New Technique to improve Power System Stabilizer performance by Genetic Algorithm

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Abstract: Principle role of a Power System Stabilizer (PSS) is to increase damping of oscillations of generator rotor by control of its excitation by using of auxiliary stabilizer signals. The design of a PSS can be performed by suitable state and optimum feedback that roots of case study is transferred to suitable points as designed results. As the large searching techniques, Genetic Algorithms (GA) is global search techniques to provide a powerful tool for optimization problems by miming the mechanisms of natural selection and genetics. To fast accessing of desired results, this paper used a modified Genetic Algorithm for suitable designing of stabilizer.

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1. Introduction

The power system stabilizers are added to the power system to enhance the damping of the electric power system. The design of PSS can be formulated as an optimal linear regulator control problem whose solution is a complete state control scheme. The implementation requires the design of state estimators that consume large time. To deal with problem, control scheme uses only some desired state variables such torque angle and speed. The desired objectives in this paper are:

Variations of the angular frequency ($\Delta\omega$) can be achieved to end value equal to zero in minimum time.

Variations of the torque angle ($\Delta\delta$) can be achieved to end value equal to minimum value in minimum time.

Different methods have been presented to achieve mentioned purposes. In [2] an optimal design for PSS has been proposed by grey prediction PID control method. However, output results related to second input wasn't considered. Also [1] was presented an adaptive back stepping method to improve of PSS performance.

For achieving desire objectives should be selected as minimum settling time, however peak value should be considered negligible. In this paper, authors propose a method to design of controller by modified genetic algorithm. Advantages of proposed method have been presented by numerical simulations for two machine infinite bus system in MATLAB software. The proposed fitness function consists of three basic genetic operators: Reproduction, Crossover and Mutation. Moreover, elitism is used for retaining proportional chromosome.

Also in fitness function is implemented some cases such as maximum function value (max), the time of peak value (t_p), settling time (t_s) and end value of function to improve output characteristics.

2. Study system

The system studied in this paper is shown in fig.1. It is two machine-infinite-bus power systems. The system study is described by following state space representation:

$$\dot{x} = Ax + Bu \qquad (1)$$

Where

$$x=[\Delta\omega_1 \quad \Delta\delta_1 \quad \Delta e'_{q1} \quad \Delta V_{F1} \quad \Delta\omega_2 \quad \Delta\delta_1 \quad \Delta e'_{q2} \quad \Delta V_{F2}]$$

Δ Denotes deviation from operation point

ω Speed

δ Torque angle

e'_q Voltage proportional to direct axis flux linkages

V_{FD} Generation field voltage

Where matrices A and B from [2], as follow:

$$A = \begin{bmatrix} -0.244 & -0.0747 & -0.1431 & 0 & 0 & 0.0747 & 0.0041 & 0 \\ 377 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & -0.046 & -0.455 & 0.244 & 0 & 0.046 & 0.13 & 0 \\ 0 & -39856 & -194988 & -50 & 0 & 39858 & -3967 & 0 \\ 0 & 0.178 & -0.0433 & 0 & -0.2473 & -0.178 & -0.146 & 0 \\ 0 & 0 & 0 & 0 & 37699 & 0 & 0 & 0 \\ 0 & 0.056 & 0.1234 & 0 & 0 & -0.0565 & -0.3061 & 0.149 \\ 0 & -677.39 & -1023422 & 0 & 0 & 677.78 & 1336416 & -50 \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & 0 & 0 & 2500 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2500 \end{bmatrix}^T$$

$$C = \begin{bmatrix} 1 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 & 0 \end{bmatrix}$$

A block diagram of the study system is shown in Fig.1. This model has been extensively used and details can be found in [2].

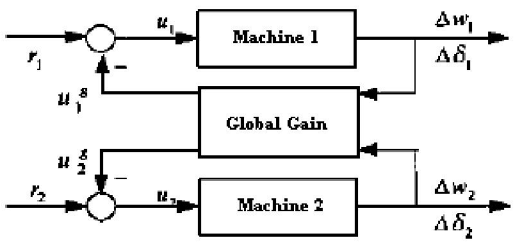

Fig 1. Block diagram for two machine infinite bus system

3. Optimal design

In this paper, authors proposed a method to choice proportional routes for PSS and forecasting step value by genetic algorithm (GA) based on performance measures of the system's responses.

The GA includes five fundamental parameters: (a) Population size, which influences amount of search points in every generation. The more population size in the GAS will increase the efficiency of searching, but it will time consuming; (b) Crossover probability, which influences the efficiency of exchanging information. The crossover probability is between 0.6 and 1; (c) Mutation probability, which occur with a small probability in the GAS. In general, the mutation probability is under 0.1. A large mutation probability in GAS will eliminate the result of reproduction and crossover, which let GAS become a random search; (d) Chromosome length, which influences the resolution of the searching result. The GAS with longer chromosome length will have the higher resolution, but it will increase the search space; (e) Generations, which influences the searching time and searching result. The GAS with larger search space and less population size, it needs more generations for a global optimum [2].

