PHOTOVOLTAIC SYSTEM INTERFACE WITH A DC-DC BOOST CONVERTER IN D-STATCOM FOR POWER QUALITY IMPROVEMENT

V. Kamatchi Kannan [1], N. Rengarajan [2]

[1]Assistant Professor, Department of Electrical and Electronics Engineering, K.S.R College of Engineering, K.S.R. Kalvi Nagar,Tiruchengode, India.
[2]Principal, K.S.R. College of Engineering, K.S.R. Kalvi Nagar, Tiruchengode, India
[1]kannan.ped@gmail.com

Abstract: *In this paper, a three-phase three-wire Distribution STATic COMpensator (DSTATCOM) which is fed by Photovoltaic (PV) array or battery operated DC-DC boost converter is proposed for power quality improvement in the distribution system. The proposed DSTATCOM consists of a three-leg Voltage Source Converter (VSC) with a DC bus capacitor. The PV array or battery operated boost converter is proposed to maintain the DC link voltage of the DC bus capacitor for continuous compensation for the load. The control of DSTATCOM is achieved by using IcosΦ controlling algorithm which is used to generate the reference currents. The switching of VSC will occur by comparing the source current with the reference current using Hysteresis based Pulse Width Modulation (PWM) current controller. The performance of the DSTATCOM is validated using MATLAB software with its simulink and Power System Blockset (PSB) toolboxes.*

Keywords: *Distribution Static Compensator, Photo Voltaic Array, Boost Converter, Voltage Source Converter, IcosΦ Controlling Algorithm.*

1. Introduction

Electricity is a convenient form of energy for lightning, heating, cooling and also produces motive power for various types of loads and power for a number of applications. Hence, the annual consumption of electricity has been increasing rapidly throughout the world. Thus, the increased usage of electricity in the modern day world challenges the economic co-operations of a power system with a greater focus on power quality [1-3]. Many researchers have focused on renewable energy source based power quality improvement in the power distribution system [4-5]. Power quality has caused a great concern to electric utilities with the growing use of sensitive and susceptive electronic and computing equipment such as personal computers, computer-aided design workstations, fax machines, uninterruptible power supplies, printers, etc. and other nonlinear loads such as fluorescent lighting, adjustable speed drives, heating and lighting control etc. Hence, in the deregulated power market, the power quality is becoming a major issue for the competing power distribution utilities. These nonlinear loads of switching converters and other power electronic devices create major power problem in the distribution system which tends to power quality problem. The various power electronic based devices called custom power devices used to mitigate the power quality problems have been proposed in the literature survey [6-7]. Among these, DSTATCOM is the most effective device [8-9].

The Distribution STATic COMpensator (DSTATCOM) is one of the shunt connected custom power device which injects current through the interface inductor at the Point of Common Coupling (PCC) so that the reactive power compensation, source current harmonic reduction and load current compensation can be achieved. The different topologies of DSTATCOM are reported in the literature such as a 4-leg VSC (Voltage Source Converter), three single phase VSC and 3-leg VSC with split capacitor DSTATCOM [10-11] etc. The proposed DSTATCOM consists of three-leg VSC with a dc bus capacitor. The operation of VSC is supported by a DC bus capacitor with proper dc voltage across it. For controlling DSTATCOM, and hence to generate the reference currents there are number of controllers reported in the literature survey such as instantaneous reactive power theory, adaptive neural network, synchronous frame theory and power balance theory [12-18]. All the above mentioned algorithms have slow response. Here, the IcosΦ controlling algorithm is proposed for generating the reference currents [19-20]. Since, after tracking the reference currents with the help of controller and by comparing it with source currents, the switching of VSC will occur and hence cancel out the disturbances caused by the nonlinear loads.
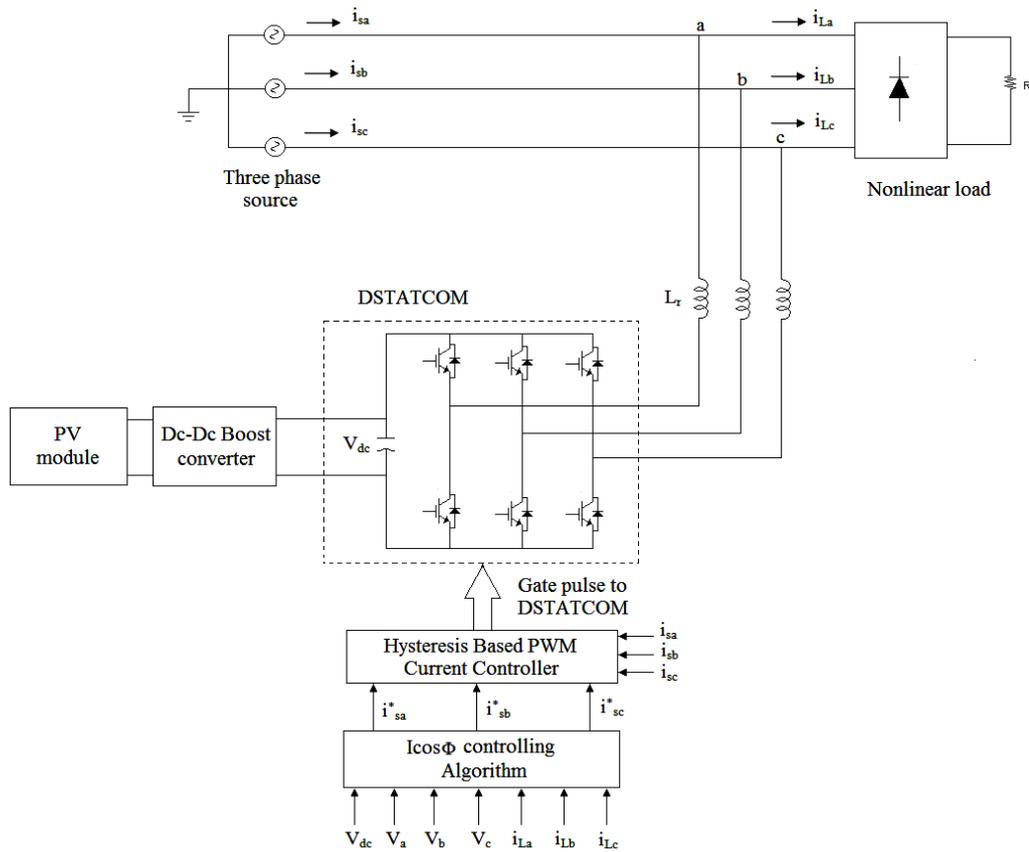
Figure 1. Circuit diagram of proposed DSTATCOM

