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A NEW APPROACH FOR INVESTIGATION OF MULTI MACHINE STABILITY IN A POWER SYSTEM

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ABSTRACT

MATLAB software package has been developed by MathWorks Inc., which is a very compatible tool for power system stability analysis and scientific numerical computation. Power system stability studies are carried out from the view point of electrical machines, power transmission, protection, automation and voltage control. Here a self sufficient MATLAB/Simulink based multi-machine model has been studied to carry out transient stability analysis of power system.

KEYWORDS: MATLAB, Power System Stability, Transient Stability, Multi Machine Power System.

Modern electrical power systems are highly complex in nature, mainly due to increasing interconnections, extra high voltage tie lines etc. In such perspective, the stability of power system continues to be of major concern and deserves utmost importance in system operation. Moreover, ever expanding systems and installation of large generating units have caused power system engineers to dedicate more focus to increasing transient conditions. Transient stability refers to capacity of power system to keep synchronism when subjected to a severe transient disturbance, which may be in the form of fault on transmission facilities, sudden loss of generation, or may be loss of large loads. In this case, there are occurrences of large excursions of generator rotor angles and other system variables. It is major importance that while steady state stability is a related to operating conditions, transient stability is related to operating conditions and disturbances [Kundur, 1994]. Repeated analysis is required for different disturbances that that are to be considered. In transient stability, disturbances may be the short circuits. The three phase short circuit causes maximum acceleration of the connected machine [Nagrath and Kothari, 2010]. Transient phenomenon is an aperiodic function of time and is of very short duration. Yet they are of considerable importance because it can eventually cause blackout in a city, shutdown of a plant etc [Wadhwa, 2010]. The electrical transient stability analysis can be carried out by various analysis tools such as MATLAB, Electrical Transient Analysis Program (ETAP), by using Electromagnetic Transients program (EMTP) or the alternative transient program (ATP) etc [Patel et. al., 2002]. MATLAB/Simulink is an important software used for high performance data analysis and visualization, developed by MathWorks Inc. It provides the correct combination of features like analysis capabilities, flexibility and powerful graphics which makes it an optimum platform to carry out power system studies/stability analysis. In this paper, MATLAB/Simulink is used to carry out a simplified, yet effective approach to study the transient stability performance of a test system.

ILLUSTRATIVE SYSTEM EXAMPLE

System Details

We consider here a 50Hz, 220kV transmission line system with two generators and an infinite bus [Nagrath and Kothari, 2010] as shown in Fig. 1.A three phase fault occurs near bus 4 at end of line 4-5.The fault is cleared by opening line 4-5.

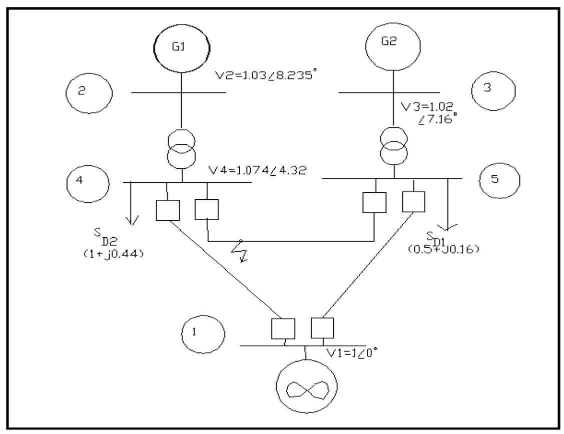

Figure 1: Multi-machine test system under consideration.

System Modeling

Load admittances, along with transient reactances are used with the line and transformer admittances to form the pre-fault augmented bus admittance matrix which contains the transient reactances of the machine. Since the fault is near bus 4, the Y_{bus} during fault conditions would be obtained by deleting 4[th] row and 4[th] column from the pre-fault Y_{bus} matrix. Reduced fault matrix is obtained by using the relationship as in equation 1:

$$Y_{kj(new)} = Y_{kj(old)} - Y_{kn(old)} Y_{nj(old)} / Y_{nn(old)} \quad (1)$$

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The loads at buses 4 and 5 are represented by the admittances calculated as Y_{L4} and Y_{L5} respectively. Once the fault is cleared by opening the circuit breakers at both ends of the line between buses 4 and 5, the pre-fault Y_{bus} has to be modified again by substituting $Y_{45} = Y_{54} = 0$.

