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# Selection of Objective Function for PSS Design Using Optimization Techniques in Multi Machine Power System

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**ABSTRACT**

Meta-Heuristic optimization techniques are becoming very popular in the design of power system stabilizer (PSS). Optimization techniques are used to maximize or minimize the value of objective function. So it is very crucial to select the objective function that is sensible to get most optimal values for PSS control parameters. In this paper, a comparative study is carried out to choose the objective function for best performance of PSS design using linearized model of multi machine power system. The particle swarm optimization (PSO) as a meta-heuristic optimization algorithm and conventional lead lag structure as PSS are used in this study. Four popular objective functions are used with PSO to find optimized PSS parameters. The comparison is carried out through generator's rotor speed response using the optimized parameters for each objective functions. The obtained results show that comprehensive damping index (CDI) as an objective function is very effective and can be used in the application of fine tuning for PSS parameters in multi machine power system.



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## INTRODUCTION

Power System Stabilizer (PSS) is one of the most important device used for power system stability improvement in multi machine power system (Kundur, P., 1994). Faults in interconnected power system tempt to grow low frequency (LF) oscillations that eventually lead to severe damage to rest of the system (Kundur, P., 1994). In order to protect the system from such unwanted and unpredicted major disturbances, PSSs are employed in excitation system of synchronous generators (Kundur, P., 1994). PSSs detect the variation in its input signal that is usually the rotor angle deviation or rotor speed deviation and provide a stabilizing signal to damp out the growing LF oscillations (Kundur, P., 1994) and thus ensuring the stability and security of power system.

The overall performance of PSS over power system oscillations depends on how correctly the PSS is tuned (Kundur, P., 1994). Meta-heuristic optimization techniques for example Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Firefly Algorithm (FA) etc. are used to search for the best parameters (Linda, M.M., N.K. Nair, 2013). The goal of such optimization techniques is to minimize (Cai, L.J., I. Erlich, 2005) or maximum (Linda, M.M., N.K. Nair, 2013) the objective function. So it is very crucial to choose the objective function in design of PSS.

In (Khaleghi, M., 2011), two individual objective functions, leading to search for the damping ratio and real part of worst eigen value, are combined to form a multi objective function. Another multi objective function is reported in (Ali, E.S., S.M. Abd-Elazim, 2012; Eslami, M., 2010) that includes an expected value of damping factor (real part of eigenvalue) as well as damping ratio. Additionally a control constant known as weight value is used to incorporate both damping factors and damping ratios functions. An objective function is presented in just maximizing the poorest damping ratio. The maximum value of damping ratio is 1. So the algebraic sum of all the damping ratios after subtracting them from maximum value 1 constitute the objective function (Cai, L.J., I. Erlich, 2005). This is also known as comprehensive damping index (CDI). So many objective functions have been used previously for PSS design. Therefore, it is important to evaluate the performance of objective functions to figure out the best one in terms of PSS design.

The aim of this paper is to present a comparative study among the most popular objective functions for meta-heuristic optimization techniques in the design of PSS. Particle Swarm Optimization is picked out in this

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study. All the declaration for PSO are kept same for all objective function to see how efficient and effective are the objective functions in finding the optimal parameter of PSS for multi machine power system. That is very important in the research of power quality and transient analysis (Hannan, M.A., K.W. Chan, 2006; Hannan, M.A., 2011).

***Two Area Power System:***

In this study, two area four machine power system (Rogers, G., 2000) is considered for the design of PSS as shown in Figure 1 by using the power system toolbox (PST). There are two areas and each one is having two generators with identical configurations. Two areas are connected through a weak tie line.

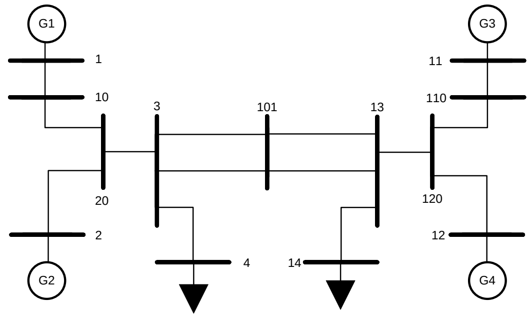


**Fig. 1:** Single line diagram of two area four machine power system.

The linearized model of power system is defined by Equation 1

$$\Delta \dot{x} = A\Delta x + B\Delta u$$
$$\Delta y = C\Delta x + D\Delta u \quad (1)$$

where A, B, C and D are the state matrix, input matrix, output matrix, and feed-forward matrix respectively. The eigenvalues, $\lambda=\sigma\pm j\omega$ of the system are determined from state matrix. The stability of the system is determined from the analysis of the eigenvalues. The real part of each eigenvalue, $\sigma$ is the damping factor and the damping ratio is calculated using Equation 2 (Linda, M.M., N.K. Nair, 2013).

$$\xi = \frac{-\sigma_i}{\sqrt{(\sigma^2 + \omega^2)}} \quad (2)$$

In this paper, PSS is the conventional lead-lag structure (Rogers, G., 2000) and it consists of one gain block, one washout block and two stages lead lag block. The input of PSS is the speed deviation of rotor.