In this paper, the Photo Voltaic (PV) module or battery with boost converter is connected to the dc bus capacitor of VSC which is used to provide the desired voltage across the dc bus for providing continuous reactive power compensation, source harmonic reduction and load compensation throughout the day. The proposed system is simulated under MATLAB environment using SIMULINK and simpowersystem tool boxes.

2. System Configuration

Figure 1 shows the basic circuit diagram of the three-phase three-wire system which is used to feed the nonlinear load continuously. The nature of the nonlinear load is to cause distortion in the current. After connecting the nonlinear load, suddenly there will be a distortion in the distribution system. In order to eliminate these distortions, the control of DSTATCOM is achieved by using the IcosΦ algorithm. The load currents, source voltages and the dc bus voltage are given as an input to the IcosΦ controlling algorithm. The controlling algorithm is used to generate the reference currents. Then the Hysteresis based PWM current controller compares the reference and source currents and gives a switching pulse to the DSTATCOM. The DSTATCOM consists of six Insulated Gate Bipolar Transistor's (IGBT) with antiparallel diode based three-leg VSC connected in shunt with the dc bus capacitor. The PV module with the DC-DC boost converter is connected with the dc bus capacitor, which is used to give a desired voltage across

the capacitor for continuous compensation. According to the gate pulse given, the switching of VSC will occur which injects a currents at the PCC through the interface inductor L_r.

3. Photovoltaic Module

Photovoltaic (PV) is one of the major power sources, becoming more affordable and reliable than utilities [21-22]. Photovoltaic is the method of converting solar radiation into direct current electricity which generates an electric power by using semiconductors that exhibit the photovoltaic effect. PV module is a connected assembly of photovoltaic cells. Hence, it will be connected in parallel to produce high current and in series to produce high voltage. Figure 2 shows the equivalent circuit of a PV cell. It consists of a current source in parallel with a diode which represents the nonlinear impedance of the pn junction and also a small series and a high parallel intrinsic resistance. The output current of the solar cell can be represented as,

$$I = I_{ph} - I_{sat}\left(e^{\frac{q(V+IR_S)}{AKT}} - 1\right) - \left(\frac{V+IR_S}{R_p}\right) \quad (1)$$

where,

I = Output current of solar cell
I_{ph} = Photocurrent
I_{sat} = Saturation current of the diode (10^{-4}A)

q = Electron charge (1.6×10^{-19} C)
V = Voltage on the load
R_s = Series intrinsic resistance
R_p = Parallel intrinsic resistance
k = Boltzman's constant (1.38×10^{-23} J/K)
T = Cell temperature (K)
A = Ideality factor
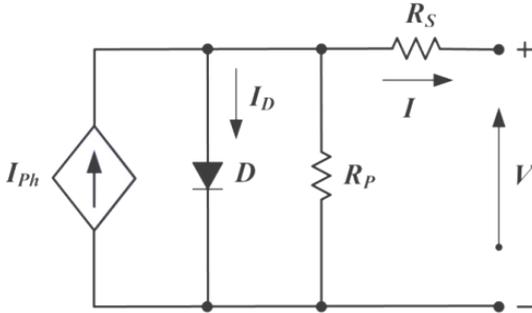
Figure 2. Equivalent circuit of a PV cell

To model the PV module in MATLAB-SIMULINK, the parameters are obtained from SHANSHAN ULICA UL-175D photovoltaic module. The solar irradiance (G) and temperature (T) were taken as standard test conditions which are 1000 Watt/m^2 and 25^{0}C respectively. The parameters to model the PV module is shown in Table 1.

