous reference (*dq*0) frame is carried out, which are more-over used to develop switching pulses for VSI as shown in Fig. 1. The produced reference filter current (i^*_{fd}, i^*_{fq} and i^*_{f0}) are fed as inputs to this dq0 current controller [5]. Conjointly, the measured actual filter currents (i_{fd}, i_{fq}, i_{f0}) which are to be controlled. The abc to *dq*0 modeling is required on the ac side of VSI (shown in Fig.1) after all, implementation of current controller is in *dq*0 frame. This is given in the following subdivisions:

(*i*) System dq0 Model

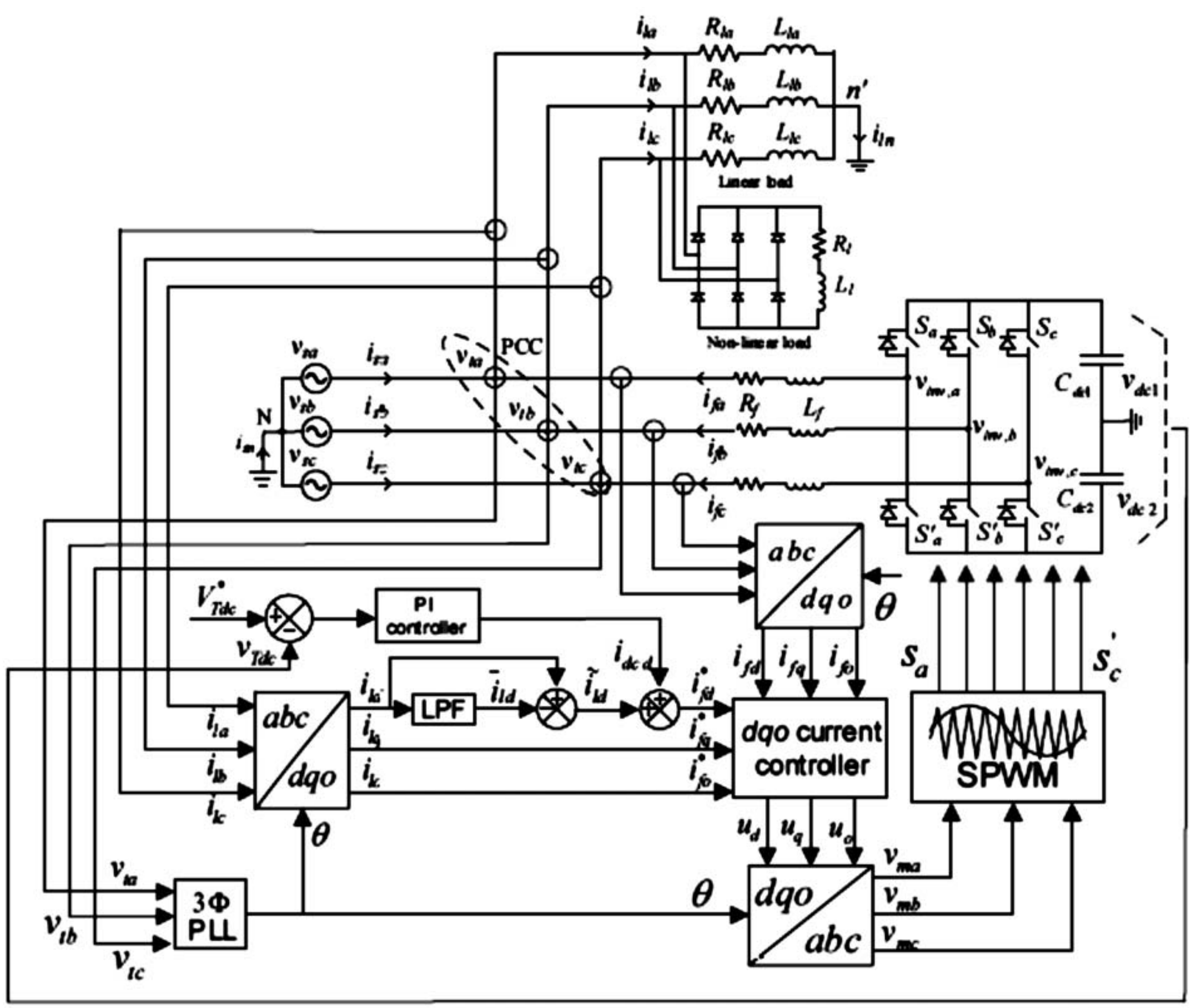

Fig. 1. Sinusoidal-PWM switching scheme using reference filter current generation.