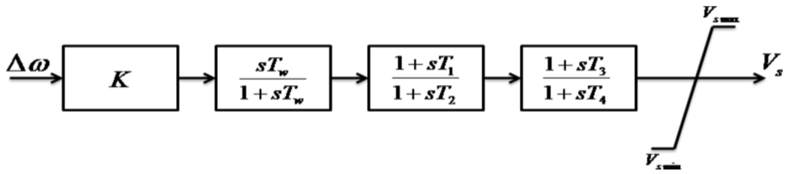


**Fig. 2:** Power System Stabilizer (PSS) Lead-Lag Structure.

From previous researches (Linda, M.M., N.K. Nair, 2013; Cai, L.J., I. Erlich, 2005; Khaleghi, M., 2011; Eslami, M., 2010), the most popular objective functions are the Equations 3 – 6. The Boundary limits are taken as $0.01 \le K \le 100$, $0.001 \le T_1, T_2, T_3, T_4 \le 2$ and $T_w$ is kept to 10 for design simplicity.

Maximize: $f_1 = \xi_{\min}$ (3)

where $\xi_{\min}$ is the lowest value of damping ratios and the goal of this objective function is to maximize this minimum value within the boundary limits.

Minimize: $f_2 = \sum_{i=1}^{n} (1 - \xi_i)$ (4)

where n is the total number of eigenvalues. This comprehensive damping index (CDI) is to be minimized.

Maximize: $f_3 = \xi_{\min} - \sigma_{\min}$ (5)

where $\xi_{\min}$ is the smallest damping ratio and $\sigma_{\min}$ is the smallest real part of eigenvalues.

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Minimize: $$f_4 = \sum_{\substack{i=1 \\ \sigma_i \geq \sigma_0}}^{n} (\sigma_0 - \sigma_i)^2 + \varpi \sum_{\substack{i=1 \\ \xi_i \geq \xi_0}}^{n} (\xi_0 - \xi_i)^2 \quad (6)$$

where $\varpi$ , $\xi_0$ and $\sigma_0$ are set to 1.35, 0.1 and -0.5 respectively.
The listed parameters in Table 1 are used in PSO.

**Table 1:** Parameter setting used in PSO.

| Population | Dimension | Max. Iter. | $C_1$ | $C_2$ | $W_{max}$ | $W_{min}$ | $V_{max}$ |
|---|---|---|---|---|---|---|---|
| 30 | 5 | 100 | 2 | 2 | 0.9 | 0.4 | 2 |

## RESULTS AND DISCUSSION

In order to compare the effectiveness of selected objective functions, simulations are carried out in linearized model using PSO to get the optimal parameters for PSS. All the settings for PSO are kept same for every objective function. Obtained optimized PSS parameters are then used to run non-linear model of two area four machines power system. For the non-linear model, a 100ms three phase fault is applied between bus-3 and bus-101. The rotor speed responses for generator 1 (G1) and 4 (G4) are compared for all four objective functions. Objective functions $f_1$, $f_2$, $f_3$ and $f_4$ are the Equations 3 -6. In Figure 3 (a) and (b), damping over LF oscillations using $f_2$ is much higher than using other objective functions for G1 as well as G4. So the comparison in Figure 3 clearly proves that comprehensive damping index (*CDI*) is much superior as an objective functions for meta-heuristic optimization techniques.

**Table 2:** Optimized PSS parameter from four objective functions.

| Objective function | *K* | $T_1$ | $T_2$ | $T_3$ | $T_4$ |
|---|---|---|---|---|---|
| $f_1$ | 8.0374 | 0.2090 | 0.0777 | 1.3700 | 0.9471 |
| $f_2$ | 9.5435 | 0.0243 | 0.0101 | 1.2103 | 0.7224 |
| $f_3$ | 7.0742 | 0.5079 | 0.5682 | 0.9206 | 0.1973 |
| $f_4$ | 10.7159 | 0.9255 | 1.7735 | 0.6801 | 0.3486 |

