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Simulation and Analysis of Static Synchronous Compensator (STATCOM) Using Instantaneous Reactive Power (pq) Theory

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Abstract — *The fast switching solid stat converter based FACTs device play important role in modern power system. Static synchronous compensator (STATCOM) is most versatile FACTs device to control power system parameters in steady-state and dynamic condition. It can control reactive power and improve the power factor of the power networks. This paper propose a control scheme based on Instantaneous reactive power (pq) Theory for compensating reactive power of linear load. In this paper, controlling of two-level, six-pulse VSC based STATCOM is presented with instantaneous reactive power(pq) theory based control strategies for reference current generation.*

Keywords-component; *Power Quality, reactive power compensation, STATCOM, VSC, Instantaneous reactive power (pq) Theory*

I. INTRODUCTION

Reactive power compensation of non-linear and/or linear loads is an important issue in the modern power system. Reactive power increase transmission system losses, reduced power transmission capability, large amplitude variations in the receiving-end voltage. Static synchronous compensator (STATCOM) provides reactive power to the system and improves the power factor of the system. Its work as dynamic operation for control system under stressed condition. In this paper the main focus is on STATCOM.It has been providing reactive power to the load and improve power factor of system. The main benefits of STATCOM are quick response time, less space requirement, optimum voltage platform, higher operational flexibility and excellent dynamic characteristics under various operating conditions [2]. **editor.ijarest@gmail.com**

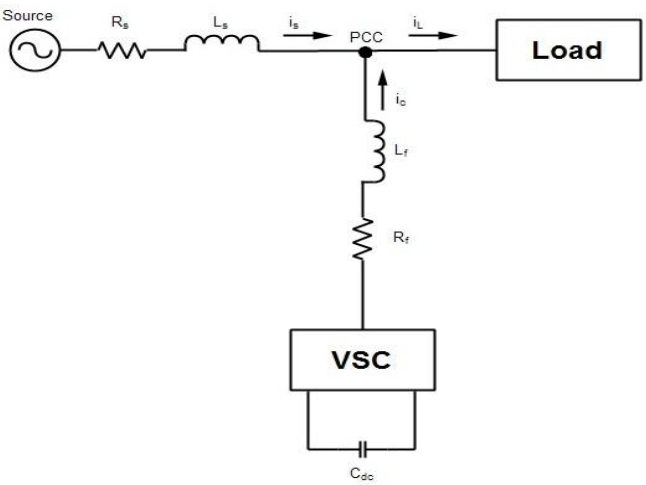


Fig.1 Single line diagram of STATCOM

STATCOM is shunt connected reactive power compensation device which is parallel connected between source and load at point of common coupling (PCC).Voltage source converter(VSC) based topology used to generate or absorb of reactive power. In this paper, STATCOM is controlled reactive power and improve power factor of system using instantaneous reactive power theory and maintain the converter DC-link voltage constant.STATCOM provide reactive power as per load demand and improve Power factor on source side.

II. SYSTEM CONFIGURATION

STATCOM system consist two groups,

a. Power Circuit: Voltage Source Converter(VSC), DC link capacitor, Interface Filter
b. Control Circuit: Reference Current Generation, Current Control

