International Journal of Innovative Technology and Exploring Engineering (IJITEE)
ISSN: 2278-3075 (Online), Volume-8 Issue-5, March 2019

Control strategies for DSTATCOM – A Comprehensive Review

Ravilla Madhusudan, PotlaLinga Reddy

Abstract: ***The central perceptive predicament in the power system is a power quality issue. The majority of the power system contamination is due to the presence of non-linear quality of loads. An increase in the usage of the non-linear type of loads leads to rising in power quality issues and becoming a severe crisis with time. To trounce the power quality issues, DSTATCOM has expanded its management because of its outstanding recital in mitigating harmonics and reactive power issues. A feat of DSTATCOM depends on control strategy. The paper presents an extensive review of control strategies for DSTATCOM in the distribution system. The reference current signal generated from the control strategy is an essential step in producing gate pulses to DSTATCOM in the distribution system. Simulation models of different control strategiesintegratedinto DSTATCOM are simulated using MATLAB/SIMULINK software.***

Index Terms**:** ***Power quality, Harmonics, DSTATCOM, Voltage Source Inverter, Active power filter.***

I. INTRODUCTION

Power quality means different for the differentunit in the power system. To the power supplier, power quality defines the measure of power provided to the client concerning his power with outstanding reliability and regulation of voltage and frequency.To the consumer, the statement of quality in power [1] focus on their ability to utilize the supplied power with precise signal magnitude and shape.

Power quality issues are not only associated with system efficiency and environmental issues, but also to uninterrupted supply and quality of power in the system. Some power quality problems are of short duration issues, and some can be long duration power quality issues. If the power quality issue persists for less than one minute, it is termed as a short duration power quality issue, and if the problem persists for more than one minute, the power quality issue is termed to be a long duration. Even a short-term power quality problem can degrade the system performance inducing unwanted operation of the power system.

The worsening of voltage or current in the power distribution system is due to the extensive usage of non-linear equipment and power electronic converters. Power electronic converters like rectifiers, thyristor converters are a non-linear type of loads and produce a significant disturbance in AC mains. Modern electrical systems, due to the widespreadof power conversion units and power electronics equipment's, cause an increasing harmonic disturbance [2-3] in the AC main currents. These harmonic currents causecontrarypropertiesin power systems such as overheating, capacitor blowing, motor vibration, excessive neutral currents, resonances with the grid and low power factor. As a result, an effective harmonic reduction of the system has become essential both to the utilities and to the users [1].

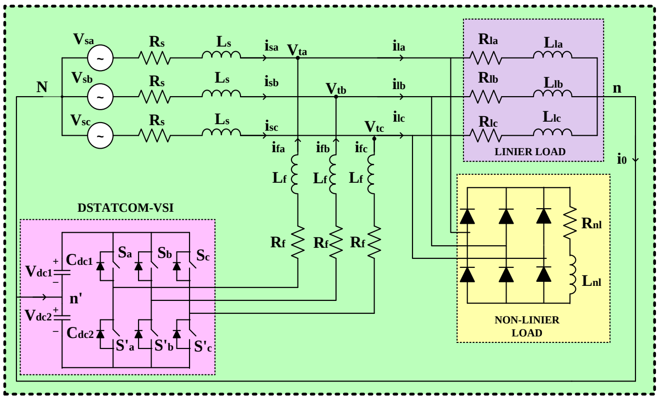

Fig.1: DSTATCOM in the distribution system

The solution over passive filters for compensating the harmonic distortion and unbalance is the FACTS based DSTATCOM. The DSTATCOM is a VSI an inverter that is connected at the common point of coupling to produce harmonic components which conceal the harmonic components from a group of nonlinear loads to ensure that the resulting total current drawn from the main incoming supply is sinusoidal [2]. DSTATCOM [4] in the distribution systemis shown in figure 1. It is mainly required to riddle the harmonized switching components generated by a shunt-VSI topology. To attain its compensation target, the shunt-VSI administer the currents at PCC for proper harmonic eradication, unbalancing the load current and reactive power of a real power flow path to aid the series-integrated VSI function and also sustain the average constant voltage across the DC storage unit. The shunt-VSI [5-7] device is always controlled [8-9] by current controlled objective. The respective switches in VSI topology are conducted or non-conducted at specific switching sequences.

Manuscript published on 30 March 2019.
***Correspondence Author(s)**
Ravilla Madhusudan, Department of Electrical and Electronic Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India – 522502, and Assistant Professor in Department of Electrical and Electronic Engineering, Sir C R Reddy College of Engineering, Eluru, Andhra Pradesh, India-534007.
Potla Linga Reddy, Professor, Department of Electrical and Electronic Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, Guntur, Andhra Pradesh, India – 522502.

By tracking the pre-defined current administered by shunt-VSI APF with the help of the hysteresis band concerning the compensation scheme [5].

The paper demonstrates a comprehensive review of control strategies for DSTATCOM in the distribution system. The reference current signal generated from the control strategy is a central step in producing gate pulses to DSTATCOM in the distribution system. Simulation models of different control strategies integrated to DSTATCOM are simulated using MATLAB/SIMULINK software.

II. CONTROL STRATEGIES FOR DSTATCOM

A. SRF Theory for DSTATCOM to Compensate Harmonics

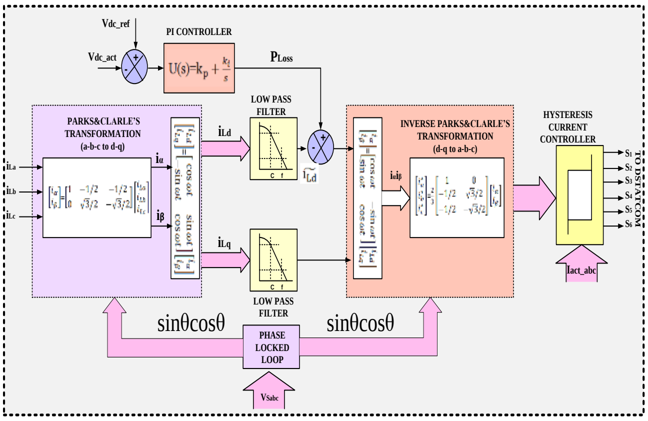

Fig.2: SRF theory for DSTATCOM

The direct $(d-axis)$ and quadrature $(q-axis)$ components are positioned based on an angle$(\theta)$with respect tothe utilizing the $\alpha-\beta$ axis in SRF theory. Generally, the Clarke's and Park's Transformation process are utilized to pertain the decouple action of reactive & active power components. The pertained equations (1) and (2) are illustrated by the Clarke's & Park's transformation process which apply to certain phase sequences.

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \quad (1)$$

$$\begin{bmatrix} i_{Ld} \\ i_{Lq} \end{bmatrix} = \begin{bmatrix} \cos\omega t & \sin\omega t \\ -\sin\omega t & \cos\omega t \end{bmatrix}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

(2)

The respective load currents on the $d-q$ frame are;

$$\begin{bmatrix} i_{Ld} \\ i_{Lq} \end{bmatrix} = \begin{bmatrix} \overline{i_{Ld}} + \widetilde{i_{Ld}} \\ \overline{i_{Lq}} + \widetilde{i_{Lq}} \end{bmatrix}$$

(3)

Where, $\overline{i_{Ld}}$,$\overline{i_{Lq}}$ represents the DC components of the load current on the $d-q$frame and $\widetilde{i_{Ld}}$,$\widetilde{i_{Lq}}$represents the AC components of the load current on the $d-q$ frame. From the Eqn. (3), it should be illustrated the $d-q$ load current components comprising of dual-terms. The LPF (Low-Pass Filter) is used to distinct the harmonic sequences $\widetilde{i_{Ld}}$, $\widetilde{i_{Lq}}$ from the $d-q$ on the half of the fundamental frequency. Acquired harmonic current components are re-transformed into actual three-phase $(a-b-c)$ quantities by employing Inverse-Park's and Inverse Clarke's transformation process as illustrated in below Eqn. (4) and (5).

