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TRANSIENT STABILITY ANALYSIS USING TIME DOMAIN METHOD

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Abstract: This paper presents transient stability analysis using time domain method in MATLAB. A Multi Machine, three generator and nine bus system is used for this analysis. A three line to ground fault is considered for this analysis. In transient stability analysis, rotor angle (δ) and rotor speed (ω) are analyzed with respect to time and with respect to each other. Critical Clearing Time (CCT) is evaluated for each generator to analyze the stability of considered system.

Index Terms: Transient stability, Critical Clearing Time, Synchronous Generator

I. INTRODUCTION

Electricity is the backbone of human life. That is why power system should be reliable and stable and that is why stability analysis is done here. Power system stability can be defined as the ability of a power system to remain in a state of operating equilibrium during normal conditions, and to regain an accepted state of operating equilibrium after a disturbance.[1][2] During normal operating conditions of the power systems (in steady state), two main conditions should be satisfied for generators: (i) Rotors should be in synchronism. (ii) Frequency of all generated voltages should be same.[4] In power system, for each generator, mechanical power and electrical power should be in balanced condition during steady state. Now if any disturbance occurs on the system then this balance is disturbed and system start to accelerate or decelerate depends on type of disturbance. If disturbance is small then analysis is known as small signal analysis and if disturbance is large then analysis is known as transient analysis. Power system must be able to withstand against these disturbances. The ability of a power system to recover and maintain synchronism is called rotor angle stability.[2] Small signal stability is the ability of the power system to maintain synchronism under small disturbances.[2] Transient stability is the ability of the power system to maintain synchronism under large disturbances.[2] The rotor of synchronous generator is driven by prime mover. The frequency of the terminal voltage of the generator depends on the speed of rotor. Rotor mechanical speed is synchronized with the frequency of the stator electrical quantities. When two or more synchronous generators are inter connected, stator voltage and current of each generator must have the same frequency. The rotors of all interconnected generators must be in synchronism during normal operating conditions of power system. Mechanical input power (Pm) from prime mover to generator shaft and generated electrical power (Pe) should be in balanced condition. When large disturbances (like a fault on the network, failure of equipments, sudden change in load, and loss of a line or generator) are developed on power system, the maintenance of rotor angle stability is known as transient stability. Due to these disturbances the synchronous machines may loss synchronism. It is important to note that, steady-state stability is a function of only the operating condition, whereas transient stability is a function of both the operating condition and the disturbances. This complicates the analysis of transient stability considerably. Transient Stability requires analysis for different disturbances. Transient stability analysis in a power system is the ability of power system to remain in synchronism before the large disturbance as well as after the large disturbance. Now a days transient stability analysis of power system is mainly performed by simulations. Calculation of critical clearing time (CCT) for a fault is a main assessment in the transient stability analysis. This paper presents the mathematical formulation of dynamic equations associated with transient stability analysis. In transient stability analysis, classical model of synchronous generator is considered.

II. SYSTEM MODEL

This section presents the system which is considered for transient stability analysis. Three generators, nine bus system is considered here. Three line to ground Fault is considered near 7 bus on 5-7 line, then after clearing the fault 5-7 line is removed. All data for generators, lines and power flow are given in [3]. Initially network Ybus matrix for given system is of 9×9. Three generators are connected in network so that these node with generators are considered as a main nodes and then network is converted into 3×3 Ybus matrix using Kron transformation.

After conversion the system into three node system, generators are considered as classical model.

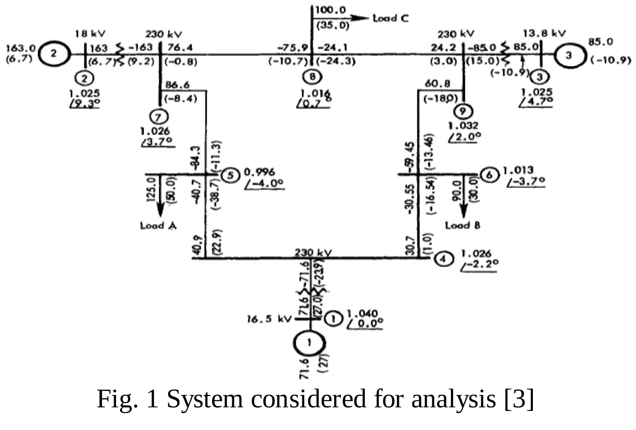


Fig. 1 System considered for analysis [3]

A. Classical Model

Equation for classical generator model is given by

$$E = \frac{x_d' \times (P - jQ)}{V'} + V \qquad (1)$$

Using Kron transformation nine bus systems is reduced to three bus system.

