



Evaluation and Improvement in Transient Instability of IEEE 9 Bus Test System Utilizing Different Excitation Control Techniques

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Abstract

In the contemporary world, especially developing countries, the demand for electricity is proliferating continuously and power is not only a criterion for fulfilling the requirement, but it is also the responsibility of engineers to provide the reliable and stable power to the consumers in a satisfactory manner. This paper discusses about the designing and improvement in "Transient Stability of IEEE 9 Bus Test System" using Power World Simulator. The simulation work explains the transients in the system due to a fault which is an evaluation of the voltage stability, Rotor angle stability, frequency stability, Active power and reactive power. The simulation is done using a GNCL model in which synchronous machine is represented using classical modeling [3]. This paper used exciter (AC7B) and PSS with AVR for improving transient instability.

Keywords- Power World Simulator, Power System Stability, Transient Stability, Load Flow Analysis, Power System Stabilizer (PSS), Automatic Voltage Regulator (AVR).

1. Introduction

Transient stability is the ability of a system which maintains the synchronism condition after subjected to the large disturbance in a power system. Tripping of transmission lines, sudden change in load and switching condition are the main causes of disturbance [1]. Due to having the disturbance, any system attains the disparity situation between the mechanical input and electrical output. If any generator has greater tendency, it will be not operated with rest of system, although it will be achieved automatically disconnected from the rest of the system. This condition is called out of step of that disconnected generator. Any damage of generator can prove to be more expensive for the whole system. [10]. In the case of imperfection of a power system, frequency is an authentic signal. Any changes in demand of power system, the speed of the generator also will be changed and due to this change in speed of the generator, resulting the whole power system speed will be affected. Thus the rate of change of frequency is used as an indicator [9].

This paper has the main objective which is related to improving the transient stability of a system when the system is subjected to certain types of disturbance. This objective has been achieved using excitation control and AVR thereby improving the stability of the system.

2. Literature Review

In 1991, it is described about the Excitation system, which consists of some components such as Automatic Voltage Regulator (AVR), Exciter, PSS, Measuring elements, Protective device and limiters device. Generator transfers the mechanical energy into electrical energy using the excitation system. So it explained the function of excitation system which improves the transient stability. [5].

In 1994, it is explained to the power system stability, disturbances and the sufficient method for improving the stability after transients with the help of theory [1].

In 1997, it is discussed about the concept of transformed TEF. Transformer TEF follows the principle of conservation [11]. In 2005, it is discussed about the analysis of optimal power flow (OPF) which has the transient stability restraint. It explained the evaluation of transient stability with the help of potential energy boundary surface method [4].

In 2012, it is found that the load shedding method for improving the transient stability, it is found that reduce the quantity to be shed than the quantity of conventional load shedding method. [7].

In 2013, it was discussed that the improvement in the steady-state stability, It explained improvement of steady state stability, improve the positive damping of the system and defeat Low frequency oscillation with the help of power system stabilizer. [8].

In 2014, it is observed that the Combined Operation of PSS And SVC For Power System Transient Stability Enhancement and it discusses about the improvement of transient stability using of PSS and enhancement the small signal stability with the help of PSS [9].

3. Model of IEEE 9 Bus Test System

Fig 1 shows the basic structure of the IEEE 9 test bus system. This system has the main components which are 3 generators (Gen#1, Gen#5, Gen#9), 3 transformers and 9 buses. The modeling of IEEE 9 bus test system and simulation results analysis the pre fault condition, during fault condition and the using of excitation method for improving the transient stability.

Generators (1, 5 and 9) which are connected through bus No. (1, 5 and 9), generate a total power is 323.36 MW. Three loads which are joined through bus 3, 6 and 7 consume 313.266 MW. This IEEE 9 Bus Test System operates at 50 Hz.

