Transient Stability of a Multi Machine Power System

Devender Kumar, Balwinder Singh Surjan

Abstract -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, specially for a multimachine system. These methods include the time domain solutions, the extended equal area criteria, and the direct stability methods such as the transient energy function. However, the most methods must transform from a multi-machine system to an equivalent machine and infinite bus system [1][3].This paper introduces a method as an accurate algorithm to analyse transient stability for power system with an individual machine. It is as a tool to identify stable and unstable conditions of a power system after fault clearing with solving differential equations. [5][6].

Key words- multimachine power system, matlab Simulink, transient stability, damping

I. INTRODUCTION

Multimachine equations can be written Similar to the one-machine system connected to the infinite bus. In order to reduce the complexity of the transient stability analysis, similar simplifying assumptions are made as follows. -Each synchronous machine is represented by a constant voltage source behind the direct axis transient reactance. This representation Neglects the effect of saliency and assumes Constant flux linkages. The governor's action are neglected and the input powers are assumed to remain constant during the entire period of simulation [4].

-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.

-Machines belonging to the same station swing together and are said to be coherent. A group of coherent machines is represented by one equivalent machine

II. MATHEMATICAL MODEL OF MULTIMACHINE TRANSIENT STABILITY ANALYSIS

The first step in the transient stability analysis is to solve the initial load flow and to determine the initial bus voltage magnitudes and phase angles. The machine currents prior to disturbance are calculated from[5].

$$I_i = S_i/V_i^* = (P_i - jQ_i)/V_i^*,\ i = 1,2,3\ldots m \qquad (1)$$

Where
m is the number of generators
V_i is the terminal voltage of the ith generator
P_i and Qi are the generator real and reactive powers.

All unknow 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[6]

$$E_i = V_i + jX_d I_i \qquad (2)$$

Next, all load are converted to equivalent admittances by using the relation

$$Y_{io} = S_i^*/V_i^2 = (P_i - jQ_i)/V_i^2 \qquad (3)$$

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

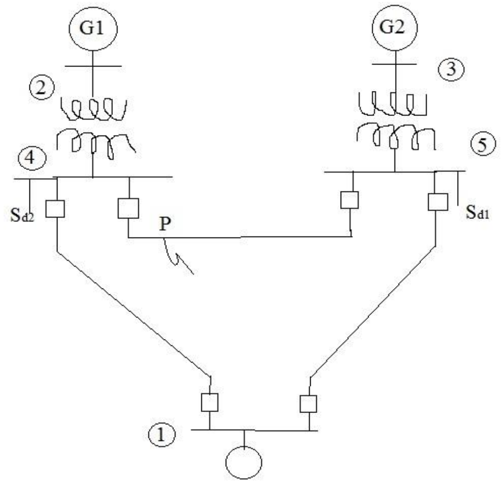

Fig 1 Power system representation for multi machine stability studies

In this system one generator is taken as reference generator and other two are studied for stability purposes. Fault occur at point p in the system, and two loads are connected to the system at S_{d1} and S_{d2}

$$I_{bus} = Y_{bus} V_{bus} \qquad (4)$$

Where
Ibus is the vector of the injected bus currents
Vbus is the vector of bus voltages measured from the reference node

Prefault bus matrix

$$Y_{prefault} = Y_{14} + Y_{41} + Y_{45}\ \ Y_{24} + B_{41}/2 + B_{45}/2 \qquad (5)$$

Manuscript received on April, 2013.
Devender kumar, Post graduate student at PEC University of technology, Chandigarh, India.
Dr. Balwinder singh surjan, Associate Proffesor and Head of the department of PEC University of technology, Chandigarh, India.

$Y_{prefault} = Y_{l5} + Y_{54} + Y_{51} + Y_{35} + B_{54}/2 + B_{51}/2$ (6)

B--- charging reactance of the system

During fault bus matrix

Since the fault is near the bus, so it is short circuited to ground.

