International Journal on Emerging Technologies **4**(1): 50-54(2013)
ISSN No. (Print) : 0975-8364
ISSN No. (Online) : 2249-3255

Optimization Techniques Based Power System Stabilizer's: An Overview

Amit Shrivastava, Manisha Dubey and Yogendra Kumar
Department of Electrical Engineering,
M.A.N.I.T Bhopal, (M.P.) India

(Received 12 October 2012, Accepted 12 January 2013)

ABSTRACT: Low frequency oscillation problems are very difficult to solve because power systems are very large, complex and geographically distributed. Therefore, it is necessary to utilize most efficient optimization methods to take full advantages in simplifying the problem and its implementation. From this perspective, many successful and powerful optimization methods and algorithms have been employed in formulating and solving this problem.This paper reviews new approaches in modern research using optimization techniques to develop power system stabilizer (PSS These techniques are such as Tabu search (TS), simulated annealing (SA), Ant Colony Optimization (ACO), Harmony search (HS), evolutionary programming (EP), bacteria foraging optimization (BFO), genetic algorithm (GA), particle swarm optimization (PSO) Bee colony, Artificial Bee Colony (ABC), SFLA algorithm, etc have been used. Research showed controllers designed based on a conventional control theory, modern and adaptive control theories, suffer from some limitations. However, Optimization techniques proved to be able to overcome theses limits. Hence, more researchers preferred to utilize these approaches for the power systems. The review efforts geared towards PSS developed based on Optimization techniques, which effectively enhance both small signal stability and transient stability and equally provide superior performances. In this paper a serious attempt is made to present a comprehensive analysis of optimization techniques for designing PSSs, which were recently proposed by various researchers.

Keywords: Power system Stabilizer, low frequency oscillation, and optimization

I. INTRODUCTION

The electrical energy has become the major form of energy for end use consumption in today's world. There is always a need of making electric energy generation and transmission, both more economic and reliable. The voltages throughout the system are also controlled to be within ±5% of their rated values by automatic voltage regulators acting on the generator field exciters, and by the sources of reactive power in the network.

For proper operation, this large integrated system requires a stable operating condition. The power system is a dynamic system. It is constantly being subjected to small disturbances, which cause the generators relative angles to change. For the interconnected system to be able to supply the load power demand when the transients caused by disturbance die out, a new acceptable steady state operating condition is reached. That is, the power system must be stable. It is important that these disturbances do not drive the system to an unstable condition.Stability in power systems is commonly referenced as the ability of generating units to maintain synchronous operation [1]. It is useful to classify the modes of instability of power systems. It is common to divide stability into the following types:

Transient stability which is the ability to maintain synchronism when the system is subjected to a large disturbance. In the resulting system response, the changes in the dynamic variables are large and the nonlinear behavior of the system is important.

Small Signal Stability which is the ability of the system to maintain stability under small disturbance. Such disturbances occur continuously in the normal operation of a power system due to small variations in load and generation.

Electro-mechanical oscillations between interconnected synchronous generators are phenomena inherent to power systems. In an N-machine power system there are (N-1) natural electromechanical modes of oscillations. The stability of these oscillations is of vital concern, and is a prerequisite for secure system operation. These oscillations can be classified into two classes.

The first is the oscillations associated with a single generator or a single plant that is called "local modes" or "plant modes". Local modes normally have frequencies in the range of 0.7 to 2 Hz. The characteristics of these oscillations are well understood. They may be studied adequately, and satisfactory solutions to stability problems are developed from a system, which has detailed representation only in the vicinity of the plant. The second is the oscillations associated with groups of generators, or groups of plants. They are called "inter-area modes". Inter-area modes have frequencies in the range of 0.1 to 0.8 Hz. The characteristics of these modes of oscillation, and the factors affecting them, are not fully understood. They are more complex to study, and to control. A detailed representation of the entire interconnected system requires studying inter-area modes [1]. For stability point of view, subsequent analysis has shown that these swings are due to poor damping characteristics caused by modern voltage regulators with comparatively high gain [1, 3].

