

Modeling of 14 Bus System with UPFC for Transient Stability Enhancement

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Abstract-The revolution of Power Electronics Technology has given opportunities for developing the FACTS devices for stable operation of power system. In the last two decades number of Power Electronic based devices are implemented and known as FACTS (Flexible AC transmission System). These devices are effectively used for voltage control, power flow control, harmonic elimination, damping oscillation and improving transient stability and minimization of losses. Static and Transient stability enhancement of IEEE 14 bus system is done with the help of UPFC. Fault is created at a bus and the results show that by properly placing UPFC, settling time of the system can be reduced considerably making the system stable with fewer oscillations.

I. INTRODUCTION

Over the past ten years, applications of renewable energy in power systems have been the most common issue mentioned amongst operators, and also encouraged with governmental policies, in order to utilize more green energy. However the penetration of renewable energy into the grid brings with it an intermittent characteristic that usually results in power quality problem [6]-[7], and possibly leading to stability concerns.

a) POWER SYSTEM MODELING

Let's analyze the method considered by the example of the simplest power system model consisting of two parts connected by AC transmission line (Fig. 2).

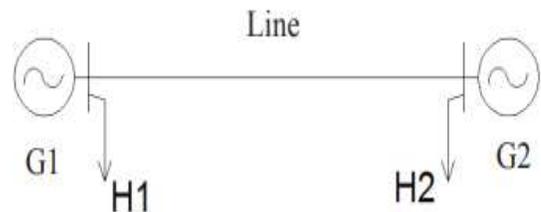


Fig.1 Simple model of AC transmission system

Following set of elements is included in the model:

Synchronous generator: The description of transient processes in synchronous generator is performed on the basis of system of Park-Gorev equations in relative units of mutual type, excluding the impact of fast transient processes in stator windings.

AC transmission line. : It is represented by a U-shaped equivalent circuit without active shunt conductivity, which corresponds to two types of active power losses: losses due to the leakage current through insulators and corona losses.

Load. : Load is represented by the constant conductivity that is sufficient, in first approximation, for the calculation of electromechanical transient processes. Variation of load values corresponds to the changes in the operation of intersystem power transmission, and makes it possible to simulate the

winter maximum and the summer minimum load conditions.

b) FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS)

After a large disturbance in a power system such as a short-circuit fault, it is very crucial to maintain system transient stability for secure operation. Following the restructuring and deregulation of the power supply industry, development of new transmission circuits are restricted because of various constraints such as environment, economy etc. This has led to the trend of utilizing the existing transmission system to its maximum possible operating limits in the competitive market. The trend, in general, leads to the system transient stability margin being reduced, making the system more vulnerable for large disturbances. One way to enhance system stability is by using series compensation which modifies the transmission line reactance to increase the stability limit. In order to improve the transient stability performance, early detection of fault, and fast fault clearance is most important.

A SVC can be continuously controlled to modify reactive power injection in order to maintain a bus voltage. The ideal model of SVC is shown in Fig. 1.1, consisting of a fixed capacitor C connected in parallel with a variable reactor L and is used for stability studies [5].

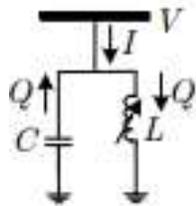


Fig.2 Ideal model of SVC for system stability studies

II. LITERATURE REVIEW

[1] This paper proposes a new control strategy of shunt flexible ac transmission system (FACTS)

devices to improve the first swing stability limit of a simple power system. It is shown that the speed based bang-bang control (BBC) is unable to use the entire decelerating area in maintaining stability. The proposed control strategy improves the stability limit first by maximizing the decelerating area and then fully utilizing it in counterbalancing the accelerating area

[2] This paper presents results on a robust linear quadratic Gaussian (LQG) damping control scheme for improving the inter-area mode oscillations of power systems. A technique is also proposed to guarantee minimum-phase/well-damped transmission zeros by appropriately “squaring” the design plant, for the purposes of efficient robust recovery. The performance of the designed system is assessed in the frequency domain and via appropriate time-domain simulations based upon the nonlinear model under a variety of scenarios.

