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GENETIC ALGORITHM AIDED DESIGN OF POWER SYSTEM STABILIZERS IN A MULTIMACHINE POWER SYSTEM

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Abstract

This paper presents a Genetic Algorithm for Power System Stabilizers (GAPSS) design in a multimachine power system. The proposed GAPSS is to find the best location and optimal parameters of the power system stabilizers (PSS) in order to improve the dynamic and transient stability of a power system over a wide range of operating conditions. The objective function allows the selection of the stabilizer parameters to shift critical closed loop eigenvalues to the left-hand side the complex S plane. Simulation studies are performed to demonstrate the effectiveness of the GAPSS under different operating conditions and disturbances.

1. Introduction

Power systems are inherently nonlinear and undergo a wide range of transient conditions. This which result in under damped low frequency speed as well as power oscillations which are difficult to be controlled. To enhance system damping, the equipped with power system stabilizers (PSSs), that provide supplementary feedback stabilizing signals in the excitation systems. PSSs extend the power system stability limit by enhancing the system damping of low frequency oscillations associated with the electromechanical modes. The power system stabilizers are widely used by power system utilities [1-6], where the gain settings of these stabilizers are fixed at certain values which are determined under particular operating condition. Since the operating point of a power system changes that lead to deterioration in the stabilizer performance. However, the PSS may not be sufficient to control the damping oscillations.

Genetic algorithms have been used successfully to solve complex design problems [7,8]. GAs are not limited by difficult mathematical models and are flexible enough to accommodate almost any type of design criterion. Another advantage of GAs is that they can be easily coupled with already developed analysis and simulation tools. Research on the application of GAs to power system on the voltage regulator loop. A signal from generators are problems has been increasing steadily as can be seen in recently published survey papers [9-11]. In particular, GAs have been used in parameter estimation and tuning of power apparatus and system controllers [12,13]. This paper presents the GAPSS to enhance power system stability of a multimachine power system. The proposed GAPSS is used to fined the best location and the optimal parameters of the PSS in order to improve the dynamic and transient stability of the power system over a wide range of operating conditions. The simulation results provided good damping of the power system under these conditions.

2. Power System Modeling

The single line diagram of the IEEE 9-bus test system is shown in figure 1. This system consists of three generating units and three constant impedance loads. Each synchronous generator is represented by a seventh order nonlinear mathematical model based on Park's equations. Each excitation system and governor system is represented by a third order model. Thus the order of the nonlinear power system model becomes thirty nine. The nonlinear differential equations of the system are solved by using Rung Kutta technique. Details of the power system data are given in [15].

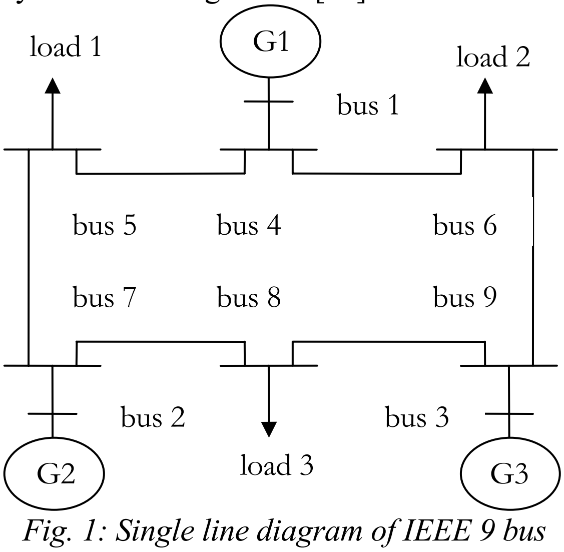

Fig. 1: Single line diagram of IEEE 9 bus system.