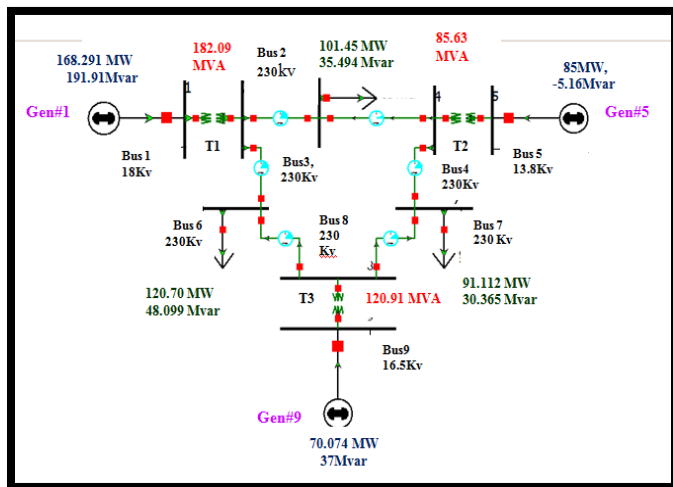


Fig1. IEEE 9 Bus Test System Model in power World Simulator

4. Cases for Representation of Power System Condition

4.1 CASE1- Pre Fault Condition of IEEE 9 Bus Test System:

Case1 discuss about the pre fault condition when all the system parameters are having normal stablized values. Following figures show the qualitative values of Voltage stability, frequency stability, rotor angle stability, Bus voltage and Speed of the three generators which have been executed with IEEE 9 Bus Test System and tables also describe the qualitative value of the system parameters in the initial condition.

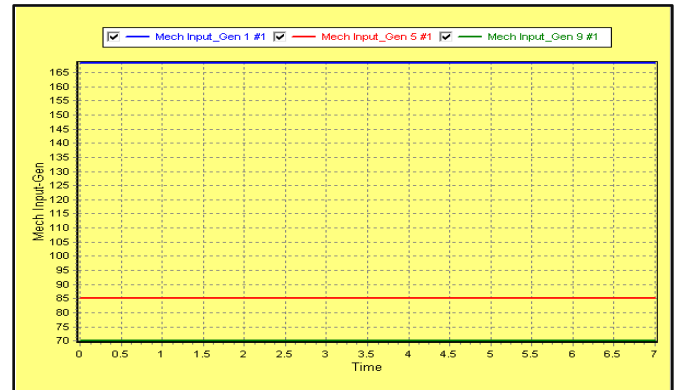


Fig2. Mechanical Input of Gen#1, Gen#5 and Gen#9 vs Time

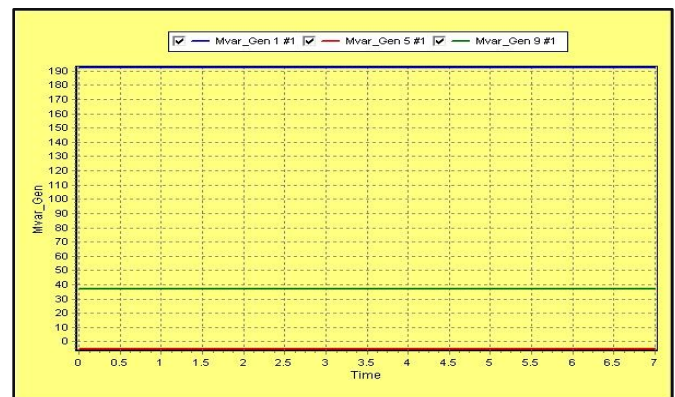


Fig 3. Reactive power of Gen#1, Gen#5 and Gen#9 vs Time.

