Transient stability enhancement of 30 bus multi- machine systems by using PSS & increasing inertia

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Abstract: In this paper the transient stability enhancement of a 30- bus multi-machine system by using Power system stabilizer and increasing inertia has been observed, as single method is not sufficient for this purpose. We have created a three phase fault at time 0.04 seconds at bus 7 and cleared at time 0.5 seconds. On implementing PSS and on increasing the inertia of the machine we achieved a better response in terms of power swing when compared with initial condition. The inertia of the machine is kept within a certain limit. And 30 bus multi-machine system maintain its own permissible operating condition.

Keyword: Transient Stability, PSS, Inertia, Three Phase Fault

1. Introduction

Power system stability of modern large inter-connected systems is a major problem for secure operation of the system. Recent major black-outs across the world caused by system instability, even in very sophisticated and secure systems, illustrate the problems facing secure operation of power systems. Stability is defined as the ability of a system to return to its normal or stable operation after having been subjected to some form of disturbance.
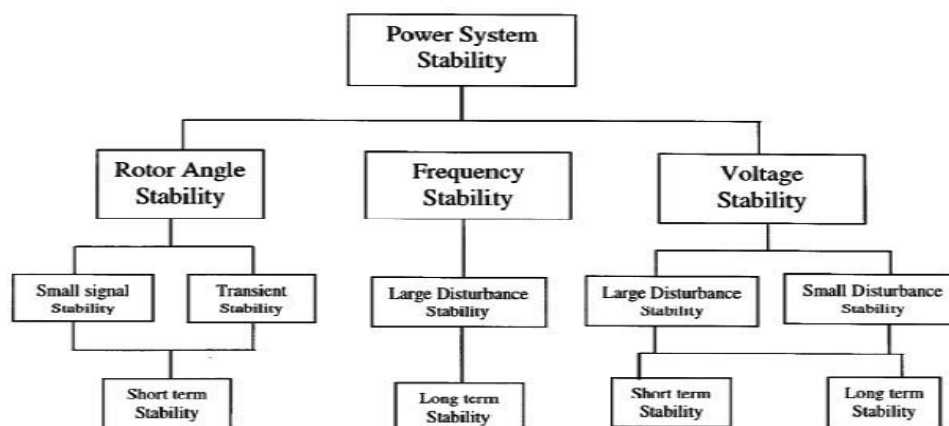

Figure 1. Classification of power system stability [1].

This mainly refers to the ability of the system to remain in synchronism. However, modern power systems operate under complex interconnections, controls and extremely stressed conditions. Further, with increased automation and use of electronic equipment, the quality of power has gained more importance, shifting focus on concepts of voltage stability, frequency stability, inter-area oscillations etc.

For the purpose of analysis the power system stability is sub divided into two major categories
i) Steady state stability. &
ii) Transient stability.

Steady-state stability refers to the ability of the power system to regain synchronism after small and slow disturbances, such as ground power changes. An extension of the steady-state stability is known as the dynamic stability. Transient stability studies deal with the effects of large, sudden disturbances, such as the occurrence of the fault, the sudden outage of a line

Transient stability of a power system is its ability to maintain synchronous operation of the machines when subjected to a large disturbance. The occurrence of such a disturbance may result in large excursions of the system machine rotor angles and, whenever corrective actions fail, loss of synchronism results among machines. Generally, the loss of synchronism develops in very few seconds after the disturbance inception.[2]

1.1. Transient Stability Analysis

The power system is almost regularly subjected to a variety of disturbances. Even the act of switching on an appliance in the house can be regarded as a disturbance. However, given the size of the system and the scale of the perturbation caused by the switching of an appliance in comparison to the size and capability of the interconnected system, the effects are not measurable. Large disturbance do occur on the system. These include severe lightning strikes, loss of transmission line carrying bulk power due to overloading. The ability of power system to survive the transition following a large disturbance and reach an acceptable operating condition is called transient stability.

