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Transient Stability Enhancement using Unified Power Flow Controller in Multi-Machine System

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Abstract **- Recent blackouts in different countries have illustrated the very important and vital need of more frequent and thorough power system stability. A sincere effort has been made to introduce a MATLAB/SIMULINK model for transient stability enhancement using one of the FACTS devices Unified Power Flow Controller. This paper presents a three different conditions i.e. pre fault, with fault, and with UPFC (steady state, LLG fault, and after fault with UPFC). Analysis of results with the help of graphical representation of rotor angle deviations i.e. delta1-2, delta1-3 and delta2-3 have been found out by varying the Fault clearing time. Any of these configurations can effectively be incorporated in a MM system and contributes highly in the transient stability enhancement of the system.**

Keywords **-** *Transient stability, Control strategy, Unified Power Flow Controller (UPFC), WSCC model, MATLAB/Simulation.*

I. INTRODUCTION

Transient stability is the ability of power system to maintain synchronism when subjected to a severe disturbance, such as a fault on transmission facilities, sudden loss of generation, or loss of a large load. The system response to such disturbances involves large excursions of generator rotor angles, power flows, bus voltages, and other system variables. With the invent of Flexible Alternating Current Transmission(FACTS) devices based on power electronics, excellent operating experiences available world-wide, these devices are becoming more mature and more reliable to improve the performance of long distance AC transmission. FACTS controllers can be classified as (i) Variable impedance type controllers and (ii) Voltage source converter based controllers.

This paper considered one of the FACTS devices UPFC. UPFC is the most versatile one that can be used to enhance steady state stability, dynamic stability and transient stability.

The UPFC is capable of both supplying and absorbing real and reactive power. Analysis of transient stability from with UPFC in MATLAB/SIMULINK WSCC model has been done. This paper considered three different conditions i.e. pre fault, with fault, and with UPFC (steady state, LLG fault, and after fault with UPFC).

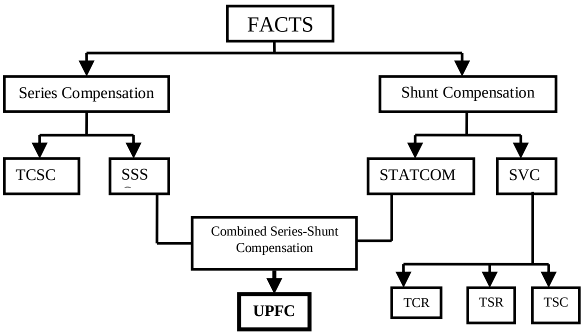

Figure1.1: Types of FACTS devices
Courtesy: Understanding FACTS by Hingorani N. G., Gyugyi Laszlo

II. CONTROL STRATEGY- UPFC

The Unified Power Flow Controller (UPFC) is the most versatile one that can be used to enhance steady state stability, dynamic stability and transient stability. The UPFC is capable of both supplying and absorbing real and reactive power and it consists of two ac/dc converters. One of the two converters is connected in series with the transmission line through a series transformer and the other in parallel with the line through a shunt transformer. The dc side of the two converters is connected through a common capacitor, which provides dc voltage for the converter operation. The power balance between the series and shunt converters is a prerequisite to maintain a constant voltage across the dc capacitor. As the series branch of the UPFC injects a voltage of variable magnitude and phase angle, it can exchange real power with the transmission line and thus improves the power flow capability of the line as well as its transient stability limit. The shunt converter exchanges a current of controllable magnitude and power factor angle with the power system. It is normally controlled to balance the real power absorbed from or injected into the power system by the series converter plus the losses by value [13]

The Unified Power Flow Controller (UPFC) devised for the real-time control and dynamic compensation of ac transmission systems, providing multifunctional flexibility required to solve many of the problems facing the power delivery industry. The following points are given below:

- Unified Power Flow Controller
- Basic operating principle of UPFC
- Conventional transmission control capabilities
- Power flow control

UNIFIED POWER FLOW CONTROLLER

The Unified Power Flow Controller (UPFC) consists of two voltage sourced converters, using gate turn-of (GTO) thyristor valves. These converters, labelled "Converter 1" and "Converter 2" in the figure 2.1, are operated from a common dc link provided by a dc storage capacitor. This arrangement functions as an ideal ac-to-ac power converter in which the real power can freely flow in either direction between the ac terminals of the two converters, and each converter can independently generate (or absorb) reactive power at its own ac output terminal [13].

