

### 3-PHASE TRANSIENT STABILITY FAULT ANALYSIS OF A SINGLE MACHINE CONNECTED TO AN INFINITE BUSBAR EMPLOYING MODIFIED HUMPAGE MODEL

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#### ABSTRACT

*Transient stability analysis has recently become a major issue in the operation of power system due to the increasing stress on power system networks. Solving this problem requires evaluation of power system's ability to withstand disturbances while maintaining the quality of service. This paper provides a study of power system stability with the aim of overcoming and preventing disturbances or perturbations in power system networks. The stability of an interconnected power system network is its ability to return to stable state after been subjected to some form of disturbances. In this regard, a 3-phase fault is inflicted on the generator bus bar of the power system network. The fault was cleared in 0.2 seconds. The swing equation and the 4<sup>th</sup> order Runge Kutta integration method were used to apply to the equation of the system which caused a change in the machine rotor angle. The static var compensator was introduced to enhance the stability of the system. The tendency of the rotor angle versus time curves was used to determine the stability or instability of test case using MATLAB code. This work employed the modified Humpage Model of power system in which a single machine connected to an infinite bus bar via the transmission network. The results so obtained is effective in planning or operation of power system because in all stability studies, the aim is to determine the machine rotor angle being disturbed returns to constant speed operation for maximum power transfer.*

Keywords: Transient Stability, Swing Equation, 3-Phase Fault, Modified Humpage, Infinite Busbar.

#### 1.0 INTRODUCTION

Stability with reference to power system is that characteristics of the system or part of the system to develop a restoring force between the elements which are equal to or greater than the disturbing force as to restore a state of synchronism between the elements (Gupta 2005).

Power system stability depends on such factors as:

- The size of the disturbance
- The time span within which stability is accessed.
- Reactance of the generator
- Generator Output
- Internal Voltage of the generator

- Magnitude of the infinite busbar voltage
- Clearing time of fault
- The physical nature of the restoring instability.
- The simple Humpage model of power system is a single machine equivalent of power system and a transmission network connected to an infinite busbar.
- The modified Humpage model of power system is a simple Humpage model with a source impedance as shown in fig 1.1
- This work was undertaken as a study in the stability of a power system applying the modified Humpage model.
- The target of every power engineer is to achieve 100% stability in power system but this has not been achieved.
- This is why power system stability studies have been a topic for concern and a subject of everyday research by power system planners and operators.
- In this work, a 3-phase transient stability fault is inflicted on the generator busbar of the test system and the fault cleared after sometime.

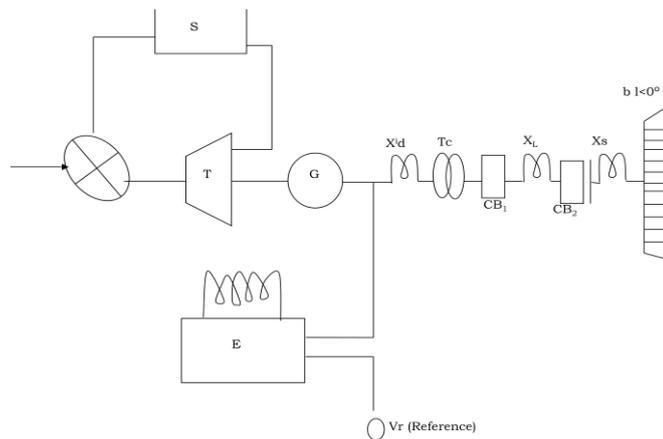


Figure. 1: Modified Humpage Model for Analysis.

The aim of this research work is to analyse the transient stability response of a 3-phase fault on a power system using modified Humpage model.

## OBJECTIVE OF STUDY

- To investigate the response employing 4<sup>th</sup> order Runge Kutta integration method on the swing equation of the system.
- To analyze using plotted rotor angle versus time curves (swing curves) to determine in (stability) of the test case. Here, the graph of rotor against time was plotted and displayed.
- To investigate the transient response of a 3-phase fault inflicted on the generator busbar of the power system network.

