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Improvement of Dynamic Stability via Coordinated Design of PSS and UPFC in a Two Machine Power System Employing Cuckoo Search Optimization Technique

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Abstract*: Sustained electromechanical oscillations pose a major challenge to the stability of large power systems. To overcome this problem, nowadays power systems are equipped with power system stabilizers (PSS). They play a vital role in increasing damping and minimizing power system instabilities. However using only PSS to reduce oscillations during faulted conditions may not be sufficient enough to maintain stability. To handle large amount of power, power electronics based Flexible AC Transmission System (FACTS) devices are being extensively used. Synchronized use of PSS along with Unified Power Controller (UPFC) can result in further improvement in reliability, controllability and mitigation of power system oscillations thus further improving the system stability. In order to enhance the system stability to a greater extent, the PID controller parameters of the PSS are dynamically tuned through a unique and robust optimization technique called Cuckoo Search (CS). So this paper primarily aims to design a unique methodology to decide the most suitable PID controller specifications using the evolutionary Cuckoo Search algorithm technique for transient stability enhancement of a two machine power system, through coordinated design of PSS and UPFC. The transient stability of the system with the proposed CS technique based PID is compared and contrasted with the conventional PID under various faulted conditions. To justify and validate the enhancement achieved by the proposed technique, the two machine system is designed using the MATLAB/Simulink environment.

Index Terms*: Cuckoo Search (CS), PID, Unified Power Controller (UPFC), stability, power system stabilizer (PSS), oscillations, optimization, Flexible AC Transmission System (FACTS).

I. INTRODUCTION

Nowadays, due to an exponential increase in the demand of electricity, complexity of power grids and limitations on building new transmission lines, power system disturbances are likely to happen.

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An ideal power system comprises of synchronous machines (generators), transformers, loads and transmission lines. Power system disturbances often lead to electromechanical oscillations [1].

As a consequence the variables of the system are under threat as they begin swinging. These oscillations can reduce power transfer capabilities and cause systems to collapse completely.

Thus to obtain constancy in power system variables and better operational performance power system stability is highly essential.

In power system the term 'stability' means the capability of a system to come back to its initial state after being subjected to a fault in the system [2]. Non-linear power systems have oscillations that are mostly caused due to reduced frequencies within the range of 0.2 to 3 Hz [3]. For mitigation of these oscillations, an economical and suitable answer to the problem is the introduction of PSS as an additional controller in the excitation system that increases the damping torque for generator rotor oscillations [4].

However the use of PSS alone is not sufficient enough to overcome non linearities in power system and the increase in loading of transmission lines over very long distances. The incorporation of PSS along with FACTS devices further enhances the system stability to a greater extent by increasing the flexibility in power transfer capability and compensating the reactive power. In addition the FACTS devices offer very rapid response, respond to regular variations in output without affecting thermal limits and stability [5]. There are many FACTS devices such as Thyristor Controlled Series Capacitor (TCSC), Static VAR Compensator (SVC), Static Synchronous Compensator (STATCOM), Static Synchronous Series Compensator (SSSC), Uniform Power Flow Controller (UPFC) etc. However UPFC as a FACTS device has the following advantages over others:

1).It is the most multi-purposed, powerful and flexible device as compared to other FACTS devices; 2). It plays a significant role by simultaneously controlling the basic power system parameters like phase angle, impedance and transmission voltage; 3)It is effective in maintaining not just transient stability but also steady state and dynamic stability.

From the literature survey it can be found that, due to certain operating conditions and non-linearity in the system lack of coordination arises between PSS and UPFC.

To combat this problem, dynamic tuning of PID parameters of PSS is necessary for its appropriate working in various range of operating conditions to improve the system performance. This could be done through many robust optimization techniques available in literature like Particle Swarm Optimization (PSO), Differential Evolution (DE), Genetic Algorithm (GA), Simulated Annealing (SA), Cuckoo Search (CS) etc.

Cuckoo Search (CS) is one such meta-heuristic novel algorithm inspired from nature based on the reproductive strategy taken up by cuckoo birds to increase their population. It can be used extensively to efficiently solve very complex global optimization problems [6]. Other optimization techniques like PSO, DE and Simulated Annealing are just special cases of CS [7]. CS outperforms all these algorithms in terms of simplicity, ease of implementation, speed of convergence to attain optimal solution and does very efficient computation [8]. CS has an added benefit of being able to deal with multi- criteria problems of optimization. It can effectively be hybridized with various swarm based techniques. Hence CS technique has been used effectively to dynamically tune the PID parameters for minimizing the fluctuations in power system parameters. The entire paper is organized in the following way. Section 2 provides an elaborate description about every part of the system configuration undertaken for study. In Section 3 the conventional and the proposed control approaches are discussed. MATLAB simulation model and results are presented, discussed and the conventional PID based PSS results are compared and contrasted with CS technique tuned PID based PSS in section 4. Finally in section 5 the conclusion from the entire study is drawn.