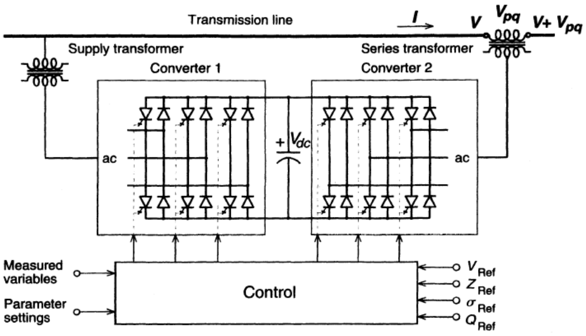

Figure 2.1: Unified Power flow Controller
Courtesy: Understanding FACTS by Narain G. Hingorani and Laszlo Gyugyi

Converter 2 provides the main function of the Unified Power Flow Controller (UPFC) by injecting a voltage Vpq with controllable magnitude Vpq and phase angle ρ in series with the line via an insertion transformer. This injected voltages acts essentially as a synchronous ac voltage source. The transmission line current flows through this voltage source resulting in reactive and real power exchange between it and the ac system. The reactive power exchanged at the ac terminal (i.e., at the terminal of the series insertion transformer) is generated internally by the converter. The real power exchanged at the ac terminal is converted into dc power which appears at the dc link as a positive or negative real power demand [11] [13].

(1) The basic function of converter 1 is to supply or absorb the real power demanded by converter 2 at the common dc link. This dc link power is converted back to ac and coupled to the transmission line via a shunt- connected transformer.
(2) Converter 1 can also generate or absorb controllable reactive power, if it is desired, and thereby provide independent shunt reactive compensation for the line. it is important to note that where as there is a closed "direct" path for the real power negotiated by the action of series voltage injection through converters 1 and 2 back to the line, the corresponding reactive power exchanged is supplied or absorbed locally by converter 2 and therefore does not have to be transmitted by the line.
(3) Thus, converter 1 can be operated at a unity power factor or be controlled to have a reactive power exchange with the line independent of the reactive power exchanged by converter 2. This means that there is no reactive power flow through the Unified Power Flow Controller (UPFC).

BASIC OPERATING PRINCIPLE OF UPFC

The Unified Power Flow Controller (UPFC) was devised for the real-time control and dynamic compensation of ac transmission systems, providing multi-functional flexibility required to solve many of the problems facing the power delivery industry.

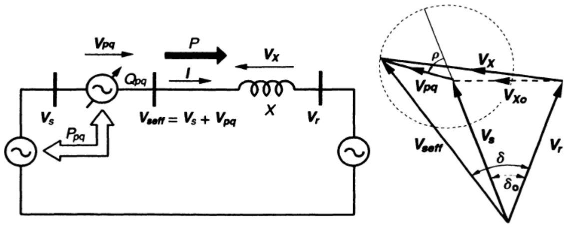

Fig. 2.2: Conceptual representation of Unified Power flow Controller in two machine system
Courtesy: Understanding FACTS by Narain G. Hingorani and Laszlo

The Unified Power Flow Controller (UPFC) is a generalized synchronous voltage source (SVS), represented at the fundamental (power system) frequency by voltage phasor *Vpq* with controllable magnitude *Vpq* ($0 \le Vpq \le Vpqmax$) and angle ρ ($0 \le \rho \le 2\pi$), in series with the transmission line, as illustrated for the usual elementary two machine system (or for two independent system with a transmission link intertie) in figure 2.2.

This arrangement the SVS generally exchanges both reactive and real power with the transmission system. SVS is able to generate only the reactive power exchanged, the real power must be supplied to it, or absorbed from it, by a suitable power supply or sink. In the Unified Power Flow Controller (UPFC). In the Unified Power Flow Controller (UPFC) arrangement the real power the SVS exchanges is provided by one of the end buses (e.g., the sending-end bus), as indicated in the figure 2.2 (this arrangement conforms to the objective of controlling the power flow by the Unified Power Flow Controller (UPFC) rather than increasing the generation capacity of the system)[13].

