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Transient Stability Analysis of 5 Bus Systems

Sonali Raj[1], Preeti Jain[2]

[1]Scholar, Electrical Department, Jabalpur Engineering College, Jabalpur, 482011, India
[2]Asst. Professor, Electrical Department, Jabalpur Engineering College, Jabalpur, 482011, India

Abstract: **This paper shows an analysis of the effect of three phase to ground fault on the transient stability for the enhancement of power system using Mi-Power. In this circuit there are 5 bus, 2 single phase transformer, 3 single phase generator and 2 load are connected to different buses. During this condition very high current flow through the system which damages the equipment. It also causes interruption to the supply provided to the customers. Initially load flow is done to obtain the power flow in the complete system which is followed by transient stability studies. In this paper transient stability studies is done in order to protect overhead transmission line, conductors and insulators, it is suggested that the faulted part to be isolated rapidly from rest of the system so as to increase stability margin and hence decrease damage.**

Keywords: **Transient stability, swing equation, Equal area criteria, critical clearing time (CCT), fault clearing time (FCT).**

1. INTRODUCTION

The transient stability is one of important items in the planning and maintaining security of power system operation .A transient stability is concerned with the ability of the power system to maintain synchronism when subjected to a severe disturbance. These disturbances can be faults such as: a short circuit on a transmission line, loss of a generator, loss of a load, gain of load or loss of a portion of transmission network. One of the requirements of transient stability analysis is to compute a transient stability index (TSI) for the contingencies. which is used to access the stability of single contingency and furthermore rank the severity of different contingencies. The Critical Clearance Time of a fault is generally considered as the best measurement of severity of a contingency and thus widely used for ranking contingencies in accordance with their severity [4]. In this paper Critical Clearing Time (CCT) is employed as a transient stability index to evaluate test system. In IEEE report, the Critical Clearing Time is defined as “the maximum time between the fault initiation and its clearing such that the power system is transiently stable”. The CCT is efficient factor for estimation of transient stability limits of large power to avoid any cascading outages which may lead to black out. The transient stability limits refers to the amount of power that can be transmitted through some point in the system with stability when the system is subjected to sever disturbance. The transient stability limits depends on duration and location of fault, construction parameters of the network and generators, and dynamic characteristics of loads. In this order the main objective of this paper is to know the effects of three phase to ground fault and fault clearing time (FCT) on the transient stability analysis.

2. SWING EQUATION

Under normal operating condition, the relative position of the rotor axis and the resultant magnetic field axis is fixed. The angle between the two is known as the power angle or torque angle. During the disturbance, rotor will decelerate or accelerate with respect to the synchronism rotating air gap MMF, and the relative motion begins. If the oscillation, the rotor locks back into synchronism speed after the oscillation, the generator will maintain its stability. If the disturbance does not involve any net changes in the power, the rotor returns to its original position. If the disturbance is created by a changes in generation, load, or in network conditions, the rotor comes to a new operating power angle relative to the synchronously revolving field. The acceleration power P_a and the rotor angle δ is known as Swing Equation. Solution of

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swing equation will show how the rotor angle changes with respect to time following a disturbance. The plot of **δ** vs time ***t*** is called the Swing Curve. Once the swing curve is known, the stability of the system can be assessed. The flow of mechanical and electrical power in generator and motor are shown in fig 2.3

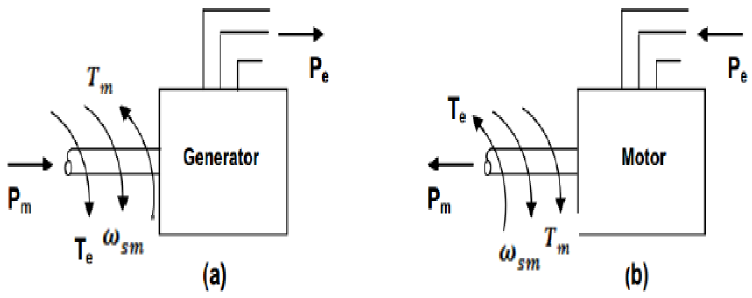

Figure 2.3: The flow of mechanical and electrical power in a generator and motor

The swing equation governs the motion of the machine rotor relating the inertia torque to the resultant of the mechanical and electrical torques on the rotor.

$$M \frac{d^2 d_m}{dt^2} = P_{m-} P_e$$

Where,

M = inertia constant, it is not really constant when the rotor speed deviates from the synchronous speed.