$Y_{bus} = Y_{jold} – Y_{nold}\, Y_{njold}/\, Y_{nnold}$ (7)

Post fault bus matrix

Once the fault is cleared by removing the line, simultaneously opening the circuit breaker at the either ends of the line between buses, prefault Y_{bus} has to be modified again.

$Y_{postfault} = Y_{jjold} – Y_{ji} - B_{ij}/2$ (8)

The diagonal elements of the bus admittance matrix are the sum of admittances connected to it, and the off-diagonal elements are equal to the negative of the admittance between the nodes. The reference is that additional nodes are added to include the machine voltages behind transient reactances. Also, diagonal elements are modified to include the load admittances. To simplify the analysis, all nodes other than the generator internal nodes are eliminated using Kron reduction formula [5]. To eliminate the load buses, the bus admittance matrix in (4) is partitioned such that the n buses to be removed are represented in the upper n rows. Since no current enters or leaves the load buses, currents in the n rows are zero. The generator currents are denoted by the vector Im and the generator and load voltages are represented by the vector E' m and Vn, respectively..

During fault power angle equation

$P_{e2} = 0$ (9)

$P_{e3} = R_e [\, Y_{33} E_3' E^* + E_3' * Y_{31} E_1'],$
since $Y_{32} = 0$
$= (E_3')^2 G_{33} + E_1' E_3' Y_{31} \cos(\delta_{31} – \theta_{31})$ (10)

Post fault power angle equations

$P_{e2} = E_2^2 G_{22} + E_1 E_2 Y_{21} \cos(\delta_{21} – \theta_{21})$ (11)

$P_{e3} = E_3^2 G_{33} + E_1 E_3 Y_{31} \cos(\delta_{31} – \theta_{31})$ (12)

Swing equations during fault

$D^2\delta_2/dt^2 = 180f/H_2 (P_{m2} – P_{e2}) = 180f/H_2 P_{a2}$ (13)

$D^2\delta_3/dt^2 = 180f/H_3 (P_{m3} – P_{e3})$ (14)

Swing equation post fault

$D^2\delta_2/dt^2 = 180f/11[3.25- \{0.6012 + 8.365 \sin(\delta_2 – 1.662^o)\}]$ (15)

$D^2\delta_3/dt^2 = 180f/9\, [2.10-\{0.1823+6.5282 \sin(\delta_3 – 0.8466^o)\}]$ (16)

$P_a = P_m - P_c – P_{max} \sin(\delta – \gamma)$ (17)

The above swing equations can be solved by point to point method

The classical transient stability study is based on the application of a three-phase fault. A solid three-phase fault at bus k in the network results in $V_k = 0$. This is simulated by removing the kth row and column from the prefault bus admittance matrix. The new bus admittance matrix is reduced by eliminating all nodes except the internal generator nodes. The generator excitation voltages during the fault and postfault modes are assumed to remain constant.

In transient stability analysis problem, we have two state equations for each generator. When the fault is cleared, which may involve the removal of the faulty line, the bus admittance matrix is recomputed to reflect the change in the networks. Next the postfault reduced bus admittance matrix is evaluated and the postfault electrical power of the ith generator.

III. SIMULATION

By using all the mathematical equations, the Simulink diagram for multimachine stability is generated. The Simulink diagram is highly complicated so it is divided into subsystem 1 and subsystem 2.

