ASSESSMENT OF TRANSIENT STABILITY OF MULTI MACHINE POWER SYSTEM USING SIMULINK MODELLING

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Abstract*:* The stability of a power system which is interconnected is defined as its capacity to come back to its normal or stable operation subsequent to having been exposed to some form of disturbance. Because of the escalating tension on power system networks, analysis of transient stability of power systems has become a considerable issue in the functioning of power systems. The paper depicts a summed up powerful model of multi machine power systems for transient stability analysis and its calculation utilizing MATLAB/SIMULINK. The created model is tried on 3-machine 8-bus power system.

Key Words**: Transient Stability, Multi Machine, Simulink, MATLAB, Power System Modelling**

1. Introduction

The stability of power system is a principle characteristic for uninterrupted power supply. The ability of a power system to remain in a state of operating equilibrium or synchronism under usual operating conditions and to return to an allowable state of equilibrium if subjected to a disturbance is called as the stability of a power system. The word "transient stability," signifies the capacity of synchronous machines to be in synchronism for the little period of time after being subjected to a large disturbance [1] such as isolating large generators, switching large loads, three phase faults etc. The main problem of power systems relying on synchronous machines is the maintenance of synchronous operation. The disturbances which are large may prompt structural changes because of the detachment of faulted portions. To design a power system which is stable for every disturbance is not possible and is not realistic. The design possibilities are chosen on the premise that they have a sensibly high likelihood of occurrence. The reaction of the system to such disturbances include generator rotor angles, large excursions power flows, bus voltages and other system variables.

The paper talks about the utilization of SIMULINK software of MATLAB in the dynamic demonstration of multi-machine power systems for transient stability simulation. SIMULINK is a product bundle created by MathWorks Inc., and is one of the most extensively utilized programming in the scholarly world and industry for demonstration, investigation and simulation of dynamical systems. It tends to be utilized for modeling direct and nonlinear systems, either in nonstop time period or sampled time span. It gives a simple drag-drop type graphical UI to fabricate the models in block diagram form [2]. Many components that are already present in the library can be used to build complex systems in the event that these built-in models are insufficient, SIMULINK permits you to have user defined blocks also. When MATLAB/SIMULINK is used for the improvement of elements of power system, it enables the users to take total advantage of dealing with control blocks and power system components, conforming new elements by comparison of the simulation results for various occasions and comprehension of the fundamental ideas of power system modeling and simulation [3-5]. All component sub models are straightforward and can easily be changed. Accentuation has been given to keeping the segment sub-models transparent and basic.

2. Analysis of Transient Stability of MultiMachine

2.1. Assumptions:

1. Every synchronous machine is represented by a voltage source which is constant and behind the transient reactance.
1. The mechanical rotor angle of every machine concurs with the voltage angle behind the machine reactance
2. Asynchronous power is not considered.
3. The incoming powers are not to vary and governors action is not considered.
4. Machines of same station swing simultaneously and are coherent.
5. Using the pre-fault bus data, all loads are converted to equivalent admittances to ground and are assumed to remain constant.
6. The mechanical rotor angle of each machine concurs with the voltage angle behind the machine reactance.

3. Simulated system: 3-machine 8-bus system

The 3-machine 8-bus system [6] is considered and is shown in Figure 1. The base MVA is 100, frequency of the system is 60Hz.

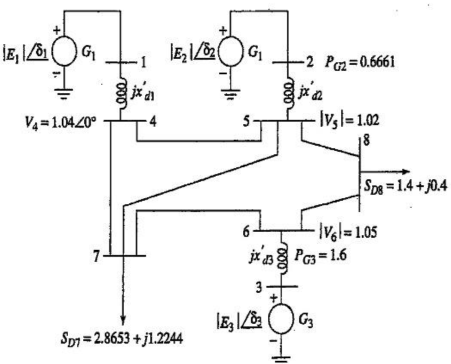

Figure 1. 3-machine 8-bus system

The system has been mimicked with a traditional model for the generators. The transient started by the disturbance is a three phase fault originating near bus 7 with line 7-6 detached in 0.10 sec.

4. Model of the system:

With the use of Simulink blocks in a single integral model, the overall system is elaborated. The signal at any point is exhibited readily just by adding a scope block or an output port. An m-file program can control any parameter within any of the block. It is particularly useful for the study of transient stability as the power system configurations differ before, during and after fault. The conditions for loading and various control measures are also taken accordingly.