II. MODELLING OF SYSTEM CONFIGURATION

In order to depict the significance and robustness of PSS along with UPFC in effectively damping oscillations, a simplified two synchronous machine power system is designed as shown in Fig.1. The system consists of two identical generators, Gen1 and Gen2, having identical governor and turbine specifications along with an excitation system equipped with PSS and Automatic Voltage Regulator (AVR). The model contains two power transformers, busbars and a purely resistive load of 5000 MW. The UPFC based FACTS device consisting of series and shunt voltage source converters is placed between Gen1 and Gen2. The System performance is examined after it is subjected to two types of faults i.e. change in line impedance and single phase triple L-G fault.

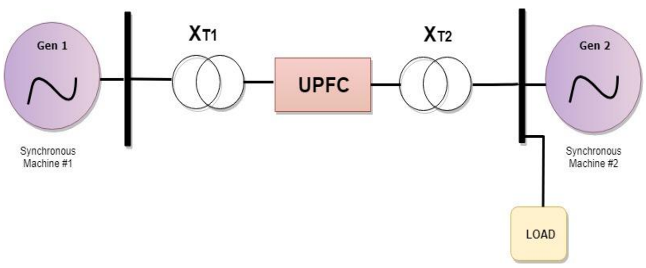


Fig. 1: Modelling of two synchronous machine power system with PSS and UPFC

A. Power System Stabiliser

In large power systems certain internal and external disturbances can cause electromechanical oscillations. These oscillations normally occur within the small range of 0.2-3 Hz. These oscillations can cause variations in power levels, voltage and current levels as well as frequency and can drastically limit the power transfer capability. In critical cases they can cause blackouts. As a result these swings in power system need to be removed not only for exact estimation of power system parameters and better system security but also for improvement of dynamic and transient stability. PSS plays an important role of extending stability of the system. This is achieved by supplying additional damping to the swinging of synchronous machine rotors through the excitation of synchronous generators [9]. The electric torque is provided to the rotor that is in phase with the speed variations to create damping [10]. The input for PSS is taken from either electrical power, frequency, rotor velocity or a blend of whereas, output is stabilized voltage (Vstab). The generic model of PSS takes the acceleration power Pa as input, which is the difference between synchronous generator's rotor active power (Pe) and turbine mechanical power (Pm) as given in equation(1):

$$P_a = P_m - P_e \tag{1}$$

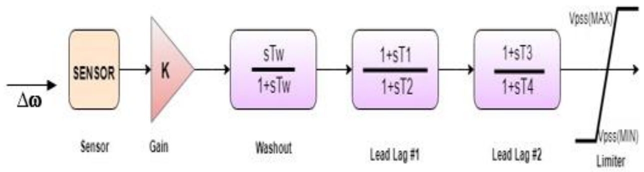


Fig. 2: Modelling of two synchronous machine power system with PSS and UPFC

Fig.2 depicts the block diagram of generic PSS where Tw is the time constant of the washout filter. T1, T2, T3 and T4 are the time constant of the lead-lag blocks so that the input signal has a phase leading in nature. It comprises of the following: 1) sensor block which is actually a low pass filter which allows only smaller magnitude frequencies to pass; 2) washout block used as high pass filter to control over damping conditions; 3) lead lag blocks so as to make the input signal phase to be leading in nature; 4) a gain K which is proportional to damping provided by PSS and 5) limiter to enhance the terminal voltage which gets reduced drastically by AVR under certain faulted conditions.

B. Unified Power Flow Controller

In the near past, due to the exponential increase in electrical energy, a large conflict over power transmission has arisen [11]. The use of FACTS devices in power system has helped a lot in overcoming this issue. In the recent years, the flexibility and effectiveness of FACTS devices in stabilizing of power systems have increased exponentially. Today FACTS devices have become a necessity in every large power system. The FACTS devices operate electrically as rapid impedance, voltage or current controllers [12].

UPFC device is a multi-variable FACTS controller used extensively in power systems to reduce harmonics and hence, improve power system operation. Fig. demonstrates the single line diagram of UPFC which consists of two voltage source converters coupled through a common DC link capacitor [13]. It is a combination of two FACTS controller used as voltage source converters i.e. static synchronous compensator (STATCOM) and synchronous series compensator (SSSC). SSSC introduces a voltage of convenient magnitude (Vse) and phase angle in series with the transmission line through a transformer connected in series, thus controlling the total power flow [14]. STATCOM introduces an alternate current (Ish) of variable level at the connected point. The dc link plays an important role in providing a path for injection of real power into the system by the series branch which is in turn taken from the parallel branch of UPFC.

