System Model Stability Studies Of A Single Line, Double Line And Three Phase To Ground Faults, Using Humpage Modified Power System

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Abstract- This work involves stability study of a power system using Humpage modified model. Humpage modified model of power system is a single machine equivalent of power system, through transmission network connected to infinite busbar, with control. The target of every power engineer is to obtain hundred percent stability in power systems, but this has never been achieved. That is why, stability studies in power systems has been a topic of concern in everyday research. In this work, a three phase, double line and single line to ground faults were respectively inflicted on the generator busbar of the test system and cleared after sometime. Runge kutta 4thorder integration method was used to provide the evolution of the generator's rotor angle(□) for each fault. Afterobtaining the electric power with the system equation, the steady state of the system was confirmed using Gauss-seidal load flow method. Afterwards, the line was compensated using static VAR compensator (SVC) and power system stabilizer (PSS) to enhance the stability and damping. Model simulation was done with sympowersystem in matlab environment and the results analyzed. The tendency of the rotor angle vs time curves was used to determine the in(stability) of the system. The transient stabilities of the single line to ground, double line to ground and three phase faults were simulated to study the effects of the power system stabilizers (PSS) and static VAR compensation (SVC) on the introduction of the different faults on three different occasions (a) when neither PSS and SVC is on during fault (b) when only PSS is on and (c) when both PSS and SVC are on.

Critical clearing time (CCT) results obtained through statistical recognition. For the three phase fault, the classical CCT was 0.6308 seconds over a period of 24secs, 0.4995 secs over a period of 15secs and 0.4460 sec in 12 secs to 0.4862 for 7.4 secs and 0.4000 sec for 5 secs. This is the most severe fault, followed by the double line to ground fault whose CCT is 0.8754 sec and the last being the single line to ground fault whose CCT was found to be 1.89sec. Examining also the different plotsof rotor angle versus time for the different faults at the three different occasions, the same is shown in the plots.

I. INTRODUCTION

STABILITY OF A POWER SYSTEM

Stability of power system is that property of a power system to operate in a steady, equilibrium state without any disturbance. Even, if there is any form of disturbance, the power system develop, restoring and damping forces that will bring the disturbance to rest and re-instate the system to its normal, steady and equilibrium state (Mohamad, 2013).

Stability is also seen in, terms of when generators run in synchronization. When generators or motors are connected to existing supply i.e synchronized, they are said to be stable. However at the occurrence of swing, machine may run at a different speed and acceleration and consequently at a different frequency other than the synchronous frequency, thus making the machine to fall out of step. In this case, the machine runs out of synchronism or loses stability (Gupta 2001).

Disturbances may comein form of voltage surge, variations in load, switching operations, lightning discharge, loss of excitation, faults etc. these disturbances bring about swing through the busbar and the swing in turn leads to loss of synchronism or falling out of step of a machine which generally affects the whole system and make it unstable. Power system stability are generally categorized into three, namely (a) steady-state stability (b) transient stability and (c) Dynamic stability (Tamura et al, 2011).

There is this ability of a power system to develop restoring forces equal to or greater thanthe disturbance following a small disturbance in form of load variations. If increase in loading takes place gradually and in small steps and the system withstands this change and performs satisfactorily, then the system is said to be in steady state stability.

Steady state stability often involves a range from single machine equivalent to a few machines connected to infinite busbar, undergoing small disturbances. The study includes the behaviour of the machine under small changes in operating conditions about an operating point on small variation in parameters (mahran, Hogy 1992). When the disturbances are relatively larger or when faults occur on the system, the system enters transient state. Generally, this is the ability of a power system to maintain synchronism when subjected to a severe, large disturbance such as the occurrence of fault, sudden line outage or sudden application of loads. These disturbances are accompanied by excursions of generator rotor angles and is influenced by non-power angle relationship. Here, the rotor angular differences, rotor speeds and power transfers undergo fast changes which are still dependent on the magnitude of the disturbance.For alarge disturbance, changes in angular differences may be so large as to cause the machine to fall out of step. This is referred to as transient instability (Pavela et al 2000).

Transient stability usually occurs within a second if the generator is close to a fault point. At the occurrence of the fault, the electrical power from the most nearby generator is reduced and the power from other generators remains unaltered. There is a resultant difference in acceleration due to the power and this produces speed difference over the time interval of the fault. It is important to clear the fault as soon as possible. This fault clearing removes one or more transmission elements and weakens the system. The changesin transmission system produce change in generator rotor angles. If the changes are such that the accelerated machines pick up additional loads, they slow down and a new equilibrium position is reached. Here our study is limited to a single machine connected to infinite busbar. At the introduction of the faultsin turn, i.e the double to ground (L,LG) the single line to ground (L-G) and the three phase to ground (L-L-G) faults, the electrical power reduced and consequently a resultant difference in the accelerationand speed difference over a time interval.

Furthermore, a power system has the ability to maintain synchronism after initial swing until the system settles down to a new steady state equilibrium conditions. A t the elapse of sufficient time,the governors of the prime movers will react to increase or reduce energy input, re-establishing a balance between energy input and the existing electrical load. This is referred to as dynamic stability.

