TRANSIENT STABILITY IMPROVEMENT IN MULTI-MACHINE SYSTEM USING UPFC

***BUDI SRINIVASARAO*[1], *G.SREENIVASAN*[2],**
[1]*Research Scholar, Electrical Department, Jodhupur National University, Rajasthan, India*
[2] *Assoc.Prof, Dept. of EEE, Intel Engineering College, Anantapur, India*

Abstract -The stability of an interconnected power system is compare to normal or stable operation after having been subjected to some form of disturbance. With interconnected systems continually growing in size and extending over vast geographical regions, it is becoming increasingly more difficult to maintain synchronism between various parts of the power system. This paper investigates the comparison of transient stability limit of a multi-machine power system with the help of a UPFC operated in perpendicular voltage control mode and their it's comparison.

Keywords: FACTS, Transient Stability limit, UPFC.

.

1. INTRODUCTION

An interconnected power system basically consists of several essential components. They are namely the generating units, the transmission lines, the loads, the transformer, static VAR compensators and lastly the HVDC lines. During the operation of the generators, there may be some disturbances such as sustained oscillations in the speed or periodic variations in the torque that is applied to the generator. These disturbances may result in voltage or frequency fluctuation that may affect the other parts of the interconnected power system. External factors, such as lightning, can also cause disturbances to the power system. All these disturbances are termed as faults. When a fault occurs, it causes the motor to lose synchronism if the natural frequency of oscillation coincides with the frequency of oscillation of the generators. With these factors in mind, the basic condition for a power system with stability is synchronism. Besides this condition, there are other important condition such as steady-state stability, transient stability, harmonics and disturbance, collapse of voltage and the loss of reactive power.

Recent progresses in power electronics and as a result in Flexible AC Transmission Systems (FACTS) technology, give the ability to have a real time control on power system parameters and improve the transient stability. UPFC is one of the most effective FACTS devices, which is the combination of series and the shunt converter, connected together by a common DC link and have abilities of two FACTS devices named Static Synchronous Series Compensator (SSSC) and Static Compensator (STATCOM) together.

Studies reported in literatures like have shown that UPFCs can be used to enhance the transient stability of the power system. All mentioned papers use Single Machine Infinite Bus (SMIB) power system for simulations.

Literature have shown that quadrature voltage injection have most effect on transient stability improvement.

As mentioned above, not much attention has been given to effects of UPFC on transient stability improvement of Multi-machine power system. In this paper a study is performed on transient stability comparison in multi-machine power systems using UPFC.

2. Multi-Machine Stability

The classical model of the power system including the synchronous machines shown in is used to study the stability of the system. This is the simplest model used in the study of the system dynamics and requires a minimum amount of data to be collected initially.

Moreover using this model the analysis can be made at a short interval of time. The time is of the order 1 sec in most power systems, during which the system dynamic response is largely dependent on the stored kinetic energy in the rotating masses. This gives a multi-port representation of a power system where always m is less than n.

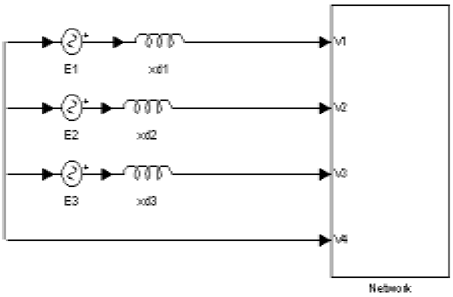


Fig: 2.1 Multi-Machine System

Owing to interconnected systems, the loads cannot be ignored for transient stability analysis. Hence the loads are converted to equivalent admittances between the generators and ground. If the load bus has a voltage V_Li, real power P_Li, reactive power Q_Li and a current I_L flowing into a load admittance

$$Y_L = G_L + jB_L then$$

$$P_L + jQ_L = V_L . I_L^* = V_L\left\{V_L^*\left(G_L - jB_L\right)\right\} = V_L^2\left\{G_L - jB_L\right\}$$

$$Y_L^* = G_L - jB_L = \left(P_L + jQ_L\right)\big/V_L^2$$

Each generator is found to have an emf source behind the transient reactance of constant magnitude. This internal voltage is calculated from the load flow study on the system. The internal angle corresponding to this voltage is calculated from the pre-transient terminal voltage as follows:

Let the terminal voltage be considered as the reference for time being. V & I can be related by the expression as

$$V.I^* = P + jQ$$

$$I = \left\{\left(P + jQ\right)/V\right\}^* = \left(P - jQ\right)/V$$

But the mathematical model we can write

$$E_i = V_i + jX_{di} I$$

$$E\angle\delta_i = V_i + jX_{di}\left\{P - jQ\right\}/V = V_i + \frac{X_{di}Q}{V} + j\frac{X_d}{V}$$

The initial generator angle δ_o is then obtained by adding the pre-transient voltage angle.

$$\delta_0 = \delta_i + \theta_i$$

The YBUS matrix is formulated for the each network condition Equivalent load admittances are connected between the load buses and the reference node

[YBUS] = [YBUS] + diag [YL]

Also the transient reactance of the generators can also be added to the YBUS so th0at it becomes augmented with the same order but with some modifications at the diagonal elements.