The lead lag power system stabilizer considered here is a speed stabilizer applied the shaft speed is applied through the PSS to the reference of the voltage regulator. The transfer function of the PSS is given by [12].

$$U(s) = k\frac{sT_w}{(1+sT_w)}\frac{1}{(1+sT_5)}\left[\frac{(1+sT_1)(1+sT_3)}{(1+sT_2)(1+sT_4)}\right]\Delta\omega(s) \quad \textbf{(1)}$$

3. Genetic Algorithms

Genetic algorithms (GAs) are considered as optimization search techniques. GA are attractive techniques that mimic natural evolution to solve problems in wide variety of domains [7], [14]. The search of any genetic algorithm starts with a random generation of a population of strings. Each generation consists of a group of population. Each population consists of a group of strings. The number of strings in a population must be even. Each string is divided into a number of substrings equals to the number of the problem variables. Each substring consists of a number of genes to represent one of the variables in a certain coding system. Floating point, decimal point, and binary coding systems could be used. In this study, the binary coding system is used. Evaluate each string in the population by using the fitness function which maps the problem objective function provided by the user.

A simple and traditional genetic algorithm is composed of three operations: *selection, crossover,* and *mutation* [7].

Selection is a process which selects the fittest string in the population by using the roulette wheel method. This selection is used in the next population. The selection depends on the value of the objective function.

Crossover is a process which takes two strings and cuts at randomly chosen position, according to the probability of crossover, to produce two “head” segments, and two “tails” segments. The tail segments are then swapped over to produce two new full-length strings.

Mutation is a process which changes any bit in each string from 0 to 1 and vice versa, at randomly chosen position according to the probability of mutation.

Appling the three operations; *selection, crossover, and mutation;* produces new strings (offspring), new population, and new generation respectively. The overall process is then repeated with the new generation until the stopping criterion is satisfied.

4. PSS Design Using Genetic Algorithm

4.1 Linearized model

The objective function of GAPSS allows the selection of the stabilizer parameters to shift critical closed loop eigenvalues to the left hand side of a vertical line in the complex S plane. Thus a linearized model of the multimachine power system is described in the state space form [16]:

$$\dot{X} = A * X + B * U \qquad \textbf{(2)}$$

where X is the state vector, U is the input vector, A is the state coefficient matrix and B is the input coefficient matrix. The model can be derived by linearizing the nonlinear equations of the system (generator, exciter, governor, and PSS) around a nominal steady state operating point. A method for building the linearized model is given in [16]. The eigenvalues of the matrix A contains the necessary information on the stability of the multimachine power system. The complex conjugate pairs of the eigenvalues are associated with the oscillatory modes in the time response. They have the form:

$$\lambda = -\alpha \pm j\beta \qquad \textbf{(3)}$$

Where β gives the frequency of the oscillations in rad/sec and the value of $1/\alpha$ defines the time constant by which the magnitude of the oscillation decay. In this case the eigenvalues are constrained to lie to the left of a vertical line corresponding to a specified damping factor.

4.2 GA based PSS

The proposed genetic algorithm is to find the optimal parameters and the best location of the PSS to maximize the following objective function:

Objective function = - real(dominant eigenvalue)

where the dominant eigenvalue is the nearest pole to the RHS of the S-plane, and the objective function is the real part of the dominant eigenvalue.

The optimization problem, namely, the selection of parameters and location of PSS is easily and accurately solved using genetic algorithms. The eigenvalues of the closed loop system are computed, and the objective function is evaluated using only those eigenvalues that need to be shifted. In a typical run of the GA, an initial population is randomly generated. This initial population is referred to as the 0th generation. Each individual in the initial population has an associated objective function value. Using the objective function information, the GA then produces a new population. The flowchart of the genetic algorithm is shown in figure 2.