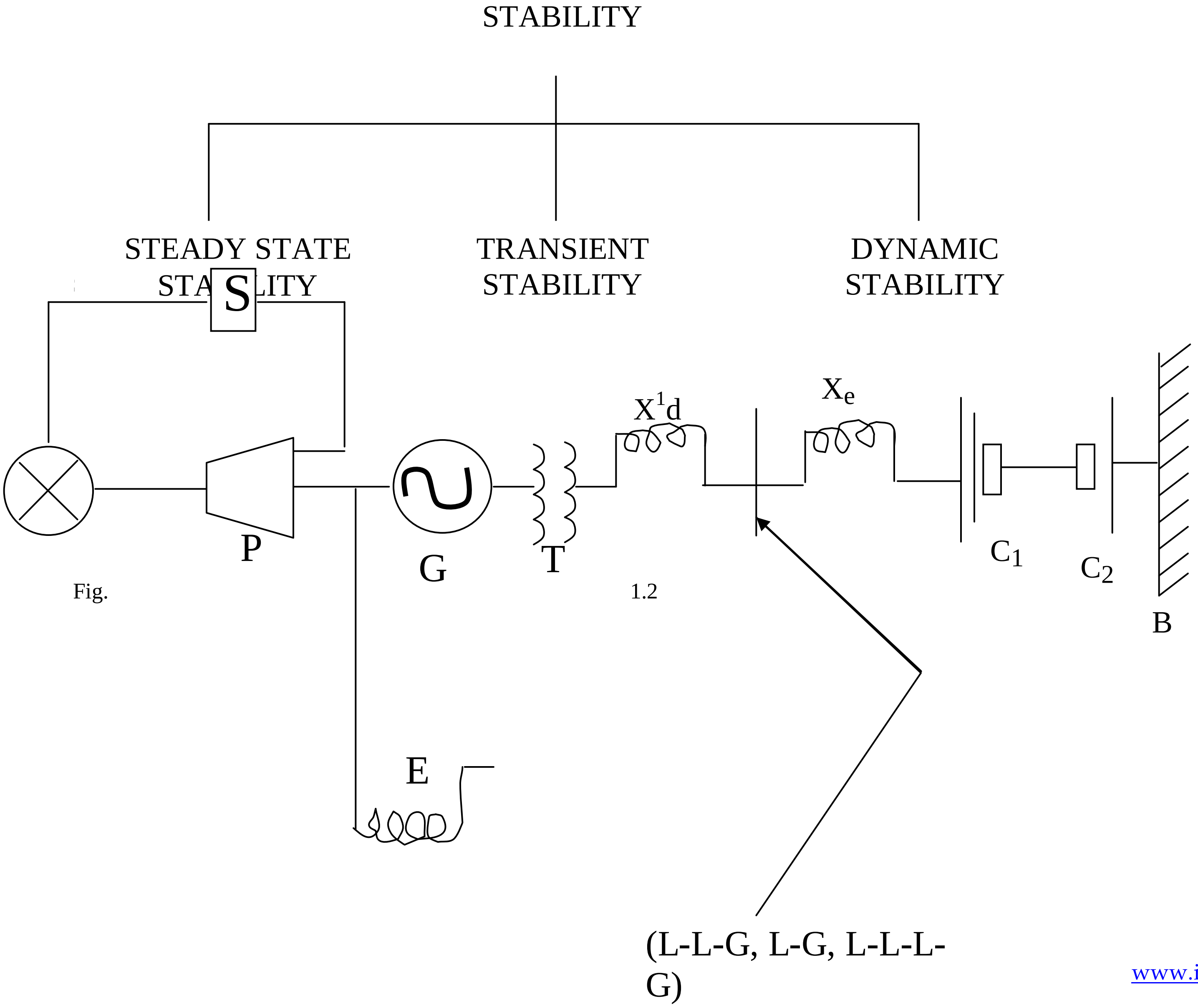

Fig. 1.2

Fig. 1.1 Power System Stability

The humpage power system is simply a system consisting of a source through transmission network to infinite busbar. Here G is the synchronous Generator for power production, P is the prime mover or turbine, S is the governor, E is the exciter that provides D.C. excitation, T is a high voltage transformer used for power transmission at a high voltage, X^1d and Xe are the internal reactance and the transmission network reactance respectively. C1 and C2 are high voltage circuit breakers, all connected to infinite busbar B.

CONCEPT OF THE ROTOR ANGLE (□)

We consider machines in terms of their input and output powers. Generators and motors are always compared because both have same constructional features but operate differently. In the case of a generator, the input is a mechanical torque while the output is an electromagnetic torque, T_E. In the case of a motor, the input is electromagnetic torque while the output is a shaft torque Ts. Under normal working condition, the relative position of the rotor axis and the stator magnetic field axis is fixed. The angle between the two is called the load or rotor angle (□) which depends upon the loading of the machine. The larger the load, the larger the load angle. The equation giving the relative motion of the rotor with respect to the stator field is called the swing equation.

SWING EQUATION

The swing equation is given as

$$M \quad \frac{d^2\square}{dt^2} \quad = \quad P_m - P_e$$

$$M \quad \frac{d^2\square}{dt^2} \quad = \quad P_m - P_{max} \, Sin \, \square$$

Where M is the Genera tor's inertia constant, P_m = Generator's shaft mechanical power, P_{max} = peak power for the power angle, P_E = electrical power = P_{max} sin □.

ENHANCEMENT USING SVC

In this paper, static VAR controller is proposed to enhance transient stability for the power system. A single bus system which contains a generator and static VAR compensator (SVC) is considered. The SVC is located at the mid-point of the transmission line. An interconnected power system consists of several essential components. They are namely; the generating unit, the transmission line, the load, the transformer, SVC etc. During the operation of the generators, there may be some disturbances such as sustained oscillation in speed or periodic variationinthe torque that is applied to the generator – stability enhancement is of great importance in power system design. Excitation control and static VAR compensator play important roles in stability enhancement of power systems. The SVC is located at the mid-point of transmission lines.

THEORY OF POWER SYSTEM STABILIZER (PSS)

The basis of a power system s stabilizer is to add damping to the generator oscillation by using auxiliary stabilizing signal(s). To provide damping, the stabilizer must produce a component of electrical torque in phase with the rotor speed variation.