in order to improvement of control system and optimum system charactristic as setteling time (t_s), peak time (t_p) and steady state value, fitness function determinate as follow:

$$f(i) = 10^6 \Big/ (a_1 \times \max_1 + a_2 \times \max_2 + a_3 \times tp_1 + a_4 \times tp_2 + a_5 \times ts_1 + a_6 \times ts_2 + a_7 \times Fin_1 + a_8 \times Fin_2)$$

where a_i (i = 1, 2, …, 8) are assessable system performance factors that are known fine factors in GA. These factors have been choice based on weight and influence of parameters. Used Chromosomes used in GA have been determined as matrices in decimal system. Length of matrices arrays considered 4 cells. In addition elite selection in stages is performed to prevent of losing the desirable Chromosome. However reproduction number has been considered 100. For more searching in search space, a new Chromosome is added to next population from 90^{th} iteration to up randomly. Population size influences amount of search point in every generation. The more population size in the GA will increase the efficiency of searching, but it will time consuming [2].

In this paper, authors provide a uniform method for mutation and crossover. In this method by using of metal slow cooling algorithm, application of mutation and crossover operators in GA algorithm decrease from 25 to 2 for 1st and last iteration respectively.

According to proposed fitness function, selected Chromosome will provide the controlled system with the desired performance of peak time, settling time and steady state.

4. Numerical results

System eigenvalues in open loop case based given matrices A, B and C are shown in table 1.

Table1. Eigenvalue of open loop system

value	parameter
-25.1 + j 445.8	λ_1
-25.1 - j 445.8	λ_2
-24.7 + j 216.6	λ_3
-24.7 - j 216.6	λ_4
-0.65 + j 78.01	λ_5
-0.65 - j 78.01	λ_6
0.67	λ_7
-0.92	λ_8

4.1 Optimal controller

In order to design an optimal feedback to transfer initial case of system to final case with consideration of an operational indexes, optimal controller have been used. However operational indexes were chosen to provide best balance between control system cost and performance.

As known, optimal controller design is aimed based on optimal factor K, where:

$$u(t) = -Kx(t) \tag{2}$$

$$K = R^{-1}B^{T}p \tag{3}$$

$$pA + A^{T}p + Q - pBR^{-1}B^{T}p = 0 \tag{4}$$

Equation (4) is riccati equation that comprises desired matrices R and Q (commonly positive diagonal matrix). By solving this equation, matrix P is obtained that lead to gains of optimal control feedback is resulted from equation (3).

Desirable values of optimal controller can be obtained by large iteration. To deal with this problem, a modified Genetic Algorithm has been proposed by authors. First optimal feedback values were designed by creating initial population size with 30 Chromosome. Matrix A_Q was determinate as follow:

$$A_Q = A - B * K \tag{5}$$

With notification to system considerations comprising settling time (t_s), peak time (t_p) and peak value, fitness of Chromosome was analyzed. Also, new populations have been created by reproduction, crossover and mutation operators for every step of generation. Matrices R and Q was resulted as follow:

$$Q = \begin{bmatrix} 89.3031 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 91.4156 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 62.2689 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 56.2735 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 62.1672 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 74.9122 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 25.9784 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 2.0884 \end{bmatrix}$$

$$R = \begin{bmatrix} 4.8552 & 0 \\ 0 & 10.2222 \end{bmatrix}$$

By running LQR2 command in MATLAB software, optimal K is resulted as follow:

$$K = \begin{bmatrix} -2093.2 & -12.521 & 1536.4 & 3.3889 & -2370.6 & 12.362 & 166.32 & 0.0013 \\ 332.07 & -3.9156 & -23.052 & -0.0006 & -3462.3 & 4.2156 & -10.247 & 0.4311 \end{bmatrix}$$

4.2 state feedback controller

To determinate state feedback values, dominant poles was designed with desired ζ , then, ω would chosen because desired pole should be located near the zero ($0 < \omega < 5$). Table 2 show desirable routs (dominant poles).

Table 2. Transferred routs to design of state feedback controller

Desired roots
-32.294 ± j 76.8884
-70.665
-92.4219
-94.8678 ± j 48.2
-93.1622 ± j 66.0966

For analysis the state feedback controller, controllability of system should be investigate. As notice to the controllability of system, by programming in MATLAB software, state feedback values were resulted. Therefore matrix K is obtained as follow:

$$K = \begin{bmatrix} -30408 & -1811.8 & 5.4129 & 0.12 & -31954 & -1.2283 & 37.615 & 0.0186 \\ 31411 & 2483.2 & -450.91 & -0.0329 & 15152 & 78.411 & -482.64 & 0.0809 \end{bmatrix}$$

The maximum number of generations to be run by the GA is 100. Figure 2 shows the optimization process of GA in case study.