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \cos\omega t & -\sin\omega t \\ \sin\omega t & \cos\omega t \end{bmatrix}\begin{bmatrix} i_{Ld} \\ i_{Lq} \end{bmatrix}$$

(4)

$$\begin{bmatrix} i_a^* \\ i_b^* \\ i_c^* \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & 0 \\ -1/2 & \sqrt{3}/2 \\ -1/2 & -\sqrt{3}/2 \end{bmatrix}\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix}$$

(5)

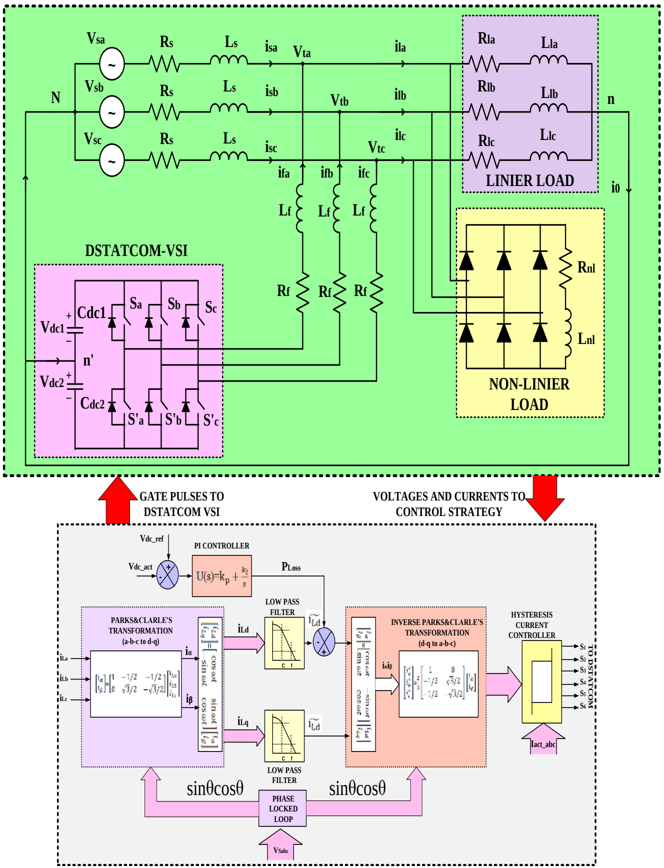

Fig.3: overall diagram of Classical Synchronous Reference Frame theory for DSTATCOM

The DC-link controller comprised of the PI regulator, which is used to regulate the DC-link voltage for maintaining the lossless voltage at shunt-VSI.The fundamental active current component is acquired by cutoff frequency -link current of the shunt-VSI is differentiatedconcerning the magnitude of the desired current to peak harmonic current. The outcome error from this process is fed to the PI controller for suppression of the dominant error inP_{Lerr}.

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

The formation of reference current in the orthogonal coordinate $(I\alpha)$ is extracted by summation of active fundamental componentsandP_{Lerr}

The component is Controller) to control the shunt-VSI of DSTATCOM. The hysteresis current controller is engaged to implement the supervision of shunt-VSI of DSTATCOM. Hysteresis loop or band (HL) is acting as the boundary limit of compensation current.

This current is controlled in between these lower/upper hysteresis limits to control the switching operation in shunt-VSI. The switching states related to ON/OFF of the VSI switches are highly dependedon compensation current; when this current is increasedthen the switch it is -VSI is depicted in Fig.2. The over-all diagrams of Classical Synchronous Reference Frame Theory (Shunt-VSI) of DSTATCOM Model is illustrated in Fig.3.

B. P-Q Theory for DSTATCOM

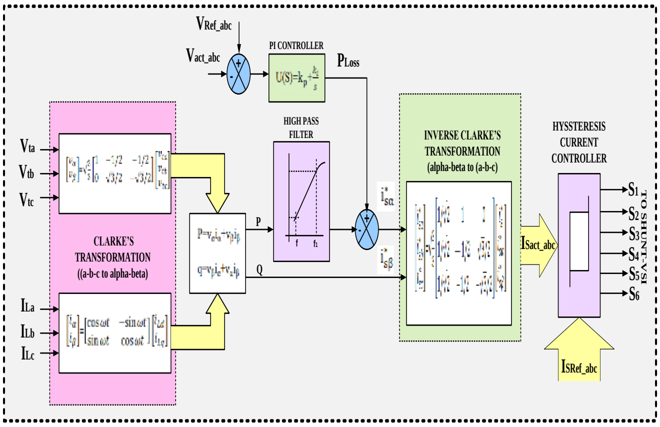

Fig.4: PQ theory for DSTATCOM

The Instantaneous Real-Reactive Power (IRP) theory is first proposed by H. Akagi in the year of 1983. The formal IRP theory is most suitable for current compensation in a three-phase power system using shunt-VSI structure and regulates DC-link voltage as a constant. The active-reactive power consignments are well with-in this orthogonal coordinated frame. The basic schematic view of formal PQ theory is depicted in Fig.4.

Real-Reactive Power theory DSTATCOMA precise measurement of input variables is the source voltage (V_{Sabc}), load currents (I_{Labc}) are fed into Clarke's transformation process. This process generates the voltage-current quantities in-terms of orthogonal coordinates $(V_{\alpha\beta}, I_{\alpha\beta})$. The instantaneous active (P) &reactive (Q) power quantities are calculated based on above specified coordinates by relevant equations. For attaining, this DC-link current of the shunt-VSI is differentiated with respect magnitude of desired current to peak harmonic current.

The outcome error from this process is fed to the PI controller for suppression of the dominant error inP_{Loss}. The formation of reference current in orthogonal coordinates $(I_\propto)$ is extracted by summation of active fundamental component and P_{Loss} component. The terms $I_{\alpha\beta}$ are again current The final reference current is compared to actual current for deriving the optimal switching states with the help of a hysteresis current controller.

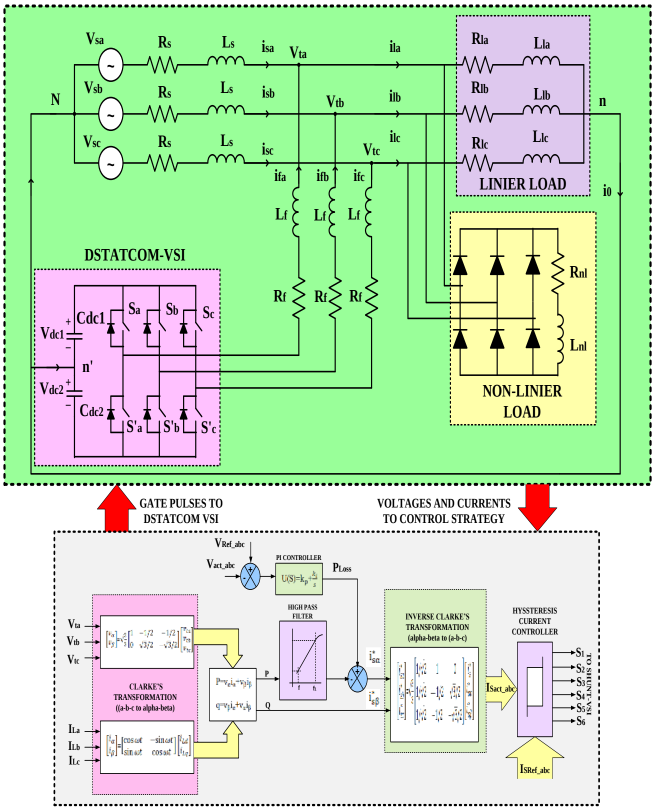

Fig.5: overall diagram of Classic Instantaneous

The three-phase source voltages and load currents are illustrated as below;

$$v_{ta} = Vm_a \sin(\omega t)$$
$$v_{tb} = Vm_b \sin\left(\omega t - \frac{2\pi}{3}\right)$$
$$v_{tc} = Vm_c \sin\left(\omega t - \frac{4\pi}{3}\right) \quad (6)$$
$$i_{La} = \sum I_{La-n} \sin(n(\omega t) - \theta_{a-n})$$
$$i_{Lb} = \sum I_{Lb-n} \sin\left(n\left(\omega t - \frac{2\pi}{3}\right) - \theta_{b-n}\right)$$
$$i_{Lc} = \sum I_{Lc-n} \sin\left(n\left(\omega t - \frac{2\pi}{3}\right) - \theta_{c-n}\right) (7)$$

The instantaneous vector coordinates, v_{ta} , i_{La} are posed on the axis-"a", their magnitudes are varied of positive-negative ways with respective to the time and true for other phases. By using a Park's transformation process these phases are transforming to $(\alpha - \beta)$ coordinates, follows as;

Published By:
Blue Eyes Intelligence Engineering and Sciences Publication (BEIESP)

