Perusal of Multimachine System for Enhancement of Power System Performance

Sharad Chandra Rajpoot
Assistant Professor
Department of Electrical Engineering
G. E. C. Jagdalpur , Bastar, Chhattisgarh, India

Prashant Singh Rajpoot
Assistant Professor
Department of Electrical Engineering
L. C. I. T, Bilaspur, Chhattisgarh, India

Sanjay Kumar Singhai
Professor
Department of Electrical Engineering
G. E. C. Jagdalpur , Bastar, Chhattisgarh, India

Krishna Kumar Saxena
Associate Professor
Department of Electrical Engineering
G. E. C. Jagdalpur , Bastar, Chhattisgarh, India

Abstract

Power systems are continually experiencing fluctuations of small magnitudes. However, for assessing stability when subjected to a specified disturbance, it is usually valid to assume that the system is initially in a true steady-state operating condition. Power system is subjected with the verity of fluctuation in their parameters. So their performance is not stable at all. This fluctuation must be mitigate as possible as under prescribe limit. In HVDC transmission system, power is generated and distributed in AC, only the transmission is done in the DC. During the ac to dc conversion power system observe the inability problems. In this way, it is essential to analysis the power system performance to enhance it. To ensure satisfactory operation and equipment safety, several limits are recognized in establishing the current order: maximum current limit, minimum current limit, and voltage-dependent current limit. Higher-level controls may be used, in addition to the above basic controls, to improve AC/DC system interaction and enhance AC system performance. Here we have adopted the PID (Proportional integral deferential) controller.

Keywords- AC/DC Power System, DC Line, Maximum Current Limit, Minimum Current Limit, And Voltage-Dependent Current Limit , Load Flow Analysis , Multi Machine System Analysis, ID Controller

---

I. INTRODUCTION

A. *Over View*

As compared with rotor long-time constants, the AC and DC-transmission systems respond rapidly to network and load changes. The time constants associated with the network variables are extremely small and can be neglected without significant loss of accuracy. The synchronous machine stator time constants may also be taken as zero.[2]

The DC link is assumed here to maintain normal operation throughout the disturbance. This approach is not valid for larger disturbances such as converter faults, DC-line faults and AC faults

Close to the converter stations, these disturbances can cause commutation failures and alter the normal conduction sequence [6].

B. *Motivation and Objective*

Supplementary controls are therefore often required to exploit the controllability of DC links for enhancing the AC system dynamic performance. There are a variety of such higher level controls used in practice. [5] Their performance objectives vary depending on the characteristics of the associated AC systems. The following are the major reasons for using supplementary control of DC links:

- Improvement of damping of AC system electromechanical oscillations.
- Improvement of transient stability.
- Isolation of system disturbance.
- Frequency control of small isolated systems.
- Reactive power regulation and dynamic voltage support.

II. MULTI-MACHINE SYSTEM

Multi machine system means one alternator connected with another alternator or synchronous motor.

Now in this day the power system structure subjected with considerable modification. This will responsible for the power system instability problem. This instability problem can be controlled by the proper analysis of transient stability, oscillation, damping of system & voltage regulation.

A. Over View

Stability means regain their original position after disturbance in given time period or condition. It is one of the important parameter for the system performance analysis. Stability may be transient, dynamic or steady state. Types of the stability shown in fig. 1

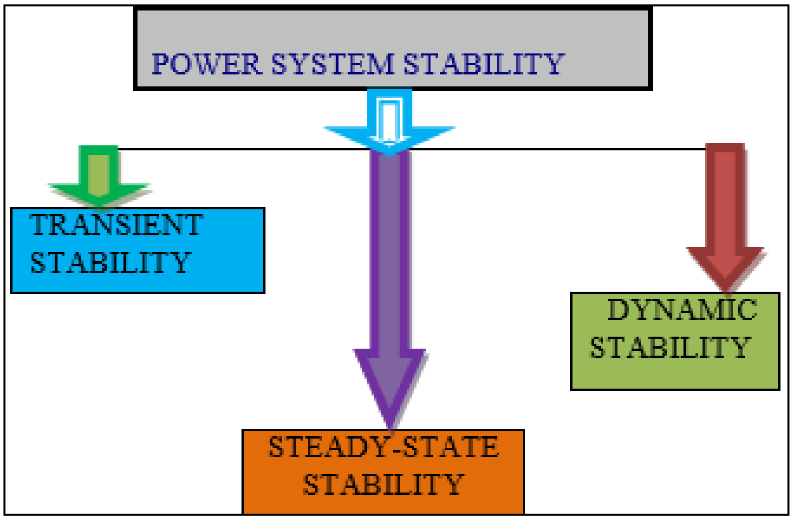

Fig. 1: Types of the Power System Stability

There are many method to steady the stability of the different types of the system.

Types of the system-

1) Single machine system.
2) Multi machine system.

Single machine system means one alternator connected with an infinite bus system, whose frequency, voltage and impedance are fixed.

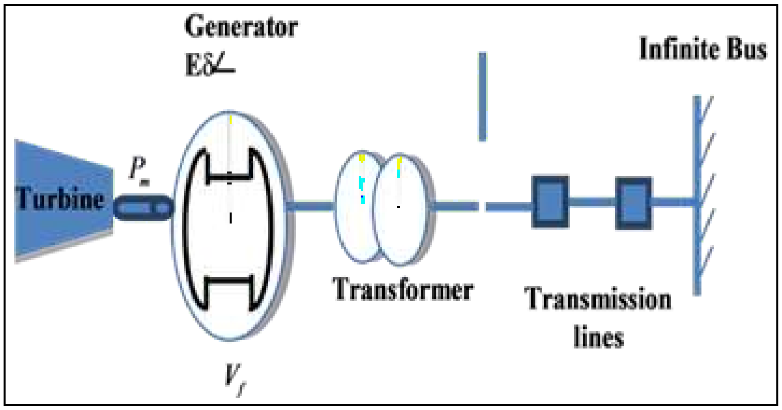

Fig. 2: single machine system

Multi machine system means one alternator connected with another alternator or synchronous motor.

