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Impact Of Different Types Of Governors/Exciters On Transient Stability

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Abstract

This paper deals with analysis of transient stability which is carried out by considering a IEEE three machine nine bus model with a balanced three phase fault at different bus bars with different combinations of exciters and governors by using PWS power system software . The simulation results with these combinations show the effectiveness of best combination of these control devices in terms of critical clearing times.

Keywords:-*Power system stability, clearing time, Governor, Exciter, transient stability.*

1. Introduction

Stability of a power system is the capacity of machines that are synchronous to shift from one constant point under operation under certain contingency to another stable point under operation lacking running out of synchronism .Generally three types of power system stability are there namely steady-state, transient and dynamic. Discussion on modeling and theoretical issues of voltage stability and rotor angle of power system has been done in [1][2]. The main objective is to check if it will or will not return to frequency of synchronous form with new stable angles of power [3]. There is a requirement of large amount of computational efforts due to the large and complex size of interconnected in transient stability analysis of power system. Because of the complex power system network, stability include the frequency, rotor angles and voltage stabilities. Information concerning power system's steady state analysis and the determination of steady state criteria of power system has been explained in [4]. An innovative technique for predicting the power system's stability of rotor angle status immediately after a large disturbance is also presented by one of the authors [5]. Transient stability analysis in terms of electrical power, rotor angle of machines, machine terminal voltage and speed has been done using power system simulation for engineers for Sarawak grid system in [6]. In [7] [8] mathematical model for multimachine system for stability have been provided and various steps have been taken for analyzing power system's mathematical model. Real time transient analysis through distributed approach has been demonstrated by various authors [9]) describing stability study for vast number of bus bars and machines. Transient stability analysis's systematic study has been conducted through the combination of direct methods and step by step integration in [10]. Michael J.Bisler and Richard C. Schaefer [11] have put forward the various factors that were causing instability of power system and he also explained the significance of rapid clearing of fault. Through [12] it has been demonstrated that with the help of control devices transient stability can been improved. For power system analysis it is necessary to consider response of governor characteristics which has been explained in [13]. In reference [14] negative damping to aggravate system's low frequency oscillation due to improper governor selection has been demonstrated. In [15][16] it has been studied that excitation system has great influence on power system stability. Explanation of appropriate excitation system models for extensive study of system stability has been done in [17].

This paper encapsulates the following information: To begin with, the power system based on IEEE three machine, nine bus system considering two governors and two exciters has been considered using PWS software. The system is simulated with balanced three phase fault applied on the bus 7 and bus 5 using different types of governor/exciter combinations.

2. System modeling

2.1 Machine Modeling

The virtual position of the rotor axis and resultant magnetic field axis is permanent under normal conditions. Power angle is the angle between the two axes. During interruption because of the acceleration or deceleration w.r.t the synchronously rotating air gap mmf a relative motion begins. The generator maintains its stability, if, the rotor locks back into synchronous speed after this oscillatory period. The rotor returns to its original position if there is no net swapping of power. Swing equation is the arithmetic configuration to describe comparative motion. The system modeling here is basically developed based on the theory of control system and the swing equation. The swing equation with respect to rotor swing angle of synchronous generator is [12]

$$M\frac{d^2\delta}{dt^2} = P_a = P_m\text{-}P_e \quad [12] \qquad (1)$$

$$M= 2\frac{H}{\omega_s} \quad [12] \qquad (2)$$

Where

P_a is the accelerating power

P_m is the mechanical power

P_e is the electrical power

ω_s is the angular velocity of synchronous rotor

δ is the synchronous machine's rotor angle

H is the inertia constant

Swing equation in terms of electrical power angle δ:

$$\frac{2}{p}M\frac{d^2\square m}{dt^2} = P_m\text{-}P_e \quad [18] \qquad (3)$$

When swing equation is converted to per unit system then it becomes:

$$\frac{2H}{\omega_s}\frac{d^2\delta m}{dt^2} = P_m\,(pu)\text{-}P_e(pu \quad [18] \qquad (4)$$

