OPEN ACCESS

International
Journal
Of Modern Engineering Research (IJMER)

Simulation and Analysis of a D-STATCOM for Load Compensation and Power Factor Improvement

Gaurav Pundlik
(B.Tech, Electrical Engineering department, Visvesvaraya National Institute of Technology (VNIT) (NIT Nagpur) Nagpur

Abstract: *Power Generation and Transmission is a complex process, requiring the working of many components of the power system in tandem to maximize the output. One of the main components to form a major part is the reactive power in the system. It is required to maintain the voltage to deliver the active power through the lines. Loads like motor loads and other loads require reactive power for their operation. To improve the performance of ac power systems, we need to manage this reactive power in an efficient way and this is known as reactive power compensation. In developing countries like India, where the variation of power frequency and many such other determinants of power quality are themselves a serious question, it is very vital to take positive steps in this direction.*
The work presented here illustrates a method to compensate for the load reactive power using a DSTATCOM
A DSTATCOM injects a current into the system to provide for the reactive component of the load current. The validity of proposed method and achievement of desired compensation are confirmed by the results of the simulation in MATLAB/ Simulink.
Index Terms: *DSTATCOM, Load compensation, Power factor correction, Reactive Power.*

I. Introduction

The power quality in the distribution system is contaminated due to high reactive power burden, distorted and unbalance load currents .Due to excessive reactive power demand, there is an increase in transmission & distribution losses, increased voltage sag, increase in the current on source side and reduction in active power flow capability of the distribution system.

Further, the operation of transformers and generators are also affected due to unbalancing of currents and it also increases the size of utility. Therefore, reactive power compensation of a distribution system is mandatory. Poor power factor loads and load balancing is an important issue in the modern power distribution system. The power indices are governed by various standards such as IEEE-519 standard hence it is extremely essential to keep the power factor close to unity. For the above stated purpose a STATCOM is used in this paper The primary requirements of any compensator are firstly ,to stay in synchronism with the ac system under all conditions and on occurrence of fault the compensator must regain synchronism immediately . Secondly to be able to regulate the bus voltage for voltage support and improved transient stability .Thirdly to inject the required amount of reactive current into the system when used for load compensation.

For load compensation, we need to generate the required amount of reactive power using some other means. Various methods are available for reactive power generation like variable impedance type reactive power generation. Here we have devices like Thyristor controlled reactor. thyristor switched capacitor , Fixed capacitor and thyristor controlled reactor combination , Thyristor switched capacitor and Thyristor controlled reactor . These devices are now not much in use because of their characteristics and losses. Now a days STATCOM is widely used for reactive power compensation and source power factor improvement.

II. Statcom

A STATCOM system is nothing but a three phase inverter connected to the grid through a reactor and a connecting transformer. In the three phase inverter instead of a DC battery , a capacitor is used to provide the DC link voltage . A controller is used to control the voltages ,phase and the frequency of the STATCOM to maintain synchronism with the grid.

The active and reactive power transfer between the power system and the STATCOM is caused by the voltage difference across this reactance. The STATCOM is connected in shunt with the power networks at customer side, where the load compensation. All required voltages and currents are measured and are fed into the controller to be compared with the commands. The controller then performs closed loop feedback control and outputs a set of switching signals to drive the main semiconductor switches (IGBT's, which are used at the distribution level) of the power converter accordingly.

By varying the amplitude of the output voltages produced, the reactive power exchange between the converter and the ac system can be controlled.

If the amplitude of the output voltage is increased above that of the ac system voltage, then the current flows through the reactor from the STATCOM to the ac system, and the STATCOM generates reactive (capacitive) power for the ac system. If the amplitude of the output voltage is decreased below that of the ac system, then the reactive current flows from the ac system to the STATCOM, and the STATCOM absorbs reactive (inductive) power. In a practical inverter, the semiconductor switches (IGBT) are not lossless, and there for the energy stored in the dc capacitor would be used up by the internal losses. However, these losses can be supplied from the ac system by making the output voltages of the converter lag the ac system voltages by a small angle.