This is achieved by modulating the generator excitation so as to develop a componentof electrical torque in phase with rotor speed deviation.

II. METHOD AND MATERIAL

- A disturbance or short-circuit was introduced in the busbar in form of (L-G), (L-L-G) and (L-L-L-G) and the faults were cleared after some time (t).
- Runge-kutta 4th order integration method was used to provide the evolution of the rotor angle (□).
- The electrical power (P_e) was obtained using the system equation.

$$Pe = \frac{|E^1|V}{X^1d+Xe} \qquad Sin\square$$

Where E^1 = Generator's terminal voltage

V = voltage at the infinite busbar which is I.P.U. X^1_d = Internal reactance of the generator, X_e = transmission network reactance, □ = rotor angle

- The steady state of the system was confirmed using Gaus – seidal load flow method
- The lines were compensated using SVC and Pss.
- The model was simulated

2.1 RESULTS

In this chapter, Humphage model equipped with static variable compensator in the middle of the transmission line is simulated with simpowersystem. Critical clearing time of this non linear model is estimated with statistical pattern recognition. Classical model of this Humphage model is used to compute this critical clearing time using Equal Area Criteria with 4th oder Runge Kutta numerical method, simulation is done matlab in environment.

SIMULATION OF HUMPHAGE MODEL WITH SIMPOWERSYSTEM

Various component of the modified humphage model of single machine to infinite busbar fig.2.1 have been modeled by simpowersystem as have been shown in chapter three. These components include the turbine synchronous generator, the power system stabilizer (PSS), static variable compensator (SVC), the transformer, and the transmission line. This system has been configured as shown in fig. 2. 1.

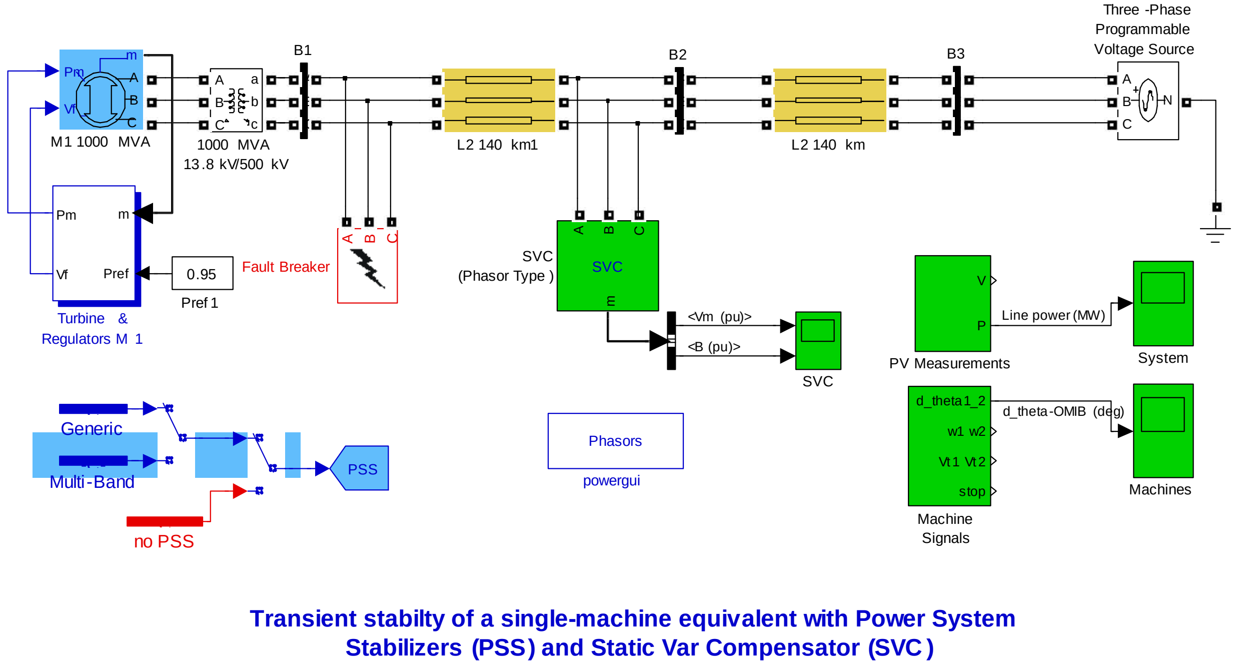

Figure 2.1: single-machine equivalent with Power System Stabilizers (PSS) and Static Var Compensator (SVC)

LOADFLOW SIMULATION

The power in the simpowersystem configuration solves the load flow through initial guess of the load flow and then iterates to get the actual load flow values at the machine terminals and buses, other quantities like the machine rotor angle, machine terminal voltage and current flowing in all the phases during steady state are also solved. All the required initialization quantities are then keyed in for transient stability simulation. Some of these calculated quantities like the initial rotor angle, the machine terminal power and voltage are used to calculate the electrical power developed by the generator which will ultimately be used to estimate the critical clearing time of faults using classical single machine model. Results of the load flow simulation are as shown

Table 2.1: Load Flow Initialization

Machine:	M1 1000 MVA
Nominal:	1000 MVA 13.8 kV rms
Bus Type:	P&V generator
Uan phase:	-3.62°
Uab:	13800 Vrms [1 pu] 26.38°
Ubc:	13800 Vrms [1 pu] -93.62°
Uca:	13800 Vrms [1 pu] 146.38°
Ia:	39784 Arms [0.9509 pu] -6.16°
Ib:	39784 Arms [0.9509 pu] -126.16°
Ic:	39784 Arms [0.9509 pu] 113.84°
P:	9.5e+008 W [0.95 pu]
Q:	4.2114e+007 Vars [0.04211 pu]
Pmec:	9.5258e+008 W [0.9526 pu]
Torque:	5.0536e+007 N.m [0.9526 pu]
Vf:	1.4675 pu

