IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 11, June 2017)

Comparative Analysis of GA and PSO Optimization for Power System Stability Parameters

Atul M. Gajare
Research Scholar
Electrical Engineering
Sri Satya Sai University of Technology & Medical Sciences

Dr. R. P. Singh
Professor
Electrical Engineering
Sri Satya Sai University of Technology & Medical Sciences

Abstract – **The designing of power transmission network is a difficult task due to the complexity of power system. Due to the complexity of the power system, there is always a loss of the stability due to the fault. Whenever a fault is intercepted in the system, the whole system goes to severe transients. These transients cause oscillation in phase angle which leads poor power quality. The nature of oscillation is increasing instead of being sustained, which leads system failure in form of generator damage. To reduce and eliminate the unstable oscillations one needs to use a stabilizer which can generate a perfect compensatory signal in order to minimize the harmonics generated due to instability. This paper presents a Power System stabilizer to reduce oscillations due to small signal disturbance. We also applied Genetic algorithm (GA) and Particle swarm optimization (PSO) for the parameter tuning of the stabilizer. The reason behind the use of GA and PSO instead of conventional methods is that it searches the parameter heuristically, which leads better results. The effectiveness of proposed stabilizers for suppressing oscillation due to change in mechanical input and excitation is examined by investigating their change in rotor angle and power angle deviation in the SMIB system.**

Keywords –**FACTS, GA, PSO, PSS SMIB.**

I. Introduction

For continuous power supply the stability of power system is a desirable key factor. Power system stability can be described as the attribute of a system that helps the system to maintain equilibrium under normal conditions and also retrieve the equilibrium condition under the condition of disturbance also. Various circumstances could lead to the conditions of instability in power system relying upon the mode of operation and system's configuration. Maintenance of synchronization is the major issue of concern particularly for those power systems that depend upon synchronous machines. The relationship between power and angle and the dynamics of generator angles affects the above mentioned synchronous attribute. Apart from the synchronization problem, the other issues that may be encountered are loading problems such as voltage collapse etc.

Stability can be evaluated by different methods:

Stochastic Methods

These methods use much more statistical data, different methods have been developed to carry out stochastic analyzes in order to maintain the transient stability of the electrical network. A Monte Carlo approach based on probabilities and pattern recognition is developed.

Evaluation of the Angular Stability to the Small Perturbations (Dynamic Stability)

The analysis of eigenvalues and the modal analysis of the linearized power system are powerful tools for studying the dynamic properties of the system. These methods are techniques that are used to determine whether the system is stable or unstable. The following sections describe these techniques in detail. Which are devices based on the recent advanced in power electronics, can be modified to participate in the damping of electromechanical oscillations. FACTS systems, such as SVC (Static VAR Compensator), TCSC (Thyristor Controlled Series Capacitor), SSSC (Static Synchronous Series Compensator), are mainly placed in the power system for various reasons, Reactive power exchanges, network voltages, etc.). However, a controller and a signal.

Additional stabilization can be added to improve stability. In addition to these main roles, FACTS can satisfy the problems of stability [1].

These systems remain very expensive to be installed solely for a reason of damping of the oscillations.

Yousef et al. [2], use LQR and LQG to design the PSS.

In the literature, several research on heuristic techniques and artificial intelligence has been

IJDACR International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 11, June 2017)