4.1. Mathematical Modelling:

All nodes are removed apart from the internal generator nodes after the calculation of Y_{bus} matrix for each network state (pre-fault, during and post fault) and the Y_{bus} matrix for the reduced network is attained. For reduction, matrix operation is used keeping in mind that there are zero injection currents at nodes except for the internal generator nodes. The nodal equation for a power system containing n generators can be written as:

$$\begin{bmatrix} Y_n \\ 0 \end{bmatrix} = \begin{bmatrix} Y_{nn} & Y_{nr} \\ Y_{rn} & Y_{rr} \end{bmatrix} \begin{bmatrix} V_n \\ V_r \end{bmatrix}$$

The *n* is used to depict generator nodes and the *r* is used for the remaining nodes. The electrical power output of machine *i* i.e the power to node *i* is given as [7]

$$P_{ei} = E_i^2 G_{ii} + \sum_{\substack{j=1 \\ j\neq 1}}^{n} E_i\, E_j Y_{ij} \cos(\theta_{ij} - \delta_i + \delta_j)$$
$$i = 1,2,3, \ldots \ldots n$$

Where $Y_{ij} = Y_{ij}\angle\theta_{ij} = G_{ij} + iB_{ij}$
= negative of the transfer admittance between nodes *i* and *j*.

and $Y_{ii} = Y_{ii}\angle\theta_i = G_{ii} + iB_{ii}$
= driving point admittance of the node *i*.

At t = 0; $P_{mi0} = P_{ei0}$;

$$P_{mi0} = E_i^2 G_{ii0} + \sum_{\substack{j=1 \\ j\neq 1}}^{n} E_i\, E_j Y_{ij0} \cos(\theta_{ij0} - \delta_{i0} + \delta_{j0})$$

Here the subscript 0 depicts conditions before transient. The corresponding values in above equations are used as due to switching during fault, network changes.

Swing equation governs the dynamics of rotor and gives its angular position. It relates accelerating power with angular acceleration and is given by [8]

$$\frac{2H}{\omega_R}\frac{d\omega_i}{dt} = P_m - P_e = P_a$$

4.2. Simulation of the model in SIMULINK:

The model of swing equation of the generators in this system is shown in Figure 2. The system in Figure 3 are for the

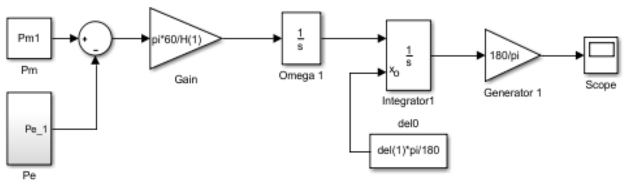

Figure 2. Swing equation model of generators

calculation of prefault and postfault electrical power outputs for generators. Fig. 4 depicts the generator power output computation. The model additionally encourages the decision of reenactment parameters, for example, start and stop times, sort of solver, step sizes, resilience and yield alternatives and so on. In the current study, an m-file program in MATLAB is used to control the fault clearing time, parameters initial value and also transition in network because of fault. When initial conditions are given, it is always better to represent the transfer functions in form of an integrator and gain with unity feedback is more convenient.