CONVENTIONAL TRANSMISSION CONTROL CAPABILITIES

The Unified Power Flow Controller (UPFC) from the standpoint of traditional power transmission based on reactive shunt compensation, series compensation, and phase shifting, the Unified Power Flow Controller (UPFC) can fulfil all these functions and thereby meet multiple control objectives by adding the injected voltage vpq, with appropriate amplitude and phase angle, to the (sending-end) terminal voltage Vs, using phasor representation, the basic Unified Power Flow Controller (UPFC) power flow control functions are illustrated in figure 2.3.

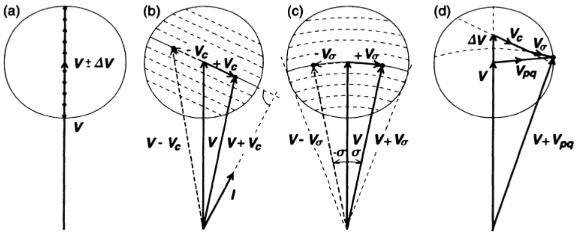

Fig. 2.3: Range of transmittable real power P and receiving end reactive power demand Q, vs. Transmission angle δ of a UPFC controlled transmission line
Courtesy: Understanding FACTS by Narain G. Hingorani and Laszlo Gyugyi

a) Voltage Regulation
b) Line Impedance Compensation
c) Phase Shifting
d) Simultaneous control of voltage, impedance and angle

(a) Voltage Regulation with continuously variable in-phase/anti-phase voltage injection, shown at a for voltage increments Vpq=+- (ρ). Functionally this is similar to that obtainable with a transformer tap-changer having infinitely small steps.

(b) Series Reactive Compensation where Vpq=/Vq is injected in quadrature with the line current I. Functionally this is similar to, but more general than the controlled series capacitive and inductive line compensation. This is because the Unified Power Flow Controller (UPFC) injected series compensating voltage can be kept constant, if desired, independent of line current variation, whereas the voltage across the series compensating (capacitive or inductive) impedance varies with the line current.

(c) Phase Shifting (Transmission Angle Regulation) where Vpq=Vσ is injected with an angular relationship with respect to Vs that achieves the desired σ phase shift (advance or retard) without any change in magnitude. Thus the Unified Power Flow Controller (UPFC) can function as a perfect phase shifter. From the practical viewpoint, the ac system does not have to supply the reactive power the phase shifting process demands since it is internally generated by the Unified Power Flow Controller (UPFC) converter.

(d) Simultaneous control of Voltage, impedance and phase angle, Simultaneous terminal voltage regulation, series capacitive line compensation, and phase shift in, is shown by equation (2.1).

$$Vpq=\Delta V+Vq+V\sigma \qquad ....(2.1)$$

where Vpq= Injected voltage of UPFC
ΔV= Voltage regulation of UPFC (volt)
Vq= Quadrature voltage (volt)
Vσ= Injected voltage with an angular relationship with respect to V_s (volt)

This functional capability is unique to the Unified Power Flow Controller (UPFC). No single conventional equipment has similar multi-functional capability.

Let
P= Active power (watt)
Q= Reactive power (volt ampere)
δ= Load angle or power angle curve (rad)
Vs=Sending end voltage (volt)
Vr=Receiving end voltage (volt)
X=Transmission line reactance (p.u.)
P_{pq}= Active power of UPFC
Q_{pq}= Reactive power of UPFC
V_x= TL reactance voltage (volt)
ρ = Phase angle (rad)

The general power flow control capability of the Unified Power Flow Controller (UPFC), from the viewpoint of conventional transmission control, can be illustrated best by the related reactive power transmission versus transmission angle characteristics o the simple two machine system shown in figure 2.3 with reference to this figure 2.2, the transmitted power P and the reactive power –jQr , supplied by the receiving-end, can be expressed as follows [13].

$$P - jQr = Vr\left(\frac{\text{Vs+Vpq−Vr}}{jX}\right)^{*} \qquad \text{..........(2.2)}$$

Where symbol * means the conjugate of a complex number and j=$\sqrt{-1}$.

