Modelling and Analysis of a Multi Machine Power System using MATLAB/Simulink

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Abstract – **"Transient stability is the ability of the power system to maintain synchronism when subjected to sever transient disturbance" [1]. This article involves the modelling and investigation of the synchronous machine through the angular position of the rotor with respect to time after a fault occurs in the system. The article presents analysis of the test system which includes multimachine power systems. The transient stability analysis of the multi machine system is analysed with the help of MATLAB R2013a.**

I. INTRODUCTION

The transient stability studies involve the determination of whether or not synchronism is maintained after the machine has been subjected to severe disturbance. This may be sudden application of load, loss of generation, loss of large load, or a fault on the system. Transient stability is the ability of the power system to maintain synchronism when subjected to sever transient disturbance [1]. The response to this type of disturbance involves large excursions of rotor angles and is influenced by nonlinear power-angle relationship. Stability depends on the initial operating state of the system and the severity of the disturbance. The system usually altered after the disturbance which may cause the system to operate in a different steady-state status from that prior the disturbance.

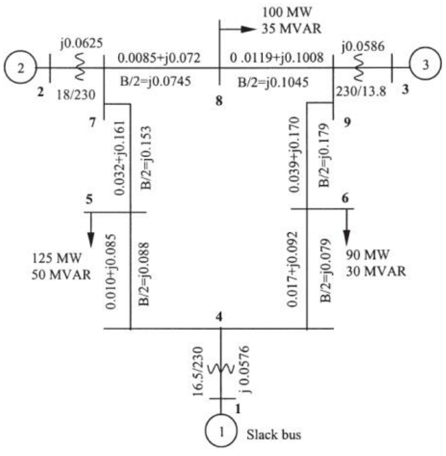

Fig 1. WSCC 3-machine, 9-bus system

Power systems are designed to be stable for a selected set of contingencies. The contingencies usually considered are short-circuits of different types: phase-to-ground, phase-to phase-to-ground, or three-phase [2]. Fig.1 depicts the standard 9-Bus system considered for the analysis. A complete model for transient stability study of a multi-machine power system was developed using Simulink. It is basically a transfer function and block diagram representation of the system equations. The major objectives are:

- To determine whether the system is stable or unstable with a critical clearing time for a three-phase fault.
- To analyze the effect of fault location and critical clearing time on the system stability, a three-phase fault is located at two different locations.
- Disturbances for preventing the serious power disruptions.
    - Increasing value of H
    - Increasing voltage set point and
    - Decreasing mechanical input power.

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II. SYSTEM MODELING

The complete system has been represented in terms of Simulink blocks in a single integral model. It is self-explanatory with the mathematical model given below. One of the most important features of a model in Simulink is its tremendous interactive capacity. It makes the display of a signal at any point readily available; all one has to do is to add a Scope block or, alternatively, an output port. Giving a feedback signal is also as easy as drawing a line. A parameter within any block can be controlled from a MatLab command line or through an *m*-file program. This is particularly useful for a transient stability study as the power system configurations differ before, during and after fault.

A. Changing Generator Inertia Constants, H

Inertia constant H is defined as the ratio of kinetic energy at rated speed to rated apparent power of the machine.

$$H=\frac{\text{stored energy in megajoules}}{\text{rating in MVA}} \qquad (1)$$

Inertia constant H simply quantifies the kinetic energy of the rotor at the synchronous speed in terms of the number of seconds it would take for the generator to provide an equivalent amount of electrical energy when operating at a power output equal to its MVA rating [6].With the transmission line open, and with D = 0, the swing equation becomes:

$$\ddot{\delta}\,(t)=\frac{\pi f_o}{H}\,P_M^0 \qquad (2)$$

The machine inertia constant H plays an important role in stability assessment. By increasing H the system stability can be improved. From the equation perspective, equation (2) indicates that enhancing H would reduce the rotor acceleration and therefore help in the stability of the machine.

B. Generator Voltage Set points

$$\frac{IE_aIIVI}{X_L+X_d}\sin\delta+\frac{V^2}{2}\left(\frac{1}{X_L+X_q}-\frac{1}{X_L+X_d}\right)\sin 2\delta \qquad (3)$$

Increasing generator voltage set point enhances the system stability. Equation (3) shows that decreasing |Ea| would lower the generator real power output curve and therefore reduce the deceleration area in the equal area criterion diagram.

C. Generator Real Power Output

Increasing generator real power output enhances the system transient stability. In steady state condition.

$$P_G\,(\delta_o)=P_M^0 \qquad (4)$$

As a result, setting up generator real power output in pre-fault period settle the value for P_M^0 .From the equal area criterion it is noted that increasing P_M^0 would decrease the deceleration area and reduce the stability. To improve the power system stability after disturbance, it is required to either decrease the fault clearing time, mechanical input power, or increase the generator inertia constants H, terminal voltage, and armature voltage.

III. SIMULATION RESULTS.

The system is simulated using power system tool box of MATLAB with a fault clearing time of 0.1s. The angular positions, relative angular positions and relative angular velocities of generators is depicted in Fig 2-4. Fig.5 shows the accelerating powers of the generators Table 1 shows the summary of the transient stability analysis of IEEE 14-bus power system under three phase fault at selected buses and lines.

