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Tuning Parameters of Power System Stabilizers Using Goh's Formulation

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ABSTRACT

The power system stabilizer (PSS) is considered to be an effective facility for improving the dynamic stability. In this paper, a nonlinear optimization based on Goh's formulation is used to determine the PSS parameters. The real part of dominant eigenvalue of the system is minimized by tuning the PSS parameters through the formulation incorporated with the genetic algorithms (GA). Numerical results for a one-machine system show that the proposed method can effectively improve the power system dynamic stability.

Key words: *Power system stabilizer, Parameter tuning, Optimization.*

I. Introduction

Due to a rapid growth in the electric power demand and improper network planning, e.g., longitudinal structure, the damping in power systems becomes deteriorated. Several unacceptable dynamic stability problems, e.g., low frequency oscillation, render more attention to electric power utilities [1-4]. The low-frequency oscillation is found to be due to the lack of mechanical-mode damping [1-8]. The power system stabilizers (PSS) are well known as a supplementary excitation control for enhancing the dynamic stability of a power system [4-8].

There are two tasks which should be achieved for the installation of the power system stabilizers: location selection and parameter tuning [6-8]. The methods based on the right and left eigenvectors can accurately locate PSS [7,8]. On the other hand, the methods for tuning the PSS parameters are diversified and can be summarized as follows:

(1) An optimal control theory was used for adjusting the parameters in [9,10]; however, proper weighting matrices for the state/control variables and iterative solutions for solving the Riccati equation are required. In [11,12], the weighting matrix could be calculated; however, only a part of eigenvalues was considered for movement to the left side of the complex plane by the pole assignment.

(2) The system order reduction was used to tune the PSS parameters in [13,14]; however, the order reduction sometimes leads to inaccurate solutions [14].

(3) Pole assignment methods were proposed in [15, 16]. However, the drawbacks of this method are likely to result in parameters outside their reasonable ranges; furthermore, the methods for assigning poles are heuristic.

(4) To avoid the above disadvantages, the problem was formulated via an optimization formulation in [17, 18]: minimize the largest real part of eigenvalues and restrict the PSS parameters by inequality constraints. Linear programming incorporating with sensitivity analysis were used to solve the problem in [17]. Owing to the usage of a quadratic model in the objective function, it is required more than two solution processes to obtain an optimal solution. As for the method in [18], because the objective function was evaluated with the sensitivities, a suboptimal/feasible solution could be obtained.

(5) Neural adaptive PSS and rule-based fuzzy PSS were also proposed in [19,20,21]. However, the PSS technology based on the artificial intelligence is still limited for practical use.

On the basis of the above discussions, a novel approach based on Goh's method [22] for formulating the problem as a nonlinear optimization problem is proposed in this paper. The real part of the dominant eigenvalue is minimized using the genetic algorithms (GA) [23] without incorporating the sensitivities. All parameters are given in a reasonable range formulated by the inequality constraints; the equality constraints are derived from Goh's formulation [22].

A fundamental control concept is provided in Sec. 2. The proposed algorithm for tuning the PSS parameters is presented in Sec. 3. The test result based on a one-machine system is discussed in Sec. 4.

II. Methodology

Goh proposed an optimization formulation to deal with the minimization of the eigenvalue with the largest real part of a system matrix in [22]. The proposed method in this paper is based on Goh's method for tuning the parameters of the system matrix to stabilize the system. The adjustable parameters are due to the PSS.

A. Problem Description

Let N(t) be an nxn matrix of continuously differentialable functions; moreover, let $\lambda_i[(N(t)]$ be an eigenvalue for N(t) for $\forall t \in D$, i = 1, ..., n. The eigenvalue with the largest real part is defined as the dominant eigenvalue. The optimization problem here is to minimize the real part of the dominant eigenvalue subject to $t \in D$. This problem can be formulated as follows:

$$\min_{t\in D} \max_{1\le i\le n} \mathrm{Re}\lambda_i[N(t)] \tag{1}$$

B. Goh's Formulation

Let the eigenvalue of N(t) be

$$\lambda_i = \rho_i + \sigma_i,\ i = 1, ..., n \tag{2}$$

where λ_i, i =1, ..., n, is the solution of the following characteristic equation for the system N(t):