Equation to remove k[th] node is represented as

$$y^{new}_{(i,j)} = y_{(i,j)} - y_{(i,j)} \times \frac{y_{(i,k)} \times y_{(k,j)}}{y_{(k,k)}} \qquad (2)$$

After Kron transformation, reduced data for pre fault, fault on and post fault are given in next to next section.

B. Mathematical System Model

$$\frac{2H}{\omega_0}\frac{d\omega_i}{dt} = p_{mi} - p_{ei} \qquad (3)$$

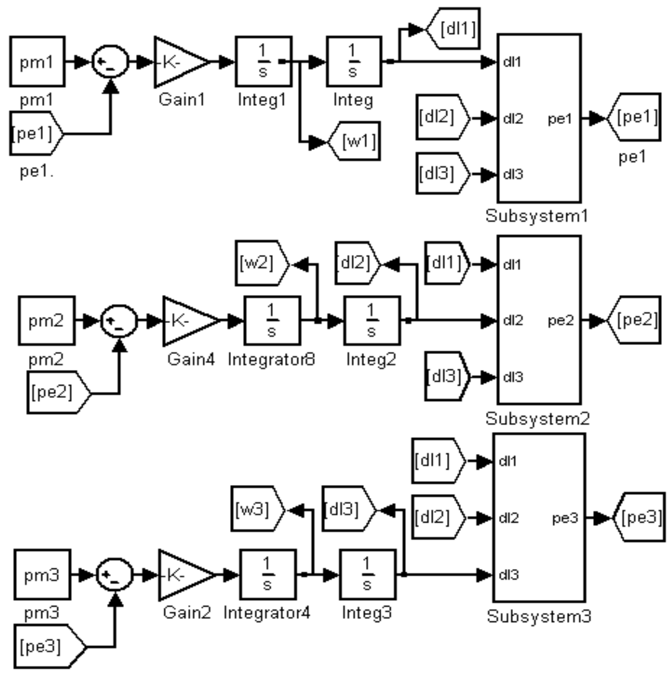
$$p_{ei} = E_i^2.G_{ii} + \sum_{\substack{j=1 \\ j \neq i}}^{n} E_i E_j Y_{ij} \cos(\theta_{ij} - \delta_i + \delta_j) \qquad (4)$$

$$\frac{d\delta_i}{dt} = \omega_i \qquad (5)$$

III. MATLAB MODELING

Using above mathematical equations (3 – 5), MATLAB model can be prepared for given system which can be used in time domain for transient stability analysis.[5]

In given system three generators are there that is why three different swing equations are used for each generator which is shown by equation (3). Equation (4) shows the power flow in system lines. Relation between generator rotor speed and rotor angle is shown by equation (5).



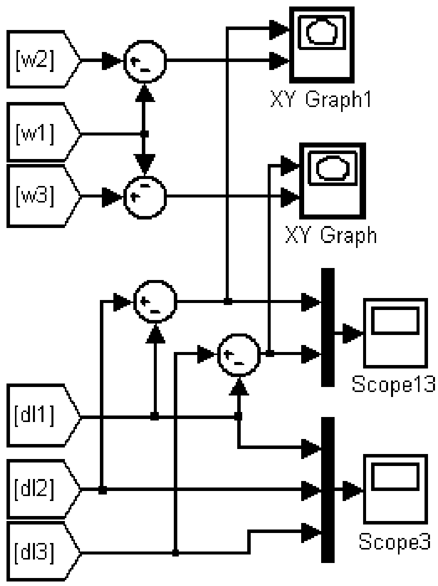


Fig. 2 MATLAB model of considered system.

