International Journal on
"Technical and Physical Problems of Engineering"
(IJTPE)
Published by International Organization on TPE (IOTPE)

ISSN 2077-3528
IJTPE Journal
www.iotpe.com
ijtpe@iotpe.com

September 2011	Issue 8	Volume 3	Number 3	Pages 32-37

A NEW ALGORITHM FOR OPTIMAL TUNING OF FACTS DAMPING CONTROLLER

A. Safari [1] H. Shayeghi [2] H.A. Shayanfar [3]

1. Department of Engineering, Ahar Branch, Islamic Azad University, Ahar, Iran, asafari1650@yahoo.com
2. Technical Engineering Department, University of Mohaghegh Ardabili, Ardabil, Iran, hshayeghi@gmail.com
3. Center of Excellence for Power System Automation and Operation, Electrical Engineering Department, Iran University of Science and Technology, Tehran, Iran, hashayanfar@yahoo.com

Abstract- This paper establishes the linearized Phillips-Heffron model of a power system equipped with unified power flow controller (UPFC) and designs the UPFC damping stabilizer to improve power system oscillation stability. The design problem is converted to an optimization problem with the eigenvalue-based objective function which is solved by the new and simple strategy of particle swarm optimization (PSO) algorithm called θ-PSO technique. Damping controller is tuned to simultaneously shift the undamped electromechanical modes to a prescribed zone in the s-plane. The effectiveness and performance of the proposed controller is demonstrated through eigenvalue analysis, nonlinear time-domain simulation and some performance indices studies. The results analysis reveals that the designed θ-PSO based UPFC controller tuned has an excellent capability in damping power system low frequency oscillations under different operating conditions.

Keywords: UPFC, θ-PSO, Dynamic Stability, Eigenvalue.

I. INTRODUCTION

Damping of power system oscillations plays an important role in dynamic stability not only in increasing the transmission capability but also in stabilizing the power system, especially after critical disturbances [1]. Among all FACTS devices, UPFC seems to be the most comprehensive and can provide the greatest flexibility with all encompassing multiple control capacities of voltage regulations, series compensations and phase shifts [2, 3]. When the UPFC is applied to the interconnected power systems, it can also provide significant damping effect on tie line power oscillation through its fast supplementary control. In the past, dynamic models of UPFC in order to design suitable controllers for damping of electromechanical oscillations [4-6] are presented.

Wang [7] presents the establishment of the linearized Phillips–Heffron model of a power system installed with a UPFC. Wang has not presented a systematic approach for designing the damping controllers. Further, no effort seems to have been made to identify the most suitable UPFC control parameter. Recently, global optimization technique like particle swarm optimization [1, 4] has been applied for FACTS damping controller parameters optimization. The PSO is a novel population based metaheuristic, which utilizes the swarm intelligence generated by the cooperation and competition between the particle in a swarm. This algorithm has also been found to be robust in solving problems featuring non-linearing, non-differentiability and high-dimensionality [8-12].

In this study, the problem of UPFC based damping controller design is formulated as an optimization problem. The damping controller is automatically tuned with optimization an eigenvalue based objective function by θ-PSO [13] such that the relative stability is guaranteed and the time domain specifications concurrently secured. Results evaluation show that the θ-PSO based tuned damping controller achieves good performance for a wide range of operating conditions and is superior to designed controller using CPSO technique.

II. POWER SYSTEM MODELING

Figure 1 shows a SMIB power system equipped with a UPFC, which is widely used for studies of power system oscillations, is adopted in this paper to demonstrate the proposed method. The UPFC consists of an excitation transformer (ET), a boosting transformer (BT), two three-phase GTO based voltage source converters (VSCs), and a DC link capacitors.