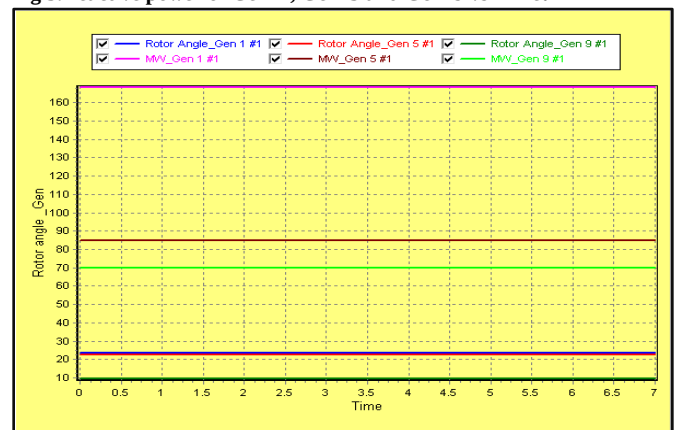


Fig4. Rotor Angle of Gen#1, Gen#5 and Gen#9 vs Time



Fig 5. Field Voltage of Gen#1,Gen#5,Gen#9 vs Time

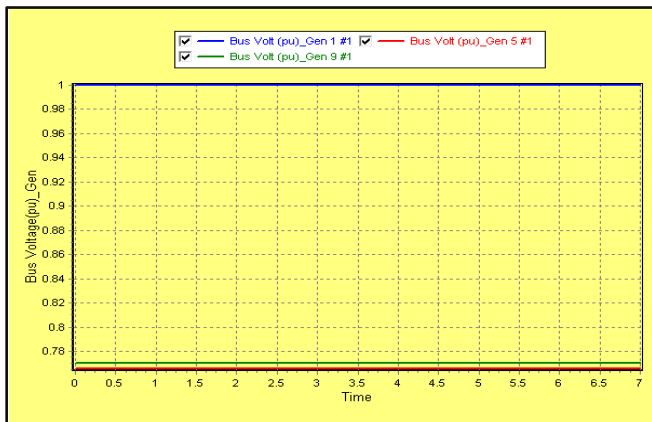


Fig 6. Bus Voltage of Gen #1, Gen#5 and Gen# 9 vs Time

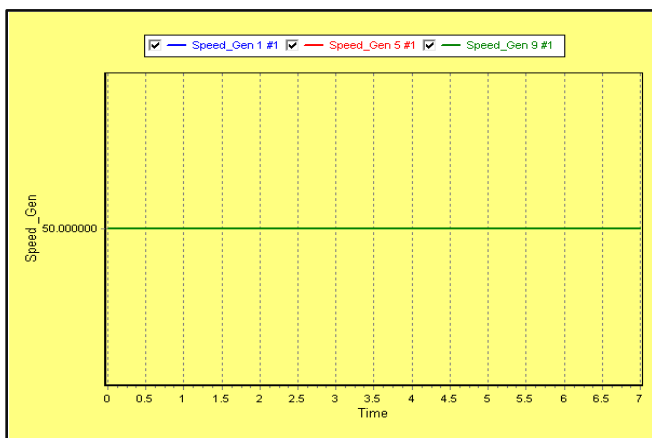


Fig 7. Frequency of Gen #1, Gen#5 and Gen# 9 vs Time

TABLE 1.Pre Fault Values of IEEE 9 Bus Test Systems

No. of Gen	Mech Input	MW Terminal	Field Voltage	Mvar
Gen1	168.29	168.29	1.4241	191.90
Gen5	85.00	85	0.7846	-5.16
Gen9	70.07	70.07	0.8859	37.00

TABLE 2. Pre Fault Values of IEEE 9 Bus Test System

Bus No	V(PU)	Frequency(Hz)	Load (MW)	Load (Mvar)
1	1.000	50		
2	0.8863	50		
3	0.8129	50	101.45	35.49
4	0.7728	50		
5	0.7661	50		
6	0.7438	50	120.70	48.10
7	0.7078	50	91.11	30.36
8	0.7453	50		
9	0.7711	50		

4.2 CASE 2 –During Fault Condition of IEEE 9 Bus Test System:

In this case the fault is introduced at Bus No. 9 of the system and due to this fault, system is showing the transients in its different parameters. The following figures show the system parameters during the fault condition. Field voltage and mechanical input will not be affected, because it is given to the system outwardly. So it will be as common with case 1.

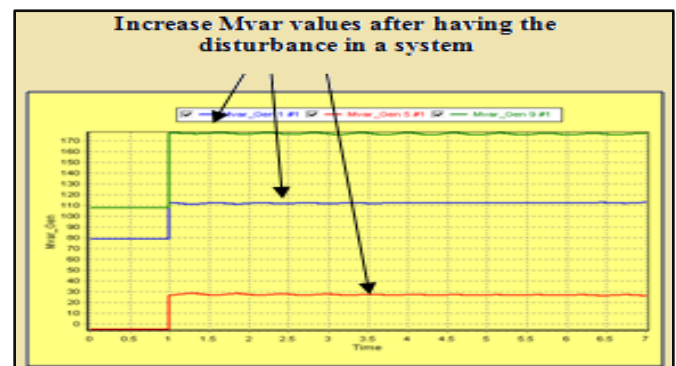
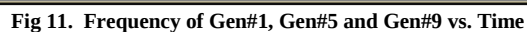
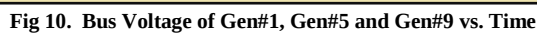
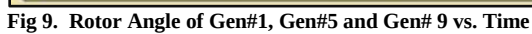


