Stabilization Of Multi Machine System Connected To Infinite Bus

Kanika Gupta, Ankit Pandey

Abstract: Transient stability analysis is today's one of the major issues for proper operation of the power systems as the stress on power systems is increasing day by day. In order to improve the power system, it requires an evaluation of system's ability to withstand the disturbances simultaneously maintaining the service quality. For transient stability analysis of power system, various techniques have already been proposed such as extended equal area criteria, the time domain solution and a few direct stability methods such as transient energy function. In most of these methods, a transformation is done from multi-machine system to an equivalent machine as well as an infinite bus system. An analysis of transient stability for the power system using an individual machine is done with the help of an accurate algorithm is done in this paper. This paper describes the fault conditions in the infinite bus bar with the multi-machine system.

Keywords: Power system stability, Stabilization of Machine, transient stability analysis, Multi Machine, Infinite Bus bar

[1]. Introduction

The importance of power system stability in the electric power system has become the major issue. We see that there are thousands of interconnected power systems of generators operating in synchronism at all times and if there is a major fault then there will be one or two generators that will go out of synchronism and they will have to be taken out of the grid There are two forms of instability in power system; the stalling of asynchronous loads i.e. voltage or load stability and the loss of synchronism between synchronous machines. The stability of the power system refers to the Continuance of intact operation following a disturbance. It depends on the operating conditions and the nature of the physical disturbance."*Power system stability enables the system to remain in a state of operating equilibrium under normal conditions and to regain an acceptable state of equilibrium after being subjected to the disturbance*."[1] If you casually look into this definition you will find that one is to emphasize on ability to remain in equal equilibrium and second point to emphasize is equilibrium between opposing forces. A power system is subjected to a variety of disturbances; it is never in steady state condition. There is a continuous fluctuation in power system, however to assess the stability in case of any disturbance, it must be taken into consideration that initially the system is in steady-state operating condition. Small disturbances in the form of load changes continuously occur. While large perturbations in the form of faults, clipping of lines, change in large load and dropping of generators comes.

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Transient stability analysis is very complex, therefore to reduce its complexity, certain assumptions are made:

- The power given as input is assumed to be constant for the entire simulation period.
- The action of the governor is neglected.
- In order to neglect the effect of saliency and assume constant flux linkage, synchronous machine is represented as a constant voltage source.
- All loads should be converted to an equivalent admittance to ground which is assumed constant, using the bus voltages before fault.
- Mechanical rotor angle of all machines coincides with voltage angle behind machine reactance.
- Asynchronous powers are neglected.
- Machines which belong to same station are coherent and a group of such coherent machines is showing a single equivalent machine[2].

[2]. Mathematical Analysis Of Multimachine Transient Stability.

First we have to calculate the initial load flow and initial bus voltage magnitude as well as phase angles[1]. Before any disturbance, the machine current is:

$$I_i = \frac{S_i^*}{V_i^*} = \frac{P_i - jQ_i}{V_i^*} \quad i = 1,2,3,\ldots.n \qquad (1)$$

where,

V_i is terminal voltage of ith generator.

P_i is real power

Q_i is reactive power

n is the total number of generators.

The armature resistance of generator is neglected and the voltage behind transient reactance is calculated.

$$E_i^{'} = V_i + jX^{'}dI_i \qquad (2)$$

All the loads are converted to an equivalent admittance by using the following relation:

$$Y_{i0} = \frac{S_i^*}{[V_i]^2} = \frac{P_i - jQ_i}{[V_i]^2} \qquad (3)$$

for the overall voltage behind transient reactance, the n bus system is added with m more buses.

