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Stability Improvement of Power System (SMIB) By Genetically Tuned Power System Stabilizer

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***Abstract*— Transients in Power system produce low frequency oscillations (LFO) that cause loss of synchronism or voltage instability. Many tools are invented to overcome instability problems & improve performance of power system. Generally conventional power system stabilizer called CPSS is used. The CPSS have limitation, it can use only in linear power system. The power systems are nonlinear those operating conditions changes constantly. Many researchers work-out to improve PSS performance over complete range of operating conditions. We focused on optimization of PSS parameters for adequate performance with all operating condition. In this paper we developed genetically optimized PSS. The effect of CPSS & genetically tuned PSS are demonstrated over SMIB.**

***Index Terms*— Frequency, CPSS, GA, CSS, SMIB**

I. INTRODUCTION

The developments of new power system networks & integrate together with existing to meet energy requirements by extra high voltage transmission line (EHV) & inter-connected grids. Secure flexible & stable operation of power system with high efficiency is strictly required. Inter connection of powers systems through relatively weak tie lines produce low frequency oscillations (LFO). These oscillation will be sustain & increase system instability. Many blackouts reported due to damping so power system stability is major concern. Power system stability means the ability of system to retrieve at its original condition after a disturbance present in a system. Voltage instability occurs when system gets disturbance, growth in load or abnormal operating conditions.

II. POWER SYSTEM

The power system model is represented by single machine infinite bus system (SMIB). The generated power of Synchronous machine is fed to the infinite bus via transmission line. The synchronous machine terminal voltage is shown by E_t while infinite bus voltage shown by E_b. Resistance & reactance of the transmission line R_e & X_e.

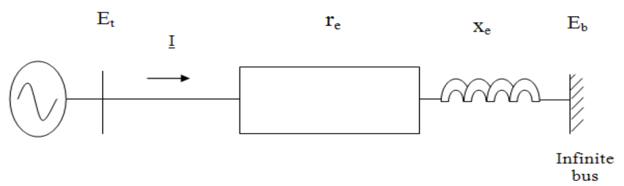

Fig.1: power system.

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The synchronous generator model 1.1(with field circuit and one equivalent damper winding on q axis) is used to present the impact of PSS on power system stability. The Phillips-Haffron model of single machine infinite bus system is developed using MATLAB/SIMULINK, which can be further incorporated for explaining the power system stability phenomena and also for research works including the development of generator controllers via advanced technologies. The non-linear simulation results are offered to validate the effectiveness of the proposed approach. The below equations and notations for the variables and parameters described are standard

$$\frac{d\delta}{dt} = w_B\,(S_m - S_{mo}) \tag{1}$$

$$\frac{dS_m}{dt} = \frac{1}{2H}\,[-D\,(S_m - S_{mo}) + T_m - T_e] \tag{2}$$

$$\frac{dE'_q}{dt} = \frac{1}{T'_{do}}\,[-E'_q + (x_d - x'_d)\,i_d + E_{fd}] \tag{3}$$

$$\frac{dE'_d}{dt} = \frac{1}{T'_{do}}\,[-E'_d + (x_q - x'_q)\,i_q] \tag{4}$$

The electrical torque T_e is expressed in terms of variables E'_d, E'_q, i_d and i_q as:

$$T_e = E'_d\, i_d + E'_q\, i_q + (x'_d + x'_q)\, i_d\, i_q \tag{5}$$

For a lossless network, the stator algebraic equations and the network equations are expressed as:

$$E'_q + x'_d\, i_d = V_q \tag{6}$$

$$E'_d - x'_q\, i_q = V_d \tag{7}$$

$$V_q = -x_e i_d + E_b cos\delta \tag{8}$$

$$V_d = x_e i_q - E_b sin\delta \tag{9}$$

Solving the above equations, the variables i_d and i_q can be obtained as:

