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ENHANCEMENT OF POWER SYSTEM INTERPRETATION THROUGH PID CONTROLLER

SHARAD CHANDRA RAJPOOT [1], PRASHANT SINGH RAJPOOT [2]
1 Assistant professor (EE) G.E.C. Jagdalpur , Bastar, Chhattisgarh, India, E-mail: scrajpoot90@gmail.com.
2 Assistant professor (EE) L.C.I.T., Bilaspur, Chhattisgarh, India, E-mail: prashantrajpoot141@gmail.com

Abstract- power system is integration of the different sub system just like generation , transmission and distribution. So there will be many chances to subject with the disturbances. These disturbance may be caused by the atmosphere or may be caused by the system itself . these disturbances will responsible for the instability of the operating power system .
If the fault occur in any location of the power system then it must be sensed as soon as possible with the help of the relay and then that faulty section must be cut out from the healthy section with the help of the circuit breakers, for proper performance of the power system. For instance, a fault on a critical element followed by its isolation by protective relays will cause variations in power flows, network bus voltages, and machine rotor speeds; the voltage variations will actuate both generator and transmission network voltage regulators; the generator speed variations will actuate prime mover governors; and the voltage and frequency variations will affect the system loads to varying degrees depending on their individual characteristics. Further, devices used to protect individual equipment may respond to variations in system variables and cause tripping of the equipment, thereby weakening the system and possibly leading to system instability.

Index Terms- AC/DC power system, HVDC Line, power flows, network bus voltages , load flow analysis , stability analysis, power system stability.

1. INTRODUCTION

The operating characteristics of synchronous and induction machines are described by sets of differential equations. The number of differential equations required for a machine depends on the details needed to represent accurately the machine performance. The performance of the power system during the transient period can be obtained from the network performance equations. The performance equation using the bus frame of reference in either the impedance or admittance form has been used in transient stability calculations.

1.1 Multi-machine 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 1

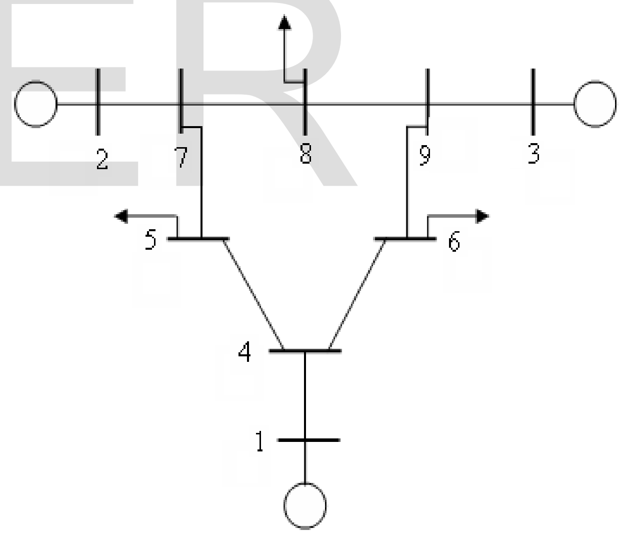

Figure 1: WSCC 9 Bus System

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. 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

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flow setting in the HVDC line. The system data is given in appendix I.

2. FAULT ANALYSIS

2.1 Case I: Uncontrolled Case

Fig. 2 is a plot of the generator angles for a grounded fault at Bus 6. 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 3.