$$P(\lambda; t) \equiv \det[\lambda I\text{-}N(t)] \tag{3-1}$$

or

$$q\,(\lambda; \rho, \sigma) \equiv \prod_{i=1}^{n}\ [\lambda - (\rho_i + j\sigma_i)],\ \lambda \in C \tag{3-2}$$

where $\prod_{i=1}^{n} [\lambda - (\rho_i + j\sigma_i)]$ is a real function of λ. Note that σ_i may be zero. For a pair of conjugate eigenvalues or any two real eigenvalues,

$$\begin{aligned}&[\lambda - (\rho_{i1} + j\sigma_i)]\ [\lambda - (\rho_{i2} - j\sigma_i)]\\ &= \lambda^2 - \lambda(\rho_{i1} + \rho_{i2}) + (\rho_{i1}\rho_{i2} + \sigma_i^2) + j\sigma_i(\rho_{i2} - \rho_{i1})\end{aligned}$$

and

$$\sigma_i(\rho_{i2} - \rho_{i1}) = 0\quad i = 1, ..., n'$$

where

$$n' = \begin{cases}(n-1)/2 & \text{n is an odd number}\\ n/2 & \text{n is an even number}\end{cases}$$

On the other hand, the function q can be expressed as:

$$q(\lambda; \rho, \sigma) = \prod_{i=1}^{n}[\lambda - (\rho_i + j\sigma_i]$$

$$\begin{cases}(\lambda - \rho_0)\displaystyle\prod_{i=1}^{n'=(n-1)/2}[\lambda^2 - \lambda(\rho_{i1} + \rho_{i2}) + (\rho_{i1}\rho_{i2} + \sigma_i^2)] & \text{n is odd} \quad (4\text{-}1)\\ \displaystyle\sum_{i=1}^{n'=n/2}[\lambda^2 - \lambda(\rho_{i1} + \rho_{i2}) + (\rho_{i1}\rho_{i2} + \sigma_i^2)] & \text{n is even} \quad (4\text{-}2)\end{cases}$$

$$\text{and } h_i = \sigma_i(\rho_{i2} - \rho_{i1}) = 0,\ i = 1, ..., n' \tag{5}$$

where

$$\rho = \begin{cases}(\rho_0, \rho_{11}, \rho_{12}, \rho_{21}, \rho_{22}, ..., \rho_{n'1}, \rho_{n'2}) & \text{n is odd}\\ (\rho_{11}, \rho_{12}, \rho_{21}, \rho_{22}, ..., \rho_{n'1}, \rho_{n'2}) & \text{n is even}\end{cases}$$

$$\sigma = (\sigma_1, ..., \sigma_n)$$

Eq. (5) indicates that $\sigma_i = 0$ or $\rho_{i2} = \rho_{i1}$. If $\sigma_i = 0$ (i $\neq$ 0), the corresponding eigenvalue is a real number for Eqs. (4-1) and (4-2). Therefore, Eq. (4-1) means that there is at least one real eigenvalue, ρ_0, and there are at most n real eigenvalues. For the same reason, Eq. (4-2) means that there is at least zero real eigenvalue, ρ_0, and there are at most n real eigenvalues. Note that $P(\lambda; t) - q(\lambda; \rho, \sigma)$ is a polynomial of order n. If $P(\lambda; t) - q(\lambda; \rho, \sigma)$ is zero for (n + 1) different solutions, it is always zero for $\forall \lambda \in C$. Therefore, Eq. (3) is equivalent to

$$\begin{aligned}g_i &= P(\lambda_i; t) - q(\lambda_i; \rho, \sigma)\\ &= \det[\lambda_i I - N(t)] - q(\lambda_i; \rho, \sigma) = 0\\ &\quad i = 1, ..., n + 1\end{aligned} \tag{6}$$

where q is defined in Eq. (4) and all λ_i, i = 1, ..., n+1, are different.