[3] This paper discusses the effect of simultaneous use of one shunt and one series FACTS device on the transient stability condition of a power system. The devices used are thyristor controlled series compensator (TCSC) and static synchronous compensator (STATCOM). The transient stability condition is assessed using trajectory sensitivity analysis (TSA). It is shown that TSA can be used to determine the optimal locations and suitable operating conditions of the two devices for transient stability improvement

[4] This paper focuses on TCSC and its role in power system stability enhancement. The general acceptance of power electronics technologies as the means for enhancing the capabilities of the transmission network is demonstrated by the Flexible AC Transmission Systems (FACTS) initiative launched by EPRI to advance research and development in this direction. Thyristor controlled series compensation (TCSC) is one of such electronics systems.

III. METHODOLOGY

a) IEEE 14 BUS SYSTEM

IEEE bus systems are used by researchers to implement new ideas and concepts. This Technical Note describes the details of the IEEE 14-bus system [1]. The system consists of loads, capacitor banks, transmission lines, and generators.

A. Bus Classification In general, a bus in an electrical power system is fed from the generating units which inject the active and reactive power into it and loads real and reactive power s from it. [n load flow studies, the generator and load (complex) powers are lumped into a net power. This net power is called bus injected power. The net power injected in the bus is given by

$$S = P + jQ = P_G + jQ_G - P_D + jQ_D \quad \dots\dots(I)$$

- 1) Load Bus
- 2) Generator Bus or Voltage Controlled Bus.
- 3) Slack (Swing) Bus

Initially the real and reactive powers are not specified at all buses, so complex power flow in the system is not known .the power loss also unknown up to completion of flow solution. So it's necessary having one bus at which the complex power is unspecified, so that it will supplies the difference in the total system load and losses. By this reason it must be a generator bus.

b) UPFC:

The schematic diagram shown in Fig.3.1 represents the basic structure of UPFC. A UPFC consists of two linked self-commutating converters share a common dc capacitor, which is connected to the ac systems through series and shunt coupling transformers. The ac/dc converters are switching voltage-sourced converters with semiconductor devices having turn-off capability. The dc sides of both converters are connected to a common dc capacitor, which provides a dc voltage support for the converter operation and functions as an energy storage element. Real power flows between the shunt and series ac terminals of UPFC through the common dc link. UPFC generates or absorbs the needed reactive power locally by the switching operation of its converters. Each converter generates or absorbs the reactive power independently, i.e., reactive power does not flow through the dc link. The real power transfer between the shunt converter and series converter sets the UPFC rating. This rating should be at least as large as the real power exchanged between the two converters

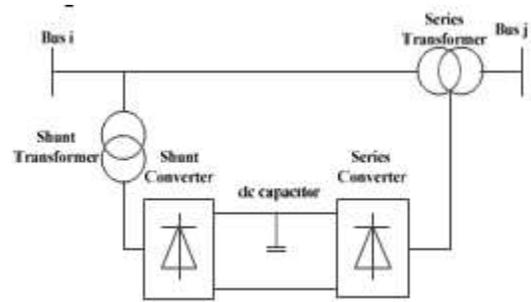


Fig. 3: Schematic diagram of the UPFC

IV. RESULTS

Case 1: Without UPFC:

In this system the fault has mainly occurred at bus 6. The active power P and reactive power Q at various buses has been shown below. In MATLAB/ SIMULINK model of 14 bus system without any compensation device is shown in figure 5.1.

