INTERNATIONAL JOURNAL OF RESEARCH IN COMPUTER APPLICATIONS AND ROBOTICS
ISSN 2320-7345

DESIGN ANALYSIS AND SIMULATION OF SRF CONTROLLER OF A STATCOM FOR REACTIVE POWER COMPENSATION

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Abstract: - Due to the high requirement of reactive power of the loads, the conventional supply may not withstand the capacities of these loads which may lead to harmonic generation and voltage flickers in the system. We introduce a control algorithm to control this reactive power called as Synchronous Reference Frame (SRF) theory. The control structure takes a feedback from the grid calculating the required reactive power that has to be compensated by STATCOM. The harmonics produced by the VSC will be eliminated by using LC filters.

I. INTRODCUTION

The utilization of STATCOM in power distribution systems reduces the harmonic content due to reactive power compensation. The load demand for the reactive power is generally supplied by the conventional source. The reactive power exchange between the STATCOM and the load is carried through VSC (Voltage source converter) by PWM technique.

a) PWM technique:

The pulse width modulation technique is generally used for the conversion of DC to AC waveforms. A full bridge inverter with six IGBTs can be used to convert DC to three phase AC. Each phase has to be phase shifted to each other by 120^0 and has to be in synchronization with the grid to which it is being connected. The pulses that have to be given to the IGBTs are generated with a reference or fundamental waveform compared with a triangular waveform. The fundamental waveform has the frequency of the grid and the triangular or carrier waveform has higher frequency to create a modulation signal. The diagram of the fundamental and the carrier waveform are shown below in fig. 7

Six pulses are formed by applying NOT gates to the three pulses produced by the comparison of the fundamental and carrier waveforms. The generated pulses are fed to the VSI (Voltage source Inverter) with G1 G2 G3 G4 G5 and G6 switches. A simple construction of VSI is shown in fig. 6

