International Journal of Advance Research and Innovation
Vol. 3(1), Jan-Mar 2015, pp. 290-300
Doi: 10.51976/ijari.311547
www.gla.ac.in/journals/ijari

Article Info
Received: 15 Feb 2015 | Revised Submission: 25 Feb 2015 | Accepted: 28 Feb 2015 | Available Online: 15 Mar 2015

Reactive Power Control in the Deregulated Electrical Power Environment using FACT Devices

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ABSTRACT

In the deregulating electricity market, many private sector power producers areparticipating actively. With growing number of the wind mills and solar power generation, the reactive power production will be more because of induction generator and inductive type load. Many blackouts havehappenedin the past decades due to more reactive power which lead to a decrease in the magnitude of real power. It is very essential to control and compensate the reactive power, increase the real power flow in the transmission line, increase the transmission efficiency, improve the system stability andbe in a safer place to save the fossil fuels for the future.
In this paper the importance of reactive power and its various compensation and control techniques are applied to a five bus deregulated test case model. The simulations were done using Matlabsimulink, for various FACT controllers such as STATCOM,SVC,SSSCand UPFC compensationand the results were tabulated and compared.

Keywords: *Reactive Power Compensation; STATCOM; Matlab/Simulink.*

1.0 Introduction

The increase in power demand in the recent years has resulted higher requirements from the power industry. Construction of more power plants, substations and transmission lines are indispensable in restructuring the electricity market [Noureddine Henini, 2014]. Circuit breakers are the frequently operated devices in the power grid [Igor Kuzle, 2011]. These circuits are at times difficult to handle because of long switching periods and discrete operation. This increases the cost and also lowers the efficiency of the power system networks [Rachid Cherkaoui 2013, C. Vyjayanthi 2009]. Severe blackouts have occurred worldwide recently because of the lack of proper controlling [D.Thukaram,2010]. This is discussed in detail in the later part of this chapter. Different approaches such as reactive power compensation [Vyjayanthi Chintamani, 2004] and phase angle shifting [M. Ouyang, 2009] could be applied to increase the stability and security of the system.

A device which is connected in series or parallel with the load and capable of supplying reactive power demanded by the load is called reactive power compensation device. Reactive power is the component of power that oscillates back and forth through the lines, being exchanged between electric and magnetic fields [H. Bentarziand A. Ouadi, 2011]. In practice, reduction in reactive power is made to improve system efficiency. To improve the performance of power system, management of the reactive power should be done efficiently. Power systems supply or consume real power and reactive power. Real power accomplishes useful work while reactive power supports the voltage that must be controlled for system reliability. Reactive power has a profound effect on the security of power systems because it affects voltages throughout the system [E. Fernandez, 2003]. It is common, that devices which consume the reactive inductive current are called reactive power receivers, while devices consuming reactive capacitive current are referred to as reactive power sources. Most of the industrial equipment consumes reactive power.

FACTS has become the technology of choice in voltage control, reactive and active power flow control, transient and steady state stabilization that improves the operation and functionality of existing power system [Youngan Deng, 2011]. Two types of compensation can be used one is series and the other is shunt compensation. In recent years

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compensators like STATCOM (static synchronous compensators), SSSC (static series synchronous compensator), UPFC (unified power flow controllers) and SVC (static Var compensator) have been developed. These quite satisfactorily do the job of absorbing or generating reactive power with a faster time response and come under Flexible AC Transmission System (FACTS). This allows an increase in transfer of apparent power through the transmission line [Jun-Denwu 2009, S.M.Abd-Elazim, 2014].

2.0 Need for Reactive Compensation Power

The main reasons for reactive power compensation in a system are:

- Increased system stability
- The voltage regulation
- Reducing losses associated with the system and
- To prevent voltage collapse as well as voltage sag
- Better utilization of machines connected to the system [Md. Rafi Khan, 2013].

Reactive power supply is essential for reliably operating the electric transmission system. Inadequate reactive power has led to voltage collapses and has been a major cause of several recent major power outages worldwide. The August 2003 blackout in the United States and Canada was not due to a voltage collapse as that term has been traditionally used; The final report of the U.S.Canada Power System Outage Task Force (April 2004) said that "insufficient reactive power was an issue in the blackout." Dynamic capacitive reactive power supplies were exhausted in the period leading up to the blackout.

On July 2, 1996, voltage instability resulted from the loss of steady state equilibrium conditions, caused by reactive power deficiency in the Idaho area. The power failure affected parts of Alberta and British Columbia in Canada, western Mexico, as well as Idaho, Montana, Utah, New Mexico, California, and Arizona, affecting more than two million people.

A voltage collapse can take place in systems or subsystems and can appear quite abruptly. Continuous monitoring of the system state is therefore required. The cause of the 1977 New York blackout has been proved to be the reactive power problem. The 1987 Tokyo black out was believed to be due to reactive power shortage and to a voltage collapse at summer peak load. These facts have strongly indicated that reactive power planning and dispatching play an important role in the security of modern power systems. [Pedro. E. Mercado, 2013]

2.1 Benefits of FACTS controllers

FACTS controllers enable the transmission owners to obtain, on a case-by-case basis, one or more of the following benefits; due to high capital cost of transmission plant, cost considerations frequently overweigh all other considerations. Compared to alternative methods of solving transmission loading problems, FACTS technology is often the most economic alternative [Dr. S. K. Srivastava, 2012]

2.2 Convenience

All FACTS controllers can be retrofitted to the existing ac transmission plant with varying degrees of ease. Compared to high voltage direct current or six-phase transmission schemes, solutions can be provided without wide scale system disruption and within a reasonable timescale.

2.3 Environmental impact

In order to provide new transmission routes for supplying to an ever increasing worldwide demand for electrical power, it is necessary to acquire the right to convey electrical energy over a given route. It is common to face environmental opposition frustrating attempts to establish new transmission routes. FACTS technology, however, allows greater throughput over existing routes, thus meeting consumer demand without the construction of new transmission lines [Hariyani Mehul. P, 2011]. However, the environmental impact of the FACTS device itself may be considerable. In particular, series compensation units can be visually obtrusive with large items of transmission equipment placed on top of high-voltage insulated platforms.

