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Reactive Power Compensation and Harmonics reduction using dq Current Reference Theory based DSTATCOM

Teja Sreenu Tadivaka,

Department of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India

T Vijay Muni,

Department of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India

R B R Prakash,

Department of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India

P Srinivasa varma

Department of Electrical and Electronics Engineering, Koneru Lakshmaiah Education Foundation, Vaddeswaram, AP, India

Abstract-

This study presents an analysis of the application of DSTATCOM (Distribution Static Synchronous Compensator) for the purpose of compensating reactive power and mitigating harmonics in distribution systems. The utilization of a distribution static compensator (DSTATCOM) has demonstrated its effectiveness as a feasible remedy for addressing power quality issues. With the continuous increase in power demand, there is a growing concern regarding power quality issues, specifically the loss in reactive power and the induction of harmonics, which are directly associated with the rise in non-linear loads. The issue pertaining to the distribution system is resolved by the utilization of DSTATCOM. The implementation of DSTATCOM enables the mitigation of power quality concerns. The utilization of Id – Iq control theory is a straightforward approach that may effectively manage the Distributed Static Compensator (DSTACOM) system, addressing reactive power concerns and mitigating harmonic distortions. The conventional Id - Iq theory is characterized by significant switching losses resulting from the presence of high-frequency harmonic currents as a reference. This study presents a unique theory for compensation of harmonics and reactive power, resulting in reduced losses and higher system efficiency. The theory introduces a current reference Id – Iq approach. The reference signal is derived from the source current, deviating from the typical approach of using harmonic reference currents. This novel method empowers the user to exercise comprehensive control over the source characteristics.

Keywords: Distribution Static compensator (DSTATCOM), harmonics, power quality, Reactive power, current reference.

1. INTRODUCTION

Power engineers must provide uninterrupted, high-quality power due to rising power use. However, non-linear loads impair power quality and impact distribution system loads. Overuse of power indicates reactive power difficulties. electricity system's major goal is to supply connected loads with uninterrupted, high-quality electricity. Power quality means maintaining nominal voltage, current, frequency, and power factor. Deviation in any parameter indicates power quality issues.

Non-linear demand causes power network disturbance. More power electronic converters in this period cause harmonics in the system since they are non-linear loads. Reactance makes loads use reactive power. Many researchers have used various methods to improve power quality. Using specialized power devices can assist in offering excellent electricity. Custom power devices like FACTS can adjust sending and receiving end voltage, line impedance, and phase angle. FACTS devices include STATCOM, UPQC, and DVR. DSTATCOM is distribution static compensator STATCOM. DSTATCOM [1-4] controls reactive power flow and nullifies harmonics.

Voltage-source electrical converter (VSI) shunt devices like DSTATCOM are used to adjust reactive power and distribution system disturbances produced by non-linear loads. DSTATCOM performance depends on the control technique. For DSTATCOM, various control methods exist. Control techniques and internal controls of a DSTATCOM are crucial to preserving power quality at PCC. DSTATCOM management algorithms [5-9] include phase shift management, decoupled current management (p-q theory), hysteresis control, and current reference Id-Iq theory for current reference component extraction. In this study, a

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Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 1, 2019

modified Id-Iq theory controls DSTATCOM [10-12], minimizing losses. Conventionally, reference currents are drawn from the fundamental component versus reference harmonic current. This allows complete hold over the source and can be easily extended for DSTATCOM DG inclusion in distribution systems.

This report plans DSTATCOM's management strategy. The distribution static synchronous compensator (DSTATCOM) with the proposed control method uses fundamental current reference Id-Iq theory for reactive power and harmonics compensation. A DSTATCOM simulation model was built using MATLAB/SIMULINK, and simulated outcomes were compared with and without it.

2. DSTATCOM CONNECTED IN DISTRIBUTION SYSTEM.

A D-STATCOM (distribution static compensator) that is schematically represented in fig.1 includes a voltage deliver tool (VSC), a dc hyperlink condenser, a coupling inductance connected in shunt to the distribution network at a point called common coupling (PCC). The VSC converts the dc voltage throughout the tool into a group of 3-phase ac output voltages. These voltages are coupled with the ac device via the electric phenomenon of the interfacing inductances. Appropriate adjustment of the component and importance of the DSTATCOM output voltages lets in powerful control of energetic and reactive power exchanges among the DSTATCOM and additionally the ac elements.