Equal area criterion is used for only the single machine system. It adopted for scrutiny of the transient stability of the single machine system. According to the equal area criterion the stability conditions are well defined as follows -

For Stable system A2 > A1

For unstable system A2 < A1

For marginally Stable system A2 = A1

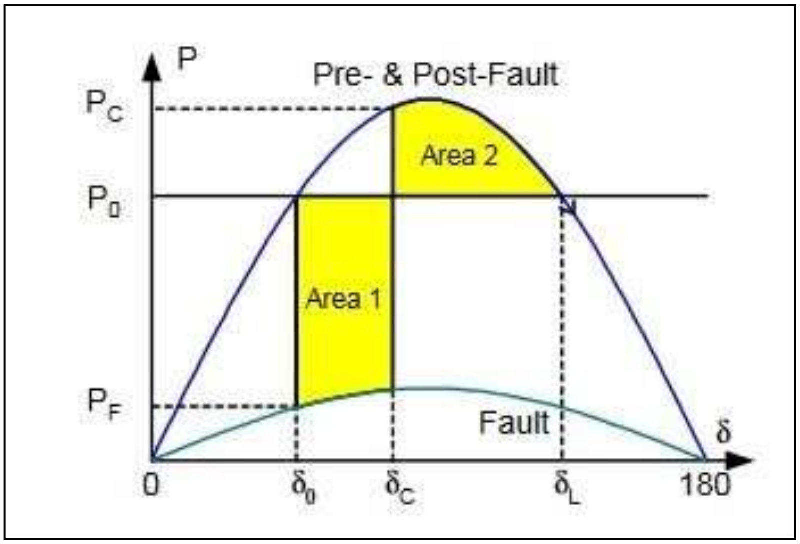

Fig. 3: Equal Area Criterion

While for the multi machine system two different methods can be adopted-
1) point to point method
2) Power swing equation

B. Swing Equation

$$\frac{2H}{\omega_S}\frac{d^2\delta}{dt^2} = P_M - P_E$$

$$J\frac{d^2\delta}{dt^2} = T_a$$

$$J\frac{d^2\theta}{dt^2} = T_a$$

III. MULTIMACHINE SYSTEM ANALYSIS

The power flow through a HVDC link can be highly controllable. This fact is utilized to strengthen the power system stability. The WSCC – 9 Bus system is considered for the stability analysis and is given in the figure 4.

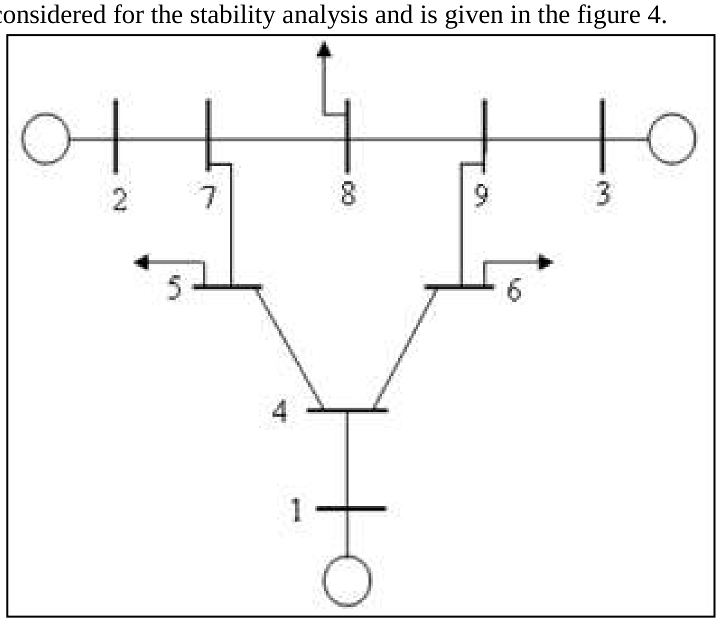

Fig. 4: WSCC 9 Bus System

The scenario adapted for our study is given below:
A fault is assumed to occur on Line 4-6, at initial time zero. It is assumed that a grounded fault occurred near to Bus 6 and the line from Bus 4 to Bus 6 is removed after 4 cycles. The HVDC line is located between buses 4 –5. Under these conditions, the impact of HVDC on system stability is presented. Initially, a case in which the HVDC line maintains the same control as in the normal state, in which the post-fault HVDC power flow setting remains the same as before, is investigated.[11] It was found that, the system becomes unstable. Then a PI controller is designed to stabilize the system. The controls are used to alter power flow setting in the HVDC line.

A. Case I: Uncontrolled Case

The HVDC line is in between buses 4 – 5. The post fault power flow setting through the HVDC line is the same as the pre-fault power flow setting. No extra control mechanism has been employed here. The plot of relative angles of the generator is shown in figure 5.