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \cdot \begin{bmatrix} v_{ta} \\ v_{tb} \\ v_{tc} \end{bmatrix} \quad (8)$$

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & \sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} \cdot \begin{bmatrix} i_{La} \\ i_{Lb} \\ i_{Lc} \end{bmatrix} \quad (9)$$

Where $(\alpha-\beta)$ coordinates are orthogonal coordinates, the formal immediate power of three phase system can be illustrated as;

$$p = v_\alpha i_\alpha + v_\beta i_\beta \quad (10)$$

The formal active power equation is defined as;

$$p = v_a . i_a + v_b . i_b + v_c . i_c \quad (11)$$

Relatively, the formal IRP theory is defined as;

$$q = -v_\beta i_\alpha + v_\alpha i_\beta \quad (12)$$

Although, the instantaneous real-reactive power is illustrated in matrix form as;

$$\begin{bmatrix} p \\ q \end{bmatrix} = \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (13)$$

The $(\alpha-\beta)$ current components can be acquired as;

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{\Delta_k} \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix} \quad (14)$$

Where,

$$\Delta_k = v_\alpha^2 + v_\beta^2 \quad (15)$$

The instantaneous real power (p), reactive power (q) can be degraded into an oscillatory & DC average components are,

$$p = \bar{p} + \tilde{p}$$

$$q = \bar{q} + \tilde{q} \quad (16)$$

Where, $\bar{p}$ and $\bar{q}$ - DC average part, $\tilde{p}$ and $\tilde{q}$ - AC oscillatory part of intended theory and the oscillatory quantity of instantaneous real power. Although, the reference supply currents $i_{s\alpha}^*$ and $i_{s\beta}^*$ into $(\alpha-\beta)$ coordinates can be evaluated as;

$$\begin{bmatrix} i_{s\alpha}^* \\ i_{s\beta}^* \end{bmatrix} = \frac{1}{\Delta_k} \begin{bmatrix} v_\alpha & -v_\beta \\ v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix}$$

These reference currents are transformed to $a-b-c$ components using Inverse transformation process as;

$$\begin{bmatrix} i_{sa}^* \\ i_{sb}^* \\ i_{sc}^* \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1 & 0 \\ 1/\sqrt{2} & -1/2 & \sqrt{3}/2 \\ 1/\sqrt{2} & -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} i_0^* \\ i_{s\alpha}^* \\ i_{s\beta}^* \end{bmatrix} \quad (17)$$

Where, i_0^* is represented as the zero-sequence current component, which should be zero in the re-wire three-phase system. The over-all diagram of Classic Instantaneous Real-Reactive Power theory (Shunt-VSI) of DSTATCOM Model is illustrated in Fig.5

C. Id – Iq Theory for DSTATCOM

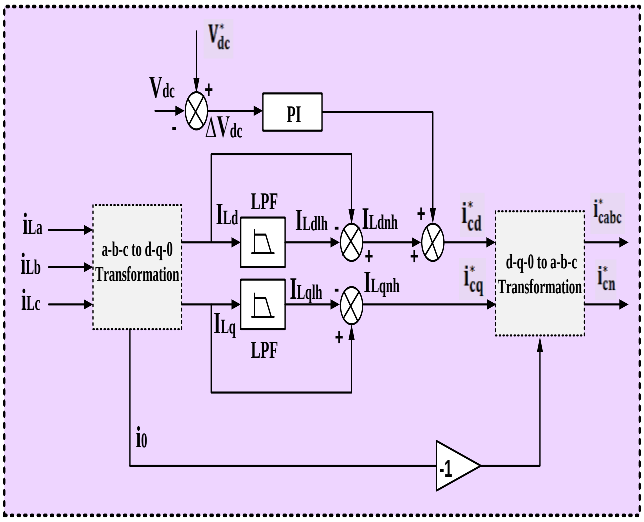

Fig.6: $Id-Iq$ control theory for DSTATCOM

The $Id-Iq$ control theory is shown in figure 6. By using instantaneous active and reactive currents I_{d-q} control technique reference current can be obtained through the nonlinear load. Calculations follow like the instantaneous power theory, but the direct axis and quadrature load currents are often obtained from equation (18). Two stage transformations provide the relation between the stationary and rotating system with active and reactive current methodology. The transformation angle 'θ' is key to all or any voltage harmonics and unbalanced voltages; as a result, $d\theta/dt$ might not be constant.

The transformation from $\alpha-\beta-zero$ frame to $d-q-0$ frame is given by

$$\begin{bmatrix} i_0 \\ i_d \\ i_q \end{bmatrix} = \frac{1}{v_{\alpha\beta}} \begin{bmatrix} 1 & 0 & 0 \\ 0 & cos\theta & sin\theta \\ 0 & -sin\theta & cos\theta \end{bmatrix} \begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} \quad (18)$$

If the d axis is within the direction of the voltage space vector and the zero-sequence part is invariant, the transformation is given by

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = K \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \quad (19)$$

$$K = \frac{1}{v_{\alpha\beta}} \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \quad (20)$$

$$K = \frac{1}{\sqrt{v_\alpha^2 + v_\beta^2}} \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \quad (21)$$

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

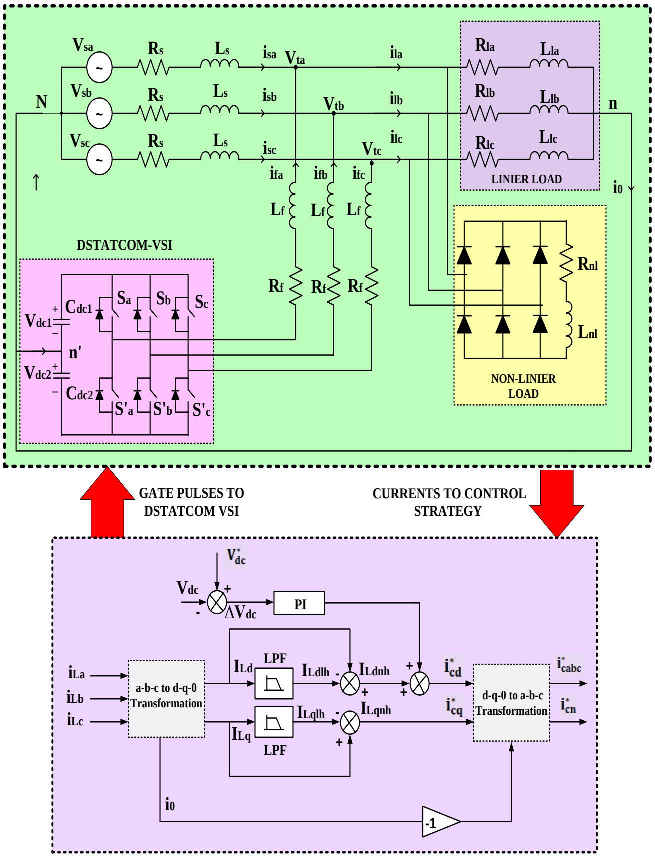

Fig.7: Over-all diagram of $Id - Iq$ theory (Shunt-VSI) of DSTATCOM

Where the transformation matrix K, satisfies $\|K\| = 1$ and $K^{-1} = K^T$

Each current component (I_d, I_q) has an average value or DC component and an oscillating value or AC component

$$i_d = \overline{i_d} + \widetilde{i_d}$$
$$i_q = \overline{i_q} + \widetilde{i_q} \quad (22)$$

The compensating strategy (for harmonic reduction) assumes that the supply should deliver the average of the direct-axis element of the load current. The reference supply current from VSI of DSTATCOM is

$$i_{sdref} = \overline{i_{Ld}}; \; i_{sqref} = i_{s0ref} \quad (23)$$

The overall diagram of $Id - Iq$ theory (Shunt-VSI) of DSTATCOM Model is illustrated in Fig.7.