Table 1. Parameters of Solar Panel

Parameters	Typical Value
Maximum Power (P_{max})	175 W
Voltage at Pmax (V_{mp})	35 V
Current at Pmax (I_{mp})	4.86 A
Short circuit current (I_{sc})	5.2 A
Open-circuit voltage (V_{oc})	43.6 V
Maximum System Voltage	1000 V
Temp. Co-efficient of (I_{sc})	0.03% / °C
Temp. Co-efficient of (V_{oc})	-0.34% / °C

The proposed DSTATCOM has three operating modes. They are day time excess power mode, day time mode, night time mode. In day time excess power mode, the voltage from the PV panel is used to charge the battery as well as it also passes through the boost converter to maintain the desired voltage across the dc bus capacitor for continuous compensation to the load. In day time mode, the battery is not charged and the PV output voltage is equal to the requirement of the boost converter input to match the dc link voltage of the three-leg VSC. In night time mode, the stored energy in the battery will be passed through the boost converter to maintain the dc bus capacitor voltage.

4. Control of DC Capacitor Voltage with Boost Converter

Boost converter also called as high efficiency step-up converter which has an output DC voltage greater than its input DC voltage. It consists of two semiconductor switches and one storage element [23-24]. Figure 3 shows the circuit diagram of a boost converter. When the switch is closed, the inductor gets charged by the PV or battery and stores the energy. The diode blocks the current flowing, so that the load current remains constant which is being supplied due to the discharging of the capacitor. When the switch is open the diode conducts and the energy stored in the inductor discharges and charges the capacitor. Therefore, the load current remains constant throughout the operation.
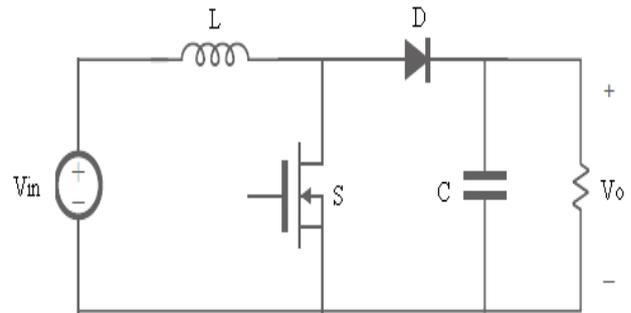
Figure 3. Circuit diagram of a boost converter

The output voltage of the boost converter can be written as,

$$V_0 = V_i \left(\frac{1}{1-D}\right) \tag{2}$$

where,

V_i, V_o - Input Voltage and Output Voltage
D - Duty Cycle, $D = \frac{T_{on}}{T_{on+}T_{off}}$
T_{on} - On time
T_{off} - Off time

The boost converter which is used to maintain the constant output voltage for all the conditions of temperature and variations in solar irradiance. The input to the boost converter is 35V and the boosted output voltage will be 670V. The switching frequency is chosen to 25 KHz. The inductor and capacitor used in the boost converter is 0.0191 mH and 7000 μF.
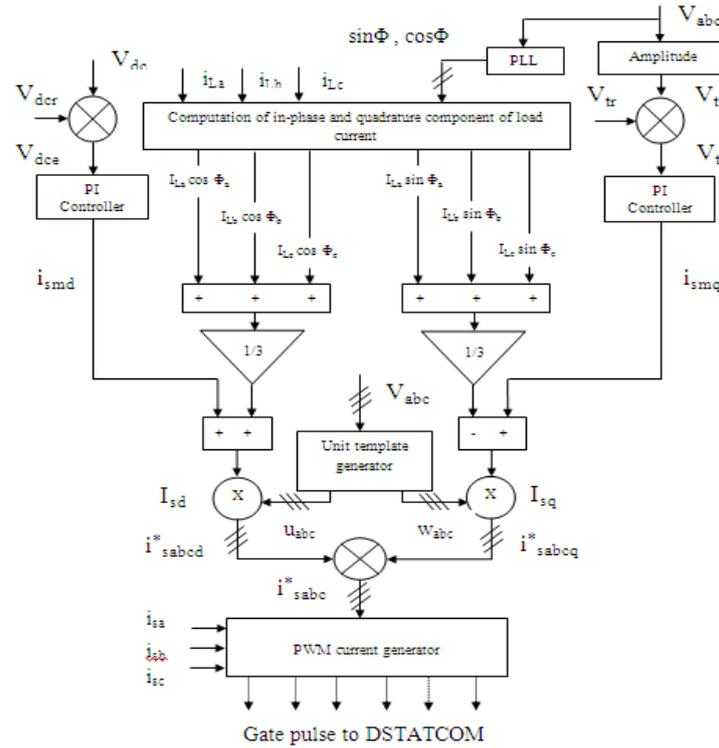
Figure 4. Block diagram of IcosΦ controlling algorithm

