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Stability Analysis of Multi-Machine SMIB System

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Abstract

Transient stability analysis has always been an issue of paramount important in power system planning and operation. Basically stability analysis method may be categorized by two major stability analysis methods. A small signal stability and transient stability transient stability method can be further divided into numerical integration and direct method. Many techniques have been proposed for transient stability analysis in power system. Purpose of this paper is to study and investigate transient stability analysis is extended for transient stability analysis of multi-machine power system. It is a tool to identify stable and unstable condition of power system after fault clearing by the help of differential equation.

Keywords- Multi-machine Power System, MATLAB Simulink, Transient Stability, Damping Numerical Method, Swing Equation.

Introduction

Synchronous machine is represented by voltage source in back of transient reactance that is constant in magnitude but change in angular position this representation neglect the effect of saliency and assume constant flux linkage and small change in speed if machine rotor speed is assumed constant at synchronous speed machine due to such effect as windage and friction are ignored mathematical model is described by following set of equation following calculation require:

(a) Transient stability analysis is to solve initial load flow,

(b) Initial bus voltage magnitude,

(C) Phase angle,

(D) Machine current.

[I] = [V] [Y]

[V] = [I] [Y]

The help of symmetrical fault analysis we By obtain

Y = 1/z

Where

V= vector of bus voltage

I=vector of bus current

Z= impedance of matrix

Y=admittance of matrix

$I_I = S_i / V_i^* = (P_i - jQ_i)/V_i^*$,

$i = 1,2,3,\ldots m$ (a)

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],

$E_i = V_i + jX_d I_i$ (b)

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

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

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

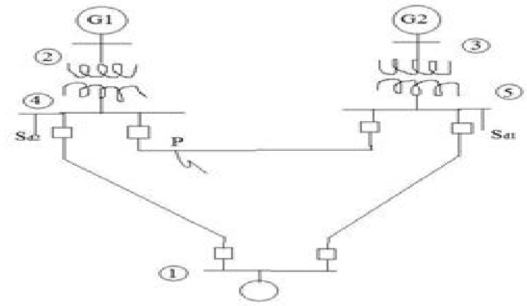


Figure 1: Power system representation for multi machine stability studies

Theory

Perfault bus matrix

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

$I_{bus} = Y_{bus} V_{bus}$ (d)

Where, I_{bus} is the vector of the injected bus currents

V_{bus} is the vector of bus voltages measured from the reference node

B--- Charging reactance of the system

During Fault Bus Matrix

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

$Y_{bus} = Y_{jold} – Y_{nold} \; Y_{njold} / Y_{nnold}$ (g)

Now we obtain prefault bus matrix by deleting 4^{th} row and 4^{th} column by using the relationship (g), then we obtain reduced bus matrix (3x3)**,** then bus no 2 decouple from other during fault and bus 3 is directly connected to bus 1 showing fault at bus 4 is zero.

Post Fault Bus Matrix

By opening circuit breaker at either end, fault is cleared prefault bus has to be modified again this is done by substituting $Y_{54} = y_{45} = 0$ and substituting the series admittance of line 4-5 and capacitive susceptance of half line from Y_{44} and Y_{55}.

Condition: Generator 1 and 2 are not connected when line 4-5 is removed.

$Y_{postfault} = Y_{jjold} – Y_{jj} – B_{ij}/2$
(h)

The diagonal elements of the bus admittance matrix are the sum of admittances connected to it.