proposed and successfully implemented to improve the dynamic stability of the power system [3-4].
Different approaches using the genetic algorithm [5-6]. The advantage of GAs over other optimization techniques is their independence from the complexity of the problems. In addition, he works on a population set [7-8]. Also, the Particle swarm optimization (PSO) method inspired by the movement of insects, birds and fish [9]. It reads genetic algorithms and evolutionary programming. Particle swarms are a new class of algorithms for solving optimization problems [10].
The objective of this paper is to ensure a maximum damping of the oscillations at low frequency by the use of the PSS. To achieve this, we propose an optimal adjustment of the parameters of the PSS. This ensures satisfactory damping of the rotor oscillations and guarantees the overall stability of the system for different operating points. Based on the analysis of the eigenvalues of the system (the real part of the eigenvalue and the damping factor), optimization of the parameters of the PSS is carried out initially by means of the Genetic Algorithms and then by the Particles Swarm Optimization.
The section-2 to section-4 deal with the general modeling of a power system adjusted to the study of stability. The stability analysis is supplemented by simulation of the Heffron-Philips model in the time domain.
Section five presents the applications of the Genetic Algorithm and Particle Swarm Optimization to the optimization of the PSS parameters installed in the system. Section six contains the results of the proposed approach for the determination of the optimal parameters of the PSS with comparative study of the results obtained by the two optimization methods. Finally, we conclude this paper with a conclusion and perspectives to complete this work.

II. Power System Stabilizer (PSS)

The problem of electromechanical oscillations is solved by adding to the generator a specific controller called: (Power System Stabilizer (PSS)). This controller detects the variations in rotor speed or electrical power of the generator and applies a signal adapted to the input of the voltage regulator (AVR). The generator can thus produce an additional damping torque that compensates for the negative effect of the excitation system on the oscillations.
PSSs, which are simple and easy to install, practical, efficient and cheaper systems, are the most widely used systems for improving stability to small disturbances.

Introduction to PSS Controllers

The additional auxiliary control of the AVR excitation system, loosely known as the PSS Stabilizer (Power System Stabilizer) has become the most common means for improving the damping of low frequency oscillations in power systems (i.e. improvement of dynamic and static stability).
The output power of a generator is determined by the mechanical torque. However, the latter can vary by the action of the field of excitation of the alternator. The PSS is added, it detects the variation of the electrical output power and controls the excitation so as to dampen the power oscillations rapidly [11].
A PSS is used to add a voltage signal proportional to the rotor speed variation in the input of the generator voltage regulator (AVR). Therefore, the entire excitation control system (AVR and PSS) must ensure the following [12]:

1. To support the first oscillations following a great disturbance; That is, ensure the transient stability of the system.
2. Maximize the damping of electromechanical oscillations associated with local modes - as well as interregional modes without negative effects on other modes.
3. Minimize the likelihood of adverse effects, namely:
   a. Interactions with high frequency phenomena in the power system such as resonance in the transport network.
   b. Local instabilities in the band of desired action of the control system.
   c. Be robust enough to enable the control system to meet its objectives for various probable operating points of the power system.

Hence, several approaches based on modern commands have been applied for the design of the PSS. Also includes optimal control, adaptive control, variable structure control and intelligent control which are developed in [13, 14 and 15].
Despite these new modern control techniques with different structures, power system exploiters prefer the conventional PSS advance / delay (Conventional Power System Stabilizer) because of its simple and reliable structure.

III. Different Configurations of PSS

The type of a PSS can be identified by the nature of its input signal. The most widespread are those having as input the power variation ΔP. However, recently, input signals such as $\Delta\omega$ (variation in velocity) and / or Δf (variation in frequency) have been adopted to improve the stability of the inter-

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 11, June 2017)

zone modes in view of the ever increasing increase in interconnections in electrical networks.
The choice of the type of PSS to adopt is according to the oscillations and modes to be damped [12].
The most common type of PSS is known as the conventional PSS (or PSS advance / delay). This type has shown its great efficiency in maintaining stability at small disturbances. This PSS uses the rotor speed variation as input. It is usually composed of four blocks, Figure 1 [16]:

- An amplifier block.
- A high-pass filter block "washout filter".
- A phase compensation block.
- A limiter

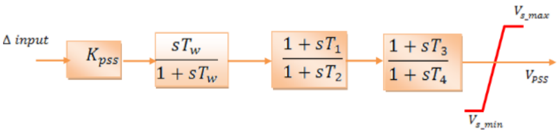

Figure 1: Conventional PSS model

Amplifier

KPSS varies from 0.01 to 50, ideally its value (KPSS) must correspond to the maximum damping. The value of the gain must satisfy the damping of the dominant modes of the system without risk of degrading the stability of the other modes or the transitory stability [17].