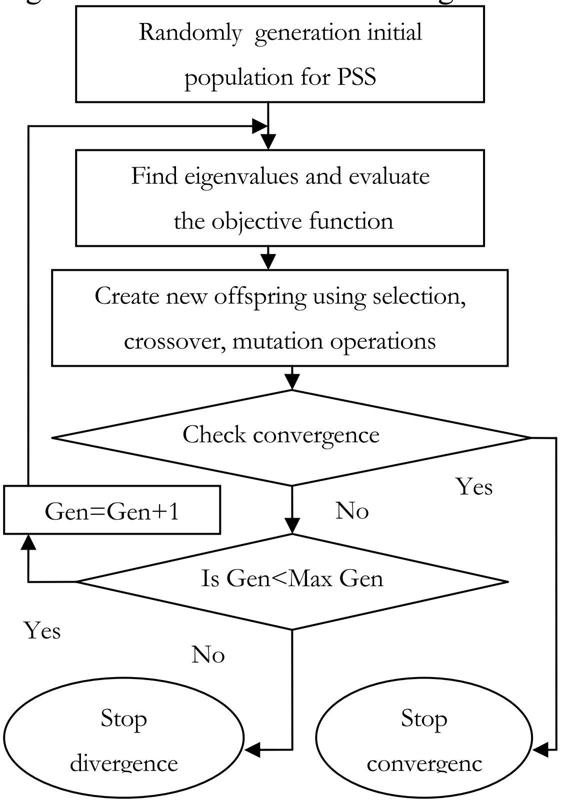

Fig. 2: A basic genetic algorithm cycle.

The genetic algorithm will calculate the objective function for each of the individuals in the current population. To do this, the system eigenvalues must be computed. Also GA then produces the next generation of individuals using the selection, crossover, and mutation operators. These steps are repeated from generation to generation until the population has converged, producing the optimum location and optimum parameters.

5. Simulation Results

Simulation results are presented to illustrate the effectiveness of the proposed GAPSS in the power system under different operating points and different disturbance such as overload, underload, line open, and three phase short circuit. The GA parameters used in this study are:

The population size = 50; maximum number of generation = 1000; crossover and mutation probabilities = 0.75 and 0.12 respectively, convergence error = 10^{-5}. The PSS parameters are $T_w = 10$, $T_2 = T_4 = 0.05$. The remaining parameters is K, T_1, T_3, and T_5 will be chosen between the upper and lower limits of 0 to 100. The GA determines the optimal location and optimal parameters of PSS by shifting the eigenvalues to left hand side of a vertical line in the complex S plane. In this study, we have chosen two different operating point as shown in table (1). The system eigenvalues are calculated and dominant ones are in table (2) because the generator at bus 1 is selected as a reference machine. Figure 3 shows the variation of the objective function with generation. GA selects the optimal location of PSS on generator at bus 2, and finds the optimal parameter of PSS.

The validity of these results are also evident from the nonlinear responses shown in figures 4, 5 ,6 ,7, and 8, when the system with PSS on generator at bus 1, bus 2, and bus 3 is subjected to severe disturbance at different operating conditions. Figure 4 shows the system responses to a 10% sudden increases in demanded active and reactive powers at bus 6. Figure 5 shows the system responses to the same disturbance but the operating point is changed.

The responses show that the voltage at all buses have reached very fastly to their steady state levels. Also, all generating units have reached very fast their new operating points with this controller.

The capability of the proposed GA to select the best location of PSS under different disturbances and loading conditions were considered as given in figures 6, 7, 8. Under these conditions, the system response without PSS is unstable. Figure 6 shows the system response to a sudden decrease 10% in the load power (P&Q) at bus 6. Figure 7 shows the system response to a complete line outage between buses 6 and 7. Figure 8 shows the system response to a three phase fault disturbance for 0.12 sec at bus 6. The responses in figure 6, 7, and 8 show that the system with PSS on the G_2 has much better performance and the oscillations are damped out.