During fault Power Angle Equation

$P_{e2} = 0$

$P_{e3} = R_e[\, Y_{33}E_3E^* + E_3{}^* \, Y_{31}E_1]$

Since $Y_{32} = 0$

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

$P_{e3} = 0.1561 + 5.531 \sin(\Delta 3 – 0.755)$ (i)

Post fault power angle equations

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

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

Pe3 =0.1823+6.5282sin(Δ3-0.8466)

Swing equations during fault

Pa(n-1) =Pm-PmaxsinΔn-1

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

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

Swing equation post fault

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

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

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

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

Results and Tables

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 (A) and subsystem (B)

Following parameter are used in simulation

Parameters	Values
E1	-1.0
E2	1.03
E3	1.02
G3	17.44
G2	0
G4	0
G1(CONSTANT)	13.08
Y21	-0.2214+j*7.6289
Y22	0.5+j*7.7895
Y23	0
D1	0

From fig B, P_{e2} =electromechanical power for machine (a), From fig A Pe1= electromechanical power for machine (b), Switch; used for post-fault and pre-fault.

We get output by the help of multi-machine system.

First we calculate pre-fault data, determine E voltage behind transient reactance for machine a,b.

During faulted mode determine generator output from power angle equation. After it we solve swing equation according to equation completely and determine post fault and line removing point, after it we draw the swing curve it is varying by vary critical clearing time of system.

Stability of both machines will depend upon oscillation

Oscillation increase = stability decrease

Oscillation decrease= stability increase

Stability is inversely proportional to oscillation

We plotted many curve torque angle and time.