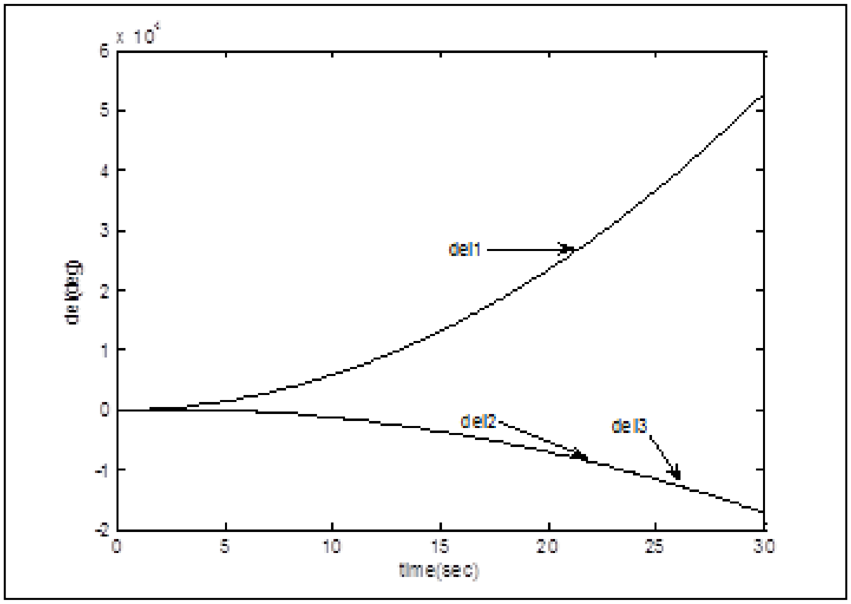

Fig. 5: Plot of generator angles without any extra control

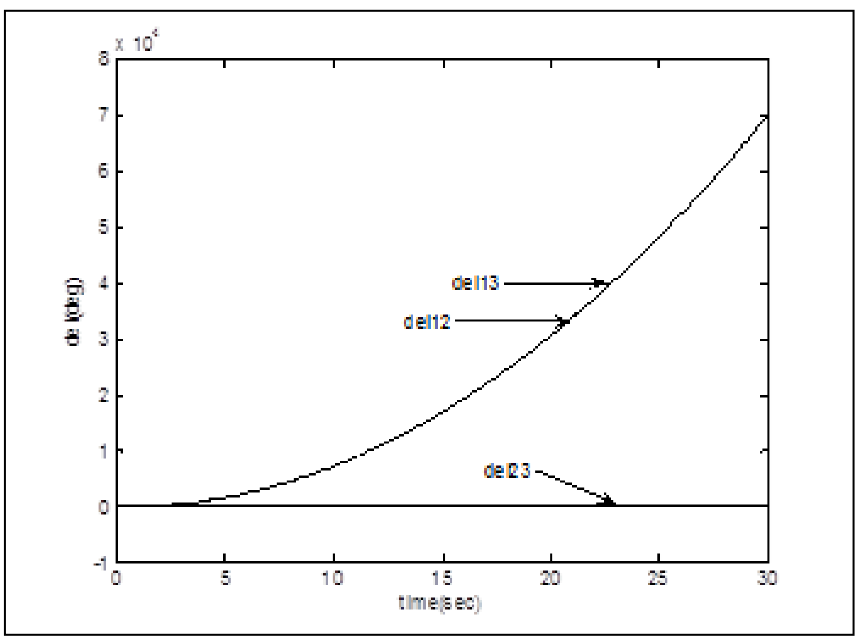

Fig. 6: Plot of relative angles with no extra control

From above Figures, it can be seen that angle of generator 1 goes unsynchronized from those of generators 2 & 3. In order to make the angle of generator 1, to be in step with those of the other two generator angles, the power mismatch at Bus 1 has to be altered. This can be achieved by changing the power flow in the HVDC line through an augmented feedback control.

When employing a feedback loop, the error signal is defined to average out the acceleration force for all the three machines as follows [9]:

$$e = \left[\frac{\frac{P\_mis(3)}{H(3)} + \frac{P\_mis(2)}{H(2)}}{2} \right] - \left[\frac{P\_mis(1)}{H(1)} \right] \qquad (1)$$

Where,
P_mis(i) = Real Power Mismatch at Bus „i"
H(i) = Moment of Inertia of generator „i‟.

HVDC system‟s current controller and line dynamics are not considered in this analysis. Accordingly, a realistic simple model for HVDC is adopted in the stability calculations. The extra energy introduced by the fault will be eventually smoothed out by an AGC as long as the machines are kept synchronized.

B. Case II: With PI Controller

System stability was augmented using a PI Controller. The control mechanism employed is given below [9]. Based on the error signal defined above, the flow in the DC line is changed as follows:

$$P_{di}^{k+1} = P_{di}^{k} - K_p e^k - K_i \int e(t)dt \qquad (2)$$

Where,
P_{di} = Active Power flow at the Inverter terminal.
K=Time step.
e= Error signal.
K_p=Proportional constant (=0.0013).
K_i= Integral constant (=0.00061).

Integral of error, I (t), is found out by trapezoidal method. The time interval [0, t] is divided into n time steps with an interval of Δt. Here k is the K^{th} time step, e_k=error at time step k and Δt= time step interval (=1/50). Accordingly, for k = 1:n

$$I_k = I_{k-1} + \frac{1}{2}\left[e_k + e_{k-1}\right]\Delta t \qquad (3)$$

With initial conditions, e_0 =0, I_0 = 0, and

$$I_k = \int_0^t e(t)\,dt \qquad (4)$$

The stabilizing control is implemented through large signal modulation of power in response to a control signal derived from the AC system variables. The effectiveness of the control can be enhanced by increased overload rating of the converters which permit short – term overloads.

Thus, the rapid controllability of power in a DC link can be used to advantage in improving the transient stability of the AC system in which the DC link is embedded. The power flow can even be reversed in a short time (less than 0.25sec). Thus, DC link control can be viewed as an alternative to fast valuing or braking resistor.

Table 1: Partial derivatives for modes with the direct voltage determined by a_i

Mode	$\frac{\partial P_{dr}}{\partial V_{tr}}$	$V_{tr}\frac{\partial Q_{dr}}{\partial V_{tr}}$	$V_{ti}\frac{\partial P_{dr}}{\partial V_{ti}}$	$V_{ti}\frac{\partial Q_{dr}}{\partial V_{ti}}$
A	*0*	*0*	*0*	*0*
A_I	*0*	*0*	*0*	*0*
B	*0*	$-\frac{S_{dr}^2}{Q_{dr}}$	*0*	*0*
B_I	*0*	$-\frac{S_{dr}^2}{Q_{dr}}$	*0*	*0*
C	*0*	*0*	$2P_l \partial I_i$	$\frac{2\partial I_i}{Q_{dr}}\left[k_\alpha S_{dr}\left(P_l + Q_l\right) - P_{dr}P_l\right]$
C_I	*0*	*0*	$P_{di} + Q_l$	$\frac{\left(P_{di} + Q_l\right)}{Q_{dr}}\left[k_\alpha S_{dr} - P_{dr}\right]$