Here,

$$M=\frac{2H}{\omega_s}$$

2.2 Governor Modeling

There has been a great impact of governors and exciters on transient stability analysis. The turbine governor system is very essential for frequency control and real power. The dynamic performance may differ immensely depending on the type of turbines, including steam, hydro etc. The angular velocity of synchronous machine is controlled by speed governors by controlling input of mechanical power. Speed governor is very vital part of power system as it greatly influences the power system stability. The steam turbine control's main purpose is to control the speed of high speed rotor through mechanical power input control. To represent variations in turbine governor systems, several types of models of turbine governor are considered [19]. In this paper two governors named TGOV1 & TGOV2 and the exciters IEEET1 & IEEET2 have been considered.

2.2.1 Steam Turbine Governor type 1(TGOV1) Steam Turbine Governor type 1 (TGOV1) is a simplified representation of steam turbine governors (Figure 1). Recognization of Governor's action, the ratio of high-pressure turbine and reheater time constant are done in this model where first block represents reciprocal of speed droop, second block represents transfer function of and third block represents and fourth block represents damping factor of turbine

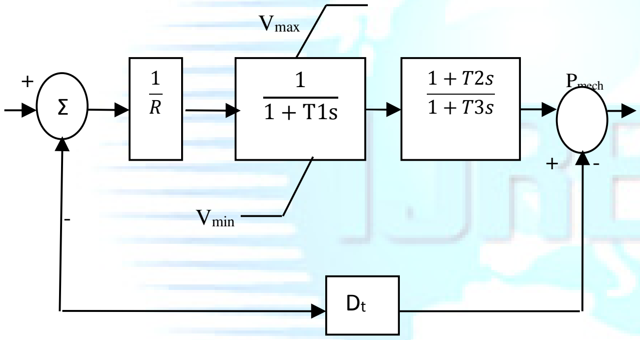


Fig 1 Block Diagram of Steam Turbine Governor type 1(TGOV1)

2.2.2 Steam Turbine Governor with fast valving (TGOV2)

Steam Turbine Governor with fast valving (TGOV2) is a simplified representation of steam turbine governors with fast valving (Figure 2). Recognization of Governor's action, the ratio of high-pressure turbine and reheater time constant are done in this model [19]. In this all parameters are same like type 1 except that in this type gain factor K has been considered and the values of time constants have been reduced.

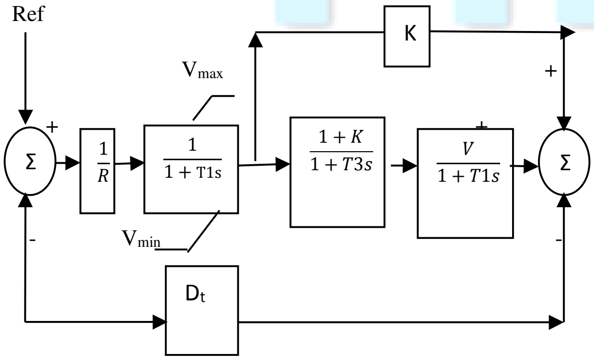


Fig 2 Block diagram of Steam Turbine Governor with fast valving (TGOV2)

2.3 Exciter Modeling

Excitation system's performance may also have a great impact on the stability of power system. The excitation system includes automatic voltage regulator and an exciter. An exciter is a device which provides the necessary field current to the alternator's rotor winding. The voltage regulator senses the need of terminal voltage of the alternator and then it actuates the exciter for the required decrease or increase of alternator's field voltage [19]. However, this is generally dependent upon the setting of parameters of the excitation system. The stability of power system can be improved by the proper setting of parameters and can increase the damping of power systems. On the other hand if improper setting of excitation system is done then the whole system may deteriorate [15]. So the excitation system with good reliabilities in terms of circuit configuration, technical requirements estimation etc is preferable.