According to the previous analysis there is a really important need for damping these oscillations. To compensate the unwanted effect of these voltage regulators, additional signals are introduced in the feedback loop of voltage regulators.

The additional signals are mostly speed deviation, AC bus frequency or accelerating power [5]. Essentially, they use the power amplification capability of the generators to generate a damping torque in phase with the speed change. This is achieved by injecting a stabilizing signal into the excitation system voltage reference-summing junction. The devices set up to provide these signals through properly chosen transfer function have been called "power system stabilizers" [1, 3, 6].

II. POWER SYSTEM STABILIZER BASICS

The basic function of a power system stabilizer is to modulate generator excitation to provide damping to the system oscillations of concern. These oscillations are typically in the frequency range of 0.2to 2.0Hz, and insufficient damping of these oscillations may limit the ability to transmit power [4].

To provide damping, the PSS must produce a component of electrical torque which is in phase with the rotor speed deviation. The implementation details differ, depending on the stabilizer input signal employed. However, for any input signal the PSS transfer function must compensate for the phase lag of the combined generator, excitation system, and power system. They collectively determine the transfer function between the PSS output and the electrical torque component which can be modulated via excitation system.

This transfer function is usually called GEP(s) and is strongly influenced by AVR gain, generated power level and system strength. Rotor speed, bus frequency or electrical powers are the most commonly used as PSSs input signals.

A comparison between speed and power input signals, and further comparison between electrical power and accelerating power as input signals to PSSs have been done. The speed signal is the most commonly used and is effective in damping these oscillations.

The practical considerations in design and implementation of PSSs are discussed. Transfer function GEP(s) can be obtained with the generator versus the power system represented as one machine to an infinite bus via external impedance. This method is commonly used by industry till today for PSS design for damping the local modes [7].

However, to design a PSS for damping inter-area modes, it is required to obtain the frequency response of GEP(s) with the detailed representation of the interconnected system.

If the machine is participating in a local and inter-area mode, it would be difficult to design a PSS which is effective in damping both the local and inter-area modes. In other words, there will be a trade-off damping between damping requirement for both modes [8].

The block diagram of a single-input PSS is shown in fig.1.

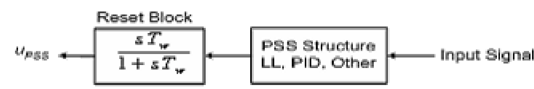

Fig. 1: PSS Structure

Various structures of PSS can be implemented .The common structures are:

(a) Lead-lag structure or conventional PSS (CPSS)

$$u_{PSS} = K\frac{sT_w}{1+sT_w}.\left(\frac{1+sT_1}{1+sT_2}\right)^P y$$

or,

$$u_{PSS} = K\frac{sT_w}{1+sT_w}.\left(\frac{1+sT_1}{1+sT_2}\right)\left(\frac{1+sT_3}{1+sT_4}\right)y$$

Where, y is the input signal.

(b) Proportional-integral-derivative structure.

$$u_{PSS} = \frac{sT_w}{1+sT_w}.\left(K_P+\frac{K_I}{s}+K_D s\right)y$$

(c) Other structures based on optimal, adaptive, variable structure, intelligent… etc.

The common input signals used are the speed, frequency, electric and accelerating power deviations. However, PSS can be either conventional PSS (one-band PSS) which is (analog or digital) or multi-band PSS.

III. TAXONOMY OF APPROACHES

Several researches have been done in the field of power system to provide stability. Various techniques are proposed by several researchers which have its advantages and disadvantages. The taxonomy that is proposed to classify the current methods applied to optimization for power system stabilizer is as follows:

1. Artificial Bee Colony Optimization
2. Shuffled Frog Leaping Algorithm (SFLA)
3. Particle Swarm Optimization
4. Differential Evolution
5. Genetic algorithms
6. Artificial Immune
7. Tabu Search
8. Simulated Annealing

A. ABC- Artificial Bee Colony Optimization

In recent times, the utilization of optimization techniques is found to be effective in dealing with the stabilization of the power systems. This paper exploits Artificial Bee Colony algorithm for better stability of the power system. Simulation results suggest that the proposed technique is better for power system stabilization when compared to the conventional techniques.

