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# Design and Analysis of PSS and SVC Controller using Crossover GSA Approach

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***Abstract:***
Power System Stabilizer (PSS) and Static Var Compensator (SVC) basically use as an additional controller to damp out the under frequency oscillation in real power system network. The tuning of PS Stabilizer and SVC for a non-linear power system have to be liberal with the ultimate objective that general power system strength can be bettered. In the cutting edge period different populaces based heuristic calculations are accessible to screen out the strength issue in the electric power system. This report presents another heuristic advancement method named as Particle Swarm Optimization adjusted Gravitational Search Algorithm (crossover PSO-GSA) to tuning the PSS and SVC parameters for a multi-machine power system for various working conditions. The recommended strategy is hearty and greatly effective as contrasted and its related heuristic system, for example, the Gravitational Search Algorithm (GSA). This calculation is connected to two areas of the machine system for little and huge unsettling influences. From the outcomes, it is seen that the proposed methodology concentrates more on improving the lively security of the power system, especially while system working conditions changes.

***Keywords:*** *PSS, SVC, Coordinated tuning, Multi-machine system, crossover PSO-GSA, Low frequency oscillations damping*

## I. INTRODUCTION

Power system protection is illustrated as the limit of a PS, for a well-known working circumstance, to recover a state of working equalization in the wake of being represented to a physical agitating impact, with every system constrained so that in every practical sense the entire system remains perfect [1]. Like a shot multi day, scientists are giving high significance to little flag strength issue, since precariousness may have untoward impacts in Power System (PS). To surmount this issue, in the PS add-on controllers are connected to keep the system from botch of accessible producing limit [2]. PSS and FACTS devices have been exhaustively connected in PS as a viable controller by method for enhancing generally speaking system solidness.

For two decades, a few specialists are portrayed the advancement of PSS and SVC parameters for upgrading the dependability edge in particular ways.

Some of them are control based strategies and the others are heuristic calculations and their half breed varieties. G. El-Saady et al [3] introduced fluffy rationale based static Var stabilizer plan for damping electromechanical methods of motions dependent on the versatile model reference approach for Single Machine Infinite Bus power system P. Lakshmi and M. A. Khan [4] portrayed the tuning of Fuzzy Logic based PSS (FLPSS) factor by its gain esteem. Support factor approach is honed for the area of PSS. The swarming hereditary calculation is connected to limit the objective part, in particular the Root Mean Square Deviation (RMSD) list. K. First class and A. Al-Naamany [5] broke down the crossover Neuro-fluffy SVC stabilizer for the change of damping under various working conditions. Fluffy joined with the neural system impedance system is utilized for planning the SVC parameters for a SMIB system.

AhadKazemi and Mahmoud VakilSohrforouzani [6] proposed another fluffy Proportional Integral (PI) to the multi-machine system and FACTS gadgets are controlled for the change of low recurrence motions. A.M. El-Zonkoly et al [7] framed a streamlining issue for the FLPSS for a SMIB system, or, in other words Particle Swarm Optimization (PSO) approach. Recreation results demonstrate that PSO based FLPSS gives better execution under different working conditions. By following the fluffy rationale standards [3-7], it is to a great degree hard to interpret the finished results of a few fluffy principles and defuzzifying the yield. It's additionally testing to decide the right arrangement of guidelines and participation capacities for complex systems. Fluffy rationale controllers require calibrating of its parameters previously execution of the reproduction with different calculations. Different control procedures, for example, Neural Network (NN) [8], H-endlessness ($H\_\infty$) [9], Sliding Mode Control (SMC) [10] and its variations based enhancement for ideal PSS configuration has been accounted for by N. Hussain et al., Hardiansyah et al., and H. Huerta et al. In these strategies, the control rule relies ahead of a linearised machine demonstrate and the control factors are set to ostensible working conditions. Basically, the significant power system whose parameter are time changing, the determination of an controller for control procedures in which the parameters of the arrangement are to be evaluated, might be simple and a settled controller is additional attractive and reasonable.