In above system MATLAB model, three sub systems are used. These sub systems provide electrical power generated by each generator as per load and circuit condition. During fault and after fault clearing electrical network is changed and its data is given in [3], According to these variable networks due to fault, subsystems in MATLAB are modeled which are shown in next figures.

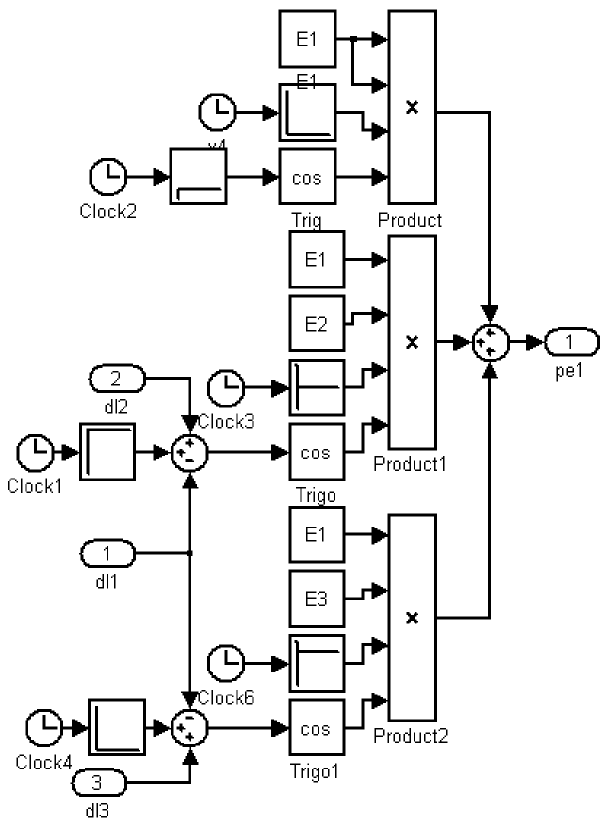


Fig. 3 MATLAB Sub system-1, Model

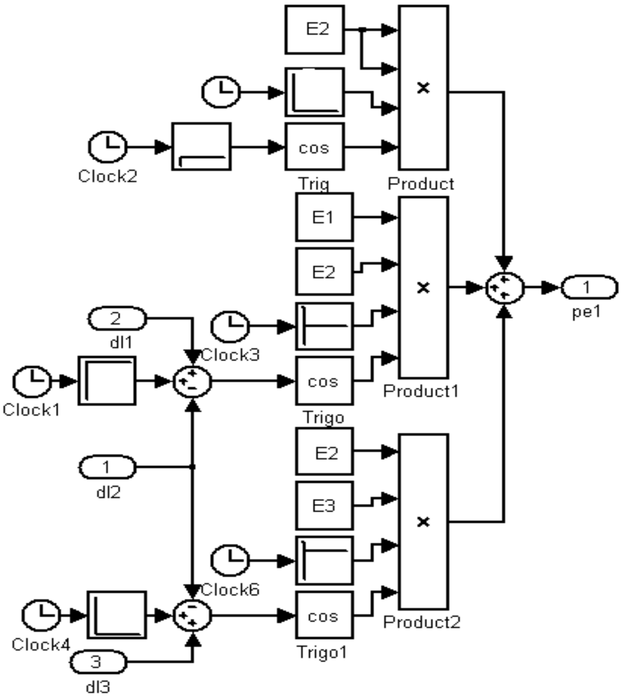


Fig. 4 MATLAB Sub system-2, Model

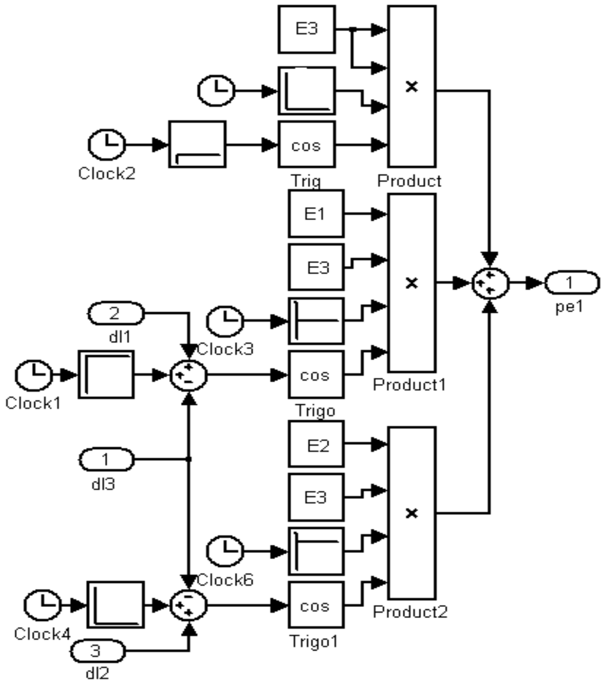


Fig. 5 MATLAB Sub system-5, Model

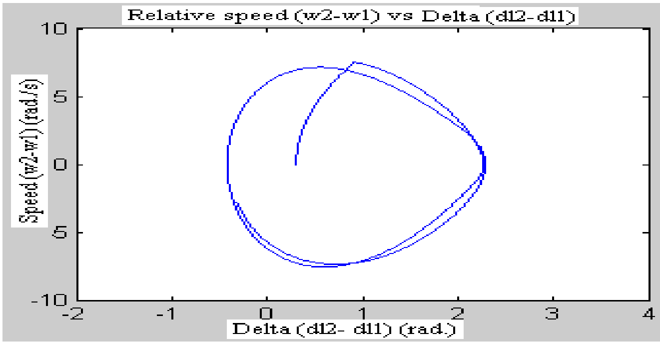
IV. SIMULATION RESULTS

Transient stability analysis is done using classical model. Aim of system simulation is to determine Critical Clearing Time (CCT). In below table