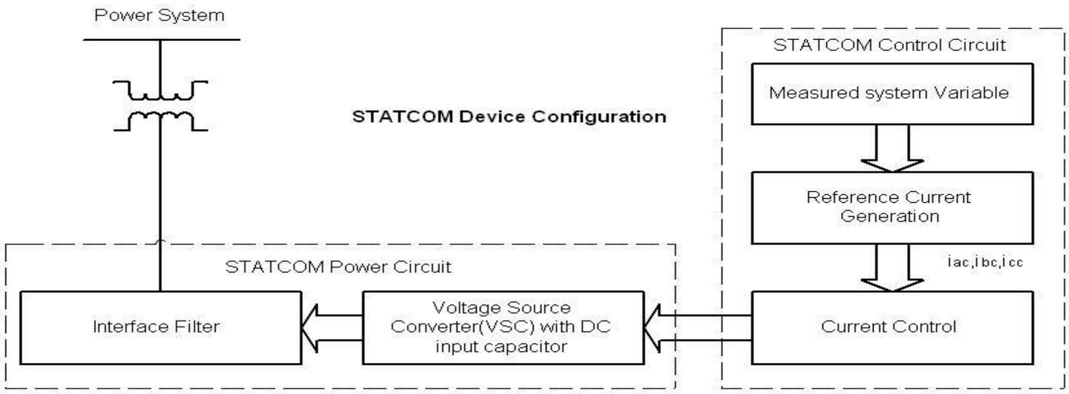


Fig.2 Block diagram for system configuration

The basic block diagram for STATCOM system configuration is shown in figure 2. The control objectives of the STATCOM are to regulate the dc-side current and give the required reactive power compensation as per load demand [4].The voltage source converter circuit convert DC power to AC power.VSC is energized by DC link capacitor. A DC link capacitor provides constant DC link voltage.VSC is connected with interface filter on AC side of converter. An interface filter provides current waveform without ripple and it's also used for cancelation of ripple from current. The interface filters are L filter or LCL filter for design of STATCOM. Same as the control circuit consist the reference current generation by using different current control methods. In this paper, instantaneous reactive power (pq) theory based methods is used for reference current generation. Reference current control by PI based current control technique and the current compared by using PWM, SPWM based control of STATCOM.

III. POWER TOPOLOGY

A Voltage Source Converter (VSC) is used to realize a STATCOM. The structure of the VSC decides the extent of compensation it can provide. For a particular type of distribution system a certain simple topology of VSC maybe sufficient but for others a more complex topology maybe required [13].Voltage source converter (VSC) based power topology is widely used for STATCOM application. The DC side of converter is capacitor as a source so the higher order of current harmonic component is present in VSC based STATCOM.The AC side of converter consider the interface filter for reduce the ripple current and gives the sinusoidal. The different types of two-level or three-level and multi-level power topologies are accepted in the design of STATCOM.Generally, two-level, six-pulse VSC topology used for compensator.

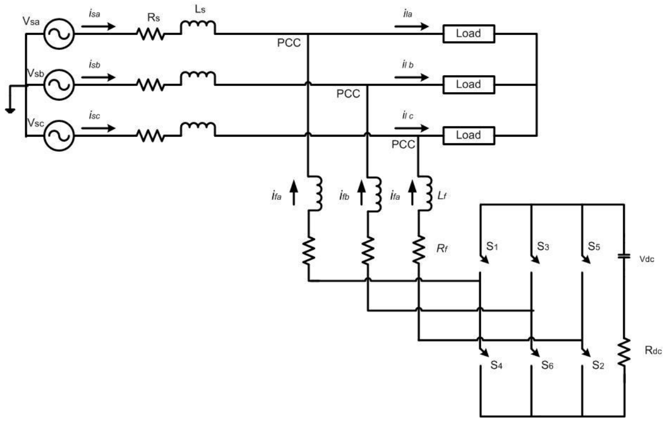


Fig.3 VSC-based STATCOM

The schematic circuit diagram of VSC-based STATCOM is shown in figure 3.Two-level VSC based STATCOM is shunt connected between source and load. Interface filters are reduced ripple of current and improve the current waveform. The linear or nonlinear loads are connected and VSC is handle the absorption or generation of reactive power.

IV. CONTROL STRETEGY

Different types of control algorithm consider for reference current generation for STATCOM. In this paper, the control strategies used for reference current generation is based time domain. Instantaneous Reactive Power (IRP) Theory is proposed by H.Akagi in 1984.It's also known as pq-theory. H.Akagi introduced the concept of instantaneous reactive power. This is the time domain method. This concept gives an effective method to compensate for instantaneous components of reactive power for three-phase system without energy storage [9].