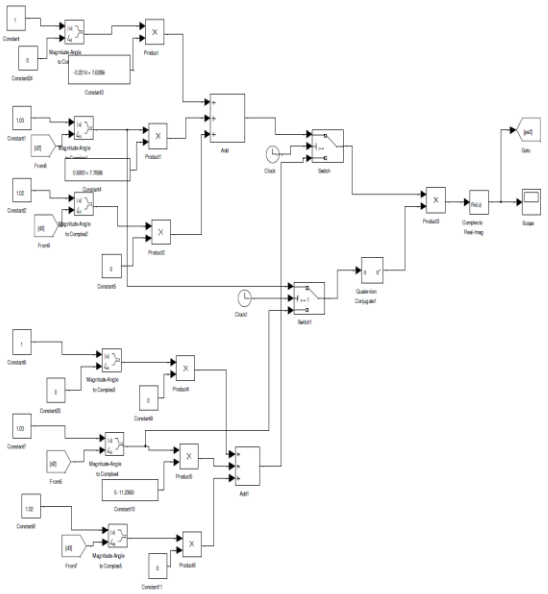

Fig 2 subsystem 1 of multimachine power system

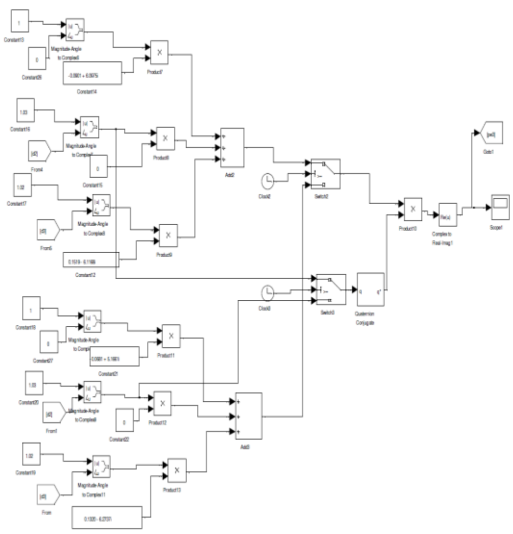

Fig 3 Subsystem 2 generated for multimachine power system

From fig 2, P_{e2} is generated and P_{e3} is generated from fig 3, P_{e2} is the electromechanical power for machine 2, and P_{e3} is the electromechanical power for machine 3. Electromechanical power is generated by using voltage and current of the machine and reactance's of pre fault and post fault condition. A switch is used for switching between pre fault and post condition of the system. By using the outputs of fig 2 and fig 3 multimachine system is generated. From the prefault load flow data determine E voltage behind transient reactance for all generators. This establishes generator emf magnitudes which remain constant during the study and initial rotor angle δ. Also record prime mover inputs to generators, P_{mk} = $P_{gk..}$ Augment the load flow network by the generator transient reactances. Shift network buses behind transient reactances.

For faulted mode, find generator outputs from power angle equations and solve swing equations step by step. Keep repeating the the above step for post fault mode and after line reclosure mode. Examine δ plots of all generator and establish the answer to the stability question.

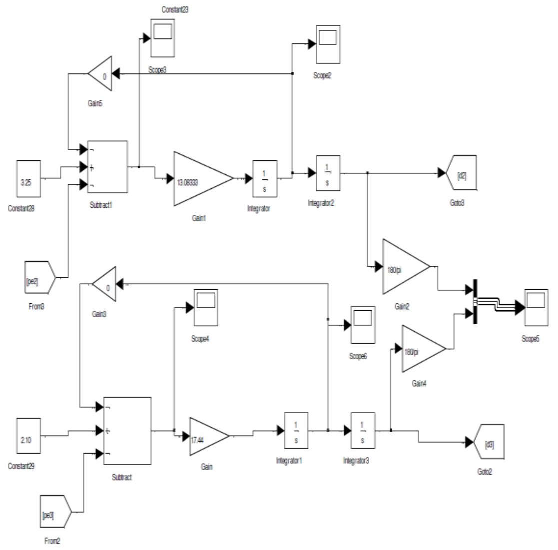

Fig 4 multimachine power system

The output of the multimachine power system is obtained between torque angle v/s time. This is also known as swing curve of the system. The output curves can be varied by changing the critical clearing time if the system. When critical clearing time of the system is low then both machine would operate in stable operation, as the critical clearing time of the system is increased then our system would move towards instability. The machine which have more oscillation would be more unstable as compared to the machine which have less oscillation. The outputs are taken at critical clearing time of 0.275 sec and 0.08 sec[7].