Proposed approach used a novel Artificial Bee Colony technique for the power system stabilization. ABC technique has better convergence than GA and NRGA techniques. The simulation results indicate that the proposed technique results in better stabilization than the existing techniques. The objective functions for the multi-machine power system taken into consideration shows better convergence with proposed ABC approach. The future scope of this approach would be to use better optimization techniques which can provide a better performance [30].

B. Shuffled Frog Leaping Algorithm (SFLA)

An optimization technique was proposed to find the optimal parameters of Power System Stabilizer (PSS). The optimization is based on a Shuffled Frog Leaping Algorithm (SFLA) aiming to find the optimal parameter set of the stabilizer. In other word, the proposed SFLA was introduced to identify the parameters of a fixed structure lead compensator through the solution of a min-max problem while satisfying the systems constraints [29].

C. Particle Swarm Optimization

Unlike the other heuristic techniques, PSO ischaracterized as simple in concept, easy to implement,computationally efficient, and has a flexible and well-balanced mechanism to enhance the global and localexploration abilities. Thus, PSO has been proposed inthe design of PSS in [14].

Das *et. al.* presented A modified Particle SwarmOptimization (PSO) algorithm with a small population for the design of optimal PSSs. The Small Population based PSO (SPPSO) was used to determine the optimal parameters of several PSSs simultaneously in a multi-machine power system. In order to maintain a dynamic search process, the idea of particle regeneration in the population was also proposed. Optimal PSS parameters are determined for the power system subjected to small and large disturbances. The advantage of the proposed approach was its convergence in fewer evaluations and lesser computations are required per evaluation [6].

A novel evolutionary algorithm-based approach to optimal design of multimachine power-system stabilizers (PSSs) was proposed. The proposed approach employed a particle-swarm-optimization (PSO) technique to search for optimal settings of PSS parameters. Two eigenvalue-based objective functions to enhance system damping of electromechanical modes were considered. The performance of the proposed PSO-based PSS (PSOPSS) under different disturbances, loading conditions, and system configurations is tested and examined for different multimachine power systems [14].

Two classical bio-inspired algorithms, which are small-population-based particle swarm optimization (SPPSO) and bacterial foraging algorithm (BFA), were presented for the simultaneous design of multiple optimal PSSs in two power systems. The SPPSO uses the regeneration concept to attain the same performance as a PSO algorithm with a large population. Both algorithms use time domain information to obtain the objective function for the determination of the optimal parameters of the PSSs [19].

Particle swarm optimization (PSO) technique was applied to design a robust power system stabilizer (PSS). The design problem of the proposed controller was formulated as an optimization problem and PSO was employed to search for optimal controller parameters. By minimizing the time-domain based objective function, in which the deviation in the oscillatory rotor speed of the generator was involved; stability performance of the systemwas improved [20].

Tuning the parameters of PSS in a multi-machine system using four advanced population based techniques was presented [21].

The algorithms were:

a) Differential Evolution based Particle Swarm Optimization (DEPSO),

b) Modified Clonal Selection Algorithm (MCSA),

c) Small Population Based Particle Swarm Optimization (SPPSO)

d) Population Based Incremental Learning (PBIL).

The comparative study was focused on the frequency domain performances. It was observed that MCSA was performing better than the other three algorithms. The performances of DEPSO and PBIL were quite similar whereas the SPPSO algorithm was not showing very good results compared to the other three [21].

Shayeghi *et.al* presented a modified Iteration Particle Swarm Optimization (IPSO) algorithm to tune optimal gains of a Proportional Integral Derivative (PID) type multiple stabilizers and non-smooth nonlinear parameters (such as saturation limits) for multi machine power system, simultaneously. The problem of robustly tuning of PID based multiple stabilizer design was formulated as an optimization problem according to the time domain-based objective function which was solved by a modified strategy of PSO algorithm called IPSO technique that has a strong ability to find the most optimistic results. In the proposed algorithm, a new index named, Iteration Best, is incorporated in standard Particle Swarm Optimization (PSO) to enrich the searching behavior, solution quality and to avoid being trapped into local optimum [25].