D	*0*	$-\frac{S_{dr}^2}{Q_{dr}}$	$2P_l \partial I_i$	$\frac{\partial I_i}{Q_{dr}}\left[S_{dr}^2 - 2P_l P_{dr}\right]$
D_I	*0*	$-\frac{S_{dr}^2}{Q_{dr}}$	$P_{di} + Q_l$	$-\frac{\left(P_{di} + Q_l\right)}{Q_{dr}} P_{dr}$

Table III: Partial derivatives for modes with the direct voltage determined by a_r

Mode	$V_{tr}\frac{\partial P_{dr}}{\partial V_{tr}}$	$V_{tr}\frac{\partial Q_{dr}}{\partial V_{tr}}$	$\frac{\partial P_{dr}}{\partial V_{ti}}$	$\frac{\partial Q_{dr}}{\partial V_{ti}}$
E	$2P_l \partial I_r$	$\frac{S_{dr}^2\left(1+\partial I_r\right) - 2P_l \partial I_r P_{dr}}{Q_{dr}}$	*0*	*0*
E_I	$P_{dr} + Q_l$	$Q_{dr} - \frac{P_{dr}}{Q_{dr}} Q_l$	*0*	*0*
F	*0*	*0*	*0*	*0*
F_I	*0*	*0*	*0*	*0*
G	$2P_l \partial I_r$	$\frac{S_{dr}^2\left(1+\partial I_r\right) - 2P_l \partial I_r P_{dr}}{Q_{dr}}$	*0*	*0*
G_I	$P_{dr} + Q_l$	$Q_{dr} - \frac{P_{dr}}{Q_{dr}} Q_l$	*0*	*0*

The plot of relative angles of the generators is as shown in figure and the plot of generator phase angles is shown in figure 9.

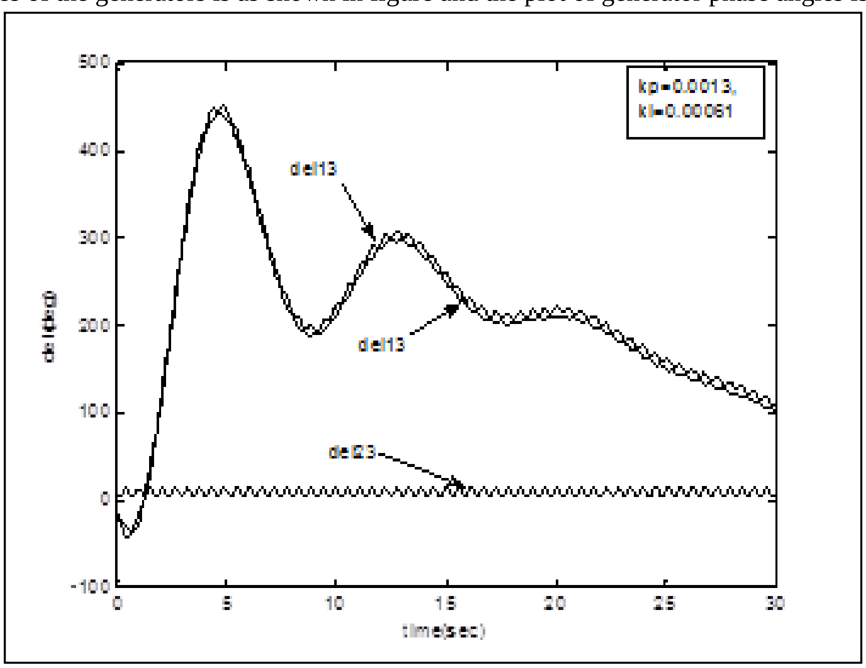

Fig. 7: Plot of relative angles with PI control

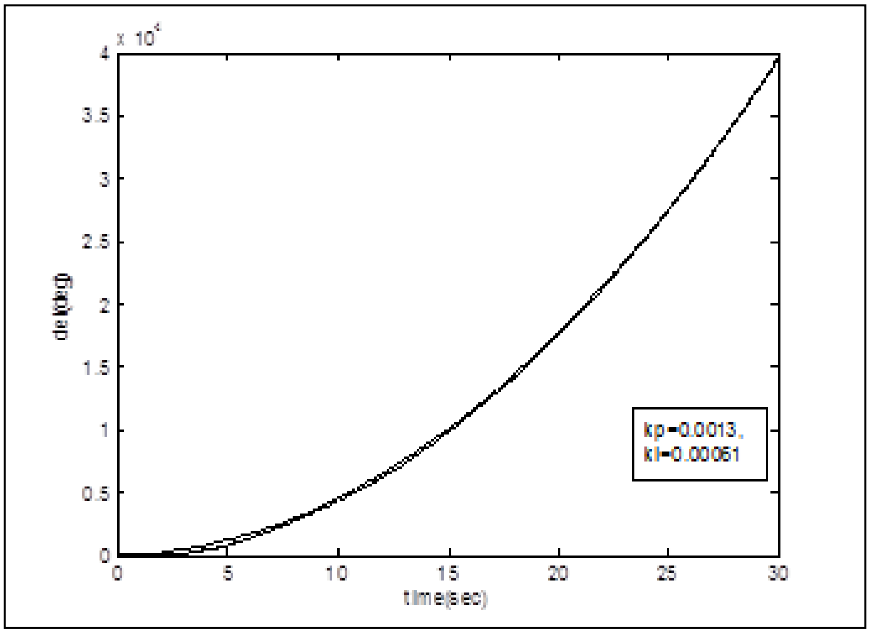

Fig. 8: Plot of Generator angles with PI control

C. Multi-machine System Considering Current Controller and Line Dynamics

Now considering the dynamics associated with the current controller and the DC line the stability study is performed again. The DC line is represented by the transfer function model.

1) Current Controller

Here, proportional integral current controller is used and is shown in figure 9.