On the basis of the above discussion, Eq. (1) can be reformulated as a nonlinear programming problem with equality and inequality constraints. Suppose that n is odd. The problem becomes as follows:

$$\min \gamma \tag{7}$$

s.t.

$$\rho_0 \le \gamma \tag{8}$$

$$\rho_{ik} \le \gamma \quad k = 1,2 \;\; i = 1,2,\ldots,n' \tag{9}$$

$$g_i = P(\lambda_i; t) - q(\lambda_i; \rho, \sigma) = 0 \;\; i = 1,\ldots,n + 1 \tag{10}$$

$$h_i = \sigma_i(\rho_{i2} - \rho_{i1}) = 0 \quad i = 1,2,\ldots,n' \tag{11}$$

$$\forall t \in D \tag{12}$$

where t is the independent variable and ρ_0, ρ_{ik}, σ_i, γ are the dependent variables.

The solution of Eqs. (7~12) provides all values of eigenvalues and parameters (i.e., t) for the system matrix N(t).

C. Genetic Algorithms

There are many methods to solve Eqs. (7~12). Since this problem is very nonlinear, any traditional optimization method will approach a local solution. This paper employs an optimization software package based on GA [23] to obtain the global optimum.

The basis of applying GA to solve the optimization problem is coding all the searching parameters to discrete or binary strings named genes. Then according to the solved problem, a fitness (objective) function is defined. For the better fitness function values, the corresponding individuals will be chosen to the mating pool for the process of reproduction. With the crossover and mutation operations, a new generation of GA is achieved. The GA is achieved by repeating each of the above processes to produce the fittest individuals. In this paper,

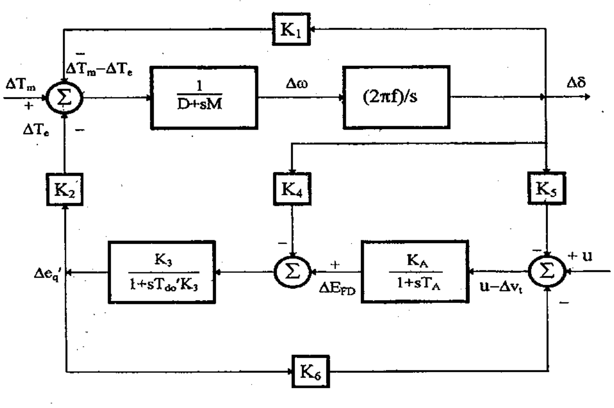

Fig. 1. Transfer function block diagram for the one-machine system.

all unknowns are coded with 16 bits individually and the fitness function is $-\gamma$.

The population size for a new generation, chromosome length, crossover rate and mutation rate control the convergence speed and optimality for GA. Generally, a large population size can result in high accuracy but increase the CPU time to converge. In this paper, "one-point crossover" and "one-bit mutation" are implemented. The population size, crossover rate and mutation rate are 250, 0.9 and 0.01, respectively, in this paper. With an elitist strategy, the individuals with the better fitness are selected to reproduce the new generations.

III. System Model

The synchronous machine model that is most widely used in the study of the dynamic stability problem is the Heffron-Phillips-deMello-Concordia model [5] as shown in Figure 1. There are two major loops in Figure 1: the mechanical loop on top and the electrical loop at the bottom.

In the mechanical loop, the incremental torque ($\Delta T_m - \Delta T_e$) is considered as the input; ΔT_m denotes the incremental mechanical torque; ΔT_e represents the incremental electric torque; the torque angle $\Delta\delta$ expresses the output. In these blocks, M, D and $2\pi f$ are the inertia constant, the mechanical damping coefficient, and the synchronous speed, respectively.

The electrical loop in Figure 1 includes a supplementary control u minus the incremental terminal voltage as the input and the incremental internal voltage $\Delta e_q'$ as the output. It has two transfer function blocks from right to left. The first block represents an exciter and voltage regulator system of the fast-response type with a time constant T_A and an overall gain K_A. The second block represents the transfer function of the field circuit affected by the armature reaction, with an effective time constant $T_{do}'K_5$ and a gain K_3. Finally, Δv_t consists of two components, $K_5\Delta\delta$ due to the torque angle variation $\Delta\delta$ and $K_6\Delta e_q'$ due to the internal voltage variation $\Delta e_q'$. Here Δv_t means $(v_t - v_{REF})$. A negative sign is given to v_t because of the negative feedback. v_{REF} is the reference voltage.

