International Journal of Research in Engineering, Science and Management
Volume-2, Issue-9, September-2019
www.ijresm.com | ISSN (Online): 2581-5792

Optimal Design of Power System Stabilizer Using a Gray Wolf Optimization Technique

Vedant Choubey[1], Kapil Parkh[2], Raunak Jangid[3]
[1]*M.Tech. Scholar, Department of Electrical Engineering, Shrinathji Inst. of Tech. & Engg., Nathdwara, India*
[2,3]*Assistant Professor, Dept. of Electrical Engineering, Shrinathji Inst. of Tech. & Engg., Nathdwara, India*

***Abstract*: This paper represents an efficient method for an optimal tuning and placement of power system stabilizer (PSS). For this purpose, gray wolf optimization (GWO) technique is used to enhance the performance of power system. Developed optimization procedure handles the problem specific constraints related to low frequency oscillations in power system and PSS. Performance of proposed PSS tuning method is tested over two area four machine power systems at different fault position and operating conditions. Performance of the proposed GWO technique is also compared to CPSS nonlinear time domain simulation. Here we consider two conditions (2 PSS and 4 PSS) which are tested for three phase fault. We obtain various graph for inter area mode of oscillations, local area speed deviation of generator. We observe the results for various cases finally we find that proposed approach provide best optimal solution of low frequency oscillations in power system.**

***Keywords*: power system stabilizer, gray wolf optimization (GWO), inter area mode of oscillation, local area mode of oscillation, two area four machine system**

1. Introduction

With the increases of daily usage of electricity i.e. the overall demand of electrical power, it is necessary to transfer power at higher level over the transmission lines. This has the effect of disturbance in the stability of power system which demands for the up gradation of the whole power system. But as it is well known that now a days to have the permission to establish new transmission line is quite difficult. It incurs a lot of cost and time too. And other factors like environmental effects have to be considered too. This has led to take a closer look and analysis the power system so as to maintain its stability within the margin while maintain its security. Previously, keeping the power system away from its stability limits ensure the better dynamic control over the whole system. Other studies were also carried out in the area so as to address the problem stability [1].

There are namely these types of stability in power system, large and small signal. Large signal stability is also known as transient stability. In case of small signal stability when there is no proper damping it occurs. While when power system encounters the serious transient disturbance like short circuit or the tripping of line it is the case of large signal stability. Starting Operating state and severity of disturbances influences the stability. The configuration of the system is so set in order to be in the stable state following set of chosen contingencies. Power system stability problem can be a concerning issue due to its insufficiency of damping such oscillations. Therefore, generator excitation system is provided with conventional lead lag power system stabilizer (CPSS) [2].

It damps out these low frequency oscillations by introducing a damping torque into generator rotor torque oscillations. It is derived from its speed, power or frequency. There have been many researches on PSS design and methods to tune its parameters. Some of the optimization techniques are Genetic Algorithm (GA), Particle Swarm Optimization (PSO), Fuzzy logic and Teacher learner based optimization (TLBO) etc. Ability of system to maintain stability under small disturbances is known as small signal stability.

These small disturbances are due to small variation in generation and load. Electromechanical oscillations between interconnected synchronous generators are phenomena inherent to power systems [3]. In this paper the optimal design of PSS and placement is applied two area four machine system and system is tested with 2 PSS and 4 PSS. Optimal design and placement done by Gray Wolf Optimization (GWO) algorithm.

2. System model

A. Two area four machine system

Fig. 1 show two area four machine system and system is divided by two areas. Each area contains two generators. The system having fundamental frequency of 60Hz and each area consists of two generators each having a rating of 900MVA and 20KV.GWO algorithm is use to applied optimal design and placement of PSS. In this case all generators are equipped with PSS [4].

