Scientific Journal Impact Factor (SJIF): 1.711

e-ISSN: 2349-9745
p-ISSN: 2393-8161

International Journal of Modern Trends in Engineering and Research
www.ijmter.com

# Designing And Performance Of Dstatcom With The Help Of Icct To Improve Power Quality With Feeding Of Variety Of Loads (L-Nl & Induction Motor Loads)

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**Abstract-** This work presents a method capable of designing DSTATCOM to reduce harmonic distortion and correct the power factor to improve power quality. The use of alternating current circuits in electrical power system has been a common practice nearly since the very inception of the interconnected power network. The most familiar loads on such a system were the constant power, constant impedance and constant current loads or a linear combination of thereof. In these cases, the voltage and current wave shapes are nearly pure sinusoidal. But this is no longer the case with modern electric power system. Massive use of the nonlinear and time varying devices has led to distortion of voltage and current waveforms. As a consequence, recently the issue of power quality has become important. Both electric utility and end users of electric power are becoming increasingly concerned about the quality of electric power. The term “power quality” has been used to describe the variation of the voltage, current and frequency on the power system beyond a limit. The performance of the system is simulated for Linear and Motor load.

**Key words:** Programmable Source, DSATACOM, Capacitive filter, Power Quality, PI & Hysteresis controller, Motor load.

## I. INTRODUCTION

Power engineers consider rising power quality and giving certain power at the lowest cost a major situation. Achievable solutions to power distribution difficulties have been recommended in the form of a number of power electronic based devices for enhanced power quality. Distribution Static Compensator (D-STATCOM), Distribution Voltage Regulator (DVR), Unified Power Quality Compensator (UPQC), BESS, HVDC Light are few of the prominent custom power devices employ at distribution level

The Distribution Static synchronous Compensator (DSTATCOM) is a chief member of the FACTS family of power electronic based controllers. It has been studied for many years, and is probably the most widely used FACTS device in present's power systems. The D-STATCOM voltage and reactive power compensation are normally related through with the magnetic of the D-STATCOM. This traditional power flow framework of the D-STATCOM neglects the impression of the high frequency effects and the switching diagnostics of the power electronics on the active power losses and the reactive power insertion.

The D-STATCOM has appeared as a hopeful device to offering not only for voltage sag reduction but also for a host of other power quality solutions such as voltage stabilization, flicker suppression, power factor correction, and harmonic control.

D-STATCOM is a shunt device that produces a balanced 3-ϕ voltage or current with capability to control the magnitude and the phase angle. Generally, the D-STATCOM configuration consists of a typical 12-pulse inverter arrangement, a dc energy storage device; a coupling transformer linked in shunt with ac system, and connected control circuits.

The simulation results show the enhancement in current control response. These methods are tested in MATLAB, and their results are obtained.

## II. SYSTEM DESIGN

A Distribution static compensator (STATCOM) is electronic based devices which enhance power quality in electrical distribution system. It is based on a power electronics voltage source converter and can act as either a source or sink of reactive AC power to an electricity network in fig .1 shows an isolated distribution system with DSTATCOM set up on it. A programmable voltage source is employed in the system. DSTATCOM in shunt configuration act as a source of leading or lagging vars applied to adjust the voltage at the point of common coupling (PCC). When the load of consumer end is less than the constant power created by the Motor load (nonlinear load), the additional power sucked up by DSTATCOM whereas when the load is outstrip the necessity of consumer end of Induction Motor load (nonlinear load) capability, DSTATCOM also acts as a source of power. DSTATCOM supplies the required reactive components of the supply current and also holding voltage at PCC terminals as well as harmonics compensation. Fig.1 shows the block diagram of system with DSTATCOM.

## III. CONTROL STRATEGY

The block diagram of DSTATCOM as shown in Fig. 1 consists of the DC link; hence the DC link voltage stay practically constant. A DC link capacitor (C1) is also attached as shown. The values of the variables for capacitor and controller are remarked in Parameter list. The block diagram for the control strategy of DSTATCOM is shown in Fig.2. It uses one proportional-integral (PI) controller for regulating the ac terminal voltage. The In-phase components of the DSTATCOM mention currents are required for charging the dc capacitor to the level of mention dc bus voltage and to see its losses. The amplitude of in-phase component of the reference supply currents ($I_{spdr}$) is kept constant at a specific value depending on actual power essential of the load. The instantaneous values for in-phase components of supply reference currents are found by multiplying $I_{spdr}$ with the in-phase unit current vectors ($u_a$, $u_b$, $u_c$) calculated from three phase sensed terminal voltages ne PI controller is applied over the realized and mention ac mains voltage. Its output is considered as the amplitude of quadrature component of the supply reference currents ($I_{spqr}$). The instantaneous values are obtained by multiplying the output of this PI controller with the quadrature unit current vectors ($w_a$, $w_b$, $w_c$) derived from unit in-phase current vectors ($u_a$, $u_b$, $u_c$) which are calculated from three-phase sensed terminal voltages. The total reference supply currents are obtained by adding respective in-phase and quadrature components.