D. Harmonic Reference Theory

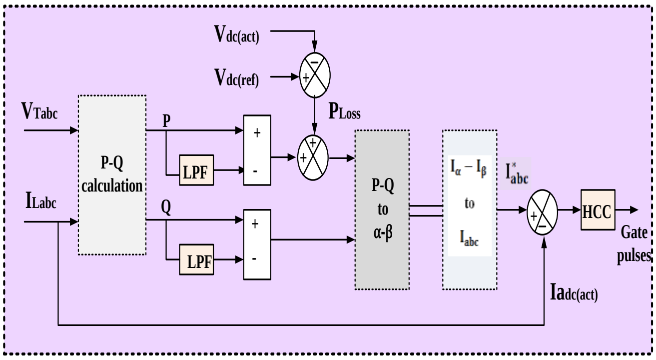

Fig.8: Harmonic reference theory

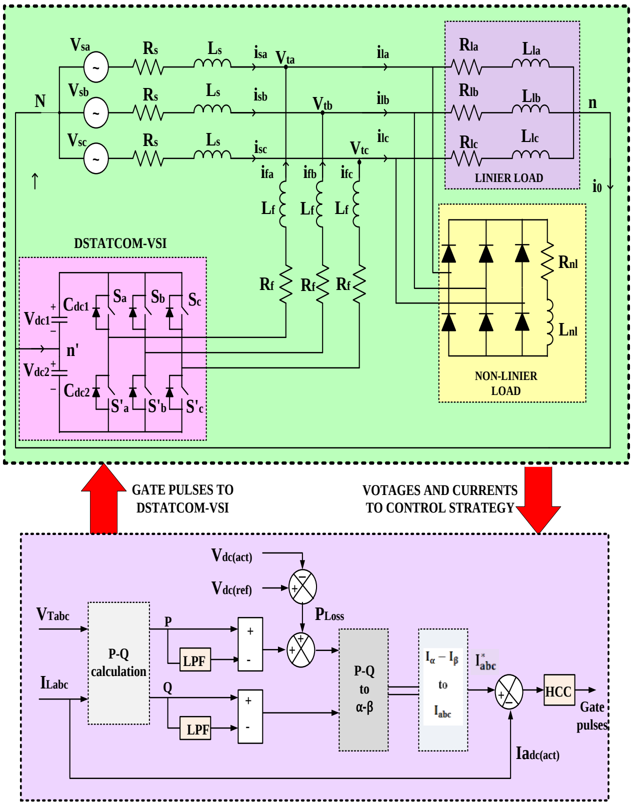

Fig.9: Over-all diagram of instantaneous harmonic power theory of DSTATCOM

Fig. 8 shows the basic instantaneous harmonic power theory based APF commonly used for the calculation of the compensating currents for DSTATCOM. Instantaneous harmonic power theory is used to control the compensating currents to the system. Reference compensating powers will be generated from the actual values of voltage and currents, is then formed into active and reactive powers. These powers are passed through LPF and compare with power loss. Finally,harmonicpower generated is then converted into $\alpha\beta 0$ transformation. Thisis compared with the filter current and signal flows through the hysteresis controller of the DSTATCOM and gate pulses will create. Many methods were available to generate control signals, but the simplicity of instantaneous harmonic power theory makes the design more accessible. In general, when the load is nonlinear, the real and imaginary powers can be divided by average and oscillating components. The over-all diagrams of the instantaneous harmonic power theory of DSTATCOM Model is illustrated in Fig.9.

III. SIMULATION ANALYSIS

The considered theoriesare developed,and results are plotted using MATLAB/SIMULINK software.

A. Analysis of DSTATCOM with SRF Theory

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

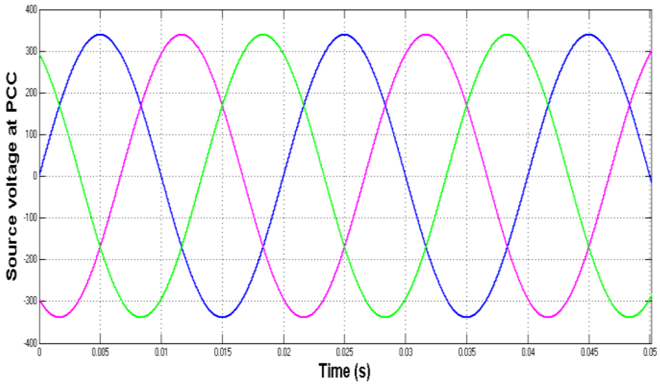

Figure 10: Terminal voltage at PCC

Figure 10 illustrates the three-phase terminal voltage at the PCC of DSTATCOM connected to the distribution system. The source voltage is undistorted, andpeak voltage is maintained constant.

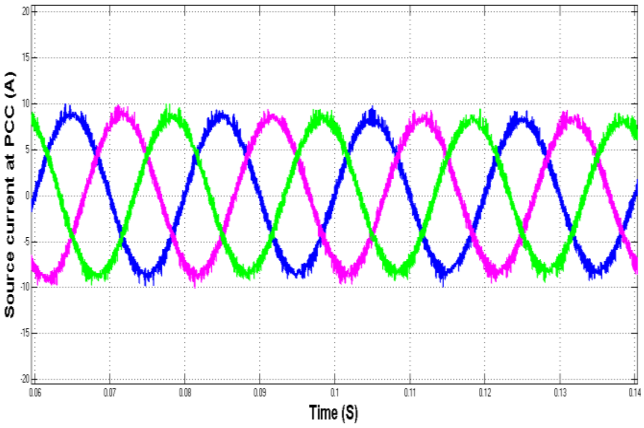

Fig.11: Source current at PCC

Figure 11 exemplifies the three-phase source voltage of distribution system connected with DSTATCOM. Currents in three phases are harmonic free (within nominal limit) with constant peak. DSTATCOM is controlled using classical SRF theory

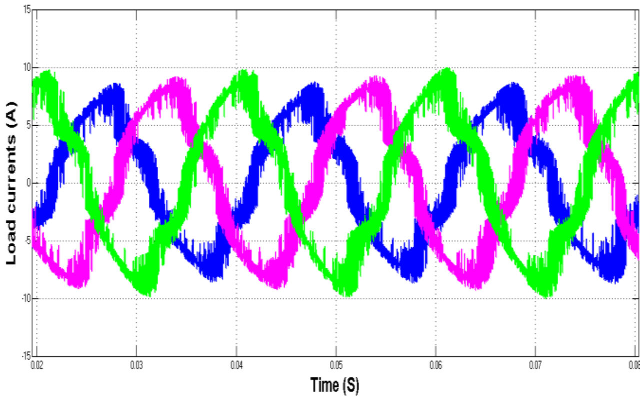

Fig.12: Load currents

Figure 12 depicts three-phase load currents to the non-linear type of load connected to the distribution system. The load is by non-linear nature, and hence currents drawn by load section are non-linear in nature.

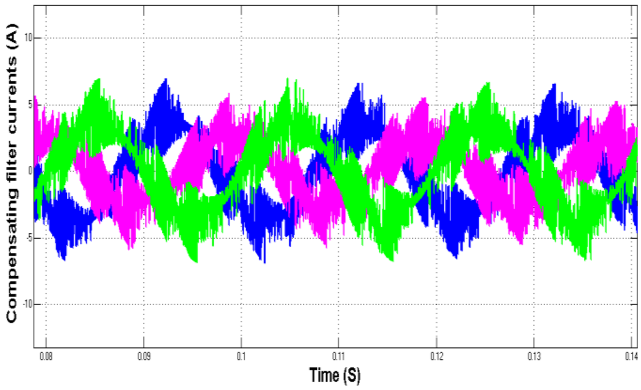

Fig.13: Compensating currents from DSTATCOM

Figure 13 shows the compensating filter currents fed to the distribution system from DSTATCOM to compensate harmonics produced from non-linear loads. Compensating currents compensate harmonics making source current distortion within minimal limits.

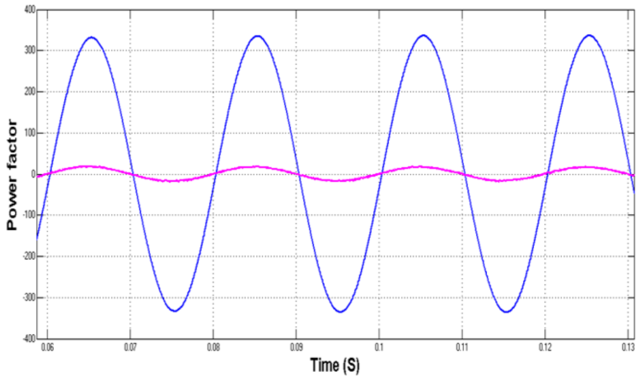

Fig.14: Power factor angle between current and voltage

The power factor is the cosine angle difference between current and voltage is shown in figure 14. The angular difference between the current and terminal voltage at PCC is almost zero, and power factor is maintained nearer unity at PCC.