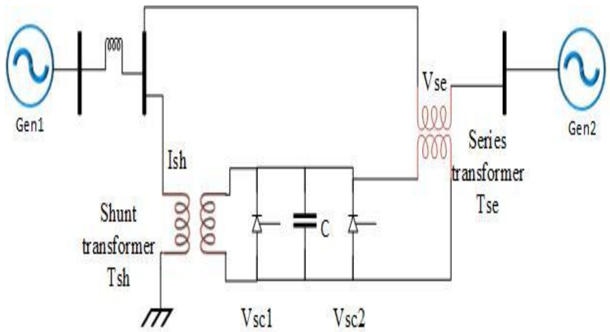


Fig. 3: Single line diagram of UPFC

$$Vs = Ve^{j\frac{\delta}{2}} \tag{2}$$

$$Vr = Ve^{j\frac{\delta}{2}} \tag{3}$$

$$P - jQr = \frac{Vs - Vse - Vr}{jX} \tag{4}$$

$$P(\delta, \text{þ}) = Po(\delta) + Pse(\text{þ}) \tag{5}$$

$$P(\delta, \text{þ}) = \frac{V^2}{X} sin\delta - \frac{VVse}{X}(cos\frac{\delta}{2} + \text{þ}) \tag{6}$$

$$Q(\delta, \text{þ}) = Qo(\delta) + Qse(\text{þ}) \tag{7}$$

$$Q(\delta, \text{þ}) = \frac{V^2}{X}(1 - cos\delta) - \frac{VVse}{X}(sin\frac{\delta}{2} + \text{þ}) \tag{8}$$

Where Øs and Vs are the phase angle and the voltage of sending end respectively, Ør and Vr are the phase angle and voltage of the receiving end respectively, Vse, P and Q represent the voltage, total active power and total reactive power respectively and δ is the power angle.

III. Control Approach For The Two Machine System

A. Conventional PID Controller

PID controller is characterized by the proportional, integral and derivative modes of control. It has a feedback system to minimize error. An overall control of system is achieved by proportional parameter, kp which also increases the rise time. The distinguishing feature of PID controller is its impeccable ability to employ three different control parameters simultaneously to get a perfect control signal [15]. The integral parameter, ki significantly reduces the steady state error and derivative parameter, kd reduces settling time and peak overshoot. Transfer function of PID controller can be mentioned as:

$$u = kpe + ki \int_0^t edt + kd\ d/dt \tag{5}$$

Where kp, ki and kd are the coefficients for the proportional, integral and derivative terms of PID representation and are always positive. Fig 4 shows the block diagram of conventional PID controller.

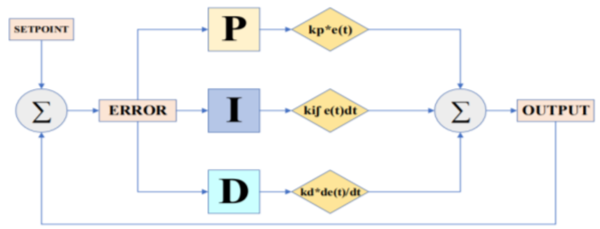


Fig. 4: Block diagram of conventional PID controller

B. Cuckoo Search Algorithm

Optimization techniques are widely used to solve various complex engineering problems. The main aim of these techniques is to maximise or minimize the main parameters of any optimization problem which is called the objective function, in order to achieve the best design relative to certain constraints. The successful use of these algorithms could be beneficial in increasing efficiency, reliability, strength and productivity of a system. Nature itself has motivated the bright idea of some of the great optimization techniques. Cuckoo Search (CS) is one such novel nature inspired optimization algorithm which is related to unique breeding behaviour of the cuckoo birds in locating nests and laying their eggs. The parasitic cuckoos often don't lay the eggs that are fertilised in their own nests, rather in other cuckoo's nest so that their babies can be raised by surrogate parents [16]. They are very precise with time and cleverly put their eggs in host's nest which will normally hatch earlier than the host's eggs. Once the foreign egg has hatched, the parasitic cuckoos deliberately remove other host's eggs from hatching to reduce competition [17]. But sometimes the host cuckoo might catch hold of the foreign egg. If they discover it, then they might either thrust aside and get rid of the egg or discard the nest at once and fly away to create a fresh nest once again at some other place. In a nutshell the CS algorithm is governed by 3 basic rules which is as follows:

1. Random selection of nest by cuckoo bird for laying a fertilised egg in it.

2. Random selection of a group of bird's nests and the carrying of best quality nests with high class eggs to successive generation.
3. Fixing the number of bird's nests to n and denoting the probability of a foreign egg to be discovered by a cuckoo host by p_a.

$$p_a \in [0,1] \tag{10}$$

Fig. 5 illustrates the flow diagram of Cuckoo Search Technique. The fitness of the optimal solution represents the best value of objective function. Metaphorically each egg of the nest corresponds to a solution and it is assumed that one cuckoo can lay only a single egg. The main strategy is replacement of bad solution in the nest with a potentially more effective solution [18]. As CS maintains stability between global and local random walk, it is very efficient for global optimization problems [17].The global and local random walks are defined as follows:

$$y_i^{t+1} = y_i^t + \dot{\alpha} s_t \otimes Hs(p_a - \epsilon) \otimes (y_j^t - y_k^t) \tag{11}$$
$$y_i^{t+1} = y_i^t + \dot{\alpha} L(s_t, \lambda) \tag{12}$$