High-Pass Filter "Washout Filter"

It eliminates very low frequency oscillations. The time constant of this filter (T_W) must be large enough to allow the signals, whose frequency is located in the useful band, to be transmitted without attenuation. However, it should not be too large to avoid leading to undesirable variations in generator voltage during the stand-by conditions.
Generally, T_W varies from 1 to 20 seconds [18]. Here it is set to 10 seconds.

Phase Compensation Block

Composed of two advance/phase delay compensators as shown in Figure 1. The phase advance is used to compensate for the phase delay introduced between the electric torque of the generator and the input of the excitation system. The time constants (T_1, T_3) and delay times (T_2, T_4) are adjustable. The range of each time constant generally ranges from 0.01 to 6 seconds.

The Limiter

The PSS is a limiter to reduce its unwanted influence during transient phases. The minimum and maximum values of the limiter range from ± 0.02 to 0.1 per-unit [17]
The function of the transfer of the PSS and described as follows:

$$V_{PSS} = K_{PSS} \frac{sT_W}{1+sT_W} \frac{(1+sT_1)}{(1+sT_2)} \frac{(1+sT_3)}{(1+sT_4)} \Delta input \qquad (1)$$

Where,
V_{PSS}: Output signal of the corrector
K_{PSS}: Gain of the corrector
T_w= Time constant of the high pass filter
T_1, T_2, T_3, T_4: Time Constant delay
$\Delta input$: Correction input signal

IV. Setting PSS Parameters

Phase Compensation Method

Consider a simple system consisting of a generator connected to an infinite set of bars. To explain the adjustment of the PSS parameters by the phase compensation method, Figure 2.
The linear model of this system can be graphically illustrated by the Heffron-Philips representation, as shown in Figure 3.
The terms $K_1, \ldots, K_6$ are the linearization constants [19].

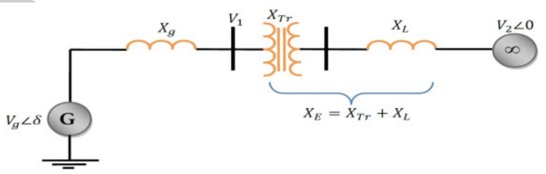

Figure 2: Synchronous generator connected to a bus [19]

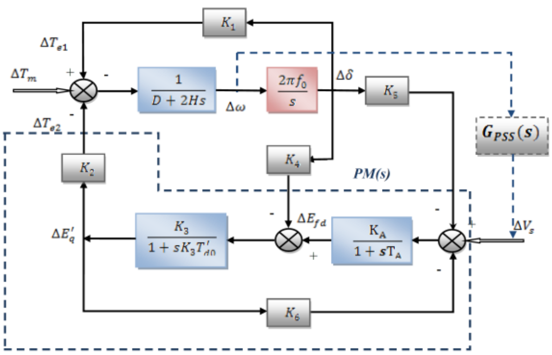

Figure 3: Heffron-Philips model of a system (Single-Machine Infinite-Bus System)

The transfer function $PM(s)$ and the phase delay of the electrical loop can be derived from the Heffron-Philips model. They are given by the following two relations:

IJDACR
International Journal Of Digital Application & Contemporary Research
International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 11, June 2017)

$$PM(s) = \frac{K_a K_3 K_2}{(1+sT_a)(1+sT_{d_0}K_3)+K_a K_3 K_6}\Big|_{s=\lambda=\sigma+j\omega} \quad (2)$$

$$phi_{PM} = PM(s)|_{s=\lambda=\sigma+j\omega} \quad (3)$$

For simplicity, we consider that the parameters to be adjusted of the PSS are the gain K_{PSS} and time constants T_1 and T_3 (where $T_1 = T_3$); the other parameters are set (where $T_2 = T_4$).
Thus, the transfer function of PSS can be rewritten as follows:

$$G_{PSS}(s) = K_{PSS}\frac{sT_W}{1+sT_W}\left(\frac{1+sT_1}{1+sT_2}\right)^2 \quad (4)$$

