Volume 5, Issue 5, May 2015 ISSN: 2277 128X
International Journal of Advanced Research in Computer Science and Software Engineering
Research Paper
Available online at: www.ijarcsse.com

Power System Stability Enhancement Using FACTS

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Abstract— In the area of instrumentation, simulations of various controllers are done by using various techniques such as LabVIEW & MATLAB/Simulink etc. Due to rapid developments in technology, the choice of software and hardware should be considered carefully along with cost. It is a reality that the cost of designing new instrumentation can be decreased significantly if displays are modelled in software rather than in hardware components. Many computer delivered simulations, control, scientific visualizations software solutions are available which uses diverse software such as MATLAB/SIMULINK, LabVIEW etc. The objective is to model multimachine system with STATCOM & UPFC controllers in Simulink/MATLAB which is very much realted to the actual physical system and analyze their response using MATLAB/Simulink. The simulated STATCOM & UPFC shows how oscillations can be damped out with STATCOM & UPFC controller. Change in the value of various parameters of the STATCOM & UPFC controller affects the stability of the system.

Keywords— Simulink , UPFC Statcom, MATLAB & Labview.

I. INTRODUCTION

Stability of power system has been a issue of great concern in system operation. This can be recognized from the fact that in steady state, the angular speed of all the generators must remain the same in the system.. The stability of a system determines whether the system can regain stability that is settle down to the original or close to the steady state after the transients disappear. In general, power system stability is the ability of the system to respond to a disturbance from its normal operation by returning to a condition where the operation is again normal.

Power system stability may be broadly defined as that property of a power system that enables it to remain in a state of operating equilibrium under normal operating conditions and to regain an acceptable state of equilibrium after being subjected to a disturbance.

Stability of a power system is classified into three main categories namely

- Steady state stability
- Transient stability.
- Dynamic stability.

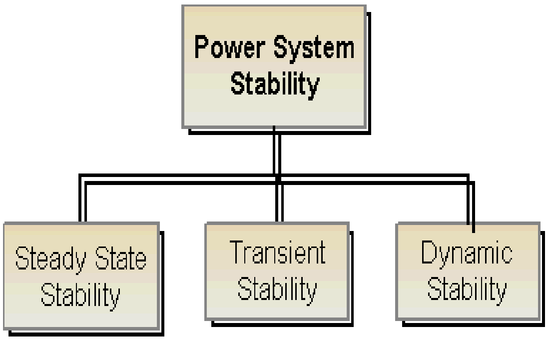


Figure 1. Power system Stability diagram

II. TRANSIENT STABILITY CONTROLLER

The loss of transient stability in a power system is due to overloading of some of the lines (or due to drastic line faults), as a consequence of tripping off of the other lines after faults or heavy loss of loads. By means of fast and flexible control over the ac transmission parameters and network topology, FACTS technology can provide power control, improve the power transfer capacity, reduce the line losses, increase power system damping and enhance the stability and security of the power system.

Flexible AC Transmission Systems (FACTS) is alternating current transmission systems including power electronics based and different static controllers with an objective to build flexibility in the system in order to improve controllability and increase power transfer capability.

By providing more flexibility, FACTS controllers can allow a line to carry power closer to its thermal rating. FACTS technology refers to device that enables flexible electrical power system operation that is controlled active and reactive power flow redirection in transmission paths. FACTS device provides continuous control of power flow or voltage, against daily load changes or even change in network topologies.

III. FACTS CONTROLLERS (STATCOM & UPFC)

FACTS Controller is a power electronic based system that provides control of one or more AC transmission system parameters. The term FACTS controllers describes power electronic based circuit configuration applied in ac transmission systems. FACTS represent flexible ac transmission system, with the term flexible' indicating the controllability of voltage and/or current. Controllable Parameters for FACTS Controllers

There are few points that are to be considered regarding the possibilities of power flow control. These are:

- Control of the line impedance X can provide a strong means of current control.
- When the angle is not large, control of X or the angle substantially provides the control of active power.
- Control of angle which in turns control the driving voltage, provides strong means of controlling the current voltage and hence active power flow when the angle is not large.
- Injecting a voltage in series with line, and perpendicular to the current flow, can increase or decrease the magnitude of the current flow. Since the driving voltage leads the current flow by 90 degree, this means injection of reactive power in series, can provide a powerful means of controlling the line current, and hence the active power when the angle is not large.
- Injecting a voltage in series with line and with any phase angle with respect to the driving voltage can control the magnitude and the phase of the current. This means that injecting the voltage phasor with variable phase angle can provide powerful means of precisely controlling the active and reactive power flow; this requires the injection of both active and reactive power in series.
- When the angle is not large, controlling magnitude of one or the other line voltages can be a very cost effective means for the control of reactive power flow through the interconnection.