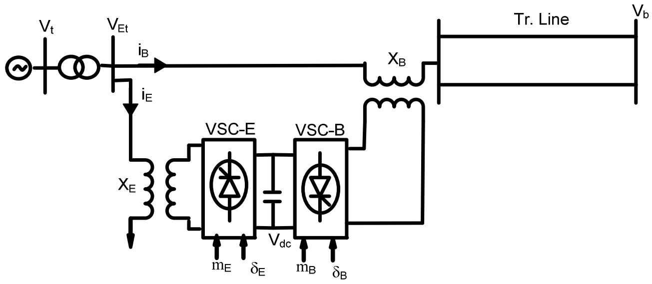

Figure 1. SMIB power system equipped with UPFC

The four input control signals to the UPFC are m_E, m_B, δ_E, and δ_B, where, m_E is the excitation amplitude modulation ratio, m_B is the boosting amplitude modulation ratio, δ_E is the excitation phase angle and δ_B is the boosting phase angle. The system data is given in the Appendix [1].

The dynamic model of the UPFC is required in order to study the effect of the UPFC for enhancing the small signal stability of the power system. By applying Park's transformation and neglecting the resistance and transients of the ET and BT transformers, the UPFC can be modeled as [1, 4, 5]:

$$\begin{bmatrix} v_{Etd} \\ v_{Etq} \end{bmatrix} = \begin{bmatrix} 0 & -x_E \\ x_E & 0 \end{bmatrix} \begin{bmatrix} i_{Ed} \\ i_{Eq} \end{bmatrix} + \begin{bmatrix} \dfrac{m_E \cos\delta_E v_{dc}}{2} \\ \dfrac{m_E \sin\delta_E v_{dc}}{2} \end{bmatrix} \tag{1}$$

$$\begin{bmatrix} v_{Btd} \\ v_{Btq} \end{bmatrix} = \begin{bmatrix} 0 & -x_B \\ x_B & 0 \end{bmatrix} \begin{bmatrix} i_{Bd} \\ i_{Bq} \end{bmatrix} + \begin{bmatrix} \dfrac{m_B \cos\delta_B v_{dc}}{2} \\ \dfrac{m_B \sin\delta_B v_{dc}}{2} \end{bmatrix} \tag{2}$$

$$\begin{aligned} \dot{v}_{dc} &= \frac{3m_E}{4C_{dc}}[\cos\delta_E \quad \sin\delta_E] \begin{bmatrix} i_{Ed} \\ i_{Eq} \end{bmatrix} + \\ &+ \frac{3m_B}{4C_{dc}}[\cos\delta_B \quad \sin\delta_B] \begin{bmatrix} i_{Bd} \\ i_{Bq} \end{bmatrix} \end{aligned} \tag{3}$$

where, v_{Et}, i_E, v_{Bt}, and i_B are the excitation voltage, excitation current, boosting voltage, and boosting current, respectively, which are obtained in [1]. The C_{dc} and v_{dc} are the DC link capacitance and voltage. The nonlinear model of the SMIB system as shown in Figure 1 is described by [14]:

$$\dot{\delta} = \omega_b(\omega - 1) \tag{4}$$

$$\dot{\omega} = (P_m - P_e - D\Delta\omega)/M \tag{5}$$

$$\dot{E}'_q = (-E_q + E_{fd})/T'_{do} \tag{6}$$

$$\dot{E}_{fd} = (-E_{fd} + K_a(V_{ref} - V_t))/T_a \tag{7}$$

where,

$$P_e = V_{td} I_{td} + V_{tq} I_{tq}$$

$$E_q = E'_{qe} + \left(X_d - X'_d\right) I_{td}$$

$$V_t = V_{td} + jV_{tq};$$

$$V_{td} = X_q I_{tq}; V_{tq} = E'_q - X'_d I_{td}$$

$$I_{td} = I_{tld} + I_{Ed} + I_{Bd}$$

$$I_{tq} = I_{tlq} + I_{Eq} + I_{Bq}$$

From Figure 1 we can have:

$$\bar{v}_t = jx_{tE}(\bar{i}_B + \bar{i}_E) + \bar{v}_{Et} \tag{8}$$

$$\bar{v}_{Et} = \bar{v}_{Bt} + jx_{BV}\bar{i}_B + \bar{v}_b \tag{9}$$

$$\begin{aligned} v_d + jv_q &= x_q(i_{Eq} + i_{Bq}) + j(E'_q - x'_d(i_{Eq} + i_{Bd})) = \\ &= jx_{tE}(i_{Ed} + i_{Bd} + j(i_{Eq} + i_{Bq}) + v_{Etd} + jv_{Etq} \end{aligned} \tag{10}$$