## 2.0 REVIEW OF RELATED LITERATURE

In Bartram, and O'Kelly (1998) in their work developed a digital model of synchronous machine with governor and voltage regulator action is used to study the transient stability of a machine connected to infinite bus bar by a double circuit transmission line.

Nasar and Balabanian (1964) in their publication, examined the relationship between synchronous generator's input mechanical power ( $P_m$ ) and the corresponding output electrical power ( $P_e$ ).

Vikramarajan, J. (1998) provided Power System Stability Improvement under three-phase fault, using

static synchronous compensator for power system stability.

## 3.0 METHODOLOGY AND MATERIALS

- A 3-phase fault is inflicted on the generator bus bar of a single machine connected to an infinite bus bar (SMIB).
- This caused a change in the power of the system resulting in the acceleration changing of the machine.
- This created a new rotor angle in the machine.

The calculation and plotting of the rotor angle of the machine revolution with time ( $\delta$  versus  $t$ ) for the fault in question was carried out with MATLAB SIMULINK.

- In this case stability or instability of the power system is determined.
- Afterwards the system was compensated by the application of power system stabilizer (PSS) and the static var compensator (SVC) located at the midpoint of the transmission line.
- This fault is subsequently cleared in 0.2 seconds.
- The fourth order (4<sup>th</sup> order) Runge Kutta Integration method was applied to the system equation to produce the evolution of the machine rotor angle ( $\delta$ ) for the fault.
- The result of the rotor angle versus time curve ( $\delta$ - $t$ ) was used to ascertain the stability or instability of the test system.

### PROCEDURE STEPS:

- From the electrical power  $P_e$  delivered by the machine (from the supplied data) the transmission steady state model is used to solve for current  $i(t)$  (Gauss Seidel)
- With the electrical power  $P_e$  obtained, the system model equations are solved by obtaining new values for rotor angle  $\delta_o$ , angular speed  $\omega_o$  at time  $\Delta t$ , mechanical power  $P_m$  is assumed constant.
- With the new values  $\delta_o$ ,  $\omega_o$ ,  $\Delta t$ , a new load flow is solved for  $P_e$  at  $\Delta t$  considering

$\Delta P_1$  which is power variation due to controls.

- System equations are solved to obtain improved estimates of  $\delta$ ,  $W$  and  $\Delta t$ .
- Repeat steps 1-4 for several iterations considering  $\Delta t$ .
- Change the configuration to reflect a fault condition.
- Steps 1-5 are repeated for several iterations using 3-phase fault consideration.
- The new machine rotor angle is plotted against time for the considered network.

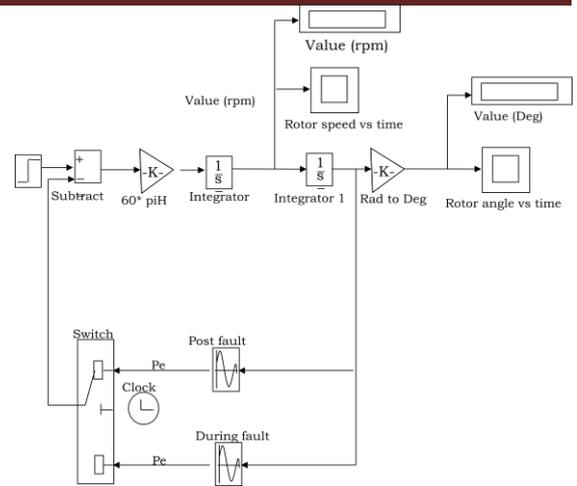


Figure 3: Digital Model of SMIB Using Simulink

To maintain stability, maintenance of synchronism between the different components of the network is necessary. However, this problem is not easy because of the complex nature and size of power system interconnection.

