Load Frequency Control for Multi Area Using Intelligent Control

[1]Ali Adil Rafea, [2]Dr. Arkan Ahmed Hussein
College of Engineering, Electrical Engineering, Tikrit University, Iraq
[1]alido90hashimy@gmail.com, [2]aalganabe@tu.edu.iq

Article Info
Page Number:11108 - 11116
Publication Issue:
Vol 71 No. 4 (2022)

Article History
Article Received: *15 September 2022*
Revised: *25 October 2022*
Accepted: *14 November 2022*
Publication: *21 December 2022*

Abstract
In this study, the load frequency control (LFC) of three connected power systems is demonstrated utilizing the sine-cosine algorithm and particle swarm optimization. In the research, a proportional-integral-derivative (PID) control technique was used. Due to the load disturbance shift in area 2, the typical PID controller is created using two ways, one of which includes the LFC loop to reduce frequency deviation and control power exchange. Both approaches use Integral Time Square Error (ITSE) as an objective function to calculate the performance index value for the Sam Interconnection Power System.As for the comparison with regard to the setting time, we note that the PSO method is the fastest response and the least time in the areas, while the SCA method is the fastest in the tie lines.But when comparing the ratio of the overshoot values, we note that the PSO method is the best response from the other in each of the areas as well as the tie lines.

1. Introduction

The power system is a system that produces electrical energy from nature or other methods. The power system contains a number of generation units connected to each other through transmission lines connecting them[1-3]. And that one of the most important things that must be taken into account or paid attention to is achieving a balance between thepowers generated and the power required, as we know that the electricity cannot be stored.In order to maintain the balance and deliver the power to the customer with the best values, we must maintain the power in the transmission lines in a stable manner, by preserving two main parts, which are frequency and voltage[4].And as we know that the loads are not fixed and that they change from time to time, and this leads to disturbances in the system, so in this research we will talk about the Load Frequency Control system [5].

Automatic Generation Control (AGC) or Load Frequency Control (LFC) is an important part of the power system that helps maintain stability and increases the reliability of the system and delivers production at the best values.This is done by monitoring transmission lines and always searching to keep the value of the Area Accuracy Error equal to zero or the lowest value that can be reached.Therefore, a lot of research was conducted to reach the aforementioned goal by using several methods to maintain the frequency in multiple areas[6-7].

There are several control strategies that have been used in the interconnected system of the power grid over the years to reach the goal that has been mentioned[8-9].The one of the most common methods is proportional integral (PI) control.PI control is very easy to implement and work and gives a good response, but performance begins to decline when the system becomes more complex and leads to disturbances whenLoads change [10]. Therefore, research required more sophisticated and comprehensive ways to work with complex systems. Therefore, Artificial Intelligent controllers are more stable such as Fuzzy, as well as Neural control [11], neuro – fuzzy controller [12, 13], sliding mode control [14, 15] One of the frequently used methods is the PID with optimization techniques, which are more robust and reliable, and an example of these techniques such as Ant Colony Optimization [16], Genetic Algorithms [17], Practical Swarm Optimization [18]. In this work, a comparison was made between two methods of controlling a system consisting of three regions, in which the PID method was used with different techniques to maintain the stability of the system from sudden frequency changes.

2.Modeling System

Each area in the power system contains major parts, which are generator, governor, turbineand the system controls and connects this region to the other region through transmission lines, and accordingly, the transfer function will be mentioned for each of what has been mentioned.

1-T/F of control system $\frac{\Delta P_W(s)}{\Delta P_V(s)} = \frac{K_D S^2 + K_P S + K_I}{K_D S^2 + S\left(K_P + \frac{f}{R_2}\right) + K_I}$ (1)

2-T/F of governor $\Delta P_V(s) = \frac{1}{1+T_g} \Delta P_g(s)$ (2)

3-T/F of turbine

Non reheated turbine $\frac{\Delta P_m(s)}{\Delta P_V(s)} = \frac{1}{1+T_t S}$ (3)

Reheated turbine $\frac{\Delta P_m(s)}{\Delta P_V(s)} = \frac{cT_r s+1}{(1+T_t S)(1+T_r S)}$ (4)

Hydro turbine $\frac{\Delta P_W(s)}{\Delta P_V(s)} = \frac{1-s\,T_w}{1+0.5\,s\,T_w}$ (5)

4-Tie – Line

$P_{ij} = \frac{|V_i||V_j|}{x_{ij}} \sin(\delta_i - \delta_j)$ (6)

V_1, V_2, V_3 : Voltage for each area

x_{ij} : Reactance of tie line

δ_i :Power angles of end voltages

3.Objective Function

The input to the control system is area control errors (ACE), which are found in each area by finding a result between the frequency and tie - line error.

$ACE_i = \Delta Ptie_i + B_i F_i$ (7)

I: represent number of areas.