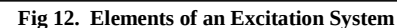
Fig 8 . Reactive Power of Gen#1, Gen#5 and Gen#9 vs. Time



No of Gen	Mech Input	MW Terminal	Field Voltage	Mvar
Gen1	168.29	135.64	1.4241	135.64
Gen5	85.00	68.48	0.7846	68.46
Gen9	70.07	50.25	0.8859	56.25

Bus No	V(PU)	Frequency	Load MW	Load Mvar
1	0.9535	57.356		
2	0.8202	57.354		
3	0.7512	57.342	86.64	38.31
4	0.7126	57.347		
5	0.7219	57.343		
6	0.6149	57.356	82.50	32.86
7	0.6032	57.356	66.14	22.05
8	0.6052	57.356		
9	0.5771	57.359		

This case using the “Excitation” method for improving the transient stability. Power system Stabilizer (PSS) Exciter and Automatic voltage regulator (AVR) are used in Generator 9 which is connected near to faulted line. The following fig describes the function of excitation system elements.



Automatic Voltage Regulator (AVR) -Automatic voltage regulator has good capability of voltage control and maintains the synchronism when system subjected to a large disturbance.

Voltage regulator gives automatic control of the system which maintain to voltage in an armature terminal. The main function of an Automatic voltage regulator is control of voltage, protection and control of the generator, Shut down in over excitation/HZ compensation, externally and internally adjustment, Accuracy in regulation.

Exciter-Exciter provides the required field current to the generator terminal for balanced the voltage Exciter is also used in the monitoring, logging and sequence control function.

Limiters and Protective Circuits-The main purpose of limiter circuits is to control the exciter limit and protective circuits to protect the system during a fault condition.

Terminal Voltage Transducer and Load Compensator – Terminal voltage transducer is sense the voltage at the terminal of the generator. It rectifies and filtered to the DC quantity. Load compensator can be provided to hold voltage according to requirement.