For stability analysis, the stability of this system under the given condition and following steps were considered.

- Simulation of single machine infinite bus using MATLAB SIMULINK.
- Developing a matlab program that can analyse the stability of single machine infinite bus under a 3-phase fault.
- Analysis and discussion of results.

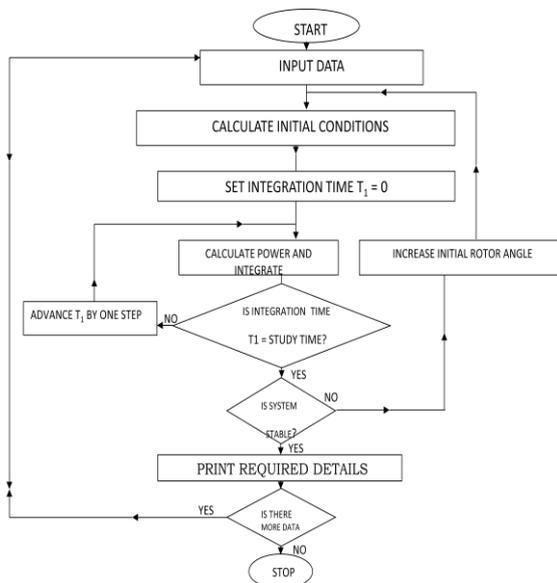


Figure 2: Flow Chat of SMIB Programme

### TRANSIENT STABILITY SIMULATION OF FAULTS

The transient stabilities of a three phase fault were simulated to study the effects of PSS and SVC under three cases.

- When PSS and SVC are off.
- When only PSS is on.
- When both SVC and PSS are on.

### 4.0 SIMULATION OF HUMPAGE MODEL WITH SIMPOWERSYSTEM

This model illustrates use of the Phasor solution for transient stability analysis of single machine system. It analyzes transient stability of a one-machine transmission system with power system stabilizers (PSS) and Static Var Compensator (SVC).

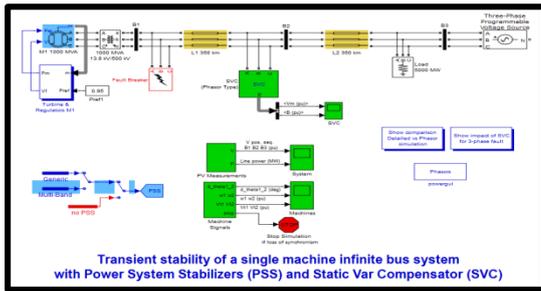


Figure 4: Single machine equivalents with Power System Stabilizers (PSS) AND Static Var Compensator (SVC).

**TABLE 1: Results for Stable Case.**  
 Fault is cleared at 0.2Sec.

S/N	Time (T) in seconds	Speed (in rad/sec)	Delta (in degrees)
1.	0	314.15932	6.3878
2.	0.0200	314.3520	26.6086
3.	0.0400	314.5430	27.2700
4.	0.0600	314.7306	28.3663
5.	0.0800	314.9133	29.8879
6.	0.1000	315.0896	31.8217
7.	0.1200	315.2582	34.1515
8.	0.1400	315.4178	36.8580
9.	0.1600	315.5676	39.9196
10.	0.1800	315.7068	43.3127
11.	0.2000	315.8349	47.0123
12.	0.2200	315.9519	50.9928
13.	0.2400	315.8131	54.9558
14.	0.2600	315.6534	58.5745
15.	0.2800	315.4763	61.8053
16.	0.3000	315.2855	64.6125
17.	0.3200	315.0839	66.9684
18.	0.3400	314.8743	68.8516
19.	0.3600	314.6589	70.2466
20.	0.3800	314.4398	71.1426
21.	0.4000	314.2186	71.5332
22.	0.4200	313.9971	71.4156
23.	0.4400	313.7766	70.7906
24.	0.4600	313.5590	69.6626
25.	0.4800	313.3460	68.0401
26.	0.5000	313.1397	65.9358
27.	0.5200	312.9427	63.3678
28.	0.5400	312.7577	60.3604