Since the phase advance of the PSS (phi_{PM}) is equal to the phase phi_{PM}, the time constant T_1 is given, any calculation made by the following relation:

$$T_1 = T_3 = \frac{\tan(\beta)}{\omega-\sigma.\tan(\beta)} \quad (5)$$

With,

$$\beta = \frac{1}{2}\left[-phi_{PM} - \tan^{-1}\left(\frac{\omega}{\sigma}\right) + \tan^{-1}\left(\frac{\omega T_\omega}{1+\sigma T_\omega}\right) + 2\tan^{-1}\left(\frac{\omega T_2}{1+\sigma T_2}\right)\right] \quad (6)$$

The gain of the PSS, for its part, is given by the following relation:

$$K_{PSS} = \frac{4\omega_n \xi H}{K_2|PM(s)||G_f(s)|}\Big|_{s=\lambda=\sigma+j\omega} \quad (7)$$

Where, ω_n is natural oscillation pulsation in rad/s given by:

$$\omega_n = \sqrt{\frac{\omega_0 K_1}{2H}} \quad (8)$$

And ω_0 is the speed of synchronism of the system, in rad/s.
The value ω_n represents the solution of the characteristic equation of the mechanical loop and is defined by the following equation (negated damping coefficient D).

$$2HS^2 + \omega_0 K_1 = 0 \quad (9)$$

Where $S = \pm j\omega_n$

Residue Method
The PSS advance/delay filter is used to compensate for the phase delay of the GEP transfer function (s). By determining the value of the phase delay, we can thus calculate the time constants (advance/delay) required to ensure the required compensation. To do this, the residual phase angle can be used.
Consider the following form of the PSS transfer function for an input/output system:

$$H(S) = K_{PSS}\frac{sT_W}{1+sT_W}\left(\frac{1+sT_1}{1+sT_2}\right)^m \quad (10)$$

Where: m is the number of compensation stages (generally $m = 2$).
Method of Placement of Poles
This method consists in determining the values of the parameters of a PSS so that all the poles of the closed loop system are placed at predetermined positions in the complex plane.
Considering the representation of the following system:

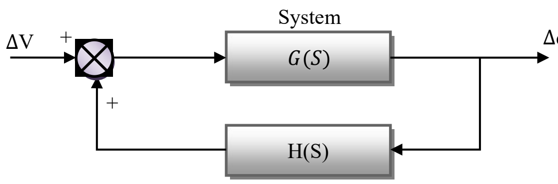

Figure 4: The closed-loop system (PSS)

Where, $G(s)$: transfer function of the system between the reference signal ΔV of the generator voltage regulator, where the PSS is to be installed, and the rotor speed variation $\Delta\omega$.
$H(S)$: PSS transfer function.
The poles of $G(S)$ are precisely the eigenvalues of the open-loop linearized system. The transfer function of the entire closed-loop system $F(s)$ becomes:

$$F(S) = \frac{G(S)}{1-G(S).H(S)} \quad (11)$$

The eigenvalues of the closed-loop system are the poles of the transfer function $F(s)$; they must satisfy the following characteristic equation:

$$1 - G(S).H(S) = 0$$

$$\Rightarrow \quad H(S) = \frac{1}{G(S)} \quad (12)$$

If $\lambda_i = 1,2,\ldots n$ are the eigenvalues previously specified, equation (12) can thus be rewritten as follows:

$$H(\lambda_i) = \frac{1}{G(\lambda_i)} \quad (13)$$

$$\Rightarrow$$

$$K_{PSS}.\frac{\lambda_i T_W}{1+\lambda_i T_W}.\frac{1+\lambda_i T_1}{1+\lambda_i T_2}.\frac{1+\lambda_i T_3}{1+\lambda_i T_4} = \frac{1}{G(\lambda_i)} \quad (14)$$

Consequently, we obtain a set of linear algebraic equations. By solving these equations, we can determine the values of the desired parameters of the PSS that ensure the precise placement of the eigenvalues.