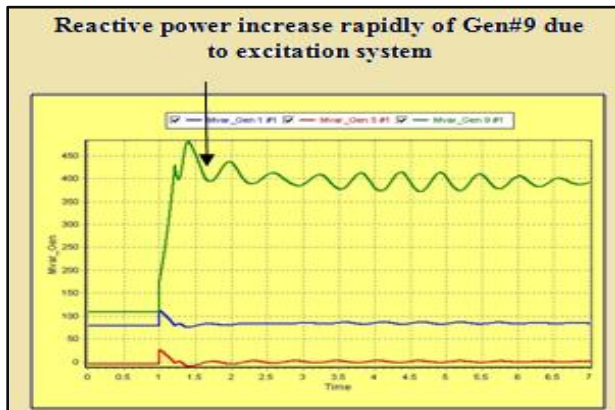


Fig 13. Mvar of Gen#1, Gen #5 and Gen#9 vs Time

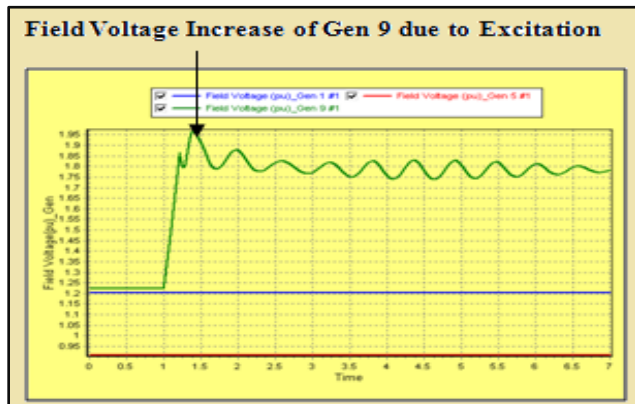


Fig 14. Field Voltage of Gen#1, Gen #5 and Gen#9 vs Time

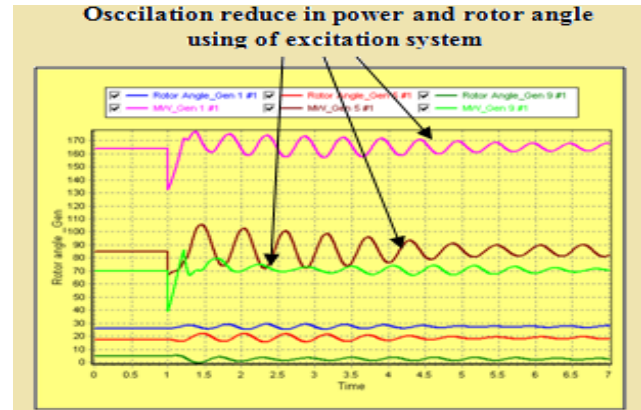


Fig 15. Rotor Angle of Gen#1, Gen #5 and Gen#9 vs Time

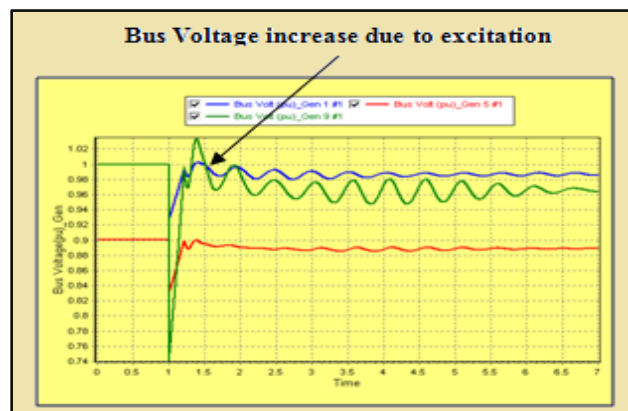


Fig 16. Bus Voltage of Gen#1, Gen #5 and Gen#9 vs Time

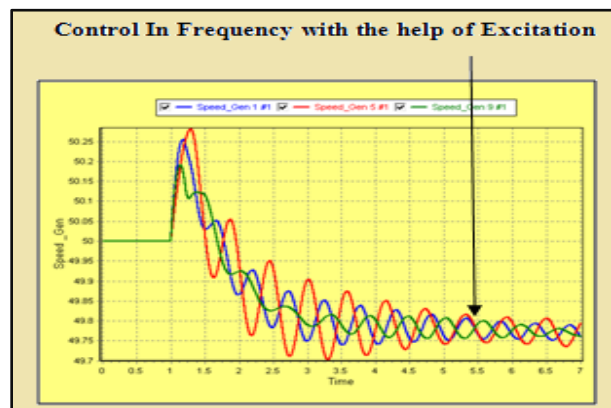


Fig 17. Frequency of Gen#1, Gen 5 and Gen#9 vs Time

TABLE 5. Gen data during the Post Fault

No of Gen	Mech Input	MW Terminal	Field Voltage	Mvar
Gen1	168.29	167.70	1.2037	83.97
Gen 5	85.00	82.39	0.9086	0.87
Gen 9	70.07	70.26	1.7825	391.87

TABLE 6. Bus Data during the Post Fault

Bus No	V(PU)	Frequency	Load MW	Load Mvar
1	0.9535	49.770		
2	0.8202	49.770		
3	0.7512	49.771	97.48	34.10
4	0.7126	49.772		
5	0.7219	49.773		
6	0.6149	49.768	112.83	44.96
7	0.6032	49.769	85.88	28.62
8	0.6052	49.767		
9	0.5771	49.766		

4. Results Obtained

TABLE 7. Parameters condition of all generators during Pre-Fault

No. of Gen	Mech Input	MW	Field Volt	Mvar	Rotor Angle
Gen1	168.29	168.29	1.4241	191.90	23.623
Gen2	85	85	0.7846	-5.16	22.688
Gen3	70.07	70.07	0.8859	37.00	9.5

TABLE 8. Parameters condition of all generators during Fault

No. of Gen	Mech Input	MW	Field Volt	Mvar	Rotor Angle
Gen 1	168.29	135.64	1.4241	135.64	23.623
Gen 5	85	68.48	0.7846	68.46	22.688
Gen 9	70.07	50.25	0.8859	56.25	9.5

TABLE 9. Parameters condition of all generators after Fault

No. of Gen	Mech Input	MW	Field Volt	Mvar	Rotor Angle
Gen 1	168.29	167.70	1.2037	83.97	27.730
Gen 5	85	82.39	0.9086	0.87	17.819
Gen 9	70.07	70.26	1.7825	391.87	2.3179

Table7 describes the condition of all three generators during the Pre- Fault condition in which all the parameters are in normal condition According the table, mechanical input, which is given to the generator are 323.36 and getting the total generating power from the generators is 323.36 MW and 223.74 Mvar which means the generation of power is equal to

mechanical input. Field voltage is 3.0317 p.u volts of all generators.