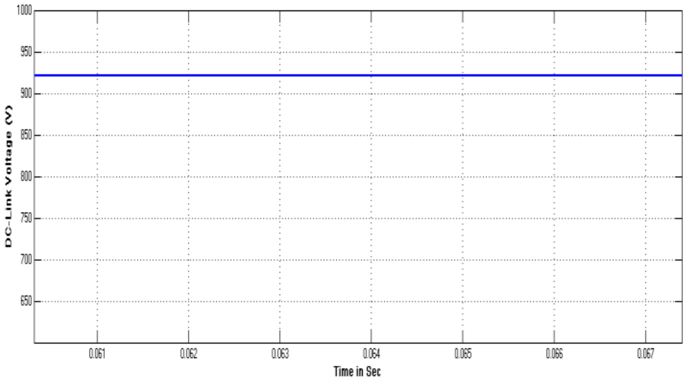

Fig.15: DC-Link Voltage

Figure 15 displays the DC-Link voltage of DSTATCOM. DC link voltage is kept constant at 920V magnitude.

Retrieval Number: E3233038519/19©BEIESP
Journal Website: www.ijitee.org

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

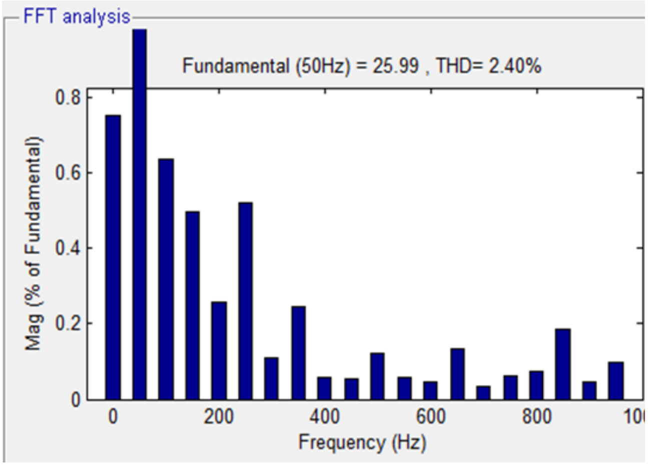

Fig.16: Distortion FFT analysis of source current

Harmonic distortion FFT analysis for source current is shown in figure 16. Distortion of 2.40% is present in source current and maintained within specified limits. DSTATCOM (controlled with SRF theory) limits the source current distortion to be within limits.

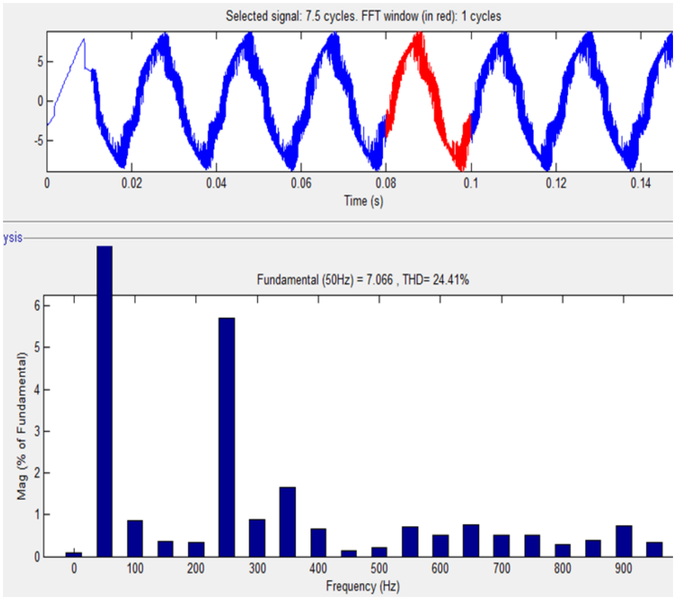

Fig.17: Distortion FFT analysis of load current

Harmonic distortion FFT analysis for load current is shown in figure 17. Distortion of 24.41% is present in load current. As the load is of a non-linear nature, load current distortion is high.

B. Analysis of DSTATCOM with PQ Theory

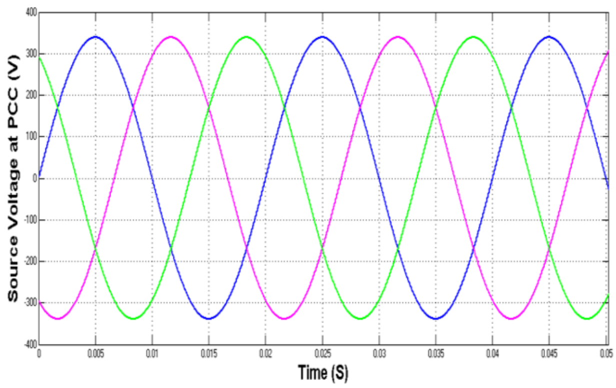

Fig.18: Terminal voltage at PCC

Figure 18 illustrates the three-phase terminal voltage at the PCC of DSTATCOM connected to the distribution system. The source voltage is the undistorted and peak voltage is retained constant.

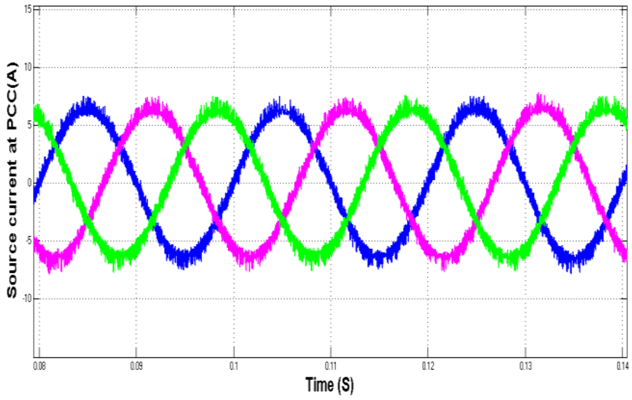

Fig.19: Source current at PCC

Figure 19 exemplifies the three-phase source voltage of distribution system connected with DSTATCOM. Currents in three phases are harmonic free (within nominal limit) with constant peak. DSTATCOM is controlled using classical PQ theory.

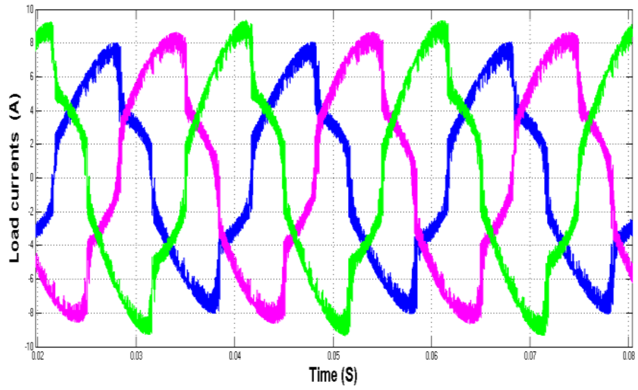

Fig.20: Load currents

Figure 20 depicts three-phase load currents to the non-linear type of load connected to the distribution system. The load is by non-linear nature, and hence currents drawn by load section are non-linear in nature.

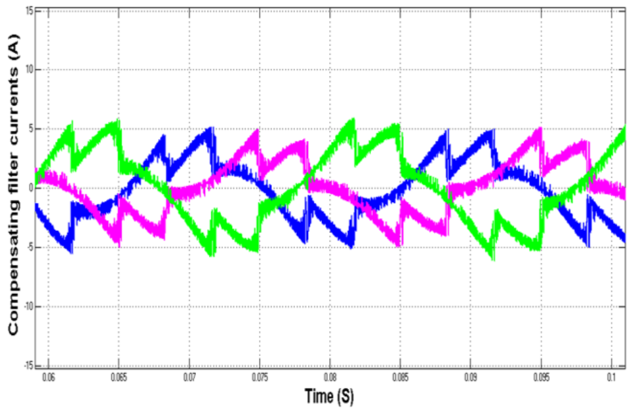

Fig.21: Compensating currents from DSTATCOM

Figure 21 displays the compensating filter currents fed to the distribution system from DSTATCOM to compensate harmonics produced from non-linear loads.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Compensating currents compensate harmonics making source current distortion within specified limits.