Control of power flow to follow a contract, meet the utilities own needs, ensure optimum power flow, minimize the emergency conditions, or a combination there of contributes to optimal system operation by reducing power losses and improving voltage profile, increase the loading capability of the lines to their thermal capabilities, including short term and seasonal power dispatch, increase the system security by raising the transient stability limit, limiting short-circuit currents and overloads, managing cascading blackouts and damping electromechanical oscillations of power systems and machines, the possibility of providing reactive power support to the grid from wind farms with inverters, detailed analysis of capability curves and cost components, reduce reactive power flows, thus allowing the lines to carry more active power, reduce loop flows, increase utilization of least cost generation and to overcome the problem of voltage fluctuations [Yongali Li 2013, Raja Sekhara Reddy Chilipi 2013, R. M. Nelms 2014].

Distributed online algorithm for optimal real-time energy distribution in the smart grid is discussed in [James L Kirtley, 2014]. Comprehensive study of DSTATCOM configurations is discussed in [Kamal Al Haddad, 2014]. Muti-objective reactive power compensation problem discussed in [Antonio Gomes Martins 2012, Ali Khazali 2011]. Reactive power required for industrial networks is discussed in [Mersiha Samardizc, 2014]. Reactive power compensation for hybrid power system is optimized by fuzzy controller in [S. P. Ghoshal, 2014].

3.0 Materials and Methods

Fig 1- shows the single line diagram of a five bus system with the FACT device connected at bus no 5.

Two sources of rating 200 Mw and lOOMw supplying power to three different loads of ratings are tabulated in Table 2. Matlab provides very good power system simulation platform tools.

The simulink diagram of five bus system is shown in Fig 2 and Fig 3 shows with STATCOM connected at bus no. 4.

A standard 5 bus system is designed and simulated using MATLAB/SIMULINK. Before compensation and after compensating with STATCOM, SVC, SSSC and UPFCareplaced at various buses.

The same above is simulated with windmill of rating 200 Mw at bus l.The results were tabulated in Table 5 for regulated system and Table 6 for deregulated system.

The Generator ratings and load ratinas are aiven in Table 1 and Table 2.

Fig 1: Five Bus Test Case Single Line Diagram with Fact Device Connected at Bus No 5

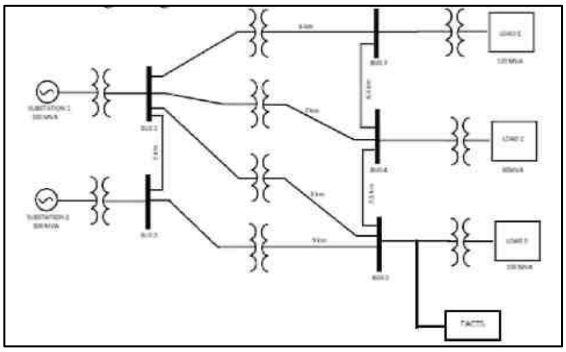


Fig 2: Simulink Diagram of 5 Bus System with STATCOM at bus 3

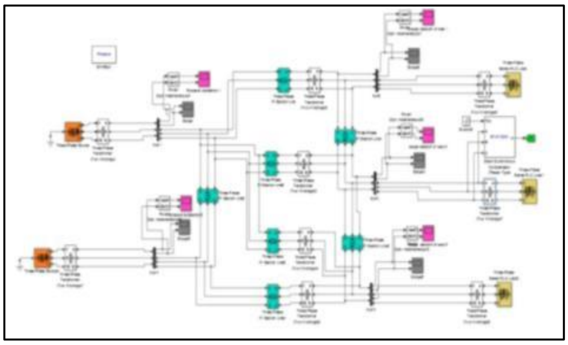


Fig 3: Simulmk Diagram of 5 bus System with wind mill and STATCOM at bus 4

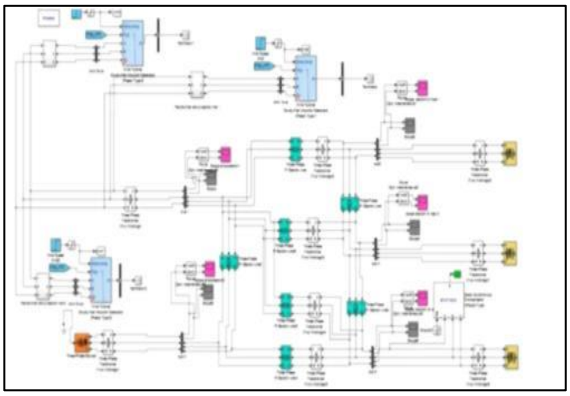


Table 1: Generator Ratings

Generator	Power Rating	Phase-To-Phase Rms Voltage (V)
G1 - three wind mill of rating 70 MW, 70MW and 60 MW each.	200e6	575
G2 - Synchronous Generator	100e6	11e3

Table 2: Load Ratings

Simlink Block	Parameter					
	Nominal Phase-To-Phase Voltage Vn(Vrms)	nominal frequency fn(hz)	Active Power P(W)	Inductive Reactive Power Ql(Positive Var)	Capacitive Reactive Power Qc(Negative Var)	Configuration
Load-1	11e3	50	66.66e6	30e6	3.33e6	Y(Grounded)
Load-2	11e3	50	53.33e6	24e6	2.66e6	Y(Grounded)
Load-3	11e3	50	80e6	36e6	4e6	Y(Grounded)

Table 3: Parameters of Transmission Lines

Simulink blocks	POSITIVE-AND ZERO-SEQUENCE RESISTANCE(OHMS/KM)[r1 r0]	POSITIVE-AND ZERO-SEQUENCE INDUCTANCE(H/KM)[L1 L0]	POSITIVE-AND ZERO-SEQUENCE CAPACITANCE(F/KM) [C1 C0]	LINE LENGTH (KM)
Pi section line-1	0.01273, 0.3864	0.9337e-3,4.1264e-3	12.74e-9,7.751e-9	10
Pisection line-2	0.01273, 0.3864	0.9337e-3,4.1264e-3	12.74e-9,7.751e-9	12
Pisection line-3	0.01273, 0.3864	0.9337e-3,4.1264e-3	12.74e-9,7.751e-9	7
Pisection line-4	0.01273, 0.3864	0.9337e-3,4.1264e-3	12.74e-9,7.751e-9	6.5
Pisection line-5	0.01273, 0.3864	0.9337e-3,4.1264e-3	12.74e-9,7.751e-9	8
Pisection line-6	0.01273, 0.3864	0.9337e-3,4.1264e-3	12.74e-9,7.751e-9	7.5
Pisection line-7	0.01273, 0.3864	0.9337e-3,4.1264e-3	12.74e-9,7.751e-9	9

The results were tabulated in Table4 for regulated system and in Table 5 deregulated systems. The Generator ratings are given in Table 1. The transmission line parameters and line length are given in Table 3. Fig 2 shows the five bus simulmk circuit diagram for regulated environment. Fig 3 shows the five bus simulinkdiagram for deregulated environment with wind source connected with bus no. 1.The Results taken from the scopes are shown in Fig. 4 and it is tabulated in graphical representation in Fig 5.