5. Proposed ICosΦ Algorithm

The block diagram of IcosΦ controlling algorithm is shown in Figure 4. It is used to extract the reference currents [25-26]. The IcosΦ algorithm is used for controlling the DSTATCOM for reactive power compensation and source current harmonic reduction. The source currents $(i_{sa}, i_{sb}$ and $i_{sc})$, the load currents $(i_{La}, i_{Lb}$ and $i_{Lc})$, the ac terminal voltages (v_a, v_b, v_c) and the dc bus voltage (V_{dc}) are sensed. The IcosΦ controlling algorithm is used to generate only the active component of the load currents i.e. ICcosΦ (where I = amplitude of fundamental load current and Φ = displacement angle of load current). Hence by combining the in-phase and quadrature component, the reference current can be generated.

The three-phase harmonic-rich load currents can be expressed as,

$$I_{La} = \sum I_{Lan} \, sin(n\omega t - \Phi_{an}) \, (for \, n = 0,1 \, to \, \infty) \quad (3)$$

$$I_{Lb} = \sum I_{Lbn} \, sin(n\omega t - \Phi_{bn}) \, (for \, n = 0,1 \, to \, \infty) \quad (4)$$

$$I_{Lc} = \sum I_{Lcn} \, sin(n\omega t - \Phi_{cn}) \, (for \, n = 0,1 \, to \, \infty) \quad (5)$$

where,

$I_{L(abc)n}$ = amplitude of nth harmonic current in a, b and c phases
$\Phi_{(abc) n}$ = phase angle of nth harmonic current in a, b and c phases
$I_{L (abc)}$ = load current in a, b and c phases

5.1. In-Phase Component of Reference Source current

The amplitude of active power component of fundamental load currents are given as,

$$I_{Lap1} = |I_{La1}| \, cos \, \Phi_{a1} = |Real \, (I_{La1})| \quad (6)$$

$$I_{Lbp1} = |I_{Lb1}| \, cos \, \Phi_{b1} = |Real \, (I_{Lb1})| \quad (7)$$

$$I_{Lcp1} = |I_{Lc1}| \, cos \, \Phi_{c1} = |Real \, (I_{Lc1})| \quad (8)$$

Hence, the amplitude of active power component of fundamental load current is extracted at zero crossing of the unit template in-phase with PCC voltages.
For a balanced source current, the magnitude of active component of reference source currents can be given as,

$$I_{sd} = \left\{ \frac{|I_{La1}| \, cos \, \Phi_{a1} + |I_{Lb1}| \, cos \, \Phi_{b1} + |I_{Lc1}| \, cos \, \Phi_{c1}}{3} \right\} + I_{smd} \quad (9)$$

where,
I_{smd} = output of the dc bus voltage PI controller of the VSC

The error in dc bus voltage of VSC at n^{th} sampling instant is given as,

$$V_{dce(n)} = V_{dcr(n)} - V_{dc(n)} \quad (10)$$

$V_{dcr (n)}$ = reference dc bus voltage
$V_{dc (n)}$ = dc link voltage of the VSC

The output of the PI controller for maintaining dc bus voltage of the VSC at the nth sampling instant is given as,

$$I_{smd(n)} = I_{smd(n-1)} + K_{pd}\{V_{dce(n)} - V_{dce(n-1)}\} + K_{id} \quad (11)$$

where,

K_{pd} and K_{id} = Proportional and integral gain constants of the dc bus voltage

$V_{dce\,(n)}$ and $V_{dce\,(n-1)}$ = Voltage errors in n^{th} and $(n-1)^{th}$ instant

The amplitude of the three-phase voltage is given as,

$$V_t = \left\{ \left(\frac{2}{3}\right)(v_a^2 + v_b^2 + v_c^2) \right\}^{\frac{1}{2}} \quad (12)$$

The unit vector in phase with $(v_a, v_b$ and $v_c)$ are derived as,

$$u_a = \frac{v_a}{V_t} \; ; \; u_b = \frac{v_b}{V_t} \; ; \; u_c = \frac{v_c}{V_t} \quad (13)$$

In-phase component of reference source currents are estimated as,

$$i_{sad}^* = I_{sd} u_a \; ; \; i_{sbd}^* = I_{sd} u_b \; ; \; i_{scd}^* = I_{sd} u_c \quad (14)$$