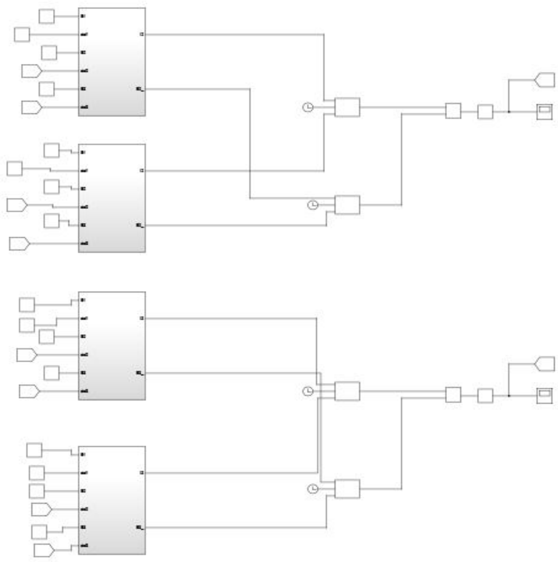


Figure 2: subsystem 1 of multi-machine power system

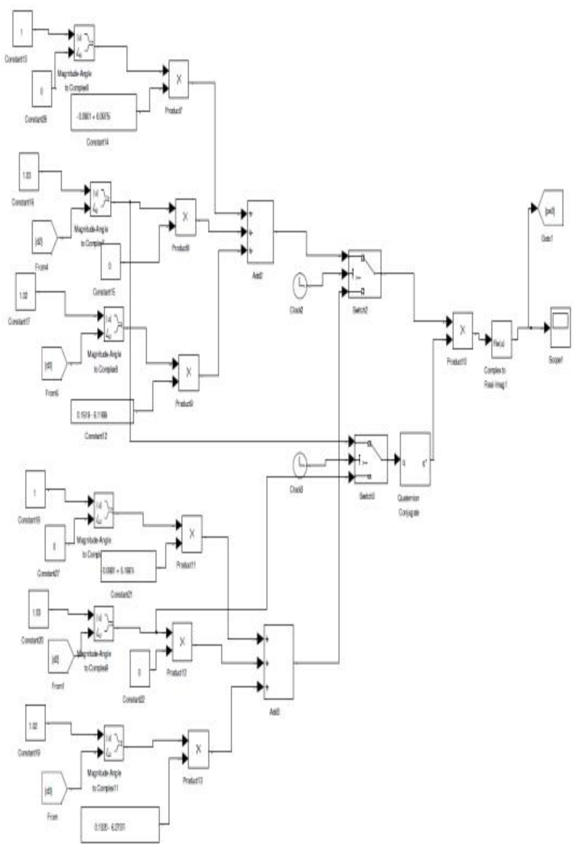


Figure 3: Machine 2 sub-systems is similar to machine 1 shown in figure 2

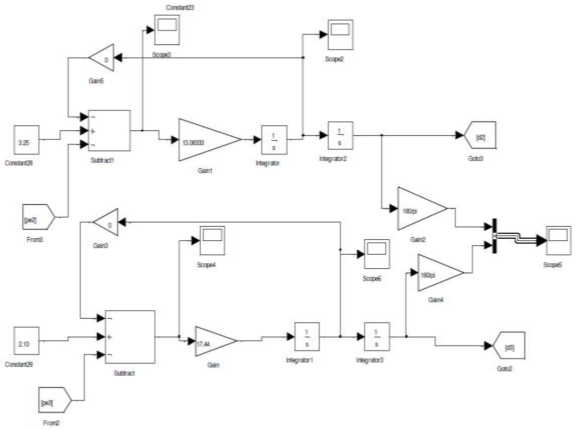


Figure 4: Multi-machine power system

Now we draw the output response of multi-machine. We draw the curve between torque angle and time.

When critical clearing time is less then both machines will stable.

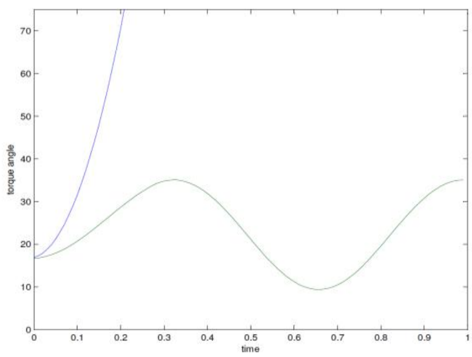
When critical clearing time is more than both machines will unstable.

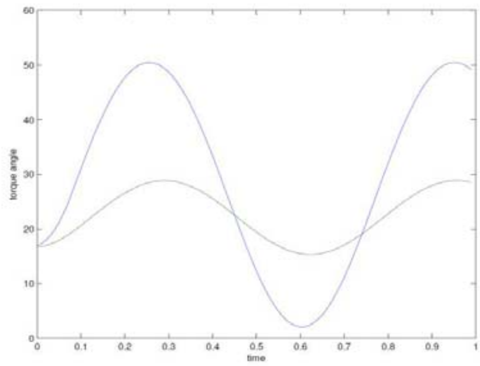
We draw many curves for different-different Critical clearing time.