4.0 Result Analysis

The Reduction in reactive power for various FACT devices and Increased Real power due to compensation is shown in Fig - 6 and Fig -7. Showing STACOM giving best result among the four FACT controllers.

Figure-4Results obtained from simulink scope at all 5 buses and for various FACT controllers.

Fig 4.1: AT Generator 1

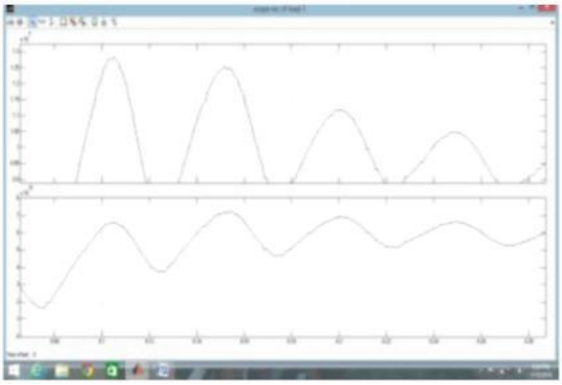


Fig 4.2: At Generator 2 before Compensation

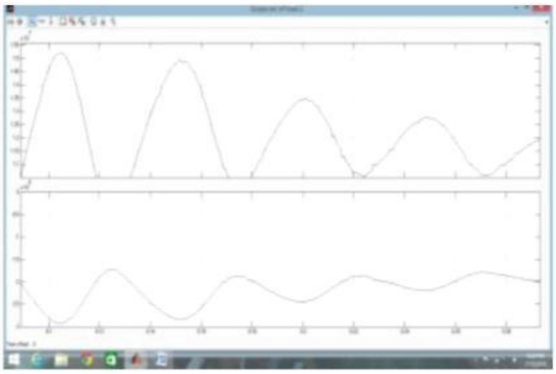


Fig 4.3: At load 3

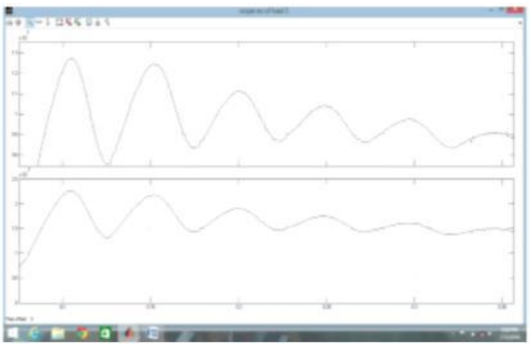
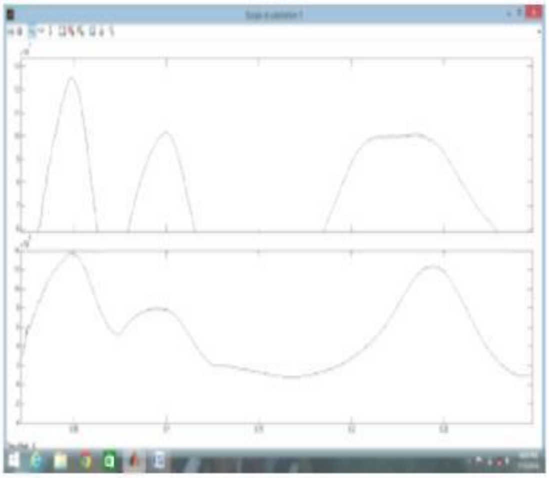