In this way the inverter absorbs a small amount of real power from the ac system to replenish its internal losses and keep the capacitor voltage at the desired level. The mechanism of phase angle adjustment can also be used to control the var generation or absorption by increasing or decreasing the capacitor voltage, and thereby the amplitude of the output voltage produced by the inverter. A STATCOM used in the distribution system is generally called as a DSTATCOM.

The basic block diagram of the STATCOM is as shown in Fig (1).

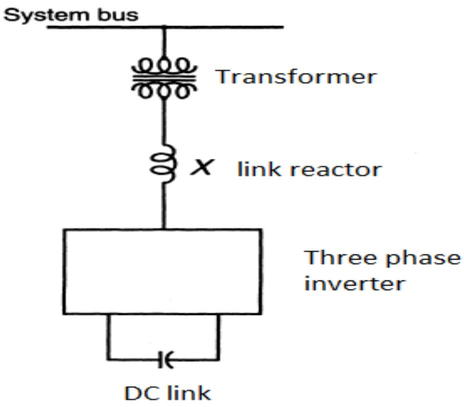


Figure 1 .Block diagram of D STATCOM

The phasor diagram for reactive power flow from the STATCOM refer Fig (2).

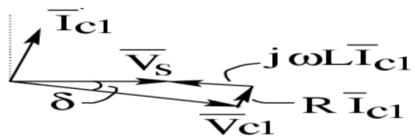


Figure (2) : phasor diagram for reactive power flow from the DSTATCOM .

The phasor diagram for reactive power flow to the D STATCOM is as shown in Fig(3).

Figure(3) : phasor diagram for reactive power flow to the DSTATCOM

III. Statcom Controller

The internal control is an integral part of the converter. Its main function is to operate the inverter power switches so as to generate a fundamental output voltage waveform with the demanded magnitude and phase angle in synchronism with the ac system. In this way the power inverter with the internal control can be viewed as a sinusoidal, synchronous voltage source behind a reactor, the amplitude and phase angle of which are controlled by the external control via appropriate reference signals.

To achieve this we have two control approaches, one where we control the dc capacitor voltage (which in turn is controlled by the angle of the output voltage) and second where we use internal voltage control mechanism PWM of the inverter in which case the dc voltage is kept constant (by the control of the angle od lag behind the grid voltage which is required for active power absorbtion , which in turn is required for losses in the STATCOM). Here we use the second type of control .

Block diagram of the control circuit:

For controlling the modulation index for PWM refer Fig (4):

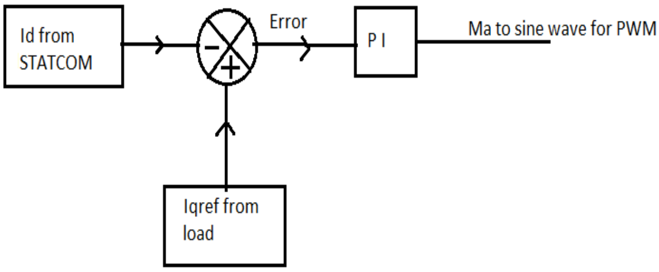


Figure (4): Control circuit for the modulation index for PWM.

The control circuit for controlling the lag behind the grid voltage the circuit is as shown in Fig(5).

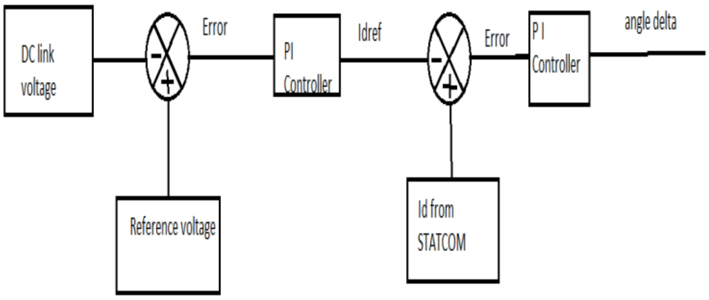


Figure (5): control circuit for the control of the angle δ .

Thus the input signals required for the controller are , the bus voltage , the inverter output current ,the reference current from the load , and the reference DC link voltage. The dc voltage reference determines the real power the STATCOM must absorb from the ac system in order to supply its internal losses. For the control of the modulation index we require two inputs those are the Iqref from the load side and the Iqstatcom .Now this Iqref is got from the load side by taking the load current and converting the abc components of this current to the equivalent dq0 components by using parks transformation which is explained later . A similar procedure is followed for the statcom currents. The q component is then compared and this error is given to the PI controller which governs the modulation index.