The transfer function block can be represented by single-input-single-output power system dynamic equations as follows:

$$\dot{x} = Ax + bu \tag{13}$$

$$y = c^T x \tag{14}$$

where x and y are the state variable and the output variable vector, respectively. The symbol u expresses the input. The symbols A, b and c denote the system coefficient matrix, input coefficient vector and the system output coefficient, respectively. The transfer function G(s) from u to y is as follows:

$$G(s) = c^T(sI - A)^{-1}b \tag{15}$$

The open loop transfer function is G(s) while the closed loop transfer function is $G(s)(1 - G(s)H(s))^{-1}$ with the PSS of a transfer function H(s). The eigenvalues of the power system including the PSS are the poles of the closed-loop transfer function and satisfy the following characteristic equation:

$$1 - G(s)H(s) = 0 \tag{16}$$

IV. Simulation

Consider a one-machine-infinite-bus system. All data are given in per unit of value except M and time constants which are in seconds.

Generator: $M = 9.26$, $T'_{do} = 7.76$, $D \cong 0$
$X_d = 0.973$, $X'_d = 0.19$, $X_q = 0.55$
Excitation: $K_A = 50$, $T_A = 0.05$
Line: $R = 0.034$, $X = 0.997$
Load: $G = 0.249$, $B = 0.262$
Initial states $P_{eo} = 1.0$, $Q_{eo} = 0.015$, $V_{to} = 1.05$

The initial d- and q-axis current and voltage components and torque angle for the initial steady states are as follows:

$V_{do} = 0.4659$, $V_{qo} = 0.941$, $i_{do} = 0.4354$
$i_{qo} = 0.8471$, $e_{qo}' = 1.024$

The K constants are

$K_1 = 0.5441$, $K_2 = 1.2067$, $K_3 = 0.6584$
$K_4 = 0.6981$, $K_5 = -0.0955$, $K_6 = 0.8159$

The system state variable vector is $[\Delta\omega, \Delta\delta, \Delta e_q', \Delta E_{FD}]^T$, where δ, ϖ, $\Delta e_q'$, and ΔE_{FD} represent the torque angle, angle frequency, internal voltage of the armature, and field voltage as seen from the armature, respectively. For the above data, the system eigenvalues are $0.295 \pm j4.96$ and $-10.393 \pm j3.283$. Because there are unstable roots, it is necessary to include PSS for improving the unstable states. The transfer function h(s) for the PSS is chosen as

$$H(s) = \frac{t_1 s + t_2}{s + k} \quad (k=20) \tag{17}$$

where $70 \le t_1, t_2 \le 700$. And the power system open loop transfer function

$$G(s) = \frac{-16.793s}{s^4 + 20.19573s^3 + 131.2114s^2 + 442.95s + 2932.086}$$

Therefore, the original characteristic equation is as follows:

$$s^4 + 20.19573s^3 + 131.2114s^2 + 442.95s + 2932.086 = 0$$

When the PSS is included, the new characteristic equation is as follows:

$$1 - G(s)H(s) = 0$$

i.e.

$$\begin{aligned} P(s; t) = \det[sI - N(t)] = {} & s^5 + 40.196s^4 + 535.126s^3 \\ & + (3067.178 + 16.793t_1)s^2 + (11791.086 \\ & + 16.793t_2)s + 58641.72 = 0 \end{aligned} \tag{18}$$

where $t = [t_1, t_2]$. Because n=5,

$$\begin{aligned} q(s; \rho, \sigma) &= (s - \rho_0) \sum_{i=1}^{n' = (n-1)/2} [s^2 - s(\rho_{i1} + \rho_{i2}) + (\rho_{i1}\rho_{i2} + \sigma_i^2)] \\ &= (s - \rho_0)[s^2 - s(\rho_{11} + \rho_{12}) + (\rho_{11}\rho_{12} + \sigma_1^2)] \\ &\quad \times [s^2 - s(\rho_{21} + \rho_{22}) + (\rho_{21}\rho_{22} + \sigma_2^2)] \end{aligned} \tag{19}$$

and $g = P(s; t) - q(s; \rho, \sigma) = 0$ (20)

The problem becomes as follows:

Minimize γ

s.t.