where i_t and v_b, are the armature current and infinite bus voltage, respectively; v_{Et}, v_{Bt}, i_B and i_E the ET voltage, BT voltage, BT current and BT current respectively from which we can obtain:

$$\begin{aligned} i_{Ed} &= \frac{x_{BB}}{x_{d\Sigma}} E'_q - \frac{m_E \sin\delta_E v_{dc} x_{Bd}}{2x_{d\Sigma}} + \\ &+ \frac{x_{dE}}{x_{d\Sigma}}(v_b \cos\delta + \frac{m_B \sin\delta_B v_{dc}}{2}) \end{aligned} \tag{11}$$

$$\begin{aligned} i_{Eq} &= \frac{m_E \cos\delta_E v_{dc} x_{Bq}}{2x_{q\Sigma}} - \\ &- \frac{x_{qE}}{x_{d\Sigma}}(v_b \sin\delta + \frac{m_B \cos\delta_B v_{dc}}{2}) \end{aligned} \tag{12}$$

$$\begin{aligned} i_{Bd} &= \frac{x_E}{x_{d\Sigma}} E'_q + \frac{m_E \sin\delta_E v_{dc} x_{dE}}{2x_{d\Sigma}} + \\ &+ \frac{x_{dt}}{x_{d\Sigma}}(v_b \cos\delta + \frac{m_B \sin\delta_B v_{dc}}{2}) \end{aligned} \tag{13}$$

$$\begin{aligned} i_{Bq} &= -\frac{m_E \cos\delta_E v_{dc} x_{qE}}{2x_{q\Sigma}} + \\ &+ \frac{x_{qt}}{x_{q\Sigma}}(v_b \sin\delta + \frac{m_B \cos\delta_B v_{dc}}{2}) \end{aligned} \tag{14}$$

where,

$$x_{q\Sigma} = (x_q + x_{tE} + x_E)(x_B + x_{BV}) + x_E(x_q + x_{tE})$$

$$x_{Bq} = x_q + x_{tE} + x_B + x_{BV}$$

$$x_{qt} = x_q + x_{tE} + x_E$$

$$x_{qE} = x_q + x_{tE}$$

$$x_{d\Sigma} = (x'_d + x_{tE} + x_E)(x_B + x_{BV}) + x_E(x'_d + x_{tE})$$

$$x_{Bd} = x'_d + x_{tE} + x_B + x_{BV}$$

$$x_{Bq} = x'_d + x_{tE} + x_E$$

$$x_{dE} = x'_d + x_{tE}$$

$$x_{BB} = x_B + x_{BV}$$

where x_E, x_B, x_d, x'_d and x_q are the ET and BT reactance's, d-axis reactance, d-axis transient reactance, and q-axis reactance, respectively. A linear dynamic model is obtained by linearizing the nonlinear model round an operating condition. The linearized model of power system is given in [1].

III. θ-PSO TECHNIQUE

The PSO method is a population-based one and is described by its developers as an optimization paradigm, which models the social behavior of birds flocking or fish schooling for food. Therefore, PSO works with a population of potential solutions rather than with a single individual [8]. The θ-PSO algorithm is newly introduced strategy of PSO which is a simple algorithm, easy to implement. It is based on phase angle vector instead of the velocity vector and an increment of phase angle $\Delta\theta_i$ vector replaces velocity vector V_i which is dynamically adjusted according to the historical behaviors of the particle and its companions. In the θ-PSO, the positions are adjusted by the mapping of phase angles, thus, a particle is represented by its phase angle θ and increment of phase angle $\Delta\theta$ and its position decided by a mapping function [13]. The θ-PSO can be described with the following equations.