Thus when modulation index increases the statcom voltage increases and the statcom currents increase because of which the Iqstatcom increases and tries to be equal to the load Iqref . For the control circuit of the angle delta . The angle delta is the angle by which the statcom output voltage will lag the grid voltage to absorb the requisite amount active power for its switching and other losses.

The inputs for this control are the DC link voltage (voltage of the capacitor) and the reference voltage (which is what ideally the capacitor voltage should be). This error drives a PI controller which gives us the reference for the active current to be drawn by the statcom . This Idref is the compared with the Idstatcom got by abc to dq0 transformation of the statcom output currents .The error of Idref and Idstatcom drives the PI controller to give us delta . Thus when delta increases , the statcom voltage lags behind the grid voltage even more and more active power is drawn to compensate for losses due to switching and to maintain the capacitor voltage constant.

IV. Parks Transformation (ABC To Dq0 Transformation)

In the case of balanced three-phase circuits, application of the dqo transform reduces the three AC quantities to two DC quantities. Simplified calculations can then be carried out on these DC quantities before performing the inverse transform to recover the actual three-phase AC results. It is often used in order to

simplify the analysis of three-phase synchronous machines or to simplify calculations for the control of three-phase inverters and their gating pulses. For this transformation there are two aspects . One is the abc to α-β transformation and the other is α-β to dq transformation.
The matrix for abc to α-β transformation is:

$$\begin{bmatrix} f_\alpha \\ f_\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \times \begin{bmatrix} f_a \\ f_b \\ f_c \end{bmatrix}$$

The matrix for α-β to dq transformation is:

$$\begin{bmatrix} f_d \\ f_q \end{bmatrix} = \begin{bmatrix} \cos(\phi) & \sin(\phi) \\ -\sin(\phi) & \cos(\phi) \end{bmatrix} \times \begin{bmatrix} f_\alpha \\ f_\beta \end{bmatrix}$$

Where ϕ is the frequency at which we want to rotate the α-β frame ± the angle between the frames.
A sample output for this transformation is:-
Input:

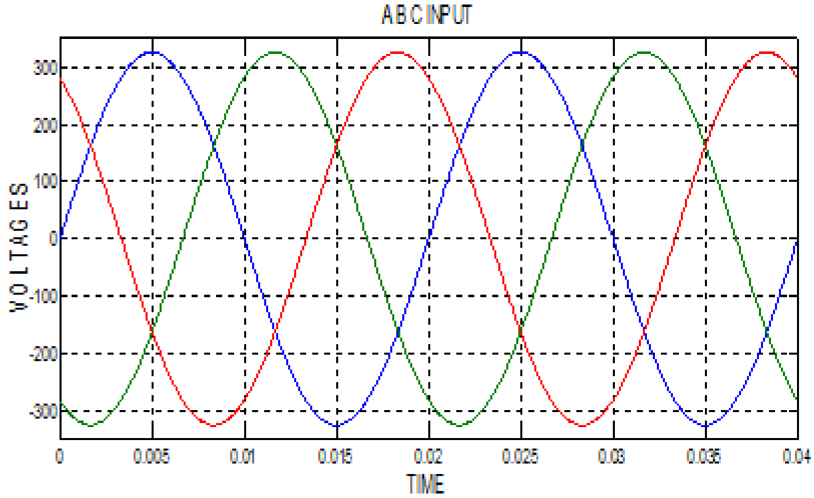


Figure (6) .Sample input for abc to dq0 transformation

Output:

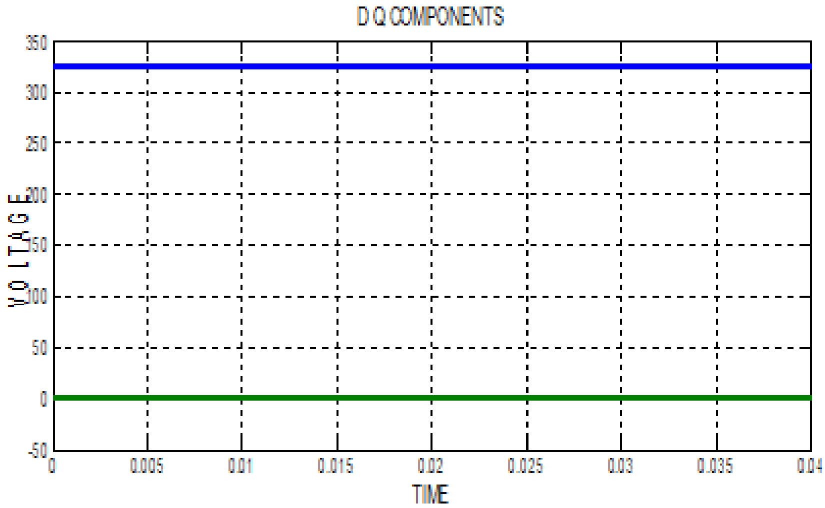


Figure (7), Sample output from abc to ddq0 transformation

V. Three Phase Pll

It is necessary for the power factor control to detect the accurate phase information of the utility voltages. Therefore, the phase-locked loop (PLL) can be considered to be an important part of grid-connected power generation systems. The block diagram for implementing the three phase PLL is as follows:

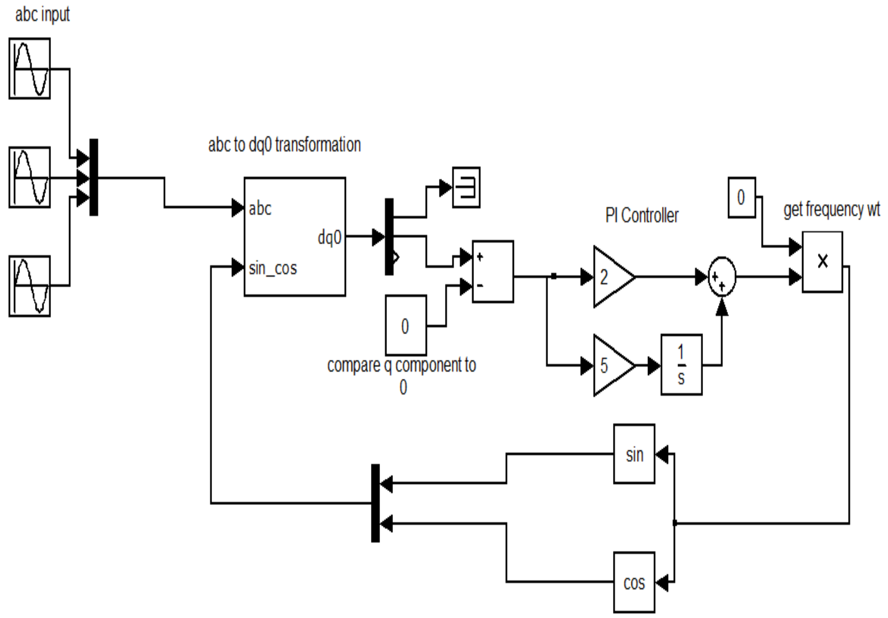


Figure (8) Implementation of three phase PLL

VI. Single Line Diagram Of The System

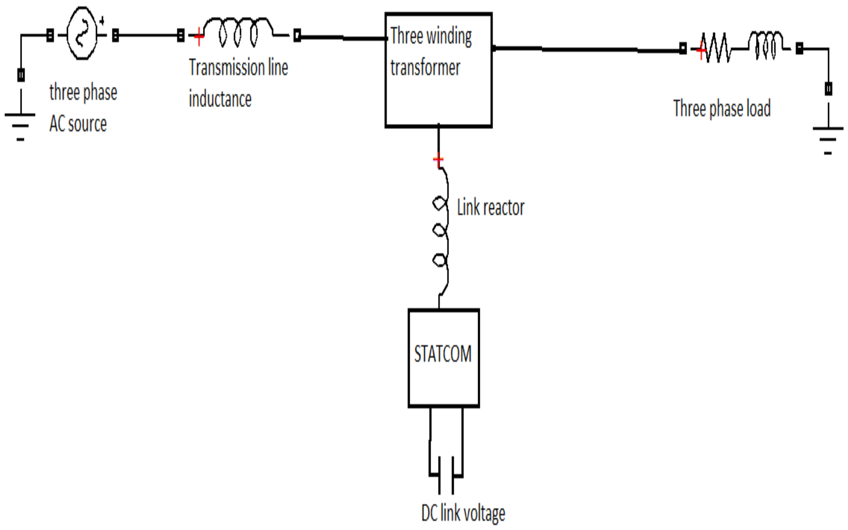


Figure (9) Single line diagram of the system

VII. Simulink Model Of The System

The simulink model for the test system is as shown it consists of a source , a inductance between the source and the point where the STATCOM is connected to the system to represent the transmission line inductance , the three winding transformer and the load. The STATCOM consists of the DC link capacitor the three phase inverter connected to the three winding transformer . It also consists of a three phase PLL connected to the load side. It consists of two control circuits. One of that of the modulation index and the lower one of the angle δ.

The modulation indexis then multiplied with the sine waves of the gating pulses which are then compared with the ramp wave to get us the gating pulses.

The waveforms are thus :

m_a*sin(wt- δ) , m_a*sin(wt-(2π/3)-δ) and m_a*sin(wt+(2π/3)-δ).

The Simulink model is as shown in Fig(10)

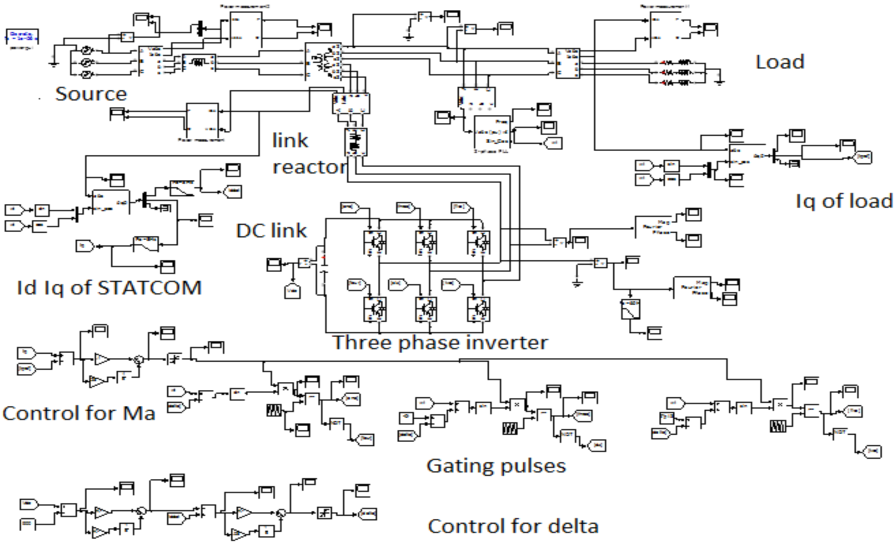
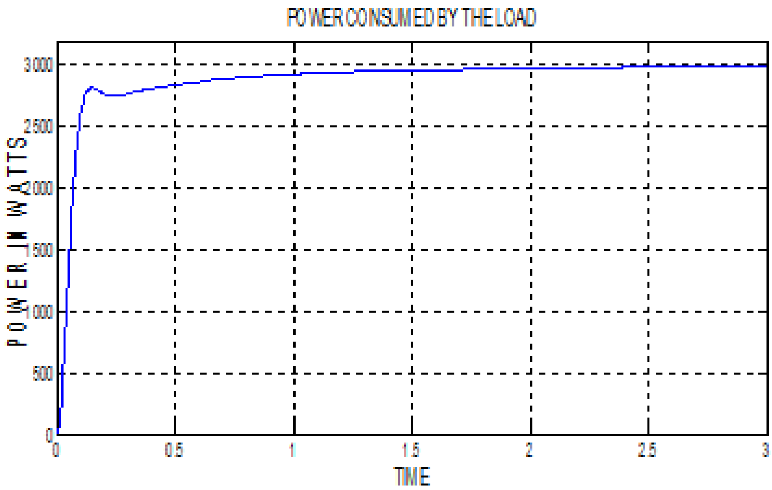


Figure (10). Simulink model of the system

The plot of the power consumption of the load side is as follows:-
Active power is shown in Fig (11)



Figure(11) : Active power consumed by the load .