2.3.1 Excitation systems of continue action in time (IEEET1)

The block diagram shown in the fig 3 is representing Excitation systems of continue action in time (IEEET1). In the blocks diagram shown in fig 1, corresponding to this kind of excitation, the first transfer function used a time constant TR, which depicts the related delay to the voltage transductor. This constant is tiny almost zero (0) in many systems. Then, there is a first adder, which evaluates the reference voltage with the transductor output voltage and calculates the voltage error applied to the regulator amplifier. Instantly a second adder combines the voltage error with the damping signal of the excitation system. Lastly, the regulator transfer function can be seen. The regulator output is then compared in another adder with the exciter unit saturation function SE = f (EFD), keeping in notice non linear function is multiplied by the excitation voltage EFD , where the feedback loop is there with the block diagram of the system that is connected from the exciter unit output (EFD) to the second adder, and then damping of excitation system behavior is allowed.[15]

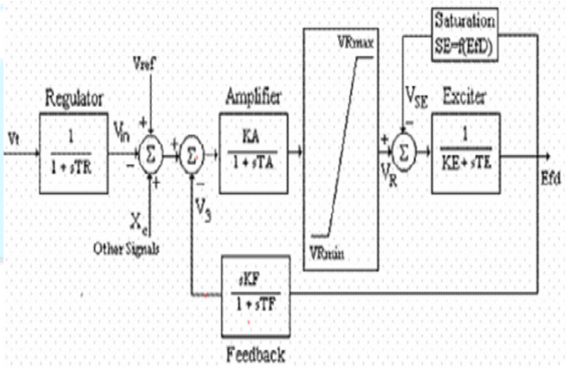


Fig 3: Block diagram of Excitation systems of continue action in time (IEEET1) [15]

2.3.2 System with rotary exciting unit and Rectifier (IEEET2)

In this system, from the regulating unit output the damping loop is obtained and the other time constant is being included by transfer function. The others features are similar to the ones found in System with rotary exciting unit and Rectifier (IEEET2).

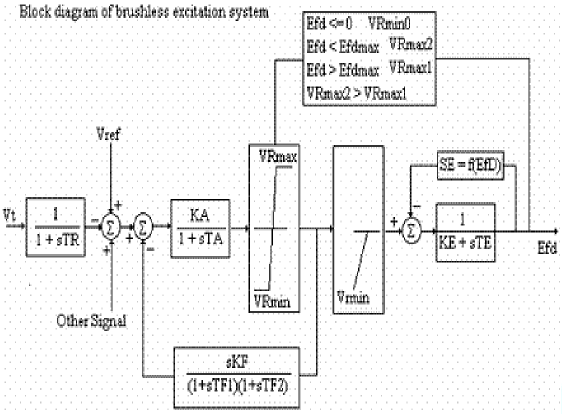


Fig 4: Block diagram System with rotary exciting unit and Rectifier (IEEET2) [15]

From above the various combinations of governors and exciters have been implemented in IEEE three machine, nine bus system. The effects of these combinations have been shown in terms of critical clearing times.

3. Simulation results and discussion

3.1 Simulation of IEEE- 9 Bus model

The simulation has been carried for IEEE three machine, nine bus bar power system network [7] using PWS software. The system frequency and base MVA are considered to be 60 Hz and 100 MVA respectively. The single line diagram of three machine power system network is shown in Fig.5.Here slack bus 1 is connected to generator G1, while generators2 (G2) and 3(G3) are connected to 2 and 3 bus bars respectively. Bus bars 5,6 and 8 are connected to loads A,B AND C. Initially for load flow analysis Newton Raphson method is used. After that transient stability analysis is carried out by checking the performance of generators (G1,G2 & G3).Different cases have been considered in this power system network's transient stability analysis under various combinations of exciters and governors.