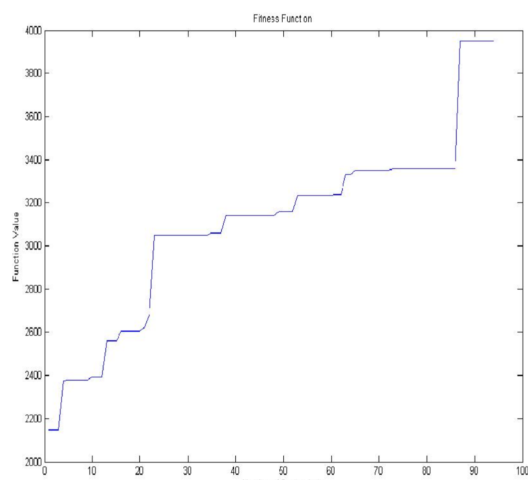

Fig2. Optimization process of GA in case study

5. Simulation Result

System response to step input are shown in fig.4 for open loop case. Results show instability of system in normal operation. Table 3 show studied parameters in the simulation.

Settling time and final value have not been desired for second input when optimum controller was used to improvement transient characteristic of stabilizer. However system stability has been improved considerably.

Table3. Studied parameters (output) in simulations

parameter	output
$\Delta\omega_1$	Out(1)
$\Delta\delta_1$	Out(2)
$\Delta\omega_2$	Out(3)
$\Delta\delta_2$	Out(4)

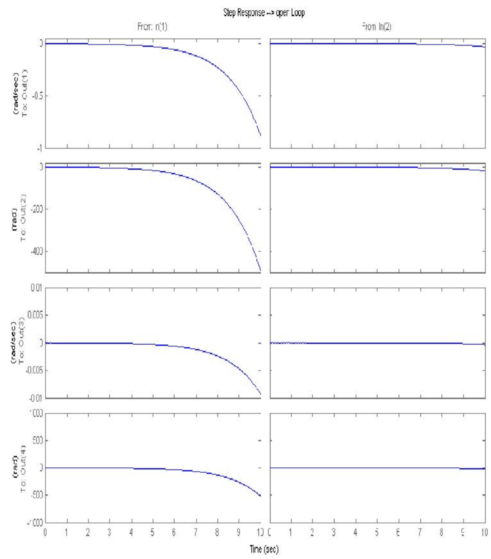

Fig3. Output response to step input for open loop case

Fig.4 and fig.5 show simulation results to step input for optimal controller and state feedback controller respectively.

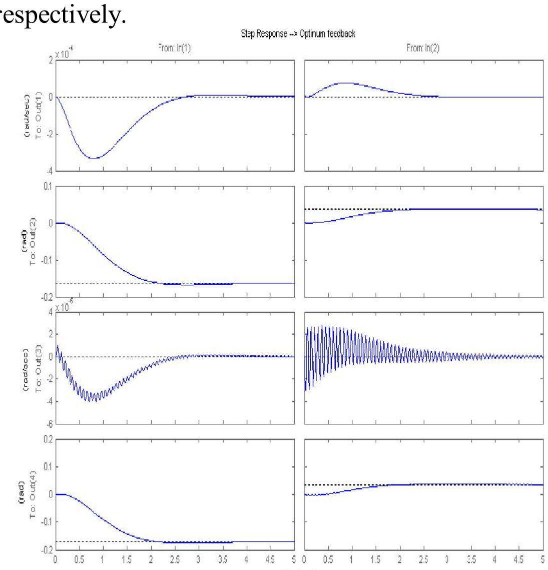

Fig4. Output response to step input with optimal controllers

While state feedback controller was used, so suitable system response was observed both inputs. In other word, state feedback controller has better performance than optimal controller for studied multi machine system.

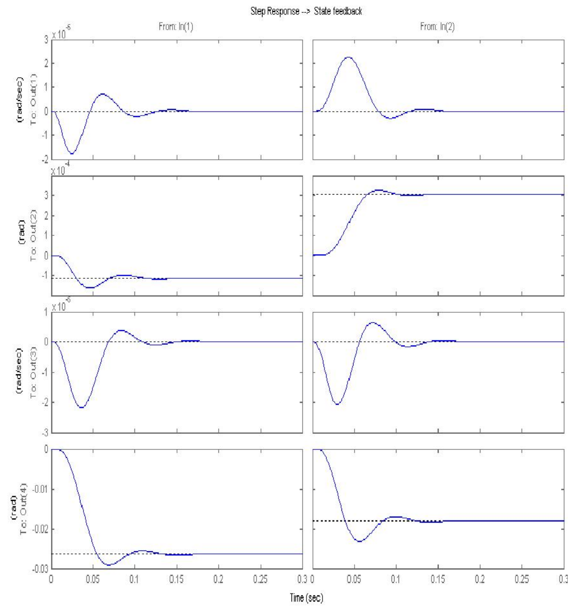

Fig5. Output response to step input with state feedback controller

6. Conclusions:

In this paper, a Genetic Algorithm method is used to design state and optimum feedback controllers for improvement PSS transient characteristics. The results for two-machine system is represented by Genetic Algorithm as simulation studies and compared with three control cases content open loop, optimum feedback controller and state feedback controller.

However, the system is stabilized by optimum feedback controller but results illustrated undesired settling time and oscillations of final values as secondary input, slightly. As shown, state feedback controller lead to suitable operation of power system stabilizer for studied two-machine system and represented more proportional results than optimum feedback controller.

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