$$\Delta\theta_{id}(t+1) = w\times\Delta\theta_{id}(t) + c_1 r_1(\theta p_{id} - \theta_{id}(t)) + c_2 r_2(\theta g_{gd} - \theta_{id}(t)) \quad (15)$$

$$\theta_{id}(t+1) = \theta_{id}(t) + \Delta\theta_{id}(t+1) \quad (16)$$

$$x_{id}(t) = f(\theta_{id}(t)) \quad (17)$$

$$F'_i(t) = \text{fitnessvalue}(x_i(t)) \quad (18)$$

with,

$$\theta_{id} \in (\theta_{\min}, \theta_{\max})$$

$$\Delta\theta_{id} \in (\Delta\theta_{\min}, \Delta\theta_{\max})$$

$$x_{id} \in (x_{\min}, x_{\max})$$

and f is being a monotonic mapping function. In this paper,

$$\theta_{id} \in (-\pi/2, \pi/2),\ \Delta\theta_{id} \in (-\pi/2, \pi/2)$$

$$f(\theta_{id}) = \frac{x_{\max} - x_{\min}}{2}\sin\theta_{id} + \frac{x_{\max} + x_{\min}}{2} \quad (19)$$

where d=1, 2, …, D; i= 1, 2, …, S.

The $\theta_i(t)$ is the phase angle of particle ith at time t; the $\Delta\theta_i(t)$ is the increment of particle i’s phase angle at time t; $\theta p_i(t)$ is the phase angle of the personal best solution of particle i at time t; $\theta g_g(t)$ is the phase angle of global best solution at time t; $F'_i(t)$ is the fitness value of particle i at time t which is identified by the function fitness value. The procedure of the θ-PSO can be summarized in Figure 2. In Figure 2, $F'_{pi}(t)$ is the personal best fitness value of particle i at time t and $F'_g(t)$ is the global best fitness value at time t.

```
initialize a population with random phase angle θi(t) and the
increment of the phase angle Δθi(t);
repeat t=1, 2, …, tmax;
    for each particle i=1, 2, …, S
        if t=1
            calculate xi(1) using Equation (6);
            calculate the fitness value F'i(1) using Equation (7);
            F'pi(1)= F'i(1); θpi(1)= θi(1);
            F'g(1)= F'i(1); θg(1)= θi(1);
        else
            update the increment of the phase angle Δθi(t) using
Equation (11) and limit Δθi(t) to (Δθmin(t), Δθmax (t));
            update θi(t) using Equation (5) and limit θi(t) to
(θmin(t), θmax(t));
            update xi(t) using Equation (6);
            update the fitness value F'i(t) using Equation (7);
            if F'i(t) < F'pi(t)
                F'pi(t)=F'i(t); θpi(1)= θi(1);
            end
            if F'i(t) < F'g(t)
                F'g(t)= F'i(t); θg(t)= θi(t);
            end
        end
    end
until the stopping criterion is met
```

Figure 2. The proposed θ-PSO technique

IV. UPFC DAMPING CONTROLLER DESIGN USING θ-PSO

In this paper δ_E is moulated in order to damping controller design. The speed deviation $\Delta\omega$ is considered as the input to the damping controller. The structure of UPFC based damping controller is shown in Figure 3. This controller may be considered as a lead-lag compensator [4]. The parameters of the damping controller are obtained using θ-PSO algorithm.

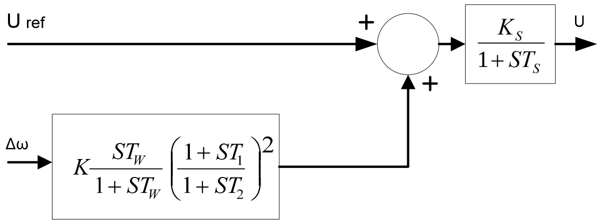

Figure 3. UPFC damping controller

To acquire an optimal combination, this paper employs θ-PSO [13] to improve optimization synthesis and find the global optimum value of fitness function. Often, the closed-loop modes are specified to have some degree of relative stability. In this case, the closed loop eigenvalues are constrained to lie to the left of a vertical line corresponding to a specified damping factor. To satisfy this case the parameters of the damping controller may be selected to minimize the following objective function [15]:

$$J = \sum_{\sigma_i \ge \sigma_o} (\sigma_o - \sigma_i)^2 \quad (20)$$

where σ_i is the real part of the ith eigenvalue, and σ_o is a chosen threshold. The value of σ_o represents the desirable level of system damping. This level can be achieved by shifting the dominant eigenvalues to the left of $s = \sigma_o$ line in the s-plane. This also ensures some degree of relative stability. The condition $\sigma_i \ge \sigma_o$ is imposed on the evaluation of J to consider only the unstable or poorly damped modes that mainly belong to the electromechanical ones. The relative stability is determined by the value of σ_o. This will place the closed-loop eigenvalues in a sector in which $\sigma_i \le \sigma_o$ as shown in Figure 4.

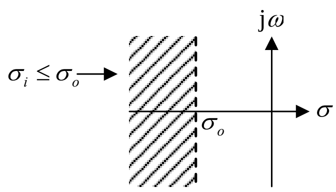

Figure 4. Region of eigenvalue location for J

The design problem can be formulated as the following constrained optimization problem, where the constraints are the controller parameters bounds:

minimize J subject to:

$$K^{\min} \le K \le K^{\max}$$
$$T_1^{\min} \le T_1 \le T_1^{\max} \qquad (21)$$
$$T_2^{\min} \le T_2 \le T_2^{\max}$$

Typical ranges of the optimized parameters are [0.01-150] for K and [0.01-1] for T_1 and T_2. The proposed approach employs θ-PSO algorithm to solve this optimization problem. In order to acquire better performance the input parameters that control the θ-PSO, i.e., number of particle, dimension size (D), the number of iteration, c_1 and c_2 is chosen as 30, 5, 60, 1.7 and 1.7, respectively. Results of controller parameter set values based on the objective function using both the proposed θ-PSO and CPSO algorithms are given in Table 1.

Table 1. The optimal parameter settings of the proposed algorithms

Controller parameter	CPSO	θ-PSO
K	81.45	95.69
T_1	0.277	0.649
T_2	0.164	0.583

V. SIMULATION RESULTS

In any power system, the operating load varies over a wide range. It is extremely important to investigate the effect of variation of the loading condition on the dynamic performance of the system. Dynamic responses are obtained for the following three typical loading conditions for $\Delta T_m = 0.1$ pu .

Case a: $P = 0.8$ pu , $Q = 0.167$ pu (nominal load)

Case b: $P = 1.20$ pu , $Q = 0.4$ pu (heavy load)

Case c: $P = 0.2$ pu , $Q = 0.01$ pu (light load)

A. Eigenvalue Analysis

The system eigenvalues with and without the proposed controllers are given in Table 2. It is clear that the open loop system is unstable but the proposed controllers stabilize the system. Obviously the electromechanical–mode eigenvalues have been shifted to the left in s-plane and the system damping with the proposed method greatly improved and enhanced.

Table 2. Eigenvalues and damping ratios of electromechanical modes

Objective functions	Nominal	Heavy	Light
Without controller	**0.139 ± i4.21, -0.033,** -3.247, -96.582	**0.215 ± i4.18, -0.054,** -3.338, -96.268	**0.009 ± i4.99, -0.002,** -3.306,-96.643
CPSO	-1.034 ± i2.634, 0.367, -4.4364, -3.2123, -2.912, -96.4182, -14.9389	-1.011 ± i2.603, 0.361, -4.3956, -3.3358, -2.870, -96.4566, -15.6908	-1.69 ± i2.712, 0.529, -4.5419, -2.8502, -3.270, -96.197, -16.1491
θ-PSO	-1.333 ± i2.129, 0.529, -9.3309, -1.6850, -2.0727, -2.5774, -96.4435	-1.183 ± i2.153, 0.481, -1.6953, -1.9723, -2.6307, -96.4872, -10.1294	-1.980 ± i1.361, 0.821, -2.7103, -3.5115, -96.209, -9.2840, -1.6576

B. Time Domain Simulation

The performance of the proposed controller under transient conditions is verified by applying a 6-cycle three-phase fault at t = 1 sec, at the middle of the one transmission line. The fault is cleared by permanent tripping of the faulted line. The speed deviation of generator at three loading conditions due to designed controller is shown in Figure 5.