Any disruption in the system will cause the imbalance between the mechanical power input to the generator and electrical power output of the generator to be affected. As a result, some of the generators will tend to speed up and some will tend to slow down. If, for a particular generator, this tendency is too great, it will no longer remain in synchronism with the rest of the system and will be automatically disconnected from the system. This phenomenon is referred to as a generator going out of step.

E-Tap allows the user to reduce very large and complex power systems into simple one line diagram and performs operations on it like load the system, subject the system to contingency and study the characteristics of faults. These virtual faults in the simulation model can be compared to the real time system faults.[15] In this paper enhancement of transient stability analysis of 30-bus multi machine system by using power system stabilizer (PSS), and increasing inertia is done. For this purpose we create a three phase fault on specified bus and then analyze the behaviour of the synchronous machine. For this work we have used the licensed version of ETAP software.

1.2. Power System Stabilizer (PSS)

Power system stabilizer provides an additional input signal to the regulator to damp power system oscillations. Some commonly used input signals are rotor speed deviation, accelerating power, and frequency deviation.[14]

The power system stabilizer uses auxiliary stabilizing signals to control the excitation system so as to improve power system dynamic performance this is very effective method of enhancing small signal stability performance.[3]. The main aim of the PSS is to provide damping with the help of a component of electrical torque in phase with the rotor speed variation, to the generator oscillation by using auxiliary stabilizing signal(s)[4].
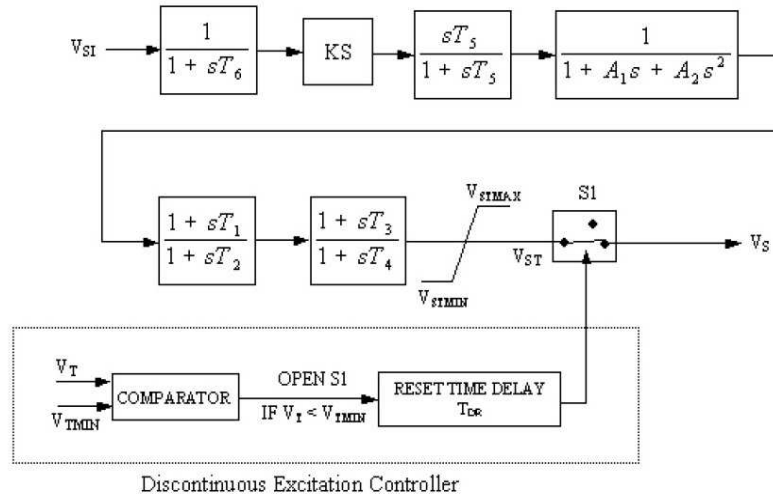

Figure 2. IEEE TYPE-1 PSS(PSS1A).