PWM based hysteresis current controller is employed over instantaneous reference supply currents and sensed supply currents. If $i_{sa} < (i_{sar}-h_b)$, the upper switch is turned 'OFF' and lower switch is

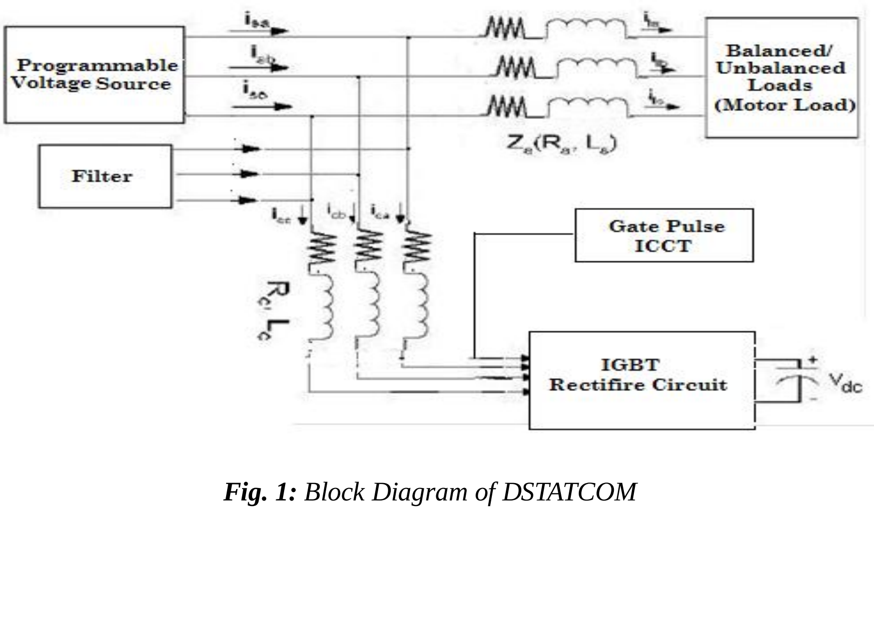



***Fig. 1:*** *Block Diagram of DSTATCOM*

turned 'ON'. If $i_{sa} > (i_{sar}+h_b)$, the upper switch is turned 'ON' and lower switch is turned 'OFF'. In this way, the switching logic for other two phases is obtained and the controller is able to regulate the currents in a band around the desired reference value.

## IV. MATHEMATICAL MODELING OF DSTATCOM

3-ϕ mention supply currents are calculated using 3-ϕ supply voltages. These reference supply currents consist of two components, one in-phase and another in quadrature with the supply voltages.

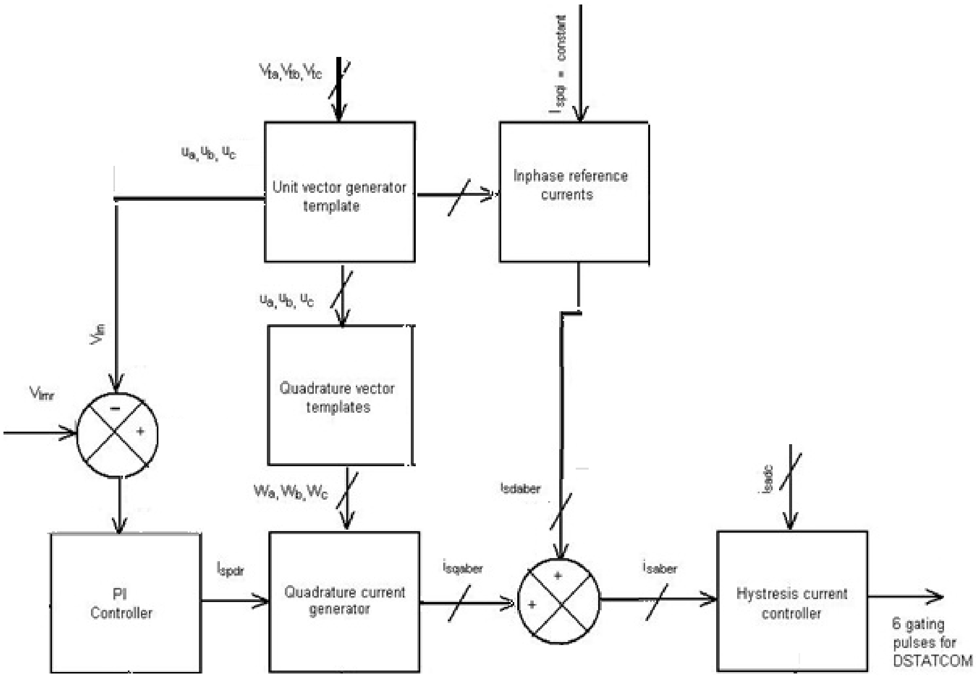



***Fig.2.****The block diagram for the control strategy of DSTATCOM*

*I) Calculation of In-Phase Components of Reference Supply Current's:*

The amplitude of in-phase component of reference supply currents ($I_{spdr}$) is kept fixed at a specific value so that DSTATCOM supplies fixed active power. Three-phase in-phase components of the reference supply currents are calculated using the in-phase unit current vectors ($u_a$, $u_b$,$u_c$) derived from 3-ϕ terminal voltage ($V_a$, $V_b$, $V_c$) using the following equations.

$u_a = V_{ta}/V_{tmn}$

$u_b = V_{tb}/V_{tmn}$

$u_c = V_{tc}/V_{tmn}$ (1)

The amplitude of the supply voltage ($V_{tmn}$) is computed as:

$V_{tmn}= \sqrt{2/3}\ (V^2_{ta} + V^2_{tb}+ V^2_{tc})$ (2)

The amplitude of in-phase component of reference supply currents is calculated as:

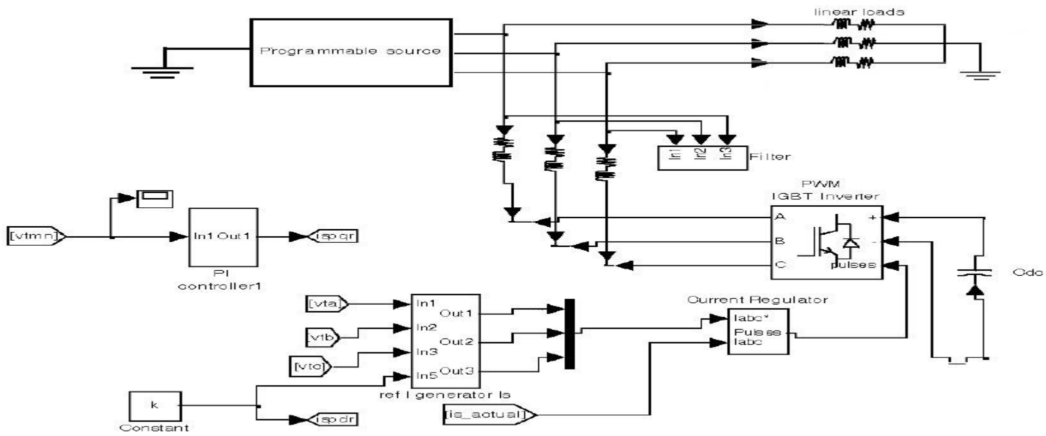



***Fig. 3: (a)*** *MIATLAB based model of DSTATCOM system with Linear Load*

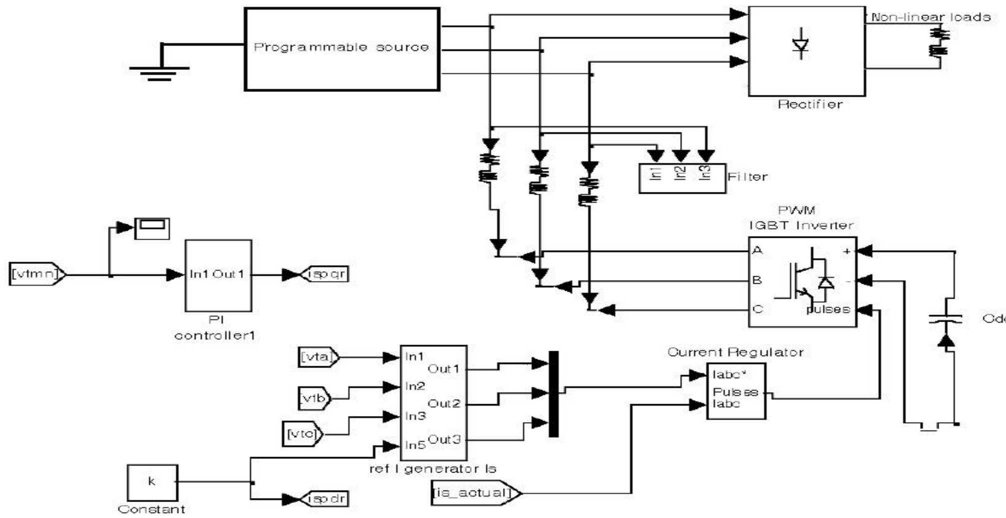



***Fig. 3: (b)*** *MIATLAB based model of DSTATCOM system with Non-Linear Load*

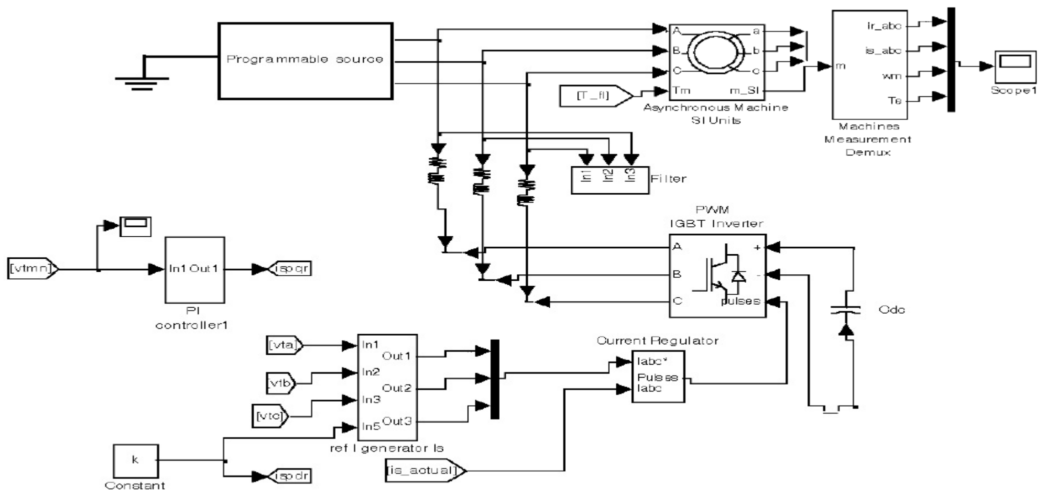



***Fig. 3: (c)*** *MIATLAB based model of DSTATCOM system with Induction Motor Load*

$I_{sadr} = I_{spdr} * u_a$

$I_{sbdr} = I_{spdr} * u_b$
$I_{scdr} = I_{spdr} * u_c$ (3)

*II) Calculation of Quadrature Components of Reference Supply Current's :-*

The amplitude of quadrature component of reference supply currents is calculated using a PI controller over the average value of amplitude of supply voltage ($V_{tm}$) and its reference counterpart ($V_{tmr}$).

$I_{spqr} = I_{spqr(n-1)} + K_{pq}\{V_{ae(n)} - V_{ae(n-1)}\} + K_{iq} V_{ae(n)}$ (4) Where $V_{ae(n)} = V_{tmr} - V_{tm(n)}$ denotes the error in $V_{tmn}$ calculated over reference $V_{tm}$ and average value of voltage of $V_{tm}$. $K_{pq}$ and $K_{iq}$ are the proportional and integral gains of the PI controller.