5.2. Quadrature Component of Reference Source Currents

The unit vectors $(w_a, w_b$ and $w_c)$ in quadrature with $(v_a, v_b$ and $v_c)$ can be calculated using the in-phase unit vectors $(u_a, u_b$ and $u_c)$ given as,

$$w_a = -\frac{u_b}{\sqrt{3}} + \frac{u_c}{\sqrt{3}} \quad (15)$$

$$w_b = \frac{\sqrt{3}u_a}{2} + \frac{(u_b - u_c)}{2\sqrt{3}} \quad (16)$$

$$w_c = -\frac{\sqrt{3}u_a}{2} + \frac{(u_b - u_c)}{2\sqrt{3}} \quad (17)$$

The amplitudes of reactive power components of fundamental load currents are given as,

$$I_{Laq1} = |I_{La1}| \sin \Phi_{a1} = |Imag(I_{La1})| \quad (18)$$

$$I_{Lbq1} = |I_{Lb1}| \sin \Phi_{b1} = |Imag(I_{Lb1})| \quad (19)$$

$$I_{Lcq1} = |I_{Lc1}| \sin \Phi_{c1} = |Imag(I_{Lc1})| \quad (20)$$

Thus, the amplitude of reactive power component of fundamental load current is extracted at zero crossing of the unit template quadrature phase of PCC voltages. For balanced source currents, the magnitude of reactive component of reference source currents can be given as,

$$I_{sq} = \left\{ -\frac{|I_{La1}| \sin \Phi_{a1} + |I_{Lb1}| \sin \Phi_{b1} + |I_{Lc1}| \sin \Phi_{c1}}{3} \right\} + I_{smq} \quad (21)$$

where,

I_{smq} = output of the ac terminal voltage PI controller of the VSC

The error in amplitude of ac terminal voltage at n^{th} sampling instant is given as,

$$V_{te(n)} = V_{tr(n)} - V_{t(n)} \quad (22)$$

where,

$V_{tr\,(n)}$ = reference ac terminal voltage

$V_{t\,(n)}$ = three-phase ac terminal voltage

The output of the PI controller for maintaining the amplitude of ac terminal voltage at the nth sampling instant is given as,

$$I_{smq(n)} = I_{smq(n-1)} + K_{pa}\{V_{te(n)} - V_{te(n-1)}\} + K_{ia}V_{te(n)} \quad (23)$$

where,

K_{pa} and K_{ia} = proportional and integral gain constants of the ac terminal voltage

$V_{te(n)}$ and $V_{te(n-1)}$ = voltage errors in n^{th} and $(n-1)^{th}$ instant

The quadrature component of reference source currents are estimated as,

$$i_{saq}^* = I_{sq} w_a \; ; \; i_{sbq}^* = I_{sq} w_b \; ; \; i_{scq}^* = I_{sq} w_c \quad (24)$$

5.3. Reference Source Currents

The reference source currents can be extracted by the sum of in-phase and quadrature components of the reference source currents and it is given as,

$$i_{sa}^* = i_{saq}^* + i_{sad}^* \quad (25)$$

$$i_{sb}^* = i_{sbq}^* + i_{sbd}^* \quad (26)$$

$$i_{sc}^* = i_{scq}^* + i_{scd}^* \quad (27)$$

Thus, these reference source currents $(i_{sa}^*, i_{sb}^*$ and $i_{sc}^*)$ are compared with the source currents $(i_{sa}, i_{sb}$ and $i_{sc})$ in hysteresis based PWM current controller for generating gate signals for IGBT switches of VSC based DSTATCOM.