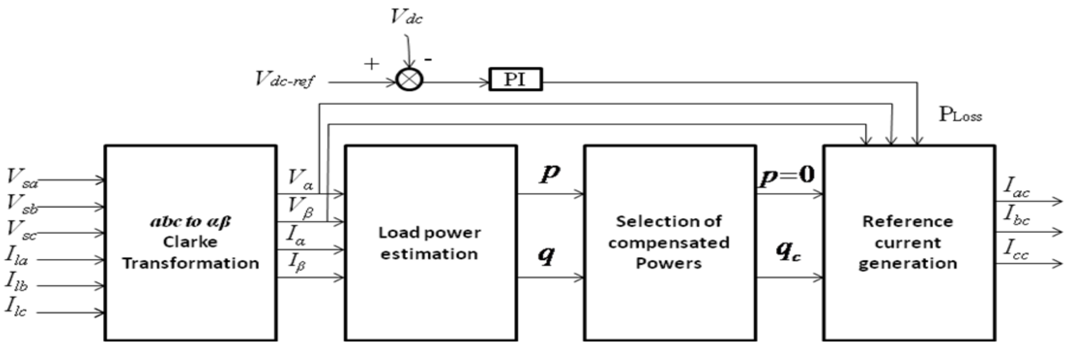


Fig.4 Block Diagram of Instantaneous reactive power (p-q) Theory

The basic block diagram for understanding of pq-theory is given in figure 4. The measured variables from the system are given in Clarke transformation for abc to αβ (alpha-beta) transformation. It's calculate the value of Vα,Vβ and Iα,Iβ.than its calculate the active and reactive power in terms of p and q.In the case of STATCOM there is only reactive power (q) is compensated and its given to inverse Clarke transformation generates reference current from αβ (alpha-beta) to Iac,Ibc,Icc.

4.1 Equations for Clarke Transformation

Instantaneous reactive power theory calculates the active and reactive power both. Active power denoted as (p) and reactive power denoted as (q). The Clarke Transformation for three phase instantaneous voltage in abc-phase V_a, V_b, V_c into αβ0-axes V_α, V_β, V_0 is given by[10]:

$$\begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

And its inverse transformation is

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_0 \\ v_\alpha \\ v_\beta \end{bmatrix}$$

Similarly, three-phase instantaneous line current i_a, i_b, i_c can be transformed on the αβ0-axes i_α, i_β, i_0 is given by:

$$\begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix}$$

And its inverse transformation is

$$\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & 1 & 0 \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix}$$

The and axes make no contribution to zero-sequence component, no zero-sequence current exists in three-phase three-wire system. So V_0 & i_0 can be eliminating from the above equations. The Clarke Transformation for voltage and current.

$$\begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix}$$

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

And its inverse transformation is

$$\begin{bmatrix} v_a \\ v_b \\ v_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & 0 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} v_\alpha \\ v_\beta \end{bmatrix}$$

Now, from the above equation three instantaneous power in terms of-the instantaneous zero sequence power p_0, the instantaneous real(active) power p and the instantaneous imaginary(reactive) power q from the instantaneous phase voltage and line current on αβ0 axes as[10]:

$$\begin{bmatrix} p_0 \\ p \\ q \end{bmatrix} = \begin{bmatrix} v_0 & 0 & 0 \\ 0 & v_\alpha & v_\beta \\ 0 & -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} i_0 \\ i_\alpha \\ i_\beta \end{bmatrix}$$

For three-phase three-wire system there is no zero sequence current components so $i_0=0$,the instantaneous power is defined on αβ axes as:

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

$$p = v_\alpha i_\alpha + v_\beta i_\beta$$

$$q = -v_\beta i_\alpha + v_\alpha i_\beta$$

The instantaneous current on axes in terms of real (active) and imaginary (reactive) power p and q define in pq-theory as:

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \frac{1}{{v_\alpha}^2 + {v_\beta}^2} \begin{bmatrix} v_\alpha & v_\beta \\ -v_\beta & v_\alpha \end{bmatrix} \begin{bmatrix} p \\ q \end{bmatrix}$$