Pm = Shaft mechanical power input, corrected for windage and friction losses.

Pe = Pa sin **δ** = electrical power output, corrected for electrical losses.

Pa = amplitude for the power angle curve.

δ*m* = mechanical power angle.

Swing curve, which is the plot of torque angle **δ** vs time ***t***, can be obtained by solving the swing equation. Two typical swing curves are shown in figure 2.4.

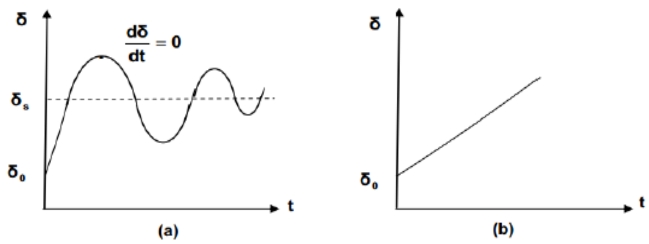

Figure 2.4: Swing curve

3. EQUAL AREA CRITERIA

The transient stability studies involve the determination of whether or not synchronism is maintained after the machine has been subjected to sever disturbance. This may be sudden application of load, loss of generation, loss of large load, or a fault on the system. In most disturbances, oscillations are of such magnitude that linearization is not permissible and the nonlinear swing equation must be solved. A method known as the *equal-area criterion* can be used for a quick prediction of stability. This method is based on the graphical interpretation of the energy stored in the rotating mass as an aid to determine if the machine maintains its stability after a disturbance. The method is only applicable to a one-machine system connected to an infinite bus or a two-machine system [7]. From the swing eqn.

$$M\frac{d^2\delta\, m}{dt^2} = P_m - P_e = P_a$$

Where P_a is the accelerating power

With increase in the electrical power increases and **δ** = **δ**1, the electrical power matches the new input power ***Pm1***. Even though the accelerating power is zero at this point, the rotor is running above synchronous speed; hence **δ** and the electrical power ***Pe*** continue to increase. Now , causing the rotor decelerates toward synchronous speed until . The energy given as the rotor decelerates back to synchronous speed is,

$$area\ A2 = area\ bde = \int_{\delta}^{\delta max}(P_m - P_e)\ d\delta \qquad \textbf{(3.22)}$$

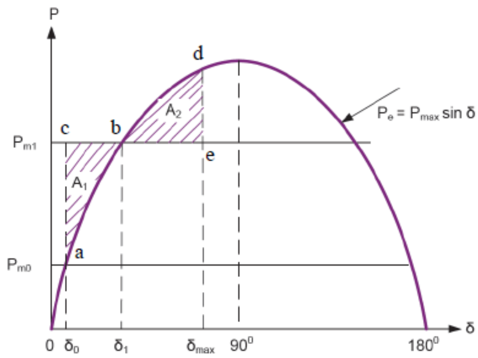

Figure 2.7: Equal area criterion - sudden change of load

The result is that the rotor swings to point b and the angle δ_{max}, at which point

$$|area\ A1| = |area\ A2|$$

This is known as the equal area criterion. The rotor angle would then oscillate back and forth between **δ0** and **δmax** at its natural frequency. The damping present in the machine will cause these oscillations to subside and the new steady state operation would be established at point ***b*** [8].