V. Power System Stability Analysis GA and PSO

In previous section the linearized equations are derived for proposed Power System Stabilizer (PSS). This section optimizes the parameters of PSS using Genetic Algorithm and Particle Swarm Optimization.
Fitness Function for PSS

$$f(d_v) = \int_0^t |(d_r - d_v)|\, dt \quad (15)$$

Where,
$d_r = 0$ (Reference speed deviation)

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 11, June 2017)

$d_v = f(v)$ (Actual speed deviation due to control variable v)
The control variable v can be given as:
$v = \{K, T_W, T_1, T_2, T_3, T_4\}$
Also v can be given for others like this.
Minimizing $f(d_v)$ will make $d_v = 0$. Which is desired.
This fitness function is in terms of Integral time absolute error (ITAE).

Genetic Algorithm
Genetic Algorithm of GA is an optimization tool that lies on the platform of Heuristic Approaches. Based on the proposal of Darwin principle of fittest survival, this method was introduced to commence optimization problems in soft computing [20]. The first category of results is termed as initial population and all the individuals are candidate solution. Simultaneous study of the population including all candidates and next phase of solutions are generated following the steps of GA [21].
An iterative application of operators on the selected initial population is the initiative process of GA. Further steps are devised based on valuation of this population. The typical routing of GA is described in following pseudo code:

1. Randomly generate initial population.
2. Employ fitness function for evaluation.
3. Chromosomes with superior fitness are valued as parents.
4. New population generation by parent's crossover with probability function.
5. Chromosome mutation with probability to defend system from early trap.
6. Repeat step 2.
7. Terminate algorithm based on satisfaction criteria.

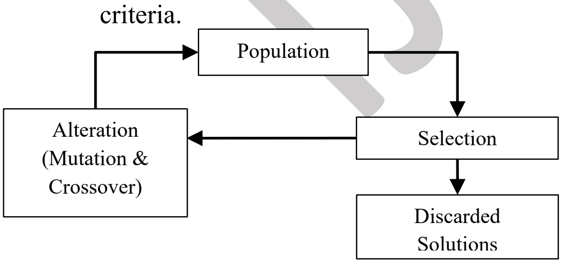

Figure 5: Genetic algorithm evolutionary cycle

Particle Swarm Optimization (PSO)
PSO is a heuristic method [22]. The evaluation of candidate solution of current search space is done on the basis of iteration process (as shown in Figure 6). The minima and maxima of objective function is determined by the candidate's solution as it fits the task's requirements. Since PSO algorithm do not accept the objective function data as its inputs, therefore the solution is randomly away from minimum and maximum (locally/ globally) and also unknown to the user. The speed and position of candidate's solution is maintained and at each level, fitness value is also updated. The best value of fitness is recorded by PSO for an individual record. The other individuals reaching this value are taken as the individual best position and solution for given problem. The individuals reaching this value are known as global best candidate solution with global best position. The up gradation of global and individual best fitness value is carried out and if there is a requirement then global and local best fitness values are even replaced. For PSO's optimization capability, the updation of speed and position is necessary. Each particle's velocity is updated with the help of subsequent formula:

$$v_i(t+1) = wv_i(t) + c_1r_1[\hat{x}_i(t) - x_i(t)] + c_2r_2[g(t) - x_i(t)] \qquad (16)$$