Init. Cond. [dw(%) th(deg) ia, ib, ica(pu) pha, phb, phc,(deg) Vf(pu)]
= [0 -69.8601 0.950933 0.950933 0.950933 -6.15745 -126.157 113.843 1.46747]

Table 2.2 CRITICAL CLEARING TIME RESULT OBTAINED THROUGH PATTERN RECOGNITION

H(sec)		24	15	12	7.4	5
Three phase to ground Fault	SPL(SVC NO) CCT	0.5985	0.4910	0.4467	0.3663	0.3142
	SPL(SVC ON) CCT	0.5995	0.4953	0.4516	0.3705	0.3181
	% CCT time gain by SVC	-0.1671	-0.8758	-1.0969	-1.1466	-1.2412
	Classical CCT estimation	0.6308	0.4995	0.4460	0.3514	0.2888
	Classical CCT error	-5.3968	-1.7312	0.1567	4.0677	8.0840
Double phase to ground Fault	SPL(SVC NO) CCT	0.8545	0.6842	0.6124	0.4897	0.4094
	SPL(SVC ON) CCT	0.8600	0.6905	0.6205	0.4952	0.4132
	% CCT time gain by SVC	-0.6437	-0.9208	-1.3227	-1.1231	-0.9282
	Classical CCT estimation	0.8754	0.6921	0.6194	0.4862	0.4000
	Classical CCT error	-2.4459	-1.1546	-1.1430	0.7147	2.2960
Single phase to ground Fault	SPL(SVC NO) CCT	2.115	1.556	1.427	1.001	0.832
	SPL(SVC ON) CCT	—	—	—	—	—
	% CCT time gain by SVC	—	—	—	—	—
	Classical CCT estimation	1.89	1.494	1.336	1.049	0.8625
	Classical CCT error	10.6383	3.9846	6.3770	-4.7952	-3.6659