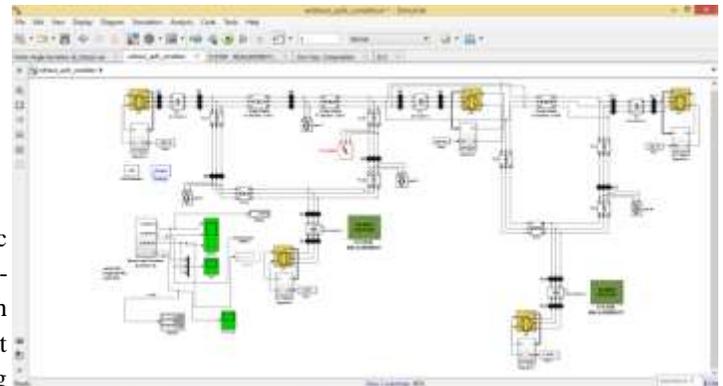
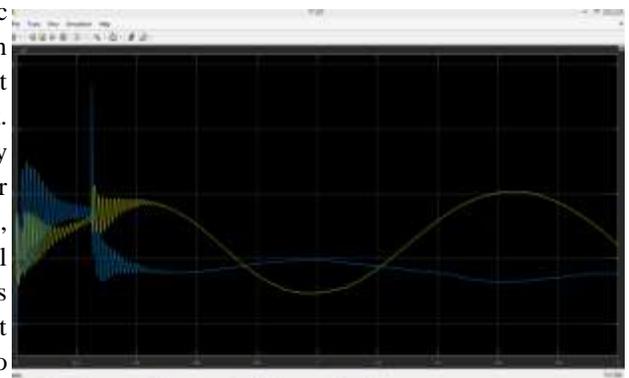
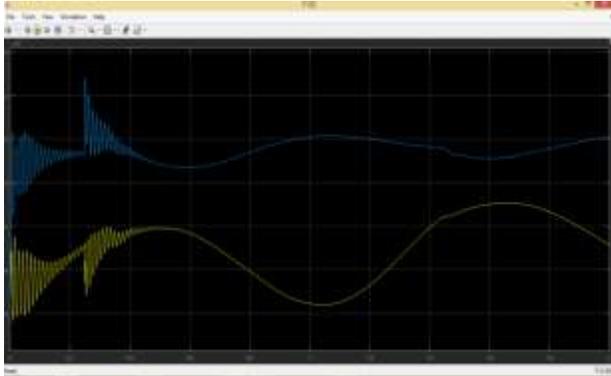


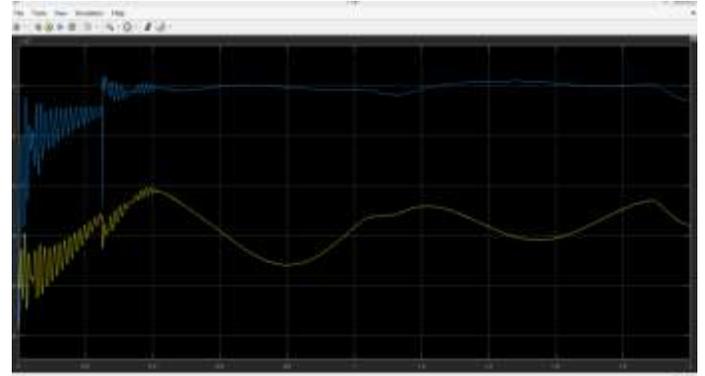
Figure 4.1: 14 bus systems having no compensation.