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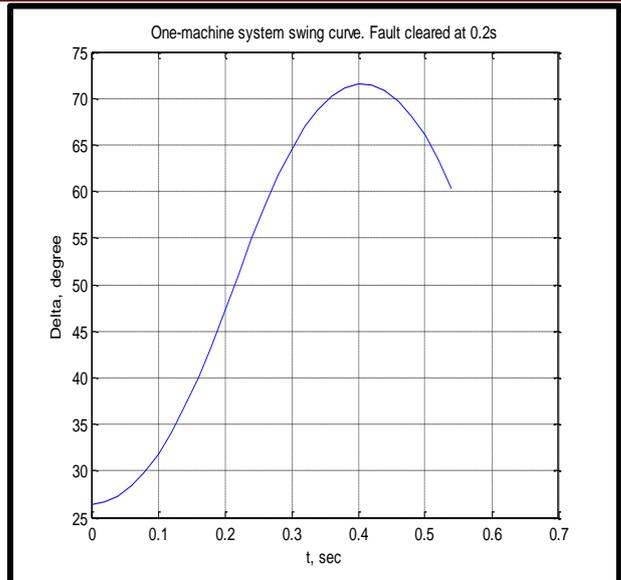


Figure 5: Swing Curve of SMIB for Stable Case

For stable case, the following parameters were used in per unit.  $P_m = 0.8, E = 1.17, V = 1, X_1 = 0.65, X_2 = 1.8, X_3 = 0.8, H = 5, f = 60, \Delta t = 0.02, t_c = 0.2, t_f = 0.54.$

**TABLE 2: Results for Critical Stable Case.**

Fault is cleared at 0.4 Sec.

Searching with a final time of 0.80 Sec  
 Critical clearing angle = 98.83 degrees

S/N	TIME	DW	DELTA
	S	RAD/S	DEGREES
1.	0	314.1593	26.3878
2.	0.0200	314.3520	26.6086
3.	0.0400	314.5430	27.2700
4.	0.0600	314.7306	28.3663
5.	0.0800	314.9133	29.8879
6.	0.1000	315.0896	31.8217
7.	0.1200	315.2582	34.1515
8.	0.1400	315.4178	36.8580
9.	0.1600	315.5676	39.9196
10.	0.1800	315.7068	43.3127
11.	0.2000	315.8349	47.0123
12.	0.2200	315.9519	50.9928
13.	0.2400	316.0578	55.2285
14.	0.2600	316.1531	59.6945
15.	0.2800	316.2385	64.3671
16.	0.3000	316.3152	69.2248
17.	0.3200	316.3843	74.2488
18.	0.3400	316.4476	79.4236
19.	0.3600	316.5067	84.7376
20.	0.3800	316.5638	90.1836
21.	0.4000	316.6210	95.7591
22.	0.4200	316.3780	101.1179
23.	0.4400	316.1444	105.9286
24.	0.4600	315.9226	110.2162
25.	0.4800	315.7142	114.0103
26.	0.5000	315.5196	117.3425
27.	0.5200	315.3387	120.2445
28.	0.5400	315.1708	122.7474

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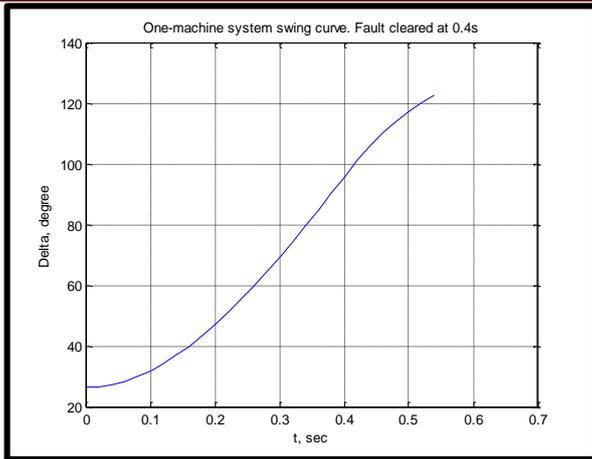