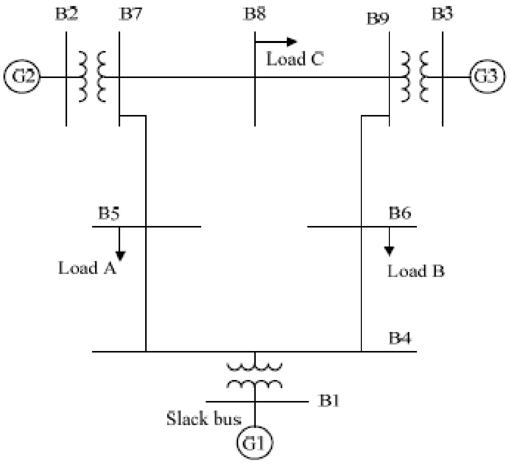


Fig 5: IEEE-9 bus system [12]

A 3 phase solid fault is applied between Bus 7 and Bus 5 for different combinations of governors and exciters using different clearing times in the system shown in fig 5.For this case various types of exciters and governors are used in ON mode under different combinations and fault is cleared by disconnecting the line 7-5 and different clearing times of 1.094, 1.230, 1.091 and 1.210 sec have been considered respectively. The rotor angles of generators G2 and G3 are calculated. The δ-t plots are then plotted.

Case I Effect on critical clearing time with simultaneous operation of IEET1 (IEEE type 1 exciter) and TGOV1 (Steam Turbine Governor of type 1)

Fig 6: Rotor angle response at a clearing time of 1.091 sec when fault at bus 7& bus 5.

From fig 6 it is found that when 3 phase balanced fault is applied on bus 7 and bus 5 then the relative rotor angles of generator 2 and generator 3 start decreasing and are quite stable at clearing time of 1.094 sec.

Fig 7: Rotor angle response at a clearing time of 1.092 sec when fault at bus 7& bus 5

It is found that when 3 phase balanced fault is applied on bus 7 and bus 5 then the relative rotor angles of generator 2 and generator 3 it increases abruptly leading to unstable condition at clearing time of 1.095 sec. as shown in fig 7.

Case II Effect on critical clearing time with simultaneous operation of IEET1 (IEEE type 1 exciter) and TGOV2 (Steam Turbine Governor with fast valving)

Fig 8: Rotor angle response at a clearing time of 1.230 sec when fault at bus 7& bus 5

From fig 8 it is clear that after the fault is applied and cleared on bus 7 and bus 5 the rotor angles of generator 2 and generator 3 start decreasing at clearing time of 1.230 sec.

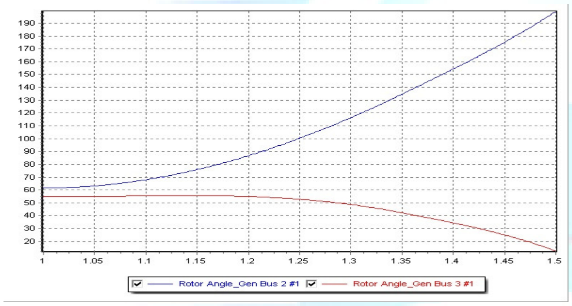


Fig 9: Rotor angle response at a clearing time of 1.231 sec when fault at bus 7& bus 5

From fig 9 it is observed that after the fault is applied and cleared on bus 7 and bus 5 the relative rotor angles swing together with time making system highly unstable at clearing time of 1.231 sec. And theses clearing times are more than the clearing times observed in case I, which makes this combination better in comparison to considered combination of case 1.

Case III Effect on critical clearing time with simultaneous operation of IEET2 (IEEE type 2 exciter) and TGOV1 (Steam Turbine Governor of type 1)

Fig 10: Rotor angle response at a clearing time of 1.091 sec when fault at bus 7& bus 5

From fig 10 it can be observed that when the same fault which was applied on above two combinations, the clearing time comes out to be 1.091 in which rotor angle started increasing initially but then started decreasing.