4.2 Flowchart of pq-theory for STATCOM

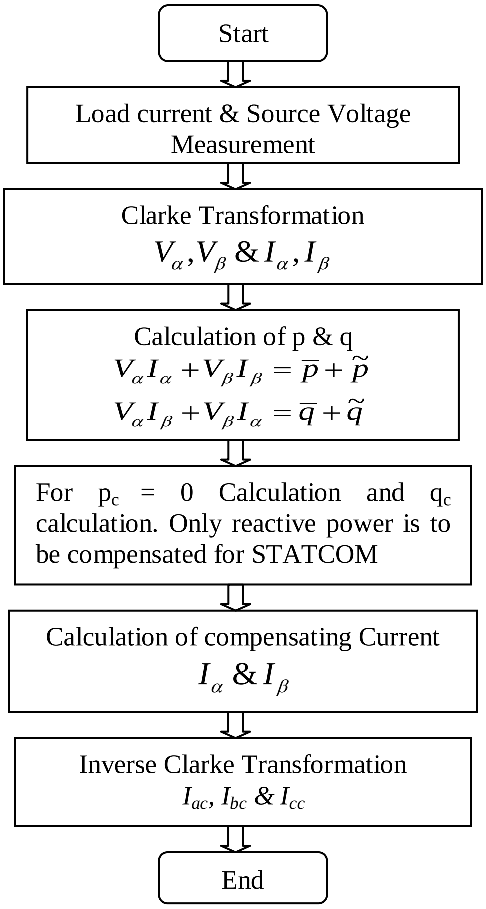
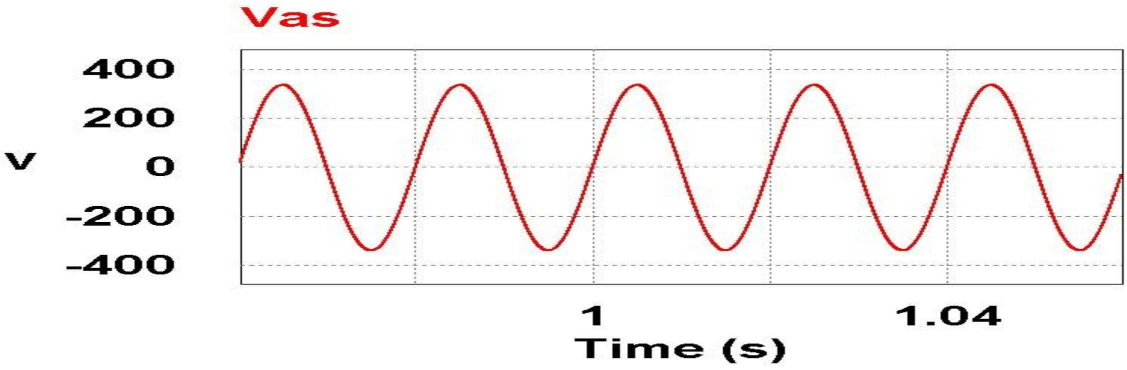


Fig.5 Flowchart of pq-theory for STATCOM

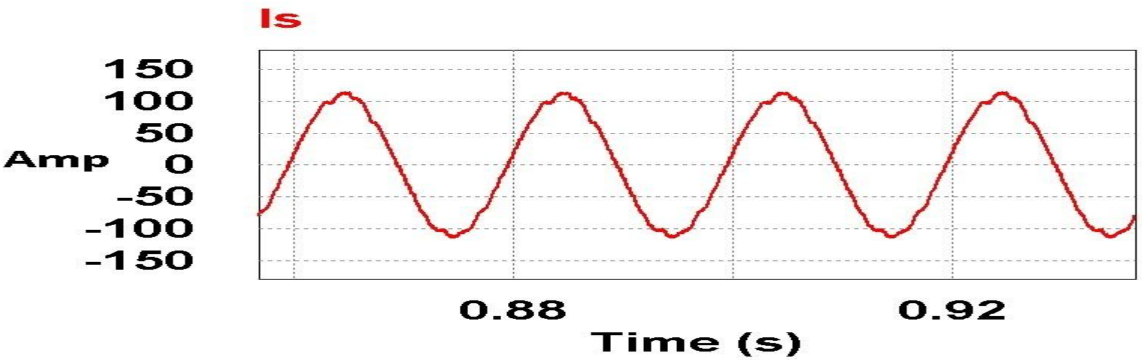
IV. SIMULATION RESULTS

The simulation results using STATCOM device for balanced load/linear load condition is shown in below waveforms. Only reactive power is compensated by STATCOM device and it's improve power factor of system.

