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SVPWM Based STATCOM for Power Quality Improvement

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Abstract

This paper describes the modeling & analysis of Static Synchronous compensator based on Space vector pulse width modulation (SVPWM).STACOM is prepared by with VSC. Mostly voltage source converter use for such aspects: Harmonic components , dc link voltage & switching frequency of semiconductor devices. The simulation is done in MATLAB/SIMULINK environment.

Keywords: Power Quality , harmonics, SVPWM, STATCOM.

I. INTRODUCTION

In Power System from generating station to distribution system to keep up system healthiness is huge mission. As load associated with system play imperative role concern with power quality problems. To keep up Power Quality balanced with respect to source side & demand side is important task. As harmonics in system tends to degrade the power quality as a result it serves voltage flicker, enlarge waste of energy & malfunction of sensitive equipment [3]. Now a days speedy growth in technology has been done, the new topologies has been invented in power electronics technology to improve performance of power system. No. of solution have been planned for improving suppression of harmonics but voltage source converter (VSC) based STATCOM have been proven to be successful solution for harmonic & power Quality improvement [3].

The functional model of STATCOM is shown in Fig.1 STATCOM is extremely punctual device as shown in fig.1 bus voltage is denoted by Vac . Iac is STATCOM injected current, STATCOM output voltage denoted by Vout. Idc & Vdc are the capacitor side current & voltage.

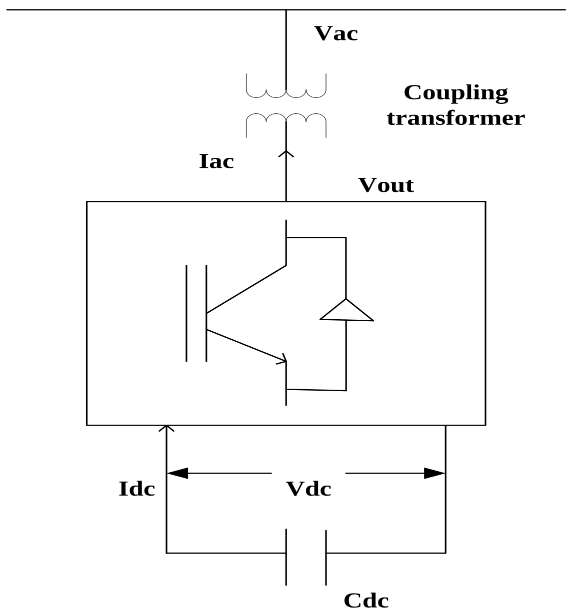


Fig.1 A functional model STATCOM

When output voltage of STATCOM, Vout is greater than bus voltage, Vac then STATCOM nature is capacitive that means STATCOM supplies reactive power. If Vout is lesser than Vac then nature of STATCOM is inductive that means STATCOM absorb the reactive power. Fig.2 shows the power exchange purpose of STATCOM.

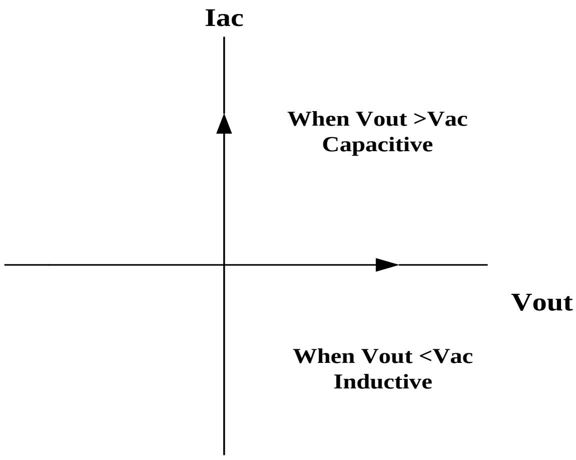


Fig.2 Power Exchange behavior of STATCOM

II. **SYSTEM MODEL**

The model considered for analysis is four machine /two area multi machine system which is shown in fig.3.The multi machine system shows the all power system equipment with the load connected to it. Firstly linear load is connected with the system and analysis of harmonics is done with MATLAB/SIMULINK environment.