The equations modeling the VSI ac side quantities shown in Fig.1.can be described in *a-b-c* fame as follows

$$v_{inv,\,abc} \;=\; R_f i_{f,\,abc} + L_f \frac{di_{f,\,abc}}{dt} + v_{t,\,abc} \tag{1}$$

Here, the output at different legs of VSI is represented by $v_{inv,\,abc}$ .The *dq*0 transformation equations are

$$v_{inv,\,d} \;=\; R_f i_{fd} + L_f \frac{di_{fd}}{dt} - \omega L_f i_{fq} + v_{td} \tag{2}$$

$$v_{inv,\,q} \;=\; R_f i_{fq} + L_f \frac{di_{fq}}{dt} + \omega L_f i_{fd} + v_{td} \tag{3}$$

$$v_{inv,\,0} \;=\; R_f i_{f0} + L_f \frac{di_{f0}}{dt} + v_{td} \tag{4}$$

The above mentioned variables $v_{in,\,d}$, $v_{inv,\,q}$, $v_{inv,\,0}$ are to be controlled to obtain required filter currents at PCC in *dq*0 frame. In the above equations (1) to (3) the terms ($-\omega L_{f\,ifq}$, $+\omega L_{f\,ifd}$) are called coupling terms. By applying Laplace transform to above equations we get $I_{fd}(s)$, $I_{fq}(s)$ and $I_{f0}(s)$ given in below following equations.

$$I_{fd}(s) \;=\; \frac{v_{inv,\,d} - v_{td}(s) + \omega L_f i_{fq}(s)}{R_f + sL_f} \tag{5}$$

$$I_{fq}(s) \;=\; \frac{v_{inv,\,q} - v_{tq}(s) + \omega L_f i_{fd}(s)}{R_f + sL_f} \tag{6}$$

$$I_{f0}(s) \;=\; \frac{v_{inv,\,0} - v_{t0}(s)}{R_f + sL_f} \tag{7}$$

In this paper sinusoidal-PWM control strategy is used for generation of switching signals Sa, Sb, Sc, Sn and S^*a, S^*b, S^*c, S^*n for top and bottom switches of VSI respectively as shown in Fig1, with modulating signals V_{ma} ,V_{mb} and V_{mc} and high frequency unit amplitude triangular carrier signals as inputs.

(*ii*) Neutral current compensation by 0 Axis controller

To a balanced and non-linear load, when the shunt active power filter is connected, the 0 axis current controller is not necessary. However, for DSTATCOM applications (*i.e*. for an unbalanced and non-linear load), the load neutral current is finite [6]. Therefore, in the current work along with '*d-q*' axis controllers 0 axis controller is necessary. Fig.1 depicts 0 axis controller with PI regulator in addition to feed forward voltage v_{t0}.

3. SIMULATION RESULTS

Validity of the three phase four wire DSTATCOM with proposed approach has been done using MATLAB Simulink model and the parameters considered for the simulation is given in the [5].The waveforms of the voltages and load currents are shown in Fig. 2. (*a*) and (*b*) respectively. Harmonic spectrum (%) of i_{la} up to 20th harmonic is shown in Fig.2. (*c*).

The total THDs are 14.68%, 16.75%, and 17.8% in phases *a*, *b*, and *c* load currents respectively. A DC link voltage of 550 V ($v_{dc1} = v_{dc2}$ = 550V) is considered in this work which comes across each capacitor and inductor of L_f of 15mH is used in this work. Now load effect compensation with PI regulator and PI plus HC regulators in *dq*0 controller is presented using simulations

PI regulator for compensating the load effects

The PI regulator is used as the current controller for the compensation of three phase source currents along with neutral current and injected filter currents using are shown in Fig.3. (*a*) and (*b*) respectively. The source currents are now balanced with unity power factor operation which has the total harmonic distortion is approximately below 4.7%, as shown in Fig. 3 (*e*). As 550 V is used as DC link voltages v_{dc1}, v_{dc2} and they are obtained using PI controller, as shown in Fig. 3. (*c*). The spectrum of compensated current is a is shown in Fig. 3.(*d*) and has an total THD of 4.57% from Fig.3.(e) indicates that there is inadequate performance with PI regulator, as the source current THDs are close to 5% limit of IEEE 519 standards.