system network data is given for three different conditions (i) Pre fault Ybus data, (ii) Fault on Ybus system, and (iii) Post fault Ybus system data. Pre fault, fault on, and post fault are considered as steady state condition, during fault condition and after fault clearing condition respectively.

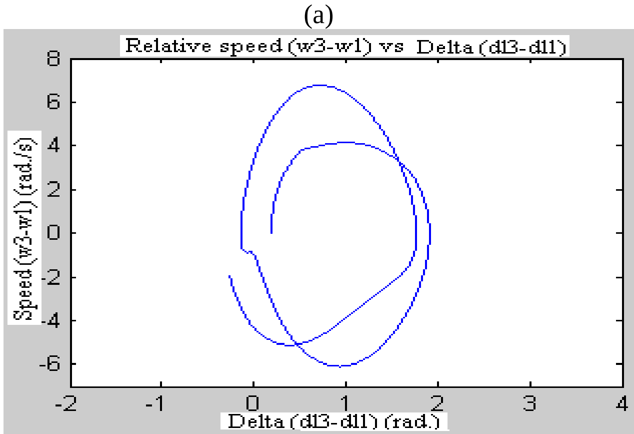
INPUT DATA [3]

Type of Network	Node	1	2	3
Pre Fault	1	0.846 - j2.98	0.287 + j1.51	0.2 10 + j1.22
	2	0.287 + j1.51	0.420 - j2.72	0.213 + jl.08
	3	0.2 10 + j1.22	0.213 + jl.08	0.277 - j2.36
Fault	1	0.657 - j3.816	0.000 + j0.00	0.070 + j0.63
	2	0.000 + j0.00	0.000 - j5.48	0.000 + j0.00
	3	0.070 + j0.63	0.000 + j0.00	0.174 - j2.79
Post fault	1	1.181 - j2.229	0.138 + j0.72	0.191+ j1.079
	2	0.138 + j0.72	0.389 - j1.95	0.199 + j1.23
	3	0.191+ j1.079	0.199 + j1.23	0.273 - j2.34