The Multi machine system consisting two areas naming as area 1 and area 2. The System Model Data sheet is given in Table 1.

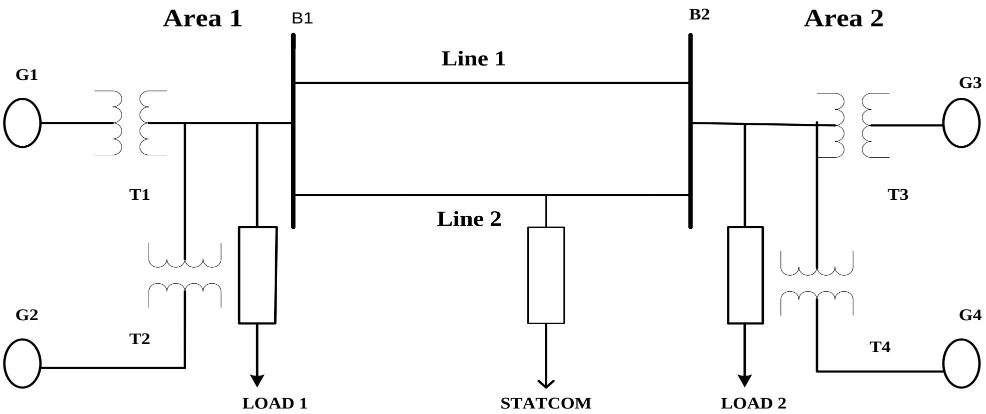


Fig.3. Diagrammatical representation of Multi machine System

Table 1. Data sheet for System Model

Areas	Device	Ratings
Area 1	Generator 1	900 MVA Xd=1.8 Xd'=0.3, Xd"=0.25 Xq=1.7 Xq'=0.55, Xq"0.25pu
	Generator 2	
	Transformer 1	900MVA,20KV Rm=Lm=500 pu
	Transformer 2	
	Load	967MW
	Transmission line	220KM

Area 2	Generator 3	900 MVA Xd=1.8 Xd'=0.3, Xd"=0.25 Xq=1.7,Xq'=0.55, Xq"0.25pu
	Generator 4	
	Transformer 3	900MVA Rm=Lm=500pu
	Transformer 4	
	Load	1767MW

III. STATCOM EQUIVALENT CIRCUIT MODEL

STATCOM consist of three phase bus , voltage source converter (VSC) ,& DC capacitor. Equivalent circuit of Static Synchronous Compensator is shown in Fig.4

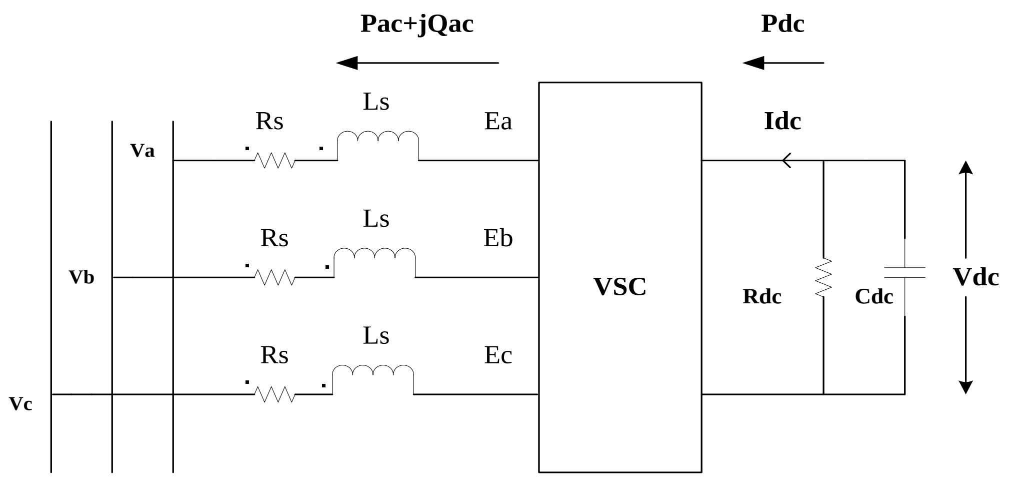


Fig.4. Comparable Circuit Model Of STATCOM

The loop equitions for static Synchronous Compensator in vector form as in equation (1)

$$\frac{diabc}{dt} = -\frac{ws\,Rs}{Ls}iabc + \frac{ws}{Ls}(Eabc - Vabc) \quad (1)$$