Here y_i^{t+1} and y_i^t represent the nest i at time t and t+1, $\dot{\alpha}$ is the scaling factor of positive step size, s_t is the step size, $\otimes$ represents point to point multiplication, ϵ random number from uniform distribution, p_a is the switching parameter between local and global walks, Hs denotes the heavy side function and $L(s_t, \lambda)$ represents the Lévy distribution defining the random walk step size [18] . Lévy distribution are used to derive Lévy flights which are random walks that are more effective than normal walks and more capable in discovering large scale search areas. The number of iteration steps can be reduced by use of Lévy flights.

The objective function is f(y) where y represents the initial population which is defined as:

$$y = (y_1, y_2, y_3, y_d)^T \tag{13}$$

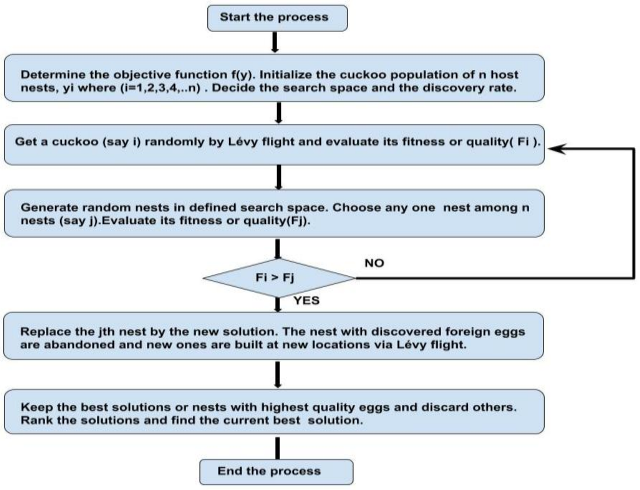


Fig. 5: Flow diagram of Cuckoo Search Technique

C. Application of Cuckoo Search in tuning of PID control parameters of PSS

As we know an optimization technique generally plays an essential role for minimization or maximization of certain parameters for the system to attain operational excellence. It can either be used to enhance the terminal voltage and active power or to reduce the variation in speed or losses occurring in a system depending on the designed objective function. In this paper the speed deviation of the rotor of the generator Δw, is considered as the objective function of the CS technique. Its performance is determined using Integral of Time weighted Absolute Errror (ITAE), which integrates the product of time and absolute error over time. ITAE control measure for tuning criterion of PID is used because of its ability in producing systems which settle quite quickly as compared to other methods [19]. The closed loop response in case of ITAE is very less oscillatory in nature [20].The general form of ITAE is given as follows:

$$\mathrm{ITAE} = \int_0^t t\,|e_t(t)|\,dt \tag{14}$$

Where,

$$e_t(t) = \Delta w = w(k) - w(k-1 \tag{15}$$

Here Δw is the change in speed deviation which is taken as an error to be minimized. In other words it is the magnitude of the variation of controlled variable from set point, w(k) is the speed deviation in present iteration and w(k-1) is the speed deviation in last iteration [28]. Using the novel CS algorithm, we can easily determine the optimal dynamic values of kp, ki and kd for maintaining better system stability.Here Δw is the change in speed deviation which is taken as an error to be minimized. In other words it is the magnitude of the variation of controlled variable from set point, w(k) is the speed deviation in present iteration and w(k-1) is the speed deviation in last iteration [28]. Using the novel CS algorithm, we can easily determine the optimal dynamic values of kp, ki and kd for maintaining better system stability.

IV. Matlab Simulation Model and Result Analysis

The Fig. 6 shows the MATLAB/Simulink model of a two machine system with coordinated use of PSS and UPFC. UPFC is placed in the middle of the transmission line. The PID control parameters are dynamically tuned through the CS Algorithm. The system is subjected to some external disturbances like single phase LLL-G fault and variations in line impedance to prove the effectiveness of CS based PID over conventional PID. The fault originates at 1 seconds and is removed at 1.2 seconds. In contrast to conventional PID, the CS based PID gives more stable results for closed loop characteristics like rise time, peak overshoot settling time etc. The detailed components, their parameters and the values of the system configuration under study is given in the Table1.

