

Contents List available at VOLKSON PRESS

New Materials and Intelligent Manufacturing (NMIM)

DOI: http://doi.org/10.26480/icnmim.01.2018.206.209 Journal Homepage: https://topicsonchemeng.org.my/



ISBN: 978-1-948012-12-6

DESIGN OF H∞ STABILIZER FOR POWER SYSTEM BASED ON GA-PSO ALGORITHM

ZHAO Jule1, HAN Guangxin 2*

- ¹Control engineering of 1701, Jilin Institute of Chemical Technology, ChengDe Street, JilinCity, China.
- ²Professor of Jilin Institute of Chemical Technology, ChengDe Street, JilinCity, China. *Corresponding Author Email: hangeorge517@163.com

This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited

ARTICLE DETAILS

ABSTRACT

Article History:

Received 26 June 2018 Accepted 2 July 2018 Available online 1 August 2018 Power system stabilizer (PSS) mainly adjusts the phase of power system and damping compensation by parameter tuning. If the operation point of power system changes, the traditional PSS can't guarantee the robustness of power system. In this paper, a H∞ stabilizer is designed for the power system, in which the weighting function is optimized by the genetic particle swarm optimization (GA-PSO). Simulation results validate the robustness of the GA-PSO H_{∞} stabilizer of power system.

KEYWORDS

Power system, Low frequency oscillation, H_∞ power system stabilizer, Robustness.

INTRODUCTION

In order to maintain the stable operation of the power system, an effective way is to suppress low frequency oscillation by increasing system damping using PSS [1]. In recent years, in order to achieve the best control effect, the research of PSS is mainly using intelligent algorithm to optimize $\,$ the parameters of power system stabilizer. The traditional PSS is designed on the basis of a operation point after the power system is linearized. Under the condition of nonlinear power system, when the operation point changes, the function of PSS will be weakened. In view of the shortcomings of the traditional PSS, this paper takes into account the interference of the system and the uncertainty of the system during the design process and transforms the system design target into the H_∞ mixed sensitivity problem [2]. The optimal weighted function is selected by the global search and optimization ability of the differential particle swarm optimization (GA-PSO). Together with the augmented controlled object which constituted by controlled system model, the desired GA-PSOH_∞ stabilizer of power system is obtained to improve the suppression energy of the low frequency oscillation.

2. POWER SYSTEM DYNAMICS

In order to analyze the dynamic characteristics of synchronous motor, the designed object G (s) selected a single machine infinity system called Heffron-Philips model, which has been linearized, as shown in figure 1 [3].

The input of the controlled system is the output excitation voltage $\,U_{E}\,$ of the excitation controller, and the controlled system output is the input of the excitation controller, it is the speed deviation $\Delta \omega$.The state variable of G(s) select $\left[\Delta\omega,\ \Delta\delta,\ \Delta E_{\rm q},\ \Delta E_{\rm fd}\right]^T$, then the state equation of the system is as follows:

$$x = Ax + b$$

$$y = Cx + D$$
(1)

$$A = \begin{bmatrix} 0 & \frac{-K_1}{T_J} & \frac{-K_2}{T_J} & 0\\ \omega_0 & 0 & 0 & 0\\ 0 & \frac{-K_4}{T_{d0}'} & \frac{-1}{T_{d0}'K_3} & \frac{1}{T_{d0}'}\\ 0 & \frac{-K_AK_5}{T_A} & \frac{-K_AK_6}{T_A} & \frac{-1}{T_A} \end{bmatrix}, b = \begin{bmatrix} 0\\0\\0\\K_A\\T_A \end{bmatrix}, C = \begin{bmatrix} 1\\0\\0\\0 \end{bmatrix}^T, D = 0$$

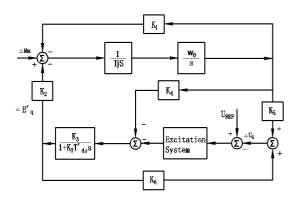


Figure 1: Structure diagram of controlled system

2.1 The standard control problem of H_{∞}

Figure 2 is a block diagram of the H_{∞} standard control problem, where uis the input control signal, y is the output measurement signal, w is the external signal, and z is the controlled output signal. P(s) is an augmented controlled object including a weighting function. K (s) is controller that need to be designed.