6. Simulation Results and Discussion

The analysis of PV or battery interfaced to boost converter operated DSTATCOM for a three-phase three-wire system has been done using MATLAB software using SIMULINK and Power System Blockset (PSB) toolboxes and hence the performance has been shown. The source current without compensation and injected current waveform is shown in Figure 5. The source current waveform is shown in Figure 6.
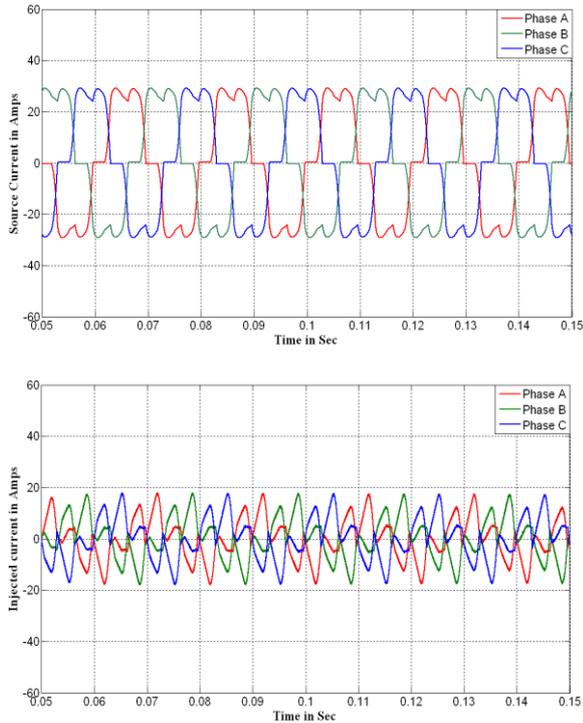
Figure 5. Source current without compensation and Injected current waveform with IcosΦ controlling algorithm
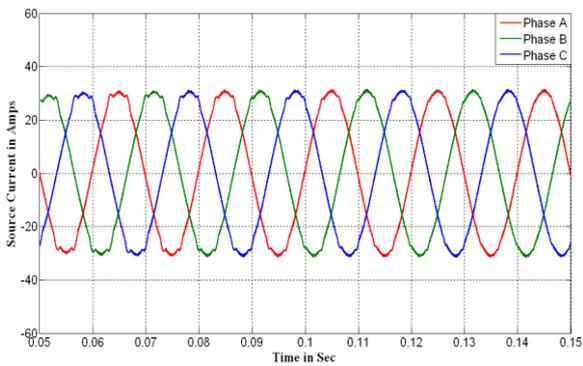
Figure 6. Source current waveform with IcosΦ controlling algorithm
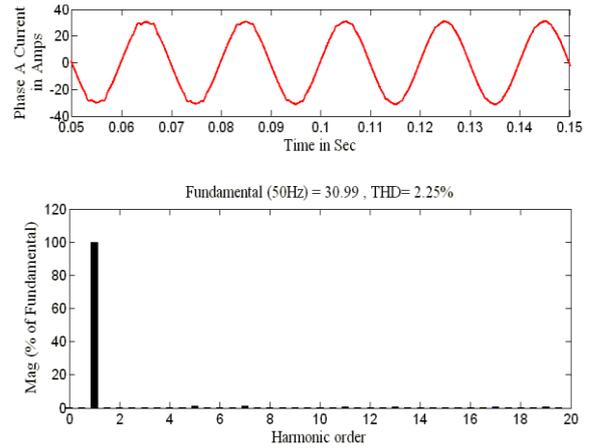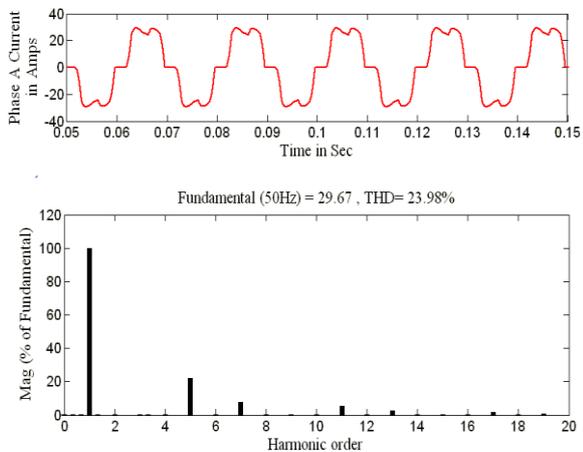
Figure 7. Phase A Current harmonics and its THD waveform for without and with controlling algorithm
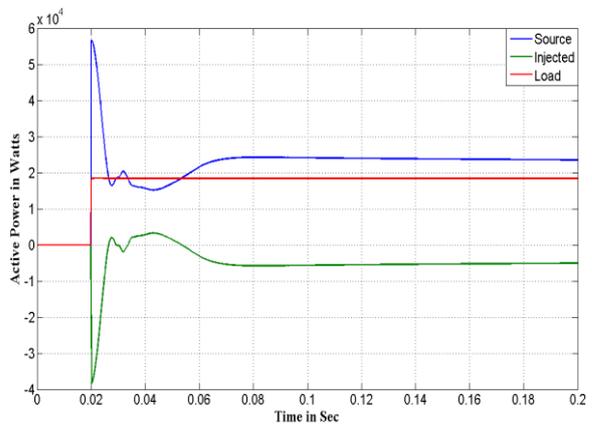
Figure 8. Active Power Waveforms
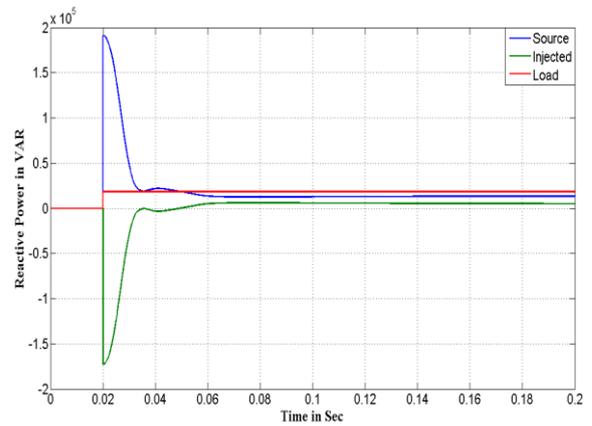
Figure 9. Reactive Power Waveforms