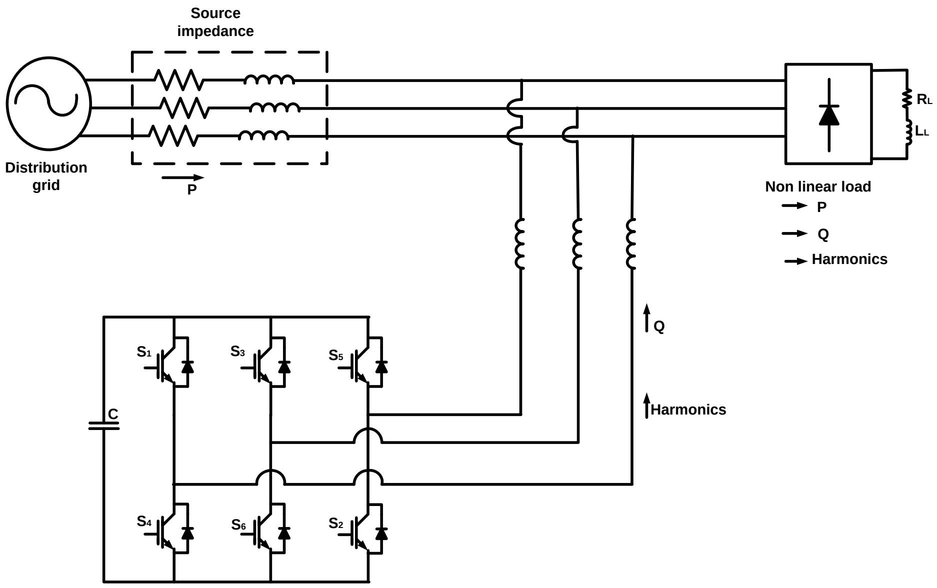

Fig.1 D-STATCOM connected in distribution system

ISSN PRINT 2319 1775 Online 2320 7876

 UGC CARE Listed (Group -I) Journal Volume 8, Issue 1, 2019

3. Control Strategy of DSTATCOM

A). Proposed fundamental current reference I_d-I_q theory.

The proposed fundamental current reference I_d-I_q theory is showed in fig.2. In this immediately energetic and reactive cutting-edge factor (I_d-I_q) method the lively currents I_{abc} may be received from the immediately lively and reactive cutting-edge additives I_d and I_q of the nonlinear load [4]. This technique is via using park transformation on segment α-β (by Clarke transformation) we are able to get (d-q) additives. In park transformation phase α-β are fed to vector rotation block wherein it is going to be turned around over an angle θ to follow the body d-q. The definitions apply in either the αβ0- or dq0-domains and for balanced sinusoidal three-phase systems would yield constant. The PLL is generates sinwt and coswt components is given to conversion blocks (abc-dq0). PI controller have an input from the difference between actual and reference DC voltages. Finally, Idc actual is generated is given to PWM generator which develops gate pluses for converter.

$$\begin{bmatrix} x_d \\ x_q \\ x_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos(\theta) & \cos\left(\theta - \frac{2\pi}{3}\right) & \cos\left(\theta - \frac{4\pi}{3}\right) \\ -\sin(\theta) & \sin\left(\theta - \frac{2\pi}{3}\right) & -\sin\left(\theta - \frac{4\pi}{3}\right) \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix}$$

(3.1)

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{sa} \\ V_{sb} \\ V_{sc} \end{bmatrix}$$

(3.2)

Likewise current i_{sa},i_{sb}, i_{sc} transformed as;

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{-1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_{sa} \\ i_{sb} \\ i_{sc} \end{bmatrix}$$

(3.3)

Inverse Clarke transformation:

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_0 \\ V_\alpha \\ V_\beta \end{bmatrix}$$

(3.4)

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 1, 2019

v_0 , v_α, v_β Are zero sequence voltage, α axis, and β axis voltages respectively

