

Understanding of Multi-Machine Simulation using Simulink Model

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Abstract---This paper describes simulation of multi-machine power system example using Simulink blocks MATLAB software. This paper also involves designing of 3 machine 9 bus system using MATLAB simulation. This model is very useful for study of stability analysis but is limited to the study of transients for only the “first swing” or for periods on the order of one second. The system is made stable by removing faulted line of given multi-machine. For Y_{bus} simulation M-file is been used and final results is plotted.

I. INTRODUCTION

Transient stability analysis has recently become a major issue in the operation of power systems due to the increasing stress on power system networks. This problem requires evaluation of a power system's ability to withstand disturbances while maintaining the quality of service. Many different techniques have been proposed for transient stability analysis in power systems, especially for a multi-machine system. Multi-machine equations can be also be written as similar to the one-machine system connected to the infinite bus and to reduce the complexity of the transient stability analysis some standard assumptions are made that

1. Mechanical power input is constant.
2. Damping or asynchronous power is negligible.
3. Constant voltage behind transient reactance model for the A synchronous machine is valid.
4. The mechanical rotor angle of a machine coincides with The angle of the voltage behind the transient reactance.
5. Passive impedances represent loads. [10]

Using the prefault bus voltages, all loads are converted to equivalent admittances to ground and are assumed to remain constant. Damping or asynchronous powers are ignored. The mechanical rotor angle of each machine coincides with the angle of the voltage behind the machine reactance.

II. MATHEMATICAL MODEL OF MULTI-MACHINE

Transient stability analysis starts by study load flow analysis and determine initial bus voltage magnitude and angles .The current calculation prior to disturbance is been calculated by

$$I_i = S_i / V_i^* = (P_i - jQ_i) / V_i^* \tag{1}$$

Where,
 $i = 1, 2, 3 \dots m$

m is the number of generators
 V_i is the terminal voltage of the i^{th} generator
 P_i and Q_i are the generator real and reactive powers. [4]

All unknown values are determined from the initial power flow solution. The generator armature resistances are usually neglected and the voltages behind the transient reactances are then obtained.

$$E_i = V_i + jX_d I_i \tag{2}$$

Then all load are converted to equivalent admittances by using the relation

$$Y_{io} = S_i^* / V_{i2} = (P_i - jQ_i) / V_{i2} \tag{3}$$

To include voltages behind transient reactances m buses are added to the n bus power system network.

The power into the network at node i , which is the electrical power output of machine i , is given by

$$P_{ei} = E^2 G_{ii} + \sum_{j=1}^n E_i E_j Y_{ij} \cos \theta_{ij} - \delta_i + \delta_j \tag{4}$$

Where
 $i = 1, 2, 3 \dots n$ and
 $Y_{ij} = Y_{ij} \angle \theta_{ij} = G_{ij} + jB_{ij}$

The system considered in this paper is as shown in fig.1 and the system's base MVA is 100 and system frequency is 50 Hz and generator one is taken as reference generator and other two generators are under observation for analysis of stability of system. Three transformers are present and taping is considered to be zero and nine buses are present. The load is distributed at bus 5, 6 and 8. For understanding stability fault is been created at bus nine and line 6-9 is been removed the line data and load data is been shown in appendix table-3 and table-4.

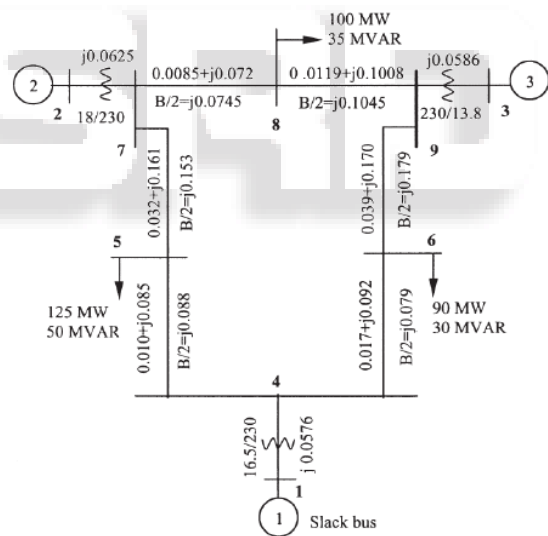


Fig.:3 machine 9 bus systems [8]