A Particle Swarm Optimization with Time Varying Acceleration Coefficients (PSO-TVAC) algorithm was proposed to design of the Power System Stabilizer (PSS) for improvement of power system low frequency oscillations. It has a strong ability to successful control the local search and convergence to the global optimum solution. The problem of robustly PSS parameter tuning was formulated as an optimization problem according to the time domain-based objective function for a wide range of operating conditions and solved by the PSO-TVAC technique which was simple robust and capable to solve difficult combinatory optimization problems [26].

A new cost function was presented for the tuning of PSS parameters. Optimization of PSS parameters has been done by Particle Swarm Optimization and Imperialist Competitive Algorithm [27].

D. Differential Evolution

optimal tuning of AVR controller and PSS parameters in the synchronous machinewas presented. The problem of obtaining the optimal controller parameters was formulated as an optimization problem and Differential Evolution (DE) algorithm was applied to solve the optimization problem. DE is a population based search algorithm for global optimization over continuous spaces.The proposed approach is found to have stable convergence characteristics and resulted in good voltage regulation and damping characteristics [23].

To overcome the drawback of CPSS a new coordinated PSS design method based on the nonlinear time-domain simulation was proposed[18] Differential evolution algorithm, which is a new branch of evolutionary algorithms,was applied to solve the nonlinear optimization problem of PSS coordination [18].

E. Genetic Algorithm

Abdel et.al demonstrated the use of genetic algorithms for the simultaneous stabilization of multimachine power systems over a wide range of operating conditions via single-setting power system stabilizers. The power system operating at various conditions was treated as a finite set of plants. The problem of selecting the parameters of power system stabilizers which simultaneously stabilize this set of plants was converted to a simple optimization problem which was solved by a genetic algorithm with an eigenvalue-based objective function. Two objective functions were presented, allowing the selection of the stabilizer parameters to shift some of the closed-loop eigenvalues to the left-hand side of a vertical line in the complex s-plane, or to a wedge-shape sector in the complex s-plane [5].

Abdel *et.al*. presentedOptimal multiobjective design of robust multimachine power system stabilizers (PSSs) using genetic algorithms.. The multimachine power system operating at various loading conditions and system configurations was treated as a finite set of plants. The stabilizers were tuned to simultaneously shift the lightly damped and undamped electromechanical modes of all plants to a prescribed zone in the s-plane. A multiobjective problem was formulated to optimize a composite set of objective functions comprising the damping factor, and the damping ratio of the lightly damped electromechanical modes. The problem of robustly selecting the parameters of the power system stabilizers was converted to an optimization problem which was solved by a genetic algorithm with the eigenvalue-based multiobjective function [16].

In the simultaneous tuning of power system stabilizers in a multi-machine power system was presented [22]. The problem of selecting the parameters of power system stabilizers in converted into an optimization problem that was solved by genetic algorithm using eigen value based objective function. The dynamic performance of the system has been investigated under small perturbation and large disturbance. The performance of genetic algorithm based PSS has been compared with the conventional power system stabilizer [22].

F. Artificial Immune

A new method of control used the artificial immune controller called the improved varela immune network controller or ivinc. the purposes of ivinc controller are to enhance the stability of power systems and to damp low frequency oscillations [17].

G. Tabu Search

To avoid computations of sensitivity factors andeigenvectors, Abido & Abdel-Magid [16] have used theTS to design a PSS for a multi-machine system. In [7] Robust design of multimachine power system stabilisers (PSSs) using the tabu search (TS) optimisation technique was presented. The proposed approach employs TS for optimal parameter settings of a widely used conventional fixed-structure lead-lag PSS (CPSS). The parameters of the proposed stabilisers are selected using TS in order to shift the system poorly damped electromechanical modes at several loading conditions and system configurations simultaneously to a prescribed zone in the left hand side of the s-plane. Incorporation of TS as a derivative-free optimisation technique in PSS design significantly reduces the computational burden. In addition, the quality of the optimal solution does not rely on the initial guess [7].