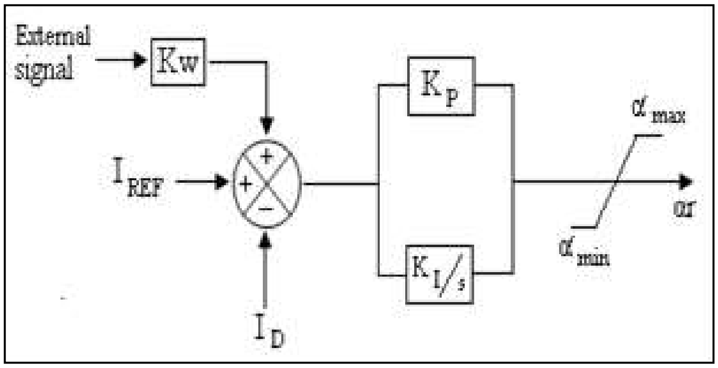

Fig. 9: Current controller

2) Auxiliary Controller

Here, a simple constant gain Auxiliary controller is employed and is shown in figure 10. The stability of the system is improved by varying the gain constant (Kw) of the above controller.

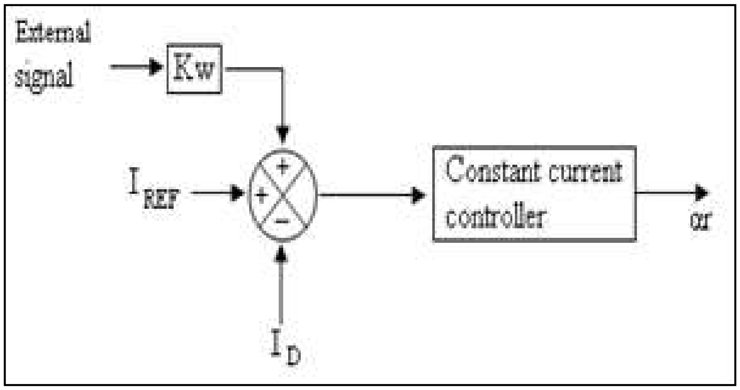

Fig. 10: Constant Gain Auxiliary Controller

3) Case 1 Uncontrolled Case

Considering the same disturbance as in previous case, stability study is performed again. Here two extra differential equations representing the current controller and the HVDC Line dynamics are to be solved using the Runge – Kutta method. Here the taps are assumed to be constant and the mode shifts are not considered [1]. Without any extra control mechanism the plots of generator angles and their relative difference will be as shown in figure 11 and figure 12.

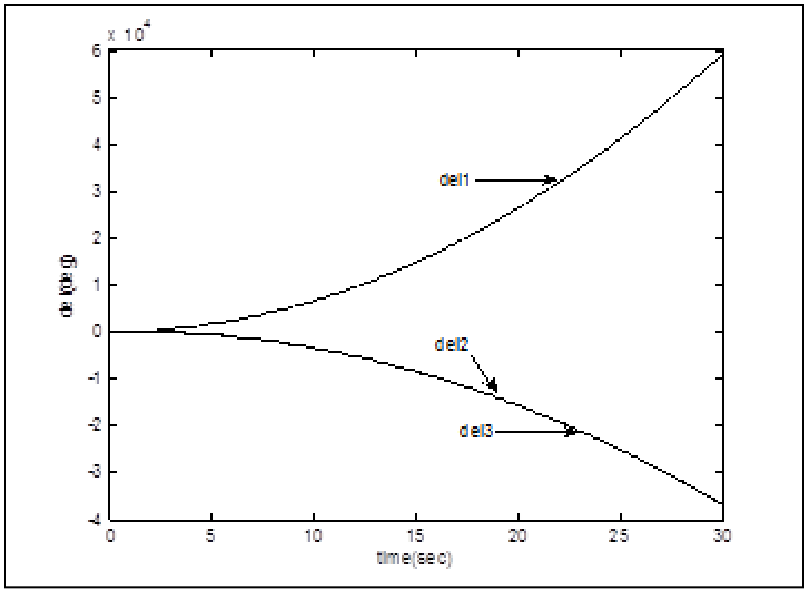

Fig. 11: Plot of generator angles with no external control signal applied

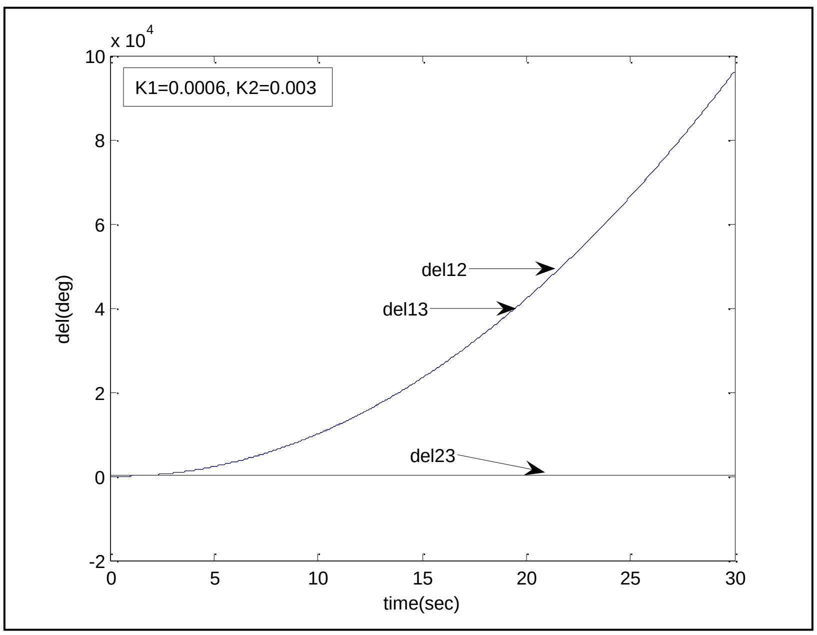

Fig. 12: Plot of relative angles without any external control signal

It is clearly seen that the system is becoming unstable, generator 2 and generator 3 are moving together whereas generator 1 falling out of synchronism, with this group. Considering the following signals:

$$error_1 = \left[\frac{\left(\omega(2)-\omega(1)\right)+\left(\omega(3)-\omega(1)\right)}{2} \right] - \left[\omega(2)-\omega(3)\right] \quad (5)$$

$$error_2 = \left[\frac{\left(del(2)-del(1)\right)+\left(del(3)-del(1)\right)}{2} \right] + \left[del(2)-del(3)\right] \quad (6)$$

$$error_3 = \left[\frac{\frac{P\_mis(3)}{H(3)} + \frac{P\_mis(2)}{H(2)}}{2} \right] - \left[\frac{P\_mis(1)}{H(1)} \right] \quad (7)$$

The signal $error_1$, represents average error in the speed differences between the three generators. The signal error2, represents average error in relative angles between the three generators. The signal error3 is defined to average out the acceleration force for all the three machines. Different combinations of the above three signals are considered, in order to improve the stability.