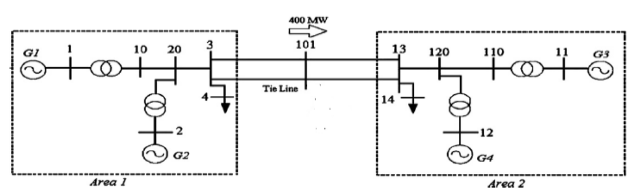

Fig. 1. Single line diagram of of Kundur's Two-Area System [5]

B. Structure of PSS

The major objective of providing PSS is to increase the power transfer in the network, which would otherwise limited by oscillatory instability. The PSS must also function properly, when the system is subjected towards large disturbances. Due to high gain and fast response excitation system gives good transient stability. The frequencies of the oscillations lies in the range of (0.2 to 2) Hz which are very low. This kind of excitation as mentioned above with fast AVR adds to the instable nature of power system. And this instable nature is accompanied by low frequencies oscillation as just mentioned which can remains there or continue to grow in magnitude. Hence, there is need of damping the instable nature i.e. low frequency oscillations efficiently. Here comes for rescue PSS which provides damping to the oscillations of rotor of the generator via controlling its excitation using auxiliary stabilizing signal. It acts as a supplementary controller in the system of excitation. Below is the basic block diagram of PSS [6].

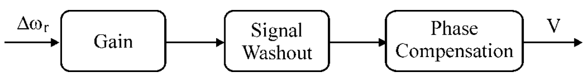

Fig. 2. Structure of PSS

It has three blocks: Gain, Signal Washout and Phase Compensation. Its input is change in speed and output is voltage which is input to AVR [7].

- *Washout Block:* The washout circuit is provided to eliminate steady-state bias in the output of PSS which will modify the generator terminal voltage.
- *Phase Compensation Block:* It provides the appropriate phase-lead characteristic to compensate for the phase lag between the exciter input and the generator electrical (air gap) torque.
- *Gain Block:* The stabilizer gain KSTAB determines the amount of damping introduced by the PSS. Gain is set to a value which results in satisfactory damping of the critical system mode(s) without compromising the stability of other modes, or transient stability, and which does not cause excessive amplification of stabilizer input signal noise [8].

C. Objective Function

For multi machine power system:

$$J=\int_{t=0}^{t=tsim}\left(\sum \Delta|w_L| + \sum \Delta|w_i|\right).t.dt \tag{1}$$

Where, t_{sim}=simulation time range

For a stipulated period of time, the time domain simulation of the above power system is worked out and from the simulation the calculation for the objective function is calculated. The prescribed range of the PSS and damping controller are limited in a boundary. Thus the following optimization problem is formulated from the above design approach [9].

Minimize J

$$\text{Subject to} \begin{cases} K_i^{min} \le Ki \le K_i^{max} \\ T_{1i}^{min} \le T_{1i} \le T_{1i}^{max} \\ T_{2i}^{min} \le T_{2li} \le T_{2i}^{max} \\ T_{3i}^{min} \le T_{3i} \le T_{3i}^{max} \\ T_{4i}^{min} \le T_{4i} \le T_{4i}^{max} \end{cases} \tag{2}$$

Where $K_i^{min}$the lower bound of the gain is K_i^{max} is the upper bounds of the gain for the controllers (PSS and damping controller). T_{ji}^{min} is the lower bound of the time constants; T_{ji}^{max} are the upper bounds of the time constants for the controllers (PSS and damping controller).

3. Placement of PSS using Grey Wolf Optimization Technique

Using GWO it is very easy to tune PSS for multi machine power system where first part of multi objective function is used to maximize the minimum damping ratios (ζ_{min}), subjected with all possible combinations of PSS placements. For every placement index minimum value of damping ratios will be evaluated using GWO and saved in array. Placement associated with maximum value of ζ_{min} that is greater than ζ_0 is best placement of PSS [9].

A. Introduction of GWO

This optimization technique is given by Mirjalili. It imitates the grey wolf hierarchy leadership as they are known for group hunting [11]. It is among the newest set of meta-heuristic optimization algorithms. It was developed for solving the double layer grids problem which takes into account the non-linearity. Its results are superior to the other algorithms in set. For the first time to learn Multi-Layer Perception (MLP) it was used.

With reference to the above statement these wolfs live pack and are basically from Canidae family. As these, live in pack they have a leader who is Alpha indicating their strict social dominant hierarchy. As Alpha is the leader, most of the decision for group is taken by him. And, hence his decision should be followed by other members of the pack. The common decision involves sleeping place, hunting, waking time etc. The Alpha may not be the strongest member of the pack but the best to manage the whole group. This implies that the discipline and organization in the pack is considered prior to the strength.

The pack has subordinates too. These are Betas helping Alpha in the process of making a decision. It means they are advisor. Also, they maintain the discipline in pack. These are also the next in line to become Alpha if the present Alpha passes away or has become old. It obeys the Alpha and gives command to other wolfs. Beta also provides feedback to the Alpha.