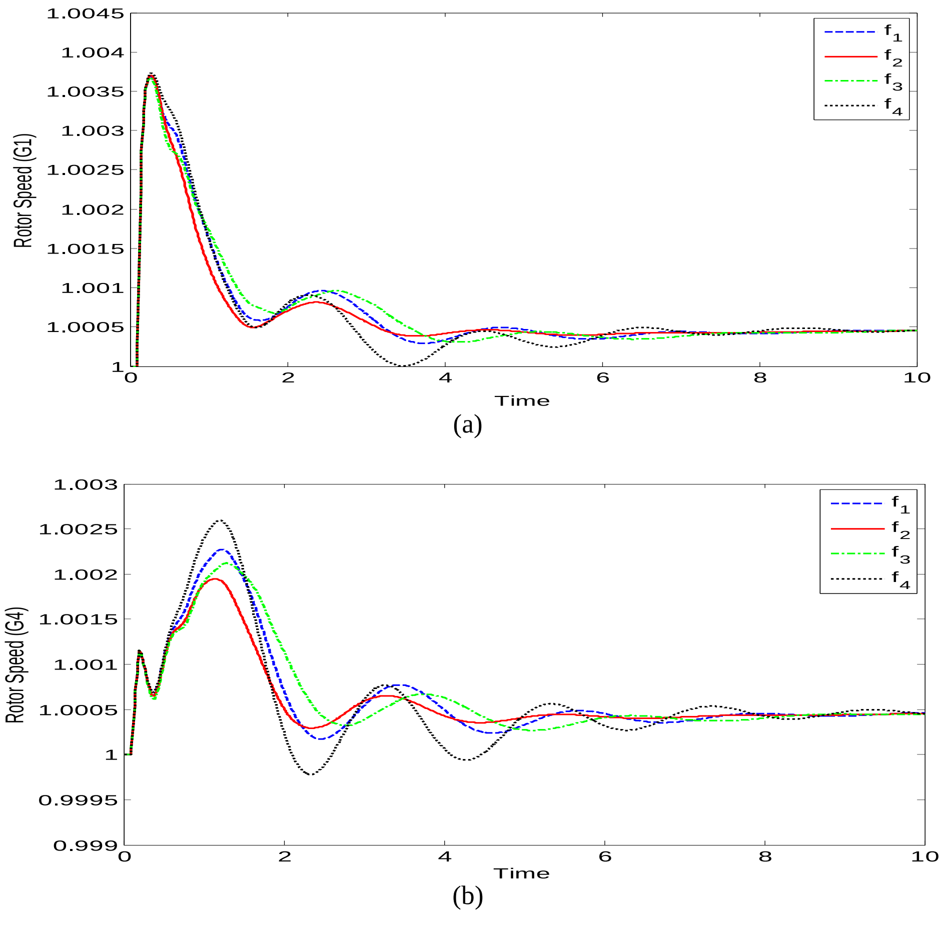


**Fig. 3:** Rotor speed deviation: (a) G1 response (b) G4 response.

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***Conclusion:***

In this paper, a comparative study is carried out for selection of objective function in the design of PSS. PSO is preferred to test the performance of four popular objective functions. The results attained after simulation validate the superiority of CDI as an excellent objective function in meta-heuristic optimization application. Therefore, CDI can be a reasonable choice for the application of multi machine PSS design in linearized model.

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## REFERENCES

Ali, E.S., S.M. Abd-Elazim, 2012. TCSC damping controller design based on bacteria foraging optimization algorithm for a multimachine power system, International Journal of Electrical Power & Energy Systems, 37: 23-30.

Cai, L.J., I. Erlich, 2005. Simultaneous coordinated tuning of PSS and FACTS damping controllers in large power systems, IEEE Transactions on Power Systems, 20: 294-300.

Eslami, M., H. Shareef, A. Mohamed, M. Khajehzadeh, 2010. A hybrid PSO technique for damping electro-mechanical oscillations in large power system, 2010 IEEE Student Conference on Research and Development (SCOReD), 13-14 Dec Putrajaya, 442-447.

Hannan, M.A., A. Mohamed, A. Hussain, M. Al-Dabbagh, 2011. Power Quality Analysis of STATCOM using Dynamic Phasor Modeling, International Journal of Electric Power System Research, 79: 993-999.

Hannan, M.A., K.W. Chan, 2006. Transient Analysis of FACTS and Custom Power Devices using Phasor Dynamics, Journal of Applied Science, 6: 1074-1081.

Khaleghi, M., M.M. Farsangi, H. Nezamabadi-pour, K.Y. Lee, 2011. Pareto-Optimal Design of Damping Controllers Using Modified Artificial Immune Algorithm, IEEE Transactions on Systems, Man and Cybernetics, 41: 240-250.

Kundur, P., 1994. Power System Stability and Control, McGraw-Hill.

Linda, M.M., N.K. Nair, 2013. A new-fangled adaptive mutation breeder genetic optimization of global multi-machine power system stabilizer, International Journal of Electrical Power & Energy Systems, 44: 249-258.

Rogers, G., 2000. Power system oscillations, Kluwer Academic Pub.