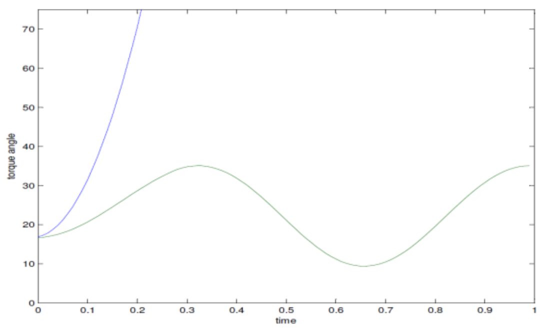

Fig 5 output response with critical clearing time 0.275 sec

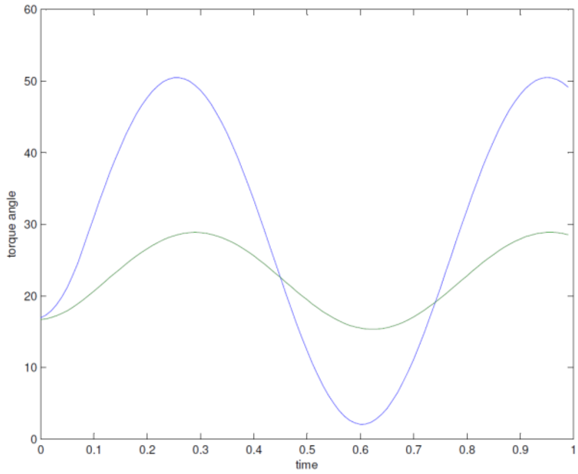

Fig 6 output response with critical clearing time 0.08 sec

From the result it is seen that machine 1 is having less oscillation than machine 2 at critical clearing time 0.08sec, but both machine are stable and when critical clearing time is increased to 0.275sec then machine 1 is still in stable condition and machine 2 is in unstable condition.

IV. INTRODUCING DAMPING INTO THE SYSTEM

Damping of the system is done to reduce the oscillation present in the system. It is done by connecting a negative gain of very low magnitude between speed and inertia gain of the system. The gain which is used to damp out the oscillation is known as the damping gain[8]. In this multi machine system our two machine are present so we have to produce damping in both these machine. Now we take three cases of damping in multimachine system, these are as follows.

Case 1 when damping is done only in machine 1

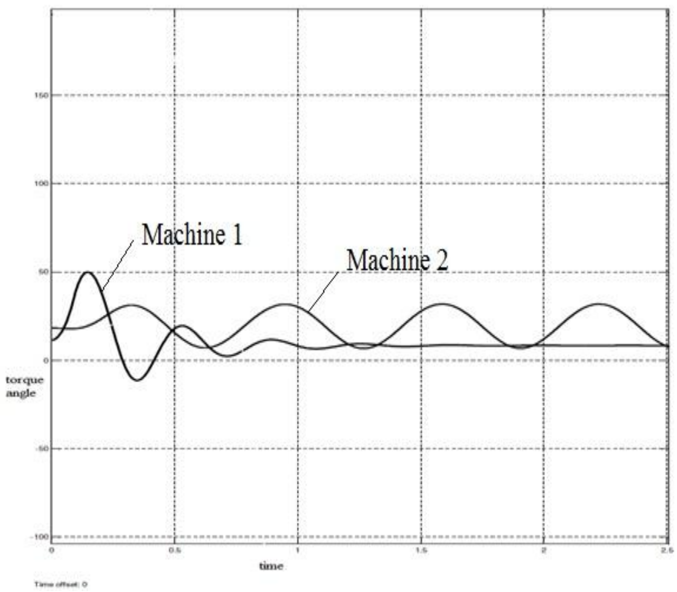

Fig 7 output response when damping is introduced in machine 1 only

By the above result we can see that our machine 1 output become stable as it reaches a sable point and all the oscillation are damp out and even the oscillation of machine 2 are decreased.