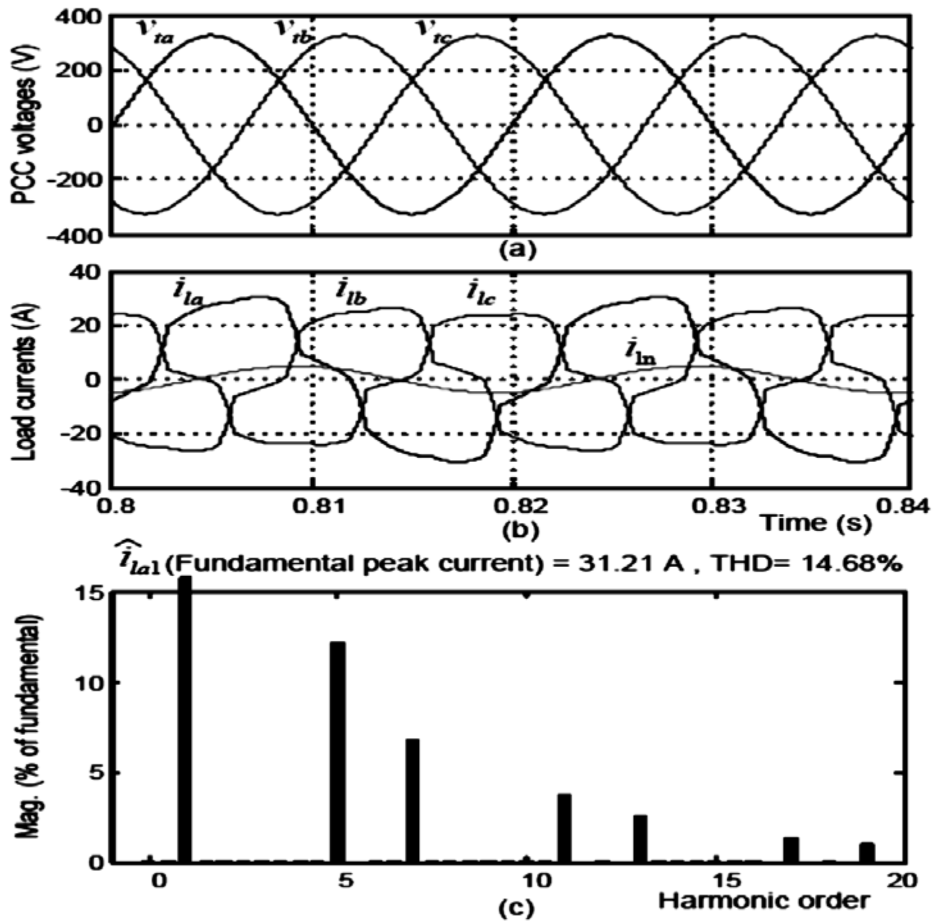

Fig. 2. Simulation results of PCC voltages, Load currents and Harmonic spectrum before compensation.

PI plus HC regulator based Compensator

Now PI plus HC regulator is used for the obtaining the better results. The voltages and compensated source currents used in the current controller are shown in Fig. 3(*a*) and (*b*) respectively.

Now THDs around 2.5% (given in Fig. 3 (*e*)) for the currents which are balanced and sinusoidal nature as compared to 4.6% with PI regulator alone. application of HC regulator minimize the error between the controlled signal and its reference, which results in better compensated source currents Source currents obtained after compensation without 0-axis controller in the *dq*0 current controller are shown in Fig. 3. These currents have large amplitude unbalance, as neutral current is not compensated. Hence, there is a need for 0-axis controller to compensate load neutral current and obtain balanced source currents. To investigate the performance of the D-STATCOM with PI and PI plus HC regulators switching control strategies simulations are performed on MATLAB platform. Detailed summary of load currents, source currents and their total harmonic distortion (THD) levels of various methods such as dqo controller with PI Regulator and Dqo controller (PI + HC regulator) with SPWM are shown in table I.