MATHEMATICAL MODELING

During Pre-fault condition:-

$$Y_{24} = Y_{42} \quad (2)$$

$$Y_{24} = Y_{42,} Y_{35} = Y_{53} \quad (3)$$

$$Y_{44} = Y_{L4} + Y_{41} + Y_{45} + \frac{B_{41}}{2} + \frac{B_{45}}{2} + Y_{24} \quad (4)$$

$$Y_{55} = Y_{L5} + Y_{54} + Y_{51} + \frac{B_{54}}{2} + \frac{B_{51}}{2} + Y_{35} \quad (5)$$

During fault condition:-

$$P_{e2} = 0 \quad (6)$$

$$P_{e3} = \left|E_3^{'}\right|^2 G_{33} + \left|E_1^{'}\right|\left|E_3^{'}\right|\left|Y_{31}\right| \cos(\delta_{31} - \theta_{31}) \quad (7)$$

Post fault condition:-

$$P_{e2} = \left|E_2^{'}\right|^2 G_{22} + \left|E_1^{'}\right|\left|E_2^{'}\right|\left|Y_{21}\right| \cos(\delta_{21} - \theta_{21}) \quad (8)$$

$$P_{e3} = \left|E_3^{'}\right|^2 G_{33} + \left|E_1^{'}\right|\left|E_3^{'}\right|\left|Y_{31}\right| \cos(\delta_{31} - \theta_{31}) \quad (9)$$

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

$$P_{ei} = \left|E_i^{'}\right|^2 G_{33} + \sum_{j=1; j \neq i}^{N} \left|E_i^{'}\right|\left|E_j^{'}\right|\left|Y_{ij}\right| \cos(\delta_{ij} - \theta_{ij}) \quad (10)$$

The swing equation are then given as follows:

$$\frac{d^2 \delta_2}{dt^2} = \frac{180 f}{H_2}(P_{m2} - P_{e2}) \quad (11)$$

MATLAB/SIMULINK SOFTWARE

The complete system given in Figure (1) has been simulated as a single integral model in Simulink. The mathematical model given above gives the transfer function of different blocks. Figure (2) shows the complete block diagram of the system for transient stability study. The subsystems shown in Figure (3) are meant to calculate the value of electrical power outputs for different generators. The model also facilitates the choice of simulation parameters such as start and stop times etc. The model can be run either directly or from MATLAB command line or from an m-file program. In the present study, the fault clearing time, the initial values of parameters as well as the changes in network due to fault are controlled through m-file program in MATLAB.

The key features [Patel et. al., 2002] of MATLAB/Simulink based model are:

- Interactive simulations with live display;
- A comprehensive block library for creating linear/nonlinear, discrete, hybrid multi-input/output systems;
- Mask facility for creating custom blocks and block libraries.

The assumptions in Multi machine stability analysis made are:

1. The asynchronous power shall be neglected.
2. Each synchronous machine is represented by a constant voltage source.
3. Governor's action is neglected and the input powers are assumed to remain constant.
4. Using the pre-fault bus data, all loads are converted to equivalent admittances to ground and are assumed to remain constant.
5. The mechanical rotor angle of machine coincides with the angle of voltage behind the machine reactance.
6. Machine belonging to same station swing together which are said to be coherent. Group of coherent machines are considered as one equivalent machine.

SIMULATION RESULTS

Case Study And Results

The system responses can be shown from the above model.

Figure (4) show the response of both generators with fault clearing time of 0.275s.

Here machine 2 is unstable while machine 3 is stable, machine 1 is reference.

Figure (5) shows system response with fault clearing time of 0.08s. Here machine 2 has large angular swings.

Transient stability depends on both the initial operating state of the system and severity of disturbance.

Usually the disturbance alters the system such that post disturbance steady state operation will be different from that prior to disturbance.

Instability is in the form of a drift due to insufficient synchronizing torque and it is referred to as first swing stability.

In large power systems, transient instability may not always occur as first swing instability associated as a single mode; it could be as a result of increased peak deviation caused by superposition of several modes of oscillation causing large excursions of rotor angle beyond the first swing [Nallagalva et. al., 2012].

In this paper first stability of machine system is analyzed and then transient stability of multi machine system is done for various fault clearing time.

Before analyzing stability, various computations are done:

1. All system data are computed on common base-100 MVA.
2. All loads are converted as constant equivalent impedances.
3. Voltage behind the transient reactance is calculated.