The STATCOM Output is shown by equation (2).

$$Ea = KVdc\cos(wt + \alpha) \quad (2)$$

Where,

Rs & Ls= transformer resistance &inductance

Eabc= Converter side AC phase voltage

Vabc=System side phase voltage

iabc=phase current

K =modulation index

Vdc,Idc&Pdc= Voltage ,current &power of DC capacitor

α = angle between bus voltage & converter output voltage

Rdc& Cdc= real power losses in switches

Pac & Qac= real & reactive power injected by STATCOM

IV. SPACE VECTOR PWM FOR THREE PHASE VSC

The Voltage source converter consist of Six switches which could either be IGBT or GTO having an anti parrel diode for current to flow through it when switches are in OFF state[2].Compared to other PWM techniques Space vector PWM (SVPWM) technique is chosen because it is easy to lesser switching losses, diminish the harmonic content & maximize DC bus utilization also modulation index could be reached above 97% with this technique more precise control is achieved.

By using SVPWM technique the gate pulse of voltage source converter (VSC) is designed.SVPWM technique is skilled by the revolving reference vector around the state diagram consisting of six basic non zero vector forming an hexagon. The Fig.6 shows the space vector in 3 phase VSC with three leg.

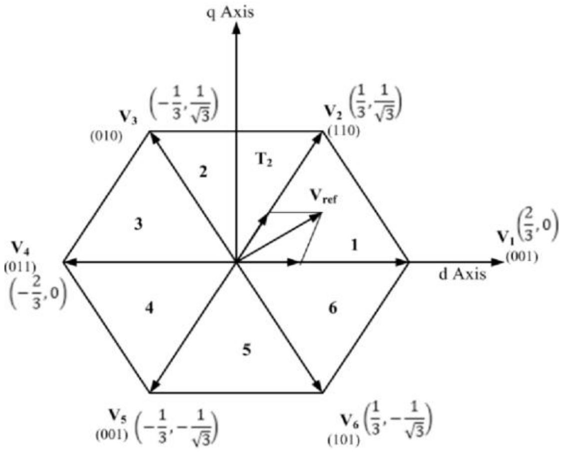


Fig. 5 Space vector modulation

Where,

$Vk = \{\frac{2}{3} Vdce^{j(k-1)\pi/3}$ for k=1,2,3,4,5…..6 (3)

$= \{0\ for$ k=0 & 7

Where,

V0&V7 = zero vectors

V1 to V6=active vectors

The fundamental principal of SVPWM is based on eight switching pattern of 3 phase voltage source converter. The switching patterns are binary codes. Switches are turned ON depend on binary codes & respective output voltage is presented in a form of Vα & Vβ in following Table.2.

Table 2. Switching Conditions of SVPWM.

Voltage Vector	a	b	c	Vα	Vβ
V0	0	0	0	0	0
V1	1	0	0	2Vdc/3	0
V2	1	1	0	Vdc/3	$Vdc/\sqrt{3}$
V3	0	1	0	-Vdc/3	$Vdc/\sqrt{3}$
V4	0	1	1	2Vdc/3	0
V5	0	0	1	-Vdc/3	$-Vdc/\sqrt{3}$
V6	1	0	1	Vdc/3	$Vdc/\sqrt{3}$
V7	1	1	1	0	0

V. SIMULATION RESULTS

Case I- With SVPWM based STATCOM, With Non-Linear Load

As Fig.6 & Fig.7 shows the simulation result three phase current with Non linear load at Bus 1(B_1) & at Bus 2(B_2) As fig.6 & Fig.7shows the three phase current waveform consisting distortion in phase current which shows the non linearity present in the system.