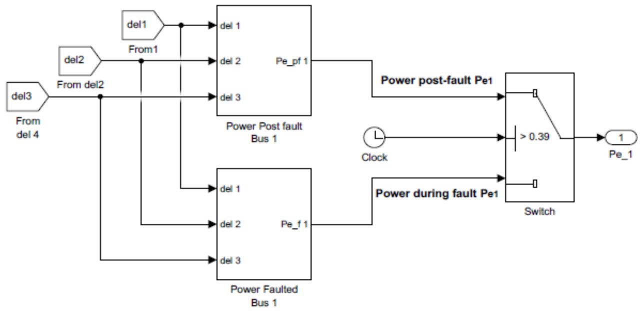

Figure 3. Prefault and postfault electrical powers P_e

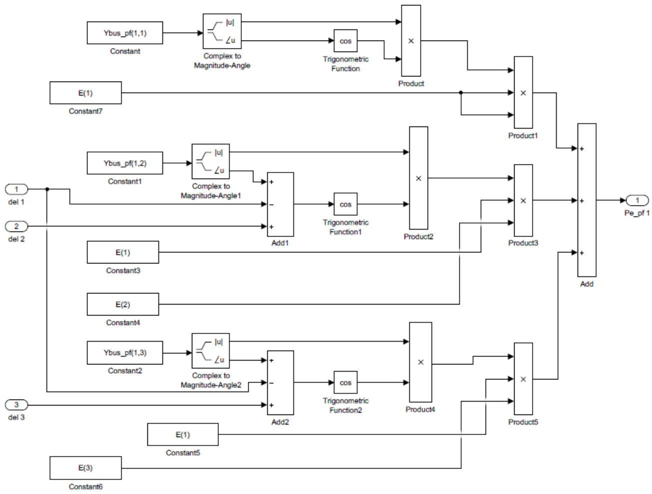

Figure 4. Electrical power output P_e computation

4. Simulation Results:

The system reaction for different estimations of fault clearing time (FCT) are shown. The fault is started close to line 7 somewhere between 6 and 7 and by detaching the line fault is cleared at various clearing times. The individual generator rotor angles and the relative angular positions are shown in Figure 5(a) and Figure 5(b) respectively.

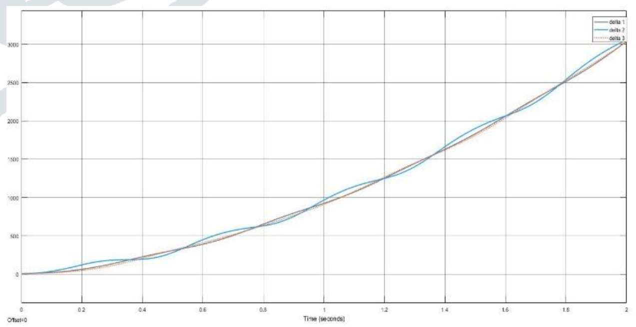

Figure 5(a). Absolute rotor angles of generators at FCT=0.2s

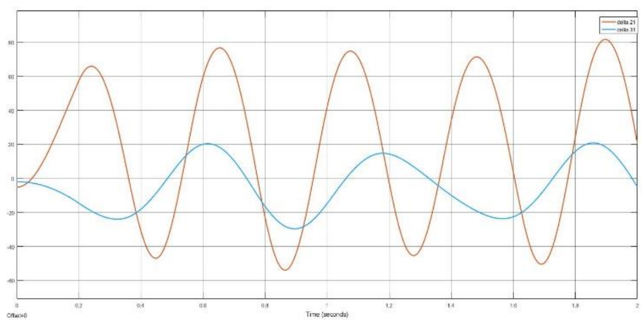

Figure 5(b). Relative rotor positions at FCT=0.2s

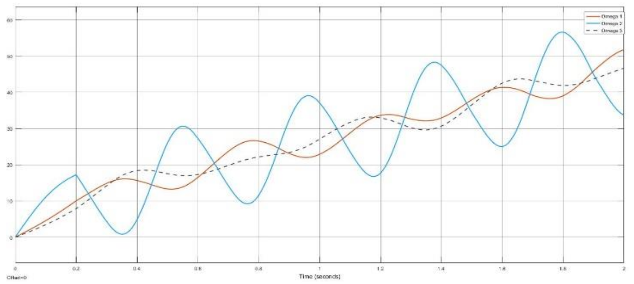

Figure 5(c). Rotor speeds at FCT=0.2s

Similarly Figure 5(c) depicts the generators angular velocities at FCT being 0.20 seconds. The outcomes show that the system is stable for this situation as system has gained synchronism after fault is cleared. Figure 6(a) and Figure 6(b) depict the system responses for fault clearing time being 0.38 seconds and is regarded as critical clearing time(CCT). From these figures it can be said the system is critically stable.

