Reduces The Harmonics And Losses By Using Control Technique Of VSI Based STATCOM

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Abstract

The Static Synchronous Compensator (STATCOM) is increasingly popular in power quality application. The Voltage Source Inverter (VSI) based STATCOM is used for eliminating current harmonics and compensating reactive power. This VSI draw or supply a compensating current from the utility such that it cancels current harmonics on the AC side. STATCOM generates a current wave such that it compensate by cancelling out the non-linear current waveform generateted by load. In this paper hysteresis controller based STATCOM is proposed. The STATCOM modeled using Simulink of MATLAB. Simula-tion result of 6 pulse VSI based STATCOM validate current control strategy to prevent harmonics current and compensate reactive power.

Index Terms:-*Power Quality, Harmonics, Voltage Source Inverter.*

I. INTRODUCTION

Power electronic based power processing offersnhigherefficiency, compact size and bettercontrollability. But onthe flip side, due to switching actions, these systems behaveas non-linear loads. This create power quality problemssuch as voltages Sag/Swell, flickers, harmonics, asymmetricofvoltage have become increasingly serious. At thesametime, modern industrial equipments are more sensitive tothese power quality problems than before and need higherquality of electrical power.Untilnow, to filter these harmonics and to compensatereactive power at factory level, only capacitor and passivefilters were used. More, new PWM based converters for motor control are able to provide almost unity power factoroperations. This situation leads to two observations: on onehand, there iselectronic equipment which generates harmonics and, on the other hand, there is unity power factor motordrive system which doesn't need power factor correction capacitor. Also, we cannot depend on this capacitor to filterout those harmonics. This is one of the reasons that the research is being done in the area of Active Power Filter(APF) and less pollutant drives. Loads, such as, diode bridgerectifier or a thyristor bridge feeding a highly inductive load,presenting themselves as current source at point of commoncoupling (PCC), can be effectively compensated by connecting an APF in shunt with the load.

The shunt APF acts as a current source and inject a compensating harmonic current in order to havesinusoidal, inphase input current. The developments in the digital electronics, communications and in process control system haveincreased the number of sensitive loads. In order to meetlimits proposed by standards it is necessary to include somesort of compensation. In the last few years, solutions basedon shunt Active filter have appeare. Its main purpose isto compensate for load currentimperfections, such as harmonics, reactive currents , and current unbalance. Thecontrol technique presented here is very simple.The system configuration under consideration is discussedin section II. The proposed control technique based on unit vector template generation is explained in section III. A SIMPOWERSYSTEM (SPS)Matlab/Simulink model based on proposed control strategy is given in the section IV. The simulationresults arediscussed in section V and final section VI concludesthe paper.

II. SYSTEM DESCRIPTION

Fig. 1 shows the basic compensation principle of shunt active power filter. A voltage source inverter (VSI) is used as the shunt active power filter . This is controlled to generates acurrent wave such that it compensate by cancelling out the nonlinear current waveform generateted by load i.e. this active power filter (APF) generates the nonlinearities opposite to the load nonlinearities. Fig. 2 shows the different waveforms i.e.the load current, desired source current and the compensating current injected by the shunt active power filter which contains all the harmonics, to make the source current purely sinusoidal.This is the basic principle of shunt active power filter to eliminate the currentarmonics and to compensate the reactive power.

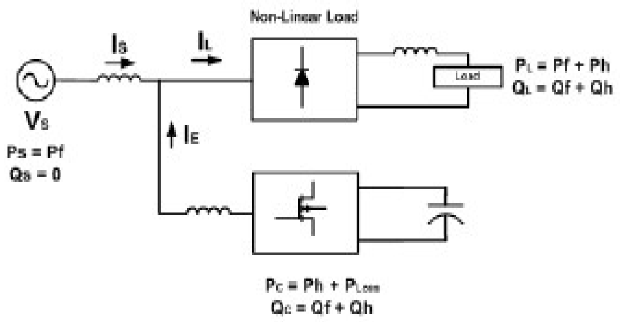


Fig. 1. Basic Compensation Technique

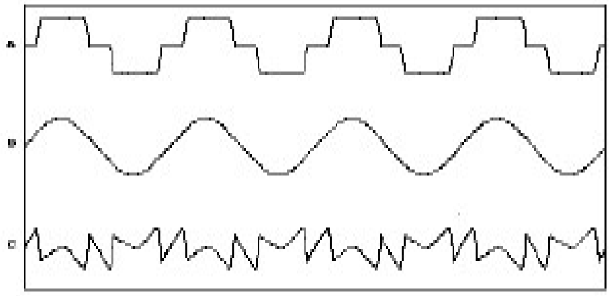


Fig. 2. Waveforms for the actual load current, desired source current and thecompensating current