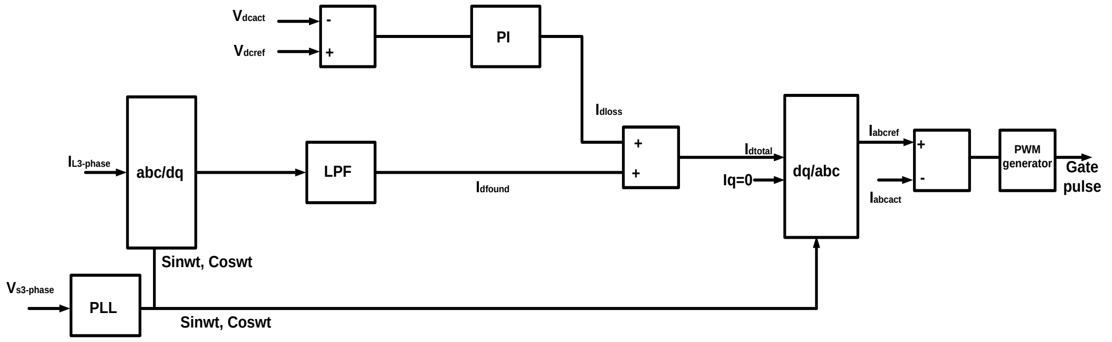

Fig.2 Proposed control algorithm

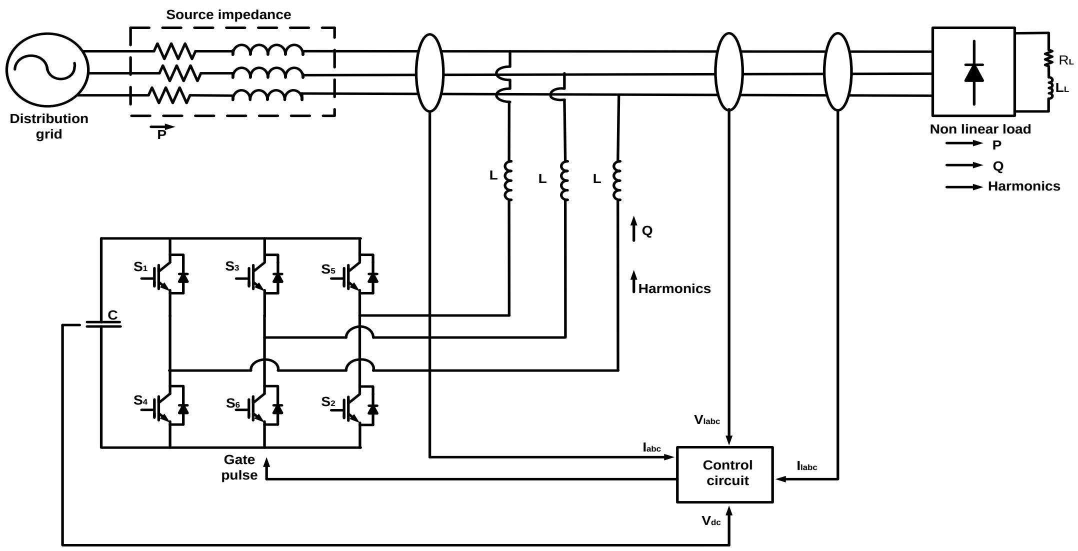

Fig 3. Block diagram of DSTATCOM with simplified control algorithm

B).Block Diagram of DSTATCOM with simplified control algorithm.

The DSTATCOM is shunted with distribution system used to compensate harmonics and reactive power when non linear loads are connected with system. From fig.3 it will shows clearly the DSTATCOM is integrated with system, for proper current reference signal a new control strategy is proposed is fundamental current reference I_d-I_q theory. This control circuit taking an current signal before PCC, after PCC in distribution and Vdc reference from converter. Here the active and reactive current component (I_d-I_q) method is compare the currents form before and after PCC, this signal controls the conduction of IGBT connected in converter based on this compensation current is generated from converter [5-6].