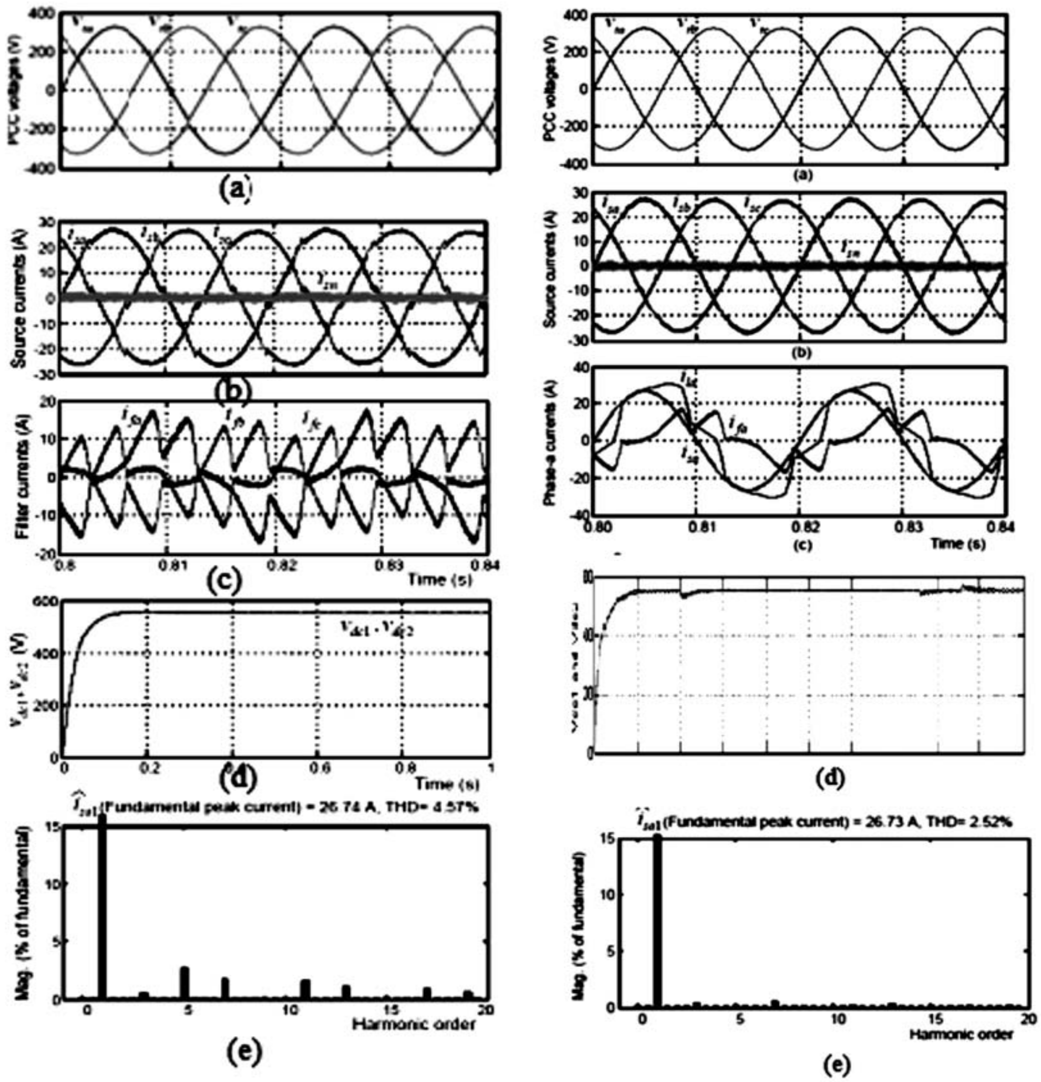

Fig 3. Simulation results obtained after compensation using PI regulator and PI plus HC regulator (*a*) PCC voltages (*b*) source currents (*c*) Injected filter currents (*d*) Dc link voltages (*e*) Harmonic spectrum of is a.

Table 1. THD% of the load and supply current.

Dqo Control Strategy	*%THD Load Currents Parameters without compensation*			*%THD Source Currents with Compensation Parameters*		
	i_{la}	i_{lb}	i_{lc}	i_{sa}	i_{sb}	i_{sc}
with PI Regulator	15.71	17.03	17.71	4.57	4.63	4.62
(PI + HC regulator) with SPWM	14.68	16.74	17.79	2.62	2.57	2.592

4. CONCULSION

It is observed that the proposed control strategies working effectively for D-STATCOM and compensate the ill effects of non linear unbalanced loads successfully. The power quality specified limits are meeting as THD obtained here is within the 5% prescribed by IEEE 519.The PI plus HC regulators along with SPWM switching control strategy has shown the better performance for harmonic cancellation due to balanced source and non-linear, unbalanced load conditions.

5. REFERENCES

1. H.Hingorani “Introducing custom power” IEEE spectrum,vol.32 no.6 June 1995 p41-48.
2. M.C. Benhabib, S. Saadate, “New control approach for four-wire active power filter based on the use of synchronous reference frame” Electric Power Systems Research, Volume 73, Issue 3, Pages 353 362, March 2005.
3. K. Karthikeyan and M. Kumar Mishra, “A novel load compensation algorithm under unbalanced and distorted supply voltages,” International Journal of Emerging Electric Power Systems, vol. 8, no. 5, 2007
4. B. Singh, K. AI-Haddad, A Chandra, “A review of active power filters for power quality improvement”, IEEE Trans. IND. Electron pp. 960- 971,1999
5. Nagesh Geddada, Mahesh K. Mishra and V. Manoj Kumar, “SRF Based Current Controller using PI and HC Regulators for DSTATCOM with SPWM Switching,” International Journal of Electrical Power and Energy Systems, Elsevier, Vol. 67,pp. 87-100, 2015.
6. O. Vodyakho and T. Kim, “Shunt active filter based on three-level inverter for three-phase four-wire systems,” IET Power Electronics, vol. 2, no. 3, pp. 216–226, May 2009.