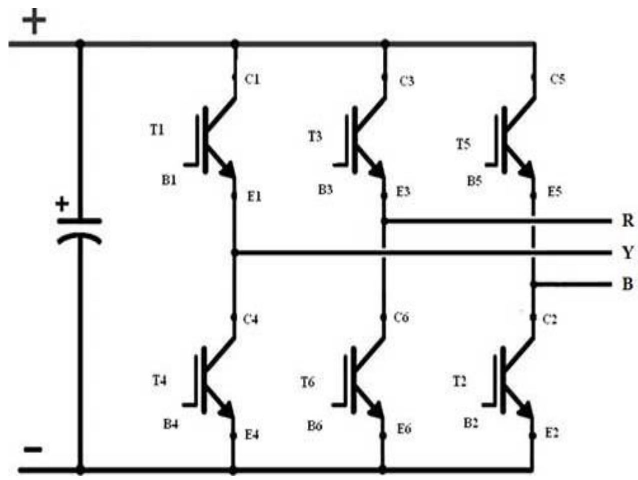

Fig. 1: Voltage source Inverter

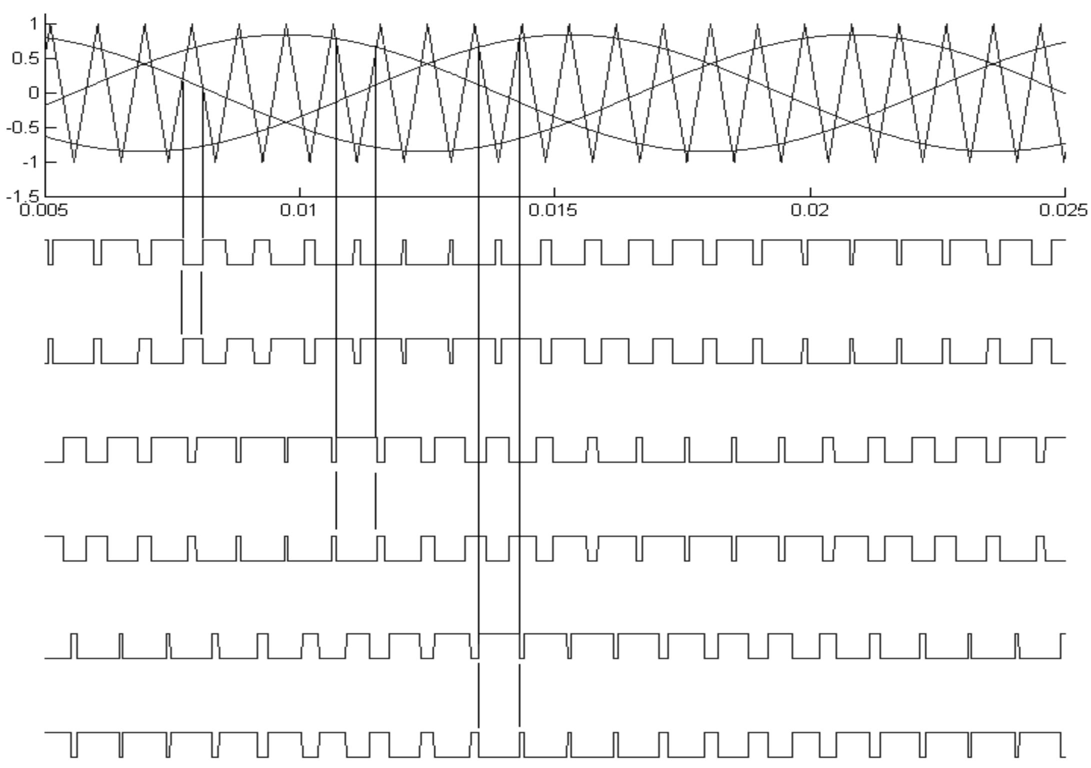

Fig. 2: Generation of pulses with respect to reference fundamental waveforms

The higher the carrier frequency the lower the harmonics developed by the inverter. To eliminate the minimum harmonics we also use LC filter to filter the higher order harmonics from the three phase AC voltage waveforms.

b) Synchronous reference frame theory:

The instantaneous reactive power theory can also be called as p-q theory, where the three phase components are converted to two phase quantities and the calculation of active and reactive power in this frame. A block diagram of p-q theory is given below in fig. 5

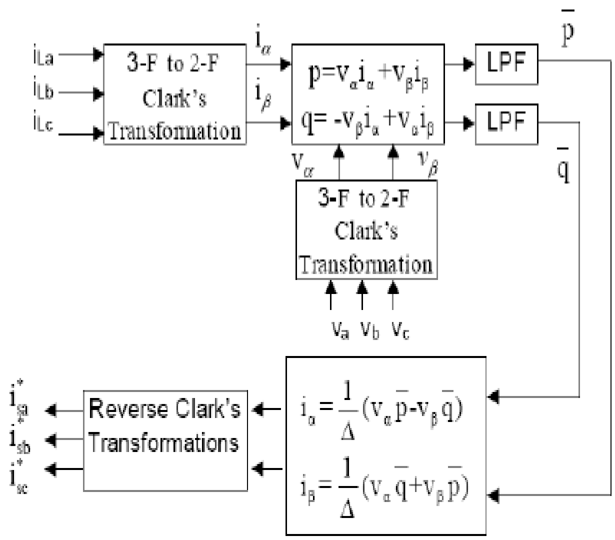

Fig. 3: Block diagram of SRF theory

The calculation comprises of Clarks transformation and Inverse Clarks transformation where the values are achieved by

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

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

The three phase instantaneous active power of the three phase system with a,b and c phase is given as

$$P_{3\phi} = v_a i_a + v_b i_b + v_c i_c$$

By using the transformation the active power can be calculated as

$$P_{3\phi}(t) = v_\alpha i_\alpha + v_\beta i_\beta + v_0 i_0$$

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February 2015

With these values of α and β the values of p and q can be calculated

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

The calculated p and q components are fed to second order filters to reduce the disturbance caused during the change in the system. The filtered outputs are now used to calculated the α and β components of the currents. The two components of the currents are converted to a, b and c reference current values by using Inverse Clarks transformation.