Wolfs which are at the lowest rank are Omega, which follows all other dominant wolfs. These play the role of scapegoat. They are the last to eat in pack. Omega may be considered least to give any significance but if the pack looses them it may cause an internal fighting. It is because of absence of all frustration and violence of all wolfs by Omegas. It helps in maintaining the dominance structure in the pack as well as satisfaction among them. In many cases, Omega also plays the role of babysitter.

If wolf doesn't belong to any rank then they comes under Delta wolfs which are above Omega wolfs and it means these follows other two ranks in the pack. Wolf falls under this category are Hunters, elders, sentinels, caretakers and scouts. Keeping watch on pack territory and alerting for danger is the responsibilities of Scouts. The duty of guard and providing protection to the pack is done by Sentinels. Elder wolfs are the one who once were Alpha or Beta in their life time and most experienced ones. Hunters Assists Alpha and Beta while hunting and arranging food for the pack. As the name suggest caretakers wolfs take care of wolfs which are weak or ill or wounded in the pack. Fig. 3 shows flow chart of GWO algorithm.

Group hunting is among the many features of their social environment. The main phases in hunting are [11],

- Tracking the prey, then chasing them and at last approaching them.
- The act of pursuing, encircling and harassing of prey until it stop moving.
- Last is attack on prey.

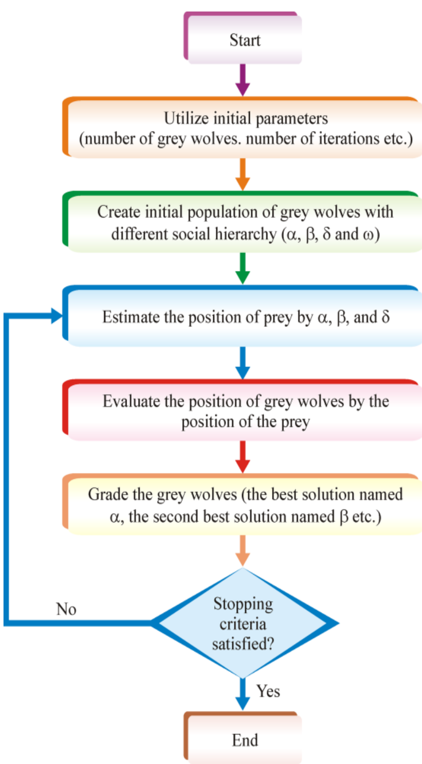

Fig. 3. Flow Chart of GWO Algorithm [11]

4. Result analysis and discussion

In this section the results of the developed simulation model under different contingencies are presented and discussed and carried out is multi machine power system two area four machine systems. The developed model is simulated without control and with CPSSs & with GWOPSS controller. The responses without and with controller are accessed to test effectiveness and toughness of the CPSS and GWOPSS controller damping controller and its concert for a wide range of operating conditions for three phase faults.

System is tested with two conditions as two PSS & four PSS. We obtain various graph as inter area mode of oscillation, local area mode of oscillation, speed deviation of generator G1, G2, G3, G4 at three phase fault.

A. MATLAB/SIMULINK Implementation of two area four machine system

Fig. 4 represents the MATLAB/SIMULINK model of Multi-Machine (two area four machine system) system incorporated with GWOPSS controller and apply 3 phase fault disturbance between bus 3,4 &13, 14. The system divided by two area as area-1 & area-2. The system tested with optimal placement of two PSS & four PSS. PSS placement is done by Roger's method. System design with optimal placement of two PSS with generators G2 & G3 & also four PSS optimal placement with generators G1, G2, G3 & G4. The various parameters of PSS shows in table1. Fig.5 shows the graph between best cost v/s iteration of GWO.