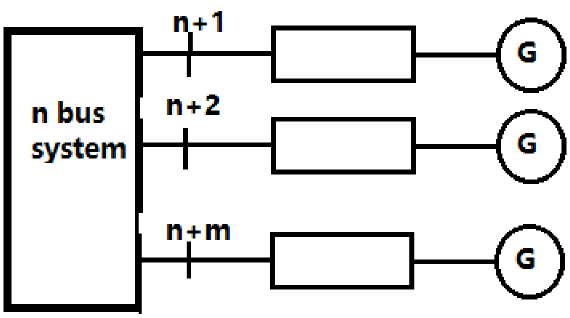

Fig.1 Power system for Transient system analysis

n+1, n+2 are buses behind transient reactances. Assuming node 0 as reference, the node voltage equation is:

$$\begin{bmatrix} I_1 \\ I_2 \\ I_3 \\ \cdot \\ \cdot \\ \frac{I_n}{I_{n+1}} \\ \cdot \\ \cdot \\ \cdot \\ I_{n+m} \end{bmatrix} = \begin{bmatrix} Y_{11} & \cdot\cdot & Y_{1n} & Y_{1(n+1)} & \cdots & Y_{1(n+m)} \\ Y_{21} & \cdot\cdot & Y_{2n} & Y_{2(n+1)} & \cdots & Y_{2(n+m)} \\ Y_{31} & \cdot\cdot & Y_{3n} & Y_{3(n+1)} & \cdots & Y_{3(n+m)} \\ \cdot & \cdot\cdot & \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot\cdot & \cdot & \cdot & \cdots & \cdot \\ Y_{n1} & \cdot\cdot & Y_{nn} & Y_{n(n+1)} & \cdots & Y_{n(n+m)} \\ Y_{(n+1)1} & \cdot\cdot & Y_{(n+1)n} & Y_{(n+1)(n+1)} & \cdots & Y_{(n+1)(n+m)} \\ \cdot & \cdot\cdot & \cdot & \cdot & \cdots & \cdot \\ \cdot & \cdot\cdot & \cdot & \cdot & \cdots & \cdot \\ Y_{(n+m)1} & \cdot\cdot & Y_{(n+m)n} & Y_{(n+m)(n+1)} & \cdots & Y_{(n+m)(n+m)} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ \cdot \\ \cdot \\ \frac{V_n}{E_{n+1}} \\ \cdot \\ \cdot \\ \cdot \\ E_{n+1} \end{bmatrix} \qquad (4)$$

OR

$$I_{bus} = Y_{bus}V_{bus} \qquad (5)$$

The elements at the diagonal of the bus admittance matrix denotes the sum of the admittances which are connected to it and the elements at the off-diagonal are denotes the negative of the admittance between nodes. Let I_m denotes the generator current, E_m denotes the generator voltage and V_n denotes the load voltage. Equation (4) can be rewritten as:

$$\begin{bmatrix} 0 \\ I_m \end{bmatrix} = \begin{bmatrix} Y_{nn} & Y_{nm} \\ Y_{nm}^t & Y_{mm} \end{bmatrix} \begin{bmatrix} V_n \\ E_m^{'} \end{bmatrix} \qquad (6)$$

$$0 = Y_{nn} V_n + Y_{nm} E_m^{'} . \qquad (7)$$

$$I = Y^t_{nm} V_n + Y_{mm} E_m^{'} \qquad (8)$$

$$V_n = -Y_{nn}^{-1} Y_{nm} E_m^{'} \qquad (9)$$

putting this value in eq(8);

$$I_m = [\, Y_{mm} - Y^t_{nm} Y_{nn}^{-1} Y^{nm} \,] E_m^{'} = Y^{red}_{bus} E_m^{'} \qquad (10)$$

thus the admittance matrix is reduced to:

$$Y^{red}_{bus} = Y_{mm} \; Y^t_{nm} \; Y_{nn}^{-1} \; Y_{nm} \qquad (11)$$

The bus admittance matrix is reduced to a dimension (m x m), where m denotes the number of generators.