Recent years, different Artificial Intelligence (AI) strategies have been defined to tackle the perplexing improvement issue by heuristic inquiry. M.A. Abido [11, 12] displayed the organized tuning of PSS and SVC parameters by utilizing Simulated Annealing (SA) calculation and the Real Coded Genetic Algorithm (RCGA) characterized by eigen value based methodology. S. M. Abd-Elazim and E.S.Ali [13] showed the use of PSS and SVC configuration by utilizing Bacterial Foraging Optimization (BFO) to three machine nine transport system.. From the investigation, nobody calculation could give an ideal goal of all this present reality solidness issues in PS. Along these lines, use of new calculations to get the worldwide optima for the solidness issue will be obvious to everyone of the analysts.

This report gives an utilization of a crossover PSO-GSA algorithm [14-15] to see the ideal parameters of the Stabilizer and SVC. The quality of the plan because of little and expansive aggravation (three phase to earth fault) on the proposed crossover PSO-GSA controller (composed PSS with SVC and PSS alone) execution is contrasted and broke down and two region four machine and thirteen transport [16] system.

## II. SYNCHRONIZED DESIGN OF PS STABILISER AND SVC

In a structured procedure of PS Stabiliser and SVC for a multi-machine PS, the linearized incremental models around a harmony position are frequently utilized [1, 2]. The state condition speaking to PS with 'n' number of machines, PSS and SVC can be composed as

$$\Delta\dot{x} = A\Delta x + Bu \qquad (1)$$

Where

$$\Delta x = \left[\delta\omega E_q^{'}\Psi_q^{''}E_d^{'}\Psi_d^{''}\right]^T, u = [\Delta V_s \Delta B_e]^T$$

This paper adapts a wide use of conventional PSS and SVC for the design process [11, 12]. The orthodox PSS is in the form of

$$\Delta v_s = \left[K_i\left(\frac{sT_W}{1+sT_W}\right)\left(\frac{1+sT_{1i}}{1+sT_{2i}}\right)\left(\frac{1+sT_{3i}}{1+sT_{4i}}\right)\right]\Delta\omega \qquad (2)$$

Where

$K_i$ - Stabiliser gain of the $i^{th}$ PS Stabilise

$T_W$ - wash-out time constant.

$T_{ki}$ - Lead-Lags time constants of the $i^{th}$ PSS (where $k = 1,2,3$ and $4$)

$\Delta v_s$ - Output signal of the $i^{th}$ PSS $\Delta\omega$ - change of machine Speed (speed deviation) i-1, 2… n-number of PSS

The information flag of the PSS is the angular speed deviation ($\Delta\omega$) and yield the output signal ($\Delta V_S$), or, in other words the reference voltage of the excitation system is appeared in fig. 1. The flag washout square goes about as a high-sit back constant Tw and it is in the scope of 1 to 20 seconds [2]. The stage remuneration square ($T_1$,$T_2$,$T_3$ and$T_4$) gives the suitable stage lead attributes to repay the stage slack between the information and yield signals. Thyristor Controlled Reactor was in parallel with a fixed capacitor bank indicated is utilized to build up the coveted SVC show. This setup is a shunt component associated with the AC system and required voltage can be setup using transformer (eqn. 3).

The conventional SVC is in the form of,

$$\Delta B_e = \frac{1}{T_r}[-B_e + K_r(V_{ref} - V_t + V_s)] \quad (3)$$

The effective susceptance and the reactance of the TCR are calculated by using (eqn. 4) and (eqn. 5)

$$B_e = -\frac{(2\pi - 2\alpha + \sin 2\alpha)}{\pi X_L} \quad (4)$$

$$X_e = X_c \frac{\pi / r_x}{\sin 2\alpha - 2\alpha + \pi(2 - \frac{1}{r_x})} \quad (5)$$