2. Description of 30 Bus Model

A 30 bus multi- machine system is taken here for the analysis purpose as shown in the figure. it consists of 30 bus , 6 generators, 4 transformers, 20 loads and 37 cables are connected in between the buses. 3 buses are in swing mode, 3 buses are voltage controlled bus and remaining 24 buses are load bus. The length of each cable is 50 km and positive, zero sequence component of impedance is (0.015240+j 0.027432) ohms per conductor per phase. The rating of generators, loads, PSS is given below in the following tables.
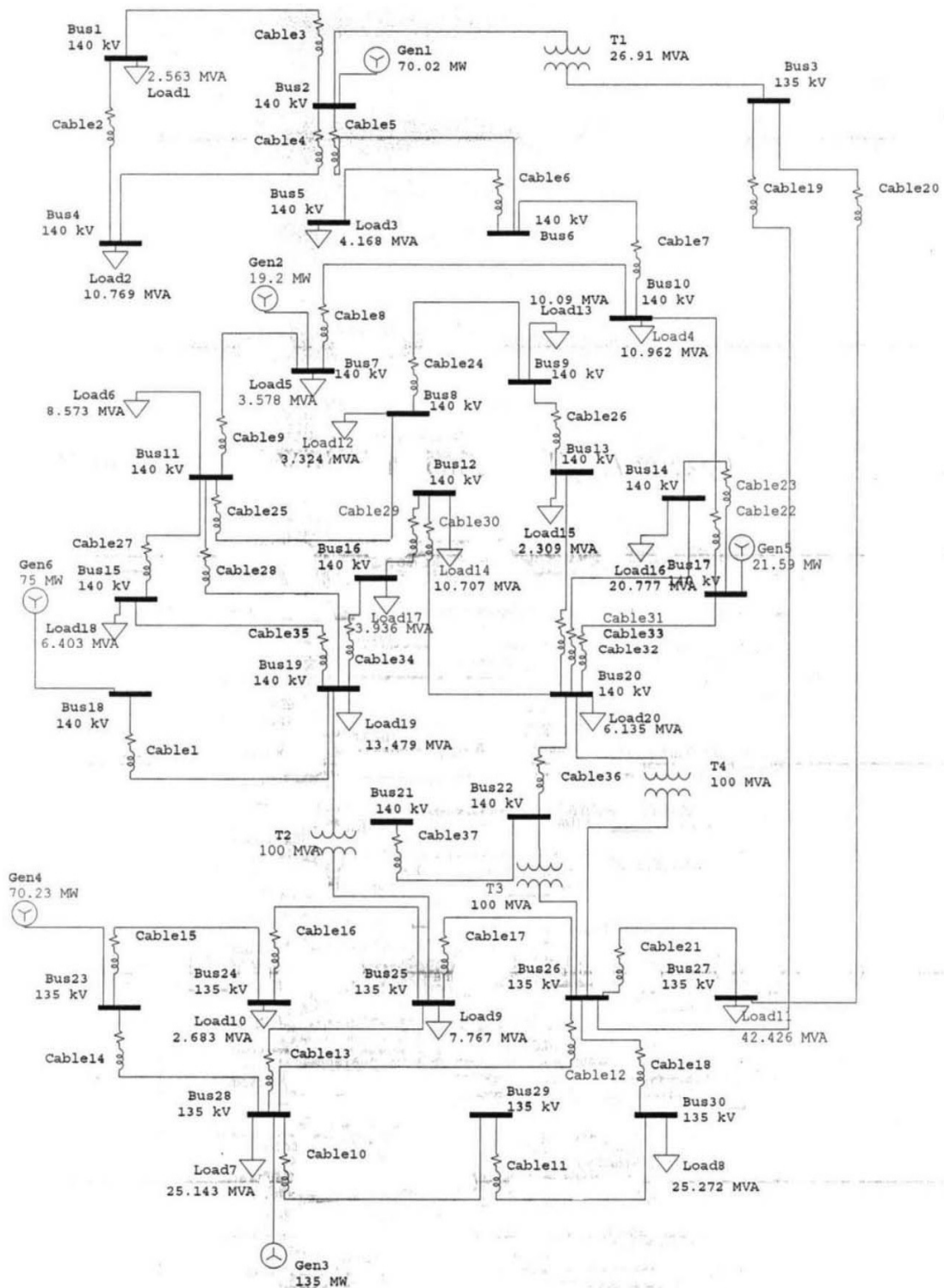
Figure 3. *30 Bus Test System.*

3. Result and Discussion

In this paper we focus on the analysis of transient stability behaviour of a 30-bus multi machine system by implementing PSS and by increasing the inertia of the synchronous machine. For this purpose we have used Accelerated gauss siedel method for initial load flow solution. The maximum number of iteration possible is 2000, the solution precision for the initial load flow is 0.000001, and the acceleration factor for the initial load flow is 1.45. The time increment for integration steps (Δt) is 0.01 and the system frequency is maintained at 50 Hz.

The inertia of the synchronous machine is initially taken

as 3 MW-Sec/MVA and is increased later on to 7 MW-Sec/MVA for the analysis purpose. The inertia of a machine affects the bulkiness of the rotor of the machine; hence inertia cannot be increased much.