Total instantaneous power drawn by the nonlinear load canbe represented as:-$P_L(t)=P_f(t)+P_r(t)+P_h(t)$ . .(01)

where f, r, h stands for fundamental, reactive, and harmonic contents.

Real power supplied by the source Ps = Pf…..(02)

Reactive power supplied by the sourceQs = 0 …...(03)

Real power drawn by the loadPL = Pf + Ph…(04)

Reactive power drawn by the loadQL = Qf + Qh....(05)

Real power supplied by the APFPc = Ph – PLoss …...(06)

Reactive power supplied by APFQc = Qf + Qh …..(07)

Where PLoss is the loss component of the APF

From the single line diagram

$i_s(t)=i_L(t)+i_c(t)$ ….(08)

The utility voltage is given by

$V_s(t)=V_m \sin \omega t$ …..(09)

The load current will have a fundamental componentand the harmonic components which can be represented as

$I_L(t)=\sum^{\infty}_{n=1} I_n \sin(n\omega t+\phi_n)$ ……(10)

$=I_1\sin(n\omega+\phi_1)+ \sum^{\infty}_{n=2} I_n \sin(n\omega t+\phi_n)$ ……(11)

Instantaneous load power pL(t) can be expressed as

$P_L(t)=V_s(t)i_L(t)$ ……(12)

$=V_m \sin \omega t\, I_1\sin(n\omega+\phi_1)+ V_m \sin \omega t \sum^{\infty}_{n=2} I_n\sin(n\omega t+\phi_n)$

$=V_m \sin \omega t\, (I_1 \sin \omega t\cos\phi_1+I_1 \cos\omega t \sin\phi_1)+ V_m \sin \omega t \sum^{\infty}_{n=2} I_n\sin(n\omega t+\phi_n)$

$=V_m I_1 \sin^2\omega t\cos\phi_1+V_m I_1 \sin \omega t\cos\omega t \sin\phi_1+ V_m \sin \omega t \sum^{\infty}_{n=2} I_n\sin(n\omega t+\phi_n)$ …(13)

$=P_f(t)+P_r(t)+P_h(t)$ …..(14)

$=P_f(t)+P_r(t)$ ……(15)

Where, the term p f (t) is the real power (fundamental),

the term pr (t) represents the reactive power and the term

ph (t) represents the harmonic power drawn by the load. For

ideal compensation only the real power (fundamental) should by supplied by the source while all other power com- ponents (reactive and the harmonic) should by the active power filters i.e. $P_c(t)=P_r(t)+P_h(t)$be supplied

$P_r(t)= V_m I_1 \sin^2\omega t\cos \phi_1$ …….(16)

$=V_s(t)\, i_s(t)$. ……(17)

$= I_1 \cos\omega t \sin \phi_1$ ……(18)

i.e.$i_s(t) = P_r(t)\backslash V_s(t)$

$= I_{sm}\sin\omega t$

Where $I_{sm} =I_1\cos \phi_1$

Since, there are some switching losses in the inverter.Therefore, the utility must supply a small overhead for capacitor leaking and inverter switching losses in addition to thereal power of load. Hence, total peak current supplied by thesource

I max =I sm+I sL ……(19)

If active power filter provide the total reactive and harmonic power, then is (t) will be in phase with the utility and pure sinusoidal. At this time, the active filter must providethe following compensation current:

is (t) = iL (t) + ic (t) ……..(20)

Hence, the accurate value of the instantaneous currentsupplied by the source, I s (t)= I max sin ωt

The peak value of the reference current I max can be estimated by controlling the DC link voltage. The ideal compensation requires the mains current to be sinusoidal and inphase with the source voltage irrespective of load currentnature. Hence, the desired source currents after compensation can be given as

I^*_{sa} = Imax sin ωt ……(21)

I^*_{sa} = Imax sin (ωt-2π/3) …….(22)

I^*_{sa} = Imax sin (ωt-4π/3) ……(23)

Where, I max (= I1 + I sL) is the amplitude of the desiredsource currents. So, these currents are taken as the referencecurrents for the shunt APF.