III. RESULT OF SIMULATION

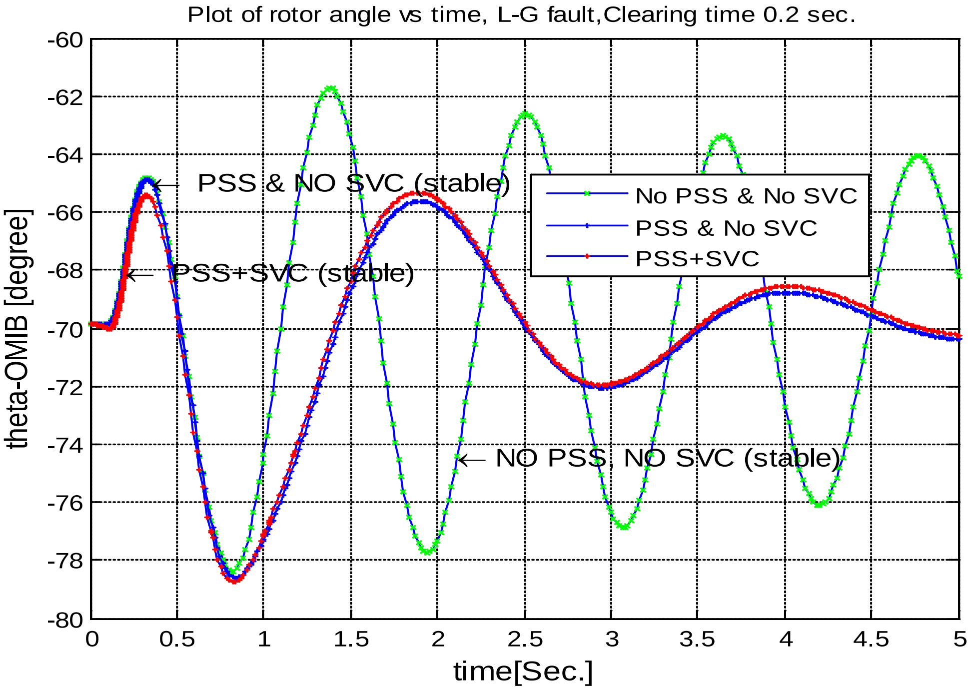

Fig. 3.1

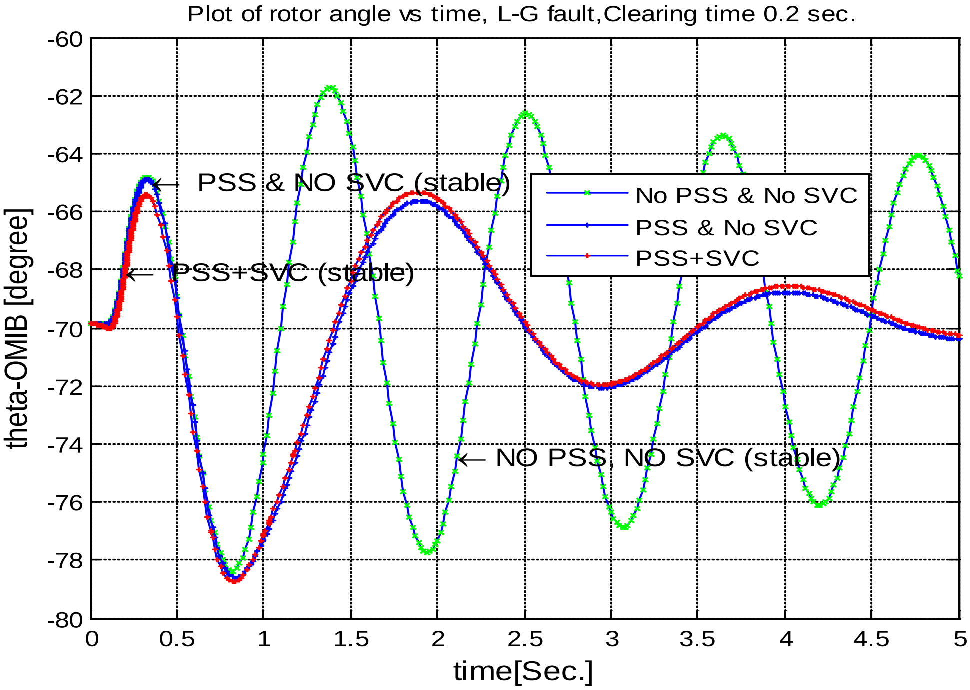

Figure 3.2: plot of rotor angle versus time for single line to ground fault

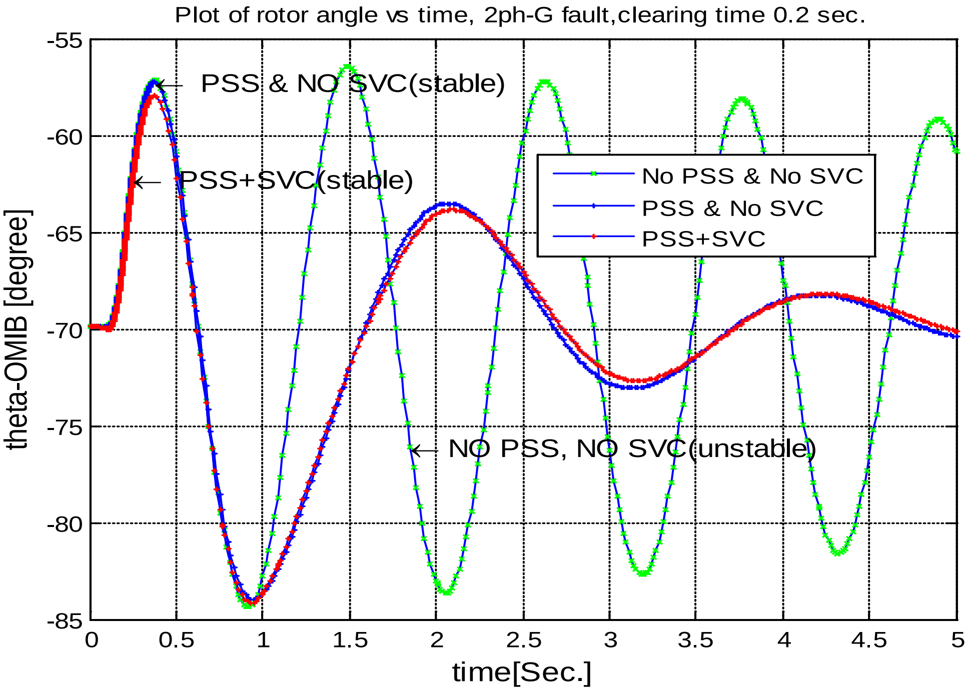

Figure 3.3: plot of rotor angle versus time for double phase to ground fault

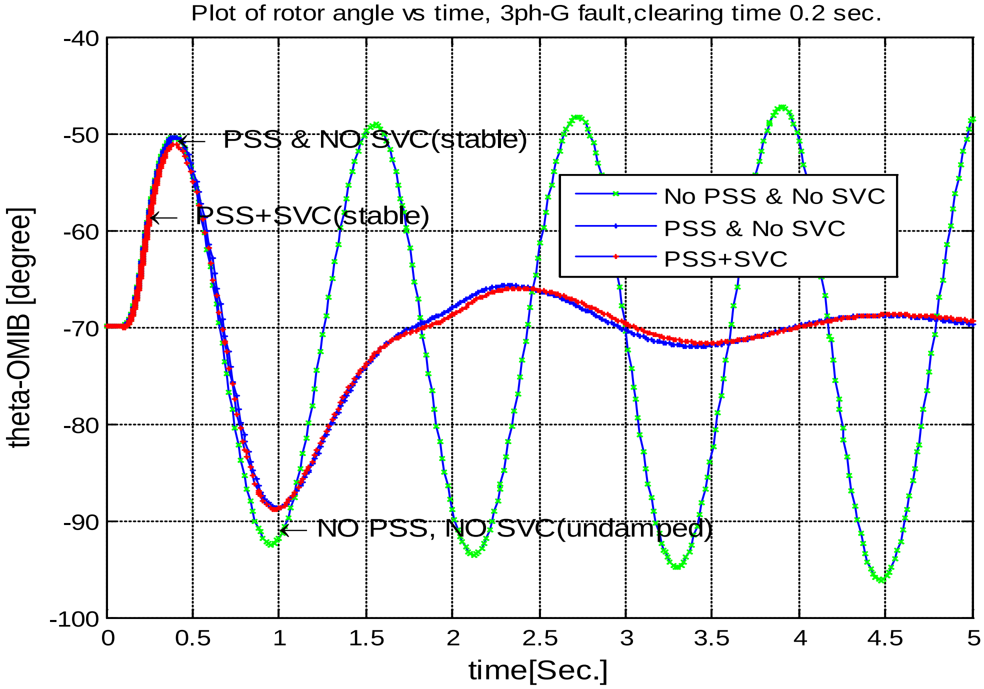

Figure 3.4: plot of rotor angle versus time for three phase to ground fault

Rotor angle – time response for SIME, PSS & No SVC at clearing time of 0.3663 Sec.