If Vpq=0, then equation (2.2), describes the uncompensated system which is as shown below:

$$P - jQr = Vr\left(\frac{\text{Vs−Vr}}{jX}\right)^{*} \qquad \text{.........(2.3)}$$

Thus, with Vpq≠0, the total real and reactive power can be written in the form:

$$P - jQr = Vr\left(\frac{\text{Vs+Vpq−Vr}}{jX}\right)^{*} + \frac{VrVpq^{*}}{-jX} \qquad \text{.........(2.4)}$$

Substituting

$$Vs = Ve^{\frac{j\delta}{2}} = V\left(cos\frac{\delta}{2} + jsin\frac{\delta}{2}\right) \qquad \text{.........(2.5)}$$

$$Vs = Ve^{\frac{-j\delta}{2}} = V\left(cos\frac{\delta}{2} - jsin\frac{\delta}{2}\right) \qquad \text{.........(2.6)}$$

And

$$Vpq = Vpqe^{\left(\frac{j\delta}{2}+\rho\right)} = Vpq\{cos\left(\frac{\delta}{2}+\rho\right) + sin\left(\frac{\delta}{2}+\rho\right)\}\text{.........(2.7)}$$

$$P(\delta,\rho) = P0(\delta) + Ppq(\rho) = \frac{V^2}{X}\,sin\delta - \frac{VVpq}{X}\cos\left(\frac{\delta}{2}+\rho\right)\text{ ....(2.8)}$$

$$Qr(\delta,\rho) = Qor(\delta) + Qpq(\rho) = \frac{V^2}{X}\,(1-cos\delta) - \frac{VVpq}{X}sin\left(\frac{\delta}{2}+\rho\right) \quad (2.9)$$

Where

$$Po(\delta) = \frac{V^2}{X}\,sin\delta \qquad \text{.......(2.10)}$$

$$Qor(\delta) = -\frac{V^2}{X}\,(1-cos\delta) \qquad \text{.......(2.12)}$$

Equation (2.10) and (2.11) represents the real and reactive power characterizing the power transmission of the uncompensated system at a given angle δ. Since angle ρ is freely variable between 0 and 2π at any given transmission angle δ(0≤δ≤π), it follows that Ppq(ρ) and Qpq(ρ) are controllable between $-\frac{VVpq}{X}$ and $+\frac{VVpq}{X}$ independent of angle δ. Therefore, the transmittable real power P is controllable between

$$Po(\delta) - \frac{VVpq}{X} \le Po(\delta) \le Po(\delta) + \frac{VVpq}{X} \qquad \text{.........(2.13)}$$

$$Qo(\delta) - \frac{VVpq}{X} \le Qo(\delta) \le Qo(\delta) + \frac{VVpq}{X} \qquad \text{........(2.14)}$$

The normalized transmitted active power

$$Po(\delta) = \frac{V^2}{X}\,sin\delta = sin\delta$$

And the normalized transmitted reactive power

$$Qo(\delta) = Qor(\delta) = -Qor(\delta) = \frac{V^2}{X}(1-cos\delta) = (1-cos\delta)$$

The relationship between real power Po(δ) and reactive power Qor(δ) can readily be expressed with $\frac{V^2}{X} = 1$ in the following form:

$$Qor(\delta) = -1 - \sqrt{1-\{Po(\delta)\}^2} \qquad \text{.........(2.15)}$$

Or

$$\{Qor(\delta)+1\}^2 + \{Po(\delta)\}^2 = 1 \qquad \text{.........(2.16)}$$

Equation (2.16) describes a circle with a radius of 1.0 around the centre defined by coordinates P=0 and Qr=-1 in a {Qr,P} plane. Each point of this circle gives the corresponding Po and Qor values of the uncompensated system at a specific transmission angle δ.

Refer again to figure (2.2) and assume that Vpq≠0. It follows from equation (2.4), or (2.8) and (2.9) that the active and reactive power change from their uncompensated values, Po(δ) and Qor(δ), as functions of the magnitude Vpq and angle ρ of the injected voltage phasor Vpq. Since angle ρ is an unrestricted variable (0≤ρ≤2π), the boundary of the attainable control region for P(δ,ρ) and Qr(δ,ρ) is obtained from a complete rotation of phasor Vpq with its maximum magnitude Vpqmax. It follows from the above equations that this control region is a circle with a center defined by coordinates Po(δ) and Qor(δ) and a radius of $\frac{VVpq}{X}$. With Vs=Vr=V), the boundary circle can be described by the following equation:

$$\{P(\delta,\rho) - Po(\delta)\}^2 + \{Qr(\delta,\rho) - Qor(\delta)\}^2 = \left\{\frac{VVpqmax}{X}\right\}^2$$