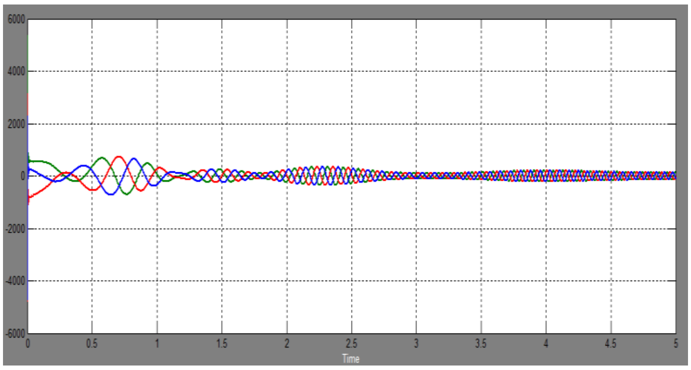


Fig.6 Simulation Result of three phase current at Bus 1(B_1)

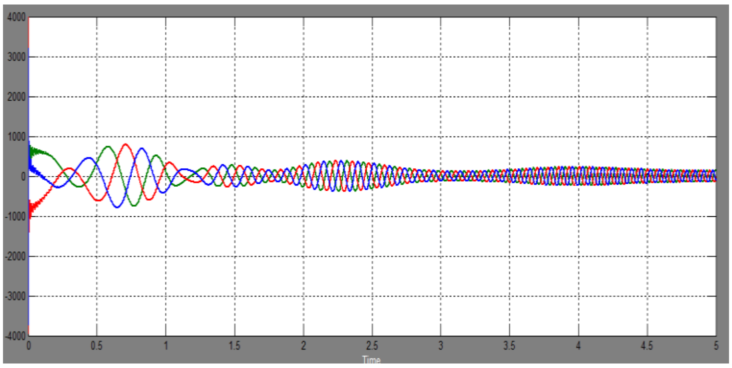
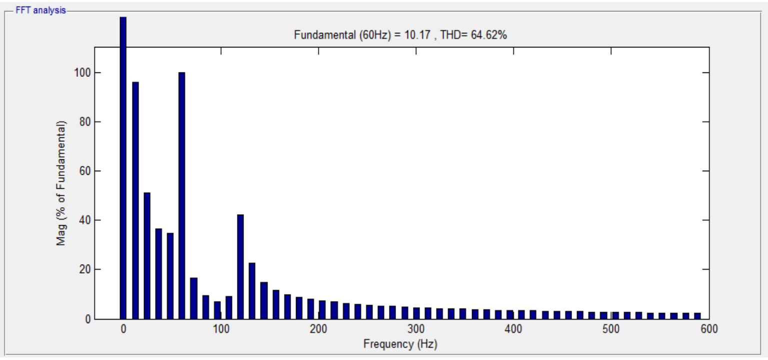


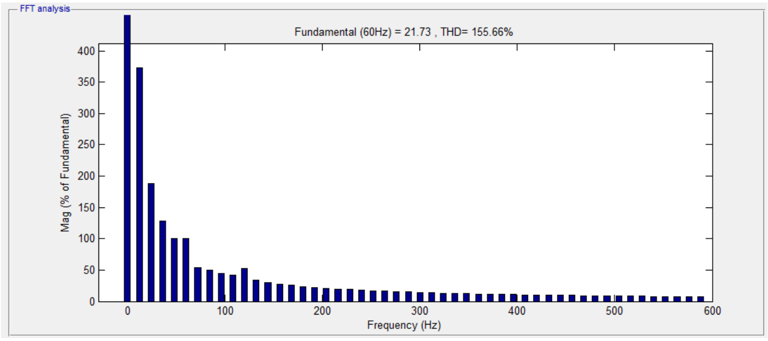
Fig.7 Simulation Result of three phase current at Bus 2(B_2)