Figure 6: Swing Curve for Critically Stable Case

For this case, the following parameters were used, all in per unit.  $P_m = 0.8$ ,  $E = 1.17$ ,  $V = 1$ ,  $X_1 = 0.65$ ,  $X_2 = 1.8$ ,  $X_3 = 0.8$ ,  $H = 5$ ,  $F = 60$ ,  $\Delta t = 0.02$ ,  $t_c = 0.4$ ,  $t_f = 0.54$ .

The program was executed and the following results were recorded.

TABLE 3: Results for Unstable Case.

Fault is cleared at 0.45 Sec.

Critical clearing time = 0.80 seconds  
 Critical clearing angle = 98.83 degrees

S/N	TIME (t) s	SPEED (dw) Rad/s	DELTA (d) degrees
1.	0	314.1593	26.3878
2.	0.0200	314.3520	26.6086
3.	0.0400	314.5430	27.2700
4.	0.0600	314.7306	28.3663
5.	0.0800	314.9133	29.8879
6.	0.1000	315.0896	31.8217
7.	0.1200	315.2582	34.1515
8.	0.1400	315.4178	36.8580
9.	0.1600	315.5676	39.9196
10.	0.1800	315.7068	43.3127
11.	0.2000	315.8349	47.0123
12.	0.2200	315.9519	50.9928
13.	0.2400	316.0578	55.2285
14.	0.2600	316.1531	59.6945
15.	0.2800	316.2385	64.3671
16.	0.3000	316.3152	69.2248
17.	0.3200	316.3843	74.2488
18.	0.3400	316.4476	79.4236
19.	0.3600	316.5067	84.7376
20.	0.3800	316.5638	90.1836
21.	0.4000	316.6210	95.7591
22.	0.4200	316.6805	101.4671
23.	0.4400	316.7450	107.3159
24.	0.4600	316.8171	113.3196
25.	0.4800	316.8254	119.1762
26.	0.5000	316.4600	124.6221
27.	0.5200	316.3232	129.7206
28.	0.5400	316.2167	134.5397

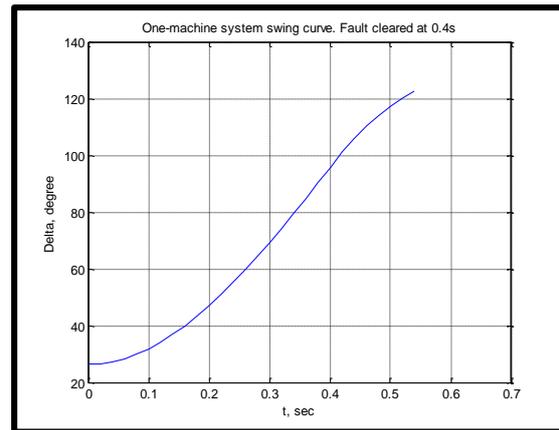


Figure 7: Swing Curve for Critically Stable Case

For this case, the following parameters were used, all in per unit.  $P_m = 0.8$ ,  $E = 1.17$ ,  $V = 1$ ,  $X_1 = 0.65$ ,  $X_2 = 1.8$ ,  $X_3 = 0.8$ ,  $H = 5$ ,  $F = 60$ ,  $\Delta t = 0.02$ ,  $t_c = 0.4$ ,  $t_f = 0.54$ .

The program was executed and the following results were recorded.