The Phase A current harmonics and its THD waveform for without and with IcosΦ controller is shown in Figure 7. The active power waveform for IcosΦ controller is shown in Figure 8. The reactive power waveform for IcosΦ controller is shown in Figure 9. The DC bus capacitor voltage waveform is shown in Figure 10.
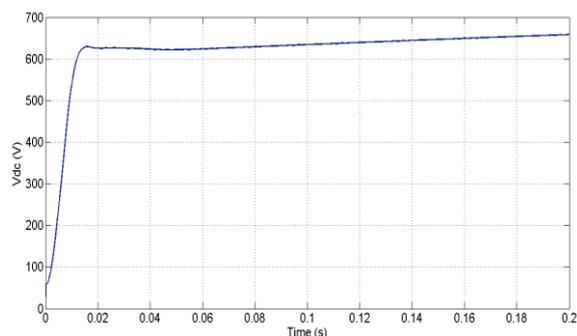
Figure 10. DC bus capacitor voltage

Table 2. Comparison of THD values of DSTATCOM before and after compensation

Phases	Before compensation	After compensation
Phase A	23.98	2.25
Phase B	23.98	2.21
Phase C	23.98	2.25

7. Conclusion

The simulation of the Photovoltaic (PV) array or battery operated DC-DC boost converter fed three-leg VSC based DSTATCOM has been carried out for reactive power compensation, source harmonic reduction and load current compensation in the distribution system. The DSTATCOM was controlled by IcosΦ algorithm. The boost converter is used to step up the voltage so as to match the dc link voltage of the three-leg VSC based DSTATCOM for continuous compensation. The comparison of THD values of DSTATCOM before and after compensation is shown in Table 2. The THD value is below the permissible limit of 5% (IEEE-519-1992). The MATLAB software with its simulink and Power System Blockset (PSB) toolboxes has been used to validate the proposed system.

APPENDIX

AC line voltage: 415 V, 50Hz
Non-linear load: Three phase bridge rectifier with R = 20Ω
AC inductor: 2.5 mH
DC bus capacitance of DSTATCOM, C_{dc}: 7000 μF
DC bus voltage of DSTATCOM: 670 V
DC voltage PI controller: K_{pd}=0.1, K_{id}=1
PCC voltage PI controller: K_{pq} =0.1, K_{iq} =1

8. References

[1] Angelo Baggini, "Handbook on power quality", New Jersey USA, John Wiley & Sons, 2008.
[2] A. Moreno-Munoz, "Power Quality: Mitigation Technologies in a Distributed Environment", London, Springer-Verlag, 2007.
[3] E. F. Fuchs and M. A. S. Mausoum, "Power Quality in Power Systems and Electrical Machines", London, U.K., Elsevier, 2008.
[4] Mukhtiar Singh, Vinod Khadkikar, Ambrish Chandra and Rajiv K. Varma, "Grid Interconnection of Renewable Energy Sources at the Distribution Level with Power Quality Improvement Features", *IEEE Transactions on Power Delivery*, vol. 26, no. 1, pp. 307-315, 2011.
[5] J. P. Pinto, R. Pregitzer, L. F. C. Monteiro and J. L. Afonso, "3-Phase 4-Wire Shunt Active Filter with Renewable Energy Interface", *Presented at the Conference of IEEE Renewable Energy & Power Quality*, Seville, Spain 2007.
[6] A. Ghosh and G. Ledwich, "Power Quality Enhancement Using Custom Power Devices", Norwell, USA, Kluwer, 2002.
[7] N. G. Hingorani, "Introducing Custom Power", *IEEE Spectrum*, vol. 32, no. 6, pp. 41-48, 1995.
[8] D. Masand, S. Jain and G. Agnihotri, "Control Strategies for Distribution Static Compensator for Power Quality Improvement", *IETE Journal of Research*, vol. 54, no. 6, pp. 421-428, 2008.
[9] T. J. E. Miller, "Reactive Power Control in Electric Systems", Toronto, Ontario, Canada, Wiley, 1982.
[10] H. Akagi, E. H. Watanabe and M. Aredes, "Instantaneous Power Theory and Application to Power Conditioning", USA, John Wiley & Sons, 2007.
[11] H. L. Jou, K. D. Wu, C. H. Li, and M. S. Huang, "Noval Power Converter Topology for Three Phase Four Wire Hybrid Power Filter", *IET Power Electronics*, vol. 1, no. 1, pp. 164-173, 2008.
[12] H. Akagi, Y. Kanazawa and A. Nabae, "Generalized theory of the instantaneous reactive power in three-phase circuits", *Electrical Engineering in Japan*, vol. 103, no. 4, pp. 58-66, 1983.
[13] M. I. Milanes, E. R. Cadaval and F. B. Gonzalez, "Comparison of control strategies for shunt active power filters in three-phase four-wire systems", *IEEE Transaction on Power Electronics*, vol. 22, no. 1, pp. 229-236, 2007.
[14] T. Furuhashi, S. Okuma and Y. Uchikawa, "A study on the theory of instantaneous reactive power", *IEEE Transactions on Industrial Electronics*, vol. 37, no. 1, pp. 86–90, 1990.
[15] H. Kim, F. Blaabjerg, B. B. Jensen and J. Choi, "Instantaneous power compensation in three-phase systems by using p-q-r theory", *IEEE Transactions on Power Electronics*, vol. 17, no. 5, pp. 701-709, 2002.
[16] A. Chandra, B. Singh, B. N. Singh and K. Al-Haddad, "An improved control algorithm of shunt active filter for voltage regulation, harmonic elimination, power-factor correction, and balancing of nonlinear loads", *IEEE Transactions on Power Electronics*, vol. 15, no. 3, pp. 495-507, 2000.
[17] B. Widrow and M. A. Lehr, "30 years of adaptive neural networks: Perceptron, Madaline, and back propagation", *Proceedings of IEEE*, vol. 78, no. 9, pp. 1415-1442, 1990.
[18] B. N. Singh, "Design and Digital Implementation of Active Filter with Power Balance Theory", *IEE Proceedings on Electric Power Applications*, vol. 152, no. 5, pp. 1149-1160, 2005.
[19] Bhim Singh and Sunil Kumar, "Control of DSTATCOM using IcosΦ Algorithm", *IEEE Conference in Industrial Electronics IECON'09*, pp. 322-327, 2009.
[20] G. Bhuvaneswari and M. G. Nair, "Design, Simulation, and Analog Circuit Implementation of a Three-Phase Shunt Active Filter Using the IcosΦ Algorithm", *IEEE Transactions on Power Delivery*, vol. 23, no. 1, pp. 1222-1235, 2008.

