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FACT Device for Reactive Power Compensation in the Deregulated Electrical Power Environment

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ABSTRACT

In the deregulating electricity market, many private sector power producers are participating 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 have happened in the past decades due to more reactive power which lead to a decrease in the magnitude of real power. It is very essential to compensate the reactive power, increase the real power flow in the transmission line, increase the transmission efficiency, improve the system stability and be in a safer place to save the fossil fuels for the future. In this paper the importance of reactive power and its various compensation techniques are applied to a five bus deregulated test case modeled and analyzed. The simulations were done using Matlab Simulink, for various FACT controllers such as STATCOM, SVC, SSSC and UPFC compensation and the results were tabulated and compared.

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1. 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 [1]. Circuit breakers are the frequently operated devices in the power grid [2]. 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 [3],[4]. Severe blackouts have occurred worldwide recently because of the lack of proper controlling [5]. This is discussed in detail in the later part of this chapter. Different approaches such as reactive power compensation [6] and phase angle shifting [7] 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 [8]. 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 [9]. 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 [10]. Two types of compensation can be used one is series and the other is shunt compensation. In recent years 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). After compensation the voltage and current were in-phase with each other. This was evident for power factor correction using D-STATCOM [11]. This allows an increase in transfer of apparent power through the transmission line [12].

2. 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 [13].

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.

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 [14].

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 [15]

2.2. 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 [16].

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, 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 [17]-[18].certain reactive powers are necessary to be supplied for the sole purpose of compensation so as to ensure the stable operation of the system [19]. Reactive power optimization is a multi-constraint, large-scale and nonlinear combinatorial optimization problem in power systems [20].

3. MATERIALS AND METHODS

Figure 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 100Mw 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 Figure 2 and Figure 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 UPFC are placed at various buses. The same above is simulated with windmill of rating 200 Mw at bus 1.The results were tabulated in Table 5 for regulated system and Table 6 for deregulated system. The Generator ratings and load ratings are given in Table 1 and Table 2.

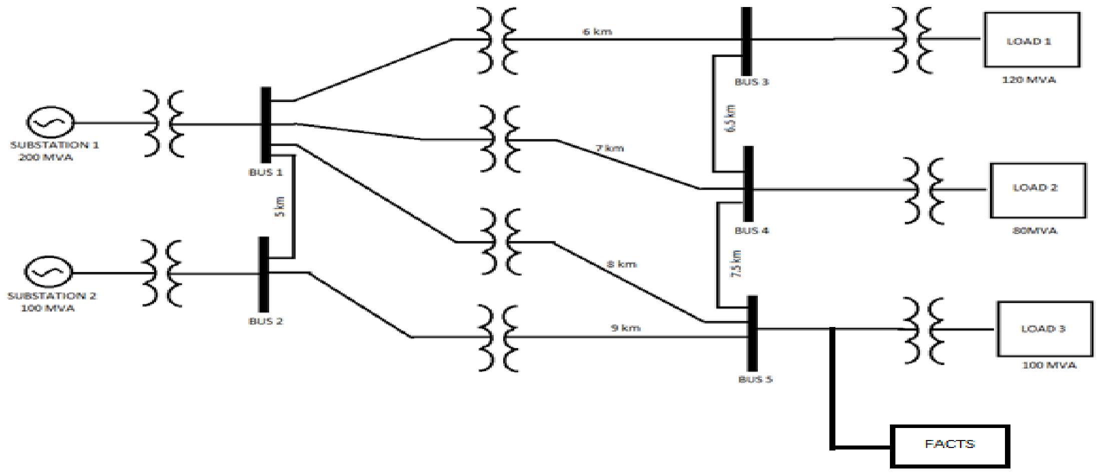

Figure 1. Five bus test case single line diagram with FACT device connected at bus no. 5

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 Q_l(Positive Var)	Capactive Reactive Power Q_c(Negative Var)
Load-1	11e3	50	66.66e6	30e6	3.33e6
Load-2	11e3	50	53.33e6	24e6	2.66e6
Load-3	11e3	50	80e6	36e6	4e6

Table 3. Parameters of Transmission Lines

Simulink blocks Pi section	line-1	line-2	line-3	line-4	line-5	line-6	line-7
Line length (km)	10	12	7	6.5	8	7.5	9

The Generator ratings are given in Table 1. The transmission line length is given in Table 3. Figure 2 shows the five bus Simulink circuit diagram for regulated environment. Figure 3 shows the five bus Simulink diagram for deregulated environment with wind source connected with bus no.1. The result is tabulated in graphical representation in Figure 4.