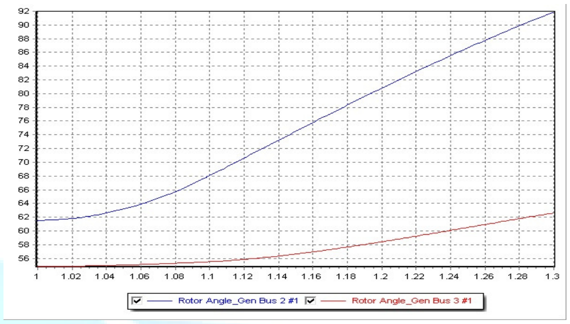


Fig 11: Rotor angle response at a clearing time of 1.092 sec when fault at bus 7& bus 5

From fig 11 it is clear that graph depicts unstable condition of generator 2 and generator 3 at 1.092 sec clearing time when balanced three phase fault was applied on bus 7 and bus 5. The clearing times in this combination are less in as found in case I and II which makes this combination less efficient in comparison to the combinations considered in case I and case II.

Case IV Effect on critical clearing time with simultaneous operation of IEET2 (IEEE type 2 exciter) and TGOV2 (Steam Turbine Governor with fast valving)

Fig 12: Rotor angle response at a clearing time of 1.210 sec when fault at bus 7& bus 5

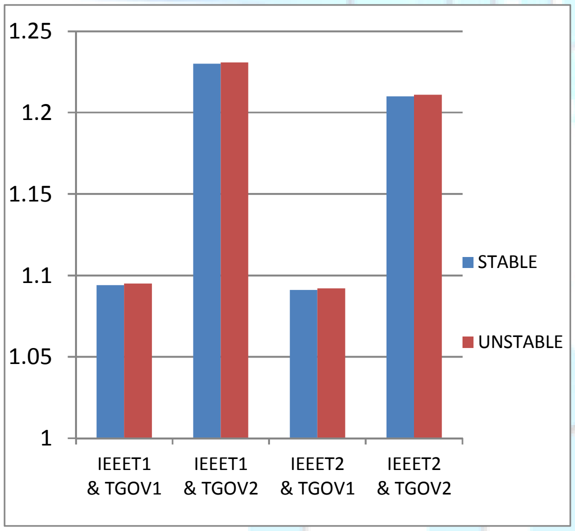
Fig 13: Rotor angle response at a clearing time of 1.211 sec when fault at bus 7& bus 5

From fig 12, it is clear that under IEEET2 &TGOV2 combination, the rotor angles of generators G2 and G3 are stable for clearing times of 1.210 while fig 13 signifies; they are unstable at 1.211sec respectively. The observed clearing times under this combination are less that case II combination but more and better than combination I and III.

Table 1: Effect of Exciter-Governor combination critical clearing times

S.No	COMBINATIONS	STABLE REGION (IN SEC)	UNSTABLE POINT
i	IEEET1 &TGOV1	1 to 1.094	1.095 sec
ii	IEEET1&TGOV2	1 to 1.230	1.231 sec
iii	IEEET2&TGOV1	1 to 1.091	1.092 sec
iv	IEEET2&TGOV2	1 to 1.210	1.211 sec

Graph 1: Showing effect of different combinations of exciter-governor models on critical clearing times



The results that are obtained by applying proposed combinations on designed system have been shown in Table 1 and graph 1. From Table 1 and graph 1, it should be noted that for the second combination that includes IEEET1 & TGOV2 the system is stable for longer time in comparison to other combinations that have been considered for cases I, III & IV.

IV. CONCLUSION

The IEEE three machine, nine bus system has been tested with different combinations of various types of Governors and exciters which then improved the transient stability by increasing the clearing time. So it is concluded that the best combination of Governor and Exciter that had the largest fault clearing time was the one which made the system to run under synchronous condition for longer time and hence making the system more stable in comparison to other combinations.

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