Authors demonstrated the robust tuning of power systems stabilizers for power systems, operating at different loading conditions. A classical lead-lag power system stabilizer was used to demonstrate the technique. The problem of selecting the stabilizer parameters was converted to a simple optimization problem with an eigenvalue-based objective function, which was solved by a tabu search algorithm. The objective function allows the selection of the stabilizer parameters to optimally place the closed-loop eigenvalues in the left-hand side of a vertical line in the complex s-plane [13].

H. Simulated Annealing

Simulated annealing is a derivative-freeoptimization algorithm and no sensitivity analysis isrequired to evaluate the objective function. All thesereasons induced the researchers [11] to design asimulated annealing based power system stabilizer.

IV. CONCLUSION

This paper presents a survey of literature on the various optimization methods applied to solve the PSS problems. A review of most of the publications on the topic was presented. Optimization methods have been initiated to solve this problem. A review of the techniques used by researchers in designing the conventional PSS only was presented.

REFERENCES

[1]. F.P. Demello and C. Concordia , "Concepts of Synchronous Machine Stability as Effected by Excitation Control", *IEEE Transactions on Power Apparatus and Systems*,Vol.**PAS-88**, No.4, April 1969.

[2]. E.V. Larsen, and D.A. Swann, "Applying Power System Stabilizers, parts I, II & III," *IEEE Transactions on Power Apparatus and Systems.*, Vol. **PAS-100**, No. 6 June 1981, , pp. 3025-3046.

[3]. P. Kundur, *Power System Stability and Control*, McGraw-Hill Press, 1994.

[4]. P.M. Anderson and A.A. Fouad, *Power System Control and Stabilit IEEE Press*, 1994.

[5]. Abdel-Magid, Y.L.; Abido, M.A.; Al-Baiyat, S.; Mantawy, A.H. "Simultaneous stabilization of multimachine power systems via genetic algorithms " *IEEE Transactions on Power Systems*, Vol. **14**, Issue 4, 1999 , pp: 1428 - 1439

[6]. T.K. Das, and G.K. Venayagamoorthy, "Optimal Design of Power System Stabilizers Using a Small Population Based PSO" *IEEE Power Engineering Society General Meeting*, 2006.

[7]. Abido, M.A.; Abdel-Magid, Y.L. "Robust design of multimachine power system stabilisers using tabu search algorithm " *IEE Proceedings Generation, Transmission and Distribution*, Vol. **147**(6): 2000, pp 387 – 394.

[8]. Abdel-Magid, Y.L.; Abido, M.A.; Mantaway, A.H. "Robust tuning of power system stabilizers in multimachine power systems " *IEEE Transactions on Power Systems*,Vol. **15**(2): 2000, pp: 735 – 740.

[9]. M.A. Abido, "Simulated annealing based approach to PSS and FACTS based stabilizer tuning," *Electrical power and energy systems*, 2000, pp247-258.

[10]. M.A. Abido, "Robust design of multimachine PSSs using simulated annealing," *IEEE Transaction on Energy Conservation*, Vol. **15**(3), September 2000, pp. 297-304.

[11]. M.A. Abido, "An efficient heuristic optimization technique for robust PSS design," EPSR 58, 2001,pp 53-62.

[12]. M.A. Abido, "Particle swarm optimization for multi-machine PSS design," *IEEE, 2001*, pp. 1346-1351.

[13]. Abido, M.A.; Abdel-Magid, Y.L. "Robust design of electrical power-based stabilizers using tabu search" Power Engineering Society Summer Meeting, 2001 Vol. **3**, 2001, pp: 1573 – 1578.