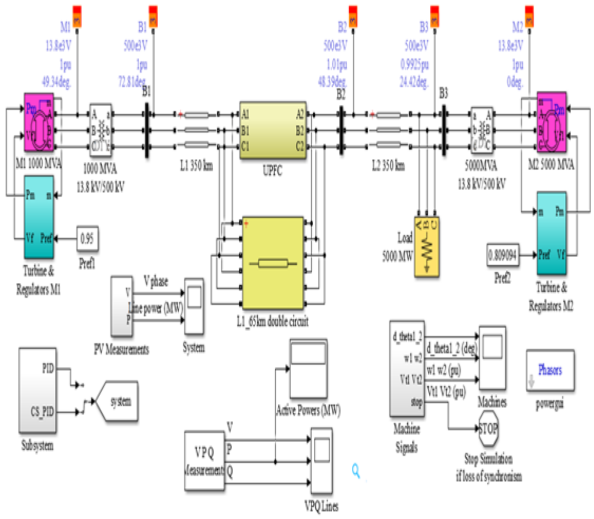
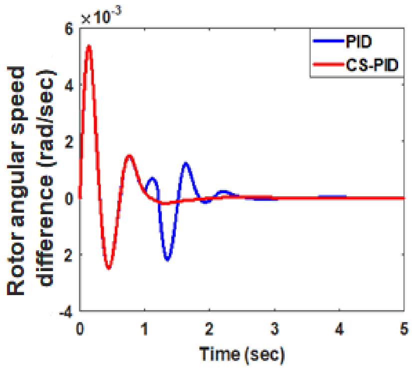
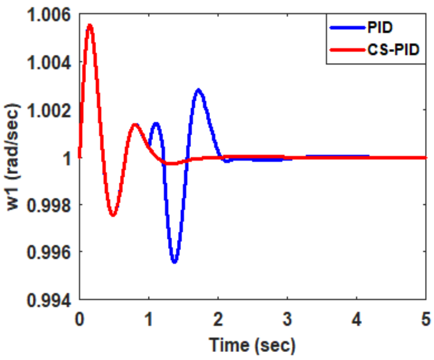


Fig.6: Simulink model of a two machine system with coordinated use of PSS and UPFC

Case 1: Single phase LLL-G fault





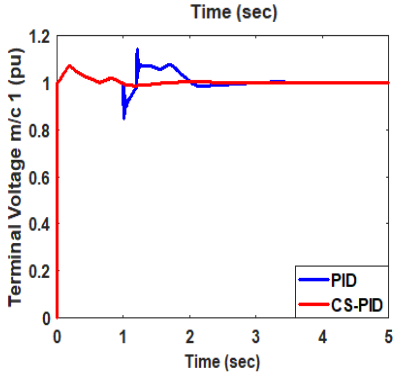
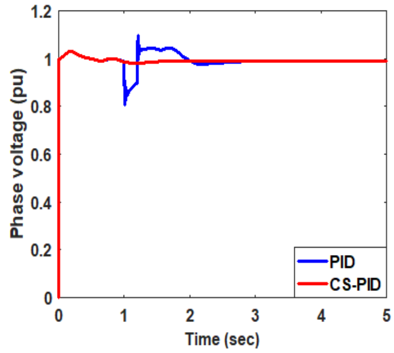


Fig. 7: Angular Speed difference (Δw) **Fig. 8:** Angular Speed of machine 1(Gen1) **Fig. 9:** Terminal Voltage of machine 1(Gen1)



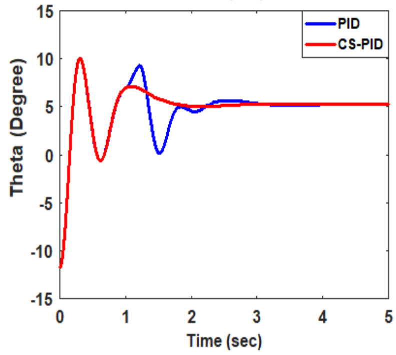
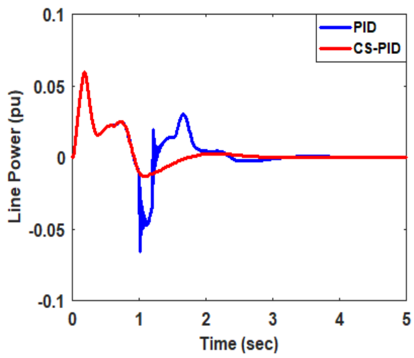
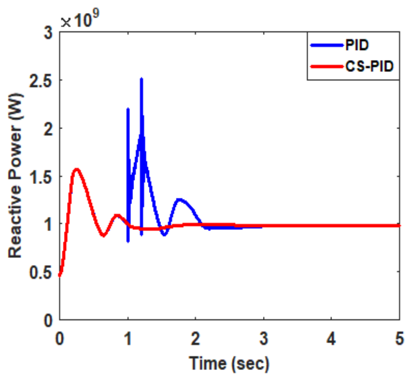