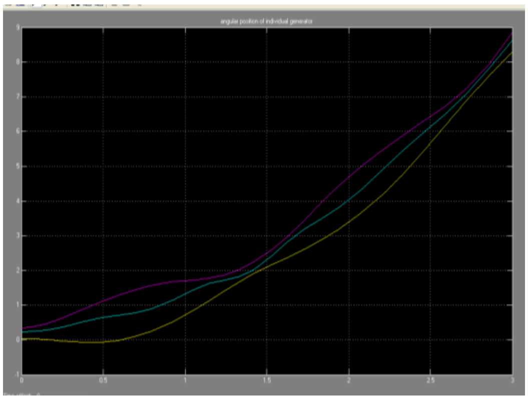


Fig 2: Angular positions of the individual generators

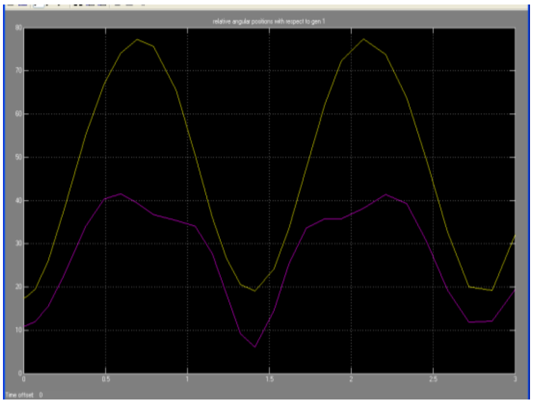


Fig.3: Relative angular positions of δ_{21} and δ_{31}

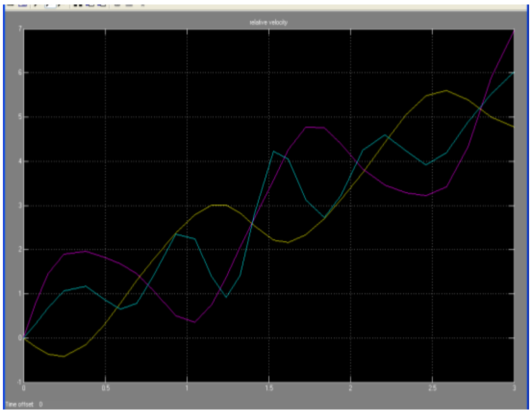


Fig 4: Relative angular velocities of ω_{12} and ω_{13}

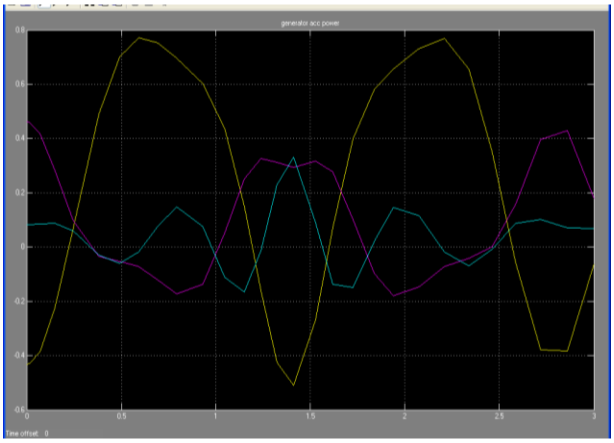
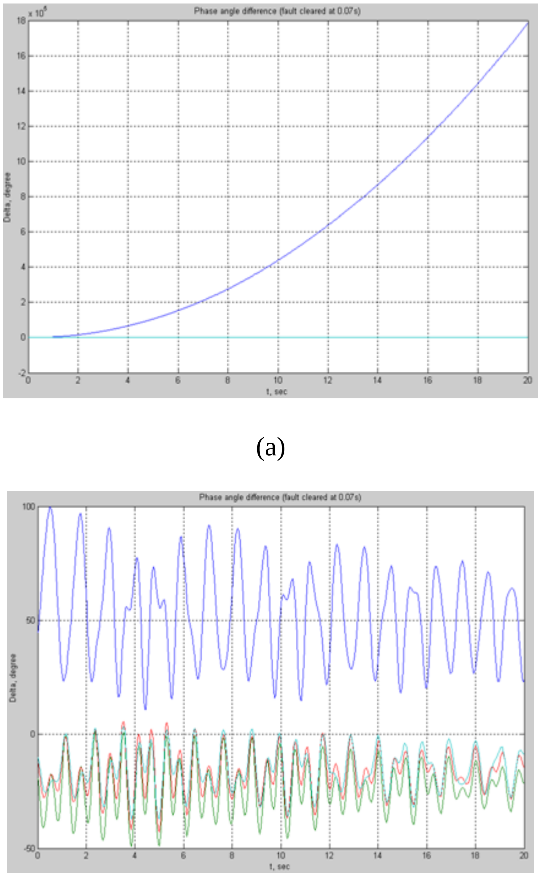


Fig 5: Generator accelerating powers

Table 1: Summary of IEEE 14-Bus Fault Analysis

Sl. No	Faulted Bus No	Removed Faulty Line	Critical Clearing Time	Clearing Time	Remarks
1	11	6-11	0.33	0.3	Stable
2	11	6-11	0.33	0.33	Unstable

Fig.6 shows the response of the machine for change in inertia constant from 5.148 to 3, it is observed in that the response improve as the inertia constant is increased from 5.148 to 7.