$$\begin{bmatrix} i^*_{fa} \\ i^*_{fb} \\ i^*_{fc} \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1/\sqrt{2} & 1 & 0 \\ 1/\sqrt{2} & -1/2 & \sqrt{3}/2 \\ 1/\sqrt{2} & -1/2 & -\sqrt{3}/2 \end{bmatrix} \begin{bmatrix} -i_o \\ i^*_{f\alpha} \\ i^*_{f\beta} \end{bmatrix}$$

The values of the reference signals are used to generate pulses with the use of PWM (Pulse Width Modulation) and generate the required modulation index pulses with synchronization to the grid.

II. MODELING OF STATCOM

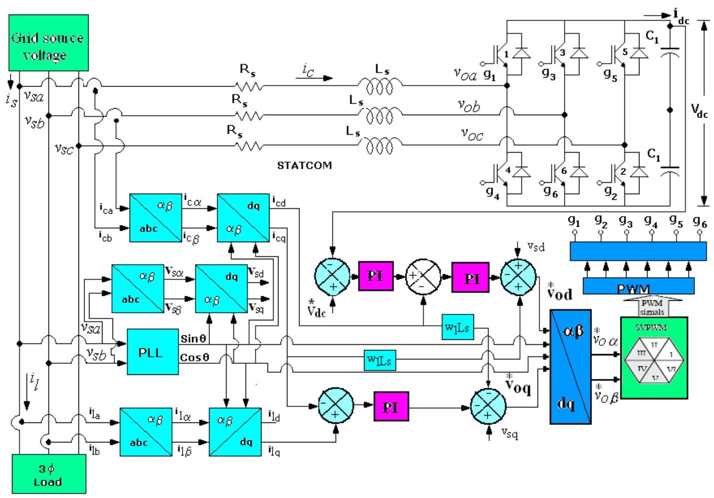

Fig 4: STATCOM with linear control

The control scheme for controlling DC link voltage as well as d and q axes current of STATCOM simultaneously as shown in Fig.6 is implemented with MATLAB SIMULINK with the parameters given in Table. I. The grid phase A voltage and current with linear load is shown in Fig.7. This Fig.7 depicts the lagging power factor of 0.7. The proposed control strategy will help for improving the power factor from 0.7 to nearly unit and this logic will also derive the conclusion for using DC link voltage. The instantaneous voltage of the system and the STATCOM are independent, but the active and the reactive currents are coupled with each other through the reactance of the coupled inductor. So it is very essential to decouple the active and reactive current from each other and design the controller for tracking the required value.