III. DESIGN OF STATCOM

STATCOM is operated in hysteresis control mode to regulate the load reactive power and eliminate harmonics fromthe supply currents. Mainly design include capacitor, Hysteresis controller based PI controller, unit vector template.

A. Design of Capacitor

The reference value of the capacitor voltage Vdc ref is selected mainly on the basis of reactive power compensationcapability. For satisfactory operation the magnitude of Vdc refshould be higher than the magnitude of the source voltageVs . By suitable operation of switches a voltage Vc havingfundamental component Vc1 is generated at the ac side of the inverter. This results in flow of fundamental frequency com ponent I s1 , as shown in Fig. 2. The phasor diagram for Vc1 >Vs representing the reactive power flow is also shown in this figure. In this I s1 represent fundamental component.

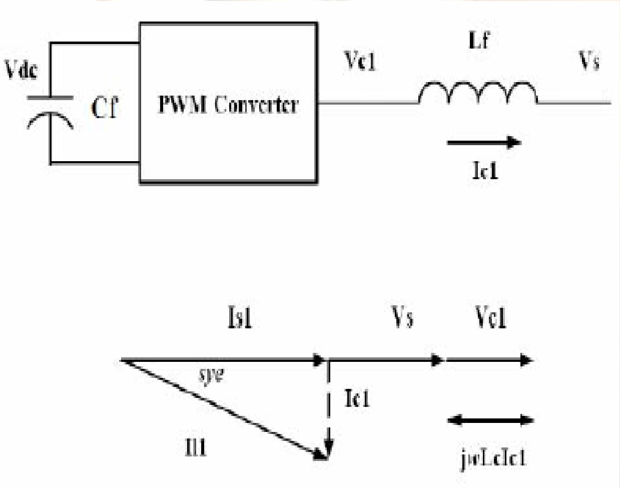
$I_{c1} = V_{c1}\text{-}V_s/\omega L_f = V_{c1}\backslash\omega L_f\,(1\text{-}\,V_s/V_{c1})$ ……(24)

$Q_{c1} = Q_{L1} = 3V_sI_{c1}$ …….(25)

$Q_{c1} = 3V_s\, V_{c1}\backslash\omega L_f\,(1\text{-}\,V_s/V_{c1})$ …….(26)

$V_{dc} = 2\sqrt{2}V_{c1}$ ……(27)

Fig. 3. Single line and vector diagrams for



STATCOM

B. Design of PI controller

The controller used is the discrete PI controller thattakes in the reference voltage and the actual voltage andgives the maximum value of the reference current dependingon the error in the reference and the actual values . Themathematical equations for the discrete PI controller are:The voltage error V (n) is given as:

$V_{(n)} = V^*(n) - V_{(n)}$ ….(28)

The output of the PI controller at the nth instant is given as:

$I_{(n)} = I(n\text{-}1)+K_p[V(n)\text{-}V(n\text{-}1)]+K_iV(n)$ …..(29)

When the DC link voltage is sensed and compared with thereference capacitor voltage, to estimate the reference current,the compensated source current will also have sixth harmonic distortion for three-phase system and second harmonics distortion for single phase system.A low pass filter is generally used to filter these rippleswhich introduce a finite delay and affect the transient response. To avoid the use of this low pass filter the capacitor voltage is sampled at the zero crossing of the source voltages.