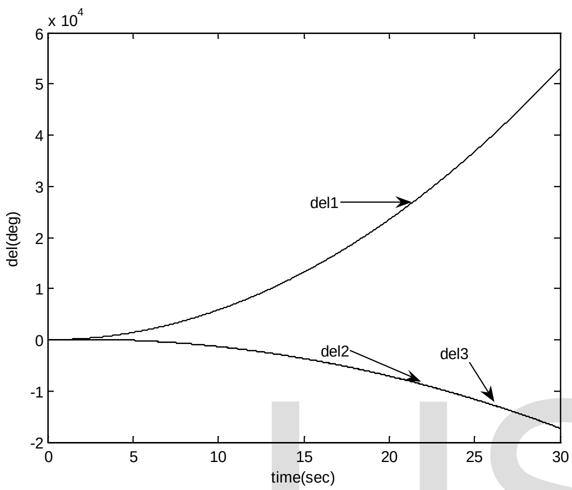

Figure 2: Plot of generator angles without any extra control

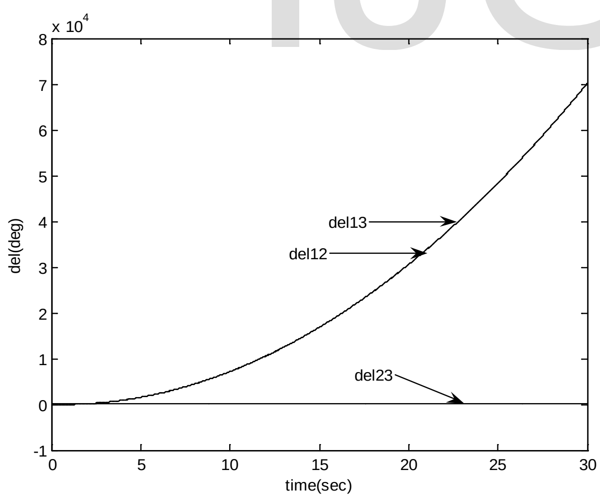

Figure 3: Plot of relative angles with no extra control

From Fig 2, 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]:

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

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.

2.2 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:

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

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

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

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

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

The plot of relative angles of the generators is as shown in figure 4 and the plot of generator phase angles is shown in figure 5.

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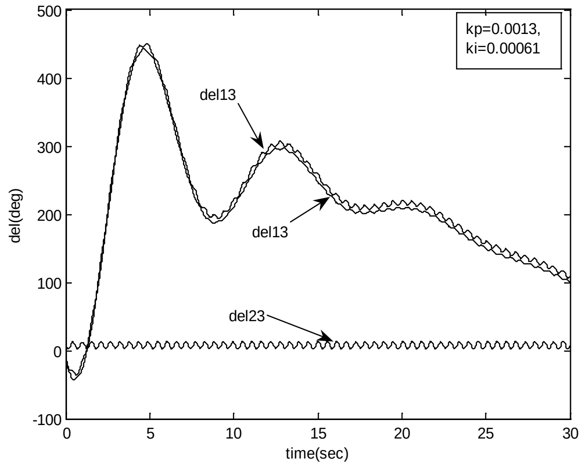

Figure 4: Plot of relative angles with PI control

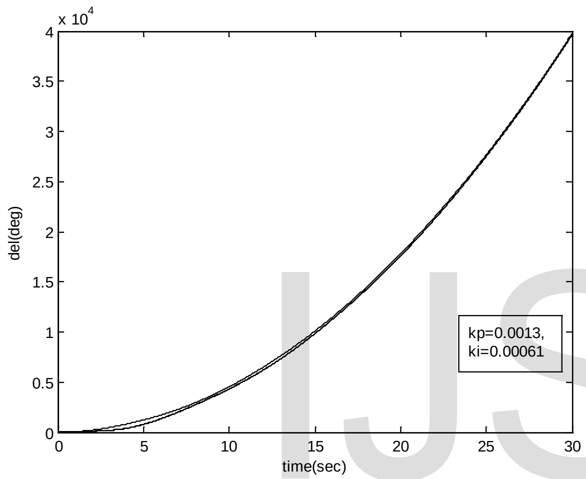

Figure 5: Plot of Generator angles with PI control

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.