$$X_e = -1/B_e \text{ and } r_x = \frac{X_e}{X_L}$$

where,

$B_e$-Effective susceptance of the TCR

$K_r$-Regulator gain

$V_t$-Terminal voltage

$X_L$-React. of the fixed inductor of SVC

A aide balancing out flag from speed could be forced on the SVC control circle. The square graph of a SVC with helper settling signal is appeared in fig. 1. This controller might be measured as a lead - lags compensation. It contains a gain square, flag washout square, limiter, and 2 phases of lead lag compensation. To get the ideal facilitated outline of the $i^{th}$ PSS and SVC to diminish the rotor point flimsiness [10], the controller gain Ki, lead-lag time constants $T_{ki}$ of PSS and time constants $T_b$, Tc and gain $T_r$ of SVC are still should be streamlined.

**A. Proposed PSS and SVC coordinated design**

In this paper two populations based heuristic techniques named as GSA and crossover PSO-GSA is utilized to amplify the improvement, combination and locate the worldwide ideal estimation of the wellness work. Two target capacities are utilized for advancement of SVC and PSS parameters. First target work included the significance of the damping proportion [11-12].

$$J = \sum_{n=1}^{pl} \sum_{\zeta_{m,n} \leq \zeta_0} [\min(\zeta_{m,n})] \quad (6)$$

where$pl$ is the no. of operating region (swing modes) included in the design procedure, and $\zeta_{m,n}$ is damping ratio, $^{th}$Eigen value and $^{th}$ operating point.

The projected objective function describes about the requirement of real part of eigen value and damping ratio, to minimize stability problem of power system.

$$J_1 = \sum_{n=1}^{pl} \sum_{\sigma_{m,n} \geq \sigma_0} [\sigma_0 - \max(\sigma_{m,n})]^2 \quad (7)$$

$$J_2 = \sum_{n=1}^{pl} \sum_{\zeta_{m,n} \leq \zeta_0} [\zeta_0 - \min(\zeta_{m,n})] \quad (8)$$

where$\sigma_{m,n}$ is the real part of the $^{th}$Eigen value of the $^{th}$ operating point, subjected to the limits that infinite boundaries are located on the PSS and SVC factors. The multi objective problems are changed into a single objective problem by assigning distinct weights to each objective ($\alpha$ =9 and $\beta$ =1 [17]).In this case, the conditions are imposed simultaneously, by fusing the two defined objective functions.

$$J_{new} = [\alpha J_1 + \beta J_2] \quad (9)$$

$$J_{new} = \left[\alpha \sum_{n=1}^{pl} \sum_{\sigma_{m,n} \geq \sigma_0} [\sigma_0 - \max(\sigma_{m,n})]^2 + \right.$$

βn=1plζm,n≤ζ0ζ0−min(ζm,n) (10)

This recommended objective function will obtain system closed-loop Eigen values in D-shaped sector in which $\sigma_{m,n} \leq \sigma_0 = -2$ and $\zeta_{m,n} \geq \zeta_0 = 0.2$ as shown in fig. (2).

Controller design difficulty to be frame as an embarrassed enhancement problematic given in eqn. (11), Where the limits are the PS Stabilizer and SVC factor:

Min.$J_{new}$ / Max.J Subject to

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$$\text{PSS}\begin{cases}\mathbf{K_{i,min}} \le \mathbf{K_i} \le \mathbf{K_{i,mx}}\\ \mathbf{T_{1i,mini}} \le \mathbf{T_{1i}} \le \mathbf{T_{1i,mx}}\\ \mathbf{T_{2i,mini}} \le \mathbf{T_{2i}} \le \mathbf{T_{2i,mx}}\\ \mathbf{T_{3i,mini}} \le \mathbf{T_{3i}} \le \mathbf{T_{3i,mx}}\\ \mathbf{T_{4i,mini}} \le \mathbf{T_{4i}} \le \mathbf{T_{4i,mx}}\end{cases}$$

$$\text{SVC}\begin{cases}\mathbf{T_{r,mini}} \le \mathbf{T_r} \le \mathbf{T_{r,mx}}\\ \mathbf{T_{b,mini}} \le \mathbf{T_b} \le \mathbf{T_{b,mx}}\\ \mathbf{T_{c,mini}} \le \mathbf{T_c} \le \mathbf{T_{c,mx}}\end{cases} \quad (11)$$

where,

$$\{i = 1,2,3, \dots . n\}$$

and "$small\ n$" is the number of electrical machines used for PS Stabiliser placement.