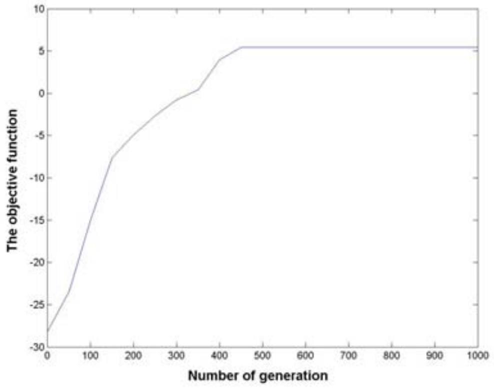

Fig. 3: Variation of generation with objective function

Table (1): The operating points

Item	Operating point 1	Operating point 2
V_{G1}	1	1
V_{G2}	1.012	1
V_{G3}	1.002	1
P_{G2}	1.75	1.63
P_{G3}	0.75	0.85

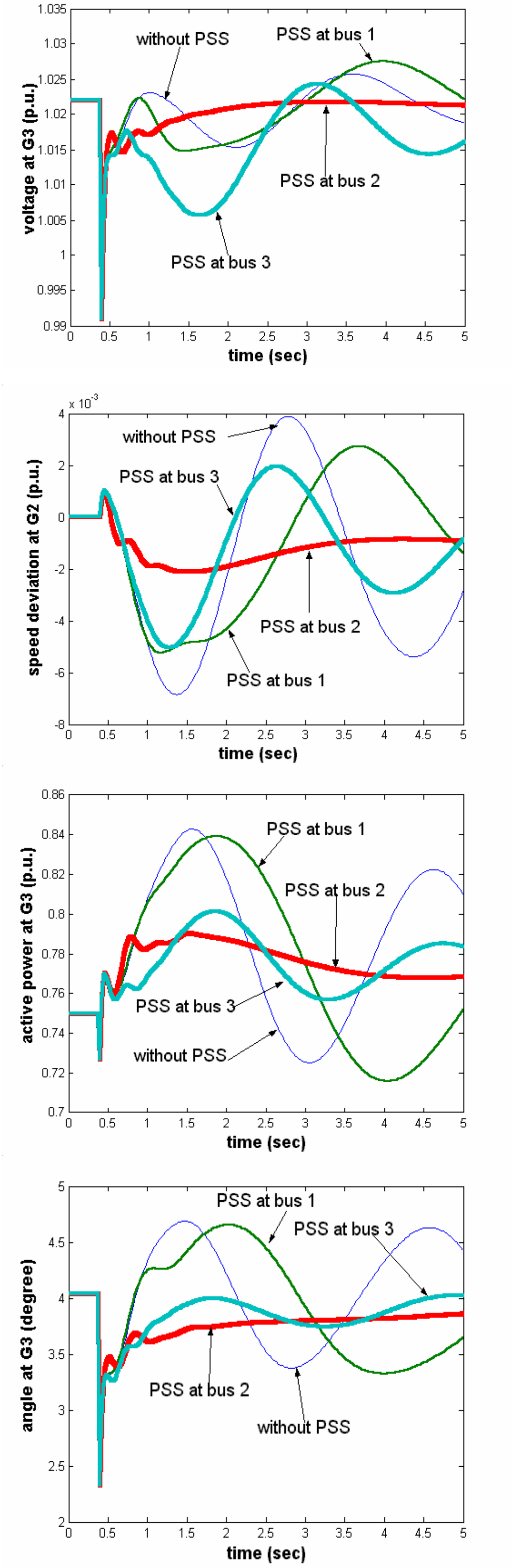

Fig. 4: System responses of sudden increase of 10% in demanded powers at load bus 6.