Hence the calculation of bus matrix during fault condition is calculated by given formula

$$Y_{bus} = Y_{jold} - Y_{nold} Y_{njold} / Y_{nnold} \tag{5}$$

And equations obtained during fault condition for 3 machine 9 bus systems is given as under

$$P_{e3} = 0.1987 + 0.0351 \cos(\delta_{31} - \theta_{31}) \tag{6}$$

$$P_{e2} = 0.5715 + 0.2679 \cos(\delta_{21} - \theta_{21}) \tag{7}$$

The calculation of bus matrix During Post Fault Condition once the fault is cleared by removing the line simultaneously opening the circuit breaker at the either ends of the line between buses

$$Y_{postfault} = Y_{jjold} - Y_{ji} - B_{ij} / 2 \tag{8}$$

And the equations obtained at post fault condition for our system is given as under

$$P_{e2} = 0.7282 + 0.4113 \cos(\delta_{21} - \theta_{21}) \tag{9}$$

$$P_{e3} = 0.1263 + 0.1149\cos(\delta_{31} - \theta_{31}) \quad (10)$$

These equations are obtain by carrying load flow analysis plus transient stability analysis through which all powers and angle are obtained.

Simulation Result and Analysis

The simulation circuit contain three generators simulated in subsystem then interface to main system. The input mechanical powers for P_{m1} , P_{m2} and P_{m3} are 0.7162, 1.629 and 0.8504 respectively and these values are obtained by conducting load flow analysis. Bus matrix after fault Y_{af} is calculated by developing m-file using ‘Newton Raphson’ method for understanding load flow calculation and transient stability analysis.

The gain block is used which represent machine inertia constant and integrator block is used twice to for each machine to give the rotor angle δ_2 and δ_3 . The power P_{e2} and P_{e3} is calculated using subsystem the detailed diagram is shown in Fig.3

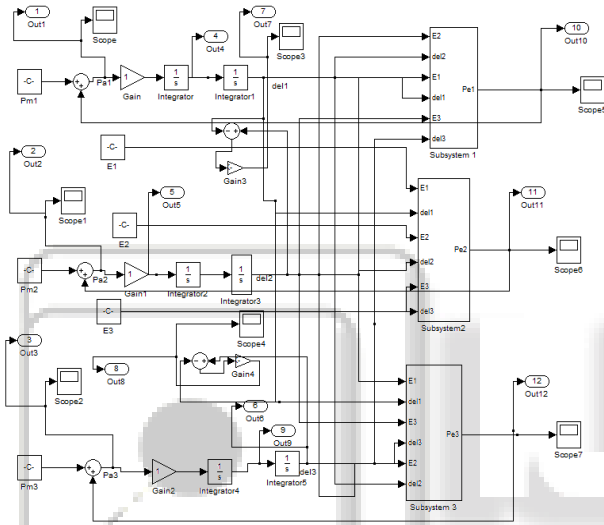


Fig.2: Simulated Circuit

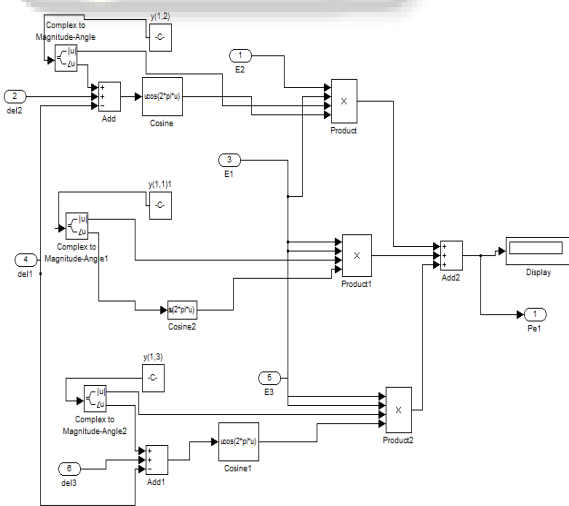


Fig.3: GEN 1 Subsystem

The graph obtained between P_a v/s t , δ v/s t and δ_{21} v/s δ_{23} is shown in Table No. 1 and 2.

Table No.1

T sec	0.06	0.04	0.05
P_e	-3.014	-3.439	-6.927
δ	0.3581	-0.0057	0.00425

Table No.2

SR.NO.	δ	
1	δ_{21}	-0.3638
2	δ_{23}	-0.3538

By studying this circuit simulated we can say that how electrical power P_e deviates w.r.t. time t in sec and also angle δ deviation w.r.t. time t in sec and the same is shown in graph as well as in table form. The graph here explains that P_e and δ angle deviation depends on bus matrix after fault Y_{af} .