## III. PARTICLE SWARM OPTIMIZATION ADJUSTED GRAVITATIONAL SEARCH ALGORITHM TO CONTROLLER DESIGN

Over the most recent two decades, numerous looks into must be improved the situation different sorts of calculations like Bacterial Foraging Optimization (BFA), PSO, Genetic Algorithm (GA) and Differential Evolution (DE) and so on [12, 13, 18, 19] to understand the flimsiness wonders in the multi-machine system. Rashid et al., proposed one of the most up to date heuristic calculation, or, in other words to a few benchmark issues. GSA demonstrated that it gives preferable assembly over GA and PSO under different circumstances. This calculation is essentially established on the Newton's law of gravity, The gravitational power between two particles is straightforwardly corresponding to the result of their masses and conversely relative to the second intensity of the length among them". This calculation displays the appropriate responses, which are gotten by different purposes in a proficient way [17]. It has been demonstrated that this calculation has great capacity to scan for the worldwide ideal, yet it experiences moderate seeking speed, particularly because of low speed in the last cycles [14].

This recommends a hybridization of PSO and GSA [14, 15] in order to determine the objective function. The point by point portrayal of the crossover PSO-GSA calculation to outline the PSS and SVC is clarified beneath:

### A. Step (1)- Position (or) Initialization

Consider a system with "N" no. of agents (masses) and the position of the $k^{th}$ agent is defined by,

$X_k = [x_k^1, x_k^2, \cdots\cdots x_k^d, \cdots\cdots, x_k^n]$,for
$k = 1, 2,3, \cdots\cdots, N$ (12)
Where, $x_k^d$- $k^{th}$ agent position in $d^{th}$ element.

### B. Step (2)- Fitness Function

Best value of each one generation with deference to time is calculated by,

$$\text{best}(t) = \underset{l \in \{1,\cdots,N\}}{\text{min. (or) max.}} \text{fit}_l(t) \quad (13)$$

### C. Step (3)- Gravitational Constant, pbest and gbest

Gravitational constant (is preliminary at the start and final stages, it will be find as a function of time (t) in order to minimize the time control function).

$$G(t) = G(G_0, t) \quad (14)$$

$$G = G_0 \times \exp\left(\frac{-\gamma \times \text{iter}}{\text{maxiter}}\right) \quad (15)$$

where,
$\gamma$-Descending coefficient
$G_0$- 100 [14]
Current $\text{max. iter}$-Maximum number of iterations

To impose PSO phenomena, calculate the $\text{gbest}(t)$using (eqn. 17)

$$\text{pbest}_k(t) = X_k \rightarrow [\text{best}(t)] \quad (16)$$

$$\text{gbest}(t) = \underset{t \neq 0}{\min}[\text{pbest}_k(t)] \quad (17)$$

At t = 0, by the PSO phenomena$(\text{pbest}_k = \text{gbest})$

### D. Step (4)- Calculation of force, total force, mass and acceleration

Force Calculation

For the duration of time"$t$" , the force between the agent "$k$" and "$l$" with respect to mass is given by
where,
(All the parameters are w.r.t definite time"$t$")
$M_{pk}(t)$- passive gravitational mass of agent .

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$M_{al}(t)$- active gravitational mass of agent $l$
- small constant
G(t) - gravitational constant.
$R_{kl}(t)$- Euclidian distance among two agents and $l$. It is given by,

$$R_{kl}(t) = \|X_k(t), X_l(t)\|_2 \quad (19)$$

Total Force Calculation

Total force action on the particle at $d^{th}$ element is given us,

$$F_k^d(t) = \sum_{l=1, l\neq k}^{N} rand_l F_{kl}^d(t) \quad (20)$$

where,
$rand_l$ - random no. among the interval [0-1].