....(2.17)

The circular control regions defined by equation (3.27) are shown in figure 3.2 (a) to (d) for V=1.0, Vpqmax=.5, and X=1.0 (per unit) with their centres on the circular arc characterizing the uncompensated system (equation 3.26) at transmission angles δ=0, 30°, 60°, and 90°. In other words, the centres of the control regions are defined by the corresponding Po(δ) and Qor(δ) coordinates at angles δ=0, 30°, 60°, and 90° in the {Qr,P} plane.

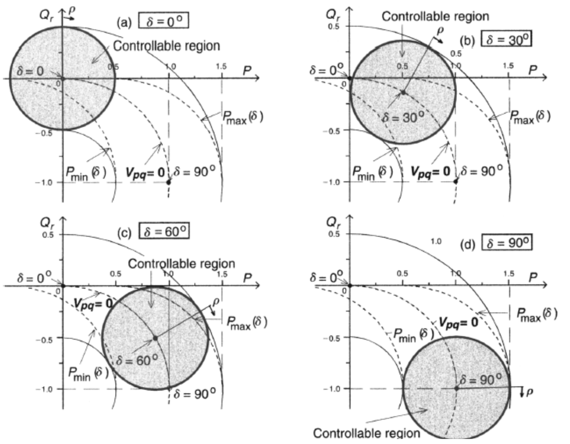

Figure 2.4: Control region of the attainable real power P and receiving Power Q end reactive power demand Q, with a UPFC controlled transmission line at (a)δ=0, (b) δ=30°, (c) δ=60°, and (d) δ=90
Courtesy: Understanding FACTS by Narain G. Hingorani and Laszlo Gyugyi

Consider the first figure 2.4 (a), which illustrates the case when the transmission angle is zero (δ=0). With Vpq=0, P, Qr are all zero, i.e., the system is at standstill at the origin of the Qr, P coordinates. The circle around the origin of the {Qr,P} plane is the loci of the corresponding Qr and P values, obtained as the voltage phasor Vpq is rotated a full revolution 0≤ρ≤2π), with the maximum magnitude Vpqmax. The area within this circle defines all P and Qr values obtainable by controlling the magnitude Vpq and angle ρ of phasor Vpq.

Furthermore, it should be noted that, although the above presentation focuses on the receiving end reactive power, Qr, the reactive component of the line current, and the corresponding reactive power, can actually be controlled with respect to the voltage selected at any point of the line.

Figures 2.4(a)-(d) clearly demonstrate that the UPFC, with its unique capability to control independently the real and reactive power flow at any transmission angle, provides a powerful new tool for transmission system control .

III. THREE MACHINE NINE BUS SYSTEM

The classical model is the simplest model used in studies of power system dynamics and requires a minimum amount of data; hence, such studies can be conducted in a relatively short time and at minimum cost. Furthermore, these studies can provide useful information. For example, they may be used as preliminary studies to identify problem areas that require further study with more detailed modelling. Thus a larger number of cases for which the system exhibits a definitely stable dynamic response to the disturbances under study are eliminated from further consideration [1].

A classical study will be presented here on a small nine-bus power system that has three generators and three loads. A one-line impedance diagram for the system is given figure 3.1.

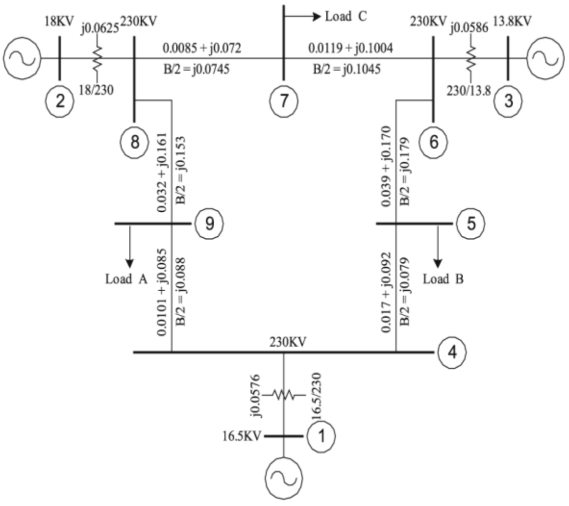

Figure 3.1: Three Machine Nine bus system impedance, all impedance are in pu on a 100-MVA

Courtesy: Power System Control And Stability by Anderson P. M., Fouad A. A.