The quadrature unit current vectors are derived from in-phase unit current vectors as:

$W_a = (-u_b + u_c)/\sqrt{3}$
$W_b = (u_a\sqrt{3} + u_b - u_c)/ 2\sqrt{3}$
$W_c = (-u_a\sqrt{3} + u_b - u_c)/ 2\sqrt{3}$ (5)

3-ϕ quadrature components of the reference supply currents ($i_{saqr}$, $i_{sbqr}$, $i_{scqr}$) are calculated using their amplitude and quadrature unit currents vectors as:

$i_{saqr} = I_{spdr} * W_a$
$i_{sbqr} = I_{spdr} * W_b$
$i_{scqr} = I_{spdr} * W_c$ (6)

*C) Calculation of Total Reference Supply Current's:-*

Three phase instantaneous reference supply currents are calculated by adding in-phase and quadrature components expressed as:

$i_{sar} = i_{sadr} + i_{saqr}$

$i_{sbr} = i_{sbdr} + i_{sbqr}$

$i_{scr} = i_{scdr} + i_{scqr}$ (7)

A hysteresis current controller is employed over the reference and sensed supply currents to create gating pulse of IGBT's of the DSTATCOM. This gives suitable gating signals for all the three lags of VSI.

## V. MATLAB BASED CIRCUITRY OF DSTATCOM

This written material illustrates the model of DSTATCOM on with programmable voltage source. A programmable supply is ingestion in to the variety of loads is show in fig 3 (a), 3 (b) & 3 (c). The PI controller is tuned to regulate the ac terminal voltage at the PCC. The power as well as control circuit are shaped in Matlab / Simulink and fig 3 (a) show system with linear load, fig 3(b) shows system with Non linear load and fig 3(c) shows system with induction load. A small capacitor filter is attached to the PCC.

The DSTATCOM configuration has a voltage source inverter molded using universal bridge from PSB toolbox library. It uses IGBTs each shunted by a reverse parallel connected fast switching freewheeling diode. The Linear and Induction Motor loads are connected to the output of the system. The linear load on the system is represented by 3-ϕ resistive-inductive (R-L load) for lagging power factor. Switches are suitably connected for building the load either balanced or unbalanced. The Induction Motor load attached is delineated in the form resistive load attached across a 3-ϕ diode rectifier. In the DSTATCOM system controller block basically contains several subsystems like measurement system, mention current generation, ac voltage regulation loop, PI controller and hysteresis current controller. Fig 3(a) shows the Simulink Circuitry of DSTATCOM with Linear Loads & fig 3 (b) shows the Circuitry of DSTATCOM with Non linear load and fig 3 (c) shows the

Circuitry of DSTATCOM with Induction Motor Loads

***Hysteresis controller**:-*

Hysteresis controller is used independently for each phase and directly creates the switching signals for the switches of the inverter. The error signal is the difference between the reference current and the actual current. If the error current outstrip the top limit of the Hysteresis band, the upper switch of the inverter arm is turned OFF and the lower switch is turn ON. If the error current crosses the bottom limit of the Hysteresis band, the lower switch is turn OFF and the upper switch is turned ON. Fig 4 shows MATLAB based circuit of Hysteresis controller

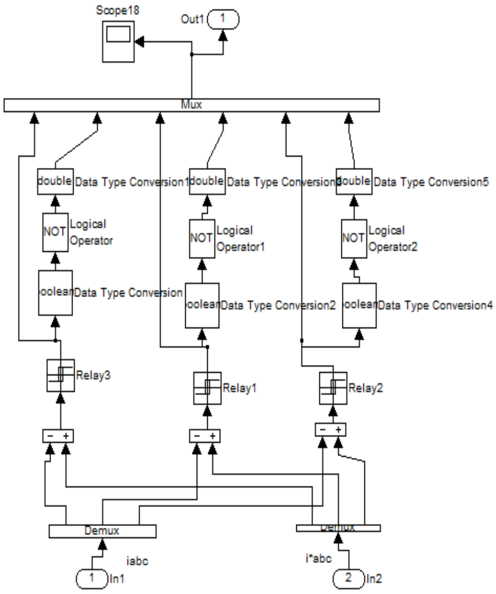



***Fig 4.** MATLAB based circuit of Hysteresis controller*

## VI. RESULTS & ANALYSIS OF VARIETY OF LOAD

### (1) LINEAR LOAD RESULT DESCUSSION

Performance characteristics of the DSTATCOM system of Linear load are given in Fig. 5 (a), (b), (c) shows Compensation current ($I_c$), $I_s$ harmonics spectrum and $I_l$ harmonics spectrum. The required parameters of the system are given in PARAMETER.

### (2) NONLINEAR LOAD RESULT DESCUSSION

Performance characteristics of the DSTATCOM system of Non-Linear load are given in Fig. 6(a), (b), (c), (d), (e) and (d) shows variation of source current ($I_s$), Load current ($I_l$), Gate pulse, $I_s$ harmonics spectrum, $I_l$ harmonics spectrum, $I_c$ harmonics spectrum. The required parameters of the system are given in PARAMETER. Shows the THD of

### (3) INDUCTION MOTOR LOAD RESULT DESCUSSION

Performance characteristics of the DSTATCOM system of Induction Motor load are given in Fig. 7(a), (b), (c), (d), (e) and (g) shows variation of Induction Motor load current wave form, Compensating current when load is Induction motor, Source voltage & current wave form when load is Induction motor,Stater current of Induction motor, Rotor speed of induction motor, Harmonics order of load current when load is Induction motor., Harmonics order of source current and voltage when load is Induction motor. The required parameters of the system are given in PARAMETER.

In this paper linear load, non linear load and induction motor load THD of Source current ($I_s$) and load current ($I_l$) is also given in table no. 1.