Table 8 shows the condition of three generators during the fault, in this case the mechanical input is 323.36 asusal case 1 but due to fault total generative power is 254.37MW from the generators .The reactive power (260.35 Mvar) will be increased to maintain the stability of a system and the Field voltage is also similar to case 1.

Table 9 describes the parameters condition of three generators during the post fault. In this case excitation system provide the field current to the terminal of generator for controlling the voltage. In this case the mechanical input is 323.36 and the total generation of power is 320.35 MW. The generation of power has improved from the case 2 and The reactive power is 476.71 Mvar which is increased due to excitation system for providing the stability to the system and Field voltage is also increased of all generators is 3.8948 p.u.Volt.

5. Conclusion

In this paper the condition of power system has been compared using three cases that are Pre Fault, During Fault, and After Fault. In the Pre Fault condition, we are getting the power 323.36 MW, which is equal to mechanical input. After introducing fault the generated power decreases from 323.36 to 254.37 MW The power drop, during fault has been improved by using the excitation system which will result insufficient generated power (320.35MW) which is approximately equal to 323.36 MW which is during a Pre fault condition. So it is concluded that during the fault if we are using the excitation system, then we can easily control the voltage and system power and can protect the whole system from transient instability.

References

1. P. Kundur, Power System Stability and Control, New York, NY: McGraw-Hill, Inc., 1994.
2. V. Vittal, "Transient stability test systems for direct stability methods," IEEE Transactions on Power Systems, vol. 7, February 1992.
3. Komal S. Shetye, Thomas J. Overbye and James F. Gronquist "Validation of Power System Transient Stability Results," IEEE Transactions on power system, 2012.



4. Yan Xia, Ka Wing Chan and Mingbo liu "Improved BFGS Method for Optimal Power Flow Calculation with Transient Stability Constraints", IEEE transaction on power system, 2005.
5. Jerkovic, Vedrana; Miklosevic, Kresimir; Spoljaric Zeljko "Excitation System Models of Synchronous Generator" Kunsong Haung, Hasan Yee "Improved Tangent Hyperplane Method for Transient Stability Studies" November 1991.
6. Gursharan S. Grewal, John W konowalec, Mak Hakim "Optimization of a load shedding scheme", IEEE July 1998.
7. G. Shahgholian "Review of power system stabilizer: Application, Modelling, Analysis and Control Strategy" Vol. 5, Issue 16, September 2014.
8. Bableskumarjha, Ramjee Prasad Gupta, Dr. Upendra Prasad "Combined Operation of PSS And SVC For Power System Transient Stability Enhancement" Journal of Engineering And Techonology Research, 2014
9. Swaroop Kumar. Nallagalva, Mukesh Kumar Kirar, Dr. Ganga Agnihotrim "Transient Stability Analysis of the IEEE 9-Bus Electric Power System.
10. Ankit Jha, Lalthangliana Ralte "Transient stability analysis using equal area criterion using simulink model" Department of Electrical Engineering National Institute of Technology Rourkela 2009.
11. D.Z. Fang, T.S. Chung, A.K. David, "Improved techniques for hybrid method in fast transient stability assessment" IEE **Gener. Trunsm. Distrib.**, Vol. 144, No. 2, March 1997.
12. Minghui Yin, C. Y. Chung, K. P. Wong, Yusheng Xue and Yun Zou "An Improved Iterative Method for Assessment of Multi-Swing Transient Stability Limit" IEEE Transaction on Power systems, Vol. 26, no.4, November 2011.
13. Ehsan Nasr Azadani, Claudio Canizares, Kankar Bhattacharya, "Modeling and Stability Analysis of Distributed Generation" IEEE PES General Meeting, July 2012.