Where:

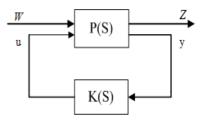


Figure 2: H_∞ standard control problem block diagram

The transfer function state space expression is shown in equation (2):

$$x' = Ax + B_1 w + B_2 u \tag{2}$$

$$z = C_1 x + D_{11} w + D_{12} u (3)$$

$$y = C_2 x + D_{11} w + D_{22} u (4)$$

The transfer function from the external input signal w to the controlled output object z is shown in equation (3).

$$T_{\text{zw}} = LFT(P(s), K(s)) = P_{11} + P_{12}K(I - P_{22}K)^{-1}P_{21}$$
 (5)

The optimal control problem of H_{∞} is as follows: for the generalized system P (s) of the controlled object, the feedback controller K (s) makes the closed-loop transfer function of the system stable and the H_{∞} norm of the transfer function from w to z. Expression is $\min_{\nu} \left\| T_{zw}(S) \right\|_{\infty} < \gamma_0$, It also

determines whether there is a feedback controller K (s), which makes the closed-loop transfer function of the system stable internally. The suboptimal control problem satisfies $\left\|\frac{1}{\gamma}\,T_{z*}(s)\right\|_{\infty}\,<\,1\,$. In which,

$$\gamma > \gamma_0$$
 , $\left\| \frac{1}{\gamma} \, T_{_{\!\!\! z_w}(S)} \right\|$ is considered as the transfer function $T_{_{\!\!\! z_w}}(S)$

which from w to z .It is made up of the generalized controlled object P (s) and the required feedback controller K (s).

2.2 Hybrid sensitivity and pole assignment problem

 H_{∞} mixed sensitivity problem mainly suppress the uncertainty of interference and controlled objects simultaneously [4]. In figure 3, G (s) is the transfer function of the controlled object, K (s) is the controller, y is the input signal of the system, the u is the control output, $W_1 \left(\mathcal{S} \right)$, $W_2 \left(\mathcal{S} \right)$,

 $W_3(S)$ and V(S) are weighting functions, w is the interference signal

before weighed. Z_1 , Z_2 and Z_3 are weighted outputs. When the function is not weighted, the absolute value of the closed-loop transfer function that interferes w to outputs Z_1 , Z_2 , Z_3 are sensitivity functions S, R and T.

The absolute value of the weighted output are : $z_1 = w_1 Sv \omega$,

 $z_2 = \mathrm{W}_2 R \mathrm{VW}$ and $z_3 = \mathrm{W}_3 T \mathrm{VW}$. The transfer function matrix

that interferes with the output is $\Phi = \left[\mathbf{w}_1 S \mathbf{v}, \mathbf{w}_2 R \mathbf{v}, \mathbf{w}_3 T \mathbf{v} \right]^T$, The mixed sensitivity problem is to design the controller K to stabilize the closed-loop system and minimize the performance index.

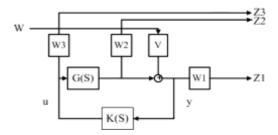


Figure 3: Mixed sensitivity and pole assignment

The open loop transfer function of the controlled object may contain the weakly damped poles near the virtual axis, which are also the closed loop

poles of the system after the controller is added to the controller, which will affect the control effect, so the weight function V is needed to adjust.

The weighted function $V=M\,/\,E$, where E is used to cancel the weak damping poles in the original system, and M is used to reset the location of the weakly damped poles.

2.3 Design of H∞ power system stabilizer

In the standard control problem, the G(s) and the weighted function of the mixed sensitivity problem and the weighted function V for reconfiguring the weakly damped poles together constitute the generalized controlled object P (s) in figure 1. After optimizing the design model, we need to select the appropriate weighting function and the weighted function V for reconfiguring the damping pole, and obtain the generalized controlled object model. The Minreal function in the robust control toolbox can be used to obtain the contact controller for the minimum controller, and the Modred function is used to reduce the controller. The selection of weighting function V follows the principle of pole placement.