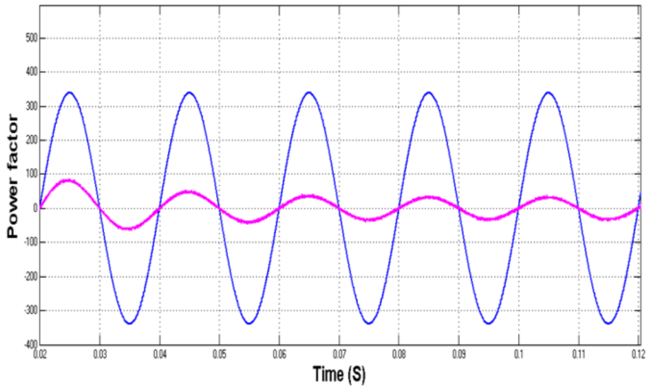

Fig.22: Power factor angle between current and voltage

The power factor angle between currents and voltage is shown in figure 22. The angular difference between the current and terminal voltage at PCC is almost zero, and power factor is maintained nearer unity at PCC.

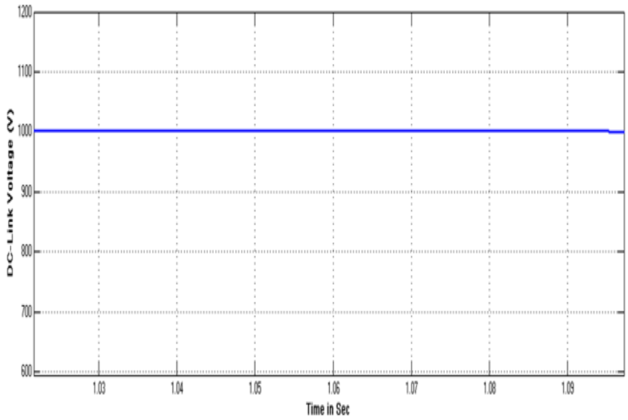

Fig.23: DC-Link Voltage

Figure 23 shows the DC-Link voltage of DSTATCOM. DC link voltage is upheld constant at 1000V magnitude.

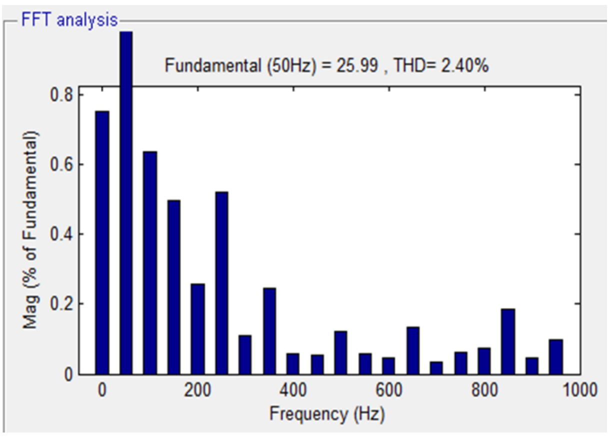

Fig.24: Distortion FFT analysis of source current

Harmonic distortion FFT analysis for source current is exposed in figure 24. Distortion of 2.40% is present in source current and maintained within specified limits. DSTATCOM (controlled with PQ theory) limits the source current distortion to be within limits.

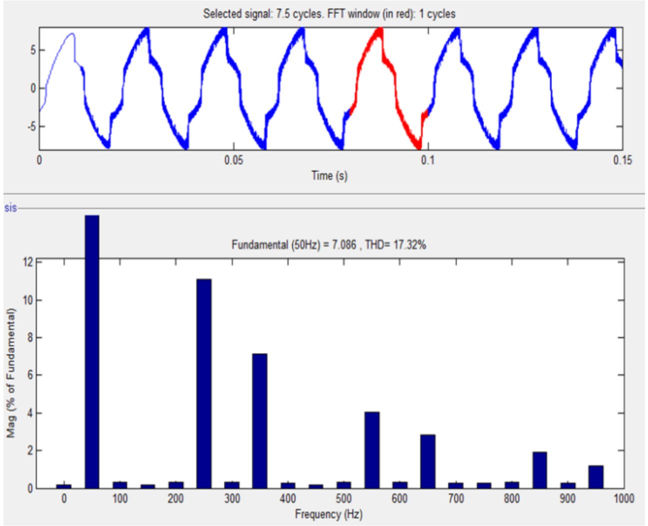

Fig.25: Distortion FFT analysis of load current

Harmonic distortion FFT analysis for load current is shown in figure 25. Distortion of 17.32% is present in load current. As the load is of a non-linear nature, load current distortion is high.

C. Analysis of DSTATCOM with Id-Iq Theory

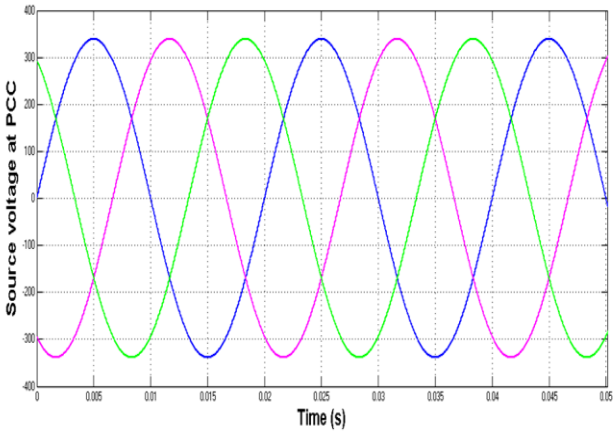

Fig.26: Source voltage at PCC

Figure 26 illustrates the three-phase terminal voltage at the PCC of DSTATCOM connected to the distribution system. The Source voltage is the undistorted and peak voltage is maintained constant.

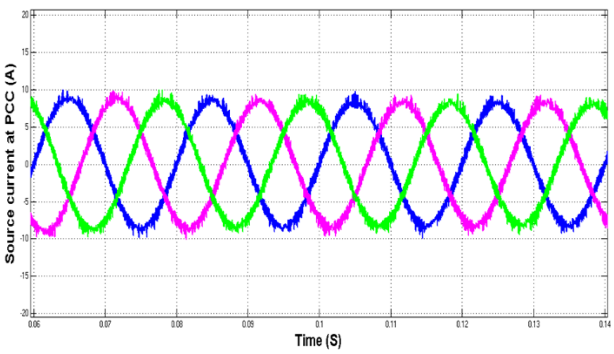

Fig.27: Source current at PCC

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

Figure 27 demonstrates the three-phase source voltage of distribution system connected with DSTATCOM. Currents in three phases are harmonic free (within nominal limit) with constant peak. DSTATCOM is controlled using classical Id – Iq theory.

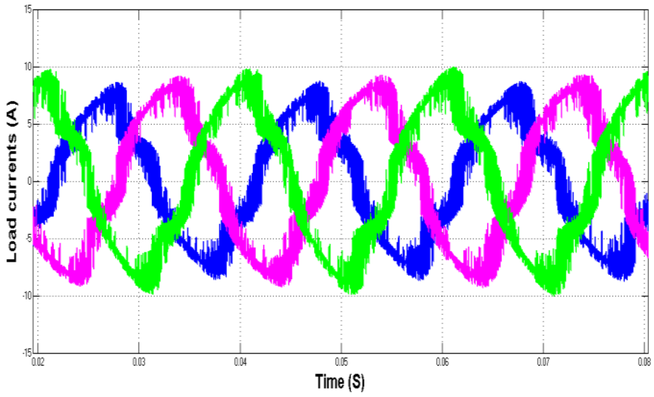

Fig.28: Load currents

Figure 28 depicts three-phase load currents to the non-linear type of loads to the distribution system. The load is of a non-linear in nature, and hence currents drawn by load section are non-linear in nature.

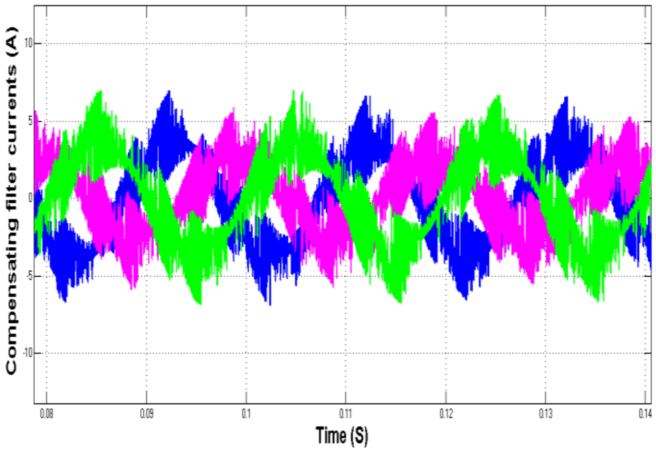

Fig.29: Compensating currents from DSTATCOM

Figure 29 shows the compensating filter currents fed to the distribution system from DSTATCOM to compensate harmonics produced from non-linear loads. Compensating currents compensate harmonics making source current distortion within nominal limits.

