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Transient Stability Enhancement of SMIB using AVR and PSS

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***Abstract**: This paper represents effect of automatic voltage regulator(AVR) and power system stabilizer(PSS) on transient stability of single machine connected to infinite bus system. SMIB system is chosen because it is simple configuration by which we can easily understand concept and effect of AVR and PSS on power system. In order to test the effect of AVR without PSS and with PSS to damp electromechanical oscillations simulation is carried out to analyze transient stability about steady state point followed by three phase fault which is not common type of fault but adequate for our purpose. Simulation is carried out with higher order model of synchronous machine in MATLAB environment and simulation result shows the effectiveness of AVR with PSS for SMIB system.*

I. Introduction

The power system stability is major concern in power system and investigated in many literature. The system response to severe disturbances involves large excursion of system variable such as rotor angle, power flows, bus voltages and other system variables[1]. The steady state stability is only function of itâĂŹs steady state operating point while transient stability is function of operating point and type of fault which make transient stability analysis more complicated.

In the early excitation system were controlled manually. In early 1920 potential of enhancing of stability through fast acting regulator were found. In the early 1950 and 1960 most of generating station added to utility system were equipped with continuously acting voltage regulator. From power system point of view excitation system should contribute effectively to control terminal voltage as well as capable to respond to severe disturbance so as to contribute to enhance transient stability of power system[1].

In the early 1960 the role of excitation system is expanded by auxiliary stabilizing signal in addition to the terminal voltage found to control field voltage to damp out electromechanical oscillations.The main objective of installing power system stabilizer to achieve improvement in stability by modulating the generator excitation to provide damping addition than AVR to provide damping additional than AVR to electromechanical oscillations of synchronous machine rotors.

PSS can be used as a controller for dynamic performance and co-ordinate it with FACTS controller such as TCSC can improve more power system stability[3]. Coordination of PSS and TCSC can more improve stability and control strategy comparison is also presented for lead-lag type controller and PI controller[4].

II. Power System Model

Single machine is connected to the infinite bus through the transmission line as shown in figure1

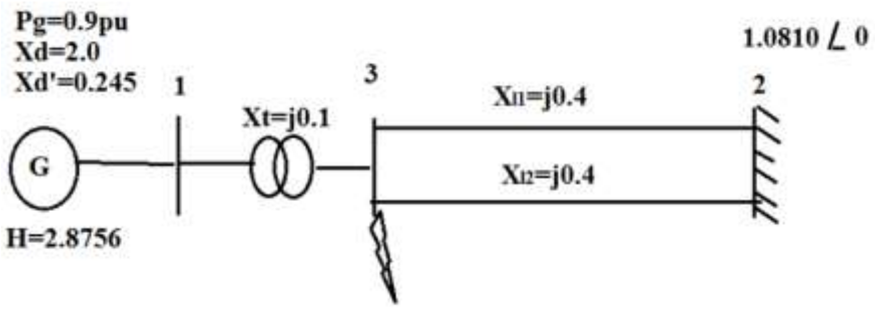

Figure 1: Single Machine with infinite system

The power system consider in this study is synchronous machine connected to infinite bus. A simplified model that gives the system dynamics is given by SMIB 1.1 model described in this section. Synchronous machine considered here to test the performance of AVR without and with PSS. Single line diagram of system as shown in figure1 .

When we apply any controller mathematical model of synchronous machine is required which may be in differential equations, state space model form or in transfer function.The power system is nonlinear system which can be represented as set of differential and algebraic equations

$$\dot{x} = f(x, u) \quad (1)$$

$$y = g(x, u) \quad (2)$$

x = the column vector called the state vector and its entries are the state variables. It contains u = the vector of inputs to the system. Inputs are external signals that have an impact on the performance of the system. It contains r input variables.

f = vector containing n first order non linear differential equations

y = the column vector of system output variables also referred as output vector.The output variables are those that can be observed on the system. It contains m output variables.

g = the vector of nonlinear functions defining the state variables in terms of state and input variables. Synchronous machine can be represented with the following set of differential equation

After solving differential equation algebraic equation need to solve to obtain generator current.

When we use another device with synchronous machine like excitation system and power stabilizer stabilizer state variable need to be added with the synchronous machine model equation to add the effect.

III. Type ST3 Excitation System Model

The excitation model is shown in figure2. To form source of excitation some static system us quantity within generator like terminal voltage, terminal current or combination of both. Such source provide controlled source rectifier in output circuit and which is designed ST3 type excitation system. In excitation system provided by lead-lag compensator which is represented by time constant T_B and T_c. The inner loop of field regulator with gain K_G and K_A and time constant given by T_A. Limit on E_{FD} is established by saturation of power system components[4].