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 1, 2019

4. Complete block diagram for DSTATCOM with proposed control strategy.

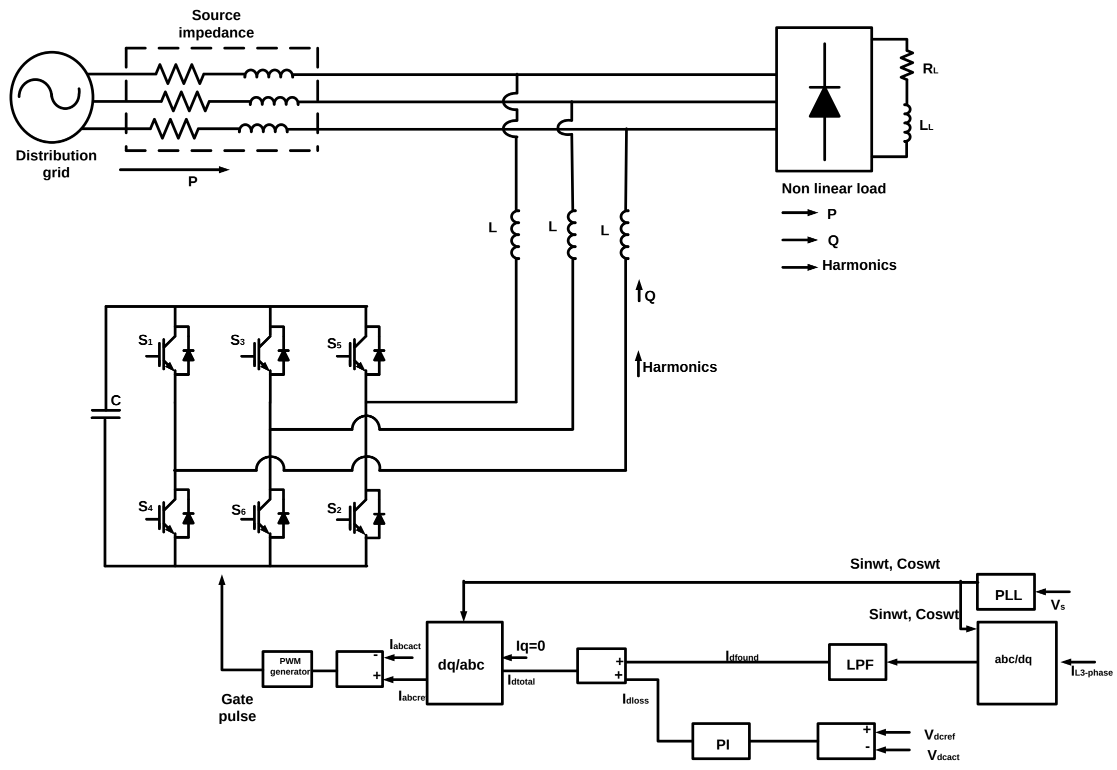

Fig.4 Complete block diagram of D-STATCOM with proposed control strategy

Fig.4 shows that complete block diagram of DSTATCOM with proposed control strategy connected with non linear load. DSTATCOM is to suppress voltage variation and control reactive power in phase with system voltage. DSTATCOM is connected to the power networks at a point of common coupling (PCC) and measurement of all required voltages and currents are fed into the controller to be compared. The feedback of the outputs were conditioned, if required, by the controller and turn ON the switches in converter.

5. Matlab/Simulink Results and Discussions

Simulation models were built for the system without DSTATCOM and with DSTATCOM. Results for the source voltage, load current containing non-linearity, source currents with disturbances, power factor and DC link voltage of VSI converter are shown for all cases. Table I shows the system parameters used to develop the models. As case 1, system without DSTATCOM was shown and as case 2, system with DSTATCOM having fixed non linear load was shown. Models were developed using Matlab/Simulink.

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 1, 2019

Table 1. Simulation Parameters.

Parameter	Value
Source Voltage (Ph-Ph RMS)	11 KV
Source Impedance	0.1+j0.282 Ω
Load Impedance	200+j37.6 Ω
DC Link Capacitance	1500 µF
Proportional Gain	0.8
Integral Gain	0.5

Case 1: Results for without DSTATCOM in Distribution system.