1604

[21] H. Altas and A. M. Sharaf, "A Photovoltaic Array Simulation Model for MATLAB Simulink GUI Environment", *Proceedings of ICCEP '07*, pp. 341-345, 2007.

[22] M. Park and In-K. Yu, "A Novel Real-Time Simulation Technique of Photovoltaic Generation Systems using RTDS", *IEEE Transaction on Energy Conversion*, vol. 19, no. 1, 164-169, 2004.

[23] M. Elshaer, A. Mohamed and O. Mohammed, "Smart optimal control of DC-DC Boost converter in PV systems", *Transmission and Distribution Conference and Exposition: Latin America (T&D-LA), 2010 IEEE/PES*, pp. 403-410, 2010.

[24] Wei Jiang, Yu-fei Zhou and Jun-ning Chen, "Modeling and Simulation of Boost Converter in CCM and DCM," *IEEE Conference on Power Electronics and Intelligent Transportation System (PEITS)*, pp. 288-291, 2009.

[25] G. Bhuvaneswari and M. G. Nair, "Design, Simulation, and Analog Circuit Implementation of a Three-Phase Shunt Active Filter Using the IcosΦ Algorithm", *IEEE Transactions on Power Delivery*, vol. 23, no. 2, pp. 1222-1235, 2008.

[26] M. G. Nair and G. Bhuvaneswari, "A novel shunt active filter algorithm: simulation and analog circuit-based implementation", *International Journal of Energy Technology and Policy*, vol. 4, pp. 118-125, 2006.

V. Kamatchi Kannan received the B.E. and M.E degrees, from Bharathiyar Univ. and Anna Univ. in 2002 and 2007 respectively. After working as a Lecturer (from 2007) in the Dept. of Electrical and Electronics Engineering in K.S.R. College of Engineering, Tiruchengode, India - affiliated to Anna Univ. and he has been working as a Sr. Assistant Professor in the Dept. of Electrical and Electronics Engineering at K.S.R. College of Engineering, Tiruchengode, India - affiliated to Anna Univ. since July 2010. His area of interest includes photovoltaic array, Converters and FACTS Controllers. He is a member of ISTE and IEEE.

Dr. N. Rengarajan received the B.Sc., B.Tech., M.E. and Ph.D. degrees, from Madras University, Anna University Bharathidhasan University and Bharathidhasan University in 1980, 1983, 1993 and 2004 respectively. After working as a Lecturer (from 1988) in the Dept. of Electronics and Communication Engineering in Mookambigai College of Engineering and as an Sr.Lecturer (from 1991) in the Dept. of Electrical and Electronics Engineering in National Institute of Technology, Trichy and in Nizwa College of Technology, Sultanate of Oman and as a Professor and Principal (from 2005) at Vivekanandha Institute of Engineering and Technology for women and at Sethu Insttiute of Technolgy. He has been working as a Principal at K.S.R. College of Engineering, Anna University since 2008. His research interest includes Power System and Control and Soft Computing Techniques. He is a member of ISTE and IEEE.