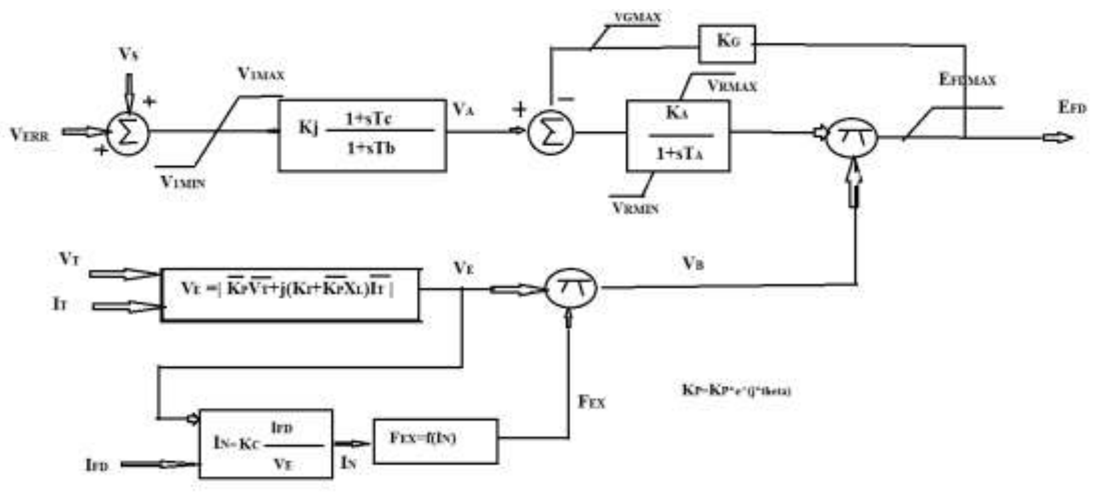

Figure 2: Type ST3 Excitation System Model

IV. Power System Stabilizer Model

The block diagram of power system stabilizer as shown in figure3 in which change in the rotor speed from steady state value used as stabilizing input for the PSS. The amount by which PSS offer damping depends upon steady state gain offered by transfer function of PSS at the oscillating frequency. This damping signal is added to the excitation system with voltage terminal signal as shown in figure2.

Transfer function of PSS is given by:

$$\frac{\Delta V_s}{\Delta w} = \frac{K_W}{1 + sT_W} \frac{sT_W}{1 + sT_W} \frac{1 + sT_1}{1 + sT_2} \frac{1 + sT_3}{1 + sT_4} \qquad (10)$$

First term represent transducer gain followed by washout filter. Then signal is passed through to two lead-lag compansator block to minimize phase lag between stabilizing input and output of PSS to stabilize the system.

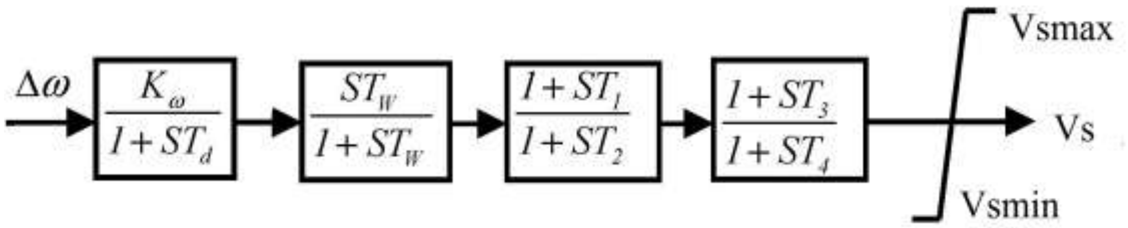

Figure 3: Power system stabilizer model

V. Simulation Result

Since AVR and PSS employed for transient stability improvement should act on adequate manner under severe transient perturbation. Performance of AVR and proposed PSS is evaluated with three phase fault on line 2-3 near bus 3 which is considered here transient in nature and cleared near bus 3 after 0.05 s and cleared at remote end after 0.1s is simulated for three different system structure.

1. Without AVR and PSS. Here synchronous machine is represented by simplified electromechanical model which is swing equation where synchronous machine is represented as constant voltage source behind transient reactance.
2. With AVR only. In this case sub-transient model of the synchronous machine is taken for study with the ST3 type excitation system.
3. With AVR and PSS.

Several states like rotor speed, excitation field voltage and electrical parameter electri- cal power transfer, voltage at fault bus, during transient stability study are taken and plotted on the same plot for the three different condition as discussed above.

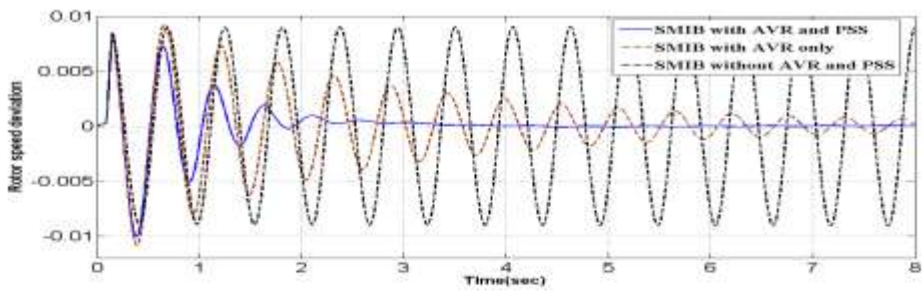

Figure 4: Speed deviation for 3 phase fault on bus 3 cleared at 0.15s near bus and cleared at remote end at 0.20s