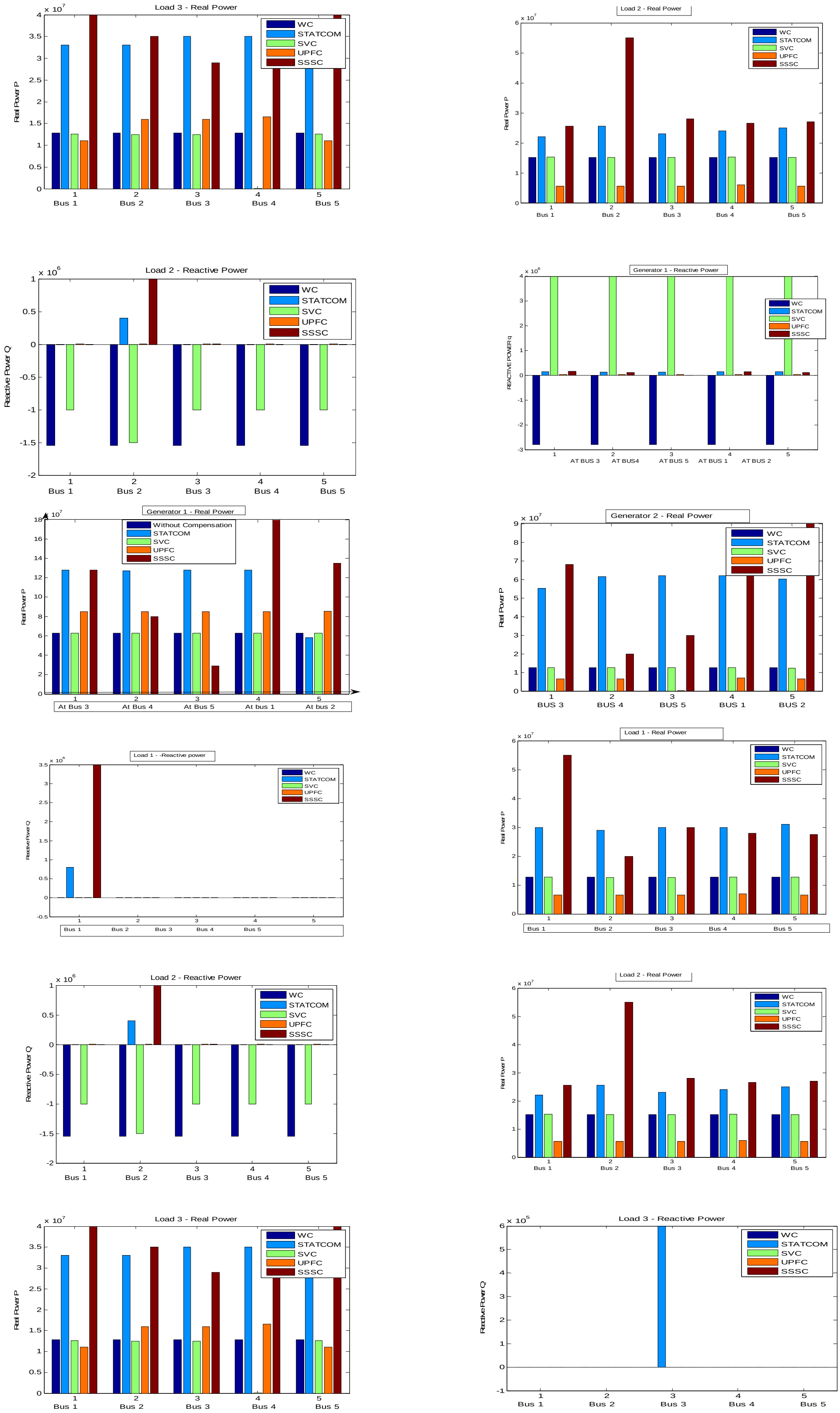

Figure 2. Result Comparision of Real and Reactive Power for various compensating devices

4. RESULT AND ANALYSIS

The Reduction in reactive power for various FACT devices and increased real power due to compensation is shown in Figure 4 and Figure 5. The figures show that STACOM gives best result among the four FACT controllers. This work can be extended to IEEE standard bus systems as future scope.

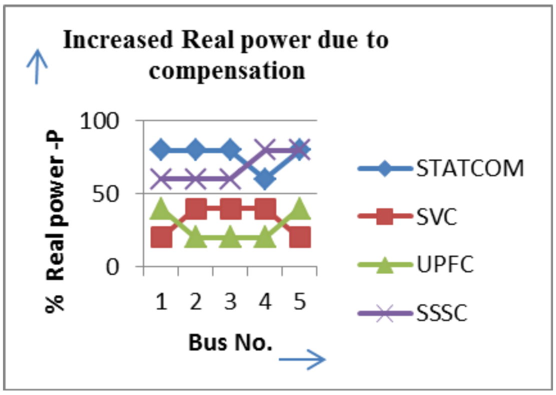

Figure 3. Real power P

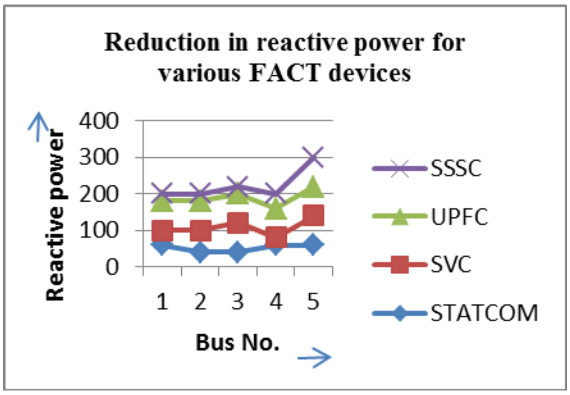

Figure 4. Reactive power Q

5. CONCLUSION

Reactive power compensation for a standard 5 bus power system network is simulated. The model is simulated in MATLAB/SIMULINK. Control system phasor blocks 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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