**Table No. 1**

| Types of Load | THD % Without Compensation | | THD % With Compensation | |
|---|---|---|---|---|
| | $i_S$ | $i_L$ | $i_S$ | $i_L$ |
| **Linear Load** | 0.41 | 0.41 | 0.10 | 0.10 |
| **Non Linear Load** | 25.74 | 25.74 | 0.14 | 3.57 |
| **Induction Motor Load** | 45.12 | 45.12 | 0.1 | 2.51 |

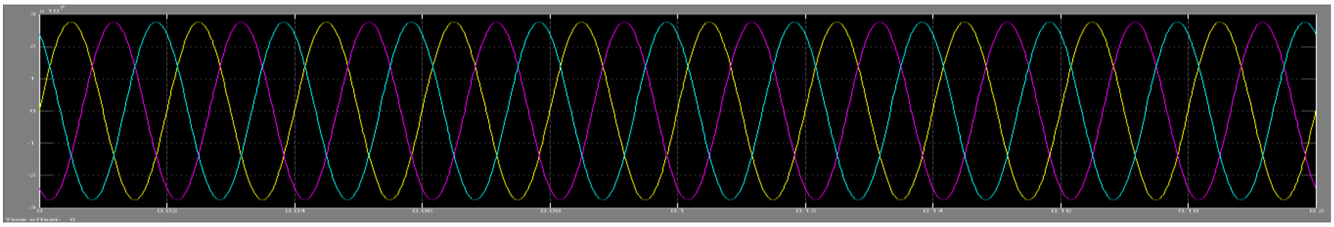


*Fig. 5 (a) Compensation current ($I_c$)*

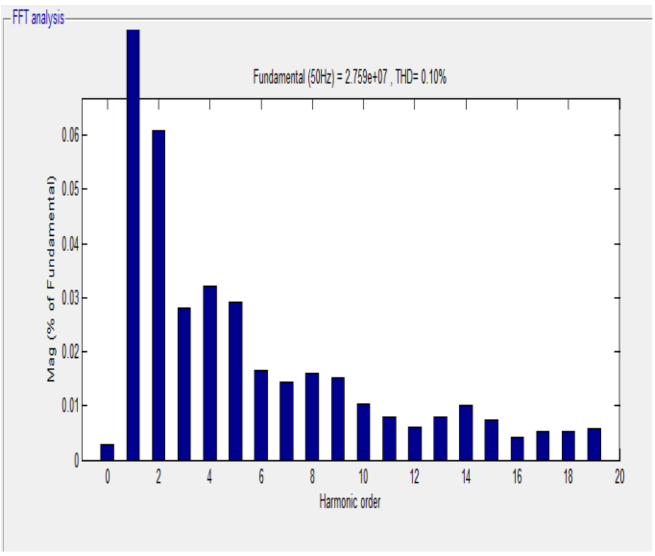



*Fig.5 (b) $I_s$ harmonics spectrum*

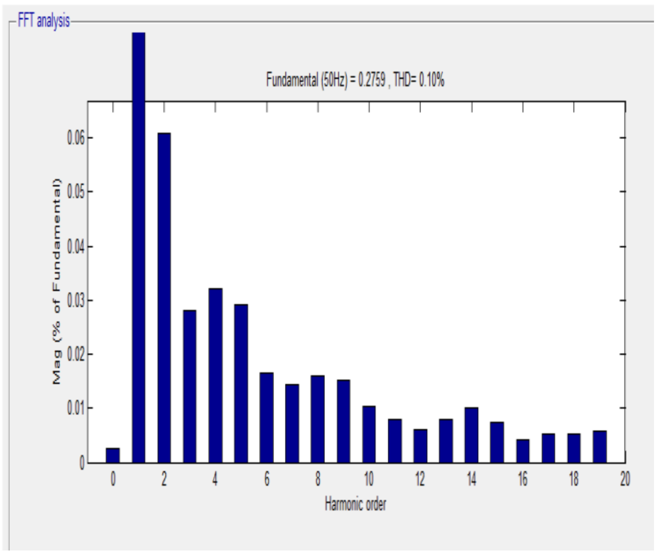



*Fig. 5 (c) $I_l$ harmonics spectrum*

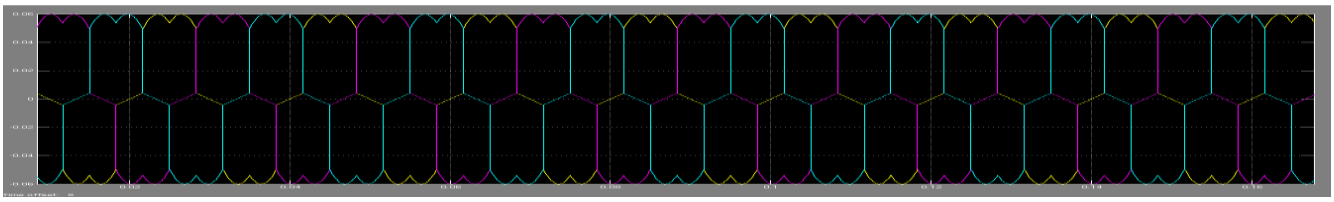


*Fig. 6(a)source current ($I_s$)*