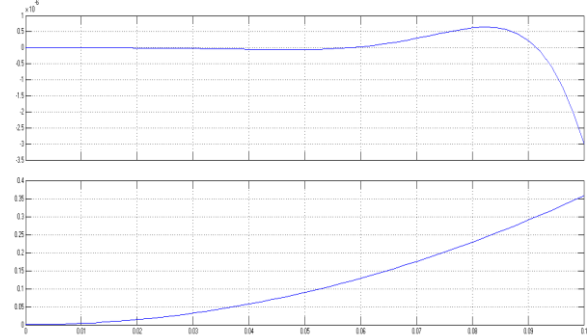


Fig.4: Plot of GEN1 power v/s Time

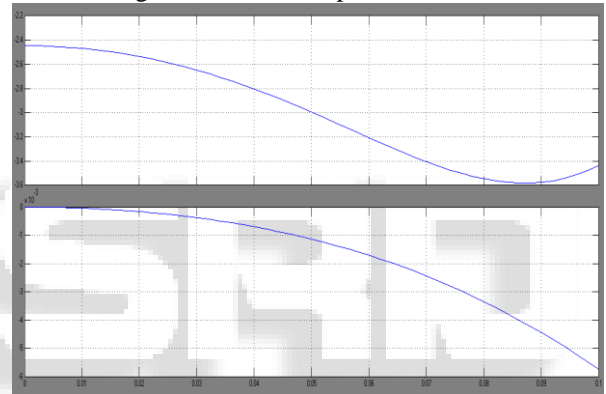


Fig.5: Plot of GEN2 δ_2 v/s Time

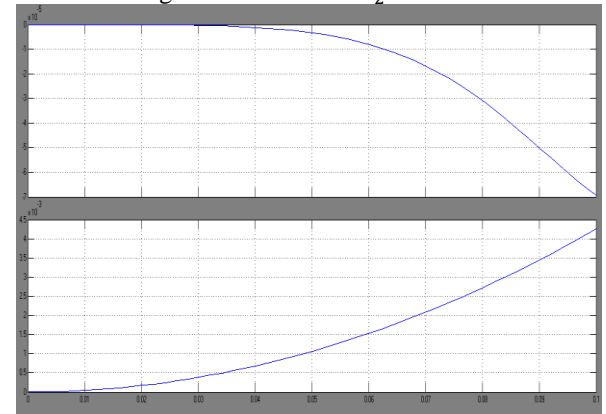


Fig.6: Plot of GEN3 δ_3 v/s time

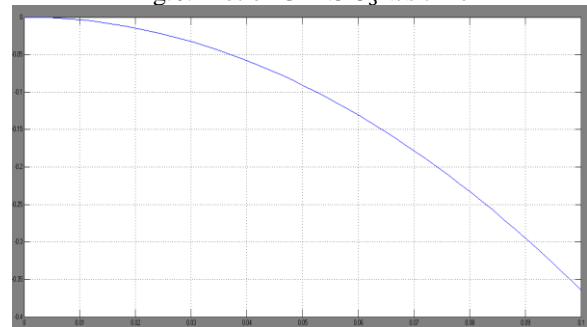


Fig.7: plot of δ_1 v/s δ_2

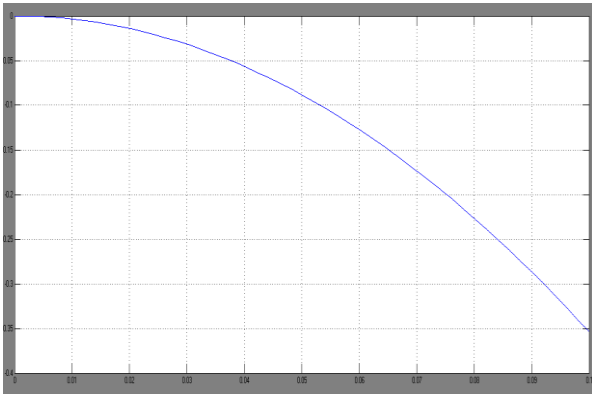


Fig.8: Plot of δ_2 v/s δ_3

This deviation of delta can be removed by decreasing critical clearing time and system is seemed to be stable as shown in graph.