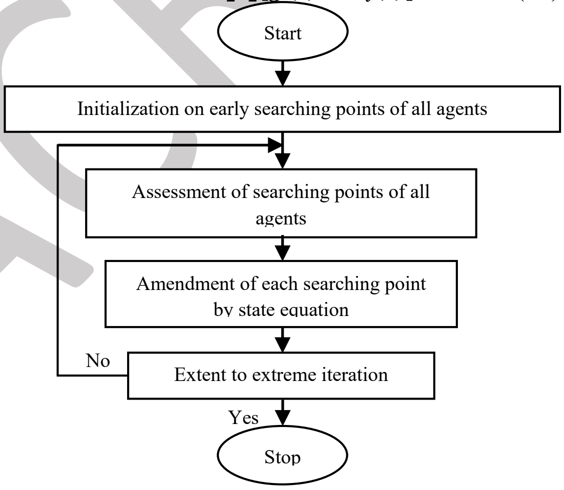

Figure 6: Flow chart of PSO algorithm

VI. Simulation And Results

MATLAB simulation is used to study proposed approach.

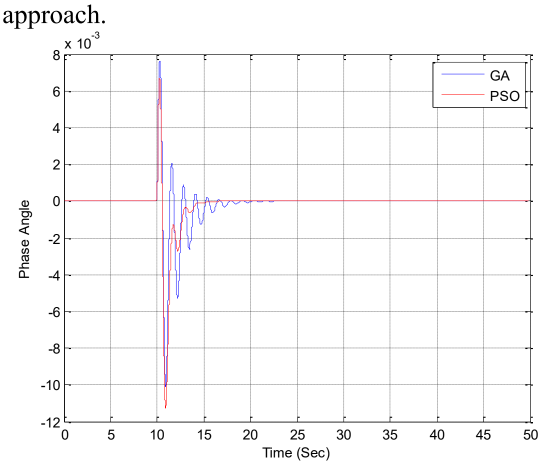

Figure 7: Comparison of phase angle deviations in SMIB for GA and PSO

IJDACR
ISSN: 2319-4863

IJDACR
International Journal Of Digital Application & Contemporary Research

International Journal of Digital Application & Contemporary Research
Website: www.ijdacr.com (Volume 5, Issue 11, June 2017)

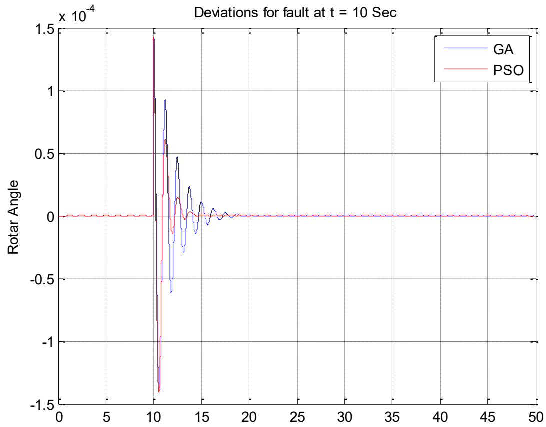

Figure 8: Comparison of rotor angle deviations in SMIB for GA and PSO

VII. Conclusion

The study presented in this paper deals with the application of GA and PSO in the optimization of the parameters of the stabilizing device of the PSS power system. The aim of the paper is to provide the necessary damping to the electromechanical oscillations of the generators, when the system undergoes perturbations around its operating point. A fitness function is derived which is aimed to minimize rotor speed deviation as a function of stabilizers parameter. It was found that the PSO based PSS outperforms the GA based PSS.

Reference

[1] Panda, Sidhartha, and Ramnarayan N. Patel., “Improving power system transient stability with an off-centre location of shunt FACTS devices”, Journal of Electrical Engineering-Bratislava- 57, no. 6, 2006.

[2] Ali M. Youcef, Ahmed M. Kassem “Optimal Power System Stabilizer Based Enhancement Of Synchronizing And Damping Torque Coefficient”, Vol7, April 2012.

[3] Balwinder Singh Surjan, Ruchira Garg P, “Power System Stabilizer Controller Design for SMIB Stability Study” International Journal of Engineering and Advanced Technology (IJEAT), ISSN: 2249 – 8958, Volume-2, Issue-1, October 2012.