DATA PREPARATION

In the performance of a transient stability study, the following data are needed [1] :

1. A load-flow study of the pre-transient network to determine the mechanical power P_m of the generators and to calculate the values of $E_i\angle\delta_{i0}$ for all the generators.

2. System data as follows:
   - The inertia constant *H* and direct axis transient reactance x'_d for all generators.
   - Transmission network impedances for the initial network conditions and the subsequent switchings such as fault clearing and breaker reclosings.

3.The type and location of disturbance, time of switching's, and the maximum time for which a solution is to be obtained.

IV. MATLAB/SIMULINK MODEL WITH UPFC

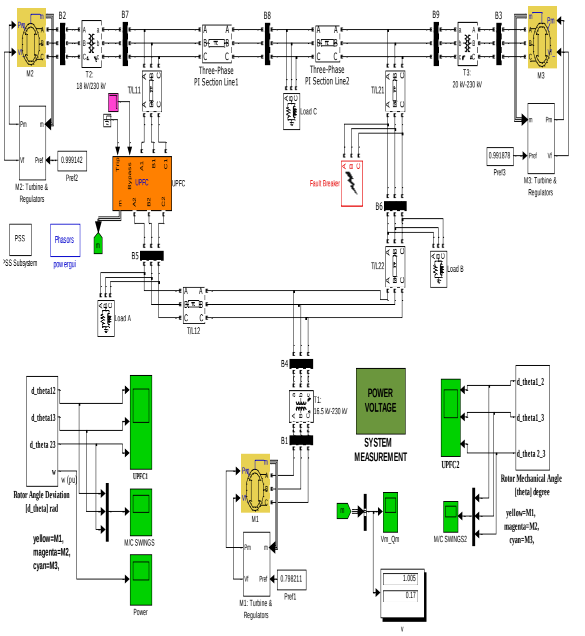

Fig.4.1- Complete MATLAB/SIMULINK model of the three machine nine bus

This model completed model of three different conditions i.e.

(i) Pre-fault condition- system in normal condition and stable condition figure 3.2.

(ii) Fault condition- LLG fault created in the system and system will be stable after 8.5 seconds figure 3.3. (iii) After fault with UPFC condition- LLG fault with UPFC is increased system stability the system will be stable in before 2.5 seconds it means system will be stable in 6 seconds than enhancement of transient stability of the system.The power system was found to become stable within 7 seconds after the initial inter-area oscillations. A LLG fault has been considered to occur at bus B8. It is assumed that the fault occurs at instant of 7th second for a fault clearing time 2.5 second.

(1) Pre-fault or Steady State Condition

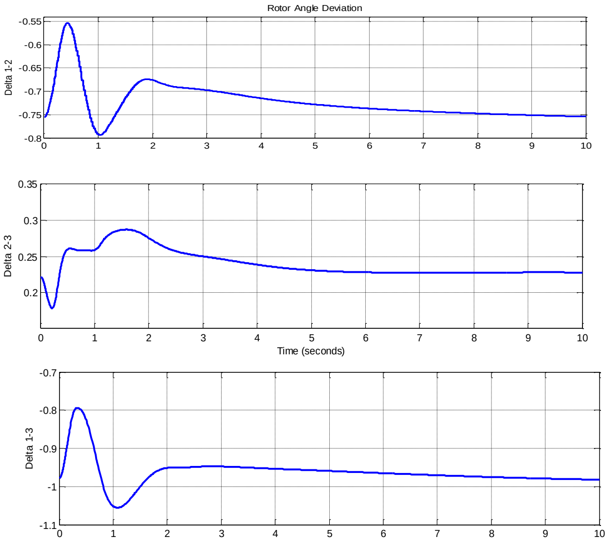

Fig. 4.2: Rotor angle deviation delta1-2, delta1-3, and delta2-3 (rad)