[14]. M.A. Abido, "Optimal design of PSSs using particle swarm optimization," *IEEE Transaction on Energy Conservation*, Vol. **17**, No. 3, September 2002, pp. 406-413.

[15]. M.A. Abido, & Y.L. Abdel-Magid, "Eigen value assignments in multimachine power systems using tabu search algorithm," *Computer and Electrical engineering*, **28**. 2002, 527-545.

[16]. Abdel-Magid, Y.L.; Abido, M.A. "Optimal multiobjective design of robust power system stabilizers using genetic algorithms " *IEEE Transactions on Power Systems*,Vol: **18**, Issue: 3 ,2003, pp: 1125–1132.

[17]. Freddy Prasetia Ridhuan, Mohd Fauzi Othman "Application Of Artificial Immune System To Design Power Systems Stabilizer" *The 5th Student Conference on Research and Development* Malaysia, 2007.

[18]. Zhenzhi Lin, C.Y. Chung, K.P. Wong, Fushuan Wen "Optimal Coordination of Power System Stabilizers for Transient Stability Enhancement", *Australasian Universities Power Engineering Conference (AUPEC'08)*, 2008.

[19]. Das, T.K.; Venayagamoorthy, G.K.; Aliyu, U.O. "Bio-Inspired Algorithms for the Design of Multiple Optimal Power System Stabilizers: SPPSO and BFA " *IEEE Transactions on Industry Applications*, Vol: **44**, Issue: 5 , 2008, pp:1445 – 1457.

[20]. Sidhartha Panda, N.P. Padhy "Robust Power System Stabilizer Design using Particle Swarm Optimization Technique" *World Academy of Science, Engineering and Technology*, **46**, 2008.

[21]. Pinaki Mitra, Chuan Yan, Lisa Grant, Ganesh K. Venayagamoorthy, and Komla Folly, "Comparative Study of Population Based Techniques for Power System Stabilizer Design" *IEEE conference, 2009*.

[22]. Simultaneous Stabilization Of Multimachine Power System Using Geneticalgorithm Based Power System Stabilizersmanisha Dubey, Aalok Dubeymaulana Azad National Institute Of Technology, Bhopal, India 2009.

[23]. B. Selvabala, Dr. D. Devaraj "Co-Ordinated Tuning of AVR-PSS Using Differential Evolution Algorithm"IEEE conference, 2010.

[24]. Mahdiyeh Eslami, Hussain Shareef, Azah Mohamed "Power System Stabilizer Design Based on Optimization Techniques".

[25]. Hossein Shayeghi, Ali Ghasemi, Heidarali Shayanfar "PID Type Stabilizer Design for Multi Machine Power System Using IPSO Procedure ", *J. Computer Science and Engineering*, **1**(2):, 2011, pp 36-42.

[26]. H. Shayeghi, A. Ghasemi "Application Of PSO-TVAC To Improve Low Frequency Oscillations" *International Journal on "Technical and Physical Problems of Engineering" (IJTPE)*, Vol. **3**, No: 4 Issue 9, 2011, pp 36-44.

[27]. Z. Rafiee, S. Ganjefar, A.F. Meyabadi "A New PSS Tuning Technique Using ICA and PSO Methods with the Fourier Transform" *Electrical and Electronic Engineering*; **1**(1), 2011, pp: 17-23.

[28]. V. Ravi, K. Duraiswamy "A Novel Power System Stabilization Using Artificial Bee Colony Optimization" European *Journal of Scientific Research*, Vol. **62**, No.4, 2011, pp. 506-517.

[29]. R. Jahani, H. Chahkandi Nejad, M. Mohammad Abadi ,H. Ghiasi Zadeh "Optimal Parameters of Power System Stabilizer for Minimizing the Maximum Overshoot using SFLA" *American Journal of Scientific Research*, Issue 32, 2011, pp. 58-68.

[30]. V. Ravi, Dr. K. Duraiswamy "Effective Optimization Technique for Power System Stabilization using Artificial Bee Colony " *International Conference on Computer Communication and Informatics (ICCCI)*, 2012, Coimbatore, INDIA.