3. WEIGHTED FUNCTION OPTIMIZATION BASED ON GA-PSO

When POS algorithm calculates extreme values of functions, premature convergence often occurs, which leads to large deviations in the solution of function extremum [5]. The genetic algorithm uses the selection, crossover and mutation operators to optimize the function. It directly uses the target function as the search information and is carried out in a probability way. It can also enhance the global optimization ability of the particle swarm optimization algorithm. It can improve the evolutionary speed of the algorithm and improve the convergence precision. The structure of the weighting function to be optimized is as follows:

$$W_1 = \frac{k_1(s + z_1)}{(s + a_1)}$$
 (6)

$$W_2 = \frac{k_2(s + z_2)^n}{(s + a_2)^n}$$
 (7)

$$W_3 = \frac{k_3(s + z_3)}{(s + a_3)}$$
 (8)

The objective function is as follows:

$$f = \int_{t_{0}}^{t} t [i | \omega_{n}(t) - \phi_{ms} |] dt$$

$$k_{1 \min} < k_{1} < k_{1 \max}$$

$$z_{1 \min} < z_{1} < z_{1 \max}$$

$$k_{2 \min} < k_{2} < k_{1 \max}$$

$$z_{2 \min} < z_{2} < z_{2 \max}$$

$$k_{3 \min} < k_{3} < k_{3 \max}$$

$$z_{3 \min} < z_{3} < z_{3 \max}$$
(9)

Among them, I is an adjustable weight factor for motor. \mathcal{O}_{n} is rotor angular velocity, $\mathcal{O}_{\mathit{mas}}$ is the steady state for rotor speed.

The steps of the GA-PSO algorithm are as follows [6]:

Step 1: Initialize the particle swarm according to the set range and population number, initialize the M of each cluster group, and the maximum iteration number is n.

Step 2: Substituting the initialized population into H_∞ stabilizer of power system. The controller is programmed and the controller is obtained. Then the controller is substituted into the Simulink model to calculate the fitness value. Then, evaluate the fitness of P group.

Step 3: Perform mutation, crossover and selection operations for all individuals in the D group. Among them, when choosing operation, the criterion is the best fitness of particle target function J.

Step 4: Select the best individual $\mbox{ Pgbest (t) }$ in the P group according to the fitness.

Step 5: Select the best individual Dgbest (t) in the D group according to the fitness.

Step 6: Compare the pros and cons of Pgbest (t) and Dgbest (t) and select the best individuals as the evolutionary basis of P group and D group.

Step 7: Reserved the best individual gbest(t) in the current whole group. If the precision requirement is satisfied or the entire evolution has reached the maximum number of iterations, then break the algorithm , and output the optimal position. Finally, decode the particle and generate the weighting function parameters, otherwise the step 2 is transferred.

4.SIMULATION RESULTS

In this paper, MATLAB simulation software is used to simulate the relative short circuit fault simulation of the transmission line three and the influence of the step disturbance on the excitation system in the Simulink environment. The parameters of the generator model are as follows:

At 6s, a 20% output voltage step response is given to the system. In the case of disturbance step input, the speed of motor and the output electromagnetic power are shown in figure 4 and figure 5 respectively.

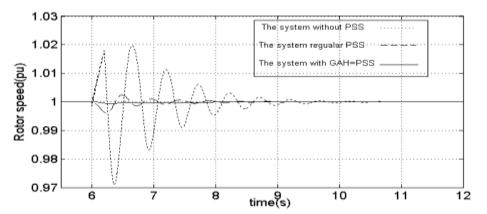


Figure 4: Speed curve in the case of step disturbance

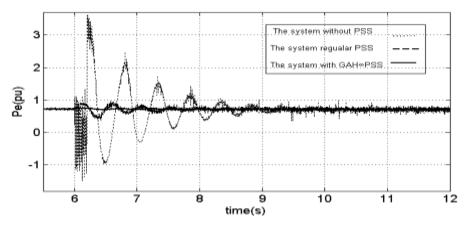


Figure 5: Electromagnetic power curve under step disturbance

Compared with the traditional PSS and non PSS control, the speed and the electromagnetic power of the GA-PSOH $_{\infty}$ control system are almost no oscillation, and the single machine infinity system has strong robustness when the single machine infinity system is disturbed by the step disturbance at 6s time [7,8].