Case II- FFT Analysis of individual phase current at B_1

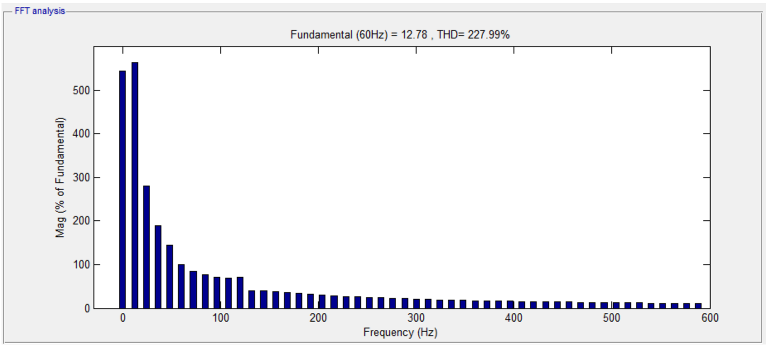
Fig.8 shows the harmonic analysis for three phase current individually naming as Phase A, Phase B, Phase C at Bus 1.The respective phases shows the harmonics present at the current at Bus 1 with the respective fig. individual & total harmonics analysis has been calculated.



Phase A (Ia)



Phase B(Ib)

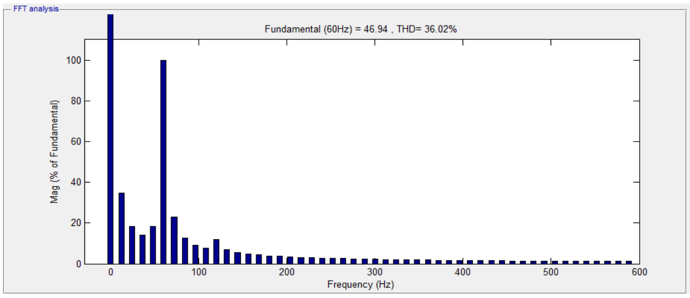


Phase C(Ic)

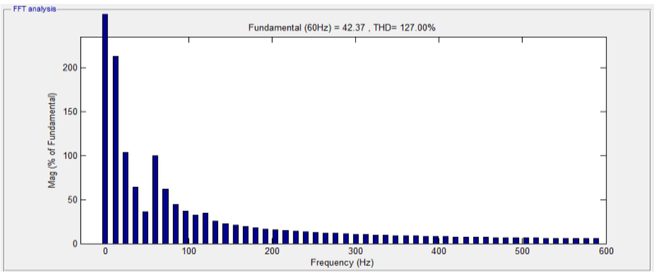
Fig.8 Total Harmonic Distortion (THD) for three phase current at Bus1 with SVPWM based STATCOM

Case III-FFT Analysis of individual phase current at B_2

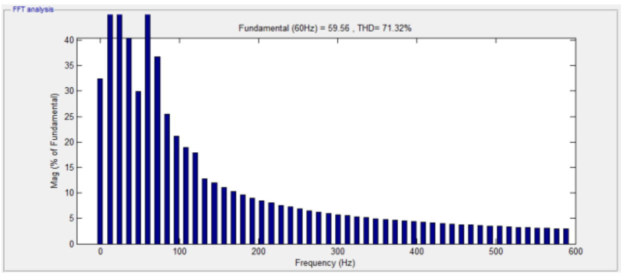
Fig.9 shows the harmonic analysis for three phase current individually naming as Phase A, Phase B, Phase C at Bus 2.The respective phases shows the harmonics present at the current at Bus2 with the respective fig. individual & total harmonics analysis has been calculated.



Phase A(Ia)



Phase B(Ib)



Phase C(Ic)

Fig.9 Total Harmonic distortion(THD) for three phase current at Bus 2 with SVPWM based STATCOM

Case IV- Graphical representation of %THD for current at Bus 1 & Bus 2

Fig.10 & Fig.11 show the graphical representation of total harmonic distortion with Non linear Load with respect to various condition respectively. Following fig .10 & 11 shows the %THD, first bar shows the % THD when system runs with non linear load & without STATCOM, Second bar shows the system with non linear load with PWM STATCOM similarly third bar shows the % harmonic distortion with non linear load with SVPWM Based STATCOM.