Case 1; Unstable

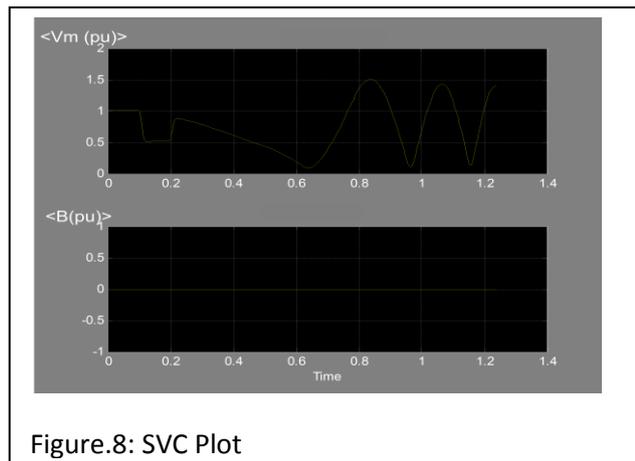


Figure 8: SVC Plot

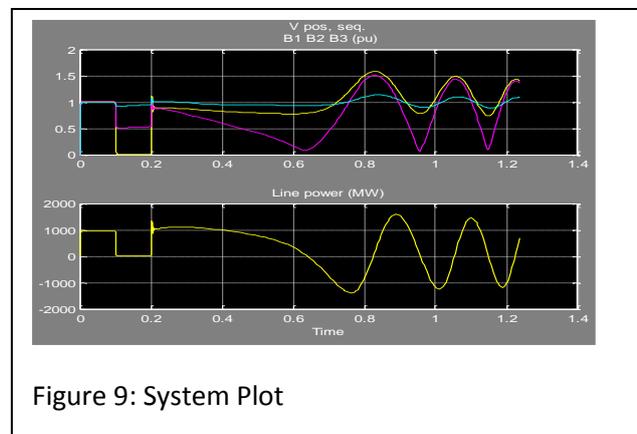


Figure 9: System Plot

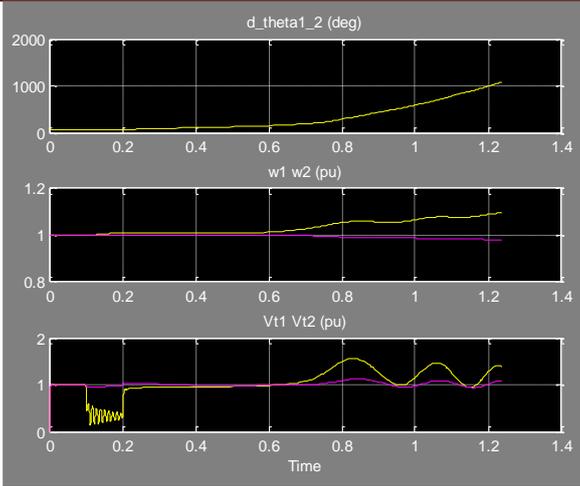


Fig. 10; Machines Plot

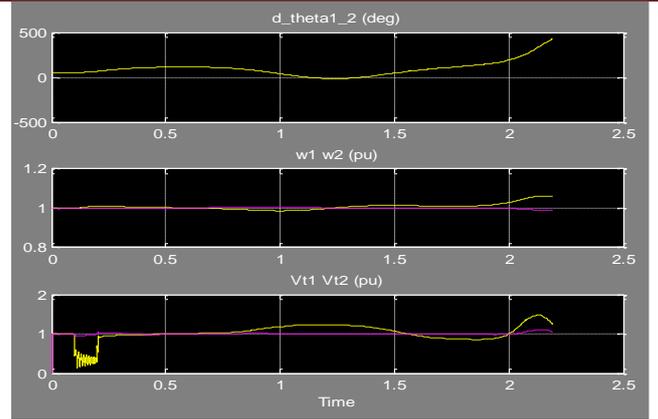


Fig. 13; Machine Plot

Case 2; Unstable

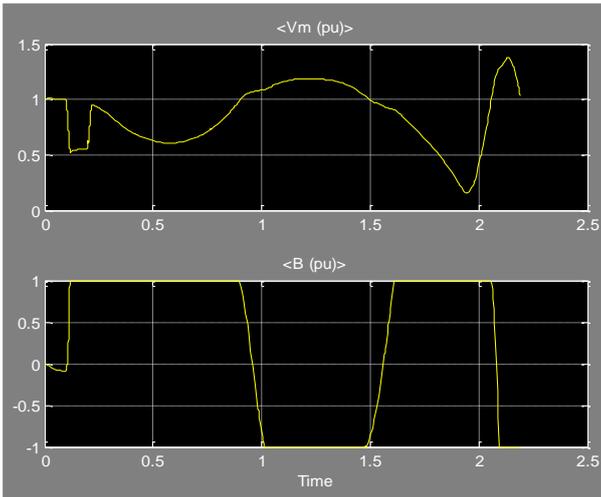


Fig. 11: SVC Plot

Case 3; Stable case

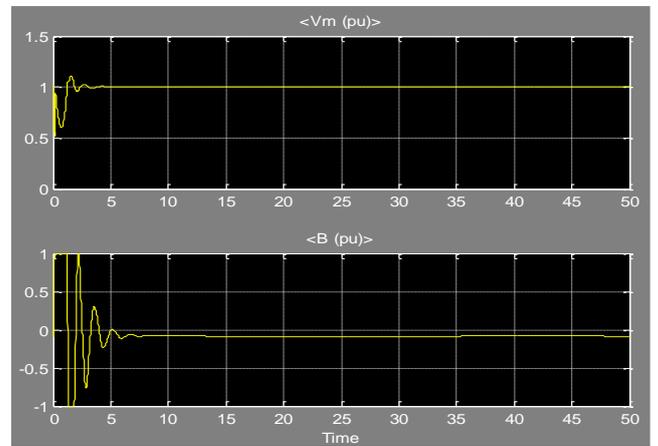


Fig. 14; SVC Plot

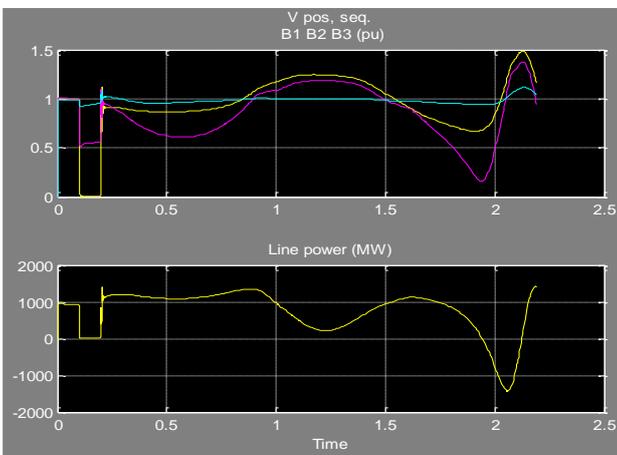


Fig. 12: System Plot

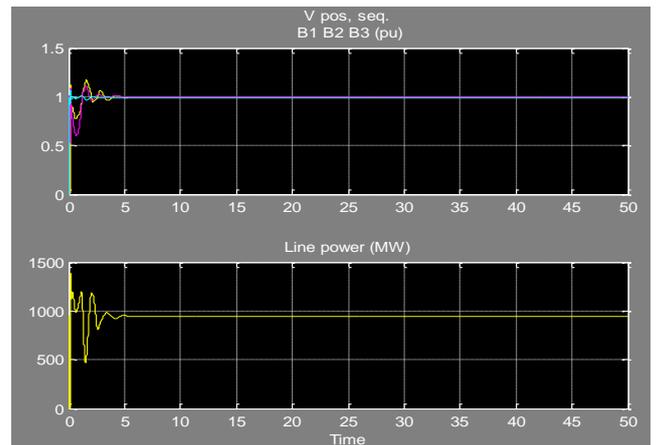
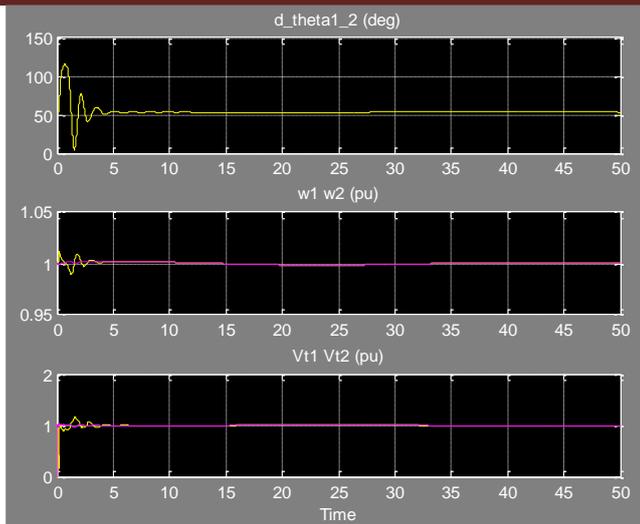
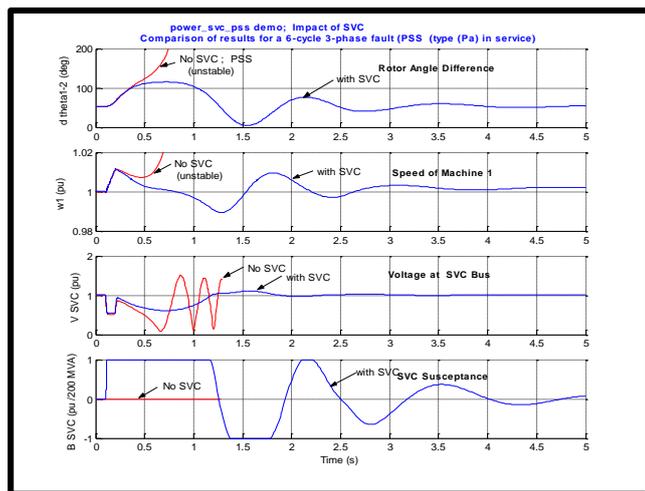


Fig. 15; System Plot



**Fig. 16: Machine Plot**

**RESULTS OF SIMULATION and ANALYSIS**



**Fig. 17: Impact of SVC and PSS For Three Phase Fault**

The results are:

- To stabilize the system thereby enhancing global stability of large interconnected power system.
- Transient was analyzed and better results obtained in a simple approach.