$$i_d = \frac{E_b cos\delta - E'_q}{X_e + X'_d} \tag{10}$$

$$i_q = \frac{E_b sin\delta + E'_d}{X_e + X'_q} \tag{11}$$

III. POWER SYSTEM STABILIZER (PSS)

The PSS is used to add damping to rotor oscillations by varying field excitation using additional stabilizing signal. The stabilizer produces an electrical torque component in phase with the rotor speed deviation to provide adequate damping. Maintaining steady state and transient stability of modern synchronous generators especially demands fast control of the terminal voltage & high performance excitation systems. It is find that fast acting exciters with high gain automatic voltage regulator (AVR) also contribute for oscillatory instability in power systems. The low frequency (0.2 to 2.0 Hz) oscillations which are exist or even grow in magnitude without any apparent reason. An effective and satisfactory solution to oscillatory instability is to provide damping to rotor oscillations. Generally this damping is providing by Power System Stabilizer (PSS) which is supplementary controllers in the excitation systems. The PSS add damping to the rotor oscillations by controlling field excitation using additional stabilizing signal.

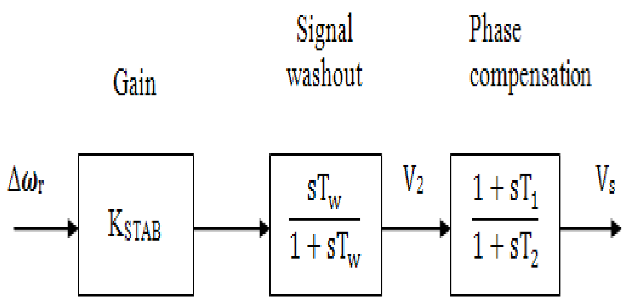

Fig. 2: Power System Stabilizer

Preturbed value from above figure, we can write:

$$\Delta V_2 = \frac{pT_w}{1+pT_w}(K_{STAB}\Delta\omega_r), \qquad p = d/dt \tag{12}$$

Hence

$$p\Delta V_2 = K_{STAB}\, p\Delta\omega_r - \frac{1}{T_w}\Delta V_2 \tag{13}$$

Taking state variables for $p\Delta\boldsymbol{\omega}_r$ in equation (13) we can rewrite above equation in state variables.

$$p\Delta V_2 = K_{STAB}[a_{11}\Delta\omega_r + a_{12}\Delta\delta + a_{13}\Delta\psi_{fd} + \frac{1}{2H}\Delta T_m] - \frac{1}{T_w}\Delta V_2 \tag{14}$$

$$p\Delta V_2 = a_{51}\Delta\omega_r + a_{52}\Delta\delta + a_{53}\Delta\psi_{fd} + \frac{K_{STAB}}{2H}\Delta T_m \tag{15}$$

Where

$$a_{51} = K_{STAB}a_{11}$$
$$a_{52} = K_{STAB}a_{12}$$
$$a_{53} = K_{STAB}a_{13}$$
$$a_{55} = \frac{1}{T_w}$$
$$a_{54} = a_{56} = 0$$
$$\Delta V_s = \Delta V_2 \frac{1+pT_1}{1+pT_2} \tag{16}$$

So

$$p\Delta V_s = \frac{T_1}{T_2}p\Delta V_2 + \frac{1}{T_2}\Delta V_2 - \frac{1}{T_2}\Delta V_s \tag{17}$$

Substituting value $p\Delta V_2$ from equation (15) we get

$$p\Delta V_s = a_{61}\Delta\omega\omega_r + a_{62}\Delta\delta + a_{63}\Delta\psi_{fd} + a_{64}\Delta V_c + a_{65}\Delta V_2 + a_{66}\Delta V_s + \frac{T_1}{T_2}\frac{K_{STAB}}{2H}\Delta T_m \tag{18}$$

Where

$$a_{61} = \frac{T_1}{T_2}a_{51}$$
$$a_{62} = \frac{T_1}{T_2}a_{52}$$
$$a_{63} = \frac{T_1}{T_2}a_{53}$$
$$a_{65} = \frac{T_1}{T_2}a_{55} + \frac{1}{T_2}$$
$$a_{66} = -\frac{1}{T_2}$$

IV. GENETIC ALGORITHM & OBJECTIVE FUNCTION

Genetic Algorithm is an extensive application widely used to solving globally optimized searching problems. The closed form optimization technique cannot be applied to some optimization problems then a genetic algorithm is a better option. Genetic Algorithm find out too many points in the given space for single parameter hence it is more closely to converge towards global minimum solution.