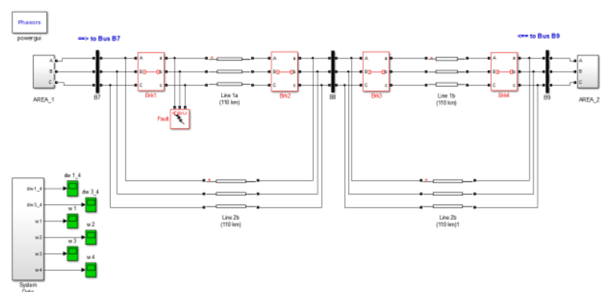

Fig. 4. MATLAB/SIMULINK implementation of the two area four machine system

Table 1
Optimal PSSs Parameters using GWO

S. No.	Parameters	GWOPSS ITAE=0.00005869			
		G_1	G_2	G_3	G_4
1	K_{PSS}	37.5870	35.265	68.7228	82.0414
2	T_1	0.0537	0.0497	0.0669	0.0518
3	T_2	0.0324	0.0212	0.0293	0.0244
4	T_3	3.6963	3.569	2.2303	3.4792
5	T_4	5.6933	6.214	5.6745	5.1969

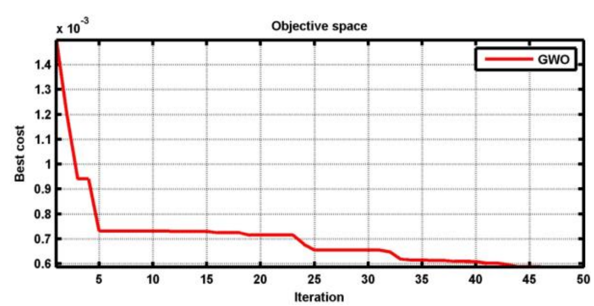

Fig. 5. Convergence of Objective Function for Best Cost in MMPS System

B. Non-linear time domain simulation

To assess the system performance, we apply three phase fault disturbance at bus 3. The faults keep up for 1 second. The various graphs are shows of speed deviation of generator (G1, G2, G3 & G4), inter area & local area mode of oscillation. The different performance is defined as no control, with CPSSs & GWOPSSs shown by blue, red, black line. Finally, we found GWOPSSs shows superior response than other. The system is use objective function of integral of the time multiplied absolute value of the Error (ITAE). The system is tested with two conditions as two PSS and Four PSS. The system performance tested as case-2 single line between 3 and 101 out of service. Fig. 10 to 17 shows various speed deviation response of generator G1, G2, G3 & G4. Another graph is inter-area mode of oscillation and local area mode of oscillation. In this condition GWOPSS technique is use to PSS design and find out the best placement of PSS in a 2 Area 4 Machine system. The proposed system is tested with three phase fault conditions. The proposed system easily damp out oscillation & improve the stability of multi-machine system. Proposed GWOPSS shows higher convergence rate & higher degree of accuracy than no control & conventional power system stabilizer. Finally proposed system successfully achieved the optimal placement of PSS and optimal tuning of PSS parameters. Table 2 comparison with settling time at two PSS and 4 PSS condition.

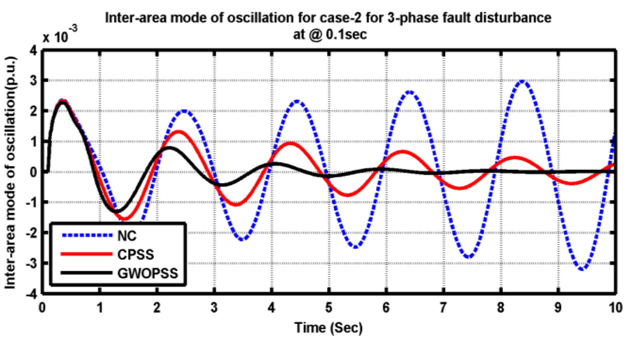

Fig. 6. Inter-Area Mode of Oscillation for Three Phase Fault Disturbance at Four PSS

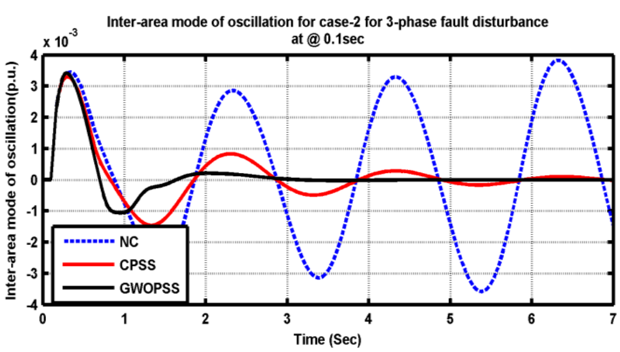

Fig. 7. Inter-Area Mode of Oscillation for Three Phase Fault Disturbance at Two PSS