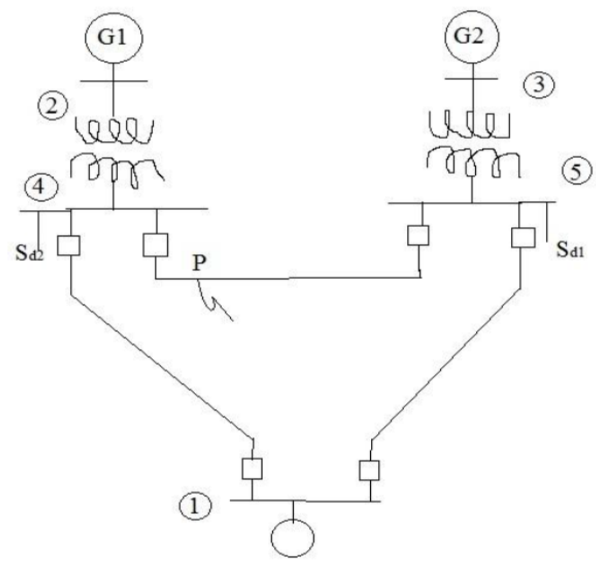

Fig. 2 Representation of 5 bus system

The machine power output can be expressed in terms of machine's internal voltages as follows.

$$S^*_{ei} = E^*_i I_i$$

Where $I_i = \sum_{j=1}^{m} E_j^{'} Y_{ij}$

So,

$$P_{ei} = \mathrm{Re}\,(E^*_i I_i)$$

$$P_{ei} = \mathrm{Re}\,(E^*_i \textstyle\sum_{j=1}^{m} E_j^{*} Y_{ij}\,) \qquad (12)$$

Expressing these voltages and admittances in polar form:

$$P_{ei} = \sum_{j=1}^{m} |E_i^{'}| |E_j^{'}| |Y_{ij}| \, \mathrm{Cos}(\theta_{ij} - \delta_i + \delta_j) \qquad (13)$$

The application of three-phase fault is basically the study of transient stability. When a three-phase fault occurs at bus k of the network, the voltage of this k^{th} bus results to Zero.

The equation (13) shows the electrical power of the i^{th} generator after fault. The post fault power is calculated after removing the faulty line from the bus admittance matrix. This post fault power determines the system stability.

[3]. Simulation

A simulation for the above is done using MATLAB/Simulink with the help of all mathematical equations. The transient stability analysis of the multimachine connected to infinite busbar has been done.