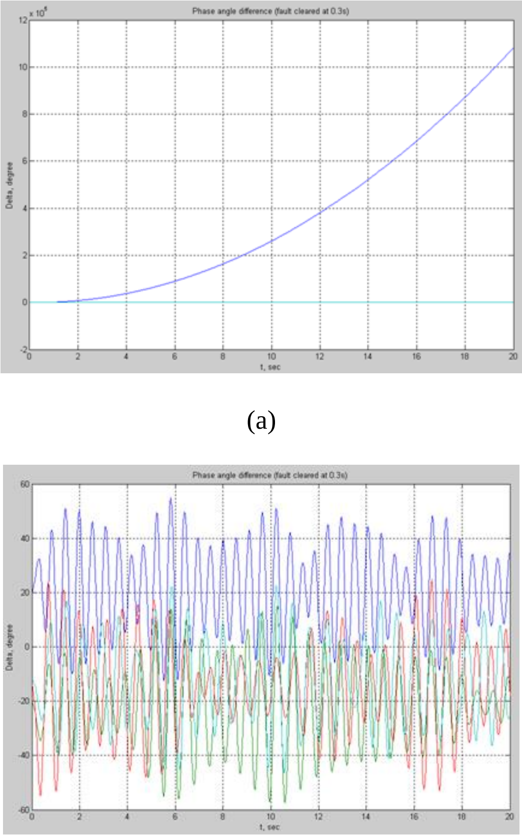


(a)

(b)

Fig 6: Response with Change in Inertia Constant H
(a)Decrease in H (b) Increase in H

Fig. 7 shows the response with change in Generator Voltage Set points. It is observed that the system gives significant stability response with generator 1's voltage set points from 1.0 to 0.95.

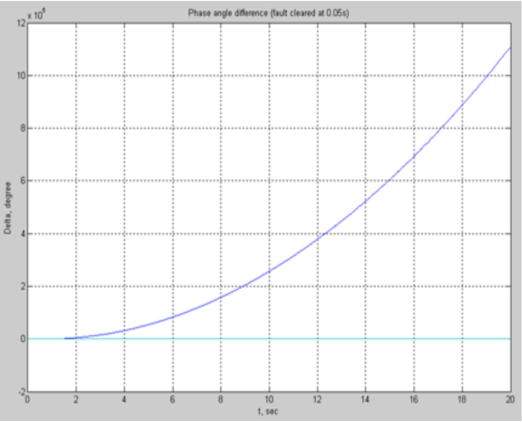


(a)

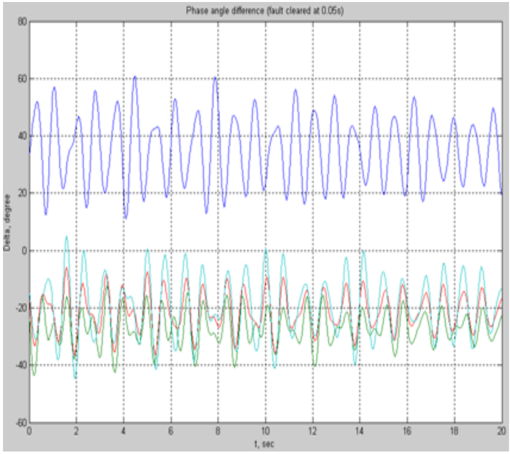
(b)

Fig 7 : Responses with Change in Voltage Set Point
(a)Decrease in Set Point (b) Increase in Set Point

Fig. 8 shows the responses with real power output. .It is noted that the system remains stable and has better performance when its subjected to higher real power output.



(a)



(b)

Fig 8: Responses with Change in Real Power output
(a)Decrease in Real Power output (b) Increase in Real Power output

IV. CONCLUSIONS

Transient stability problems are significant areas including the sustained synchronism of a particular generators after a severe disturbance such as fault. During the analysis Synchronism is retained at a steady state condition after the transient period. Transient stability analysis of IEEE 14-bus electrical power system and WSCC 3-machine, 9-bus system are performed & is found that the critical clearing time t_{ccr} for the fault on the line far from the generating station fault is higher as compared to that of the fault on the closer to the generating station which is station .It is analysed in a way that the fault is cleared which is closer to the generating station is cleared first than that is far from the generating station. It can be noticed that transient stability of multimachine systems can improved by increasing value of H, increasing voltage set point and decreasing mechanical input power. Typically, for a transient stability study the model facilitates fast and precise solution of nonlinear differential equations namely the swing equation. The modeling and analysis of a multimachine system greatly improves the stability of a system.

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