- Genetic Algorithm is powerful searching method based on the mechanics belongs to natural selection and natural genetics.
- Genetic algorithm based on a population of strings, searching many parallel peaks, opposition to a single point.
- Genetic Algorithm used strings of characters which defining set of parameter.
- Genetic Algorithm follows probabilistic transition rules rather than deterministic rules.
- Genetic Algorithm directly utilized objective function information & not required derivatives or other auxiliary knowledge.

GA method is applied to find out the optimal settings of controller. Genetic algorithm optimization technique is used to minimize performance index which is integral error (AIE) type. Speed deviation has been chosen as an error function. Objective function given is

$$\text{Minimize } J_e = \int_0^\infty |e(t)|\,dt$$

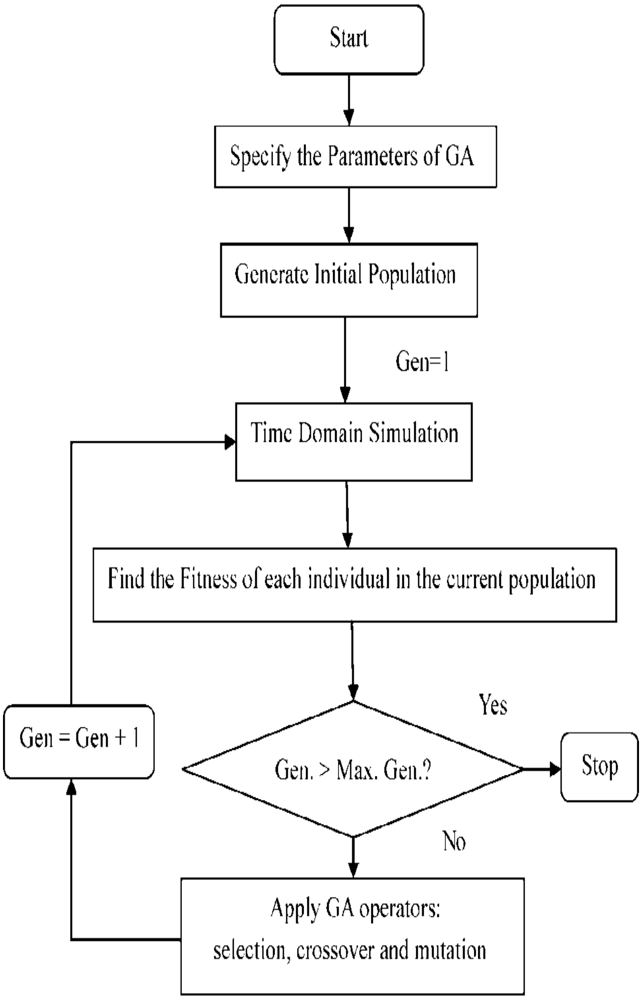

FIG.3: FLOW CHART OF GENETIC ALGORITHM.

V. SIMULATION & RESULTS

The power system model represented by SMIB as defined in equations above is simulated by using MATLAB. The oscillations are developed with 5% increase in reference voltage setting and mechanical torque input of synchronous machine. The power system stabilizer (PSS) is introduced in system and performance is observed.