Reactive power is shown in Fig (12)

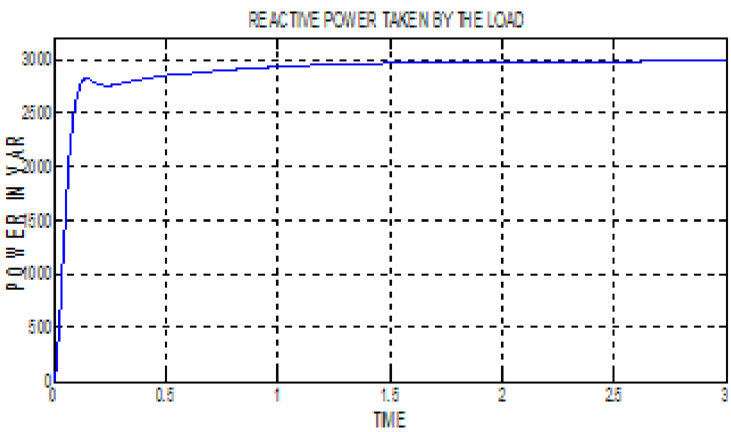


Figure (12) : Reactive power consumed by the load

A plot of the load currents is shown in Fig(13)

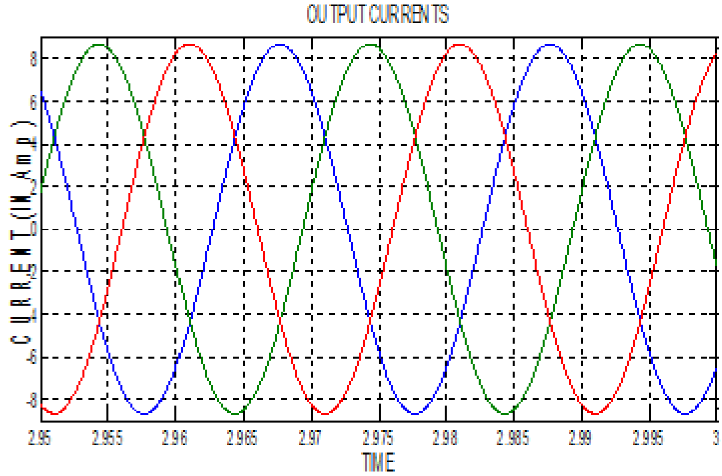


Figure (13) Aplot of the load side currents

The plots of the D STATCOM are:
A plot of the STATCOM current is shown in Fig (14).

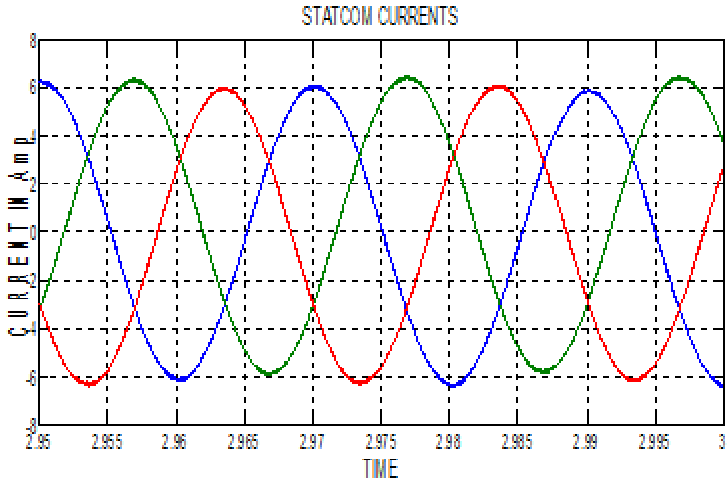
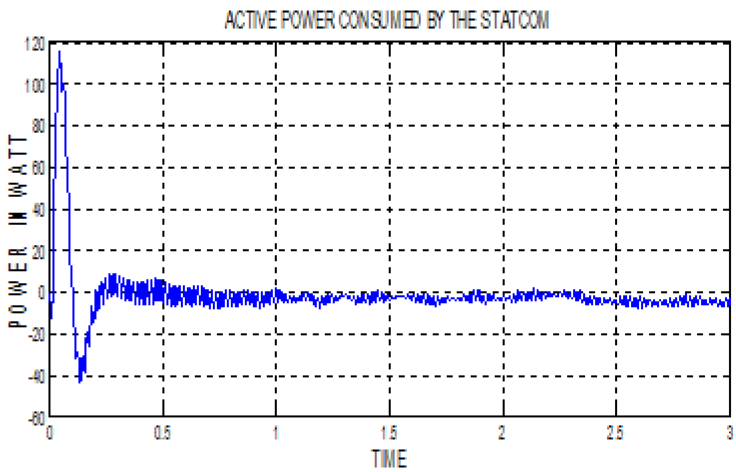