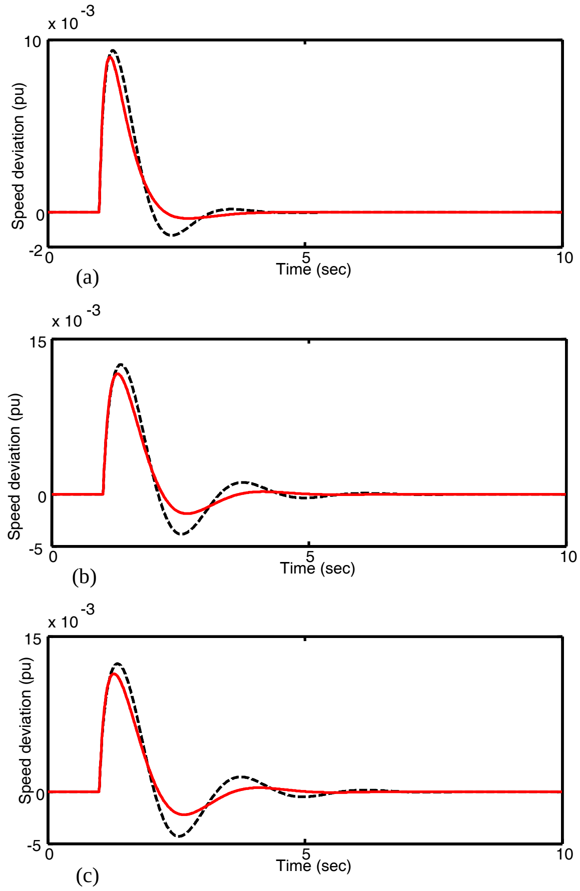

Figure 5. Dynamic responses for $\Delta\omega$ at (a) Light (b) Nominal and (c) Heavy loading; Solid (θ-PSO) and Dashed (CPSO)

It can be seen that the proposed controller has good performance in damping low frequency oscillations and stabilizes the system quickly. Also, Figure 6 shows the electrical power deviation (ΔP_e), rotor angle variations ($\Delta\delta$) and control signal deviation with δ_E based controller, respectively.

To demonstrate performance robustness of the proposed method, two performance indices: the Integral of the Time multiplied Absolute value of the Error ($ITAE$) and Figure of Demerit (FD) based on the system performance characteristics are defined as [1, 16]:

$$ITAE = 1000\int_0^{10} |\Delta\omega| \cdot t dt$$
$$FD = (OS \times 300)^2 + (US \times 1000)^2 + T_s^2 \qquad (22)$$

where, speed deviation ($\Delta\omega$), overshoot (OS), undershoot (US) and settling time of speed deviation of the machine is considered for evaluation of the $ITAE$ and FD indices. It is worth mentioning that the lower the value of these indices is, the better the system response in terms of time-domain characteristics.

Numerical results of performance index *ITAE* and *FD* with the disturbances considered for all system loading cases are given in Table 3. This demonstrates that the overshoot, undershoot, settling time and speed deviations of the machine are greatly reduced by applying the proposed algorithm based tuned controller.