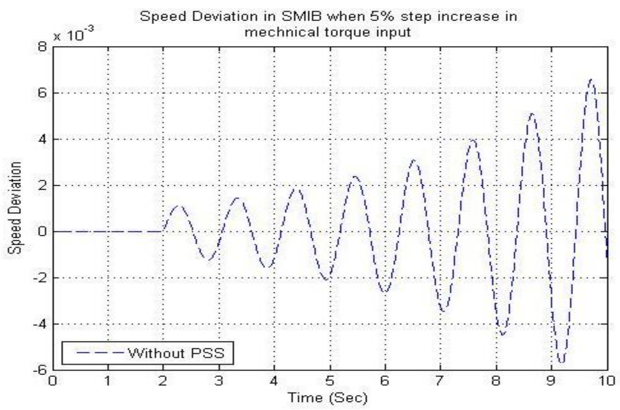

Fig. 4: Speed deviation for 5% step increase in mechanical torque input without PSS.

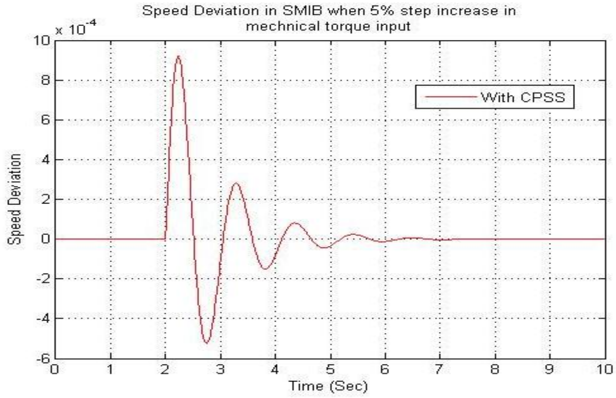

Fig. 5: Speed deviation for 5% step increase in mechanical torque input with CPSS.

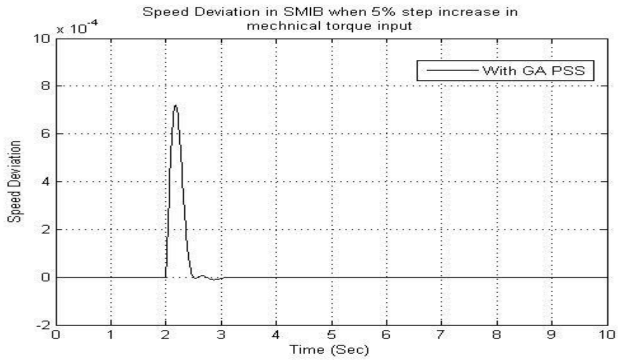

Fig. 6: Speed deviation for 5% step increase in mechanical torque input with GA-PSS.

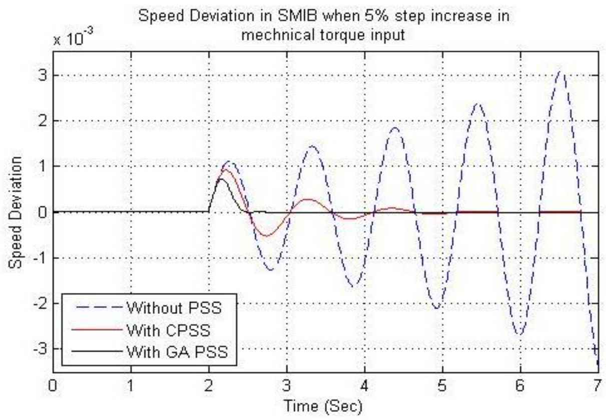

Fig. 7: Speed deviation Comparision for 5% step increase in mechanical torque input.

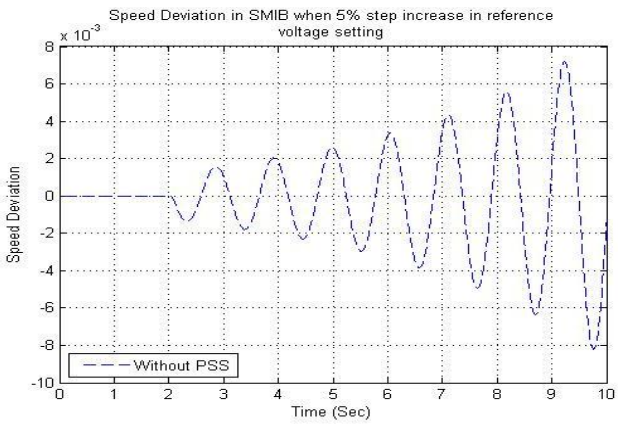

Fig. 8: Speed deviation for 5% step increase in reference voltage setting without PSS.