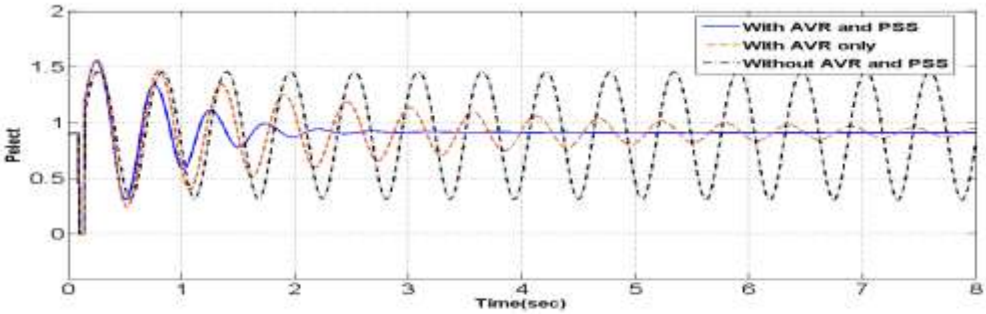

Figure 5: Electrical power transfer during and after fault

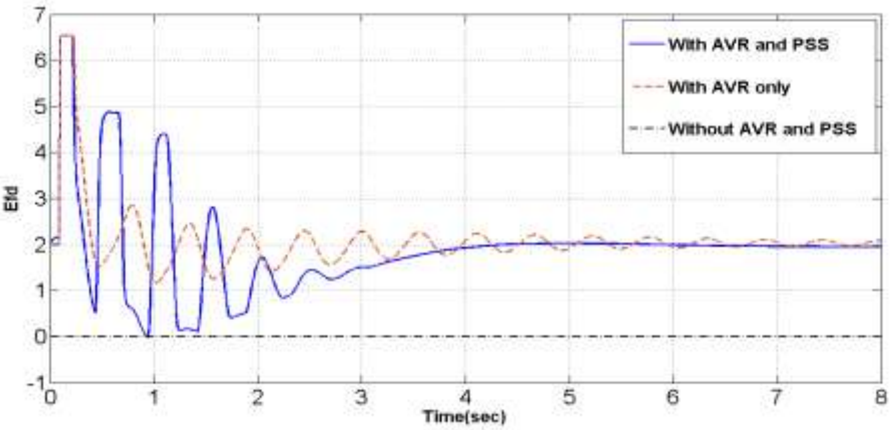

Figure 6: Field voltage change for 3-phase fault at machine1

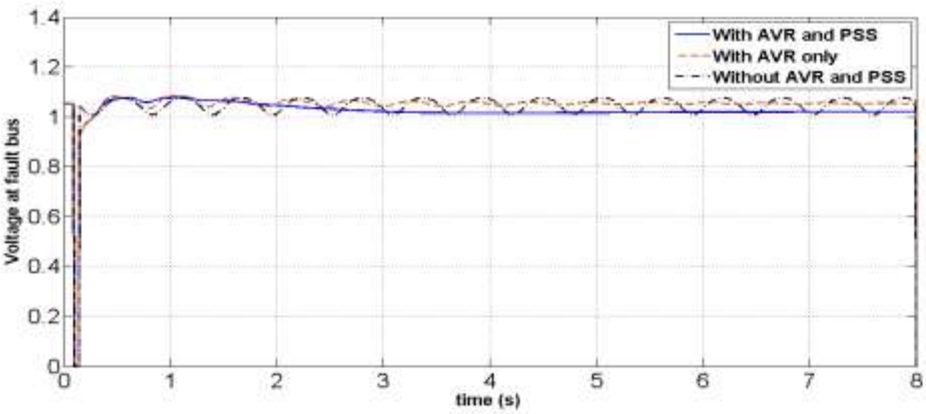

Figure 7: Change in voltage at fault bus 3

VI. Conclusion

In this paper PSS, AVR have been proposed to enhance transient stability of power system. From the time domain simulation with different case on SMIB power system under three phase fault have been demonstrated that AVR with PSS equipped system the swing have been settled down quickly than with only AVR. Here without AVR and with damping effect neglected power system become undamped system. Considerable damping is provided with AVR and after employing AVR with PSS with changing in field voltage AVR will damp out swing caused by severe distur- bances.

VII. APPENDIX

I. SMIB data

Base MVA=100

All the SMIB data is given in p.u as follows:
H=2.8756, $T'_{qo} = 0.66, T_{qo}" = 0.061, T'_{do}$

$= 5.0, T_{do}" = 0.031, r_a = 0, X_q = 1.91, X'_q$

$= 0.42, X_d =$
$2, X'_d$

$= 0.245, X''_d = 0.2, V = 1.0810$

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