Fig 4.4: At Generator 1 bus



Compensation with STATCOM

Fig 4.5: At Generator 2 bus

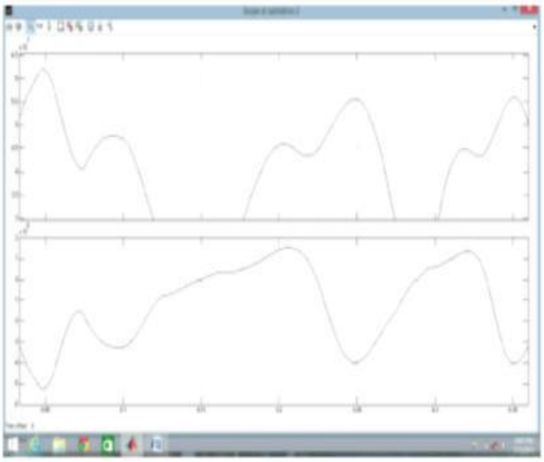


Fig 4.6: At load 1

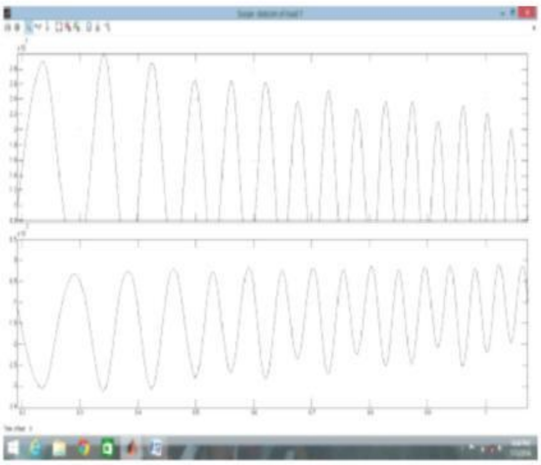


Fig 4.7: At load 2

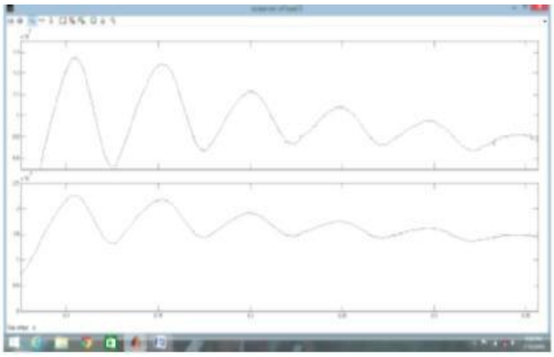


Fig 4.8: At load 3

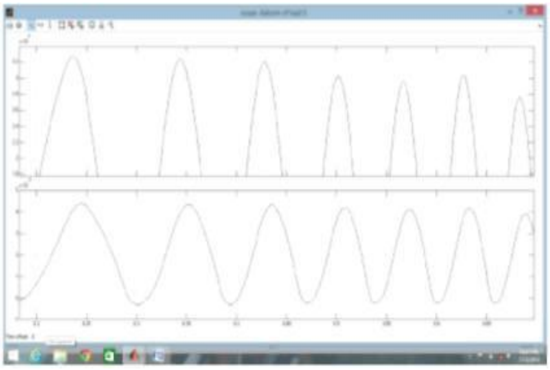


Fig 4.9: UPFC Compensation at G1

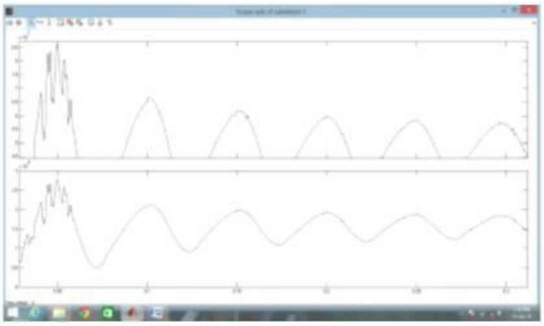


Fig 4.10: At Generator G2

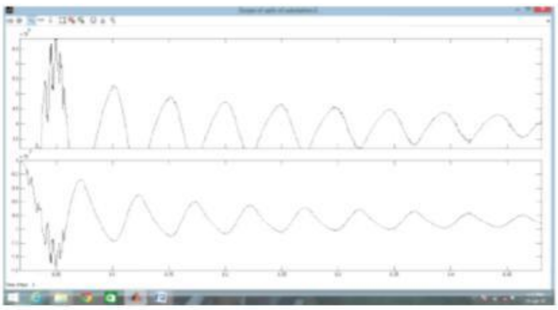


Fig 4.11: Compensation using sssc at Substation 1, bus 2

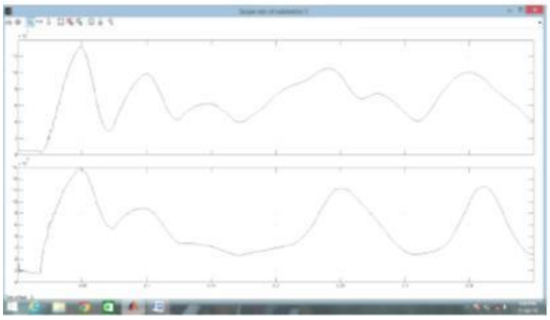


Fig 4.12: SVC at Generator G2 - Result of Load 2

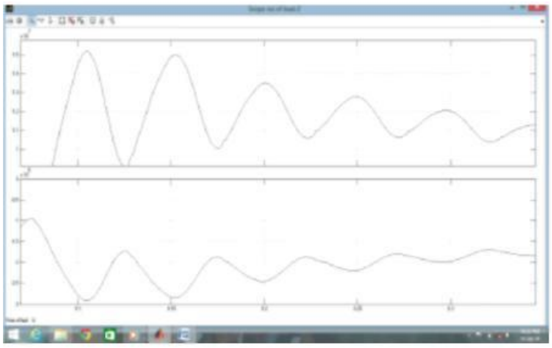


Fig 4.13: SVC at load 1