IV. STATIC SYNCHRONOUS COMPENSATOR (PHASOR TYPE)

The Static Synchronous Compensator (STATCOM) is a shunt device of the Flexible AC Transmission Systems (FACTS) family using power electronics to control power flow and improve transient stability on power grids . The STATCOM regulates voltage at its terminal by controlling the amount of reactive power injected into or absorbed from the power system. When system voltage is low, the STATCOM generates reactive power (STATCOM capacitive). When system voltage is high, it absorbs reactive power (STATCOM inductive).

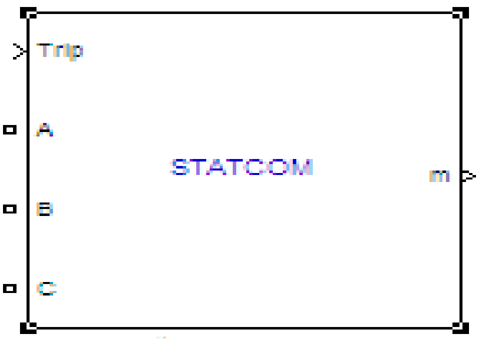


Figure 2.Statcom block

The variation of reactive power is done by means of a Voltage-Sourced Converter (VSC) connected on the secondary side of a transformer. The VSC uses forced-commutated power electronic devices (GTOs, IGBTs or IGCTs) to synthesize a voltage V2 from a DC voltage source. The principle of operation of the STATCOM is explained in the figure 3.2 showing the active and reactive power transfer between a source V1 and a source V2. In this figure, V1 shows the system voltage to be controlled and V2 is the voltage generated by the VSC.

V. SYSTEM MODELLING AND SIMULATION

STATCOM & UPFC controller has been predicted to be used for power-system performance improvements, particularly, the improvement in the system stability, damping of power oscillations, prevention of voltage collapse, dynamic voltage control etc.

Multi-Machine System Modeling

The popular Western System Coordinated Council (WSCC) 3-machines 9-bus practical power system with loads assumed to be represented by constant impedance model. WSCC system is widely used and found very frequently in the relevant literature as presently appearing in references .

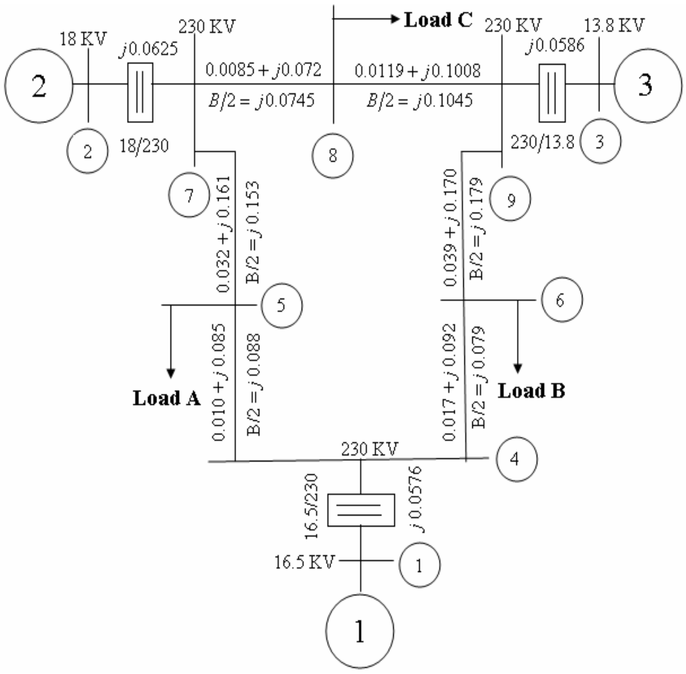


Figure 3. shows multi-machine system.

The base MVA of the system is 100, and system frequency is 60 Hz. The complete system has been represented in terms of MATLAB. This model finds its utility for transient stability study the reason being power system configuration differs before fault and after fault. Multi-machine system with all the required components is modeled. All time constants are in seconds.