III. SIMULATION AND RESULTS

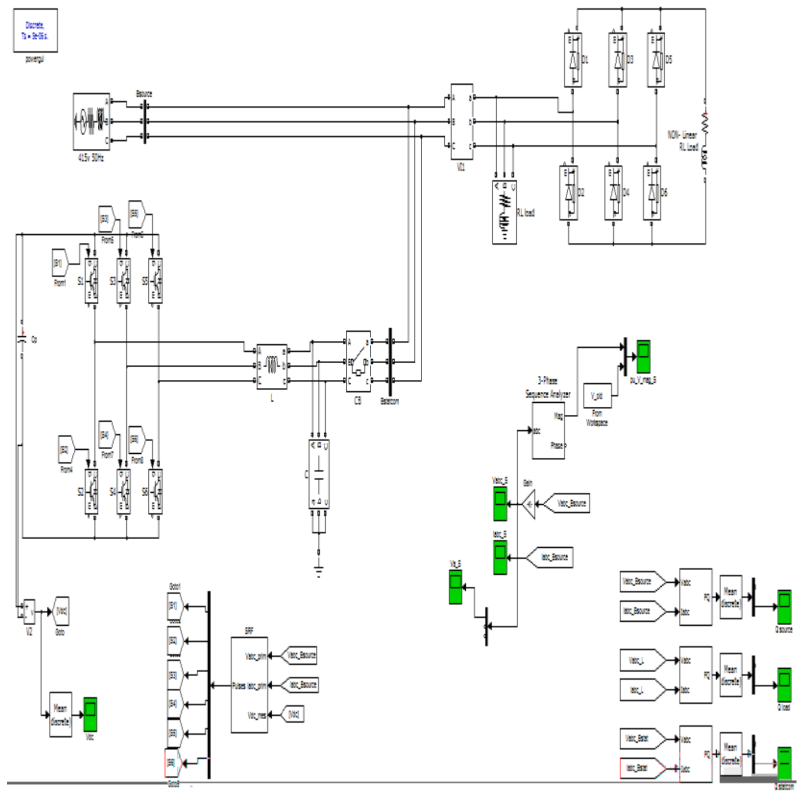

Fig. 5: STATCOM with SRF control model

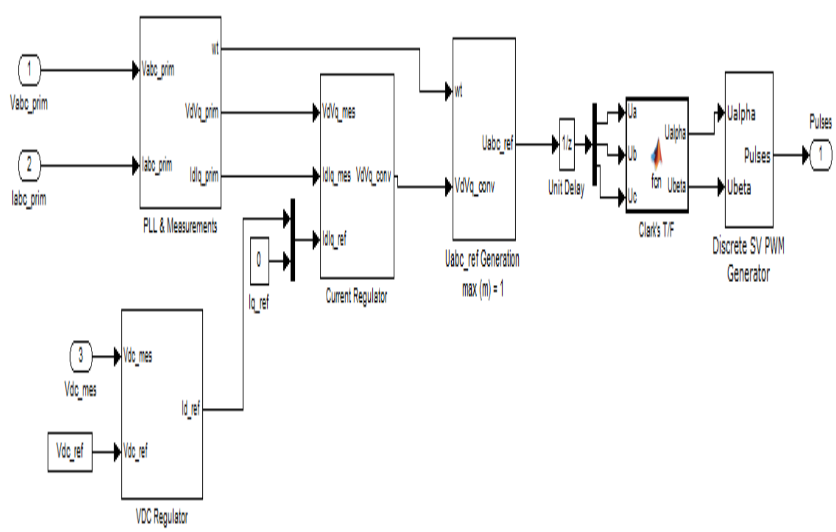

Fig. 6: SRF control model

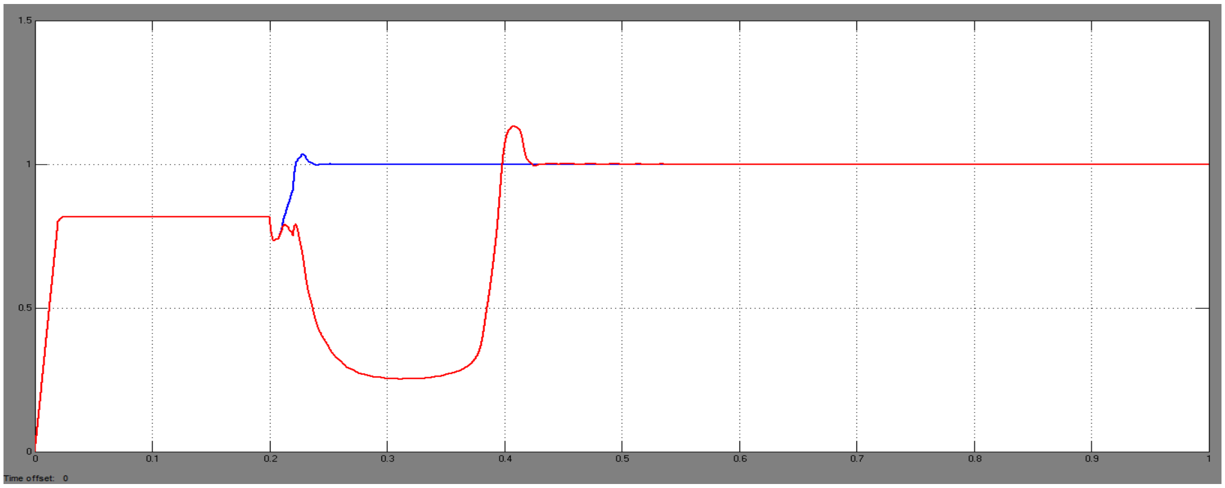

Fig. 7: Phase magnitude Voltage comparison at PCC in pu.