Figure (14) STATCOM currents

Active power taken by the STATCOM is shown in Fig(15) .



Figure(15) Plot of the active power taken by the STATCOM.

Note that the active power here is negative because it is being taken from the source not given unlike the reactive power which is given and is shown as positive.

The reactive power given by the STATCOM is shown in Fig(16) .

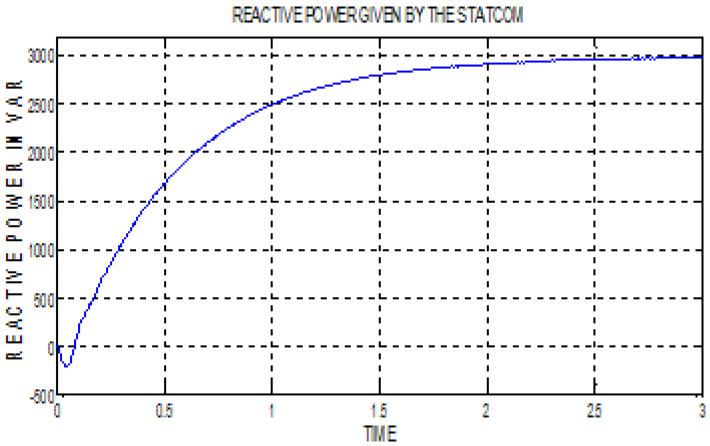
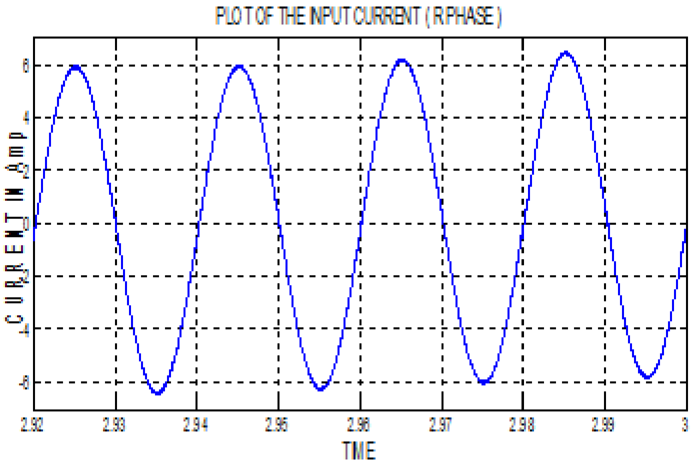


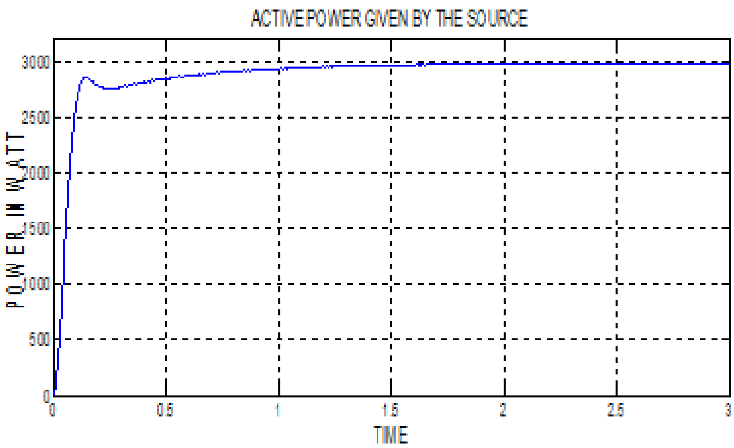
Figure (16) .Reactive power given by the STATCOM

The plots concerning the source evaluation are:-
Source current (of R phase) is shown in Fig(17).