4. EFFECT OF FAULT CLEARING TIME

In order to know the effect of fault clearing time (fct) on transient stability a disturbance in the form of a three phase to ground fault occurs at t=0.225 sec at bus 4, cleared by opening the line connecting the nodes 4-5.If the fault is cleared rapidly the angular deviation is less and subsequently the system may become stable. This angular deviation increases if the fault clearing time increases and ultimately if the fault is cleared after critical clearing time the system will lose synchronism.

Model Configuration:

I have performed transient stability analysis on 5 bus system which comprises of 3 single phase Generator 2 single phase Transformer and 2 load,. The base voltage taken as 230 volts and system frequency is 50 Hz, base MVA as 100 MVA. The basic Single line diagram of system considered as follow single line diagram of 5 Bus power system for Transient Stability Analysis.

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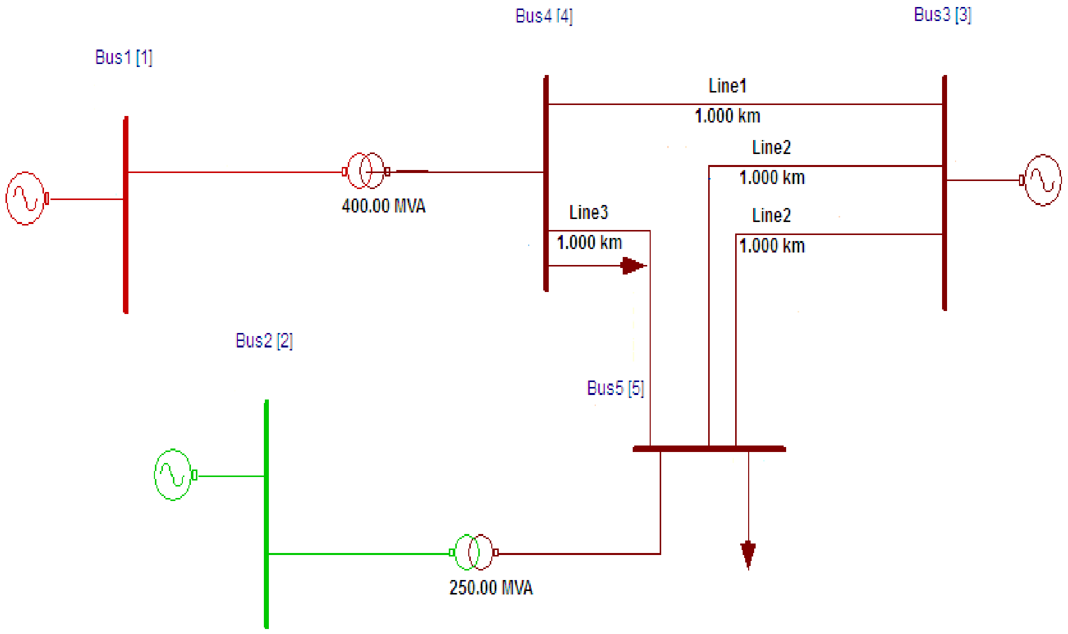
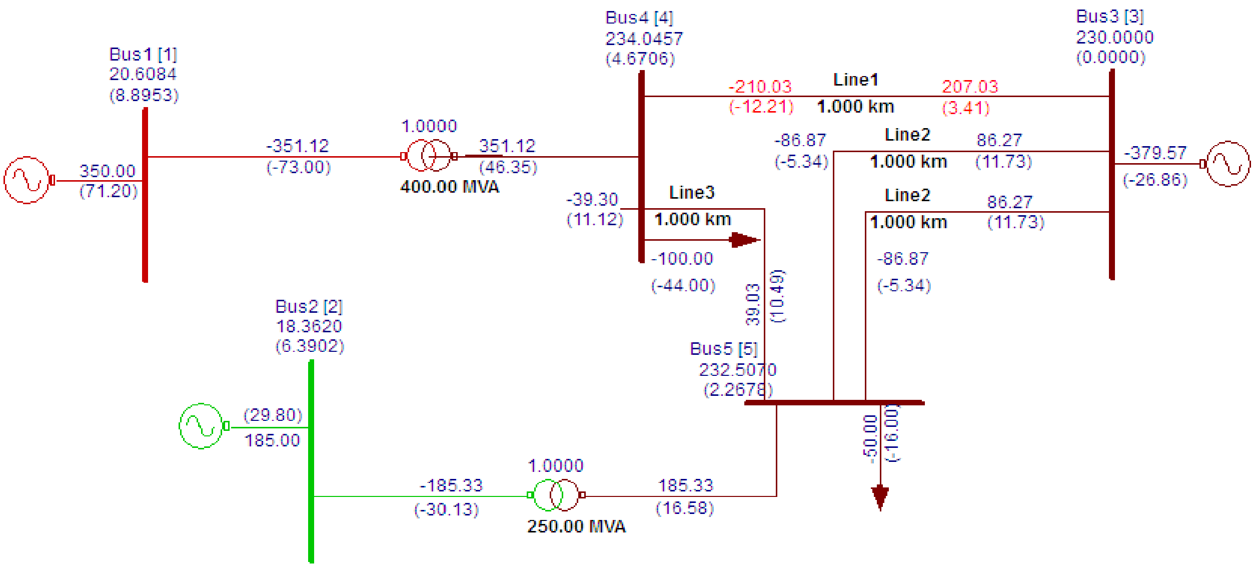