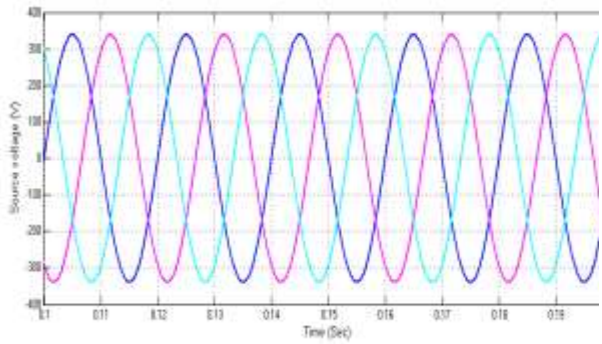

Fig.5 Source voltage without DSTATCOM

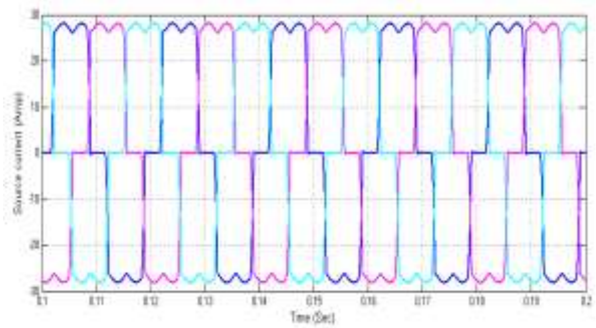

Fig.6 Source current without DSTATCOM

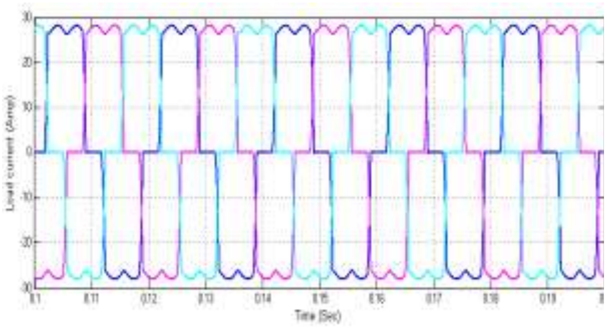

Fig.7 Load current without DSTATCOM

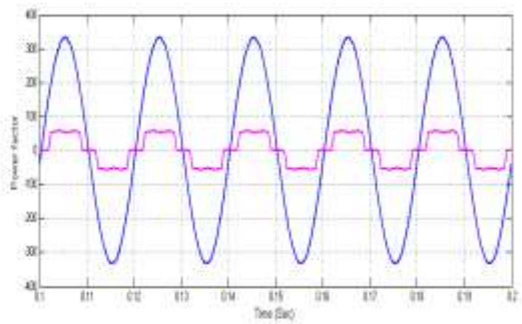

Fig.8 Power factor without DSTATCOM

Fig.5 shows the simulation result of three phase source voltage wave form at non linear load connected in Distribution system without DSTATCOM. The peak amplitude of source

ISSN PRINT 2319 1775 Online 2320 7876

Research paper UGC CARE Listed (Group -I) Journal Volume 8, Issue 1, 2019

voltage is 320V. Fig.6 shows the source current waveforms at non linear load connected in Distribution system without DSTATCOM. Due to non linear load nature the current contains harmonics as showed and has peak current of 28A. as shown, both source current and load curent contains harmonics as no compensation was placed. Fig.7 shows the simulation results of three phase load current wave form at non linear load connected in distribution system with magnitude of 28amps. Fig.8 shows the simulation results of power factor without using D-STATCOM.