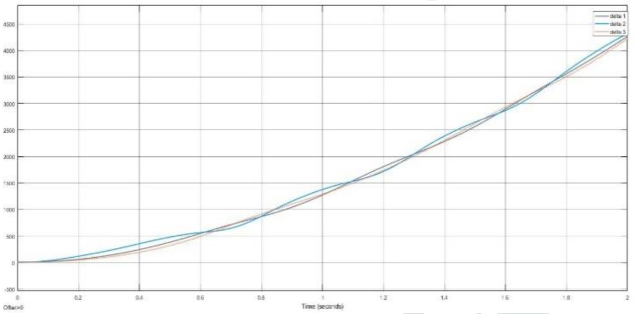

Figure 6(a). Absolute rotor angles of generators at FCT=0.38s

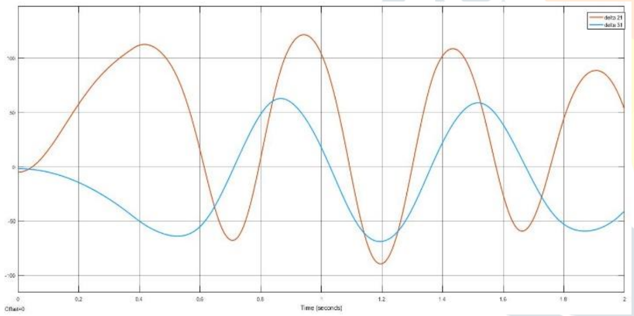

Figure 6(b). Relative rotor positions at FCT=0.38s

As we move forward to fault clearing time being 0.39 seconds it is seen that the generators fall out of synchronism. The condition is seen in Figure 7(a), (b) and (c).

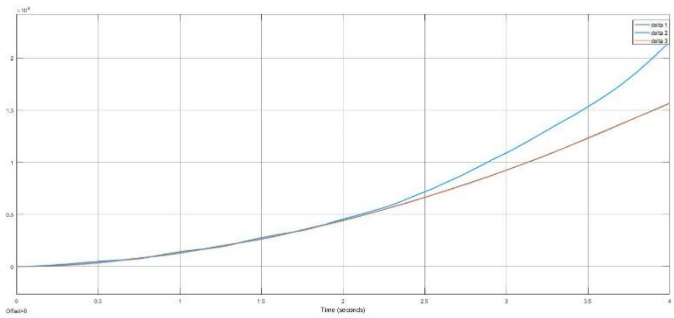

Figure 7(a).Angular positions of generators at FCT=0.39s (out of synchronism)

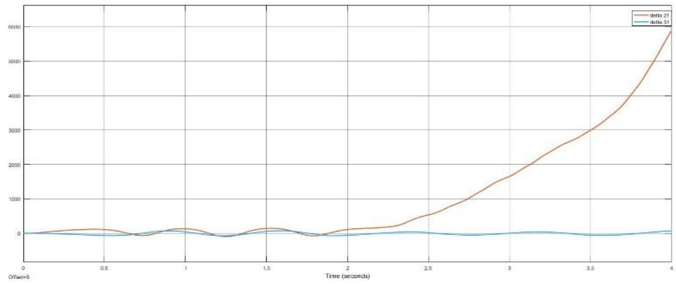

Figure 7(b). Relative angular positions at FCT=0.39s

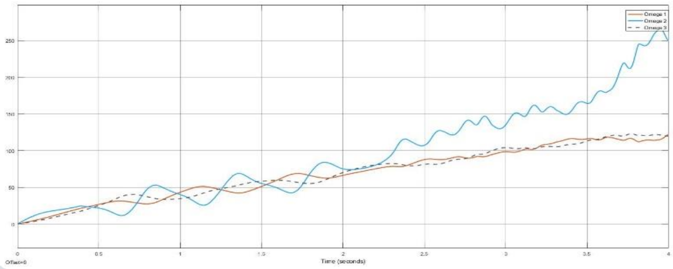

Figure 7(c). Rotor speeds at FCT=0.39s

5. Conclusion:

The paper deals with an absolute model for study of transient stability of a multi-machine power system was created utilizing Simulink. System equations are represented with the help of transfer functions and block diagrams. A variety of block components are promptly accessible in different Simulink libraries and furthermore in other perfect tool stash, for example, Power System block set, Controls Toolbox, Neural Networks block set and so on. A Simulink model is very easy to use, with colossal intuitive limit and boundless various leveled model structure.

Also in this paper the stability analysis of 3-machine 8-bus systems has been contemplated. When undergoing a three phase fault it can be determined through analysis whether the system is stable or unstable for a specific fault clearing time. When fault clearing time is less the relative swing between the generator phase angles is also less as seen from the phase angle characteristic. As the fault clearing time is increases to 0.39 seconds the system becomes unstable because the generator 2 phase angle continues increasing without limit. Thus the fault should be cleared with a given time in order to maintain synchronism of the machines otherwise the multi machine system will fall out of order thereby leading to interrupted power supply.

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