[4] F. S. Al-Ismail, M. A. Abido “The Impact of STATCOM Based Stabilizers on Power System Stability, Using Intelligent Computational Optimization Approach”, 2011 IEEE.

[5] Sidhartha Panda and Narayana Prasad Padhy “MATLAB/SIMULINK Based Model of Single-Machine Infinite-Bus with TCSC for Stability Studies and Tuning Employing GA”, International Journal of Electrical and Electronics Engineering 2007.

[6] Ali H. Ahmad, Ahmed A. Abdelqader “Power System Stabilizer Design Using Real-Coded Genetic Algorithm”, 2011 2nd International Conference on Control, Instrumentation and Automation.

[7] M. A. Abido, Y. L. Abdel-Magid, “Analysis and Design of Power System Stabilizers and Fact Based Stabilizers Using Genetic Algorithms”, devilla, 24-28 June 2002.

[8] A. Al-Hinai, Membre, IEEE “Dynamic Stability Enhancement Using Genetic Algorithm Power System Stabilizer”, 2010 IEEE.

[9] Mahdiyeh Eslami, Hussain Shareef and Azah Mohamed, “Optimal Tuning of Power System Stabilizers Using Modified Particle Swarm Optimization”, Proceedings of the 14th International Middle East Power Systems Conference (MEPCON’10), Cairo University, Egypt, December 19-21, 2010, Paper ID 184.

[10] M. A. Abido, “Optimal design of power–system stabilizers using particle swarm optimization”, IEEE Trans, On Energy Conversion, 17(3) (2002)406-413.

[11] E.V. Larsen and D.A. Swann, Applying power system stabilizers part-II: Performance Objectives and Tuning Concepts, IEEE Trans. Power App. Sys, 100 (6) (1981) 3025-3033.

[12] Anders Hammer, “Analysis of IEEE Power System Stabilizer Models”, Master of Science in Electric Power Engineering, Norwegian University of Science and Technology Department of Electric Power Engineering, June 2011.

[13] Do Bomfim, Antonio LB, Glauco N. Taranto, and Djalma M. Falcao. "Simultaneous tuning of power system damping controllers using genetic algorithms." IEEE Transactions on Power Systems 15, no. 1 (2000): 163-169.

[14] Panda, Sidhartha, and Narayana Prasad Padhy. "Power system with PSS and FACTS controller: modeling, simulation and simultaneous tuning employing genetic algorithm." International Journal of Electrical, computer and systems Engineering 1, no. 1 (2007): 9-18.

[15] Ahmad, Ali H., and Ahmed A. Abdelqader. "Power system stabilizer design using real-coded genetic algorithm." 2nd International Conference on Control, Instrumentation and Automation (ICCIA), pp. 25-31, 2011.

[16] Rafiee, Zahra, Soheil Ganjefar, and Abas Fattahi. "A new PSS tuning technique using ICA and PSO methods with the Fourier transform." In 2010 18th Iranian Conference on Electrical Engineering, pp. 806-811. IEEE, 2010.

[17] Jiang, Zhenhua. "Design of power system stabilizers using synergetic control theory." In Power Engineering Society General Meeting, 2007. IEEE, pp. 1-8. IEEE, 2007.

[18] Anderson, Paul M., and Aziz A. Fouad. Power system control and stability. John Wiley & Sons, 2008.

[19] Yao-Nan Yu, Electric power system dynamics, Academic Press Inc., 1983.

[20] J. H. Holland, “Adaptation in Natural and Artificial Systems”, University of Michigan Press, 1975.

[21] D.E. Goldberg, “Genetic Algorithms in Search, Optimization, and Machine Learning”, Addison-Wesley, 1989.

[22] James Kennedy and Russell Eberhart, “Particle Swarm Optimization”, In Proceedings of the IEEE International Conference on Neural Networks, Vol. 4, pp. 1942–1948, 1995.