4) Case 2

Considering the signal error3 as the control input, the plot of relative angles is as shown in the figure no 10.

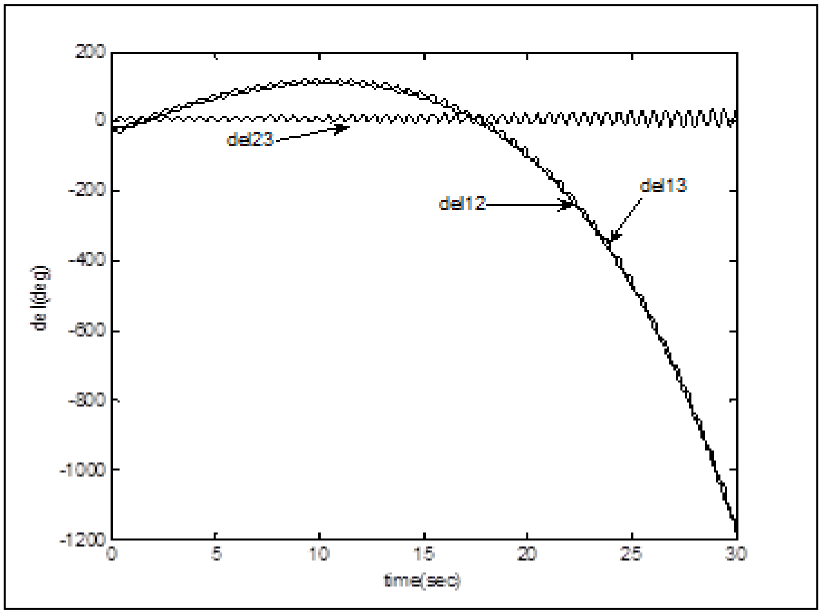

Fig. 13: Plot of relative angles with error3 as the control signal

5) Case 3

Considering the combination of error1 and error2 signals as the control input, the plot of relative angles is as shown in figure 14.

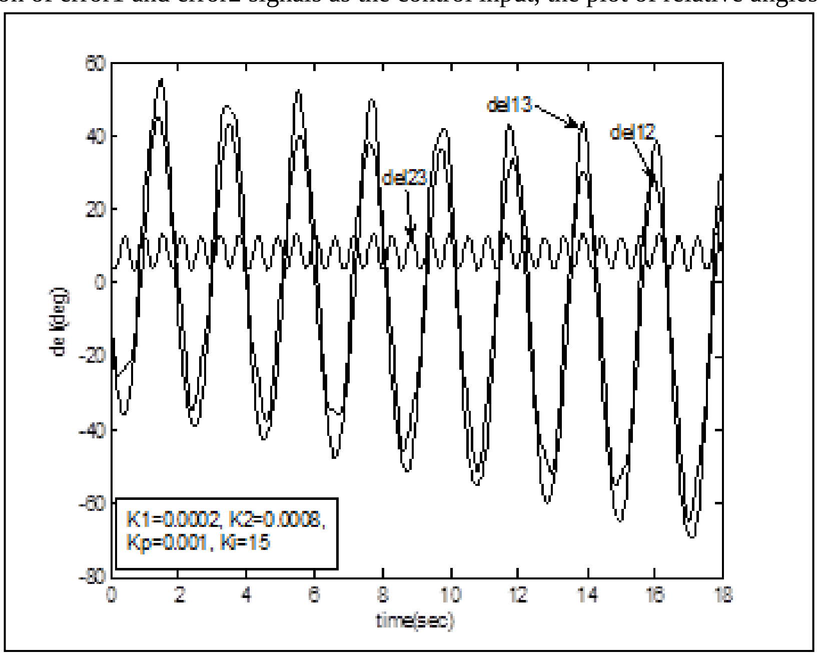

Fig. 14: Plot of relative angles with error1 and error2 as control signals

6) *Case 4*

Considering the combination of error1 and error3 signals to generate the required control signal, the plot of relative angles will be as shown in the figure no 12.

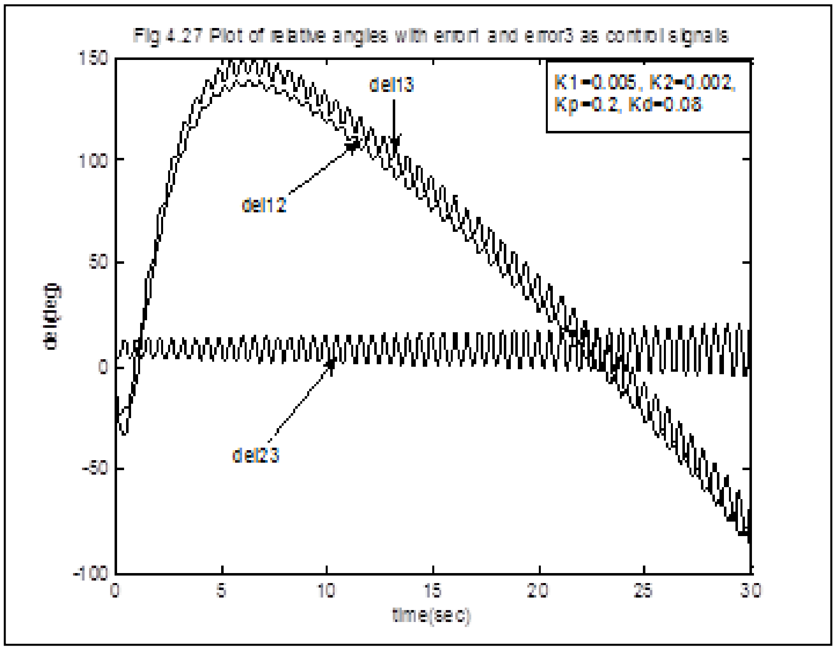

Fig. 15: Plot of relative angles with error1 and error3 as control signals

7) *Case 5*

Considering the combination of error2 and error3 signals to generate the control signals, the plot of relative angles will be as shown in figure no 16.