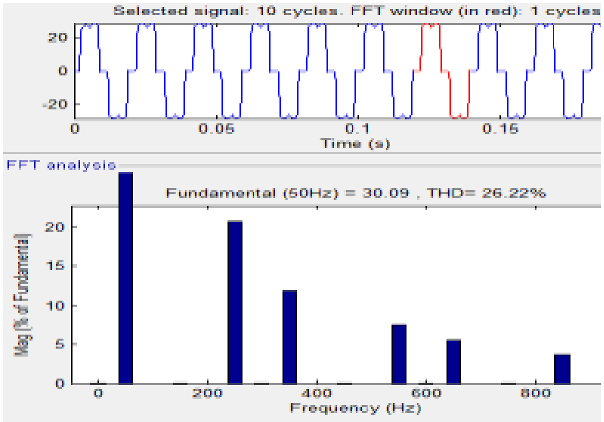

Fig.9 THD analysis of current through load

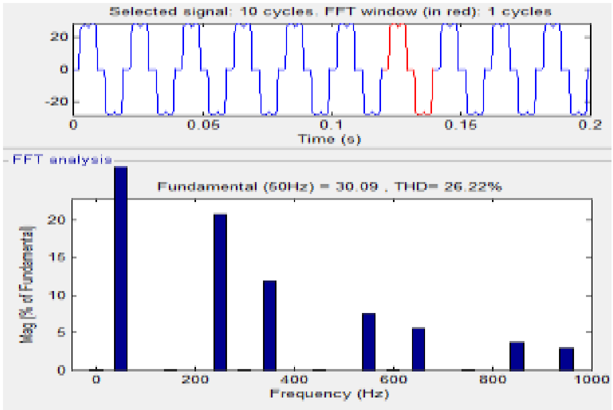

Fig.10 THD analysis of Source current

Fig.9 depicts the THD in load current. The THD in source current without DSTATCOM is 26.22% and Fig 10 shows the THD plot for source current. The % THD value of source current without DSTATCOM is 26.22%. This thd value indicates presence of harmonics in source current and load current.

Case 2: System with DSTATCOM

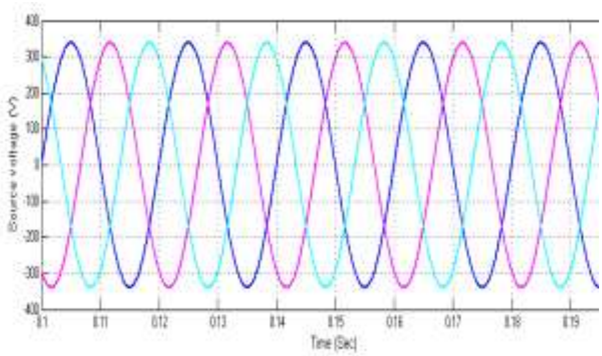

Fig.11 Source voltage with DSTATCOM

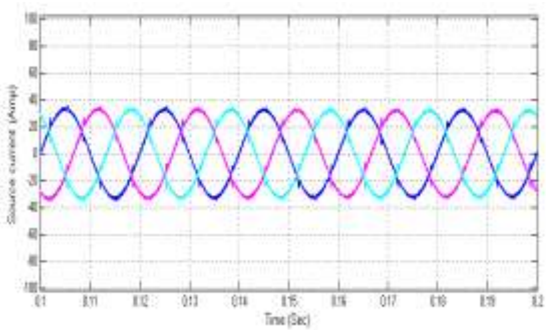

Fig.12 Source current with DSTATCOM

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Fig.11 shows the simulation result of three phase source voltage wave form with non linear load connected in distribution system with DSTATCOM. The peak amplitude of source voltage is 320V. Fig.12 shows the source current waveforms with non linear load connected in distribution system with DSTATCOM. Due to non linear load nature the source current contains distortions without DSTACOM but here the source curent is sinusoidal beacause the DSTACOM compensates the harmonoics and reactive component. It has peak current of 30A

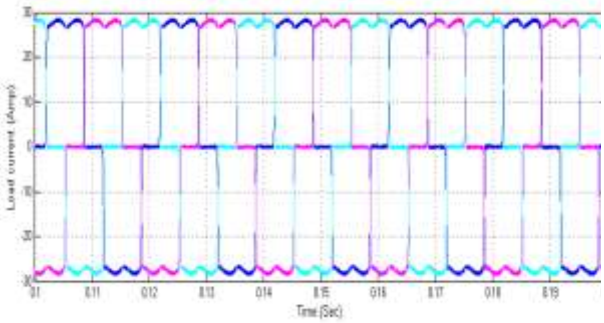

Fig.13 Load current with DSTATCOM

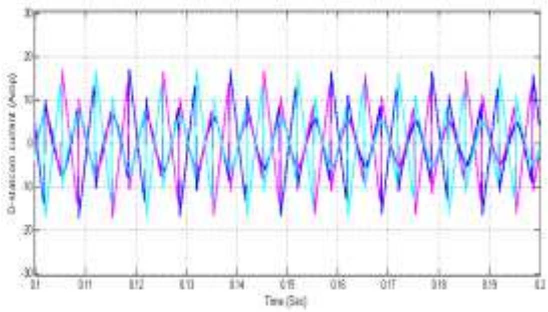

Fig.14 Compensating current

Fig.13 shows the simulation results of three phase load current wave form with magnitude of 28amps. Fig.14 shows the compensating DSTATCOM current waveforms injected in to distribution system for harmonic nullification. But load current draws non-linear components as observed from the result.