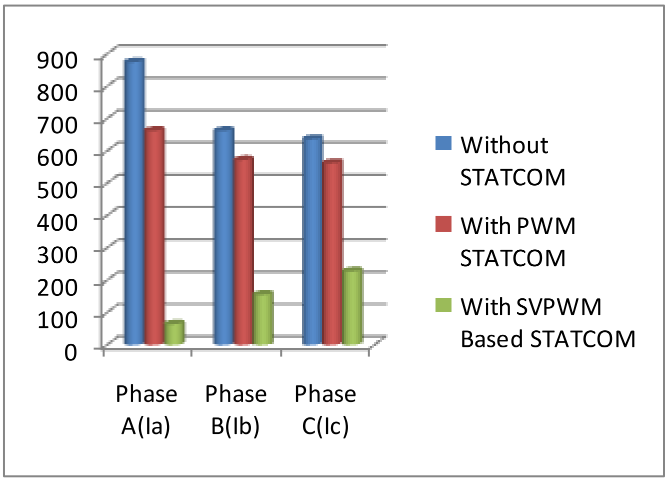


Fig.10 Graphical representation of three phase current %Total harmonic distortion(THD) at Bus 1

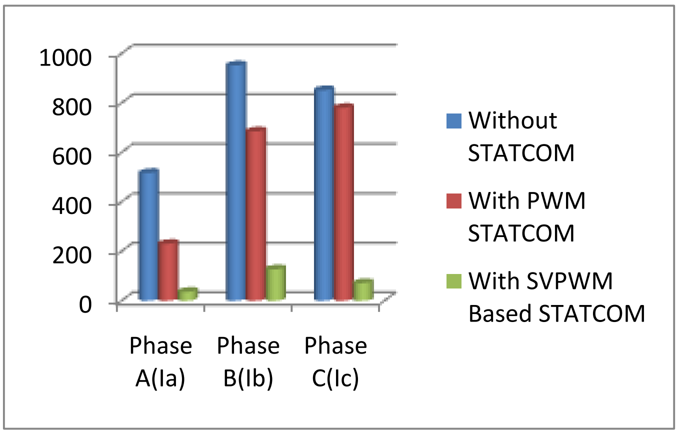


Fig .11 Graphical representation of three phase current %Total harmonic distortion(THD) at Bus 2

Case IV- Graphical representation of %THD for Voltage at Bus 2

Following fig .12 shows the %THD, first bar shows the % THD when system runs with non linear load & without STATCOM, Second bar shows the system with non linear load with PWM STATCOM similarly third bar shows the % harmonic distortion with non linear load with SVPWM Based STATCOM.

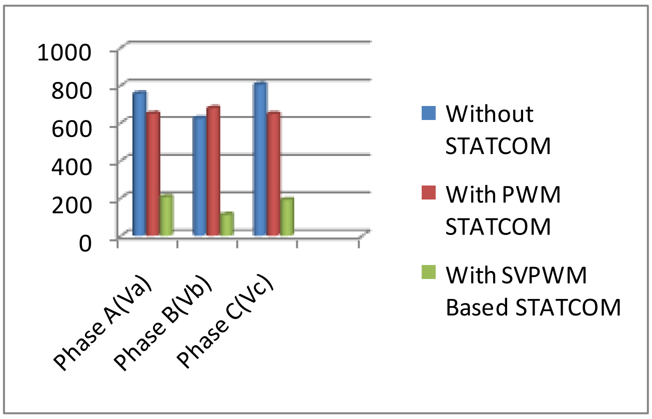


Fig .12 Graphical representation of three phase voltage %Total harmonic distortion(THD) at Bus 2

VI. CONCLUSION

In this paper STATCOM with advance control technology called space vector pulse width modulation (SVPWM) has been studied. As STATCOM is from family of FACTS devices is one of the solution for suppression of harmonics of the system.

The multi machine with non linear load is studied with the help of SVPWM based STATCOM result in reduction of current total harmonic distortion (THD) at both the Buses connected in the system with respect to bus 1 %THD reduces at bus 2 as STATCOM is connected nearer to bus 2. By using such multifunctional device not only system quality get increased but also system becomes healthy.

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