2.2.1 Current Controller

Here, proportional integral current controller is used and is shown in figure 6

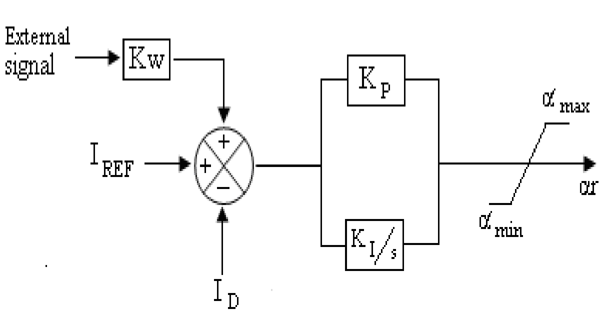

Figure 6: Current controller

2.2.2 Auxiliary controller

Here, a simple constant gain Auxiliary controller is employed and is shown in figure 6. The stability of the system is improved by varying the gain constant (K_w) of the above controller.

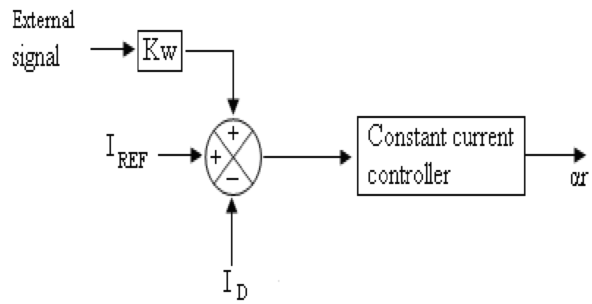

Figure 6: Constant Gain Controller

2.3 ANALYSIS OF DIFFERENT CASE

2.3.1 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 7 and figure 8.

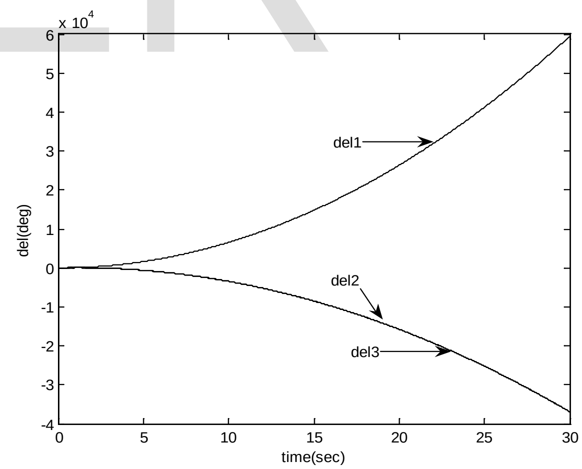

Figure 7: Plot of generator angles with no external control signal applied

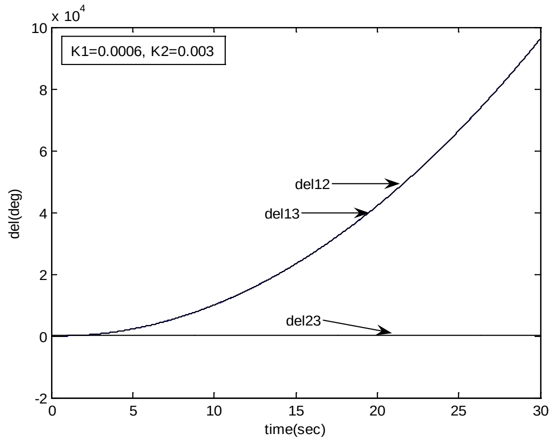

Figure 8: Plot of relative angles without any external control signal

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:

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

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

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

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.

2.3.2 Case 2

Considering the signal $error_3$ as the control input, the plot of relative angles is as shown in the figure no 9.