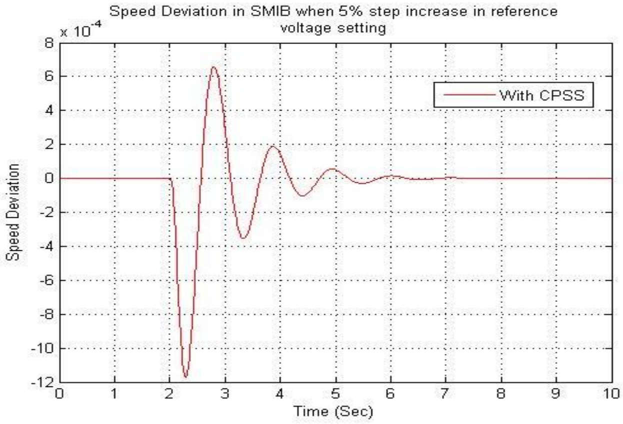

Fig. 9: Speed deviation for 5% step increase in reference voltage setting with CPSS.

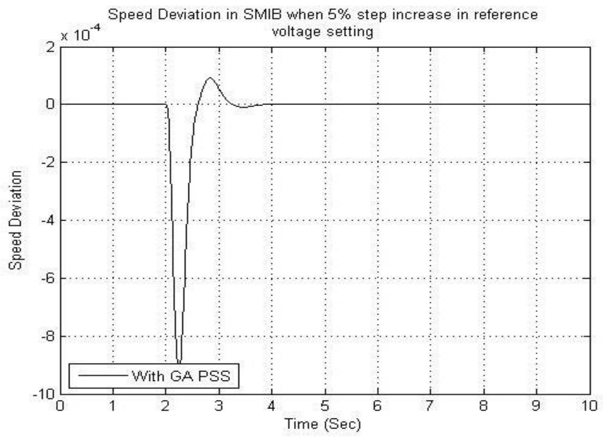

Fig. 10: Speed deviation for 5% step increase in reference voltage setting with GA-PSS.

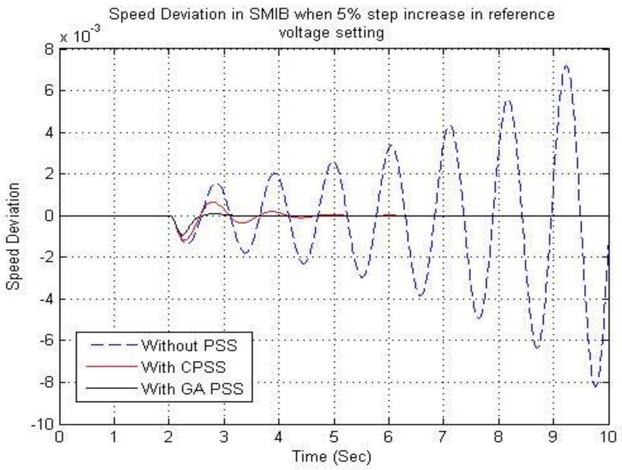

Fig. 11: Speed deviation comparison for 5% step increase in reference voltage setting

VI. ACKNOWLEDGMENTS

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VII. CONCLUSION

The behaviors of power system without & with power system stabilizer are observed. Conventional power system stabilizer (CPSS) is used to deviates low frequency oscillations. The genetically tuned power system stabilizer improves stability performance of power system with effectively damp out of low frequency oscillation. Results show that proposed model is suitable for stability analysis of power system with power system stabilizer.

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