(2) LLG Fault Condition

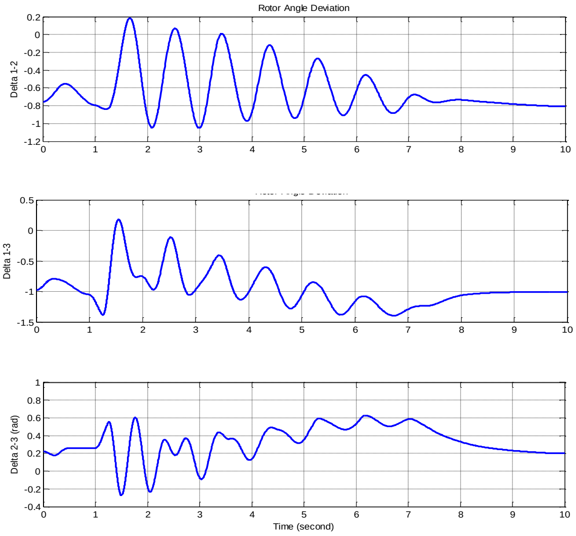

Fig. 4.3: Rotor angle deviation delta1-2, delta1-3, and delta2-3 (rad) with LLG Fault at Bus-6

(3) After Fault with UPFC

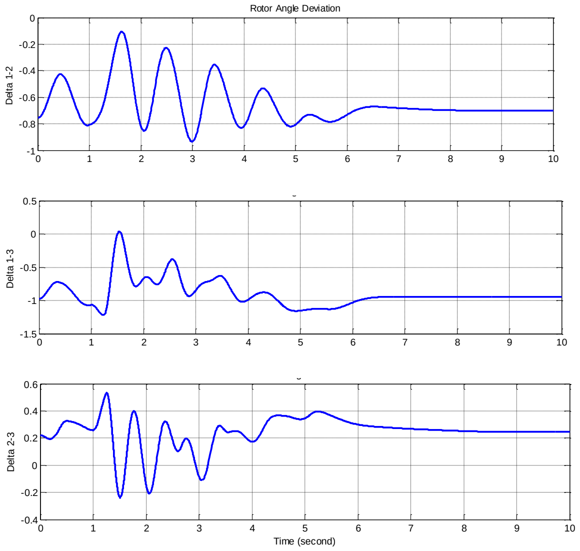

Fig. 4.4: Rotor angle deviation with UPFC delta1-2, delta1-3, and delta2-3 (rad)

V. CONCLUSION

The MATLAB/SIMULINK model of a classical three machine nine bus system for three conditions of fault, pre Fault (steady state), during fault (without UPFC), and after fault (with UPFC) considering the total simulation time of 10 sec for each condition. The details of the fault time, transmission line at which the fault occurs, and the time taken to restore the transmission line are as given below:

The three conditions of LL-G fault are as given below:

Pre Fault condition - 10 <≤ t
During Fault condition - Fault occurred in transmission line 6-9,i.e t =1.0 to 1.25 Secs
Post Fault condition - Line 6-9 is removed, i.e. at t =1.25), Line is restored (t >1.25)
System will be stable before 2.5 seconds

Considering the above Conditions the behaviour of the transmission line is examined here. The MATLAB simulation result of the classical three machine nine bus system on which the research was carried out is in terms of rotor angle deviation (δ). The fault occurred during the period between 1 to 1.25 sec and after 1.25 sec the line was removed. The relative variation in rotor angle and the change in angular speed of the rotor are examined during the fault time without UPFC. After fault, and with UPFC the relative variation in rotor angle and relative change in angular speed starts to damp out after time 1.25 sec and the line is restored. The enhancement of transient stability of the three machine nine bus system by the use of UPFC is studied by the comparison simulation results by MATLAB/SIMULINK.

VI. REFERENCES

[1] Anderson, P.M.; Fouad, A.A.; 'Power System Control AND Stability' – Wiley India Pvt. Ltd.

[2] Acha, Enrique; Fuerte Esquivel, Claudio R.; Ambriz- Perez, Hugo; Camacho, Cesar Angeles-'FACTS Modelling and Simulation in Power Networks'- Wiley India Pvt. Ltd.