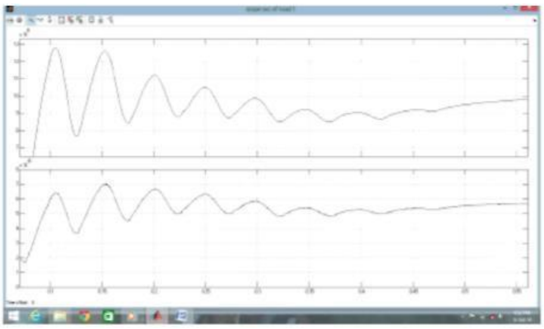


Fig 4.14: 3SVC at load 3

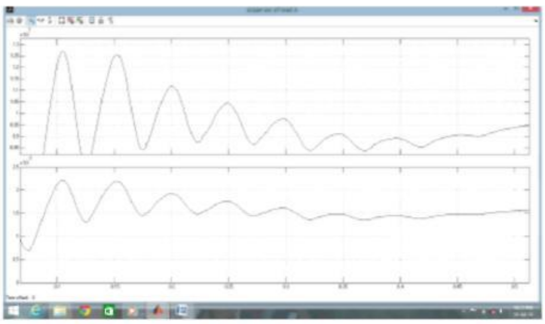


Fig 4.15: Compensation Using SVC at Load 2, Bus 4

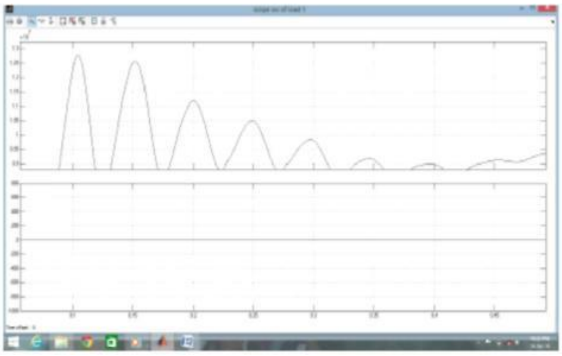
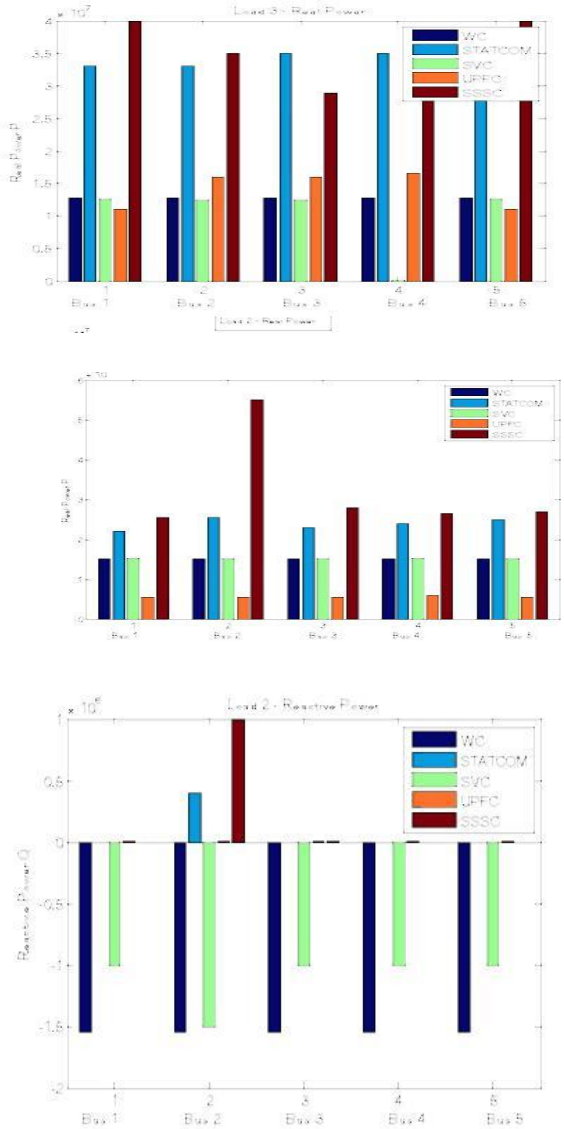
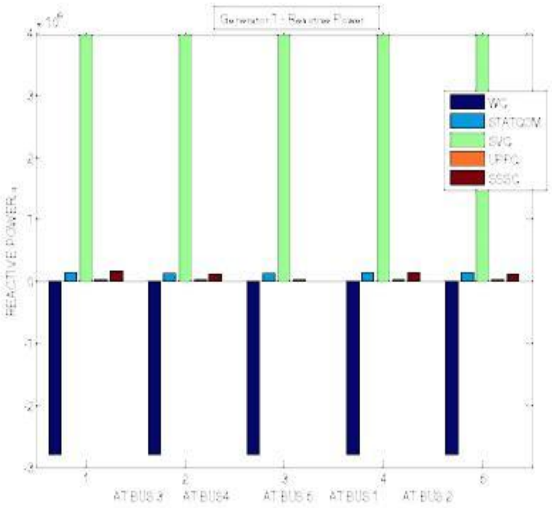
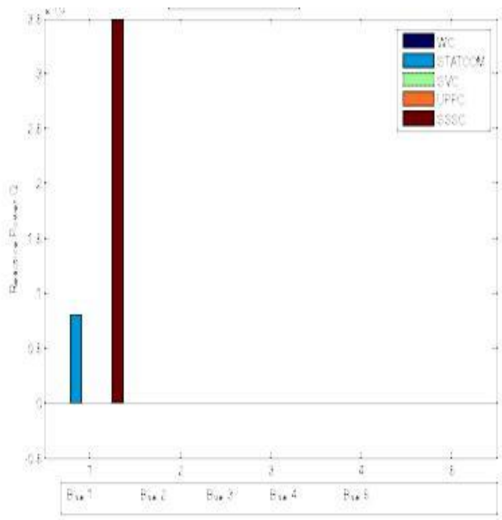
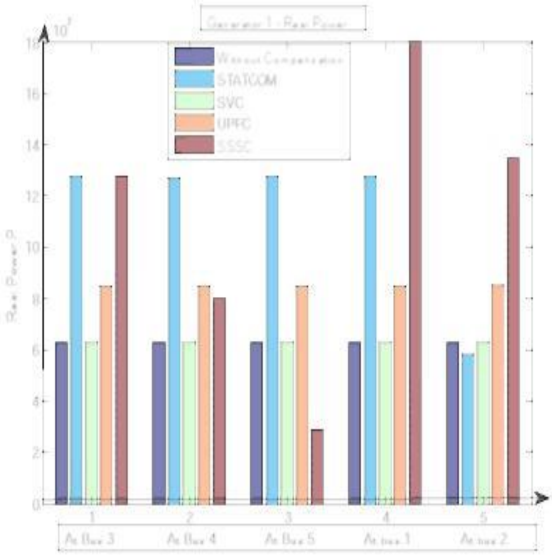


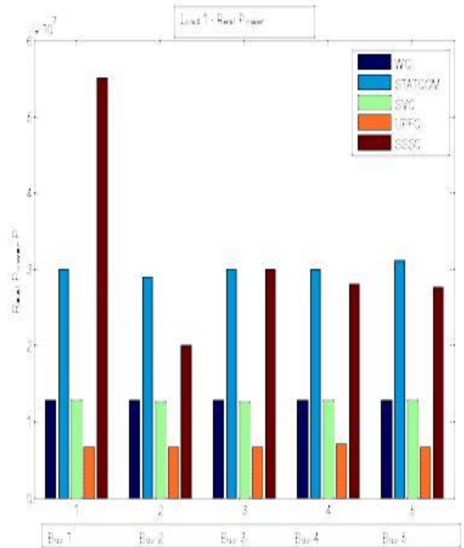
Fig 4: Comparision of Real and Reactive Power for Various Compensating Devices

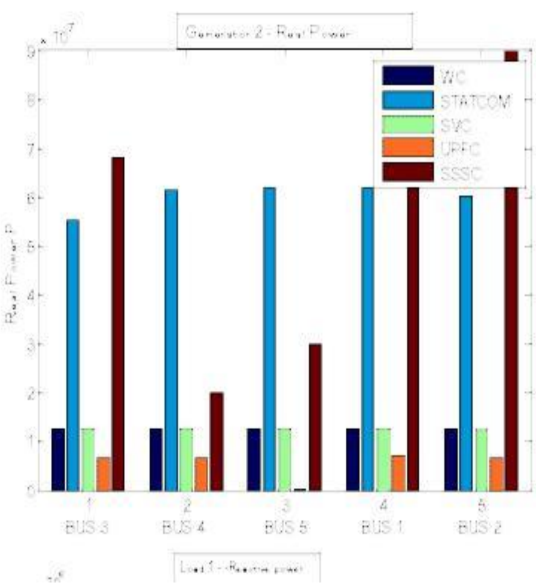


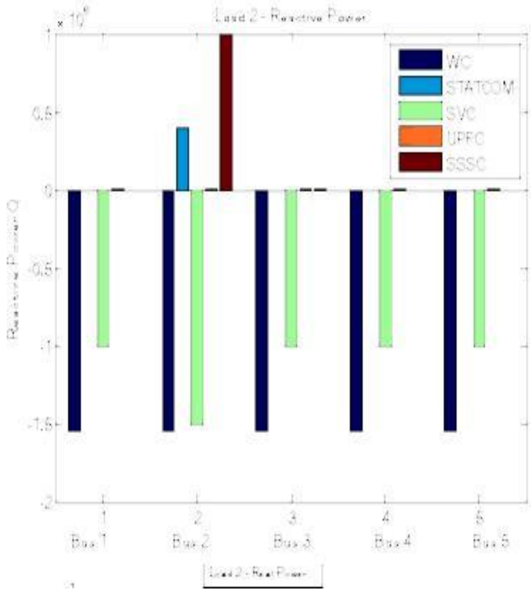

Generator 1 - Reactive Power
WC
STATCOM
SVC
UPFC
SSSC
REACTIVE POWER
AT BUS 3
AT BUS4
AT BUS 5
AT BUS 1
AT BUS 2