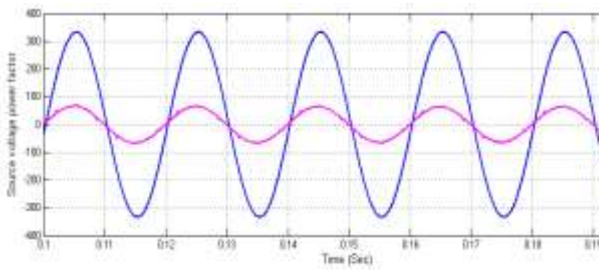

Fig.15 Power factor with DSTATCOM

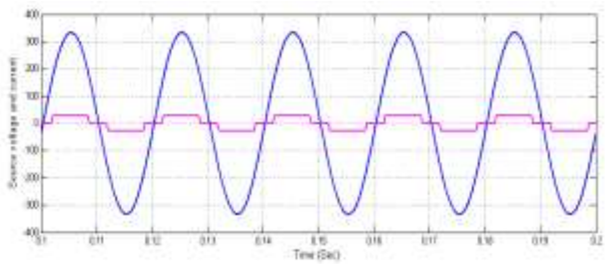

Fig.16 load voltage and current

Fig.15 shows the simulation results of power factor with DSTATCOM, the power factor was maintained around unity. Fig.16 shows the simulation results of load voltage and current waveform. The magnitude of voltage value is 320 volts, and the magnitude of current value is 20 amps.

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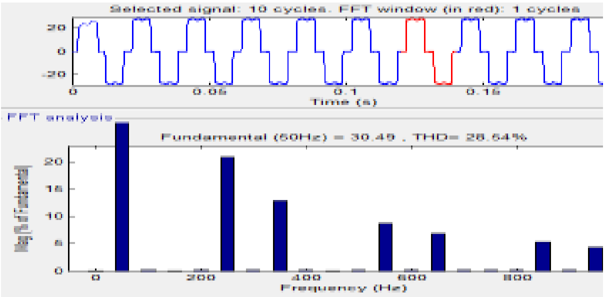

Fig.17 THD in current through load

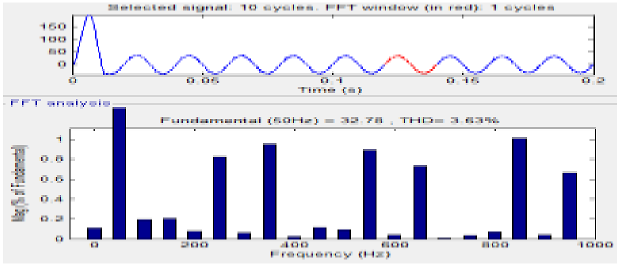

Fig.18 Harmonic Distortion of current in source

Fig.17 shows THD plot for the load current. The %THD value of load current with DSTATCOM is 28.54%. Fig.18 shows harmonic distortion FFT analysis in current through source and is 3.63%. Reduction in THD value can be clearly observed in source current since DSTATCOM is connected to compensate harmonics. THD comparison was listed in table 2.

TABLE: 2 THD COMPARISION

PARAMETERS	THD of Source current without DSTATCOM	THD of Source current with DSTATCOM
Nonlinear load	26.22%	3.63%

Conclusion

This paper depicts a novel control strategy over conventional method of I_d-I_q theory based compensation of harmonics and reactive power compensation in power system. In conventional method of I_d-I_q theory of controlling inverters, reference currents were obtained from harmonic current which increases losses as harmonic current will have high frequency. But here fundamental current was sent as reference signal reducing losses. Proposed I_d-I_q theory for DSTATCOM proves satisfactory when performed on power system as shown in results. DSTATCOM effectively reduces harmonic contents in source current which can be observed with only 3.63% of THD when compared to 26.22% THD in source current without DSTATCOM. Since the switching of inverter power components are carried out with fundamental frequency, switching losses are reduced thus improving the system efficiency.

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