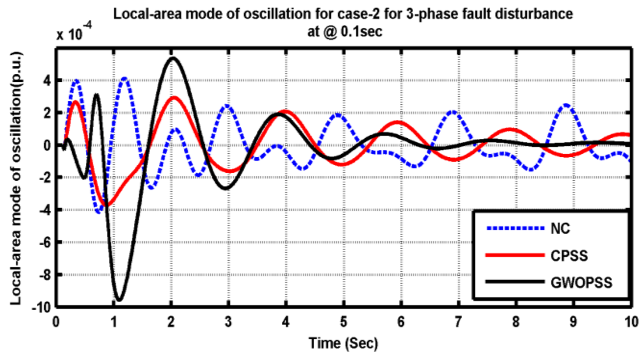

Fig. 8. Local-Area Mode of Oscillation for Three Phase Fault Disturbance at Four PSS

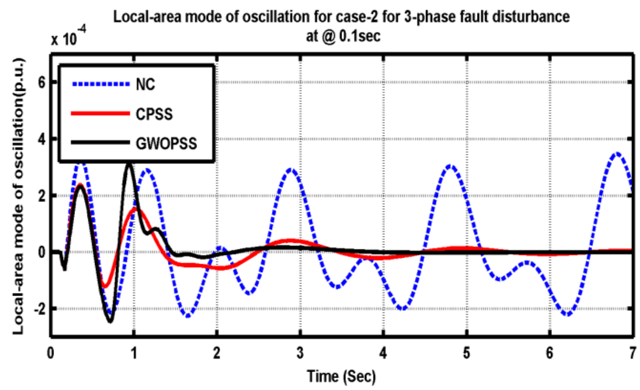

Fig. 9. Local-Area Mode of Oscillation for Three Phase Fault Disturbance at Two PSS

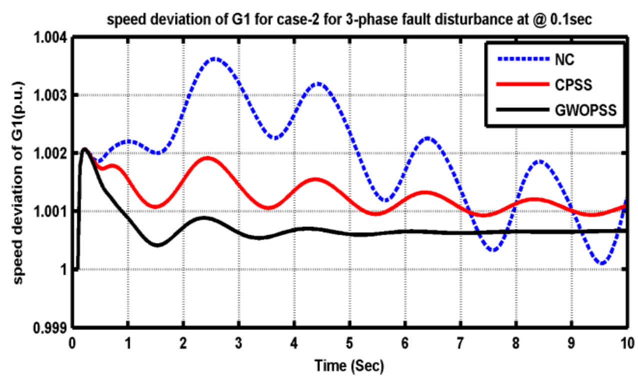

Fig. 10. Speed Deviation of Generator G1 for Three Phase Fault Disturbance at Four PSS

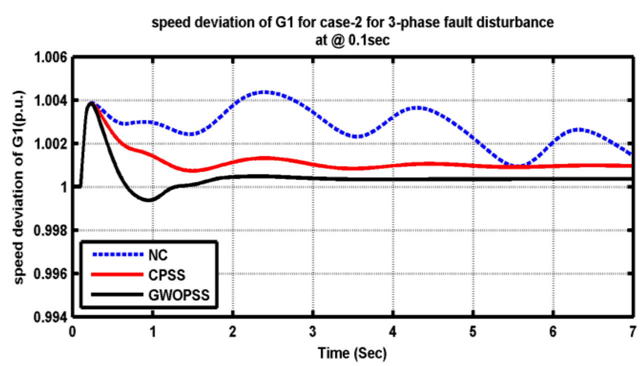

Fig. 11. Speed Deviation of Generator G1 for Three Phase Fault Disturbance at Two PSS

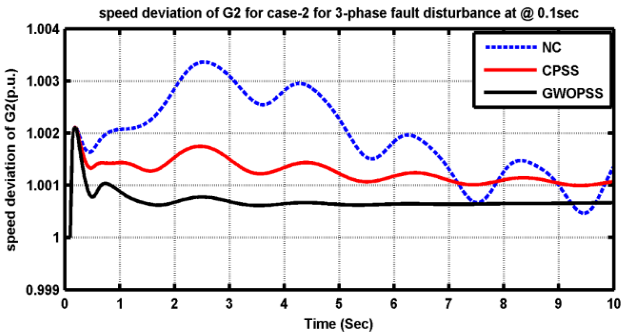

Fig. 12. Speed Deviation of Generator G2 for three Phase Fault Disturbance at Four PSS