Fig. 10: Phase Voltage **Fig. 11:** Rotor Angle





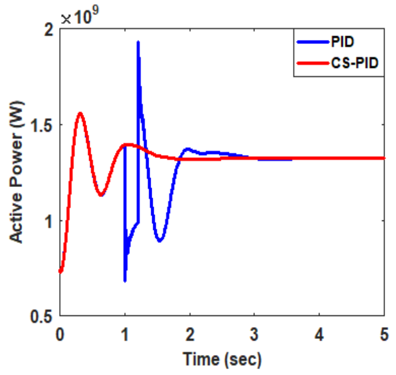
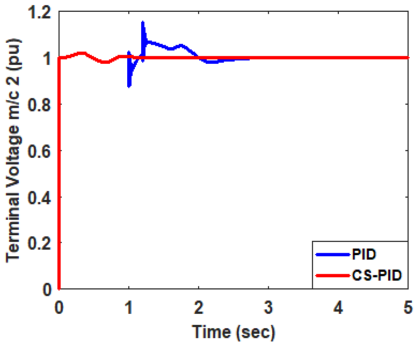


Fig. 12: Line Power **Fig. 13:** Reactive Power **Fig. 14:** Active Power



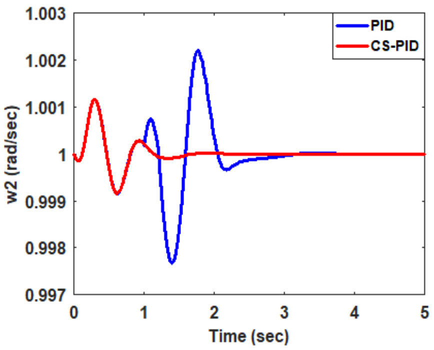
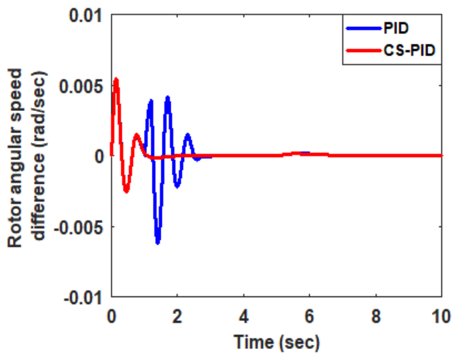


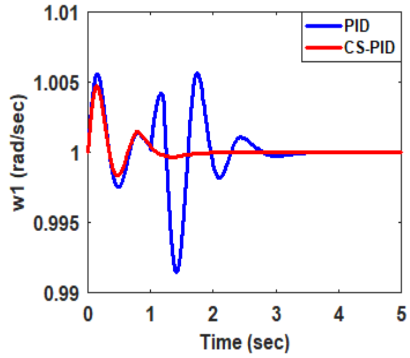
Fig. 15: Terminal Voltage of machine 2 (Gen2) **Fig. 16:** Angular Speed machine 2 (Gen2)

Fig. 7 compares the conventional PID with CS based PID in terms of speed deviation between machine 1 and machine 2. CS based PID shows greater damping than only PID. Fig. 8 and Fig .9 show the angular speed and terminal voltage of machine 1 respectively. With CS the system shows faster transient stability in contrast to conventional PID. The phase voltage performance of the two machine system is depicted in Fig. 10. Fig. 11 and Fig. 12 demonstrate the rotor angle of two machine system and the line power respectively. In case of CS the system

Case 2: Change in Line Impedance

responds more quickly and stabilizes faster than only conventional PSS. Fig. 13 and Fig. 14 represent the reactive and active power of the system respectively. The unified PSS and UPFC along with CS algorithm show better results in terms of rise and settling time as compared to PSS and UPFC without CS. Finally the terminal voltage and angular speed of machine 2 is shown in Fig. 15 and Fig. 16 respectively. Thus it is very distinct that the performance of system under CS based PSS yields much better result than only use of conventional PSS.





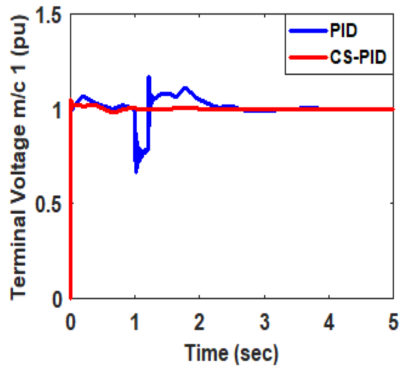
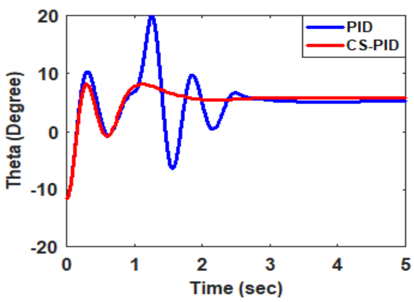
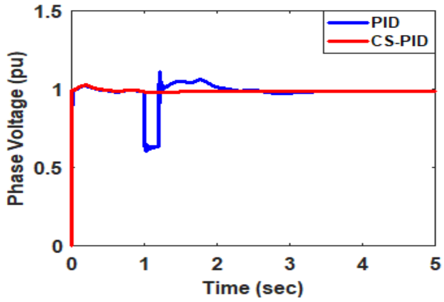


Fig. 17: Angular Speed difference (Δw) **Fig. 18:** Angular Speed of machine 1(Gen1) **Fig. 19:** Terminal Voltage of machine 1(Gen1)