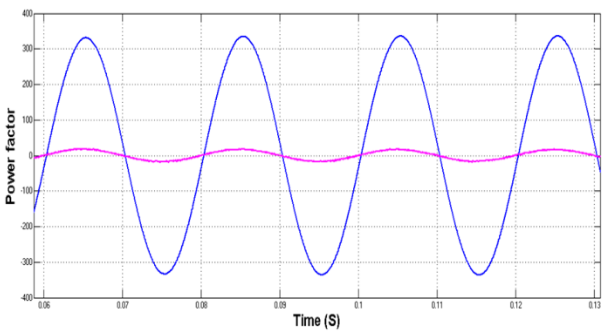

Fig.30: Power factor angle between current and voltage

The power factor cosine angle difference between current and voltage is shown in figure 30. The angular difference between the current and terminal voltage at PCC is almost zero and power factor is maintained nearer unity at PCC.

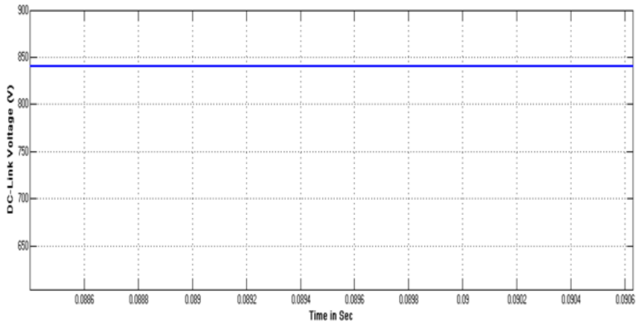

Fig.31: DC-Link Voltage

Figure 31 shows the DC-Link voltage of DSTATCOM. DC link voltage is maintained constant at 840V magnitude.

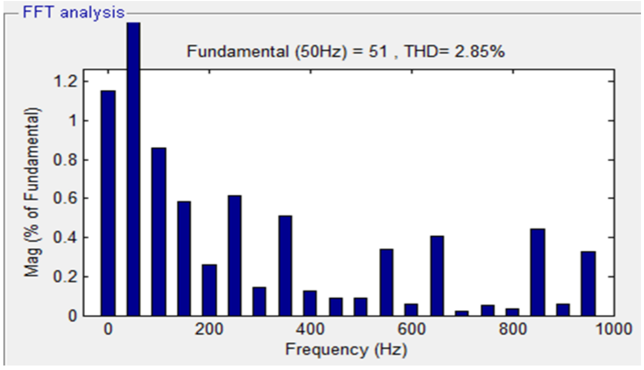

Fig.32: Distortion FFT analysis of source current

Harmonic distortion FFT analysis for source current is shown in figure 32. Distortion of 2.85% is present in source current and maintained within specified limits. DSTATCOM (controlled with Id – Iq theory) limits the source current distortion to be within limits.

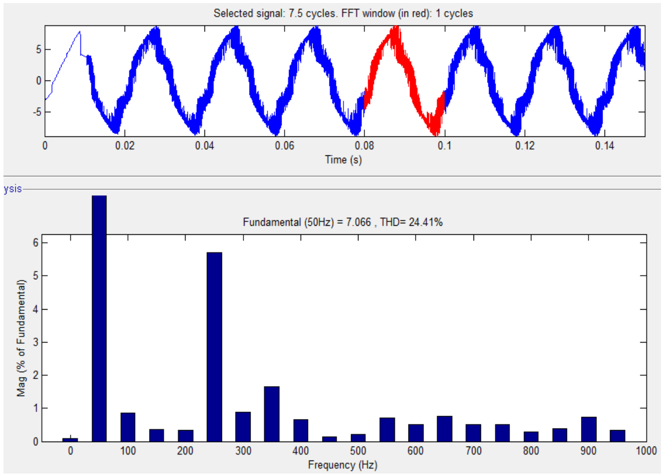

Fig.33: Distortion FFT analysis of load current

Harmonic distortion FFT analysis for load current is shown in figure 33. Distortion of 24.41% is present in load current. As the load is of a non-linear nature, load current distortion is high.

D. Analysis of DSTATCOM with Harmonic Current Reference Theory

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

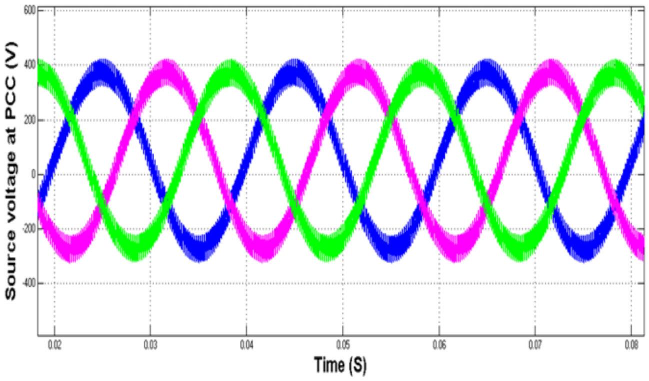

Fig.34: Source voltage at PCC

Figure 34 illustrates the three-phase terminal voltage at the PCC of DSTATCOM connected to the distribution system. The source voltage is the undistorted and peak voltage is maintained constant.

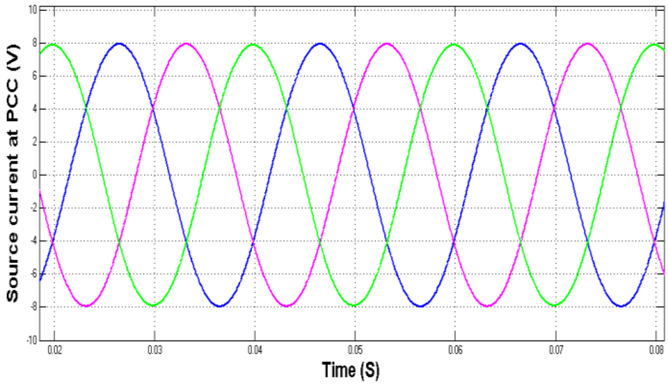

Fig.35: Source current at PCC

Figure 35 illustrates the three-phase source voltage of distribution system connected with DSTATCOM. Currents in three phases are harmonic free (within nominal limit) with constant peak. DSTATCOM is controlled using classical harmonic current reference theory.

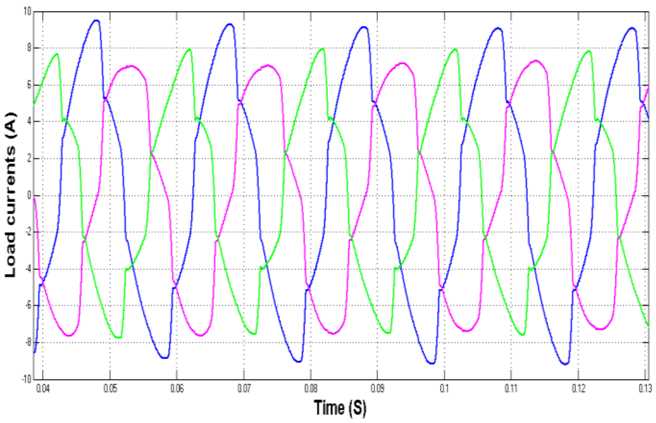

Fig.36: Load currents

Figure 36 depicts three-phase load currents to the non-linear type of load connected to the distribution system. The load is a non-linear nature and hence currents drawn by load section are non-linear in nature.