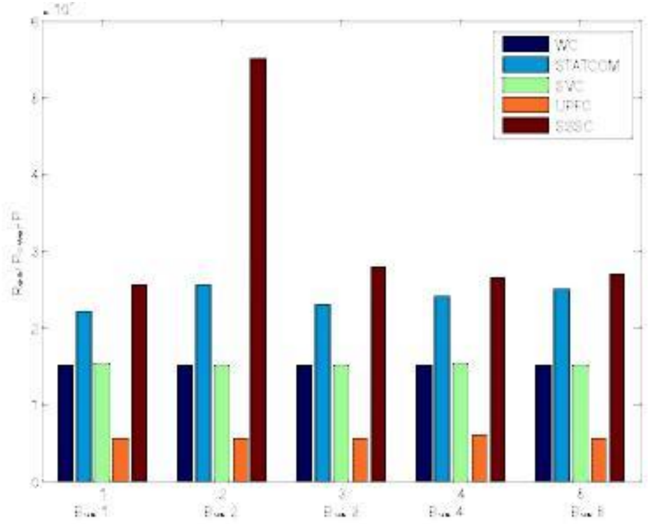

WC
STATCOM
SVC
UPFC
SSSC
Reactive Power Q
Bus 1
Bus 2
Bus 3
Bus 4
Bus 5

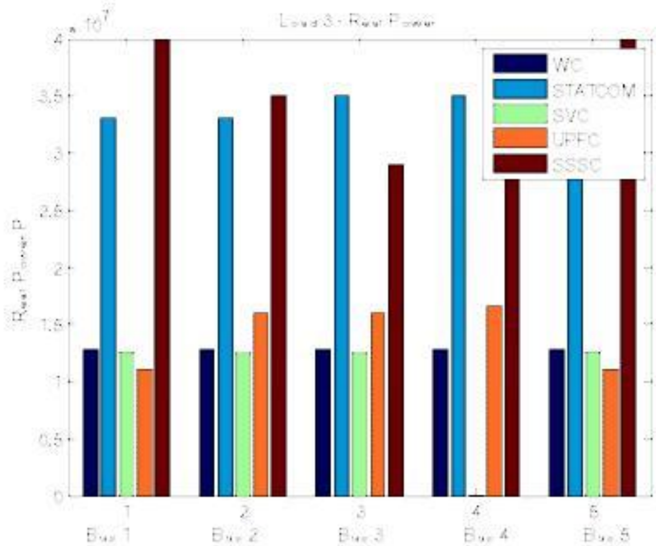

Generator 1 - Real Power
Without Compensation
STATCOM
SVC
UPFC
SSSC
Real Power P
At Bus 3
At Bus 4
At Bus 5
At bus 1
At bus 2


Load 1 - Real Power
WC
STATCOM
SVC
UPFC
SSSC
Real Power P
Bus 1
Bus 2
Bus 3
Bus 4
Bus 5


Generator 2 - Real Power
WC
STATCOM
SVC
UPFC
SSSC
Real Power P
BUS 3
BUS 4
BUS 5
BUS 1
BUS 2
Load 1 - Reactive power


Load 2 - Reactive Power
WC
STATCOM
SVC
UPFC
SSSC
Reactive Power Q
Bus 1
Bus 2
Bus 3
Bus 4
Bus 5
Load 2 - Real Power


WC
STATCOM
SVC
UPFC
SSSC
Bus 1
Bus 2
Bus 3
Bus 4
Bus 5


Load 3 - Real Power
WC
STATCOM
SVC
UPFC
SSSC
Real Power P
Bus 1
Bus 2
Bus 3
Bus 4
Bus 5

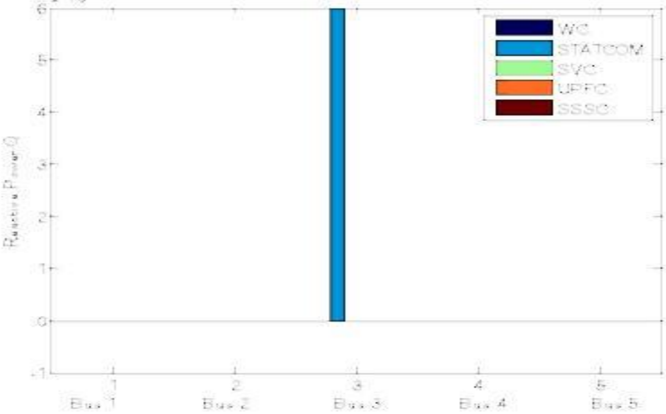

Load 3 - Reactive Power
WC
STATCOM
SVC
UPFC
SSSC
Reactive Power Q
Bus 1
Bus 2
Bus 3
Bus 4
Bus 5