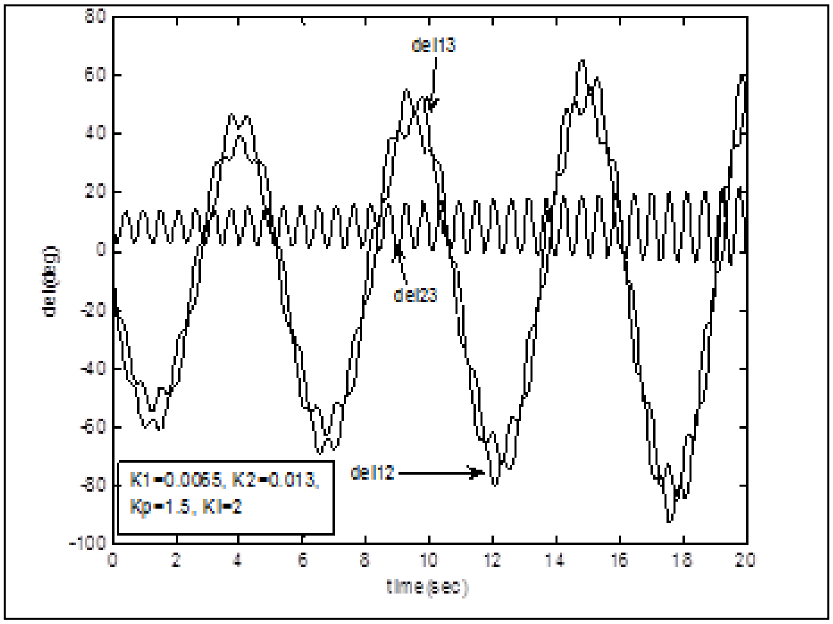

Fig. 16: Plot of relative angles with error2 and error3 as control signals

8) *Case 6*

Considering the combination of all the three signals to generate the control signal, the plots of the relative angles with different gains are as shown in figure (17) and figure (18).

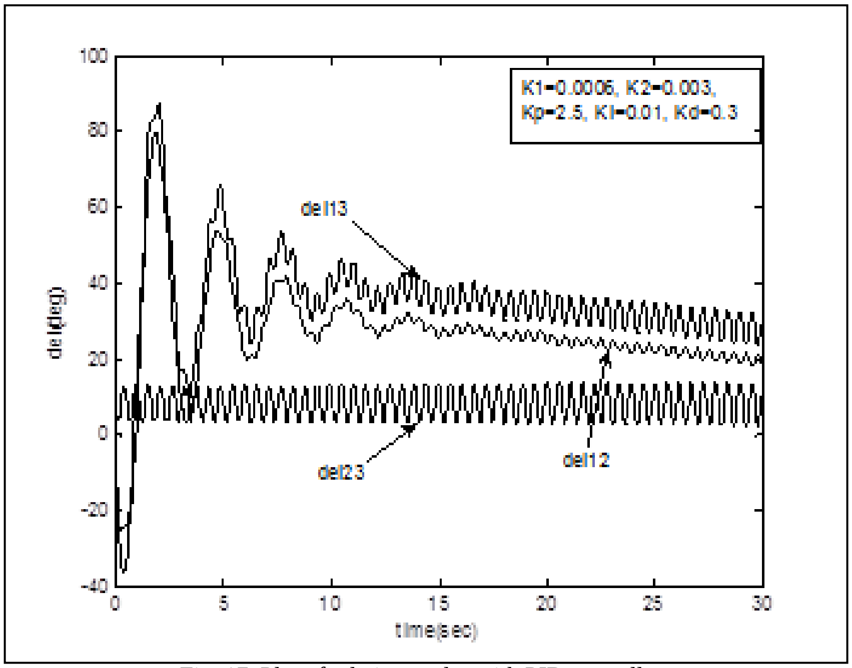

Fig. 17: Plot of relative angles with PID controller.

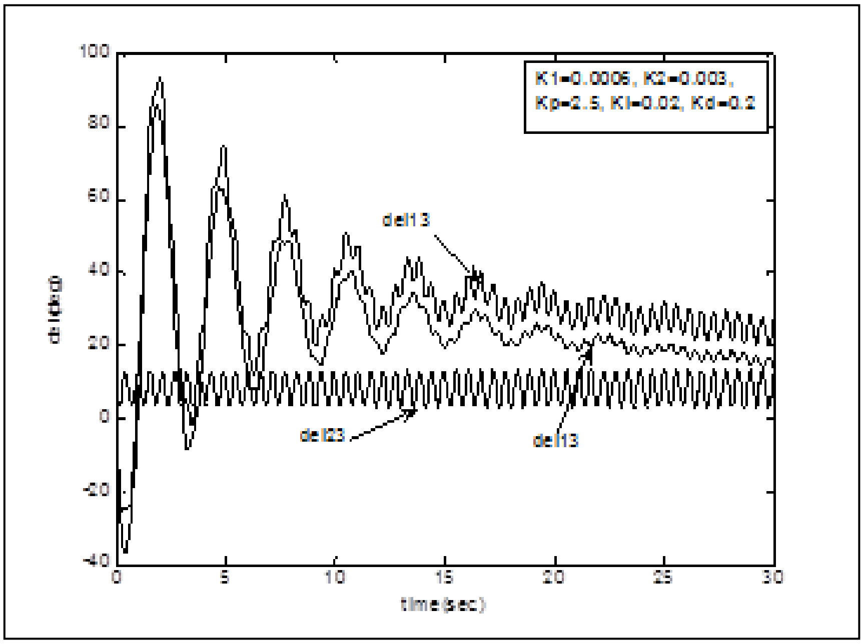

Fig. 18: Plot of relative angles with PID controller

The study reveals that the system can be stabilized by using a controller which produces the control signal given in equation 8.