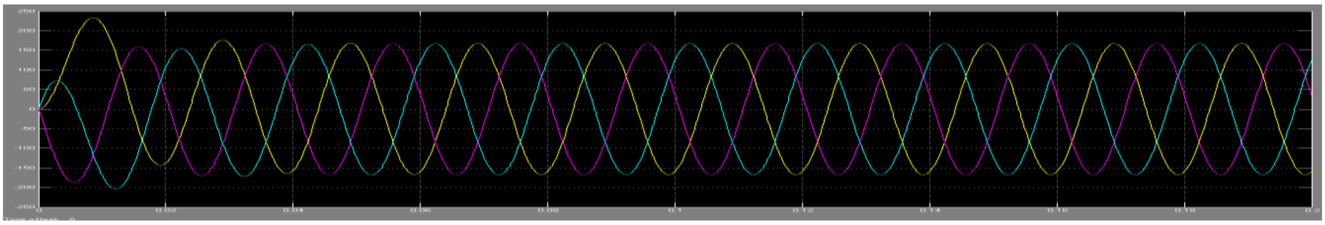


*Fig. 6 (b) Load current ($I_l$)*

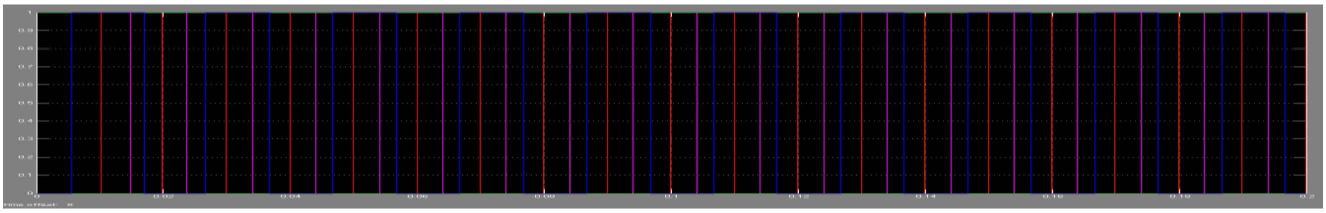


*Fig. 6 (c) Gate pulse*

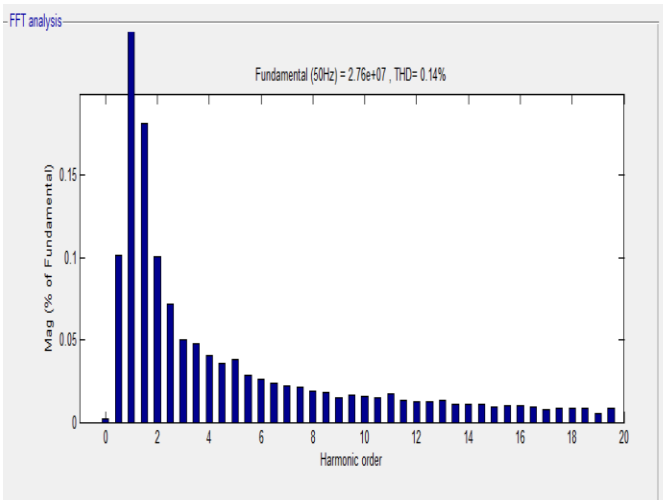



*Fig. 6 (d) $I_s$ harmonics spectrum*

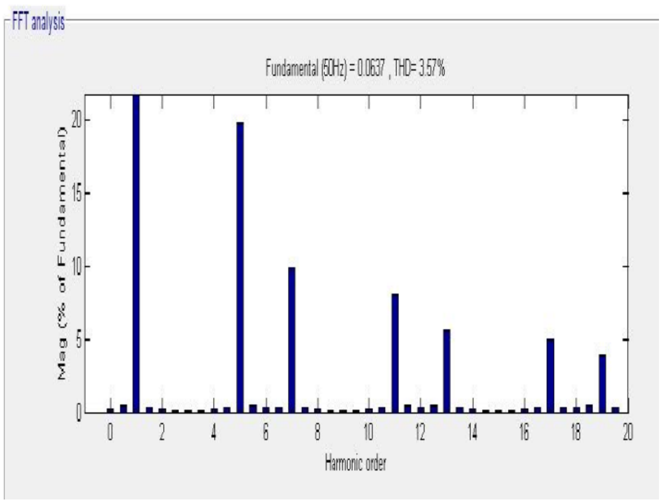



*Fig. 6 (e) $I_l$ harmonics spectrum*

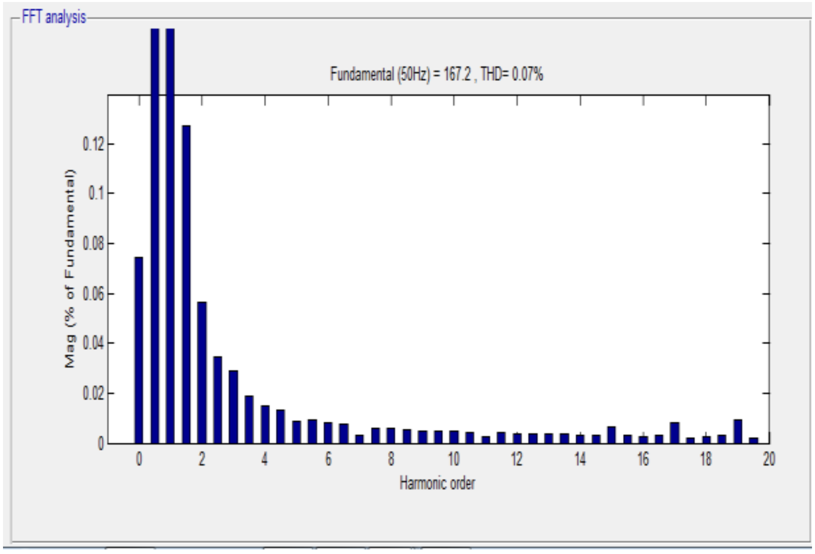



*Fig.6 (f) $I_c$ harmonics spectrum*

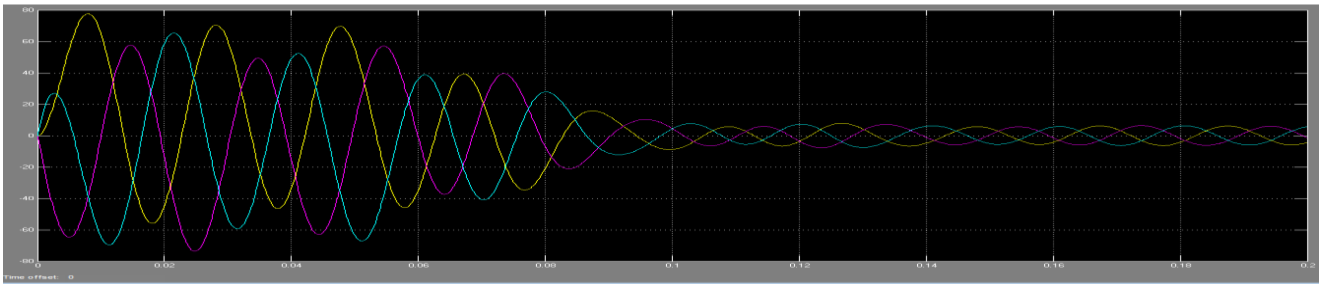
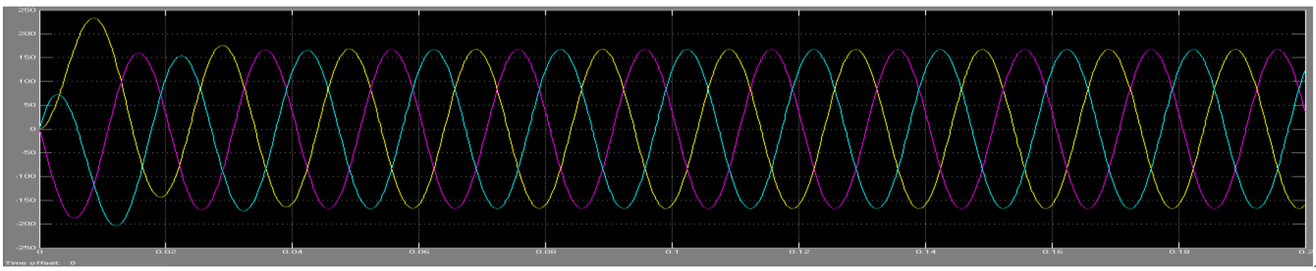


*Fig. 7 (a) Induction Motor load current wave form*



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*ig. 7 (b) Compensating  current when load is Induction motor.*