Table 4: Simulation Output for Deregulated Electrical Power Environment

STATCOM Placed at Buses for compensation	Bus no.	Before compensation			STATCOM COMPENSATOR									
					Comp at Load1-bus no.2		Comp at Load2-bus no.4		Comp at Load5-bus no.3		Comp at G1-busno.1		Comp at G2 –bus no.3	
		P(MW)	Q(Mvar)	S	P(MW)	Q(Mvar)	P (MW)	Q(Mvar)	P (MW)	Q(Mvar)	P (MW)	Q(Mvar)	P (MW)	Q(Mvar)
G1 bus(swing)	1	62.7e6	-2800000		12.8e7	14e4	12.7e7	13.7e4	12.8e7	13.8e4	12.5e7	14e4	5.8e7	14e4
G2 bus	2	12.5e6	-0.00000006		5.5e7	1.3e6	6.15e7	1.2e6	6.2e7	1.2e6	6.2e7	1.5e6	6e7	1.2e6
Load 1	3	12.8e6	7e-8		3e7	8e5	2.9e7	-0.0004e4	3e7	-0.025e6	3e7	-0.0003e4	3.1e7	-0.00025e4
Load 2	4	15.2e6	-1550000		2.2e7	-0.004e4	2.55e7	4e5	2.3e7	-0.025e5	2.4e7	-0.004e4	2.5e7	-0.004e4
Load 3	5	12.8e6	2.25e-7		3.3e7	4.3e-7	3.3e7	4.3e-7	3.5e7	6e5	3.5e7	4.5e-7	3.6e7	4.6e-7
SVC COMPENSATOR														
Svc placed at Buses for compensation	Bus no.	Before compensation			Comp at Load1-bus no.3		Comp at Load2-bus no.4		Comp at Load 3-bus no.5		Comp at G1-bus no.1		Comp at G2 –bus no.3	
		P(MW)	Q(Mvar)	S	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)
G1 bus(swing)	1	62.7e6	-2800000		6.25e7	4e6	6.25e7	4e6	6.25e7	4e6	6.25e7	4e6	6.25e7	4e6
G2 bus	2	12.5e6	-0.000006e2		12.5e6	0	12.5e6	0	12.4e6	0	1.25e7	-0.0006e4	12.2e6	0
Load 1	3	12.8e6	7e-8		1.28e7	0	1.255e7	0	1.255e7	0	12.8e6	5e-8	12.8e6	7e-8
Load 2	4	15.2e6	-1550000		1.53e7	-1000000	1.51e7	-1500000	1.51e7	-1000000	1.53e7	-1000000	1.52e7	-1000000
Load 3	5	12.8e6	2.25e-7		1.255e7	1.25e-7	1.25e7	1.5e-7	1.25e7	10	1.255e-7	2.25e-7	1.255e7	2.25e-7
UPFC COMPENSATOR														
Upfc placed at Buses for comp	Bus no.	Before compensation			Comp at Load1-bus no.3		Comp at Load2-bus no.4		Comp at Load3-bus 5		Comp at G1-busno.1		Comp at G2 –bus no.3	
		P(MW)	Q(Mvar)	S	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)
G1 bus(swing)	1	62.7e6	-2800000		8.5e7	2.55e4	8.5e7	2.55e4	8.5e7	2.55e4	8.5e7	2.55e4	8.55e7	2.55e4
G2 bus	2	12.5e6	-0.0006e4		6.55e6	-0.0008e4	6.5e6	0.8e-7	6.55e-7	0	7e6	-0.001e4	6.55e6	-0.0006e4
Load 1	3	12.8e6	7e-8		6.5e6	-0.0002e5	6.5e6	0	6.5e6	0	7e6	-0.2e8	6.55e6	-0.00002e4
Load 2	4	15.2e6	-1550000		5.5e6	1.5e-7	5.5e6	1.5e-7	5.5e6	1.5e-7	6e6	1.5e-7	5.5e6	1e-7
Load 3	5	12.8e6	2.25e-7		1.1e7	-0.002e4	1.6e7	0	1.6e7	-0.0005e4	1.65e7	-0.001e4	1.1e7	-0.0000002
SSSC COMPENSATOR														
Sssc placed at Buses for comp	Bus no.	Before compensation			Comp at Load1-bus no.3		Comp at Load2-bus no.4		Comp at Load5-bus		Comp at G1-busno.1		Comp at G2 –bus no.3	
		P(MW)	Q(Mvar)	S	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)
G1 bus(swing)	1	62.7e6	-2800000		12.8e7	16e4	8e7	12e4	2.9e7	0.6e-7	1.8e8	1.5e5	13.5e7	12e4
G2 bus	2	12.5e6	-0.00000006		6.8e7	1.2e6	20e6	-0.0025e4	3e7	0.3e-7	6.5e7	1.5e6	9e7	2.5e6
Load 1	3	12.8e6	7e-8		5.5e7	3.5e6	20e6	0	3e7	0.6e-7	2.8e7	0	2.75e7	0
Load 2	4	15.2e6	-1550000		2.55e7	-0.0025e4	55e6	1e6	2.8e7	0.4e-7	2.65e7	-0.004e4	2.7e7	-0.00000025
Load 3	5	12.8e6	2.25e-7		4e7	4e-7	35e6	3e-7	2.9e7	0.6e-7	3.8e7	3.5e-7	4e7	3.5e-7