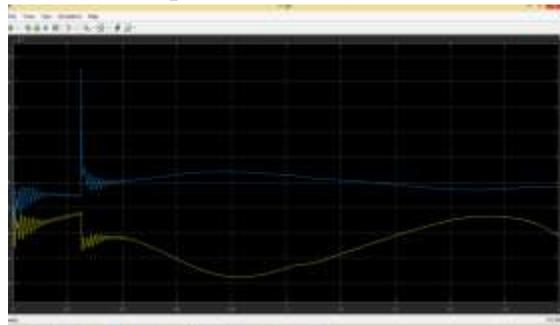
Graph 4.1 : P and Q at bus 4



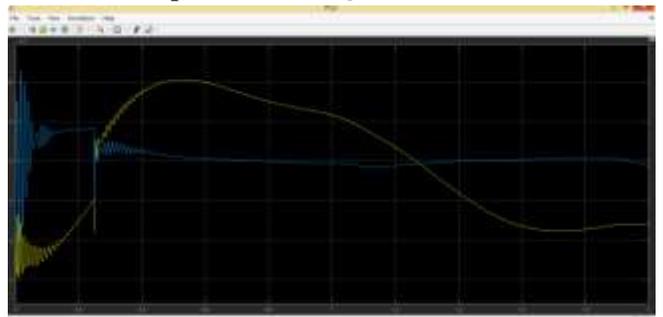
Graph 4.2 : P and Q at bus 5



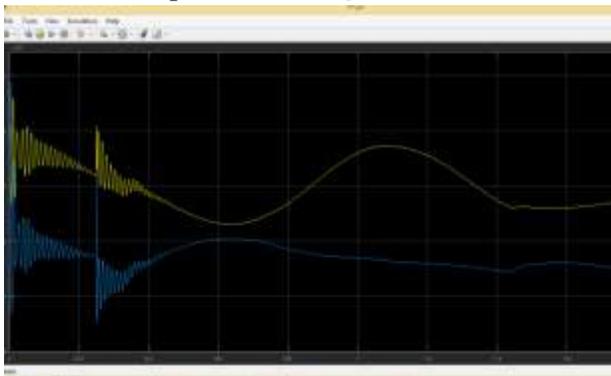
Graph 4.6 : P and Q at bus 11



Graph 4.3 : P and Q at bus 6



Graph 4.7 : P and Q at bus 14

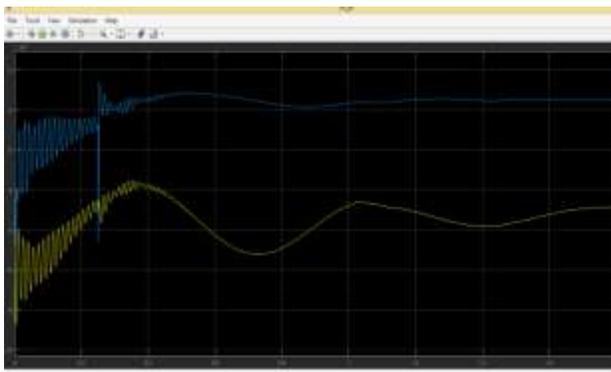


Graph 4.4 : P and Q at bus 7

The value of reactive power at bus 4 is found to be 3.853×10^7 and that at bus 6 is 1.616×10^7 . For bus 7 and 12 the reactive power was 1.559×10^7 and 0.359×10^7 respectively. These are the buses which are in direct contact with the load.

Case 2: with UPFC having 3 phase LLLG Fault

Unified Power Flow Controller has been used as compensating device in 14 bus system. The reactive power has improved as compared to that in case 1 at various buses which has been described as below. Also 14 bus system with UPFC has been shown in figure:



Graph 4.5 : P and Q at bus 9

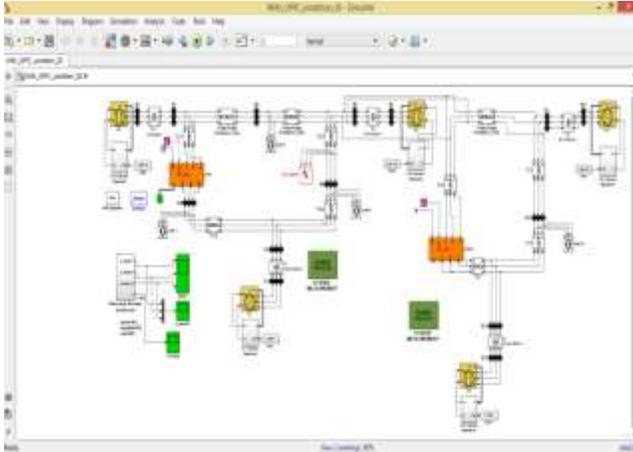
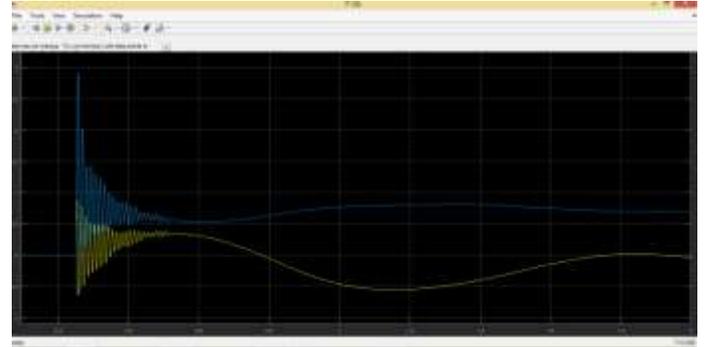
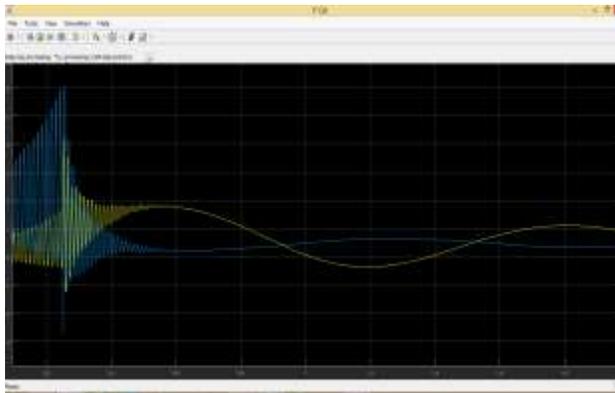