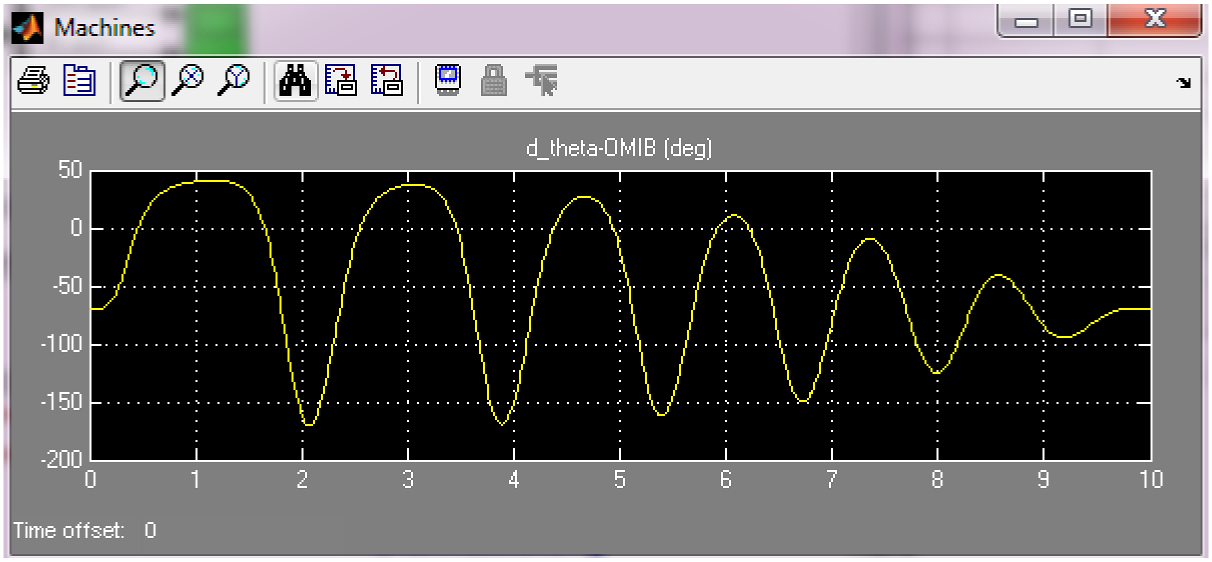

Figure 3.5: 3Φ-GRotor angle – time response for SIME, PSS & No SVC at clearing time of 0.36635 Sec

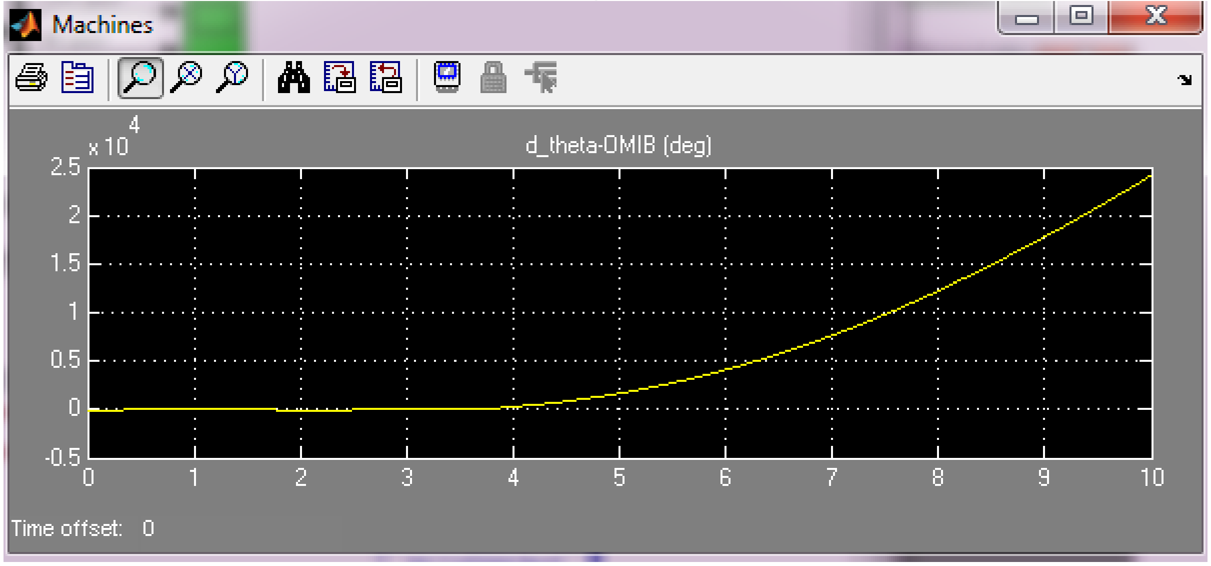

Figure 3.6: 3Φ-GRotor angle – time response for SIME, PSS & No SVC at clearing time of 0.3664 Sec