[YBUS] = [YBUS] + diag [- jx_d]

Where x_d= [xd1 x_{d2} x_{d3} …… xdm 0 0 …. n] where m ---- number of the machines n --- number of buses.

Finally all the nodes except for the generators are eliminated and the modified YBUS is obtained. Also all nodes have zero injection currents except for the internal generator nodes.

Current vector pumped into the network is indicated as

$$I_{BUS,i} = -\frac{E_m\angle\delta_{0i}}{X_{di}} \; for\ i = 1\ to\ r$$

$$I_{BUS,i} = 0.0\ for\ i = m+1\ to\ n$$

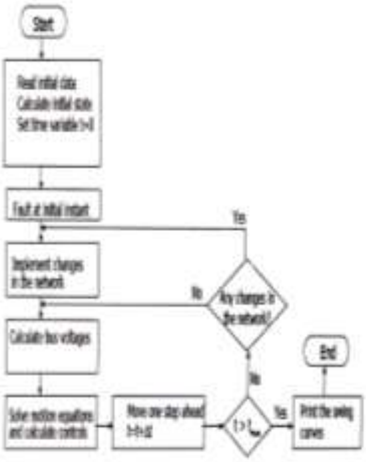
From the above equations, the bus voltages at time t=0 (fault occurrence) can be calculated as

$$[V_{BUS}] = [Y_{BUS}]^{-1}\,[IBUS]$$

Y_{BUS} differs for the during fault and post fault conditions. Hence using appropriate Y_{BUS} modifications, the V_{BUS} can be got for various operating conditions.

Using the above the values the electrical power delivered by every generator is calculated as

$$P_{ei} = \left\{E_i V_i / X_{di}\right\}\sin\left(\delta_i - \theta_i\right)$$



3. Unified Power Flow Controller (UPFC)

The Unified Power Flow Controller (UPFC) is the most versatile member Flexible AC Transmission Systems (FACTS) family using power electronics to power flow on power grids. The UPFC uses a combination of a shunt controller (STATCOM) and a series controller (SSSC) interconnected through a common DC bus. The Unified Power Flow Controller (UPFC) is a power electronic co which can be used to control active and reactive power flows in a transmission injection of (variable) voltage in series and reactive current in shunt.

UPFC MODEL:

The UPFC model that used in this paper is shown in fig. 3.1. It consist of a series voltage source representing the UPFC series branch, the ***Iq*** parallel current source representing the UPFC parallel reactive compensating effect and the ***Ip*** parallel current source representing the UPFC parallel active current [5].

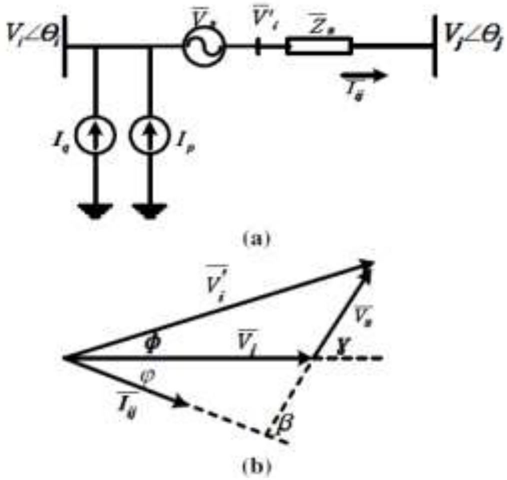


Fig.3.1 UPFC model connected between buses i and j in the power system (a) and its related phasor diagram (b)

As described in the previous section, for transient stability calculations we need to model the UPFC with appropriate loads. Injection model of UPFC models series branch as loads that depend on related bus voltages. This model is shown in Fig. 3.1 [5].