$\rho_0 \le \gamma$
$\rho_{11} \le \gamma$
$\rho_{12} \le \gamma$
$\rho_{21} \le \gamma$
$\rho_{22} \le \gamma$
$70 \le t_1 \le 700$
$70 \le t_2 \le 700$
$h_1 = \sigma_1(\rho_{12} - \rho_{11}) = 0$
$h_2 = \sigma_2(\rho_{22} - \rho_{21}) = 0$

and Eq. (20) (see Appendix).

In this case, the population size, string length, crossover rate, mutation rate are set to be 550, 16 bits, 0.95, 0.01, respectively, in a GA software package. The optimum values for all variables are follows:

$\rho_0 = -24.974,\ \rho_{11} = \rho_{12} = -3.805,$

$\rho_{21} = \rho_{22} = -3.806,\ \sigma_1 = 6.048,\ \sigma_2 = 5.613,$

$t_1 = 91.78\ ,\ t_2 = 536$

Figures 2 and 3 illustrate the state responses for $\Delta\omega$ and $\Delta\delta$, respectively. It can be found that the unstable system responses can be enhanced with the PSS.

V. Conclusion

In this paper, a new method based on Goh's optimization formulation is proposed for the determination of PSS parameters. The Goh's formulation leads to a set of equality and inequality constraints. The parameters of the PSS can be restricted with inequality constraints. The dominant eigenvalue can be minimized using GA. The eigenvalues and all parameters can be obtained without pole assignment. The test results show that the state response can be effectively improved with the proposed method.

Appendix

This Appendix provides the relation between P(s; t) and q(s; ρ, σ). Obviously, P(s; t) and q(s; ρ, σ) are in terms of unknown t and ρ, σ, respectively, where s is an unused parameter. More specifically, in Section 4:

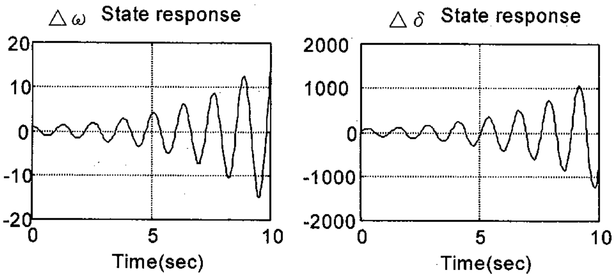

Fig. 2. $\Delta\omega$ sand $\Delta\delta$ become unstable without PSS.

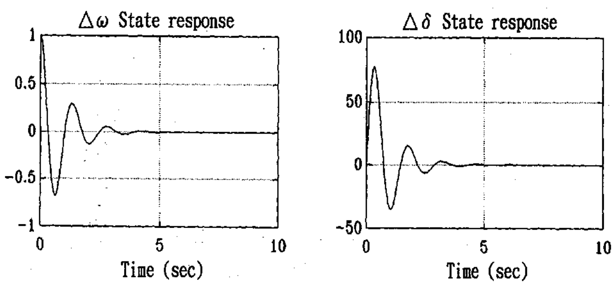

Fig. 3. $\Delta\omega$ sand $\Delta\delta$ become stable with PSS.