To enhance the execution of the GSA algorithm by the $K_{best}$ agent .$K_{best}$is an element of time, with the underlying quality $G_0$ toward the start and diminishing with time. In such a route, toward the starting, all specialists apply the power, the cycle builds, $K_{best}$ is diminished straight and toward the end there will be a single operator pertaining force to the others. Eqn. (20) can be composed as,

$$F_k^d(t) = \sum_{l=k_{best}, l\neq k}^{N} (rand_l \times G(t) \times F_{kl}^d(t)) \quad (21)$$

3.4.1 Gravitation and Inertia mass

Gravitation and inertia masses are determined by subsequent equations (suppose the gravitational mass is equal to inertial mass),

$$m_k(t) = \frac{fit_k(t) - worst(t)}{best(t) - worst(t)} \quad (22)$$

$$M_k(t) = \left[\frac{m_k(t)}{\sum_{l=1}^{N} m_l(t)}\right] \quad (23)$$

where,
$fit_k(t)$ - Fitness value of the $k^{th}$ agent at time ' .

3.4.4Acceleration

Through the law of gravitational motion, the acceleration of the $k^{th}$agent and $d^{th}$ element direction at time is initiated by subsequent equation,

$$a_k^d(t) = \left[\frac{F_k^d(t)}{M_{kk}^d(t)}\right] \quad (24)$$

where,
$M_{kk}^d(t)$- Inertial mass of the agent K.

Step (5)- Updating Position and Velocity:

Velocity could be simplified with including the current velocity and its acceleration by the relationship between pbest and gbest of its positions using PSO approach. Likewise, the location also updated with its previous location and speed.

$$v_k^d(t+1) = w \times v_k^d(t) + \left(C_1' \times rand_k \times a_k^d(t)\right) + \left(C_2' \times rand_k \times \left(gbest(t) - x_k^d(t)\right)\right) \quad (25)$$

$$x_k^d(t+1) = x_k^d(t) + v_k^d(t+1) \quad (26)$$

where,
$rand_k$ - Random no. between the interval [0-1].

### E. Step (6)- convergence Criterion:

To acquire the most excellent result for the global optima, this algorithm stops it's looking through the best arrangement by greatest cycles given in the issue.Parameters used for the PSS and SVC design problem.

### F. Parameters used for PSS and SVC design

To find an optimal solution using the proposed crossover PSO-GSA algorithm, the following parameters has been used for PSS and SVC, which are given in table.1. Twenty autonomous trials are created with 100 iterations per experiment has been done using MATLAB (MATrixLABoratory) package.

### G. Location of PSS

By the overview, cooperation factor based methodology gives ideal areas of PSS [16] to upgrade the rotor point solidness in a more secure way. The interest factors are figured by utilizing the privilege and left eigenvectors of the system lattice comparing to the predetermined working condition. The little flag investigation of the test system is taken out without interfacing the PSS at the settled working point (Base case). By depending on the support factor speed motion for every one of the swing mode comparing to the generator, PSS is situated on the worry generator whose speed

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cooperation factor is the most elevated an incentive among every one of them. By examining the cooperation factors, the estimation of its extent proposes that positive esteem suggests the relating generator shaft will add damping to the mode [16]. The reproduction is done by an exceptionally arranged bundle called 'PST' made by Roger et al [20] and is given in table 2 and 3.

### H. Boundary limits for controllers: GSA and crossover PSO-GSA

GSA and crossover PSO-GSA is utilized to found the optimum solutions of PSS and SVC parameter. To obtain the optimum functioning of the algorithm, the parameters of both GSA and crossover PSO-GSA are carefully adapted for both the objective functions. The parameters used for Conventional PSS (CPSS) and SVC are 10.00, 0.05, 0.015, 0.08, 0.01 seconds for $K_i, T_1, T_2, T_3$ and $T_4$ respectively for all the four generators 10, 0.65 and 0.2 for $T_R, T_b$ and $T_c$ for the SVC [20]. The wide range of the optimized factors of CPSS are [0.01, 200] for $K_i$[0.001, 2] for $T_1$ to $T_4$,SVC are [0.01, 100] for $T_R$, [0.5, 2] for $T_b$ and [0.1, 0.5] for $T_c$ [20].