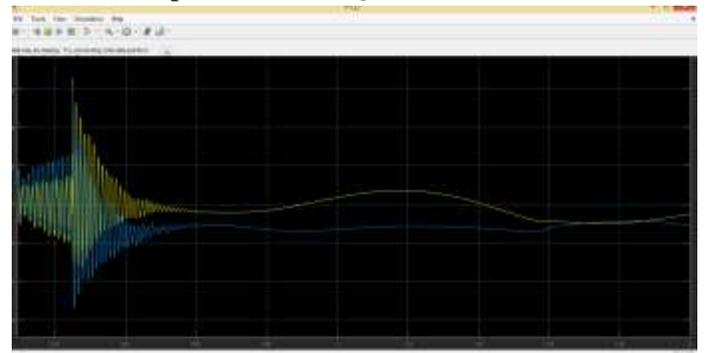
Fig 4.2: 14 bus system having UPFC



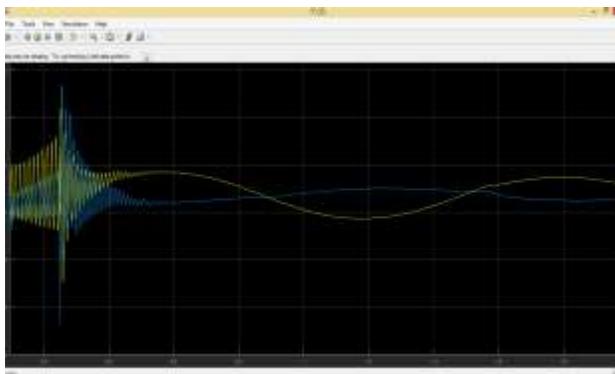
Graph 4.10 : P and Q at bus 6



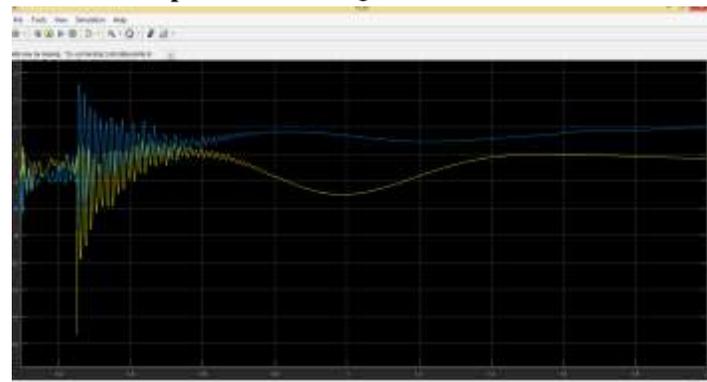
Graph 4.8 : P and Q at bus 4



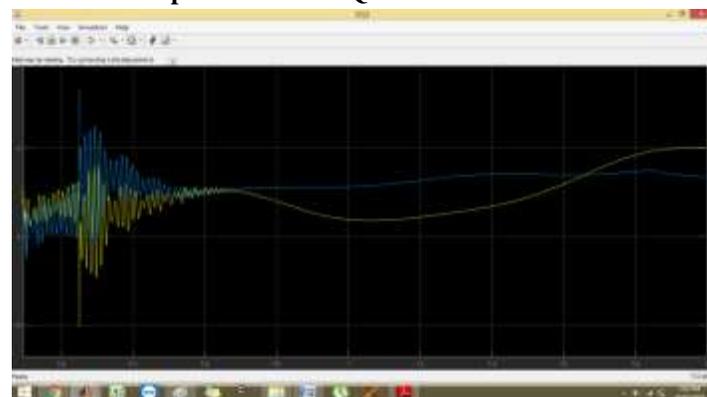
Graph 4.11 : P and Q at bus 7



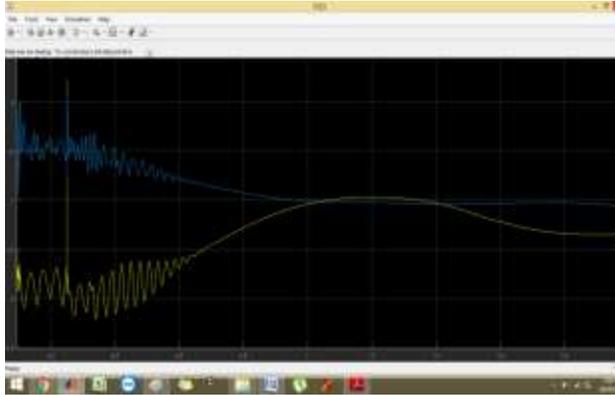
Graph 4.9 : P and Q at bus 5



Graph 4.12 : P and Q at bus 9



Graph 4.13 : P and Q at bus 11



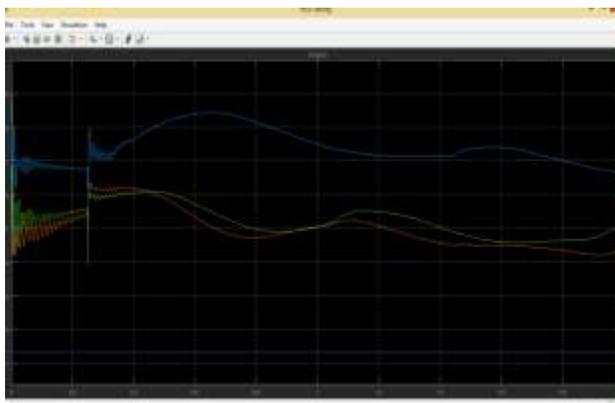
Graph 4.15 : P and Q at bus 12

The value of reactive power at bus 4 is found to be 3.734×10^7 and that at bus 6 is 6.984×10^7 . For bus 7 and 12 the reactive power was 4.602×10^7 and 3.507×10^7 respectively. These are the buses which are in direct contact with the load.

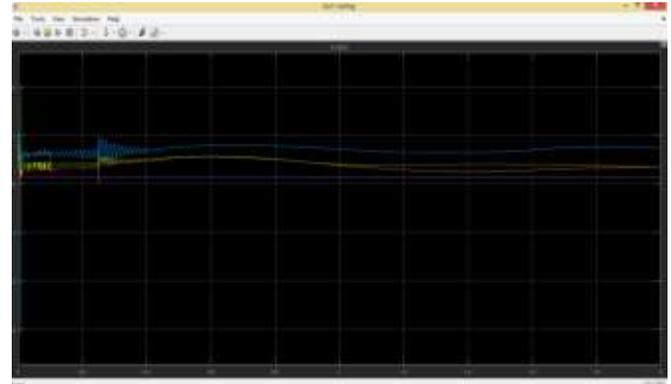
Table1: Comparison of reactive power output at the buses

Buses	Case 1	Case 2
Bus 4	3.253×10^7	3.734×10^7
Bus 6	1.616×10^7	6.984×10^7
Bus 7	1.559×10^7	4.602×10^7
Bus 12	0.359×10^7	3.507×10^7

Swings in the machine:



Graph 4.16 : Swing in the various machines in 14 bus system without UPFC



Graph 4.17 : Swing in the various machines with UPFC

The modeling of the system by using UPFC controller enhances the power inputs at various bus terminals. This will in turn enhance the power carrying capacity of the system being fed to the load. Also use of UPFC in this system enhances the power system stability by reducing the swing in the machines.

CONCLUSION

The modeling of 14 bus system has resulted in improvement of reactive power injected into the grid at various buses. Also the stability in the system has been achieved by using a FACTS device UPFC as it has reduced the swings in the various machines.

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