The 3- phase fault is created at bus 7 at time 0.04 sec and is cleared after time 0.5 sec. the electromechanical oscillations of electrical power is reduced and field voltage is also kept limited, due to this reason excitation is maintained. The various plots of electrical power, field current, and terminal current individually initial, without PSS and with PSS and inertia combined respectively of generator 6 are as shown in figures.
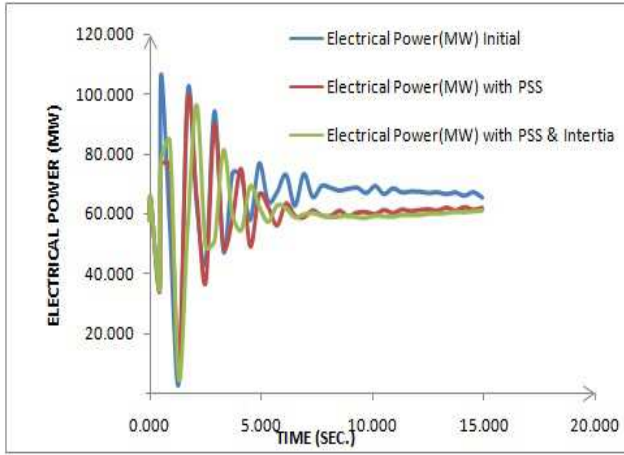

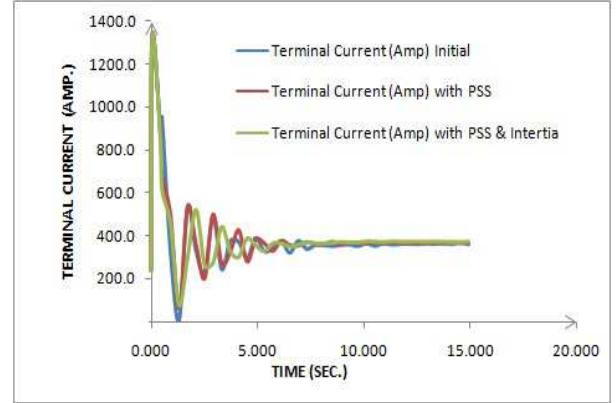**Figure 5.** *Terminal current of Generator 6.*

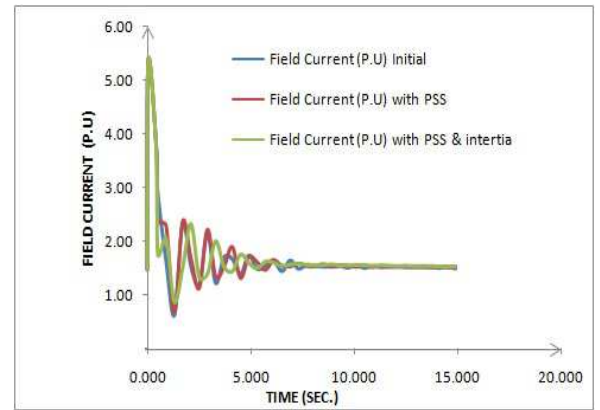**Figure 4.** *Electrical Power of Generator.*

Figure 6. *Field current of Generator 6.*

Table 1. *Synchronous machine parameters.*

Machine			Rating		Positive sequence impedence(%)								Zero seq. Z(%)		
ID	TYPE	MODEL	MVA	KV	R_a	X_d''	X_d'	X_d	X_q''	X_q'	X_q	X_1	X/R	R_0	X_0
Gen1	Generator	Subtransient, Round-Rotor	82.376	140	1	19	28	155	19	65	155	15	7	1	7
Gen2	Generator	Subtransient, Round-Rotor	22.588	140	1	19	28	155	19	65	155	15	7	1	7
Gen3	Generator	Subtransient, Round-Rotor	158.824	135	1	19	28	155	19	65	155	15	7	1	7
Gen4	Generator	Subtransient, Round-Rotor	82.624	135	1	19	28	155	19	65	155	15	7	1	7
Gen5	Generator	Subtransient, Round-Rotor	25.4	140	1	19	28	155	19	65	155	15	7	1	7
Gen6	Generator	Subtransient, Round-Rotor	88.235	140	1	19	28	155	19	65	155	15	7	1	7