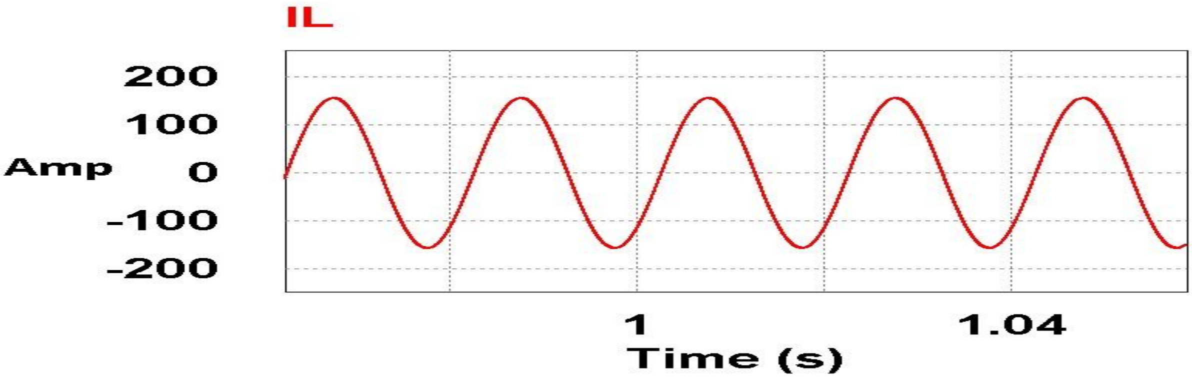
5.1 Source Voltage



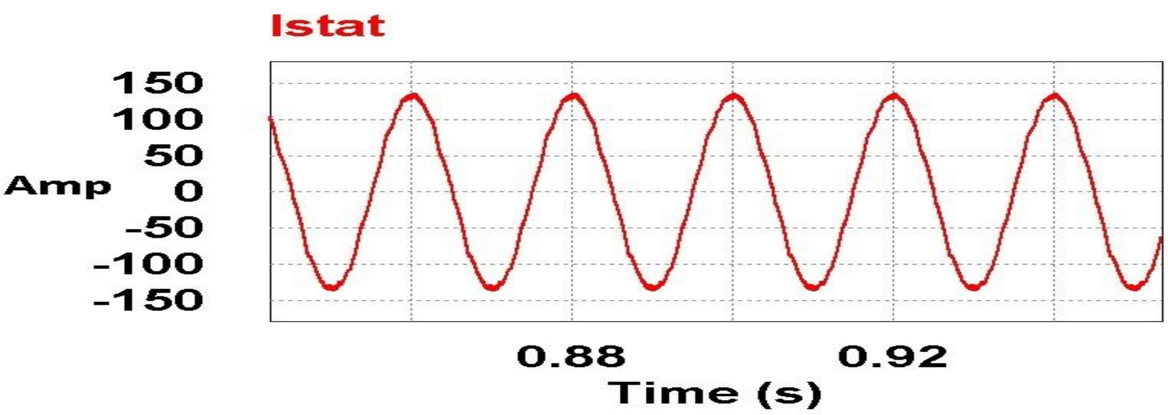
5.2 Source Current



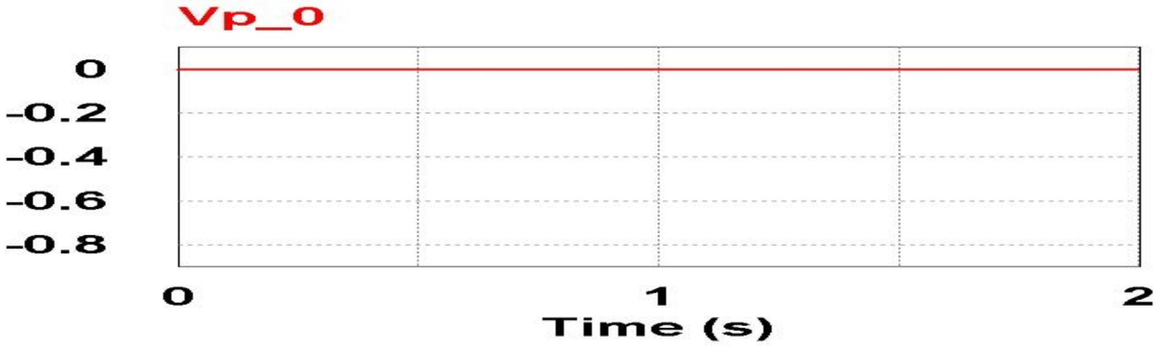
5.3 Load Current



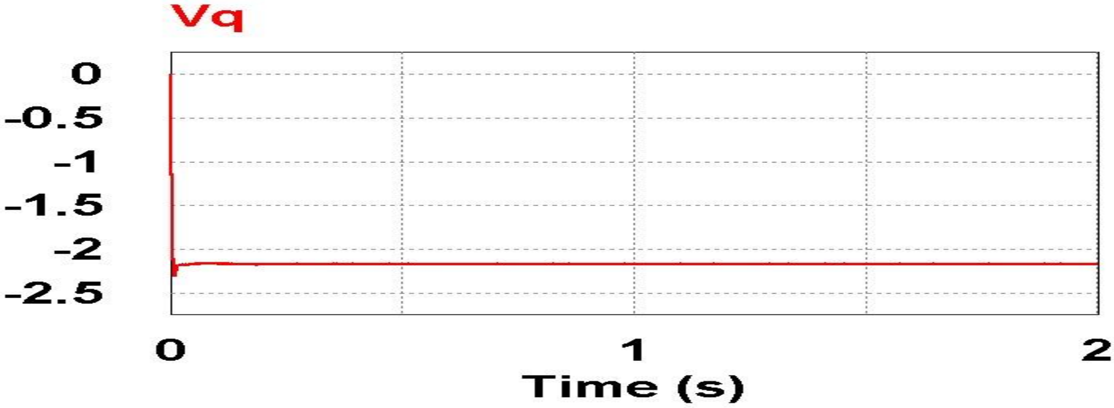
5.4 STATCOM Current



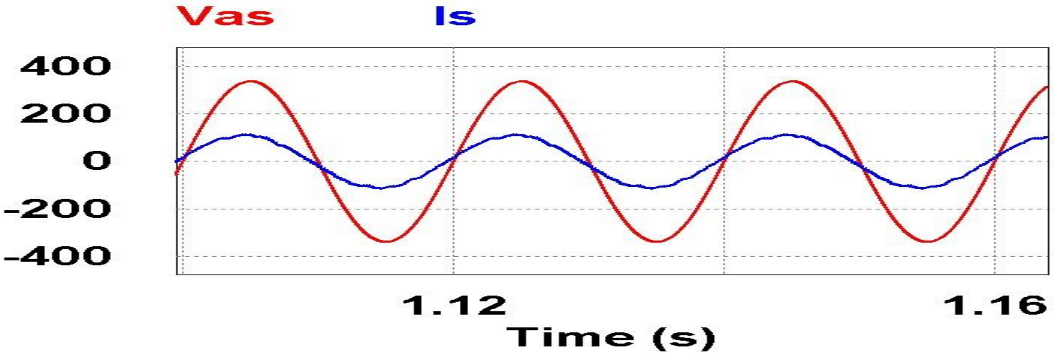
5.5 Active Power (P)



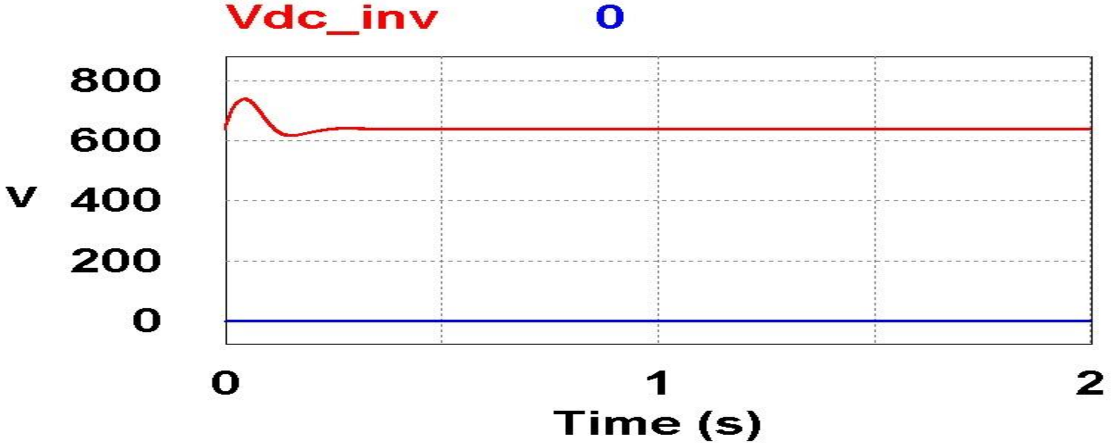
5.6 Reactive Power (Q)



5.7 Source Voltage and Current (Power Factor)



5.8 Inverter DC Voltage



V. FOOTNOTES

STATCOM is shunt connected device to control reactive power and improve power factor of system. The STATCOM is versatile and high speed response device. The instantaneous reactive power pq-theory based control strategy which works in time domain. It directly calculates active and reactive power from three phase source voltage and load current samples. Its only compensates reactive power in case of STATCOM to improve the power factor on source side. This method works on steady state and transient operation.

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