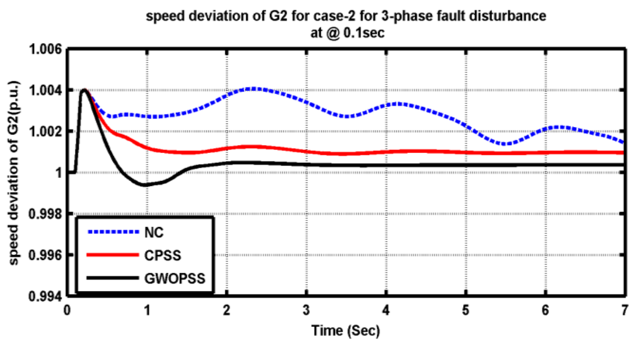

Fig. 13. Speed Deviation of Generator G2 for Three Phase Fault Disturbance at Two PSS

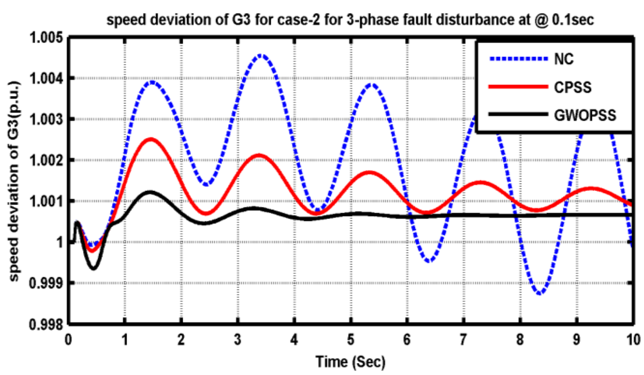

Fig. 14. Speed Deviation of Generator G3 for Three Phase Fault Disturbance at Four PSS

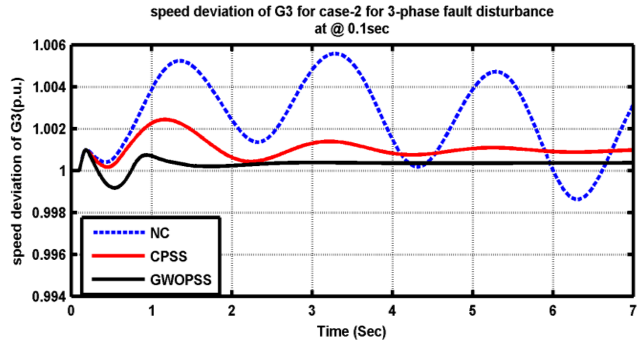

Fig. 15. Speed Deviation of Generator G3 for Three Phase Fault Disturbance at Two PSS

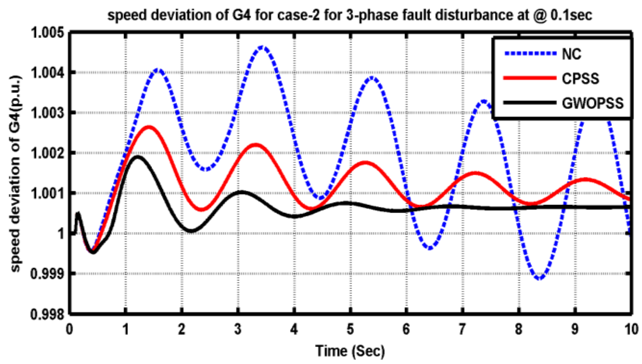

Fig. 16. Speed Deviation of Generator G4 for Three Phase Fault Disturbance at Four PSS

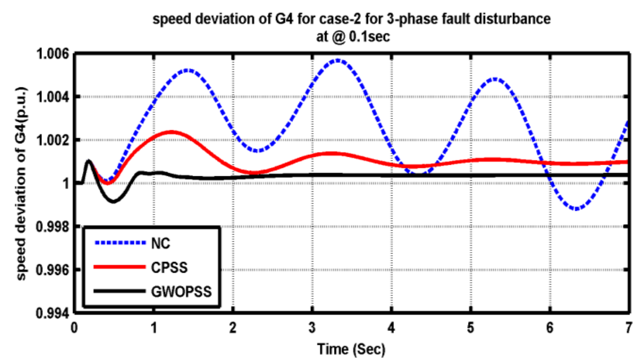

Fig. 17. Speed Deviation of Generator G4 for Three Phase Fault Disturbance at Two PSS