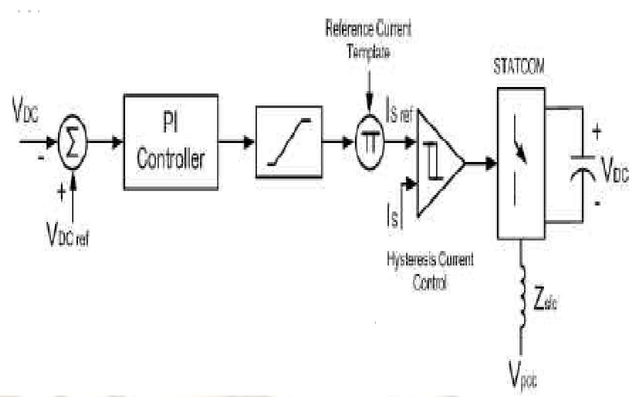


Fig. 4. Closed loop Schematic block diagram of STATCOM

C. Hysteresis Controller

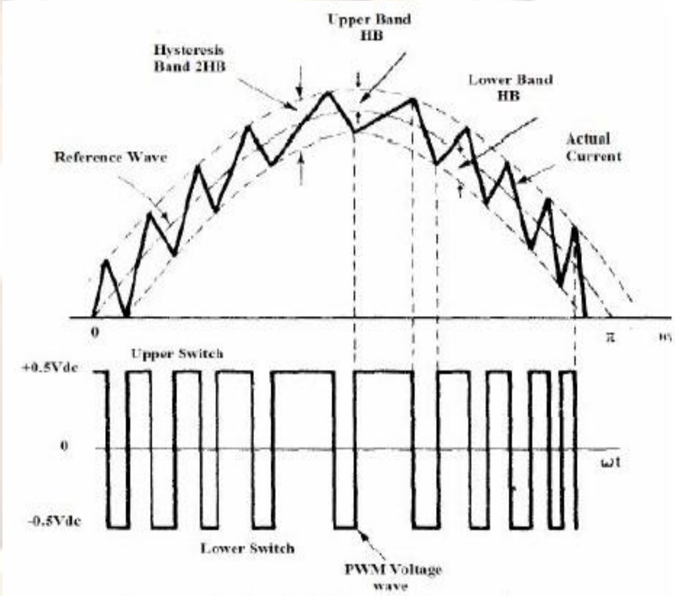


Fig. 5. Basic principal of hysteresis controller

With the hysteresis control, limit bands are set on either side of a signal representing the desired output waveformThe inverter switches are operated as the generated signals within limits. The control circuit generates the sine reference signal wave of desired magnitude and frequency, andit is compared with the actual signal. As the signal exceeds aprescribed hysteresis band, the upper switch in the halfbridge is turned OFF and the lower switch is turned ON. Asthe signal crosses the lower limit, the lower switch is turnedOFF and the upper switch is turned ON. The actual signalwave is thus forced to track the sine reference wave withinthe hysteresis band limits.

D. Pulse Generation Technique

Pulse generation is main and important part of thistechnique. Here we have used hysteresis technique forswitching technique.