Case 2 When damping is done only in machine 2

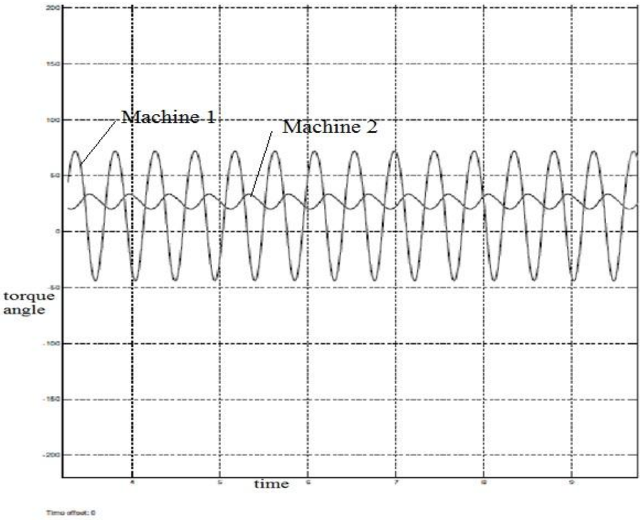

Fig 8 output response when damping is done only in machine 2

By this response we can see that machine 2 is in stable condition and machine 1 oscillation are increased

Case 3 when damping is done in both machine 1 and machine 2

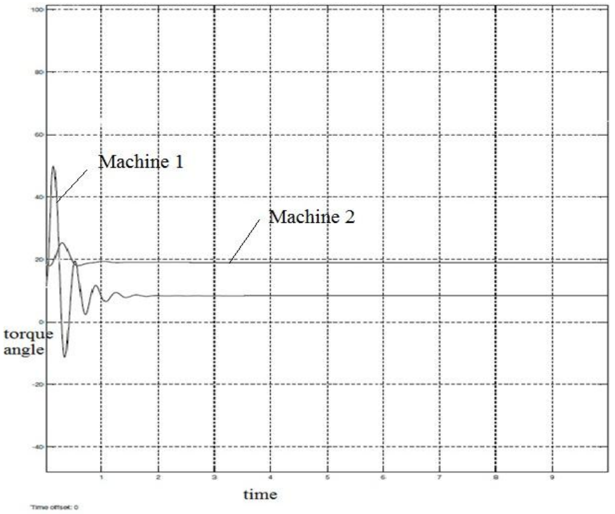

Fig 9 output response when damping is done in bath machine 1 and machine 2

Now we can conclude that both machine 1 and machine 2 are in stable mode as both saturate at a point and oscillations are removed from the system, so by introducing damping into the system our system can be made stable from unstable condition.

V. CONCLUSION

This analysis allows to assess that the system is stable, unstable and also allows to determine the critical clearing time of power system with three-phase faults. These results can be used effectively in planning or operation of power systems.

REFERENCES

[1]. La Van Ut: Analysis and Control Stability for Power System, Science and Technology Press, 2000.

[2]. Ho Van Hien: Transmission and Distribution of Power System, National University of HoChiMinh City Press, 2003.

[3]. Prabha Kundur: Power System Stability and Control, McGraw-Hill International Editions, 1994.

[4]. Hadi Saadat: Power System Analysis, McGraw-Hill International Editions, 1999.

[5]. John J. Grainer, Willam D. Stevenson JR: Power System Analysis, McGraw-Hill International Editions, 1999.

[6]. Carson W. Taylor: Power System Voltage Stability, McGraw-Hill International Editions,1994.

[7]. I. J. Nagrath and D. P. Kothari “Modern Power System Analysis” Tata McGraw-Hill, 2003

[8] Power system stability by Mrinal K Pal