At 6s, a 0.2s output voltage step response is given to the system. In the case of disturbance step input, the speed of motor and the output electromagnetic power are shown in Figure 3-1 and figure 3-2 respectively.

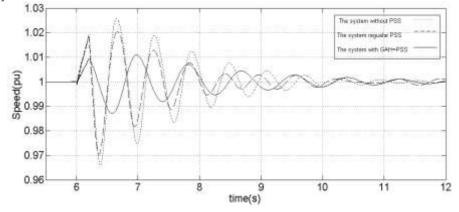


Figure 6: Speed curve of three phase circuit fault

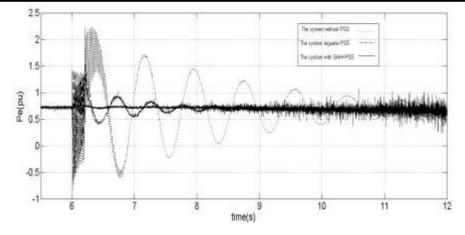


Figure 7: Electromagnetic power curve under three phase short circuit fault

Compared with the traditional PSS and non PSS control, the amplitude and the oscillation frequency of the GA-PSOH $_{\infty}$ PSS control system are obviously lower than those of the traditional PSS and non PSS control, and the single machine infinity system has a strong robustness [9,10].

5. CONCLUSION

From the simulation results of two different conditions, the system uncertainty is taken into account in the design process. The H infinity control theory is used to design the power system stabilizer. The GA-PSOH $_\infty$ PSS designed by the hybrid algorithm of genetic and particle swarm optimization and the partial pole placement technique is better than the traditional PSS. The H_∞ PSS avoids the work of selecting weighted functions many times by experience. By global optimization, the optimal weighted function is determined, which greatly improves the robustness of the single machine infinity system and has good dynamic quality and adjustment performance.

REFERENCES

- [1] Jun, Y. 2017. Research on power system stabilizer of excitation system [D]. Tianjin University.
- [2] Han, Y.Y. 2011. Design of H_ infinity power system stabilizer based on particle swarm optimization [D]. Southwest Jiao Tong University.
- [3] Mengjing, F. 2017. PSS2B power system stabilizer parameter tuning [D]. Zhengzhou University.
- [4] Li, L. 2017. Design of H_ infinity power system stabilizer based on genetic algorithm to optimize weights [D]. Shandong University.
- [5] Zhenbo, Y., Wei, G., Youliang, X., Chen, C. 2016. Genetic optimization synchronous motor fractional PID predictive function excitation controller

- [J]. Electrical automation, 38 (02), 4-6.
- [6] Jianbo, W., Yili, L., Jiguo, L., Exchange, D. 2018. PSS parameter optimization and tuning based on differential evolution particle swarm optimization [J]. Computer and digital engineering, 46 (01), 53-58.
- [7] Bouchama, Z., Essounbouli, N., Harmas, M.N., Hamzaoui, A., Saoudi, K. 2016. Reaching phase free adaptive fuzzy synergetic power system stabilizer [J]. International Journal of Electrical Power and Energy Systems,77.
- [8] Safari, A. 2013. A PSO Procedure for a Coordinated Tuning of Power System Stabilizers for Multiple Operating Conditions [J]. Journal of Applied Research and Technology, 11 (5).
- [9] Saoudi, K., Harmas, M.N. 2014. Enhanced design of an indirect adaptive fuzzy sliding mode power system stabilizer for multi-machine power systems [J]. International Journal of Electrical Power and Energy Systems, 54
- [10] Yingchao, L. 2017. Research on PSS4B parameter tuning of new power system stabilizer based on improved PSO algorithm [D]. Southwest Jiao Tong University.

ABOUT THE AUTHORS

ZHAO Jule (1993-): Male, Luoyang City, Henan Province, postgraduate of Jilin Institute of Chemical Technology, mainly researching on industrial process control.

HAN Guangxin (1971-): Male, Shulan City, Jilin Province, Ph. D., Professor of Jilin Institute of Chemical Technology, mainly engaged in process control, robot motion control and restraint system control.