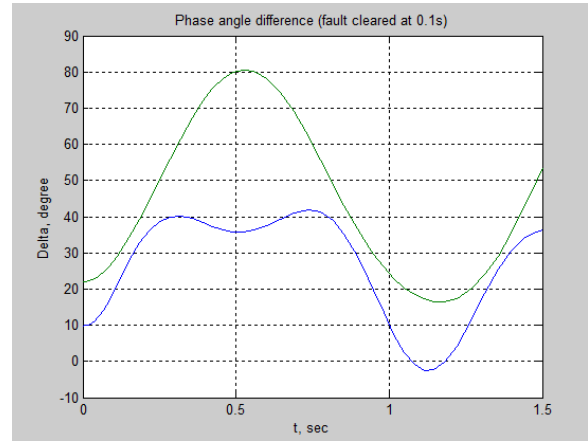


Fig.12:-Plot Delta v/s time for 0.1

III. CONCLUSION

A complete model for transient stability study of multi machine i.e. 3 machine 9 bus system has been developed using MATLAB/Simulink and it has been explained that electrical power and angle δ depends on bus matrix after fault Y_{af} . The system is made stable by removing the line and by decreasing the critical clearing time.

In actual power systems these can be implemented by using the circuit breakers of much smaller critical clearing time. The relevant protective schemes should also be revisited and modified appropriately.

APPENDIX

Table No. 3:-Line Data

Bus No.	Bus No.	R PU	X PU	$\frac{1}{2} B$
1	4	0	0.0576	0
2	7	0	0.0625	0
3	9	0	0.0586	0
4	5	0.010	0.085	0.088
5	7	0.032	0.161	0.153
4	6	0.017	0.092	0.079
6	9	0.039	0.170	0.179
7	8	0.0085	0.072	0.745
8	9	0.0119	0.1008	0.1045

Table No.4:-Load data

Bus No.	MW	MVAR
1	0	0
2	0	0
3	0	0
4	0	0
5	125	50
6	90	30
7	0	0
8	100	35
9	0	0

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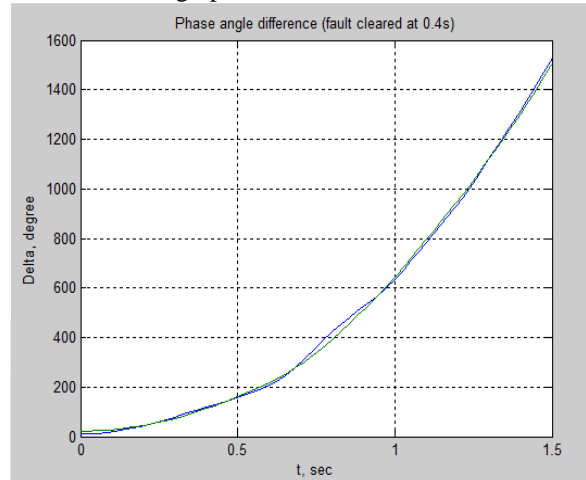


Fig.9: Plot Delta v/s time for 0.4 sec

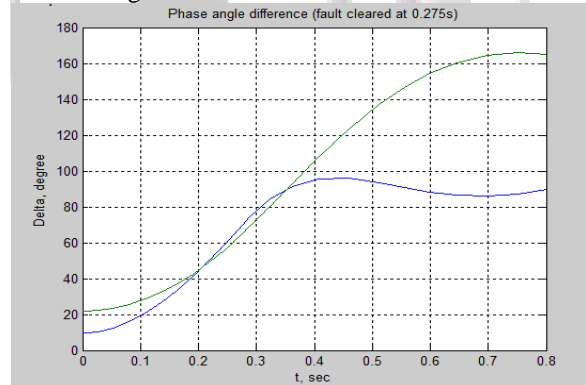


Fig.10: Plot Delta v/s time for 0.275

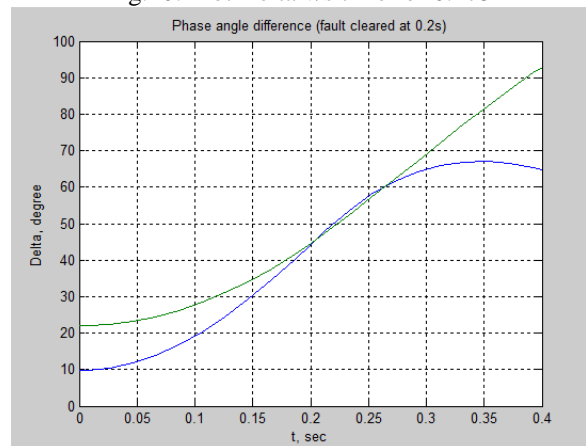


Fig.11: Plot Delta v/s time for 0.2 sec

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