Figure(17). Source current

Active power Supplied by the Source is shown in Fig(18).



Figure(18) Active power supplied by the source .

The reactive power supplied by the source is shown in Fig (19).

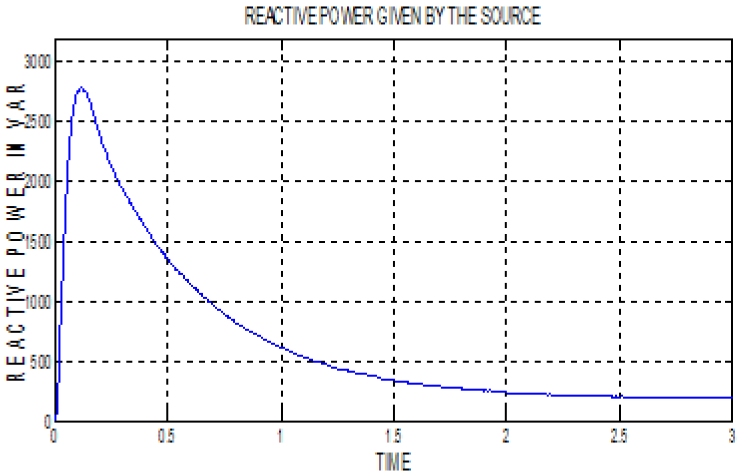


Figure (19) Reactive power supplied by the source

Note that here some reactive power is still given by the source because of the reactance kept near the source to represent the source inductance and the inductance of the transmission lines

VIII. Conclusion

The comparison between load side current and the source side current gives us that the source side current is lesser in magnitude than the load side current as the source does not have to supply reactive power. This indicates that a higher amount of load can be supplied from the same transmission line on using a STATCOM to compensate for the reactive power of the load . Thus power transfer capacity is increased.

The source active power is seen at 3000 W and the reactive power at 200 VAR. Thus the source power factor is 0.9977 (close to 1).Thus the source power factor correction is achieved.

The reactive power supplied by the STATCOM and that consumed by the load are equal .Thus the reactive power of the load is given by the STATCOM .Thus load compensation by the STATCOM is achieved .

IX. Future Work

The possibilities for the future work in the field of STATCOM and load compensation are many. A multilevel inverter can be used. The control circuit can employ fuzzy controller PR controller or adaptive PI fuzzy controller. The devices can be set to work on PV cells or wind power.

REFERENCES

[1] N.G.Hingorani,"Flexible AC Transmission", IEEE Spectrum, vol. 30, pp.40-44,1993.
[2] K.K. Sen, "STATCOM: Theory, Modeling, Applications,"in IEEE PES 1999 Winter Meeting Proceedings, pp. 11 77-1183.
[3] Mohan, T. M. Undeland, andW. P. Robbins, Power Electronics: Converter Applications and Design. New York: Wiley. 1995.
[4] Sangita Nandurkar, Design and Simulation of three phase Inverter for grid connected Photovoltic systems, Proceedings of third biennial national conference NCNTE – 2012 Feb 24-24
[5] H. Rashid, "Power Electronics" 2nd edition, Elsevier, Inc, Publication, California, U.S.A 2007.
[6] pierre Giroux , Modeling and Simulation of a Distribution STATCOM using Simulink's Power System Blockset, IEEE industrial electronics society
[7] B.S.Krishna Varma , Simulated Control System Design of a Multilevel STATCOM for Reactive Power Compensation , ICAESM- 2012 March 30,31 2012 .
[8] Ravilla Madhusudan ," Modeling and Simulation of a Distribution STATCOM (D-STATCOM) for Power Quality Problems-Voltage Sag and Swell Based on Sinusoidal Pulse Width Modulation (SPWM) ", ICASEM- 2012 March30 ,31 2012
[9] Dr. P.Linga Reddy ," A DSTATCOM-Control Scheme for Power Quality Improvement of Grid Connected Wind Energy System for Balanced and Unbalanced Non linear Loads ", IJMER vol 2 issue 3 may 2012 pp 661-666 .