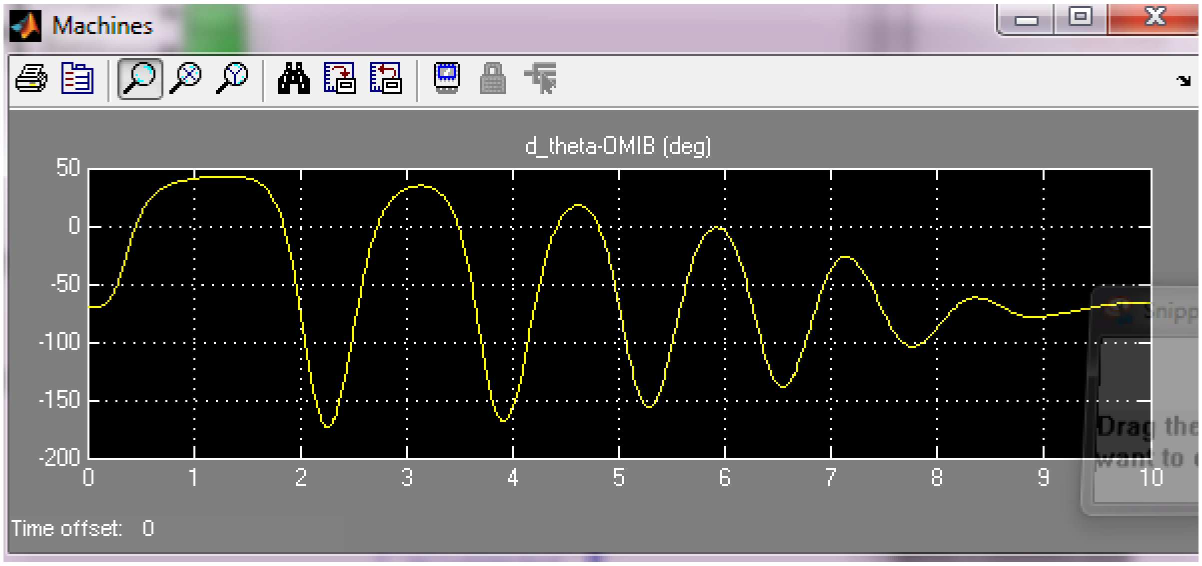

Figure 3.7: 3Φ-GRotor angle – time response for SIME, PSS & SVC ON at clearing time of 0.3705 Sec.

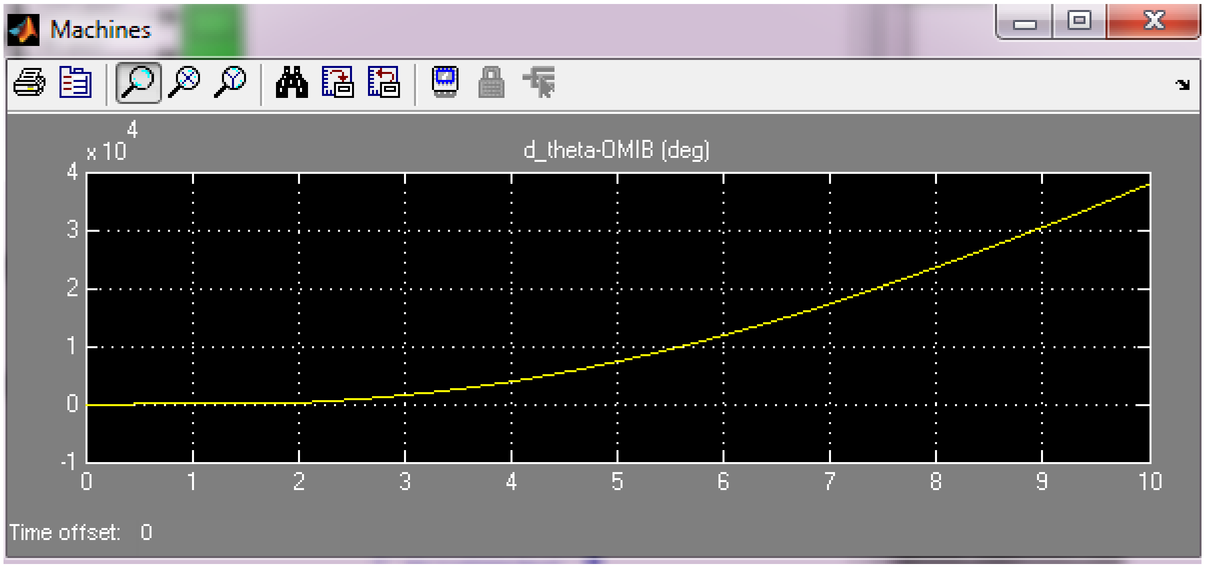

Figure 3.8:3Φ-GRotor angle – time response for SIME, PSS & SVC ON at clearing time of 0.3706 Sec.