Control signal, error = Kp*error1+ Ki*error2 + Kd*error3 (8)

Here the signal error2 is the equivalent to the integral of the signal error1, and the signal error3 is equivalent to the differential of the signal error1. Hence, the controller proposed above is equivalent to a PID controller. Then the control signal can be equivalently represented as in equation 9.

error= Kp e(t)+Ki Ie(t)+Kd De(t) (9)

Considering this, the methodology used in variable gain PID controller scheme can be applied to the above controller, to improve its performance. In the next chapter, a Fuzzy PID controller scheme is proposed to improve the stability of the system.

IV. CONCLUSION

The transmission line performance improves with the help of the variation in the control signal of the neighboring line as shown in figures 15 to 20.

Here we have anomaly the performance of the transmission line with & without control signal. Performance of the transmission line without any external control signal with the application of the distinct fault, has observed which has been shown in fig. 12. After that we have applied the control signal then conclude that the system performance enhance relative to the system without external control signal. It is distinguish that stability of the multi-machine system is enhanced with the variation in the three parameter phase angle, average acceleration & relative speed, represent in figures.

This hypothesis represents that, the control techniques can be developed & applied in power transmission line, for boost the stability of the power system.

V. SCOPE OF FUTURE WORK

By using fuzzy logic the gains of the P-term, I-term and D-term of the control signal, specified in the last chapter, are adjusted in every sampling interval in accordance to a set of linguistic control rules and in conjunction. This feature is desirable because as the operating conditions of a system begin to change, deterioration in performance will result if a fixed gain controller is applied.

REFERENCES

[1] P. Kundur, "Power System Stability and Control", McGraw- Hill, Inc., 1994.
[2] Prabha Kundur, John Paserba, "Definition and Classification of Power System Stability", IEEE Trans. on Power Systems., Vol. 19, No. 2, pp 1387- 1401, May 2004.
[3] A. Panosyan, B. R. Oswald, "Modified Newton- Raphson Load Flow Analysis for Integrated AC/DC Power Systems",
[4] T. Smed, G. Anderson, "A New Approach to AC/DC Power Flow", IEEE Trans. on Power Systems., Vol. 6, No. 3, pp 1238- 1244, Aug. 1991.
[5] Stagg and El- Abiad, "Computer Methods in Power System Analysis", International Student Edition, McGraw- Hill, Book Company, 1968.
[6] Jos Arrillaga and Bruce Smith, "AC- DC Power System Analysis", the Institution of Electrical Engineers, 1998.
[7] K. R. Padiyar, "HVDC Power Transmission Systems", New Age International (P) Ltd., 2004.
[8] "IEEE Guide for Planning DC Links Terminating at AC Locations Having Low Short-Circuit Capacities", The Institute of Electrical and Electronics Engineers, Inc., 1997.
[9] Garng M. Huang, Vikram Krishnaswamy, "HVDC Controls for Power System Stability", IEEE Power Engineering Society, pp 597- 602, 2002.
[10] Choo Min Lim, Takashi Hiyama, "Application of A Rule-Based Control Scheme for Stability Enhancement of Power Systems", pp 1347- 1357, IEEE 1995.
[11] Sharad Chandra Rajpoot, Prashant Singh Rajpoot and Durga Sharma," Power system Stability Improvement using Fact Devices",International Journal of Science Engineering and Technology research ISSN 2319-8885 Vol.03, Issue. 11, June-2014, Pages: 2374-2379.
[12] Sharad Chandra Rajpoot, Prashant singh Rajpoot and Durga Sharma,"Summarization of Loss Minimization Using FACTS in Deregulated Power System", International Journal of Science Engineering and Technology research ISSN 2319-8885 Vol.03, Issue.05,April & May-2014,Pages:0774-0778.
[13] Sharad Chandra Rajpoot, Prashant Singh Rajpoot and Durga Sharma, "Voltage Sag Mitigation in Distribution Line using DSTATCOM" International Journal of ScienceEngineering and Technology research ISSN 2319-8885 Vol.03, Issue.11, April June-2014, Pages: 2351-2354.
[14] Prashant Singh Rajpoot, Sharad Chandra Rajpoot and Durga Sharma, "Review and utility of FACTS controller for traction system", International Journal of Science Engineering and Technology research ISSN 2319-8885 Vol.03, Issue.08, May-2014, Pages: 1343-1348.
[15] Sharad Chandra Rajpoot, Prashant Singh Rajpoot and Durga Sharma, "A typical PLC Application in Automation", International Jou rnal of Engineering research and TechnologyISSN 2278-0181 Vol.03, Issue.6, June-2014.
[16] Iba K. (1994) „Reactive power optimization by genetic algorithms", IEEE Trans on power systems, May, Vol.9, No.2, pp.685-692.
[17] Sharad Chandra Rajpoot, Prashant Singh Rajpoot and Durga Sharma,"21st century modern technology of reliable billing system by using smart card based energy meter",International Journal of Science Engineering and Technology research,ISSN 2319-8885 Vol.03,Issue.05,April & May-2014,Pages:0840-0844.
[18] Prashant singh Rajpoot , Sharad Chandra Rajpoot and Durga Sharma,"wireless power transfer due to strongly coupled magnetic resonance", international Journal of Science Engineering and Technology research ISSN 2319-8885 Vol.03,.05,April & May-2014,Pages:0764-0768.