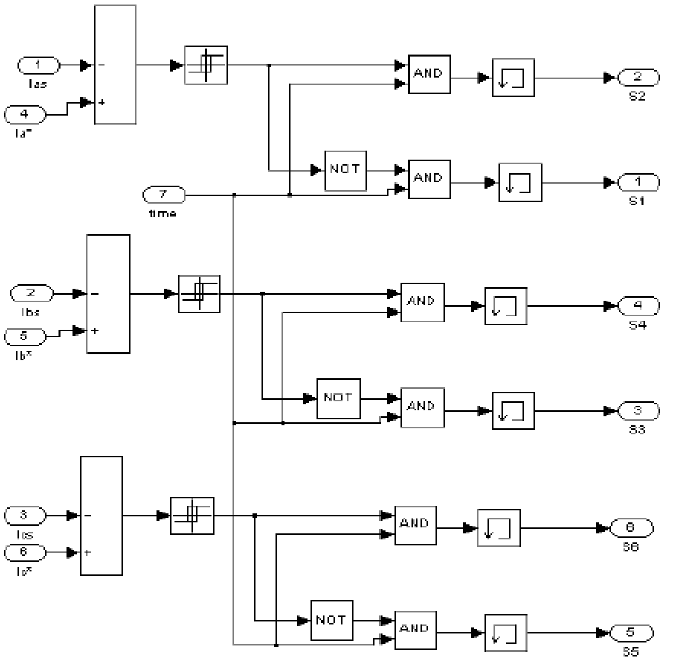


Fig. 6. Pulse generation diagram

E. Extraction of Unit Vector Template

The schematic diagram of unit vector template generation is shown in Fig. 7

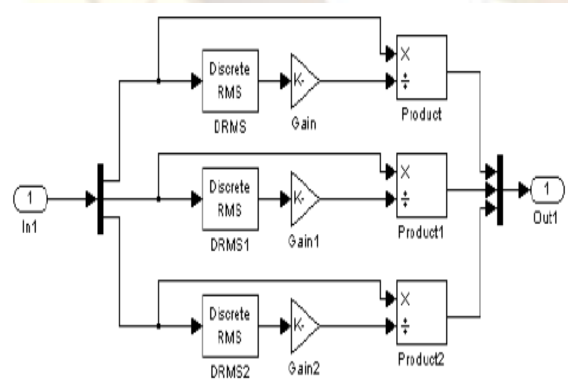


Fig. 7. Extraction of unit vector template

The input source voltage at PCC is sensed and rms valueof the voltage is measured. This rms value is multiplied bysquare root of two. This peak voltage id divided by inputsupply voltage. Which will give us the unit vector templateof the three phase.

IV. OPERATION OF SIMULATION MODEL

The operation of the simulation model shown in Fig. 8.First the capacitor voltage is sensed which is compared withthe reference voltage and the error signal is given to the PIcontroller for processing to obtain the maximum value (I m) of the reference current. This signal is now delayed by1200 for getting the reference current for phase b, which isfurther delayed by 1200 to get the reference current for thephase c. these reference currents are now compared with theactual source currents and the error is processed in the hyste-resis controller to generate the firing pulses for the switchesof the inverter.

V. SIMULATION RESULTS

Fig. 9 shows the supply voltage, supply current and injected current wave forms of the line current before the