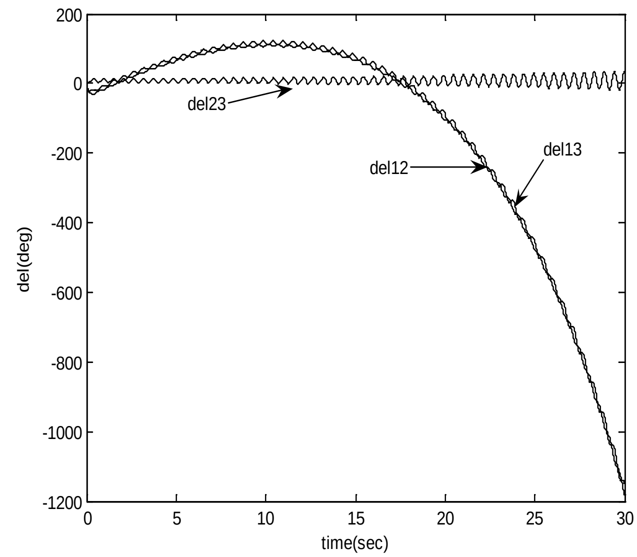

Figure 9:Plot of relative angles with $error_3$ as the control signal

2.3.3 Case 3

Considering the combination of $error_1$ and $error_2$ signals as the control input, the plot of relative angles is as shown in figure no 10.

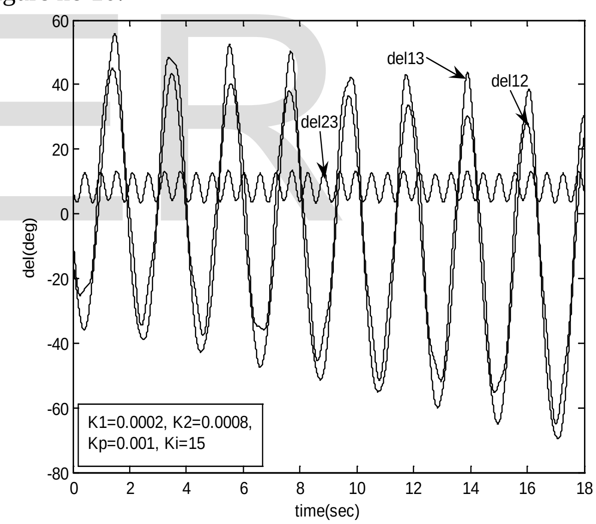

Figure 10: Plot of relative angles with $error_1$ and $error_2$ as control signals

2.3.4 Case 4

Considering the combination of $error_1$ and $error_3$ signals to generate the required control signal, the plot of relative angles will be as shown in the figure no 11.

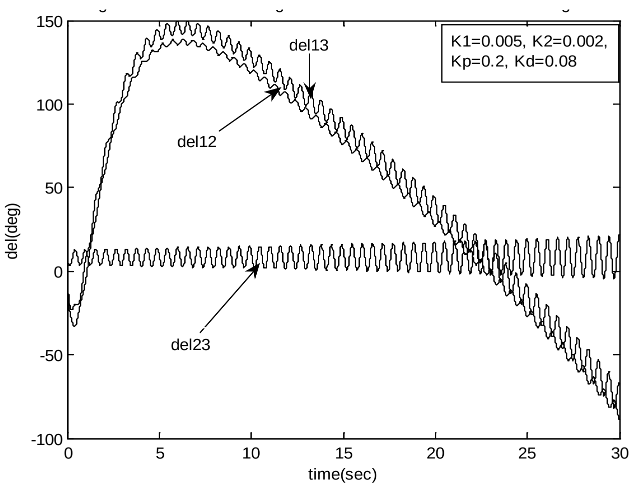

Figure 11: Plot of relative angles with $error_1$ and $error_3$ as control signals

2.3.5 Case 5

Considering the combination of $error_2$ and $error_3$ signals to generate the control signals, the plot of relative angles will be as shown in figure no 12.