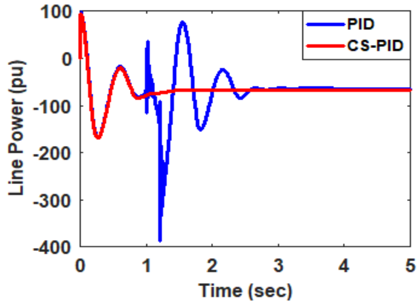
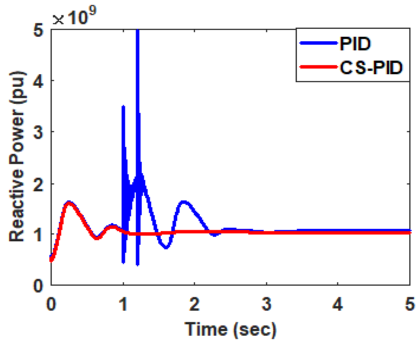


Fig. 20: Rotor Angle **Fig. 21:** Phase Voltage **Fig. 22:** Line Power



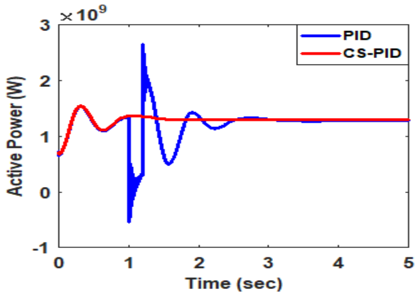
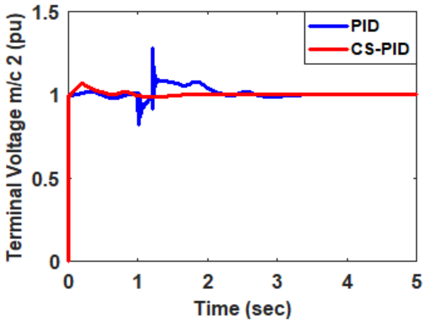


Fig. 23: Reactive Power **Fig. 24:** Active Power



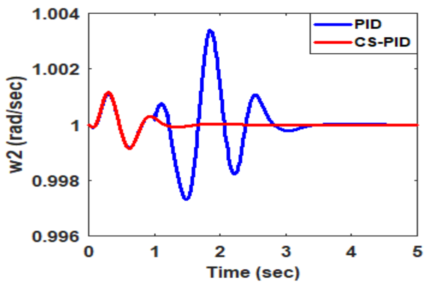


Fig. 25: Terminal Voltage of machine 2 (Gen2) **Fig. 26:** Angular Speed of machine 2 (Gen2)

Here the system is subjected to change in line impedance with change in inductance from 0.8737e-3 H/km to 1.9456e-3 H/km and change in resistance from 0.01755 ohms/km to 1.25 ohms/km. In Fig. 17 the deviation in angular speed of machine 1 and machine 2 is shown. With the application of CS, the settling time reaches faster than that of conventional PSS. Fig. 18 and Fig. 19 depicts the angular speed and terminal voltage of machine 1 respectively. Fig.20 shows the rotor angle of two machine system. Fig 21 and Fig 22 represent the phase voltage and the line power of two machine system respectively. The reactive and active power is shown in Fig, 23 and Fig.24 respectively. Fig. 25 and Fig. 26 illustrate the terminal voltage and angular speed of machine 2. In all these figures the CS based PID outperforms the conventional PID in terms of better stability, rise time, peak time and settling time. The detailed values of the parameters undertaken in the system model is given in Table 1.

Table 1: Values of Parameters Used In The System Model

Parameters	Values
Transmission Line	Number of phases=3 Frequency Used =60Hz Resistance per unit length=0.01755 Ω/Km Inductance per unit length= 0.8737e-3 H/Km Inductance per unit length= 0.8737e-3 H/Km length of Line =350 Km
Synchronous Machine Gen1	XL=0.18,Xd=1.305,

Synchronous Machine Gen 2	X'd=0.296, X"d=0.252, Xq=0.474, X"q=0.243
Transformer T1	
Transformer T2	XL=0.18,Xd=1.305, X'd=0.296, X"d=0.252, ,Xq=0.474X"q=0.243
UPFC	60Hz ,1000MVA, 13.8KV/500KV
	60Hz ,5000MVA, 13.8KV/500KV
	Nominal voltage= 500e3V L-L
	Frequency=60Hz
	Shunt convertor power rating= 100e6 VA
	Series converter power rating= 100e6 VA

V. CONCLUSION

In this paper a two machine system with coordinated design of PSS and UPFC is designed using MATLAB/SIMULINK environment. The control parameters of the conventional PID controller are dynamically tuned using robust Cuckoo Search algorithm. The various system parameters are found out and the proposed CS based PSS-PID is compared and contrasted with conventional PSS-PID. The results of the proposed technique demonstrate better system stability, flexibility, faster transient and dynamic response when subjected to various disturbances like single phase LLL-G fault and change in line impedance. Hence the fluctuations in power system variables like power, current and voltage levels are minimized to a greater extent.