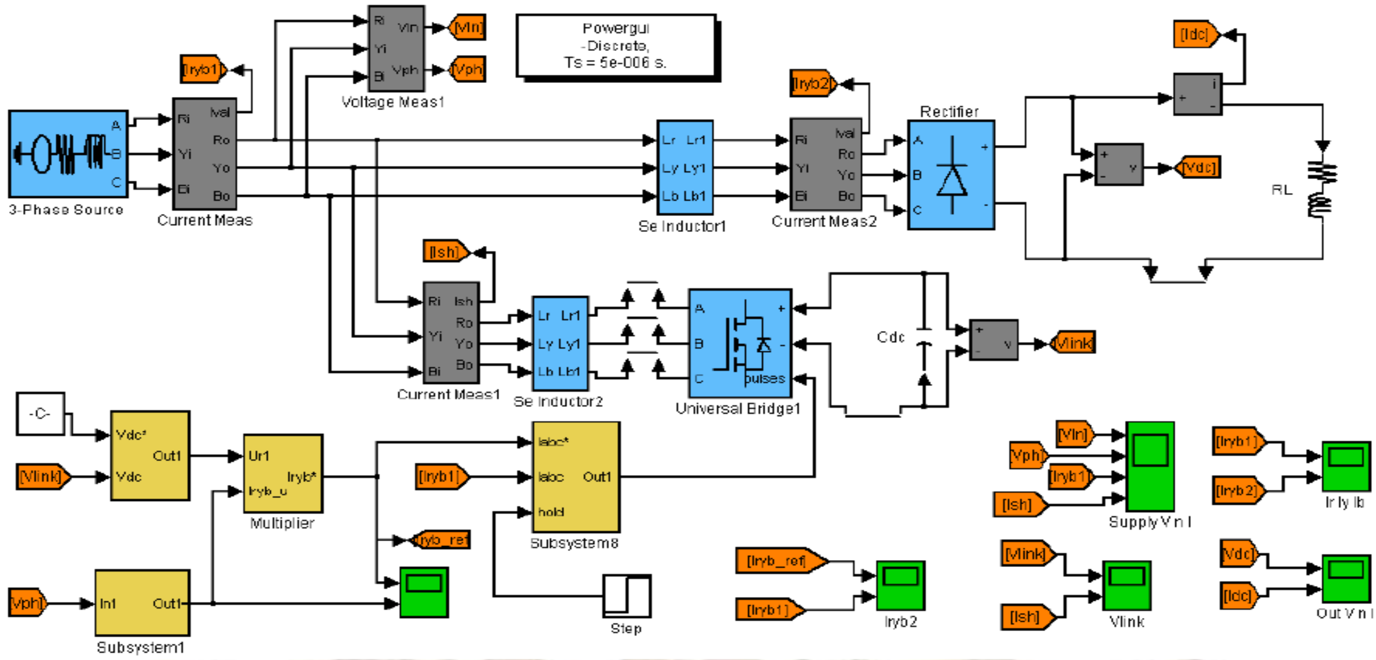


Fig. 8. Overall Control circuit of STATCOM based on MATLAB Simulink

shunt current and after the shunt current injection. The overall simulation run time is 0.2 sec. the control strategy isstarted after 0.1 sec. After 0.1 sec the PI controller acted to settle the reference DC link voltage and current from theshunt converter injected to make the supply current sinusoidal. It is observed that after the control strategy started thewave shape of the line current at the input side is improvedin term of the harmonic distortion. It is also observed thatthe supply voltage does not affected. Fig. 10 shows the Loadvoltage and current remain unaffected throughout the operation.

Fig. 11 shows the current on the main line side beforeinjection and frequency contain in it. Fast Fourier Transformation (FFT) analysis of the same current is carried out andthe Total Harmonic Distortion (THD) in this case is 25.59%.Fig. 12 shows the current on the main line side after injection and frequency contain in it. FFT analysis of the samecurrent is carried out the THD in this case is 3.93%.