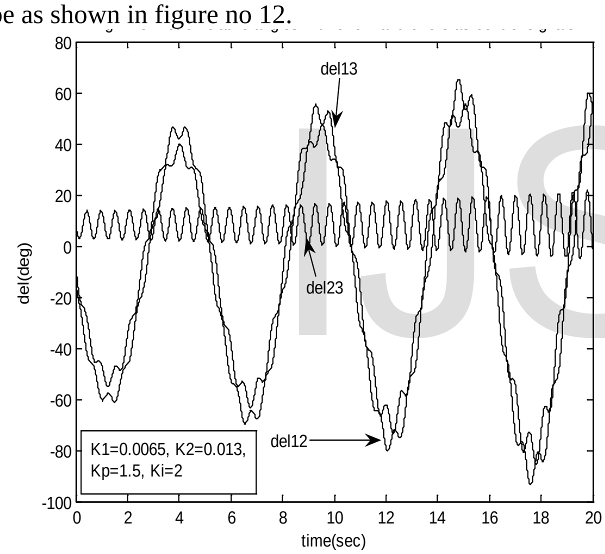

Figure 12: Plot of relative angles with $error_2$ and $error_3$ as control signals

2.3.6 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 (13) and figure (14).

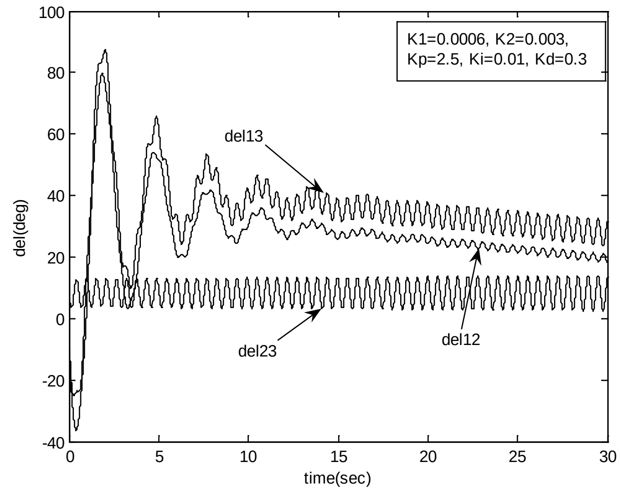

Figure no 13: Plot of relative angles with PID controller.

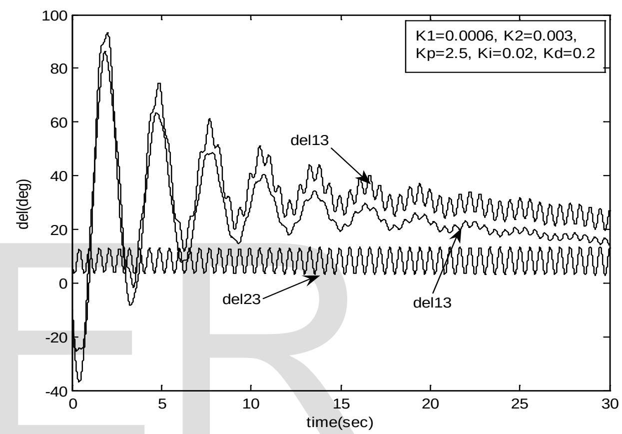

Figure 14: Plot of relative angles with PID controller

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

$$error = K_p*error_1 + K_i*error_2 + K_d*error_3 \quad (8)$$

Here the signal $error_2$ is the equivalent to the integral of the signal $error_1$, and the signal $error_3$ is equivalent to the differential of the signal $error_1$. Hence, the controller proposed above is equivalent to a PID controller. Then the control signal can be equivalently represented as in equation 9.

$$error= K_p\, e(t)+K_i\, Ie(t)+K_d\, De(t) \quad (9)$$

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.

4. CONCLUSION

If the proper control is achieved then the performance of the multi-machine system can be tremendously enhanced up to desired level of requirements.

Yet we have not only observed the Plot of generator angles without any extra control in fig. no. 2 and Plot of relative angles with no extra control in fig. no. 3 , but also observed the Plot of relative angles with PID controller in fig. no. 14. After that we can conclude that by adopting proper control signal in feedback the error can be mitigates. These error can be control by the adjustment of relative speed , phase angle and average acceleration. If the error mitigates then the performance of the system will automatically enhanced .

The control mechanisms can be depicted and integrated for HVDC power inflection, to boost the stability of the power system.

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.

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