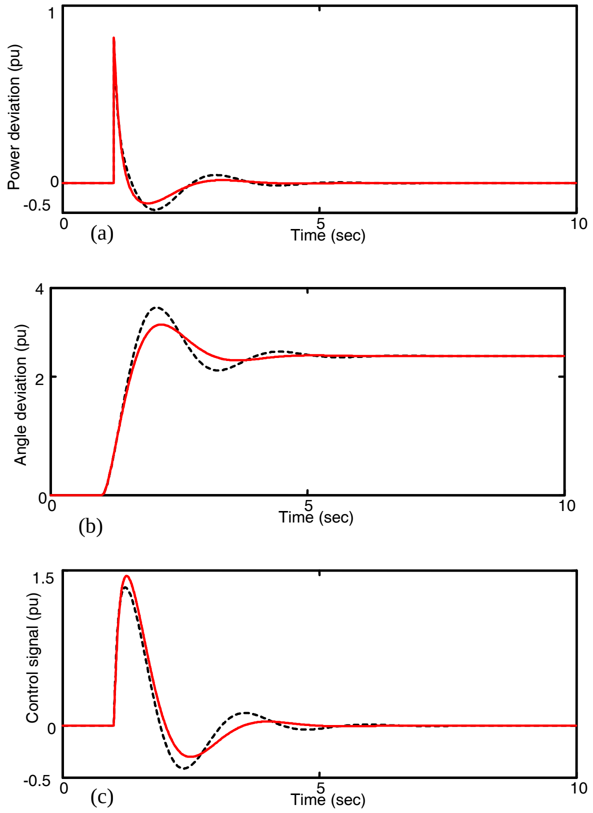

Figure 6. Dynamic responses at nominal loading (a) ΔP_e (b) $(\Delta\delta)$ and (c) ΔU; Solid (θ-PSO) and Dashed (CPSO)

Table 3. Values of performance indices of ITAE and FD

Algorithm	Light		Nominal		Heavy	
	ITAE	*FD*	*ITAE*	*FD*	*ITAE*	*FD*
CPSO	2.2072	7.040	5.5226	22.857	6.3411	25.851
θ-PSO	1.6866	6.382	3.5492	10.003	3.9610	16.423

VI. CONCLUSIONS

A novel method of designing a power oscillation damping controller for a UPFC has been proposed. The design problem is converted into a constraints optimization problem which is solved by a θ-PSO technique with the eigenvalue-based objective function. The eigenvalue analysis and non-linear time domain simulation results show the performance and effectiveness of the proposed controller and their ability to provide good damping of electromechanical low frequency oscillations. The system performance characteristics in terms of ITAE and FD indices reveal that the θ-PSO based damping stabilizer demonstrates that the overshoot, undershoot, settling time and speed deviations of the machine in comparison with designed CPSO based damping stabilizer.

APPENDIX

The nominal parameters of the system are given below:

Generator: $M = 8$ MJ/MVA, $D = 0.0$, $T'_{do} = 5.044$

$X_d = 1.0$ pu, $X_q = 0.6$ pu, $X'_d = 0.3$ pu

Excitation system: $K_a = 100$, $T_a = 0.01$ s

Transformer: $X_{tE} = 0.1$ pu, $X_E = X_B = 0.1$ pu

Transmission line: $X_{BV} = 0.3$ pu, $X_e = 0.5$ pu

UPFC parameters: $m_E = 0.40$, $m_B = 0.80$

$\delta_E = -85.35$, $\delta_B = -78.21$

Parameters of dc link: $V_{dc} = 2$ pu, $C_{dc} = 1$ pu

REFERENCES

[1] H. Shayeghi, H.A. Shayanfar, S. Jalilzadeh and A. Safari, "A PSO based Unified Power Flow Controller for Damping of Power System Oscillations", Energy Conversion and Management, Vol. 50, No. 10, pp. 2583-2592, 2009.

[2] L. Gyugyi, "Unified Power-Flow Control Concept for Flexible AC Transmission Systems", IEE Proc. Gen. Transm. Distrib., Vol. 139, No. 4, pp. 323-31, 1992.

[3] N.G. Hingorani and L. Gyugyi, "Understanding FACTS: Concepts and Technology of Flexible AC Transmission Systems", Wiley-IEEE Press, 1999.

[4] A.T. Al-Awami, Y.L. Abdel-Magid and M.A. Abido, "A Particle-Swarm-based Approach of Power System Stability Enhancement with Unified Power Flow Controller", International Journal Electrical Power and Energy System, Vol. 29, pp. 251-259, 2007.

[5] N. Tambey and M. Kothari, "Unified Power Flow Controller based Damping Controllers for Damping Low Frequency Oscillations in a Power System", IEE. Proc. Gener. Transm. Distrib., Vol. 150, No. 2, pp. 129-140, 2003.