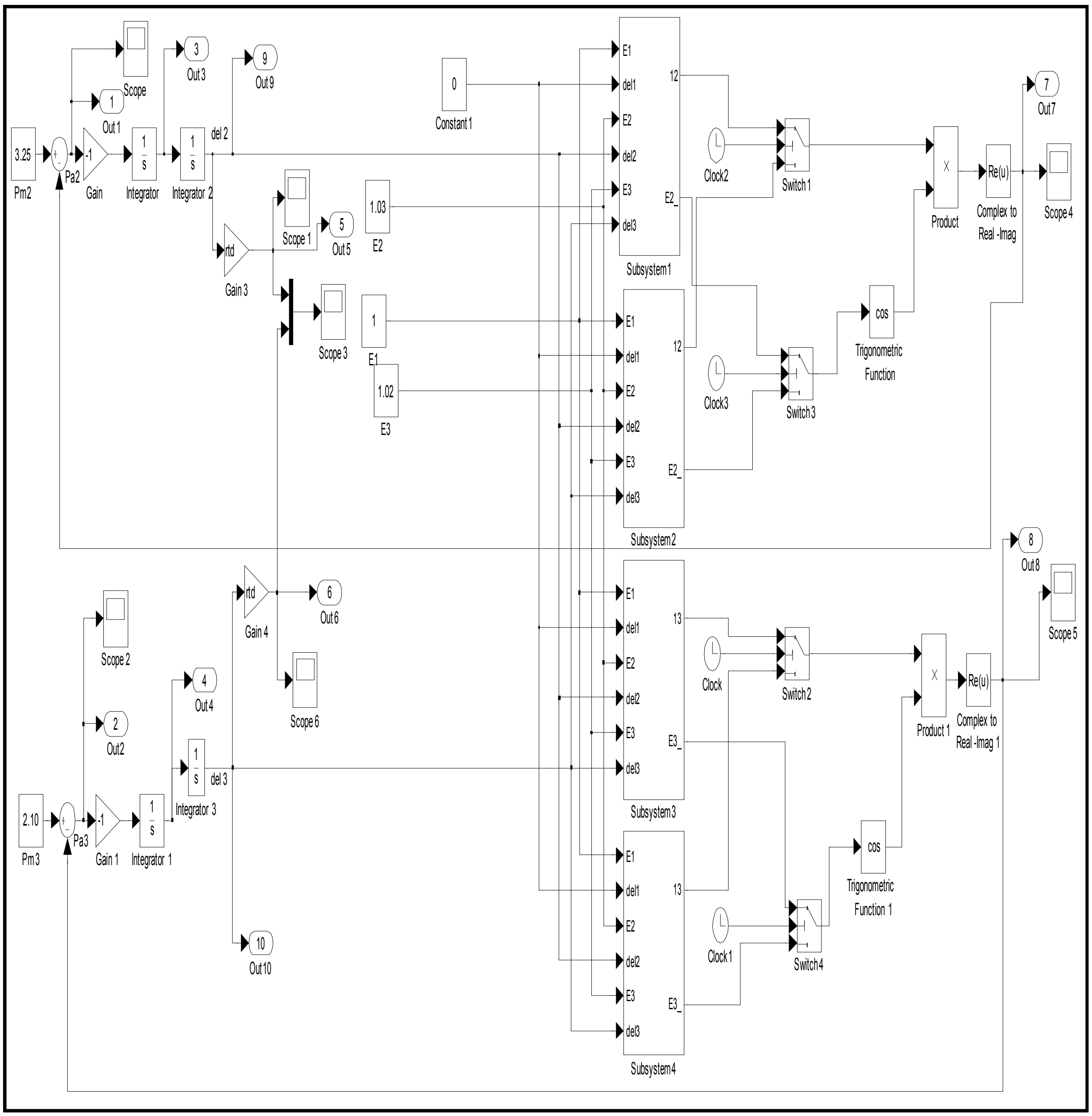

Figure 2: Complete block diagram of the system for transient stability study.