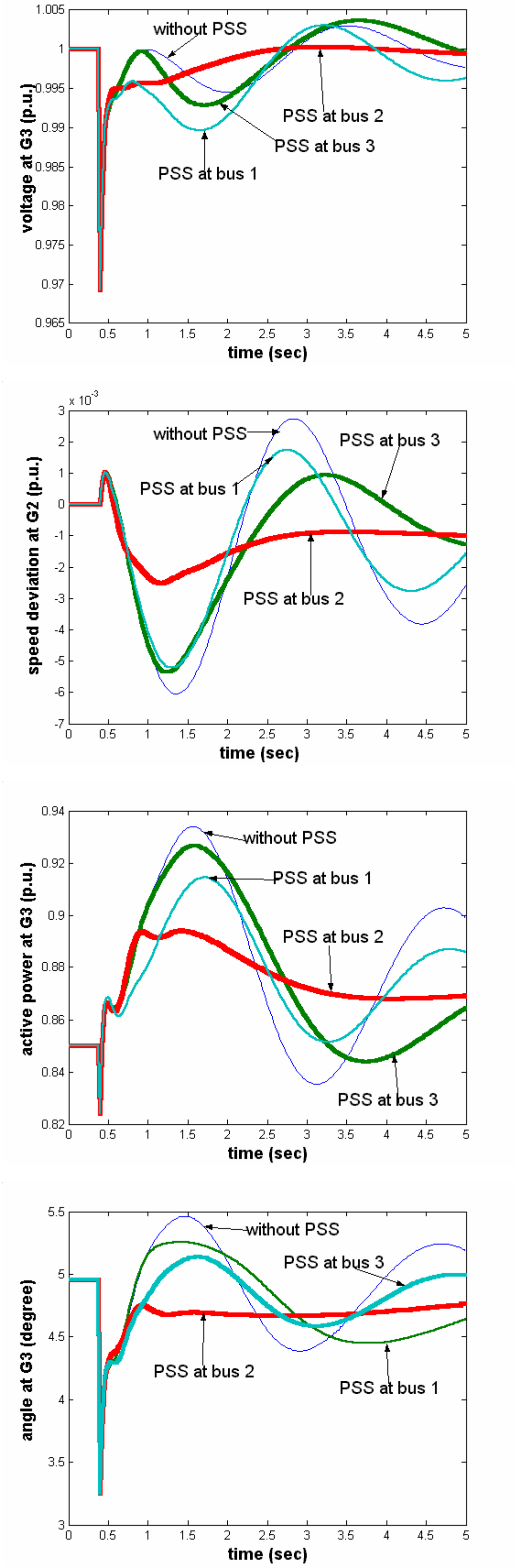

Fig. 5: System responses of sudden increase of 10% in demanded powers at load bus 6 at other operating point.

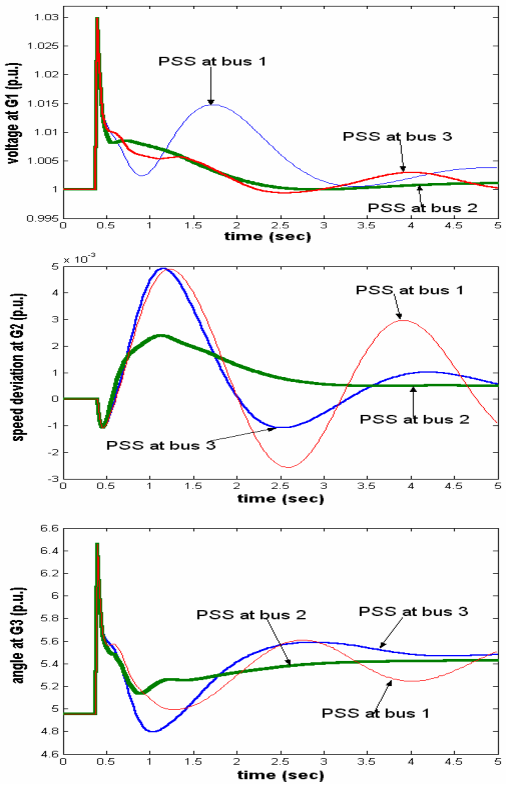

Fig. 6: System responses of sudden decrease of 10% in demanded powers at load bus 6.