Three phase to ground fault:

In this case a three phase to ground fault occurs on line4-5 near bus 4 and the fault is cleared by simultaneously opening the circuit breaker at the ends of line 4-5 at 0.225 seconds (fault clearing time). Rapid clearing of the faults promotes power system stability. Indeed, increasing the speed of fault clearing is often the most effective and economical way to improve the transient stability of the power system. Rapid fault clearing is desirable for an additional reason. It decreases the damage to overhead transmission line conductors and insulators at the point of fault. After a fault occurs the synchronous machines' rotors will accelerate differently, so the angle between two equivalent machines will not be constant, and the system may become unstable. To determine whether a power system is stable after disturbances, it is necessary, in general, to plot and inspect the swing curves. If these curves show that the angle between any two equivalent machines tends to increase without limit, the system is unstable. If, on the other hand ,after all disturbances, the angle between the two equivalent machines of every possible pair reaches maximum values and thereafter decrease, it is probable, although not certain, that the system is stable.



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5. RESULT

From Node	From Name	To Node	To Name	Ckts No.	Forward FlowMW	Forward FlowMVAR	MWLoss MW	MVARLoss
1	Bus1	4	Bus4	1	349.04	71.99	0.003	26.317
2	Bus2	5	Bus5	1	185.00	29.90	0.001	13.499
3	Bus3	4	Bus4	1	-206.85	-3.92	2.995	8.768
3	Bus3	5	Bus5	1	-86.36	-11.88	0.601	-6.380
3	Bus3	5	Bus5	1	-86.36	-11.88	0.601	-6.380
4	Bus4	1	Bus1	1	-349.04	-45.67	0.003	26.317
4	Bus4	3	Bus3	1	209.85	12.69	2.995	8.768
4	Bus4	5	Bus5	1	39.19	-11.02	0.267	-21.623
5	Bus5	2	Bus2	1	-185.00	-16.40	0.001	13.499
5	Bus5	3	Bus3	1	86.96	5.51	0.601	-6.380
5	Bus5	4	Bus4	1	-38.93	-10.61	0.267	-21.623
5	Bus5	3	Bus3	1	86.96	5.51	0.601	-6.380

Total power generation : 154.47 MW 74.19 MVAR
Total reactive compensation : 0.00 MVAR
Total capacitivei copensation : 0.00 MVAR
Total inductive compensation : 0.00 MVAR
Total power losses : 4.47 MW 14.20 MVAR
Over all P mismatch : 0.001 MW
Percentage P losses : 2.893