- This is because of high efficiency and desirable effect – both in the improvement of setting time and damping of oscillation created as a result of the 3-phase fault.
- Development of simulations and test cases using matlab code was achieved.

The incorporation of PSS and SVC to the power system network during fault situation made the transient stability to be effective.

- Simulation model of Modified Humpage Power System employing matlab software was achieved.
- Improved Voltage control, damping of oscillation and transient stability of the single machine infinite bus power system.
- Protective components should be subjected to predictive, preventive and routine maintenance and replaced appropriately.
- Transmission line system networks should be subjected to planned and routine maintenance.
- In all power system networks, it is necessary to introduced both PSS and SVC for system to remain stable after undergoing a transient fault and power oscillation damping.

**CONCLUSION**

The Swing Curves as shown chapter four show that the transient stability of a power system has been determined. The similarity of these curves to those determined by earlier stability studies confirms the accuracy of the model and formation of system equation. For transient stability to be effective, during fault situations, both PSS and SVC should be incorporated in the power system network. As can be seen from the simulation, the system is naturally unstable without PSS and SVC even for small disturbances. After incorporating the PSS and SVC, the system became stable with a 3phase fault.

These results can be effective in planning or operation of power systems because in all stability studies, the aim is to determine machines rotor angle being disturbed returns to constant speed operation.

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