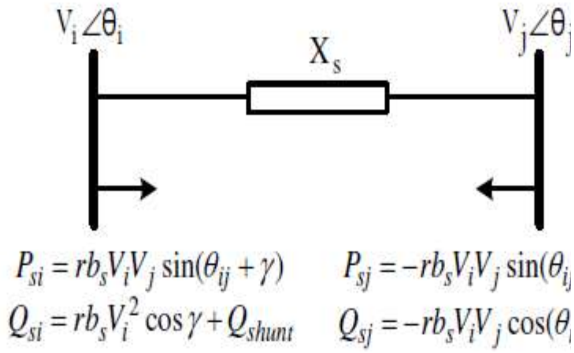


Fig 3.2 Injection model of UPFC

In this model V_s is the series injected voltage vector, $V_s = rV_i$, X_s is series reactance of the series transformer, $BS=1/X_s$ and γ is the angle between the series injected voltage and the sending end bus voltage.

4. SIMULATION RESULTS

Investigations performed on the standard IEEE 30 bus system for determining the transient stability. Mat lab programming, has been done to test the systems for stability under various operating conditions. These results are based on performance index namely Transient Stability Index. This index is compare for certain predefined outages on different operating conditions and tested upon the standard IEEE 30 bus system.

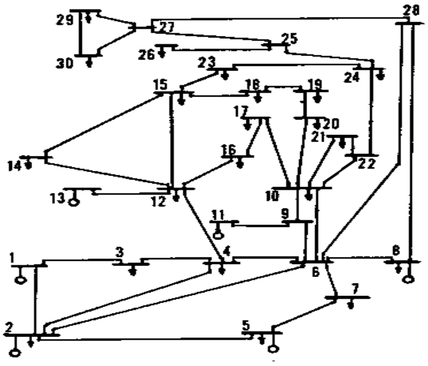
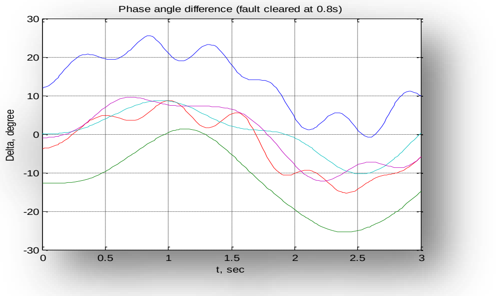


Fig 4.1 Typical IEEE 30 bus system

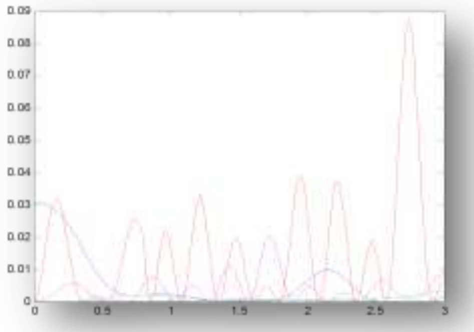
Whenever a fault occurs on a bus or on a transmission line various parameters like voltage, kinetic energy, potential energy, rotor swing angle etc., of the machines connected to the corresponding buses are also subjected to variations. These variations are mainly responsible for unstable and stable nature of the buses in the systems. The forthcoming graphs shows these comparisons experienced in the parameters of the machines in the standard buses explained above for the 3 phase short circuit at bus no.3s and bus no.5 respectively.

Without UPFC

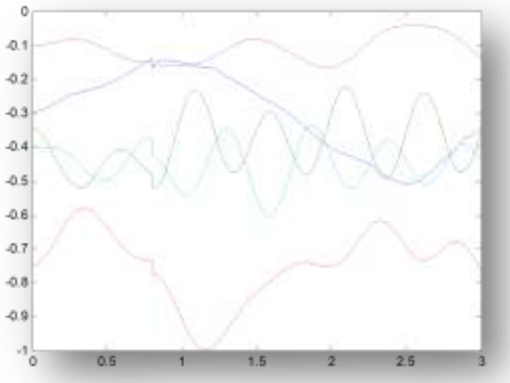
Fault clearing time=0.8 sec
Total analysis time=3 sec
Fault bus=Bus No 29
Trip [29, 30]