Table 2. *Dynamic parameters of Synchronous Machine.*

Machine	Connected bus	Time cons.(sec.)				H(Sec.),,D(MW pu/Hz)&Saturation					Grounding	
ID	ID	T_{d0}''	T_{d0}'	T_{q0}''	T_{q0}'	H	%D	S100	S120	Sbreak	Conn.	Type
Gen1	Bus2	0.03	6.5	0.03	1.25	12	0	1.7	1.18	0.8	WYE	SOLID
Gen2	Bus7	0.03	6.5	0.03	1.25	12	0	1.7	1.18	0.8	WYE	SOLID
Gen3	Bus28	0.03	6.5	0.03	1.25	12	0	1.7	1.18	0.8	WYE	SOLID
Gen4	Bus23	0.03	6.5	0.03	1.25	12	0	1.7	1.18	0.8	WYE	SOLID
Gen5	Bus17	0.03	6.5	0.03	1.25	12	0	1.7	1.18	0.8	WYE	SOLID
Gen6	Bus18	0.03	6.5	0.03	1.25	12	0	1.7	1.18	0.8	WYE	SOLID

Table 3. Mechanical parameters of synchronous machine.

Machine ID	TYPE	Generator/Motor WR^2	RPM	H	Coupling WR^2	RPM	H	Prime Mover/Load WR^2	RPM	H	Equivalent Total WR^2	RPM	H
Gen1	Gen.	475476.97	1500	3	330193	1800	3	330193	1800	3	1426432.75	1500	9
Gen2	Gen.	13379	1500	3	90541	1800	3	90541	1800	3	391137.09	1500	9
Gen3	Gen.	916730	1500	3	636618	1800	3	636618	1800	3	2750189.75	1500	9
Gen4	Gen.	476904	1500	3	331183	1800	3	331183	1800	3	1430711	1500	9
Gen5	Gen.	146609	1500	3	101812	1800	3	101812	1800	3	439827.56	1500	9
Gen6	Gen.	509295	1500	3	353677	1800	3	353677	1800	3	1527884.75	1500	9

WR^2: kg-m^2 H: MW-Sec/MVA

Table 4. POWER SYSTEM STABILIZER (PSS) INPUT DATA Type: PSS1A.

Generator ID	VSI	KS	VSTMax	VSTMin	VTMin	TDR	A1	A2	T1	T2	T3	T4	T5	T6
Gen 1	SPEED	3.15	0.9	-0.9	0	0.2	0	0	0.76	0.1	0.76	0.1	1	0.1
Gen 2	SPEED	3.15	0.9	-0.9	0	0.2	0	0	0.76	0.1	0.76	0.1	1	0.1
Gen 3	SPEED	3.15	0.9	-0.9	0	0.2	0	0	0.76	0.1	0.76	0.1	1	0.1
Gen 4	SPEED	3.15	0.9	-0.9	0	0.2	0	0	0.76	0.1	0.76	0.1	1	0.1
Gen 5	SPEED	3.15	0.9	-0.9	0	0.2	0	0	0.76	0.1	0.76	0.1	1	0.1
Gen 6	SPEED	3.15	0.9	-0.9	0	0.2	0	0	0.76	0.1	0.76	0.1	1	0.1

Table 5. LOAD RATING.

LOAD	RATING (MVA)
1	02.563
2	10.769
3	04.168
4	10.962
5	03.578
6	08.573
7	25.143
8	25.272
9	07.767
10	02.683
11	42.426
12	03.324
13	10.090
14	10.707
15	02.309
16	20.777
17	03.936
18	06.403
19	13.479
20	06.135

4. Conclusion

The paper presents the improved behaviour of transient stability of a 30-bus multi machine system when implemented with PSS and when inertia is increased, using E-TAP software. The comparison of transient stability performances of the multi machine system initial, with PSS, and with PSS and inertia combined is performed and found that the power swing is damped out, and we get better response in terms of electromechanical oscillations.

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