VI. MATLAB/SIMULINK MODEL OF MULTI-MACHINE (3-MACHINE 9-BUS) SYSTEM

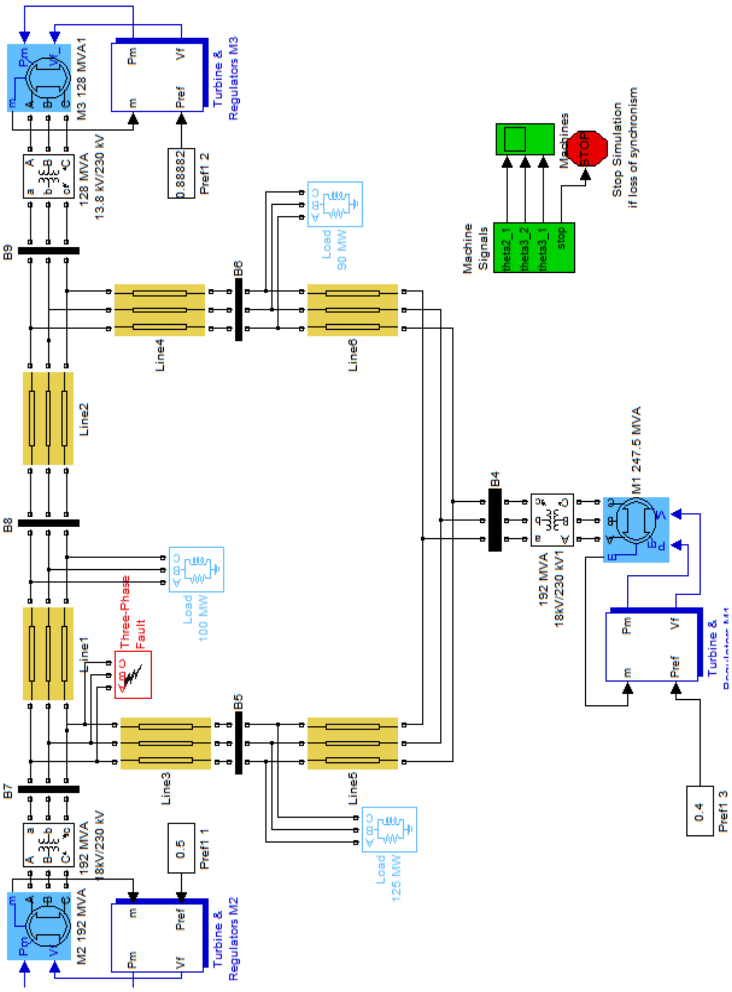


Figure 4. MATLAB/Simulink model of Multi-Machine System

VII. SIMULATION RESULTS FOR MULTI-MACHINE SYSTEM

(a)STATCOM is placed between Bus 5 and Bus 4

STATCOM for the various cases has the following rating**.**

Nominal Voltage = 230KV
Frequency = 60Hz
Converter Rating = 100MVA
Converter Impedence [R(pu),L(pu)] = [0.44/30,0.22]
Converter Initial current [Mag(pu),Ph(deg)] = [50,35]
Vac Regulator Gain [Kp, Ki] = [100 2000]
Vdc Regulator Gain [Kp, Ki] = [0.0001, 0.0032]
Current Regulator Gain [Kp, Ki ,Kf] = [0.3, 19, 0.33]