Table 2
Two Area Four Machine System at 2 PSS & 4 PSS Conditions

S. No.	Generator Speed Deviation	Without Controller (Settling Time) Seconds	With CPSS Controller (Settling Time) Seconds	With Coordinated (GWO PSS) Tuned 2 PSS (Settling Time) Seconds	With Coordinated (GWO PSS) Tuned 4 PSS (Settling Time) Seconds
1	Inter-Area Mode of Oscillation	Highly Oscillatory	9.9451	6.9656	2.7738
2	Local-Area Mode of Oscillation	Highly Oscillatory	9.6234	7.7011	3.5285
3	Speed deviation G_1	Highly Oscillatory	9.9249	7.4376	2.6970
4	Speed deviation G_2	Highly Oscillatory	9.8644	7.2515	2.5500
5	Speed deviation G_3	Highly Oscillatory	9.9419	6.5499	2.5177
6	Speed deviation G_4	Highly Oscillatory	9.9260	8.0829	2.6270

5. Conclusion

Finally, main propose of system is improve the stability of the system and table tabulated with different controller with different settling time. Finally, we got superior response when apply GWOPSS controller and two types method as two PSS & 4 PSS. We got optimal placement of PSS. So system is tested with 4 PSS system shows superior response and settling time. So minimum number of 2 PSS is required but we increase number of PSS and their optimal tuning then system response completely improves. The GWOPSS shows superior response and increase stability of system.

References

[1] P. Kundur P, N. J. Balu and M. G. Lauby, "Power System Stability and Control," McGraw- Hill, New York, 1994.

[2] Monika, Balwinder Singh, Rintu Khanna, "Power System Stability and Optimization Techniques: An Overview", in *International Journal of Engineering Research and Applications, National Conference on Advances in Engineering and Technology (AET)*, 29th March 2014.

[3] Mahdiyeh Eslami, Hussain Shareef and Mohammad Khajehzadeh, "Optimal Design of Damping Controllers Using a New Hybrid Artificial Bee Colony Algorithm", *Electrical Power and Energy Systems*, vol. 52, pp.42–54, 2013.

[4] P. M. Anderson, and A. A. Fouad, "Power System Control and Stability," 2nd ed., Piscataway, N. J., Wiley-Interscience, 2003.

[5] Abedinia, Mohammad S. Naderi, A. Jalili and B. Khamenehpour ,"Optimal Tuning of Multi-Machine Power System Stabilizer Parameters Using Genetic-Algorithm," in *International Conference on Power System Technology*, 2010.

[6] Mahdiyeh Eslami, Hussain Shareef, Azah Mohamed and Mohammad Khajehzadeh, "An Efficient Particle Swarm Optimization Technique with Chaotic Sequence for Optimal Tuning and Placement of PSS in Power Systems," in *Electrical Power and Energy Systems*, vol. 43, pp. 1467–1478, 2012.

[7] M. Eslami and H. Shareef, "Artificial bee colony algorithm for optimal design of power system stabilizer," in *2012 10th International Power & Energy Conference (IPEC)*, Ho Chi Minh City, 2012, pp. 1-6.

[8] F. A. Dolat-Khahi, E. Roshandel and H. Davazdah-Emami, "Inter-area power oscillation control in a multi-machine power system by coordinating the PSS and UPFC operation," *2017 IEEE 4th International Conference on Knowledge-Based Engineering and Innovation (KBEI)*, Tehran, 2017, pp. 0866-0871.

[9] Eslami, Mahdiyeh, et al., "An efficient particle swarm optimization technique with chaotic sequence for optimal tuning and placement of PSS in power systems," in *International Journal of Electrical Power & Energy Systems*, vol. 43, no. 1, pp. 1467-1478, 2012.

[10] D. Chitara, K. R. Niazi, A. Swarnkar and N. Gupta, "Cuckoo Search Optimization Algorithm for Designing of a Multimachine Power System Stabilizer," in *IEEE Transactions on Industry Applications*, vol. 54, no. 4, pp. 3056-3065, July-Aug. 2018.

[11] Seyedali Mirjalili, Seyed Mohammad Mirjalili, Andrew Lewisr, "Grey Wolf Optimizer", in *Advances in Engineering Software*, vol. 69, pp. 46–61, 2014.