Table: 5. Simulation Output for Regulated Electrical Power Environment

STATCOM Placed at Buses for compensation	Bus no.	Before compensation			STATCOM COMPENSATOR									
					Comp at Load1-bus no.2		Comp at Load2-bus no.4		Comp at Load5-bus no.3		Comp at G1-busno.1		Comp at G2 –bus no.3	
		P(MW)	Q(Mvar)	S	P(MW)	Q(Mvar)	P (MW)	Q(Mvar)	P (MW)	Q(Mvar)	P (MW)	Q(Mvar)	P (MW)	Q(Mvar)
G1 bus(swing)	1	17.6 e6	58.6e6	200 e6	22.6e6	-0.29e-6	18.2e6	-2.95 e-6	27.4e6	-0.65e-6	97.3e6	-1.28e6	45.4 e6	-0.76 e6
G2 bus	2	13.6 e6	40 e6	100 e6	22.44 e6	- 0.28e-6	18.1 e6	- 2.89e-6	27.8e6	0.67 e-6	91.1 e6	-1.47 e6	52.2 e6	-0.42e6
Load 1	3	20 e6	1.57 e6	100 e6	23.65 e6	0.7e6	17.8 e6	-3.3e-6	26.8e6	0.49 e-6	90.6e6	-1.44 e6	45.28 e6	-0.67e6
Load 2	4	16 e6	0.4808 e6	80 e6	22.08e6	-0.259e-6	19.2e6	0.85e6	26.9e6	0.50e-6	90.60e6	-1.44 e6	45.27e6	-0.665e6
Load 3	5	25 e6	-1.128 e6	120 e6	21.78 e6	-0.25e-6	17.63 e6	-2.8e-6	27.75e6	0.10 e6	90.5 e6	-1.42 e6	45.27e6	-0.66 e6
SVC COMPENSATOR														
Svc placed at Buses for compensation	Bus no.	Before compensation			Comp at Load1-bus no.3		Comp at Load2-bus no.4		Comp at Load 3-bus no.5		Comp at G1-bus no.1		Comp at G2 –bus no.3	
		P(MW)	Q(Mvar)	S	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)
G1 bus(swing)	1	17.6 e6	58.6e6	200 e6	21.48e6	0.258 e-6	26.98 e6	-4.307e6	26.25 e6	0.488 e-6	90.35e6	-1.371 e6	40.06e6	-0.653 e6
G2 bus	2	13.6 e6	40 e6	100 e6	21.46 e6	-0.258 e-6	26.97 e6	-4.307e6	26.27 e6	0.48 e-6	90.04 e6	-1.386 e6	45.39 e6	-0.6392 e6
Load 1	3	20 e6	1.57 e6	100 e6	21.39e6	0	26.92e6	-4.29 e6	26.18e6	0.482 e-6	90.0 e6	-1.37 e6	45.04 e6	-0.649 e6
Load 2	4	16 e6	0.4808 e6	80 e6	21.43 e6	0.251 e-6	26.85 e6	-4.286e6	26.19 e6	0.482 e-6	90.0 e6	-1.37 e6	45.04 e6	-0.649 e6
Load 3	5	25 e6	-1.128 e6	120 e6	21.42e6	0.250 e-6	26.91 e6	-4.296e6	26.16 e6	0	90.0 e6	-1.378 e6	45.04 e6	-0.65 e6
UPFC COMPENSATOR														
Upfc placed at Buses for comp	Bus no.	Before compensation			Comp at Load1-bus no.3		Comp at Load2-bus no.4		Comp at Load3-bus 5		Comp at G1-busno.1		Comp at G2 –bus no.3	
		P(MW)	Q(Mvar)	S	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)
G1 bus(swing)	1	17.6 e6	58.6e6	200 e6	9.04 e6	0.001 e-6	7.81 e6	-1.44 e-6	33.6e6	-0.91 e-6	134e6	1.16e6	40.69e6	-0.306e6
G2 bus	2	13.6 e6	40 e6	100 e6	9 e6	0.0094 e-6	7.78 e-6	-1.16 e-6	33.6e6	-0.88e-6	81.94e6	-0.14e6	102e6	0.66e6
Load 1	3	20 e6	1.57 e6	100 e6	27.6 e6	-2.52 e6	17.82 e6	-0.59 e-6	26.92e6	0.375 e-6	90.2e6	-1.37e6	45.12e6	-0.65e6
Load 2	4	16 e6	0.4808 e6	80 e6	18.2 e6	0.176 e-6	26 e6	-2.85 e6	26.95 e6	0.365 e-6	90.2e6	-1.38e6	45.2e6	-0.65e6
Load 3	5	25 e6	-1.128 e6	120 e6	18.3 e6	0.178 e-6	17.9 e6	-0.65 e-6	28e6	-4.45e6	90.25e6	-1.38e6	45.2e6	-0.65e6
SSSC COMPENSATOR														
Sssc placed at Buses for comp	Bus no.	Before compensation			Comp at Load1-bus no.3		Comp at Load2-bus no.4		Comp at Load5-bus		Comp at G1-busno.1		Comp at G2 –bus no.3	
		P(MW)	Q(Mvar)	S	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)	P(MW)	Q(Mvar)
G1 bus(swing)	1	17.6 e6	58.6e6	200 e6	18.901e6	0	18.6496	0	28.223e6	0	120e6	1e6	45.4e6	-0.74e6
G2 bus	2	13.6 e6	40 e6	100 e6	18.901e6	0	18.6496	0	28.223e6	0	90.775e6	-1.53e6	82.8e6	1.2e6
Load 1	3	20 e6	1.57 e6	100 e6	35.6e6	2.3e6	18.649e6	0	28.23e6	0	90.7755e6	-1.53e6	45.4e6	-0.74e6
Load 2	4	16 e6	0.4808 e6	80 e6	18.901e6	0	34.8e6	2.75e6	28.23e6	0	90.7755e6	-1.53e6	45.4e6	-0.74e6
Load 3	5	25 e6	-1.128 e6	120 e6	18.901e6	0	18.6496	0	41.4e6	5.2e6	90.775e6	-1.539e6	45.4e6	-0.74e6

Fig 5: Real Power (P)

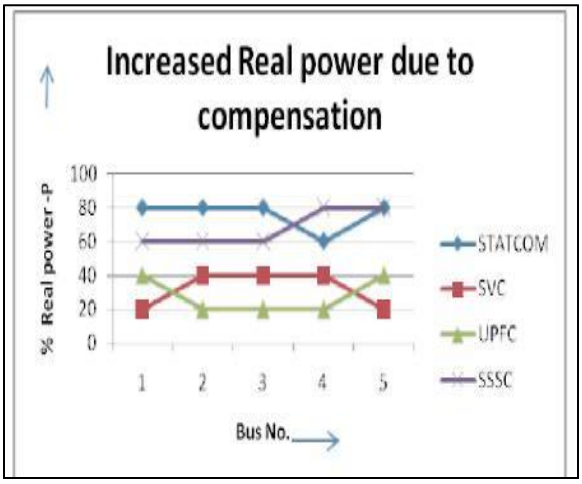
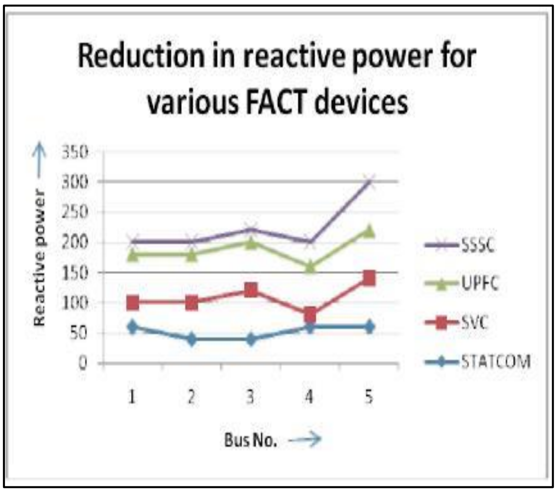


Fig 6: Reactive Power (Q)



5.0 Conclusion

Reactive power compensation for a standard 5 bus power system network is simulated. The model is simulated in MATLAB/SIMULINK. Control system phasorblocks of STATCOM, SVC, SSSC and UPFC are used and these FACTS devices are placed at various positions of the designed 5 bus system and the results are tabulated for a comparison to find the best compensating device of the designed 5 bus system. After the placement of FACTS controllers in the 5 bus, enhancement of real power and reduction of reactive power is obtained. FACTS control the output power system network in a robust manner. It is very essential for the placement of such devices as they enhance the power quality, power factor, voltage regulation and also reduces losses and thus transmission efficiency increases and can have stable power

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