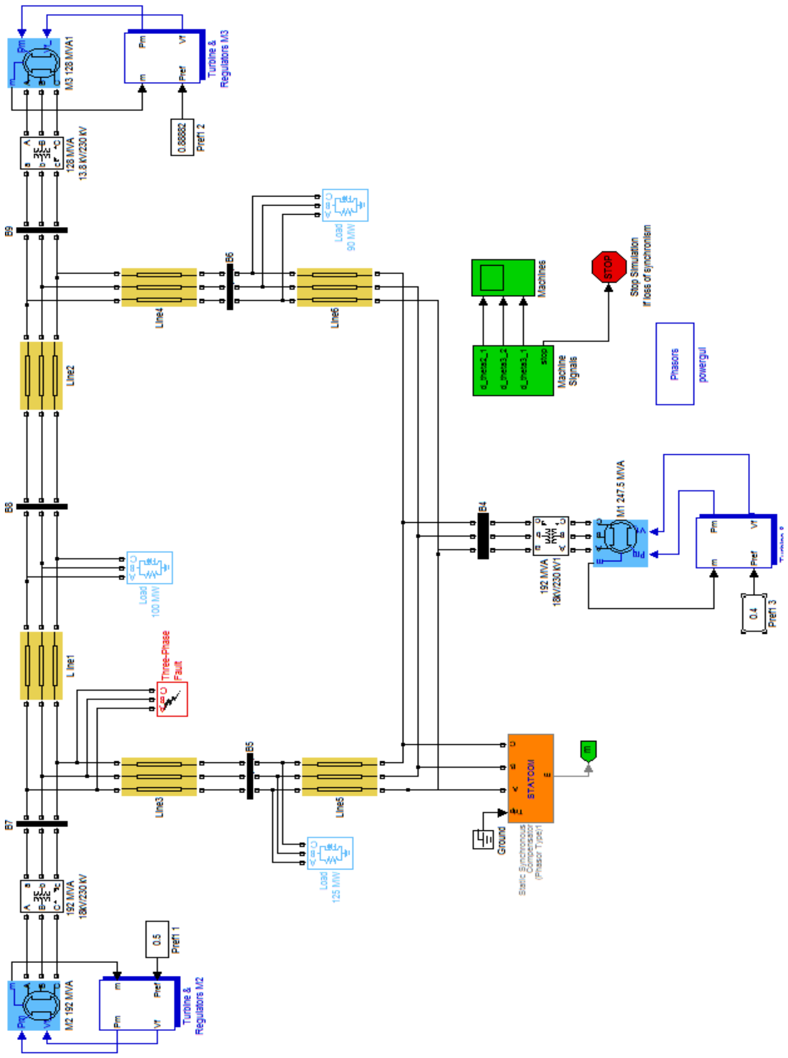


Figure 5. MATLAB/ Simulink model of Multi-Machine System with STATCOM Between Bus 5 and Bus 4

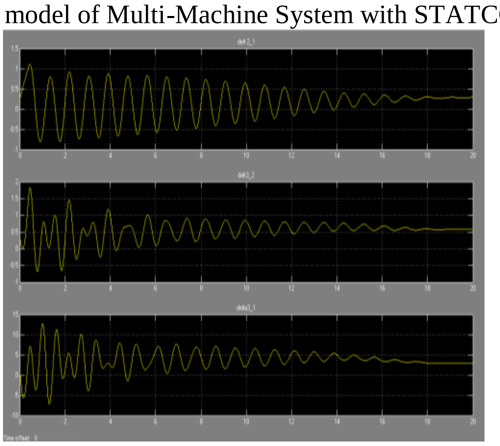


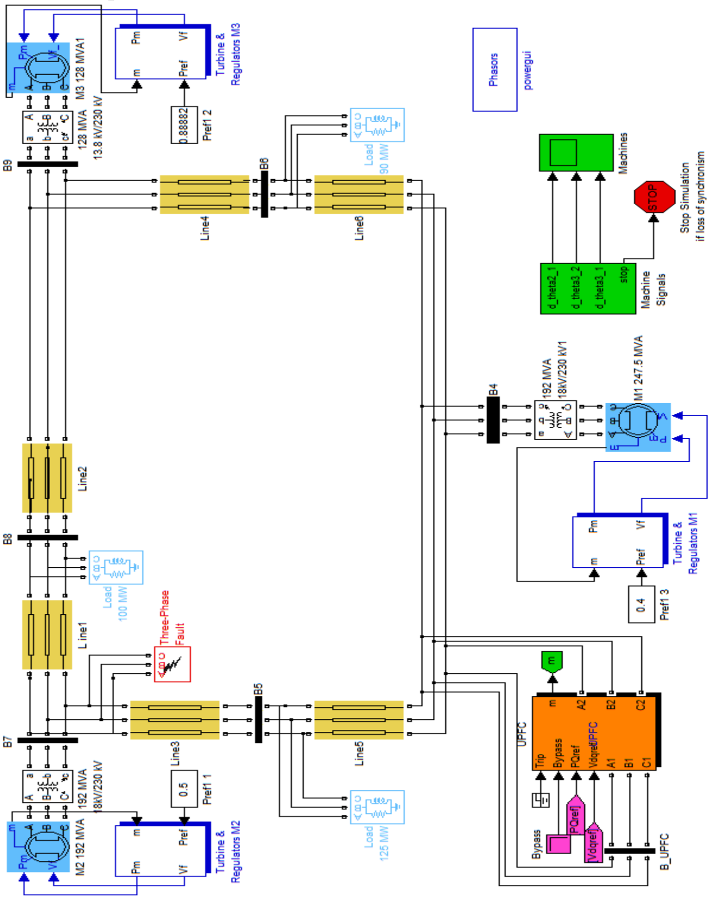
Figure 6: shows the relative angular positions for delt2_1, delt3_2and delt3_1 multi-machine system with STATCOM controller placed between Bus 5 and Bus 4 and fault taking place between Bus 5 and Bus 7.The total simulation time taken is 20 sec.