$$P(s;t) = \det[sI-N(t)] = s^5 + 40.196s^4 + 535.126s^3 + (3067.178 + 16.793t_1)s^2 + (11791.086 + 16.793t_2)s + 58641.72 = 0 \quad \text{(A-1)}$$

$$q(s;\rho,\sigma) = (s-\rho_0)\sum_{i=1}^{n'=(n-1)/2}[s^2 - s(\rho_{i1}+\rho_{i2}) + (\rho_{i1}\rho_{i2}+\sigma_i^2)]$$
$$= (s-\rho_0)[s^2 - s(\rho_{11}+\rho_{12}) + (\rho_{11}\rho_{12}+\sigma_1^2)] \times [s^2 - s(\rho_{21}+\rho_{22}) + (\rho_{21}\rho_{22}+\sigma_2^2)] \quad \text{(A-2)}$$

From Eq. (20),

$$g = P(s;t) - q(s;\rho,\sigma) = 0 \quad \text{(A-3)}$$

Comparing the coefficients between Eqs. (A-1) and (A-2), one can obtain the following equality constraints:

$$\rho_0 + \rho_{11} + \rho_{12} + \rho_{21} + \rho_{22} = -40.196 \quad \text{(A-4)}$$

$$\rho_0(\rho_{11}+\rho_{12}+\rho_{21}+\rho_{22}) + (\rho_{11}+\rho_{12})(\rho_{21}+\rho_{22}) + \rho_{11}\rho_{12} + \sigma_1^2 + \rho_{21}\rho_{22} + \sigma_2^2 = 535.126 \quad \text{(A-5)}$$

$$\rho_0[(\rho_{11}+\rho_{12})(\rho_{21}+\rho_{22}) + \rho_{11}\rho_{12} + \sigma_1^2 + \rho_{21}\rho_{22} + \sigma_2^2] + (\rho_{11}+\rho_{12})(\rho_{21}\rho_{22}+\sigma_2^2) + (\rho_{21}+\rho_{22})(\rho_{11}\rho_{12}+\sigma_1^2) = -3067.178 - 16.793t_1 \quad \text{(A-6)}$$

$$\rho_0(\rho_{11}+\rho_{12})(\rho_{21}\rho_{22}+\sigma_2^2) + \rho_0(\rho_{21}+\rho_{22})(\rho_{11}\rho_{12}+\sigma_1^2) + (\rho_{11}\rho_{12}+\sigma_1^2)(\rho_{21}\rho_{22}+\sigma_2^2) = 11791.086 + 16.793t_2 \quad \text{(A-7)}$$

$$\rho_0(\rho_{11}\rho_{12}+\sigma_1^2)(\rho_{21}\rho_{22}+\sigma_2^2) = -58641.72 \quad \text{(A-8)}$$

Reference

1. T. Johanson, B. Wrang, L. Makela, Y. Laiho and T. Carlsen, "Stability Problems in the Nordic Power System," CIGRE, 31-06, 1982.
2. V. Arcidiacono, E. Ferrari, R. Marconato and G. Manxoni, "Problems Posed in Power System Planning by Electromechanical Oscillation Damping and Means for Solution," CIGRE, 31-15, 1982.
3. P.A. Rusche, D.L. Hackett, D.H. Baker, G.E. Gareis and P.C. Krause, "Investigation of the Dynamic Oscillation of the Ludington Pumped Storage Plant," *IEEE Trans. on PAS*, PAS-95, No. 6, pp. 1854-1862, Nov./Dec. 1976.
4. Y.Y. Hsu, S.W. Shyue, and C.C. Su, "Low Frequency Oscillations in Longitudinal Power Systems: Ex-