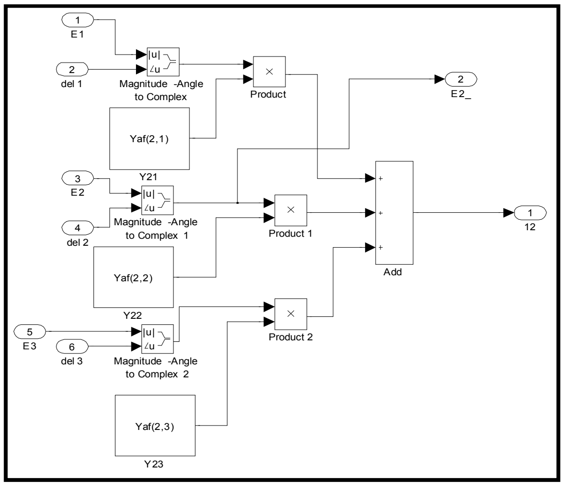

Figure 3: Subsystem 1.

System responses are shown in figure (4) and figure (5):-

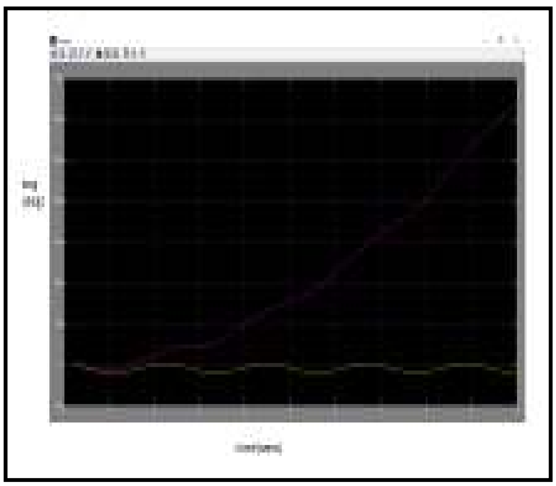

Figure 4: Swing curves for machines 2 and 3; machine 1 is reference (infinite bus).

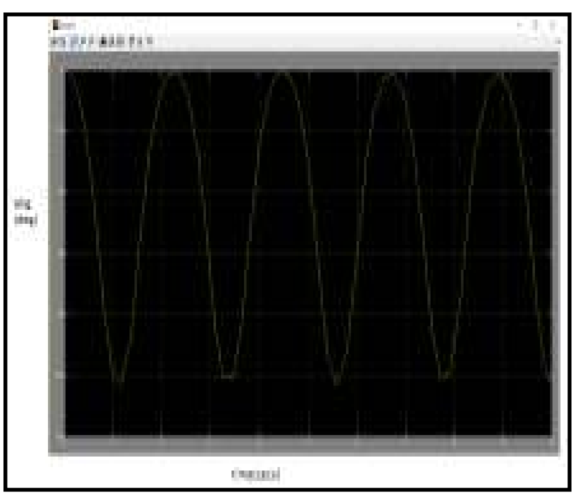

Figure 5: Swing curve for machine 2 for a fault clearing time of 0.08secs.

The line and transformer data is given in Table 1. Bus data of the system is provided in Table 2.

Table 1: Line and transformer data

Bus to bus	Resistance (p.u)	Reactance (p.u)	Susceptance (p.u)
Line 4-5	0.018	0.11	0.113
Line 5-1	0.004	0.0235	0.098
Line 4-1	0.007	0.04	0.041
Trans: 2-4	-	0.022	-
Trans:3-5	-	0.04	-

Table 2: Bus data

Bus no.	**Voltage**	**Bus type**	**Voltage**		**Generation**		**Load**	
			Real e	**Imag f**	**P_g**	**Q_g**	**P_l**	**Q_l**
1	$1\angle 0$	slack	1.00	0.0	-3.8	–0.2	0	0
2	$1.03\angle 8.35$	PV	1.019	0.14	3.25	0.7	0	0
3	$1.02\angle 7.16$	PV	1.012	0.12	2.10	0.3	0	0
4	$1.017\angle 4.32$	PQ	1.014	0.76	0	1.0	1.0	0.4
5	$1.0112\angle 2.69$	PQ	1.010	0.04	0	0	0.5	0.2

CONCLUSION

As we know, transient stability refers to the conditions of stability in response to sudden changes of large magnitude. Steady state stability limit is simple for analysis and can be calculated accurately, but transient stability limit is lesser than the former and is therefore the deciding factor for normal power transfer [Rao, 2010]. Here a complete model for transient stability study of a multi-machine power system was developed using MATLAB/Simulink which is not only best suited for analytical purpose but also possesses interactive capacity for a detailed transient stability study which facilitated fast and precise solution of non linear differential equation i.e. the swing equation. Due to these advantages, this study can be utilized for initiating rapid fault clearing and immediate restorative actions to maintain normal power flow.

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