Table 1. Stability time for STATCOM placed between Bus 5 and Bus 4

It is clear from the table that the time required by delt3_1 to get stable is minimum i.e 17 seconds.

b) UPFC is placed between Bus 5 and Bus 4

UPFC for the various cases has the following rating.
Nominal Voltage = 500KV Frequency = 60Hz Shunt Converter Rating = 100MVA
Shunt Converter Impedence [R(pu),L(pu)] = [0.22/30,0.22]
Series Converter Rating = 100MVA
Max. injected voltage(pu)=0.1
Shunt Converter Impedence [R(pu),L(pu)] = [0.16/30,0.16]
D.C link nominal voltage(v)=40000V
D.C link total equivalent capacitance(F)=750micro farad
Vac Regulator Gain [Kp, Ki] = [5 1000]
Vdc Regulator Gain [Kp, Ki] = [0.001, 0.020]
Current Regulator Gain [Kp, Ki] = [0.5, 25]/3
Series converter control parameters[Kp, Ki]=[0.025 1.5]



Figue 7 MATLAB/ Simulink Model Of Multi-Machine System With STATCOM Between Bus 5 And Bus 4

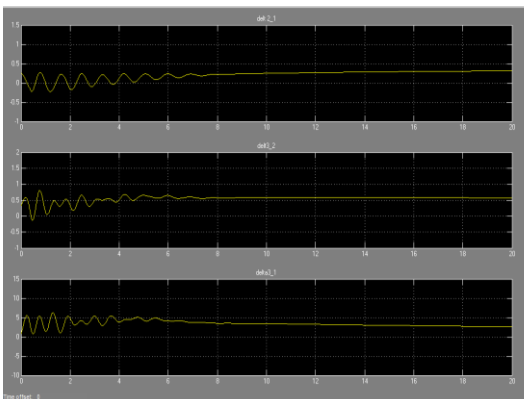


Figure 8 shows the relative angular positions for delt2_1, delt3_2and delt3_1 multi-machine system with UPFC controller placed between Bus 5 and Bus 4 and fault taking place between Bus 5 and Bus 7.The total simulation time taken is 20 sec.

Table 2 : Stability time for UPFC placed between Bus 5 and Bus 4

It is clear from the table that the time required by delt3_1 to get stable is minimum i.e 6 seconds.

FAULT POSITION	STATCOM POSITION	Stability time for delt2_1 (in sec.)	Stability time for delt3_2 (in sec.)	Stability time for delt3_1 (in sec.)
Between Bus 5 &Bus 7	Between Bus 5 & Bus 4	18	17.6	17

FAULT POSITION	UPFC POSITION	Stability time for delt2_1 (in sec.)	Stability time for delt3_2 (in sec.)	Stability time for delt3_1 (in sec.)
Between Bus 5 & Bus 7	Between Bus 5 & Bus 4	8	7	6

VIII. RESULTS

The results of those graphs are given below with both devices STATCOM & UPFC:-

FACTS CONTROLLER	STATCOM	UPFC
STATCOM & UPFC POSITION :- Between Bus 4 & Bus 5		
Stability time for delt2_1(in sec)	18	8
Stability time for delt3_2(in sec)	17.6	7
Stability time for delt3_1(in sec)	17	6

IX. CONCLUSION

The power system stability has been compared and discussed for improvement of a 3-machine 9 bus system by station & UPFC. The dynamic behaviour of the power system is compared with the presence of STATCOM & UPFC in the system in the event of a major disturbance. Then the performance of UPFC for power system stability improvement is compared with the STATCOM . It is clear from the simulation results that there is a considerable improvement in the system performance with the use of UPFC for which settling time in post fault is found to be around 4.7 sec.

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