REFERENCES

1. Izadi, H. and Effatnejad, R., 2015. Power system stabilizers and control of reactive power compensator in multi-machine by Particle Swarm Optimization algorithm. *Indian Journal of Science and Technology*, *8*(3), pp.254-262.
2. Bhattacharyya, B., Gupta, V.K. and Kumar, S., 2014. UPFC with series and shunt FACTS controllers for the economic operation of a power system. *Ain Shams Engineering Journal*, *5*(3), pp.775-787.
3. Swam, S.C. and Pandey, A., 2013. Real and Reactive Power Flow Analysis & Simulation with UPFC Connected to a Transmission LineI. *International Journal of Science and Research (IJSR)*.
4. Al Khazim, H.A. and Al Turki, Y.A., 2018. PSS and SVC Unified Power Oscillation Damping control for a SMIB model. *International Journal of Applied Engineering Research*, *13*(7), pp.5087-5092.
5. Khodabakhshian, A., Esmaili, M.R. and Bornapour, M., 2016. Optimal coordinated design of UPFC and PSS for improving power system performance by using multi-objective water cycle algorithm. *International Journal of Electrical Power & Energy Systems*, *83*, pp.124-133.
6. Liu, X. and Fu, M., 2015. Cuckoo search algorithm based on frog leaping local search and chaos theory. *Applied Mathematics and Computation*, *266*, pp.1083-1092.
7. Narwal, A. and Prasad, B.R., 2016. A novel order reduction approach for LTI systems using cuckoo search optimization and stability equation. *IETE Journal of Research*, *62*(2),pp.154-163.
8. Narwal, A. and Prasad, R., 2015, June. A novel order reduction approach for LTI systems using Cuckoo Search and Routh Approximation. In *Advance Computing Conference (IACC), 2015 IEEE International* (pp. 564-569). IEEE.
9. Patel, V., Kumar, V. and Kumar, D., 2018. Coordination of SVC and PSS for stability enhancement of DFIG-based offshore wind farm connected to a multi-machine system.
10. Mostafa, H.E., El-Sharkawy, M.A., Emary, A.A. and Yassin, K., 2012. Design and allocation of power system stabilizers using the particle swarm optimization technique for an interconnected power system. *International Journal of Electrical Power & Energy Systems*, *34*(1), pp.57-65.
11. Bhattacharyya, B., Gupta, V.K. and Kumar, S., 2014. UPFC with series and shunt FACTS controllers for the economic operation of a power system. *Ain Shams Engineering Journal*, *5*(3), pp.775-787.
12. Jordehi, A.R., 2015. Brainstorm optimisation algorithm (BSOA): An efficient algorithm for finding optimal location and setting of FACTS devices in electric power systems. *International Journal of Electrical Power & Energy Systems*, *69*, pp.48-57.
13. Hassan, L.H., Moghavvemi, M., Almurib, H.A. and Muttaqi, K.M., 2014. A coordinated design of PSSs and UPFC-based stabilizer using genetic algorithm. *IEEE transactions on Industry Applications*, *50*(5), pp.2957-2966.
14. Kasilingam, G. and Pasupuleti, J., 2015. Coordination of PSS and PID controller for power system stability enhancement–overview. *Indian Journal of Science and Technology*, *8*(2), pp.142-151.
15. Pan, I., Das, S. and Gupta, A., 2011. Tuning of an optimal fuzzy PID controller with stochastic algorithms for networked control systems with random time delay. *ISA transactions*, *50*(1), pp.28-36.
16. Mulani, K., Talukdar, P., Das, A. and Alagirusamy, R., 2015. Performance analysis and feasibility study of ant colony optimization, particle swarm optimization and cuckoo search algorithms for inverse heat transfer problems. *International Journal of Heat and Mass Transfer*, *89*, pp.359-378.
17. Arora, S. and Singh, S., 2013, August. A conceptual comparison of firefly algorithm, bat algorithm and cuckoo search. In *Control Computing Communication & Materials (ICCCCM), 2013 International Conference on* (pp. 1-4). IEEE.
18. Mareli, M. and Twala, B., 2018. An adaptive Cuckoo search algorithm for optimisation. *Applied computing and informatics*, *14*(2), pp.107-115.
19. Dong, Y., Zhang, Z. and Hong, W.C., 2018. A Hybrid Seasonal Mechanism with a Chaotic Cuckoo Search Algorithm with a Support Vector Regression Model for Electric Load Forecasting. *Energies*, *11*(4), p.1009.
20. Sulaiman, M.H. and Mohamed, M.R., 2014, March. Solving economic dispatch problems utilizing Cuckoo Search algorithm. In *Power Engineering and Optimization Conference (PEOCO), 2014 IEEE 8th International* (pp. 89-93). IEEE.