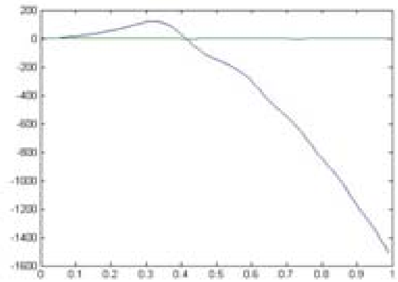
Tc increase = un-stability increase

Tc decrease = stability increase

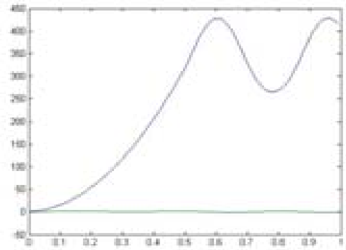
Tc = critical clearing time



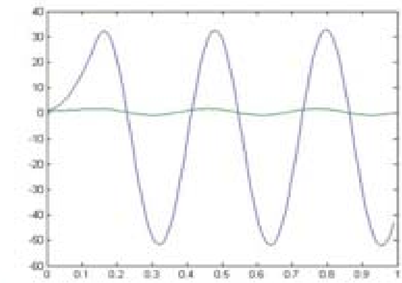




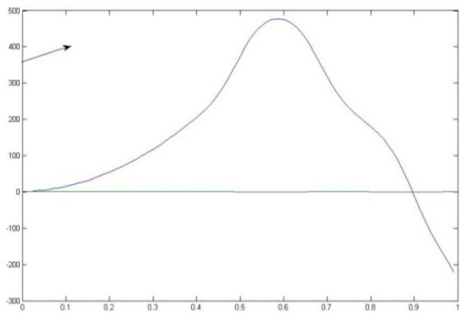
(1) 0.3



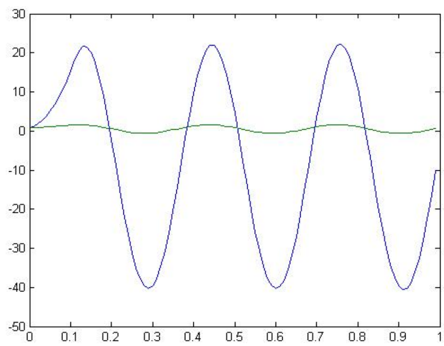
(2) 0.5



(3) 0.14



0.4



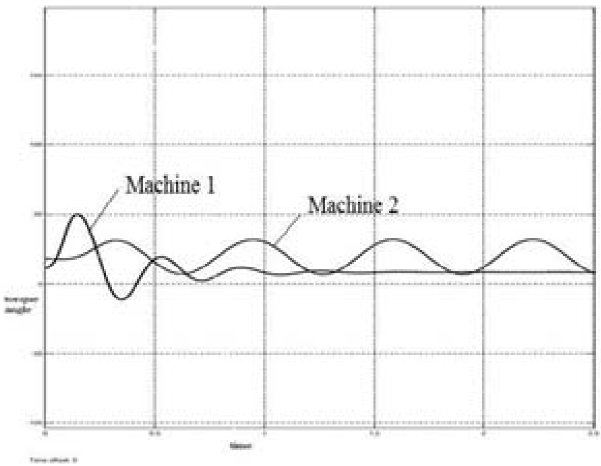
0.11

Damping behavior in multi-machine system (e)

Mainly the meaning of damping is to remove oscillation (disturbance of waves). In multi- machine power system, a low magnitude negative gain is connected to reduce oscillation now we draw the behavior of two machines which produced damping.

Case 1 When damping is done only in machine 1 output response when damping is done only machine1

Case 2 When damping is done only in machine 2



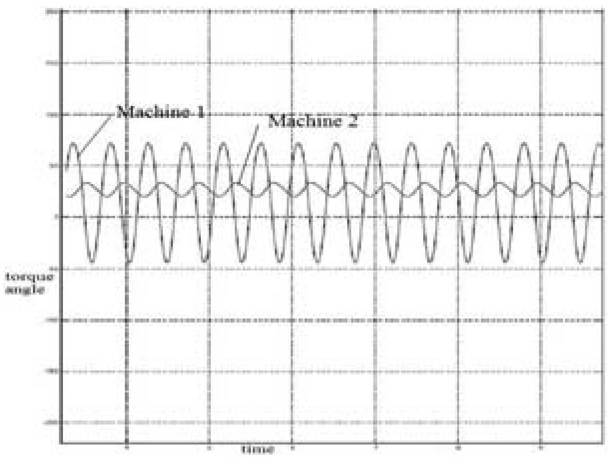


Fig 8 Output response when damping is done only in machine 2

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

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

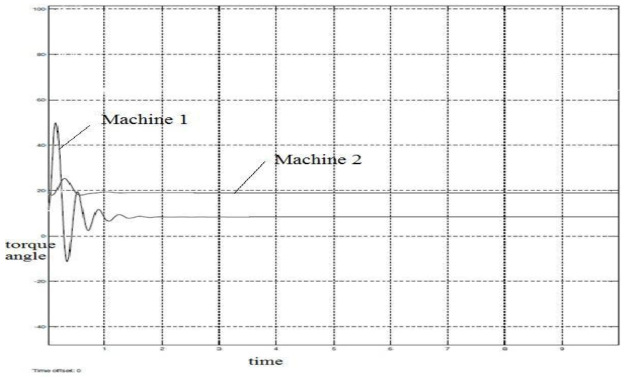


Figure 9: Output response when damping is done in both machine A and machine B

Conclusion

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.

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