### I. Simulation Results

By observing the figure (4-7), clearly defines for each and every phenomenon (like PSS alone, and PSS along with SVC (coordinated)) about its convergence and its aptitude to achieve the global optimum within a minimum iteration. From the designs, crossover PSO-GSA algorithm delivers better convergence, when likened with the closely related GSA for all the stages with two objective functions. Table 4 & 5 display the optimal values of PSS, SVC and coordinated PSS+SVC using GSA and crossover PSO-GSA correspondingly.

Table 6, shows the various system Eigen values & Damping Ratio (DR) of electromechanical mode for three dissimilar combinations of controllers. Unmistakably the system with PSS is affliction from small Damping Factor (DF) and DR for dissimilar loading circumstances. furthermore, the projected crossover PSO-GSA synchronized controller shift significantly the swing mode eigen values to the left half of the S-plane also the values of the DF and DR with the projected controller are notably enhanced. Hence, compared with the GSA coordinated control, the proposed crossover controller significantly improves the PS stability and develops the restraining quality of slack modes.

### J. Large disturbance-fault condition

To examine the response of the system during huge interruption, simulations were conceded for the whole time period of 5s as of a preliminary period 0sec [20]. A 3phase to ground fault at bus 3, on line 3-101 disconnecting the faulted transmission line at 0.1 sec and reclosing the same line after 0.05 sec. Figure 9 demonstrates the alternator rotor speed angle deviation of $G_1$ against $G_2$, $G_3$ and $G_4$ with PSS under faulted condition. From fig. 8, the designed PSS using GSA & Crossover PSO-GSA afford a commendable damping for the system, but the modified PSS with PSO-GSA performs better than GSA. The same fault is further applied to the synchronized (PSS+SVC) controller. The response of the alternator speed angle deviation of $G_1$ against $G_2$, $G_3$ and $G_4$ under the fault is shown in fig. 9. With the new crossover PSO-GSA using proposed objective function, the oscillations are well damped.

## IV. NUMERICAL EXAMPLE - TWO AREA-FOUR MACHINE SYSTEM

This sample system having four generators associated with fourteen tr. lines in among thirteen buses. These Four machines are separated into 2 zones. Area-1 consists of alternator 1 and 2 and Area-2 consists of alternator 3 and 4. These 2 zones are connected with the tie line bus 101 associated with SVC such as looked in figure (3) [20].

## V. CONCLUSION

In this article, crossover PSO-GSA is projected and connected for PSS SVC configuration researches, the ideal fine-tuning of Stabiliser and SVC factors to damp the under frequency oscillation from the multi-machine control system. The viability

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of the projected strategy is tried on the two-area power system during small and transient disturbances. Eigen value examination indicates worthy restraining of system modes, especially the under frequency modes, When the controllers are tuning using crossover PSO-GSA. Simulation result shows that the oscillation of synchronous machines can be quickly damp out from the power system with the modified controller.