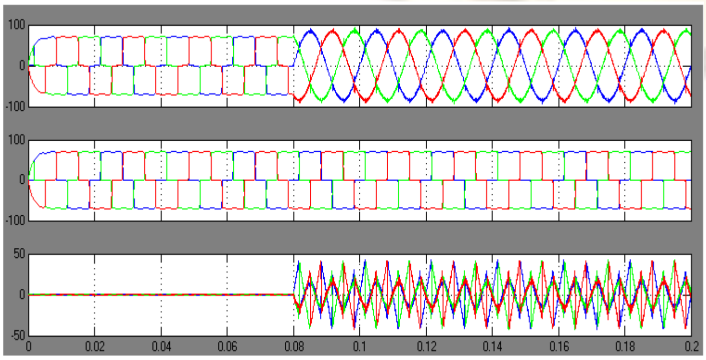


Fig. 9. Supply voltage, current and injected current

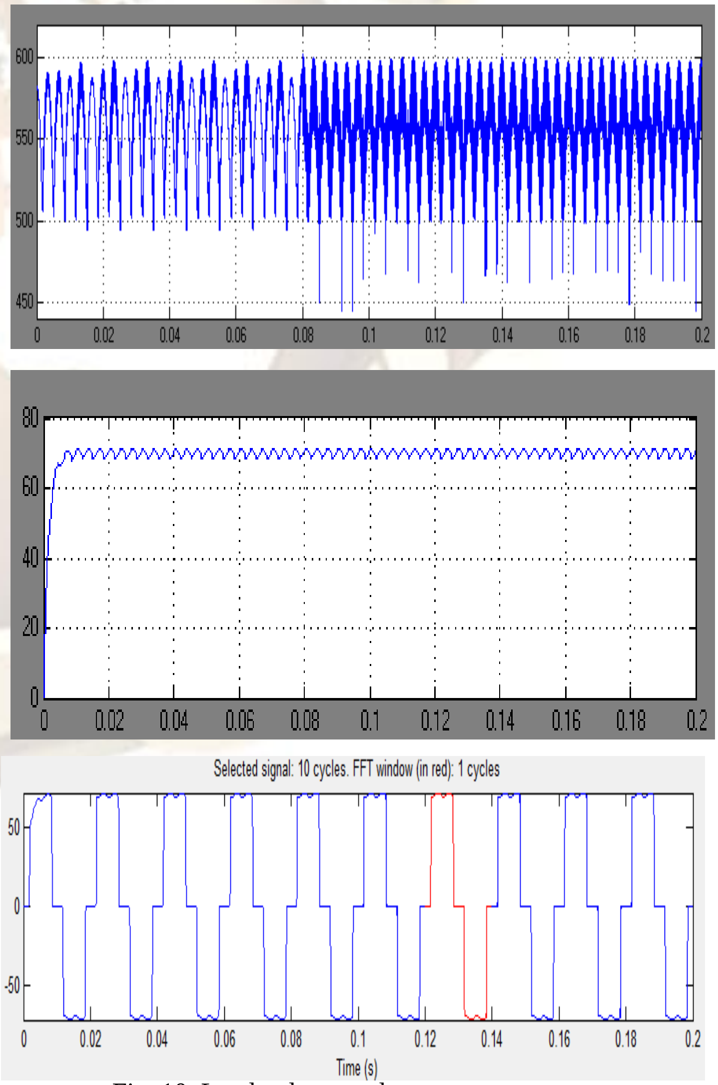


Fig. 10. Load voltage and current

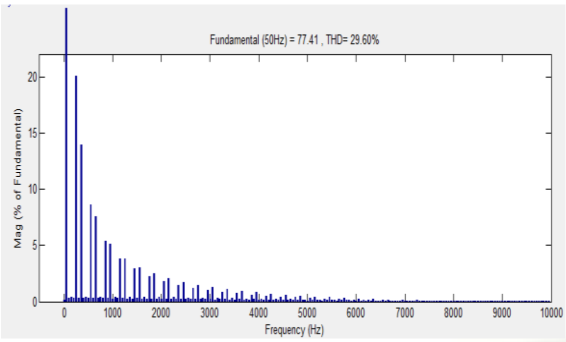
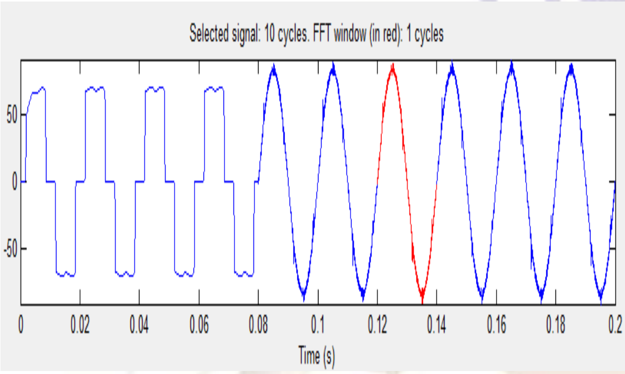


Fig. 11. FFT analysis of supply current before control



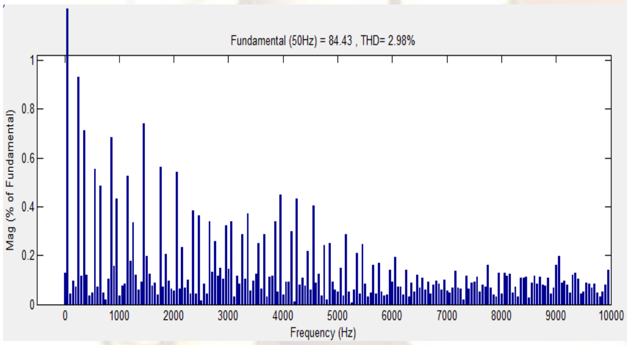


Fig. 12. FFT Analysis of supply current after using STATCOM

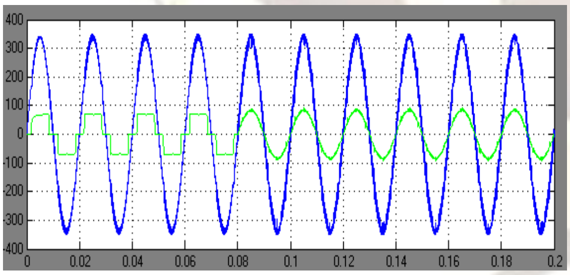


Fig. 13. Power filter wave forms

VI. CONCLUSION

A very simple hysteresis current controller based controltechnique with help of unit vector template is proposed forSTATCOM. A MATLAB/Simulink based model has beensimulated. Simulation result shows the input currentharmonics produced by nonlinear load is reduced after usingthe control strategy. FFT analysis shows the reduction inTHD is remarkable.

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