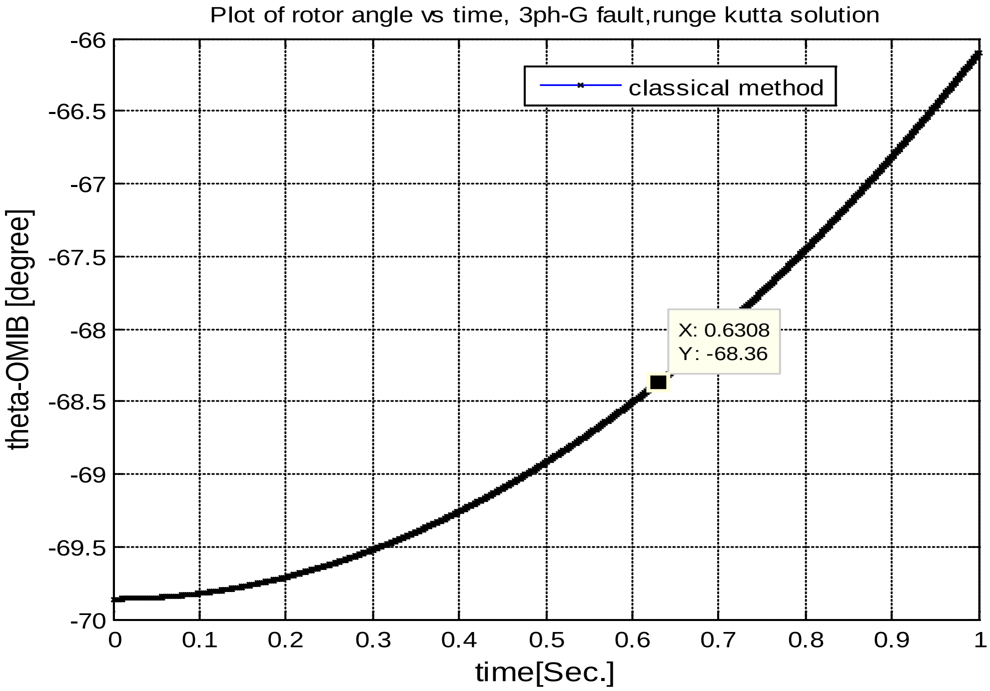

Figure 3.9: plot of rotor angle versus time (runge kutta solution), 3Ph-G, H=24 sec

IV. CONCLUSION

In this transient stability studies of a machine connected to infinite busbar using modified Humpage model for double line to ground fault and single line to ground fault, the Humapage model was equipped with static variable compensator in the middle of the transmission line. This was the first stage of enhancement and the line was simulated with sympower system. Also the classical model was used to compute the critical clearing time using equal area criteria with the order Runge Rulta numerical method, simulation was done in matlab environment.

Although the scope is not meant to go beyond the introduction of double line to ground and single line to ground fault, I found it necessary to also include the three phase to ground fault because this will help me to draw a good comparative analysis. In the fault analysis, different types of faults were introduced at the busbar and the fault were analysed. The results show that during fault voltages and currents, the system is greatly affected by the three phase to ground fault. Here the classical critical clearing time estimation for the three phase to ground fault was found to be 0.6308 sec followed by the classical critical clearing time for the double line to ground fault which was estimated to be 0.8754sec and lastly the single line to ground fault has its classical critical clearing time to be 1.89 sec.

From the above extract, it becomes imperative to say that the three phase to ground fault is the most severe fault on the transmission system followed by the double line to ground fault. The last severe fault is the single line to ground fault.

REFERENCES

[1] Anderson, P.M. (2000). Analysis of faulted power system, Lowa State University press New York

[2] Anderson, P.M. and Fouad, A.A. (1995). Power system control and stability. The IEEE press.

[3] Armando, L. Jaime, D.L. (2010). Stability and transient Energy method for the classroom, IEEE centre for power engineering.

[4] Ankit Jha (2008 -09)

[5] Bablesh, K.J. Gupta, R.P. and Upendra, P. (2014). Combine Operation of SVC, PSS and Increasing Inertia of machine for power system transient stability enhancement .

[6] Bickford, J.P. and Reed, J.R. (1976). Computation of Power System Transient,

[7] Bollen,M.H.J.(2000). Power quality problems, voltage sags and interruption. IEEE Press New York.

[8] Chatter JEE D. Ghosh, A (2007) Transient stability Assessment of power system containing series sand shunt compensators IEEE Trans ‘ on power system.

[9] Dandeno, P.L. Karas, A.N. McClymont, K.R. and Waston W, (1968). Effect of high speed Rectifier Exicaiton system on Generator stability limits, IEEE Trans, vol. 1968.

[10] Dong, Y. Pota H.R. (2011) Transient stability Margin prediction using equal Area criterion IEEE.

[11] Dugan, R.C. et al (2004). Electrical Power system quality, McGraw-Hill, New York, USA 2004.

[12] Elgerd, O.I. (1970). Electric energy system theory, McGraw-Hill, New York.

[13] Haque, M.H. (2008). Evaluation of first Swing stability of a large power system with various FACTs Devices IEEE Trans 2008.

[14] I Gupta, B.R. (1999). Power system analysis and design wheeler publisher.

[15] IEEEJ, (1999). Technical Committee, standard models of power system IEEJ report.

[16] Karami, A. (1990). Power system transient stability merging estimation using neural networks Electrical power and energy system.

[17] Lucas JR (2005) Power system fault analysis.

[18] Lyambo, P.K. Izonova R. (2007). Transient stability Analysis of IEEE 14 bus Electrical Power System. IEEE conf.

[19] Micheal, J.B. and Richard C.S. (2005). Understanding power system stability.

[20] MO, N. Zou Zy, Chan K.W. and Pong T.Y. (2007). Transient stability constrained optimal power flow using particles warm optimization" IET Generation, Transmission Distribution.

[21] Morison, G.K. Guo, B. and Kundur P. (1993). Voltage stability analysis using static and dynamic approaches "IEEE Trans.

[22] Murthy P.S.R. (2007). Power system analysis B.S Publication USA.

[23] Nur A,M. (2013) Power system matlab software.

[24] Nur, M.D. Mehdi, H.S. Muhit M.S. and Hassam MH. (2014). Fault analysis and Electrical protection of Distribution Transformer.

[25] Savulescu, S.C. (2009). "Real time stability assessment in modern power system control centers.

[26] Sulistiawati I.B. amd Abdullah M. Adis (2012). Prediction of critical clearing time of Java -Bali 500kv power system under multiple Bus Load changes using Neural Network Base Transient Stability.

[27] Tamurd, S. Murata, T. and Takeda I. (2011). New Approach For steady state stability Analysis of synchronous machine IEEE transaction on energy conversion.

[28] Tang C.K. (1993). Transient stability index from conventional Time domain simulation IEEE PES.

[29] Wagner C.F, Evans R.D. (1933). Symmetrical component McGraw-Hill, New York. P 442.

[30] W.D. Stevenson (1982). Elements of Power system analysis McGraw-Hill, New York.

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