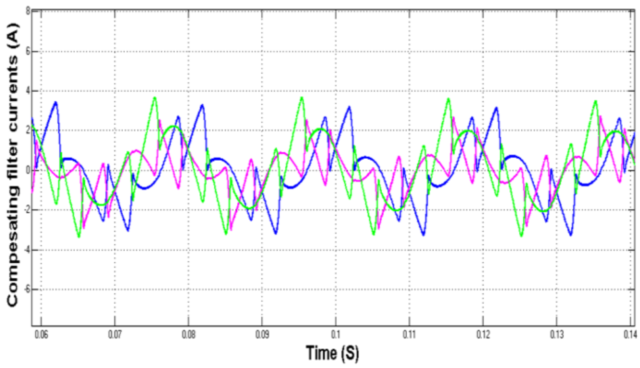

Fig.37: Compensating currents from DSTATCOM

Figure 37 shows the compensating filter currents fed to the distribution system from DSTATCOM to compensate harmonics produced from non-linear loads. Compensating currents compensate harmonics making source current distortion within nominal limits.

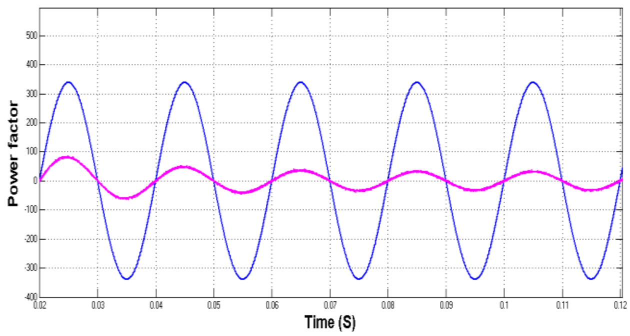

Fig.38: Power factor angle between current and voltage

The power factor cosine angle difference between current and voltage is shown in figure 38. The angular difference between the current and terminal voltage at PCC is almost zero, and power factor is maintained nearer unity at PCC.

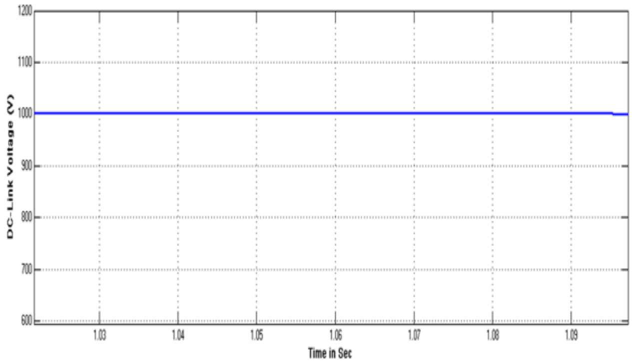

Fig.39: DC-Link Voltage

Figure 39 shows the DC-Link voltage of DSTATCOM. DC link voltage is maintained constant at 1000V magnitude.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)

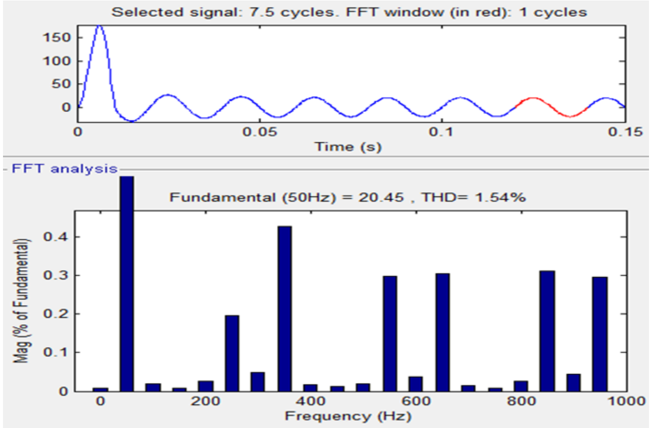

Fig.40: Distortion FFT analysis of source current

Harmonic distortion FFT analysis for source current is shown in figure 40. Distortion of 1.54% is present in source current and maintained within specified limits. DSTATCOM (controlled with harmonic current reference theory) limits the source current distortion to be within limits.

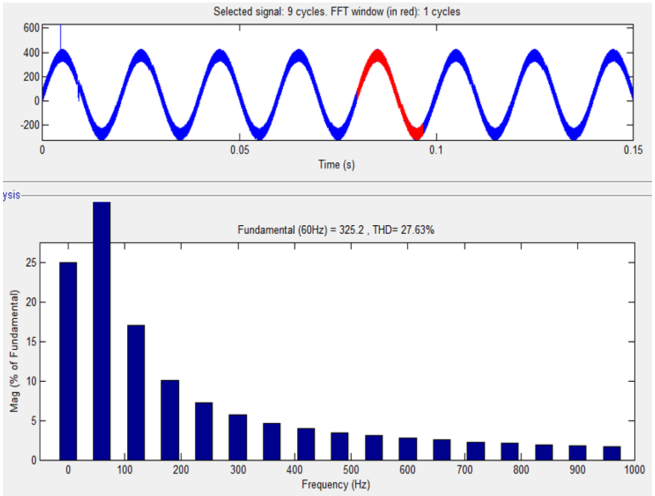

Fig.41: Distortion FFT analysis of load current

Harmonic distortion FFT analysis for load current is shown in figure 41. Distortion of 27.63% is present in load current. As the load is of a non-linear nature, load current distortion is high. Table I illustrates the comparison of different parameters regarding different control strategies for DSTATCOM.

Table I: Comparison of control strategies for DSTATCOM

	SRF Theory	PQ Theory	$Id - Iq$ Theory	Harmonic reference theory
THD in source current	2.40%	2.40%	2.85%	1.54%
Simplicity	Involves complex calculations	Involves complex calculations	Simple	Comparatively, not simple

Table I illustrates that in THD reduction, distortion in the source current is better in DSTATCOM controlled with harmonic current reference theory. Operational simplicity is found in Id – Iq theory for DSTATCOM reducing the complex calculations.

IV. CONCLUSION

The use of power electronic devices very much increases in industrial and domestic applications. The non-linear power electronic devices or components draw only non-linear currents from the source leaving harmonic components in the source currents at PCC. When other loads are connected to PCC, the source delivers harmonic currents to the loads. Use of DSTATCOM can mitigate harmonic pollution in the system which induces compensating components to the distribution system. The paper presents a comprehensive review of control strategies for DSTATCOM in the distribution system. Distortion in the source current is better in DSTATCOM controlled with harmonic current reference theory. Operational simplicity is found in Id – Iq theory for DSTATCOM reducing the complex calculations.

REFERENCES

1. V. Khadkikar "Enhancing electric power quality using UPQC: A comprehensive overview" IEEE Trans. Power Electron. vol. 27 no. 5 pp. 2284-2297, 2012.
2. M. BarghiLatran, A. Teke and Y. Yoldaş, "Mitigation of power quality problems using distribution static synchronous compensator: a comprehensive review," in IET Power Electronics, vol. 8, no. 7, pp. 1312-1328, July 2015
3. K. Venkatraman, M. P. Selvan and S. Moorthi, "Predictive current control of distribution static compensator for load compensation in distribution system," in IET Generation, Transmission & Distribution, vol. 10, no. 10, pp. 2410-2423, 7 July 2016.
4. C. Kumar M.K. Mishra "A modified DSTATCOM topology with reduced VSI rating DC link voltage and filter size" Int. Conf. Clean Electrical Power pp. 325-331 11–13 June 2013.
5. A. Luo H. Xiao F. Ma et al. "Distribution static compensator based on an improved direct power control strategy" IET Power Electron. vol. 7 no. 4 pp. 957-964, 2014.
6. C. Kumar M.K. Mishra "An improved hybrid DSTATCOM topology to compensate reactive and nonlinear loads" IEEE Trans. Ind. Electron. vol. 61 no. 12 pp. 6517-6527, 2014.
7. T. S. Saggu, L. Singh, and B. Gill, "Harmonics Mitigation in a Steel Industry Using 11-Level Cascaded Multilevel Inverter-Based DSTATCOM," in Canadian Journal of Electrical and Computer Engineering, vol. 40, no. 2, pp. 110-115, Spring 2017.
8. T. Zaveri B. Bhalja N. Zaveri "Comparison of control strategies for DSTATCOM in three-phase four-wire distribution system for power quality improvement under various source voltage and load conditions" Electr. Power Energy Syst. vol. 43 pp. 582-594, 2012.
9. B. Singh P. Jayaprakash D.P. Kothari "New control approach for capacitor supported DSTATCOM in three-phase four wire distribution system under non-ideal supply voltage conditions based on synchronous reference frame theory" Electr. Power Energy Syst. vol. 33 pp. 1109-1117, 2011.

Published By:
Blue Eyes Intelligence Engineering
and Sciences Publication (BEIESP)