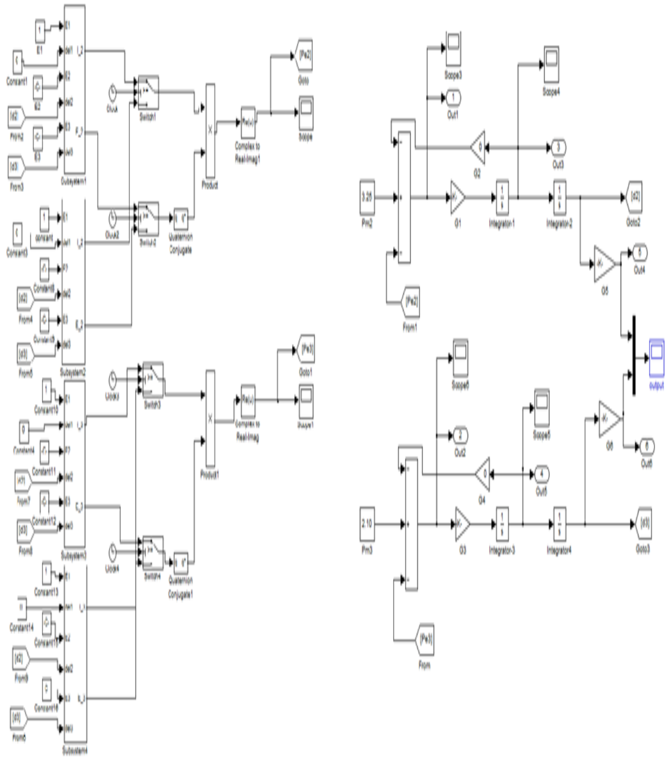

Fig.3 SIMULINK model of a multimachine system

The 5 bus system is described with a SIMULINK model. Modeling the multi machine system including the power network and its controller in SIMULINK environment requires the “electric blocks” from the Power System Block set and control blocks from SIMULINK library. The design of this SIMULINK model is carried out on MATLAB R2012a.The SIMULINK model is shown in Fig.3. The two constant block having different values which generates the real or constant value are connected to the sum block which requires three inputs “-+-“and configures the block to add the middle input to the first input and then subtracts third input. The gain block multiplies the first input by the constant value and is connected to the output block which displays the output. The integrator block output the integral of its input at the current time step and we can see the following results on output scope. The following example of a 5 bus system illustrates that the fault is occurred at point P near the bus 2, then in that case the when a three phase short circuit fault occurs, the voltage of the nearby bus becomes zero so when V=0, the power transferred or power supplied from the generator (P_e) will go to zero as V=0 so $P_{eout=}$ EV/X sin δ. Since voltage is zero then this whole value will get zero. Since there is no electrical power output from this generator whereas mechanical power input of generator remains same i.e. Pe becomes 0 and Pm remains same. So the rotating mass of the synchronous machine connected to the bus 2 is going to accelerate as output is zero and input is very large. This acceleration means the phase angle or rotor angle of this machine will keep on increasing and it will keep on accelerating. So all we are trying to study here is rotor angle dynamics of the multimachine which is occurring because of the mismatch between Pe output and Pm input to the system.

[4]. Simulation results

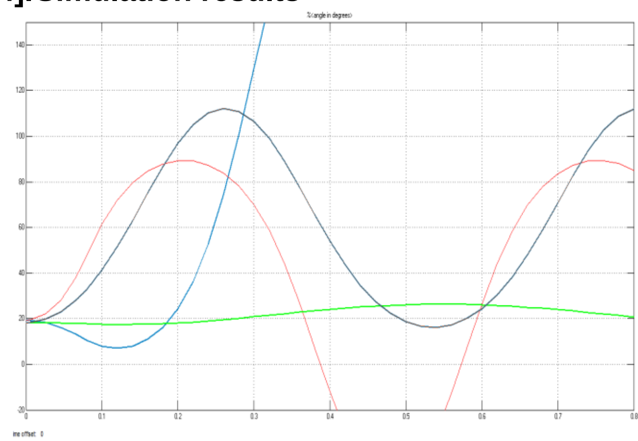

Figure4. (a) Fault clearing of machines 2(light blue highlighted) and 3 (green) at .0275 seconds

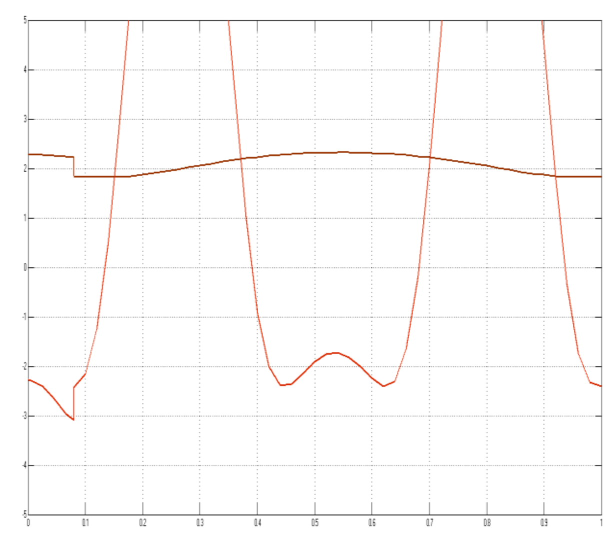

Figure4. (b) Fault clearing of machines 2(red highlighted) and 3(brown highlighted) at .08 seconds

In these two waveforms we can see that taking machine 1 as a reference bus, fig 4(a) shows that machine 2 is instable while machine 3 is stable with some oscillations which will damp out after some time whereas figure 4(b) shows both the machines are stable but with different angular swings.

[5]. Conclusion

The paper has offered a tutorial nature explanation for the detailed transient stability analysis of a multimachine system. We have concluded that thestabilityofmultimachineinterconnectedconnectedinthepowersystem isanalyzedincaseofmostsever3phaseshortcircuitfaultbyusing fivebus interconnectedsystem.The3phaseshortcircuitoccursneartogenerator2so ifthefaultisclearedwithinatimeof0.08secondsbothmachinesarestable whereasiffaultclearedafter 0.275second,theGenerator2willbeunstable whilegenerator3willhavelarge oscillationswhichwillbedampoutaftersome time and generator3 willbecomestable.

[6]. Reference

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