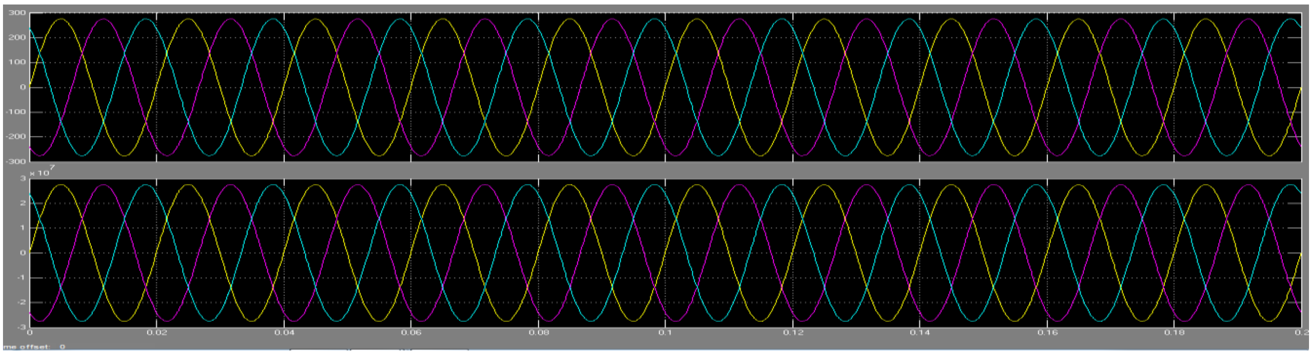

*Fig. 7 (c) Source voltage & current wave form when load is Induction motor*

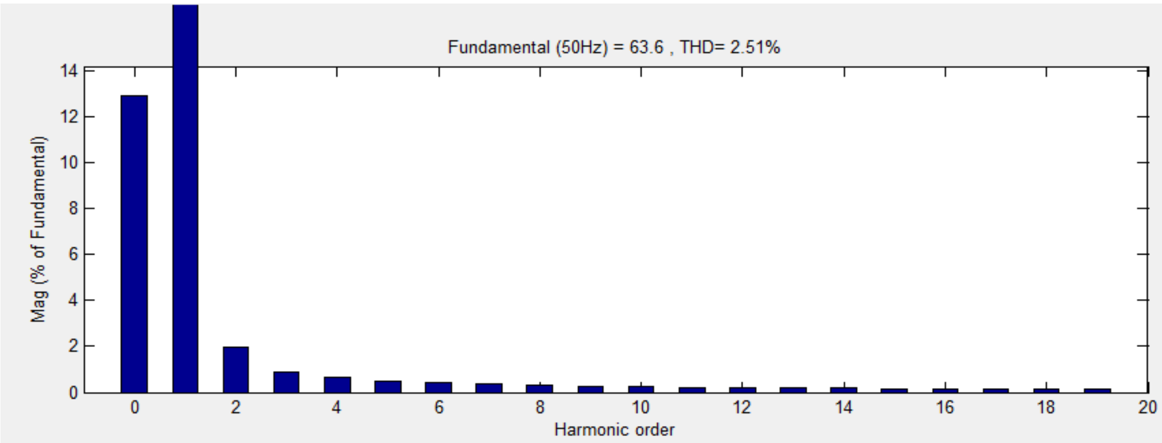


*Fig. 7 (f) Harmonics order of load current when load is Induction motor.*

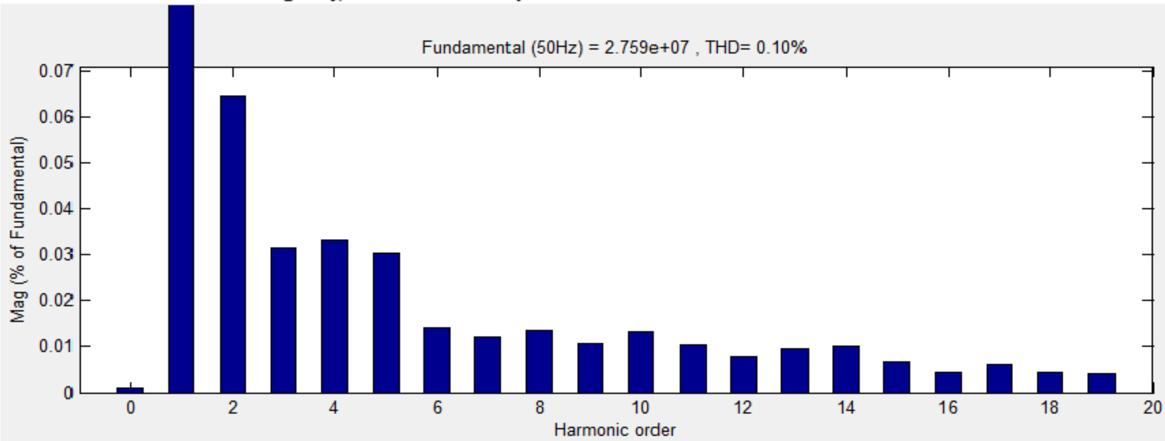


*Fig 7 (g) Harmonics order of source current and voltage when load is Induction motor*

 

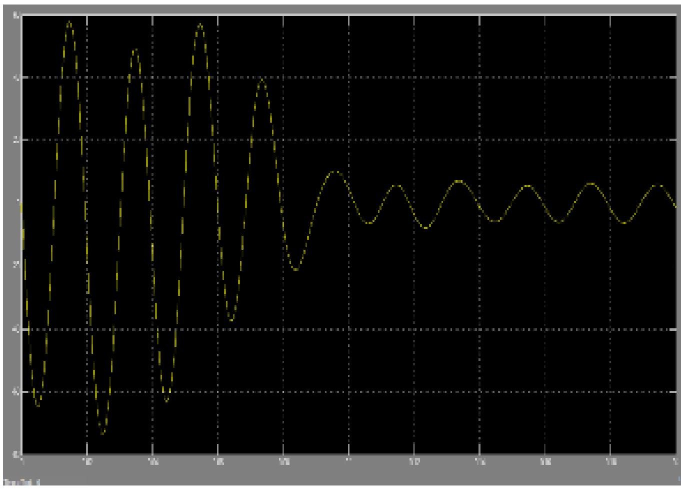

*Fig 7 (d) Stater current of Induction motor.*

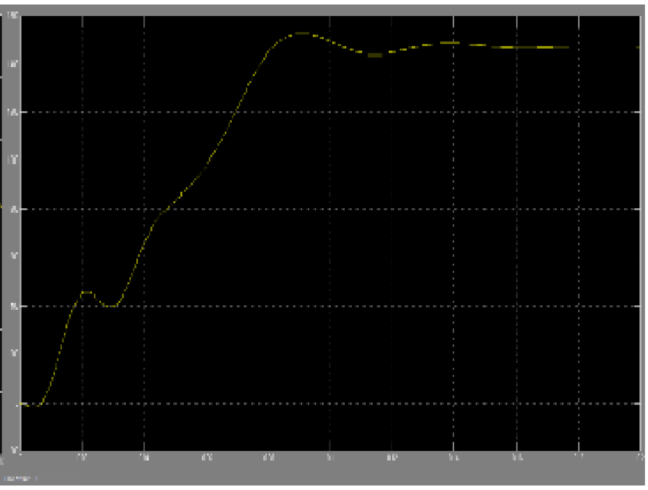

*Fig 7 (e) Rotor speed of Induction motor*

## VII. CONCLUSION

A model of D-STATCOM has been developed in MATLAB environment using Power System Block-set. The performance of the developed model is tested under a wide variety of loading conditions. It is found that DSTATCOM is capable of minimizing the harmonics and reactive power compensation. Indirect current control technique has been applied over the sensed and reference supply currents for DSTATCOM and it has been found to be a simple technique. Only one PI controller is required to regulate terminal voltage and thus reduces computation effort. The control algorithm of the DSTATCOM is flexible and has been tested for power quality improvement for linear as well as nonlinear and Induction motor loads. DSTATCOM is able to reduce harmonics in voltage at PCC and supply currents to less than 5% IEEE 519 standards. DSTATCOM reduces harmonics in load current to a large extent and provides quality power.

## PARAMETERS

Nominal Power ($P_n$ )– 3730 VA, Voltage (line -line) ($V_n$)– 338 $V_{rms}$, Frequency ($F_n$) – 50 Hz , Stator Resistance ($R_s$) – 1.115 ohm and Inductance ($L_{ls}$)– 0.005974 H, Rotor Resistance ($R_{r'}$)- 1.083 ohm and Inductance ($L_{lr'}$)- 0.005974 H, Mutual Inductance ($L_m$)- 0.2037 H, Inertia (J) – 0.02 $Kgm^2$ , Friction Factor (F) – 0.005752 N.M.S. , Pole Pair (p) – 2,$L_c$= 5mH, $R_c$ = 0.1Ω, $h_b$=0.5A, $C_1$=5000F, $R_l$ = 1000 Ω, P = 0.43, I = 0.15, D = 0.

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