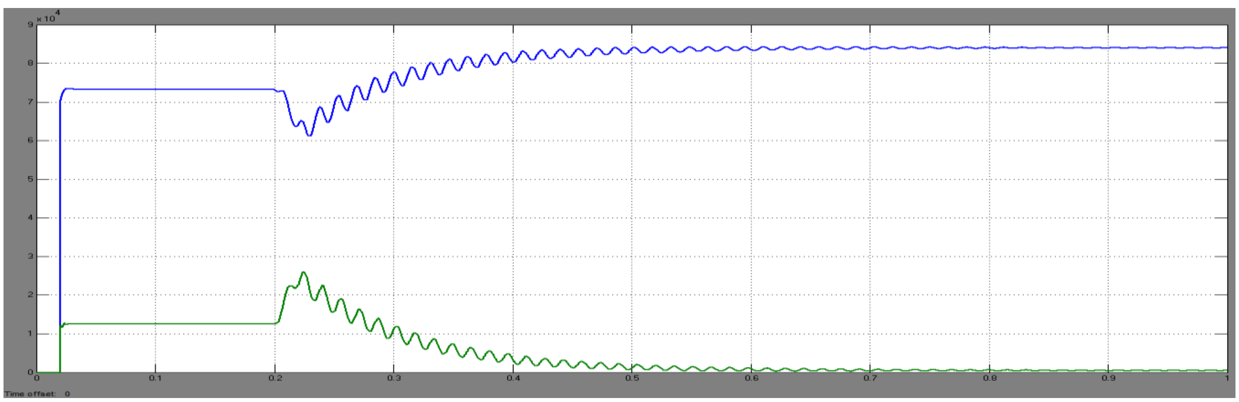

Fig. 8: Source active & reactive power

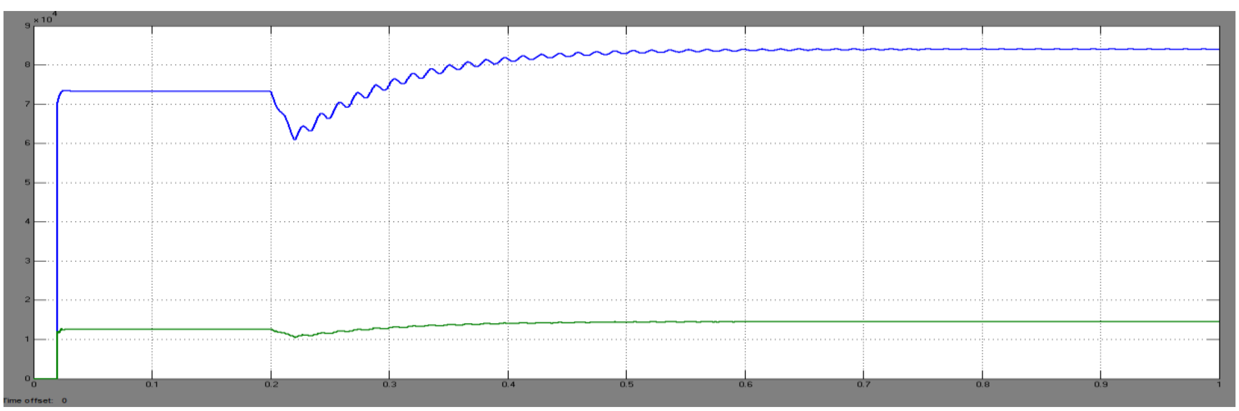

Fig. 9: Load active & reactive power

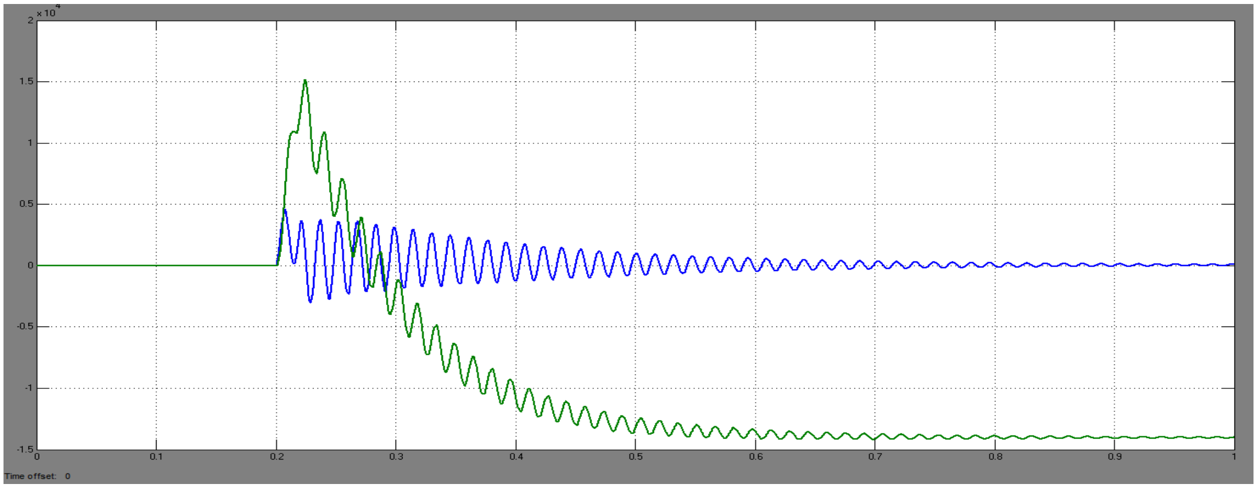

Fig. 10: STATCOM active & reactive power

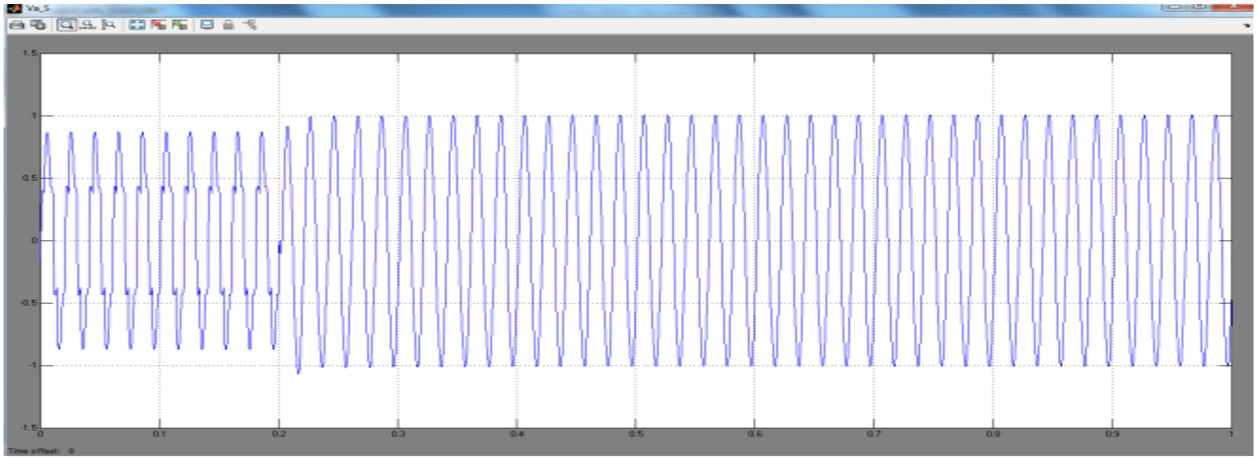

Fig.11.single phase voltage

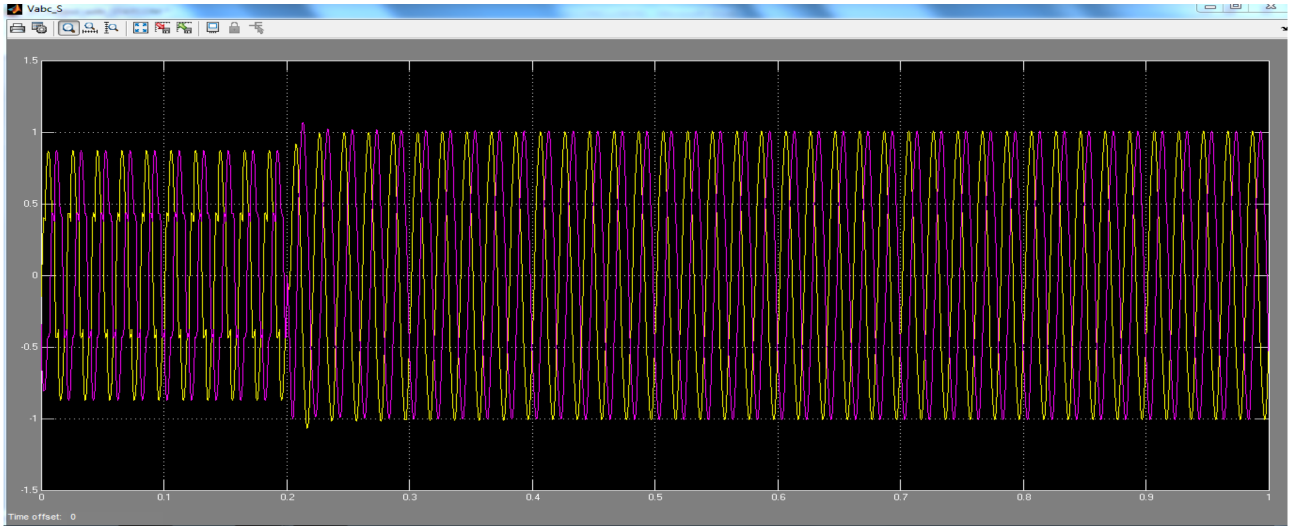

Fig.12.three phase voltages

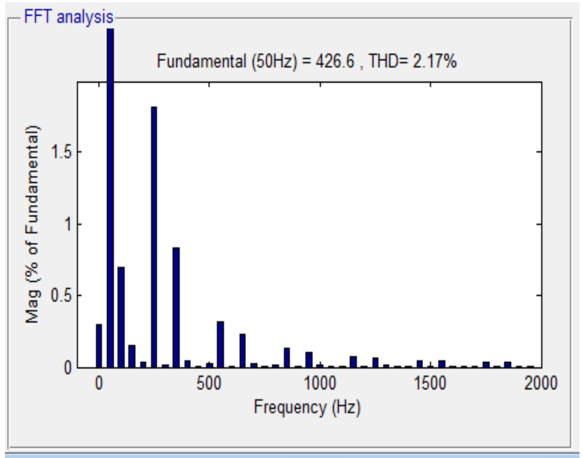

Fig.13.THD of Source voltage

IV. CONCLUSION

The paper presents the STATCOM-based SRF control scheme for power quality improvement in grid connected generating system and with non linear load. The power quality issues and its consequences on the consumer and electric utility are presented. The operation of the control system developed for the STATCOM in MATLAB/SIMULINK for maintaining the power quality is simulated. It has a capability to cancel out the harmonic parts of the load current. It maintains the source voltage and current in-phase and support the reactive power demand for the generator and load at PCC in the grid system, thus it gives an opportunity to enhance the utilization factor of transmission line. The integrated generation and STATCOM with BESS have shown the outstanding performance. Thus the proposed scheme in the grid connected system fulfills the power quality norms as per the IEC standard 61400-21.

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