[6] A.J.F. Keri, X. Lombard and A.A. Edris, "Unified Power Flow Controller: Modeling and Analysis", IEEE Transaction on Power Delivery, Vol. 14, No 2, pp. 648-654, 1999.

[7] H.F. Wang, "A Unified Model for the Analysis of FACTS Devices in Damping Power System Oscillations - Part III: Unified Power Flow Controller", IEEE Transaction on Power Delivery, Vol. 15, No. 3, pp. 978-983, 2000.

[8] J. Kennedy, R. Eberhart and Y. Shi, "Swarm Intelligence", Morgan Kaufmann Publishers, San Francisco, 2001.

[9] M. Clerc and J. Kennedy, "The Particle Swarm-Explosion, Stability, and Convergence in a Multidimensional Complex Space", IEEE Transaction on Evolutionary Computation, Vol. 6, No. 1, pp. 58-73, 2002.

[10] R. Poli, J. Kennedy and T. Blackwell, "Particle Swarm Optimization: An Overview", Swarm Intelligent, Vol. 1, pp. 33-57, 2007.

[11] H. Shayeghi, A. Jalili and H.A. Shayanfar, "Multi-Stage Fuzzy Load Frequency Control using PSO", Energy Conversion and Management, Vol. 49, pp. 2570-2580, 2008.

[12] A. Safari, H. Shayeghi and H.A. Shayanfar, "Optimization based Control Coordination of STATCOM and PSS Output Feedback Damping Controller using PSO Technique", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 5, Vol. 1, No. 4, pp. 6-12, December 2010.
[13] W. Zhong, S. Li and F. Qian, "θ-PSO: A New Strategy of Particle Swarm Optimization", Journal Zhejiang University Science, Vol. 9, No. 6, pp. 786-790, 2008.
[14] A. Safari, H. Shayeghi and H.A. Shayanfar, "A Chaotic Optimization Algorithm to Output Feedback Damping Controller Design for a STATCOM", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 4, Vol. 1, No. 3, pp. 44-50, September 2010.
[15] A. Jalilvand, A. Safari and R. Aghmasheh, "Design of State Feedback Stabilizer for Multimachine Power System using PSO Algoritm", Proc. IEEE International Multitopic Conferenc, December 2008.
[16] N. Rezaei, A. Safari, H.A. Shayanfar, "Robust Design of Power Oscillation Damping Controller for IPFC using Particle Swarm Optimization", International Journal on Technical and Physical Problems of Engineering (IJTPE), Issue 7, Vol. 3, No. 2, pp. 10-16, June 2011.

BIOGRAPHIES

Amin Safari received the B.Sc. and M.Sc. degrees in Electrical Engineering in 2007 and 2009, respectively. Currently, he is a Ph.D. student of Power Electrical Engineering at Iran University of Science and Technology, Tehran, Iran. His areas of interest in research are Application of Artificial Intelligence to Power System Control Design, FACTS device and Fuzzy Sets and Systems.

Hossein Shayeghi received the B.S. and M.SE. degrees in Electrical Engineering in 1996 and 1998, respectively. He received his Ph.D. degree in Electrical Engineering from Iran University of Science and Technology, Tehran, Iran in 2006. Currently, he is an Assistance Professor in Technical Engineering Department of University of Mohaghegh Ardebili, Ardebil, Iran. His research interests are in the Application of Robust Control, Artificial Intelligence to Power System Control Design, Operation and Planning and Power System Restructuring. He is a member of Iranian Association of Electrical and Electronic Engineers and IEEE.

Heidar Ali Shayanfar received the B.Sc. and M.Sc. degrees in Electrical Engineering in 1973 and 1979, respectively. He received his Ph.D. degree in Electrical Engineering from Michigan State University, U.S.A., in 1981. Currently, he is a Full Professor in Electrical Engineering Department of Electrical Engineering, Iran University of Science and Technology, Tehran, Iran. His research interests are in the Application of Artificial Intelligence to Power System Control Design, Dynamic Load Modeling, Power System Observability Studies and Voltage Collapse. He is a member of Iranian Association of Electrical and Electronic Engineers and IEEE.