## REFERENCES

1. P.Kundur, J.Paserba, V.Ajjarapu, G.Andersson, A.Bose, C.Canizares, N.Hatziargyriou, D.Hill, A.Stankovic, C.Taylor, T.VanCutsem, and V.Vittal, Definition and classification of power system stability IEEE/CIGRE joint task force on stability terms and definitions, IEEE Transaction on Power Systems, vol. 19, no. 2, 2004, pp. 1387–1401.
2. P.Kundur, Power System Stability and Control, McGraw-Hill, Inc., 1993.
3. G.El-Saady, M.Z.El-Sadek and M.Abo-El-saud, Fuzzy adaptive model reference approach based power system static VAR stabilizer, Electric Power Systems Research, No.45, 1998, pp. 1-11.
4. P.Lakshmi and M.Abdullah Khan, Stability enhancement of a multimachine power system using fuzzy logic based power system stabilizer tuned through genetic algorithm, Electric Power and Energy Systems, No.22, 2000, pp. 137–145.
5. K.Ellithy and A.Al-Naamany, A hybrid neuro-fuzzy static var compensator stabilizer for power system damping improvement in the presence of load parameters uncertainity, Electric Power Systems Research, No.56, 2000, pp. 211-223.
6. AhadKazemi and Mahmoud VakilSohrforouzani, Power system damping using fuzzy controlled facts devices, Electric Power and Energy Systems, No.28, 2006, pp.349–357.
7. A.M.El-Zonkoly, A.A.Khalil and N.H.Ahmied, Optimal tuning of lead-lag and the fuzzy logic power system stabilizers using particle swarm optimization, Expert Systems with Applications, No.36, 2009, pp. 2097–2106.
8. N.Hussain, Al-Duwaish and ZakariyaM.Al-Hamouz, A neural network based adaptive sliding mode controller: Application to a power system stabilizer, Energy Conversion and Management, No.52, 2011, pp.1533–1538.
9. Hardiansyah, Seizo Furuya and Juichi Irisawa, A robust power system stabilizer design using reduced order models, Electric Power and Energy Systems, No.28, 2006, pp.21–28.
10. H.Huerta, A.G.Loukianov and J.M.Canedo, Robust multimachine power systems control via higher order sliding modes, Electric Power Systems Research, No.81, 2011, pp.1602–1609.
11. M.A.Abido, Simulated annealing based approach to PSS and FACTS based stabilizer tuning, Electric Power and Energy Systems, No.22, 2000, pp.247–258.
12. M.A.Abido and Y.L.Abdel-Magid, Coordinated design of a PSS and an SVC based controller to enhance power system stability,. Electric Power and Energy Systems, No.25, 2003, pp.695–704.
13. S.M.Abd-Elazim and E.S.Ali, Coordinated design of PSSs and SVC via bacteria foraging optimization algorithm in a multimachine power system, Electric Power and Energy Systems, No.41, 2012, pp.44–53.
14. SeyedAliMirjalili, SitiZaitonMohdHashim and HosseinMoradianSardroudi, Training feedforward neural networks using hybrid particle swarm optimization and gravitational search algorithm, Applied Mathematics and Computation, vol. 218, 2012, pp.11125–11137.
15. S.Mirjalili and S.Z.Mohd. Hashim, A new hybrid PSOGSA algorithm for function optimization, IEEE International Conference on Computer and Information Application, 2010, pp.374-377.
16. M.Klein, G.Rogers, and P.Kundur, A fundamental study of inter-area oscillations in power systems. IEEE Transactions on Power Systems, 6(3), 1991, pp.914– 921.
17. EsmatRashedi, HosseinNezamabadi-pour and SaeidSaryazd, GSA: A Gravitational Search Algorithm, Information Sciences, vol. 179, 2009, pp. 2232–2248.
18. H.Shayeghi, A.Safari and H.A.Shayanfar, PSS and TCSC damping controller coordinated design using PSO in multi-machine power system, Energy Conversion and Management, No.51, 2010, pp.2930–2937.
19. Sidhartha Panda, Robust coordinated design of multiple and multi-type controller using

*January - February 2020*
*ISSN: 0193 - 4120 Page No. 6220 - 6227*

differential evolution algorithm, Electric Power and Energy Systems, No.33, 2011, pp.1018–1030.

20. G.Rogers, Power system oscillations. Massachusetts: Kluwer Academic Publishers; 2000.
21. MahdiyehEslami, HussainShareef, Azaz Mohamed and Mohammad Khajehzadeh, An efficient particle swarm optimization technique with chaotic sequence for optimal tuning and placement of PSS in power systems, Electric Power and Energy Systems, No.43, 2012, pp.1467–1478.