[3] Byerly, R. T, Sherman D.E.;- 'Stability Program data Preparation manual'- Westinghouse Electric Corp., 1970.

[4] Chen, H.; Wang, Y.; Zhou, R.- 'Transient and Voltage Stability Enhancement via Co-ordinate Excitation and UPFC Control'- IEE Proceeding- Generation, Transmission, Distribution, Vol. 148, No. 3, May 2001.

[5] Cresap, R., L.; Taylor, C., W., and Kreipe, M., J.,- "Transient Stability Enhancement by 120-degree Phase Rotation"- IEEE Transactions on Power Apparatus and Systems, Vol. PAS-100, No. 2, February1981.

[6] Dizdarevic N., Tesnjak S.;- "Converter Rating Powers of UPFC"-IEEE.

[7] Ebrahimpour Reza;-"Transient Stabililty Assessment of a Power System by Mixture of Experts"- International Journal of Engineering, Issue 1, Vol. 4

[8] Eleschova, Z.; Smitkova, M.; and Belan, A.;- "Evaluation of Power System Transient Stability and Definition of the Basic Criterion"- International Journal of Energy, Issue 1, Vol. 4, 2010.

[9] Gholipour Eskandar, Saadate Shahrokh;- "Improving of Transient Stability of Power Systems Using UPFC "-IEEE Transaction Power Delivery, Vol. 20, No. 2, April 2005

[10] Ghosh Arindam; Chatterjee Dheeman;- "Application of Trajectory Sensitivity for the Evaluation of the Effect of TCSC Placement on Transient Stability"- International Journal of Emerging Electric Power Systems, Issue 1, Vol. 8, 2007.

[11] Gyugyi, L.;- 'A Unified Power Flow Control Concept for Flxible AC Transmission Systems,'- IEEE Proceedings- C, Vol. 139, Iss. No.4, July 1992.

[12] Hassan Lokman H., Moghavvemi M., Mohamed Haider A. F.;- 'Power System Oscillations Damping using UPFC- Based Stabilizer', - American Journal of Applied Science, Year:2010, Vol. No. 7, pp1393-1395.

[13] Hingorani, Narain G; Gyugyi, Laszlo – 'Understanding FACTS' – IEEE Press, New York; 2001.

[14] Husain, Ashfaq;- 'Electrical Power System' - CBS Publishers & Distributors Pvt. Ltd.; Reprint 2012.

[15] Jain Shailendra,- 'Modeling and Simulation using MATLAB-SIMULINK'- John Wiley and Sons, Ltd.

[16] Kimbark Edward Wilson; - 'Power System Stability' – IEEE Press Power System engineering Series, INC., New York, Vol. No 1.

[17] Kothari, D. P.; Nagrath, I. J.; -'Power System Engineering' – Tata McGraw-Hill Publishing Company Limited, New Delhi; 1998.

[18] Kumar S. V. Ravi, Nagaraju S. Siva;- 'Transient Stability Improvement using UPFC and SVC'-ARPN Journal of Engineering and Applied Sciences, Vol. 2, Issue 3, June 2007.
[19] Kumar Prechanon;-'Application of UPFC to Increase Transient Stability of Inter-Area Power System'- Journal of Computers, Vol. 4, No. 4, April 2009.
[20] Kumkratug Prechanon;- 'Improvement of Transient Stability of Power System by Thyristor Controlled Phase Shifter Transformer'-American Journal of Applied Sciences, Iss. No. 1546-9239, 2010.
[21] Kundur Prabha; - 'Power System Stability and Control'- McGraw-Hill, INC., Kowsalya M., Ray K. K., Shipurkar Udai, Saranathan; - 'Voltage Stability Enhancement by optimal Placement of UPFC',- JEET, Year:2009, Vol. 4, No. 3, pp.310-314
[22] Kumar Saini Manish, Kumar Yadav Narsh, Mehra Naveen;- "Transient Stability Analysis of Multi-Machine Power System with FACTS Devices using MATLAB/Simulink Environment"-IJCEM, Vol. 16, Issue 1, January 2013.
[23] MATLAB/SIMULINK 7.10.0 (R2010a)- Software.
[24] Machowski Jan, Bialek Janusz W., Bumby James R.,- 'Power System Dynamics Stability and Control'- John Wiley and Sons, Ltd.

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