Rotor Angle Variations



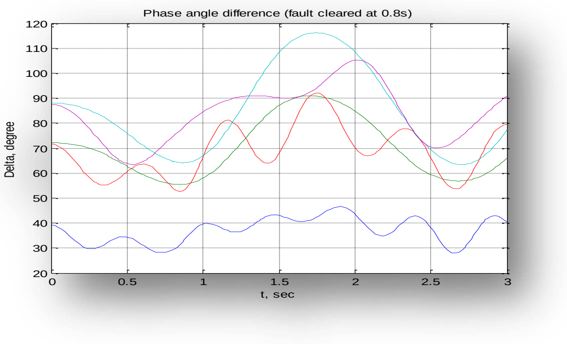
Potential Energy variation



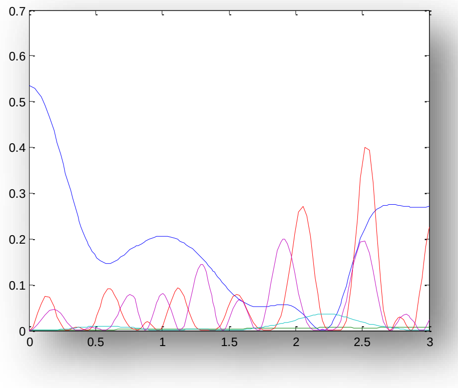
Kinetic Energy variation

With UPFC

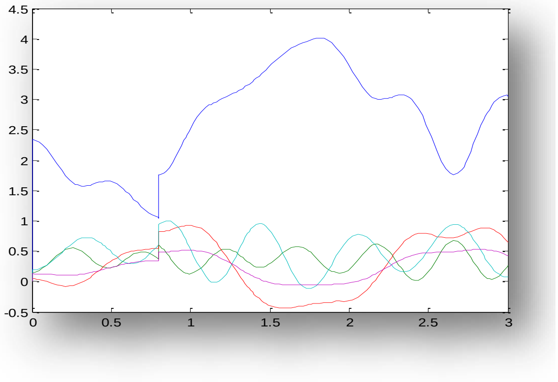
Fault clearing time=0.8 sec
Total analysis time=3 sec
Fault bus=Bus No 29
Trip [29, 30]
Nearer bus=6 Far bus=21



Rotor Angle Variations



Potential Energy variation



Kinetic Energy variation

5. CONCLUSION

In the paper, comparison of transient stability is achievable with UPFC. The computer simulations indicate that the attainable response of the control is very fast. Thus the UPFC is extremely effective in handling dynamic system disturbances. This paper proposed a scheme to compare the performance indices which identify the stable and unstable machines in a given power system for a particular operating conditions. The most important comparison parameters that have been taken into consideration for determining these indices are liability to rotor swing angle. A hybrid approach towards transient stability is being performed where this method is highly accurate as far as the calculation the stable and unstable systems are considered. The measure of the faults is severity is computed in terms of energy functions in corporate into time domain analysis and its comparison.

6. REFERENCES

[1]Enhancement of multi-machine transient stability limit using UPFC Vivekanand.k, Rambabu.ch, Dr.Y.P.obulesu

[2] A. Nabavi-Niaki, M. R. Iravani, “Steady State and Dynamic Models of Unified Power Flow Controller for Power System Studies,” IEEE Transactions on Power System, Vol. 11, No. 4, November 1996, pp. 1937-1943

[3] S. Limyingcharoen, U. D. Annakkage and N.C. Pahalawaththa, “Effects of Unified Power Flow Controller on Transient Stability,” IEE Proc. Gener. Transm. Distrib., Vol. 145, No. 2, March 1998, pp. 182-188

[4] H. Chen, Y. Wang and R. Zhou, “Transient and Voltage Stability Enhancement via Coordinated Exitation and UPFC Control,” IEE Proc. Gener. Transm. Distrib. Vol. 148, No. 3, May 2001, pp. 201-208

[5] M. Noroozian et. al., “Improving Power System Dynamics by Series-Connected FACTS Devices,” IEEE Transactions on Power Delivery, Vol. 12, No. 4, October 2003, pp. 1635-1641

[6] E. Gholipour and S. Saadate, "Improving of transient stability of power systems Using UPFC", IEEE Trans, on PD, Vol. 20, No. 2, pp. 1677-1682, 2005.

.[7] P. Kumkratug and M.H. Haque, "Versatile model of a unified power flow controller in a simple power system", IEE Proc- GTD, Vol. 150, No. 2, pp. 155-161, 2003.

[8] S. Robak, M. Januszewski and D.D. Rasolomampionona, "Power system Stability enhancement using PSS and UPFC Lyapunov-based controllers: A comparative study", Proc. of the Bologna Power Tech Conference, June 23-26, 2003, Bologna, Italy.

[9] M. Norrozian, M. Ghandhari, G. Andersson, J. Gronquist and I. Hiskens "A Robust control strategy for shunt and series reactive compensations to damp electromechanical oscillations", IEEE Trans, on PD, Vol. 16, No. 4,pp 812-817, 2001.

[10] M.H. Haque “stability improvement by FACT devices: A comparision between STATCOM and SSSC”, proc. Of the IEEE GM 2005, 12-16 June, 2005.