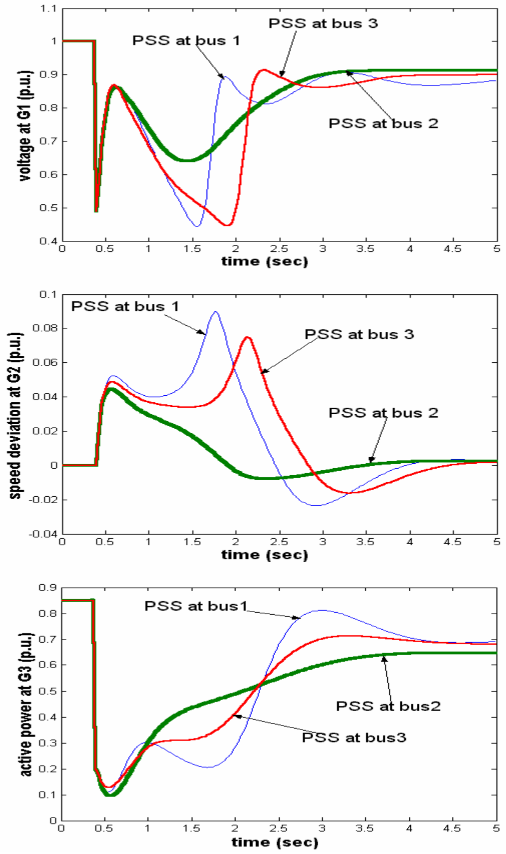

Fig. 7: System responses to a line open between bus 6 and bus 7.

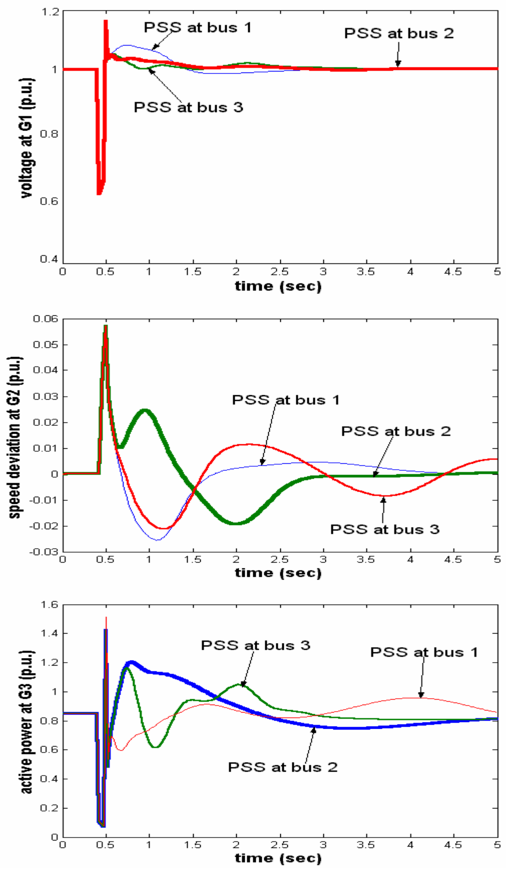

Fig. 8: System responses to a three phase short circuit of 0.12 sec at bus 6.

Table (2): The eigenvalues of the system

Item	Operating point 1	Operating point 2
Without PSS	-1.0904±2.0268i	-0.8563±1.8451i
PSS at bus1	-1.2327±1.7952i	-0.9889±1.7452i
PSS at bus2	-4.8922±3.9005i	-5.4231±3.7938i
PSS at bus3	-2.0199±1.3659i	-2.3007±1.6534i

6. Conclusions

The paper introduced a GAPSS that applied to a multimachine power system. The procedure is based on a genetic algorithm technique. The algorithm has been used to select the optimal location and optimal parameters of power system stabilizers. Simulation results showed that the GAPSS is capable of selecting the optimal parameters and best location of PSS under different operating conditions and disturbances.

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