Results of load flow study

No.	Name	Island	Zone	Rated KV	Vact-KV	V-mag	Ang-Deg / Pload	Pgen / Qload	Qgen / Q-comp
1	Bus1	1	1	20.000	20.608	1.03042	8.895	349.039	71.987
							0.000	0.000	0.000
2	Bus2	1	1	18.000	18.362	1.02011	6.417	185.000	29.899
							0.000	0.000	0.000
3	Bus3	1	1	230.000	230.000	1.00000	0.033	-379.570	-27.693
							0.000	0.000	0.000
4	Bus4	1	1	230.000	234.089	1.01778	4.696	0.000	0.000
							100.000	44.000	0.000
5	Bus5	1	1	230.000	232.526	1.01098	2.302	0.000	0.000
							50.000	16.000	0.000

Line flow and line losses

From Node	From Name	To Node	To Name	Ckts No.	Forward FlowMW	Forward FlowMVAR	MWLoss MW	MVARLoss
1	Bus1	4	Bus4	1	349.04	71.99	0.003	26.317
2	Bus2	5	Bus5	1	185.00	29.90	0.001	13.499
3	Bus3	4	Bus4	1	-206.85	-3.92	2.995	8.768
3	Bus3	5	Bus5	1	-86.36	-11.88	0.601	-6.380
3	Bus3	5	Bus5	1	-86.36	-11.88	0.601	-6.380
4	Bus4	1	Bus1	1	-349.04	-45.67	0.003	26.317
4	Bus4	3	Bus3	1	209.85	12.69	2.995	8.768
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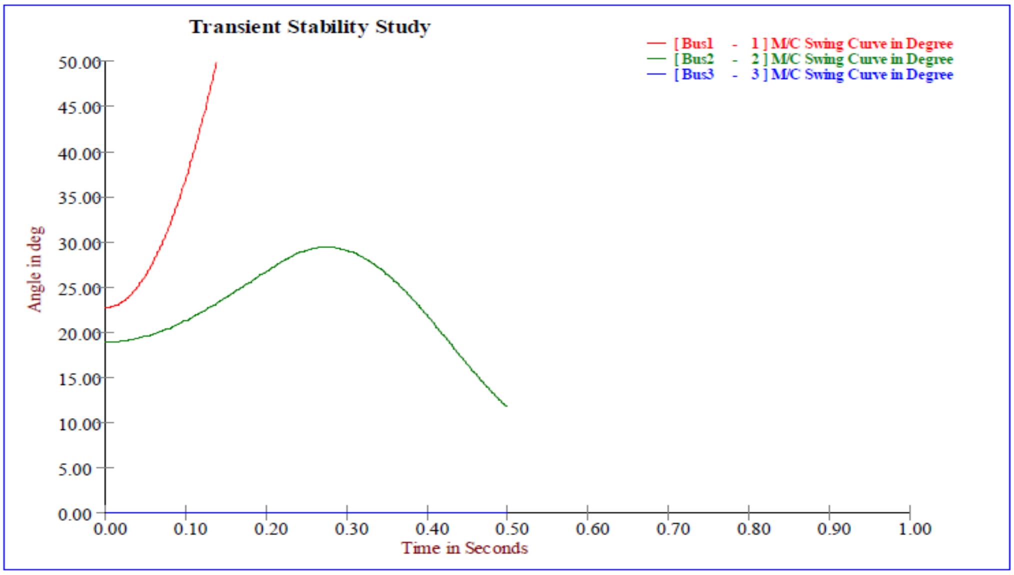

Graph between Change in Machine Angle V/S Time

6. CONCLUSION

In this study the effect of three phase to ground fault on the transient stability studies of a power system is presented and discussed. In above power network the disturbance in Gen 1 is considered then transient stability analysis is done using Mi Power. From the result above after simulation it is concluded that when the generator outage occurs, the system becomes unstable due to the continuous increase in the rotor angle of machine 1. While the machine 2 is in stable condition. The system remains unstable till the fault is cleared.

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