perience with Dynamic Stability of Taiwan Power System," *IEEE Trans. on Power Systems*, Vol. PWRS-2, No. 1, pp. 92-96, Feb. 1987.
5. Y.N. Yu, *Electric Power System Dynamics*, Academic Press, New York, 1983.
6. F.P. DeMello, P.J. Nolan, T.F. Laskowski, and J.M. Undrill, "Coordinated Application of Stabilizers in Multimachine Power Systems," *IEEE Trans. on PAS*, Vol. PAS-99, No. 3, pp. 892-901, May/June 1980.
7. Y.Y. Hsu and C.L. Chen, "Identification of Optimum Location for Stabilizer Applications Using Participation Factors," *IEE Proceedings-C*, Vol. 134, No. 3, pp. 238-244, May 1987.
8. E.Z. Zhou, O.P. Malik and G.S. Hope, "Theory and Method for Selection of Power System Stabilizer Location," *IEEE Trans. on Energy Conversion*, Vol. 6, No. 1, pp. 170-176, March 1991.
9. Y.N. Yu, K. Vongsurity, N. Wedman, "Application of an Optimal Control Theory to a Power System," *IEEE Trans.on PAS*, Vol. PAS-89, No. 1, pp. 55-60, Jan. 1970.
10. Y.N. Yu and C. Siggers, "Stabilzation and Optimal Control Signals for a Power System," *IEEE Trans. on PAS*, Vol. PAS-90, pp. 1469-1481, July/Aug. 1971.
11. Y.N. Yu and H.A.M. Moussa, "Optimal Power System Stabilization through Excitation and/or Governor Control," *IEEE Trans. on PAS*, pp. 1166-1173, May/June 1972.
12. Y.N. Yu, A.M. Moussa, "Optimal Stabilization of a Multimachine System," *IEEE Trans.on PAS*, pp. 1174-1182, May/June 1972.
13. S. Elangoran, and C.M. Lim, "A New Stabilizer Design Technique for Multimachine Power Systems," *IEEE Trans. on PAS*, Vol. PAS-104, pp. 2393-2400, Sep. 1985.
14. A. Feliachi, X. Zhang, and C.S. Sims, "Power System Stabilizer Design Using Optimal Reduced Order Models, Part II, Design," *IEEE Trans. on Power Systems*, Vol. 3, No. 4, pp. 1676-1684, Nov. 1988.
15. C.L. Chen and Y.Y. Hsu, "An Efficient Algorithm for the Design of Decentralized Output Feedback Power System Stabilizer," *IEEE Trans. on Power Systems*, Vol. 3, No. 3, pp. 999-1004, Aug. 1988.
16. R.J. Fleming, M.A. Mohan, and K. Parvatisam, "Selection of Parameters of Stabilizers in Multimachine Power Systems," *IEEE Trans. on PAS*, Vol. PAS-100, No. 5, pp. 2329-2333, May 1981.
17. S.Abe and A. Doi, "Coordinated Synthesis of Power System Stabilizers in Multimachine Power Systems," *IEEE Trans. on PAS*, PAS-103, pp. 1473-1479, June 1984.
18. L. Xu and S. Ahmed-Zaid, "Tuning of Power System Controllers Using Symbolic Eigensensitivity Analysis and Linear Programming," *IEEE Trans. on Power Systems*, Vol. 10, No. 1, pp. 314-320, Feb. 1995.
19. P. Shamsollahi and O.P. Malik, "Application of Neural Adaptive Power System Stabilizer in a Multi-machine Power System," *IEEE Trans. on Energy Conversion*, Vol. 14, No. 3, pp. 731-736, Sep. 1999.
20. N. Hosseinzadeh and A. Kalam, "A Rule-based Fuzzy Power System Stabilizer Tuned by a Neural Network," *IEEE Trans. on Energy Conversion*, Vol. 14, No. 3, pp. 773-779, Sep. 1999.
21. R. Segal, M.L. Kothari, S. Madnani, "Radial Basis Function (RBF) Network Adaptive Power System Stabilizer," *IEEE Trans. on Power Systems*, Vol. 15, No. 2, pp. 722-727, May 2000.
22. C.J. Goh and K.L. Ted, "On Minimax Eigenvalue Problems via Constrained Optimization," *Journal of Optimization Theory and Applications*, Vol. 57, No. 1, April 1988.
23. GeneHunter 2.1, Ward Systems Group, Inc., 1998.

使用Goh表示式調整電力系統穩定器參數

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摘　要

電力系統穩定器是一種有效改進動態穩定度的設備。本文以Goh表示式爲基礎的非線性最佳化技巧，配合基因演算法來決定電力系統穩定器之參數，使系統主特徵值的實部最小。文中使用一單機系統做模擬，以證實本文所提方法之可行性。

關鍵詞：電力系統穩定器，參數調整，最佳化。