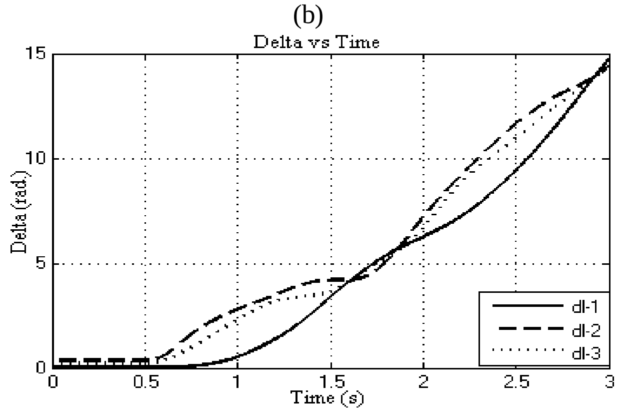
V. RESULTS OF SYSTEM SIMULATION



(a)

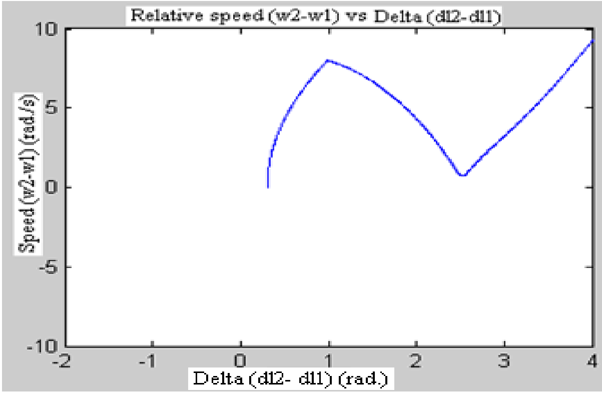


(b)

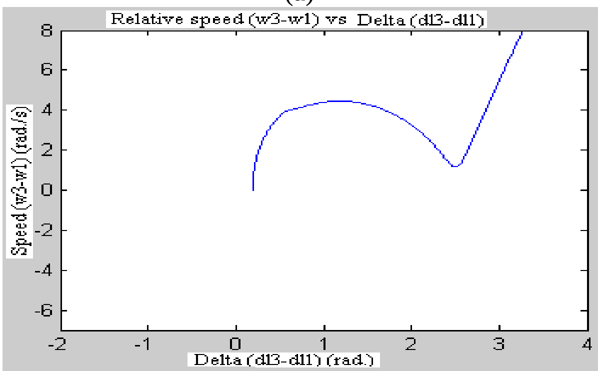


(c)

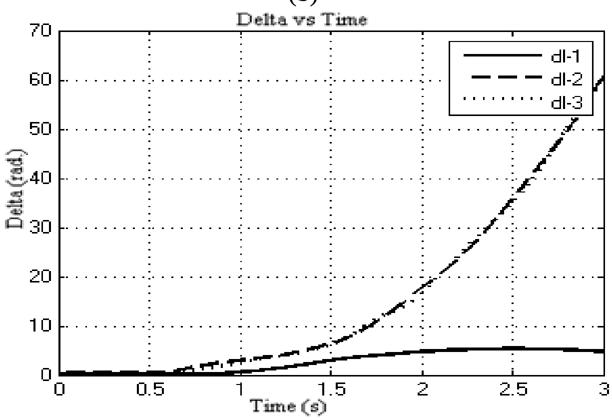
Fig. 6 Simulation results (a, b and c) where Fault Clearing Time is 0.16 second



(a)



(b)



(c)

Fig. 7 Simulation results (a, b and c) where Fault Clearing Time is 0.17 second

System is simulated first for fault clearing time 0.16 second, in which graphs shows relation of relative speed, rotor angle and time. Result for 0.16 fault clearing time, shows that system is stable. When system is simulated for fault clearing time 0.17 second, in which graphs shows relation of relative speed, rotor angle and time. Result for 0.17 second fault clearing time, shows that system is unstable.

VI. CONCLUSION

This paper presents transient stability analysis using time domain method for given system. The transient stability of the system can be evaluated in terms of Critical Clearing Time (CCT). Due to three line to ground fault, system becomes unstable that can be observed after the simulation of given system in terms of critical clearing time.

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