Control input to the power system is:

$u_i = K_{P,i} ACE_i + K_{I,i} \int ACE_i dt + K_{D,i} \frac{d}{dt}(ACE_i)$ (8)

Now performance index can be selectthe integral time of square error (ITSE)

$ITSE = \int_0^{T_{Final}} t * \left[\left(\Delta f_1{}^2 + \Delta f_2{}^2 + \Delta P_{tie\,12}{}^2\right)\right] dt$(9)

4. Control Methodology

4.1. Particle Swarm Optimization (PSO)

This technique depends on the intelligence of the bird and its movement

$$v_i^{k+1} = wv_i^k + c_1 rand_1 \times \left(pbest_i - s_i^k\right) + c_2 rand_2 \times (gbest_i - s_i^k)$$

(10)

Where, v_i^k velocity of agent i at iteration k

w =Weighing function

c_i =*Weighing factor*

$rand_i$ =Random number between 0-1

$pbest_i$ =*P-best of agent i*

s_i^k =Current position of agent i at iteration k

$gbest_i$ = g-best of the group

$$w = \frac{maxiter - iter}{maxiter}$$

Iter:current number of iteration

Axiter: maximum number of iterations

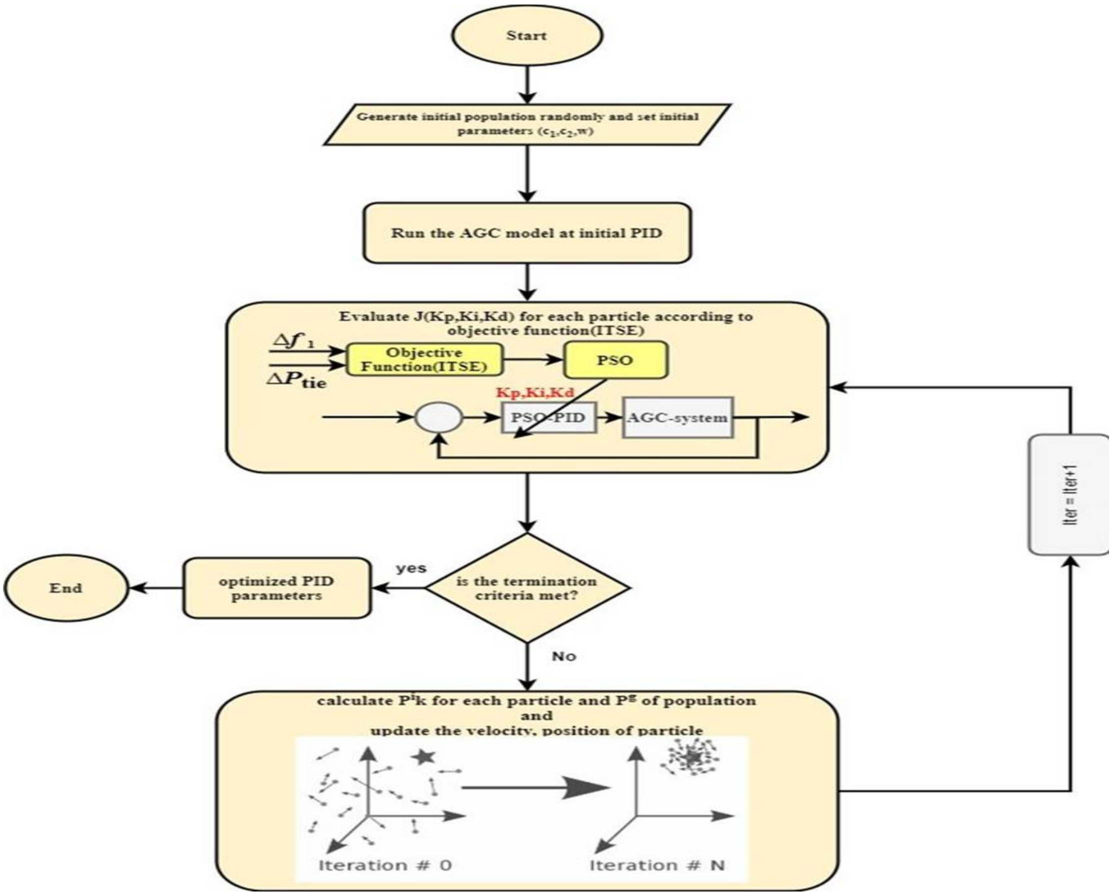

Fig (1) Flow diagram illustrating the particle swarm

4.2.Sine Cosine Algorithms

The SCA is a mathematical algorithm in which the main reliance is on the mathematical properties of the sine and the cosine, and as we know that these functions work within the space of the circle, so it has been used and developed so that the researcher can determine his whereabouts[19]. The equation of the function is:

$X_i^{t+1} = X_i^t + r_1 \times \sin(r_2) \times |r_3 P_i^t - X_i^t| (11) X_i^{t+1} = X_i^t + r_1 \times \cos(r_2) \times \left|r_3 P_i^t - X_{i_i}^t\right|$

(12)

$$X_i^{t+1} = \begin{cases} X_i^{t+1} = X_i^t + r_1 \times sin(r_2) \times |r_3 P_i^t - X_i^t| r_4 < 0.5 \\ X_i^{t+1} = X_i^t + r_1 \times \cos(r_2) \times |r_3 P_i^t - X_i^t| \, r_4 \geq 0.5 \end{cases} \quad (13)$$

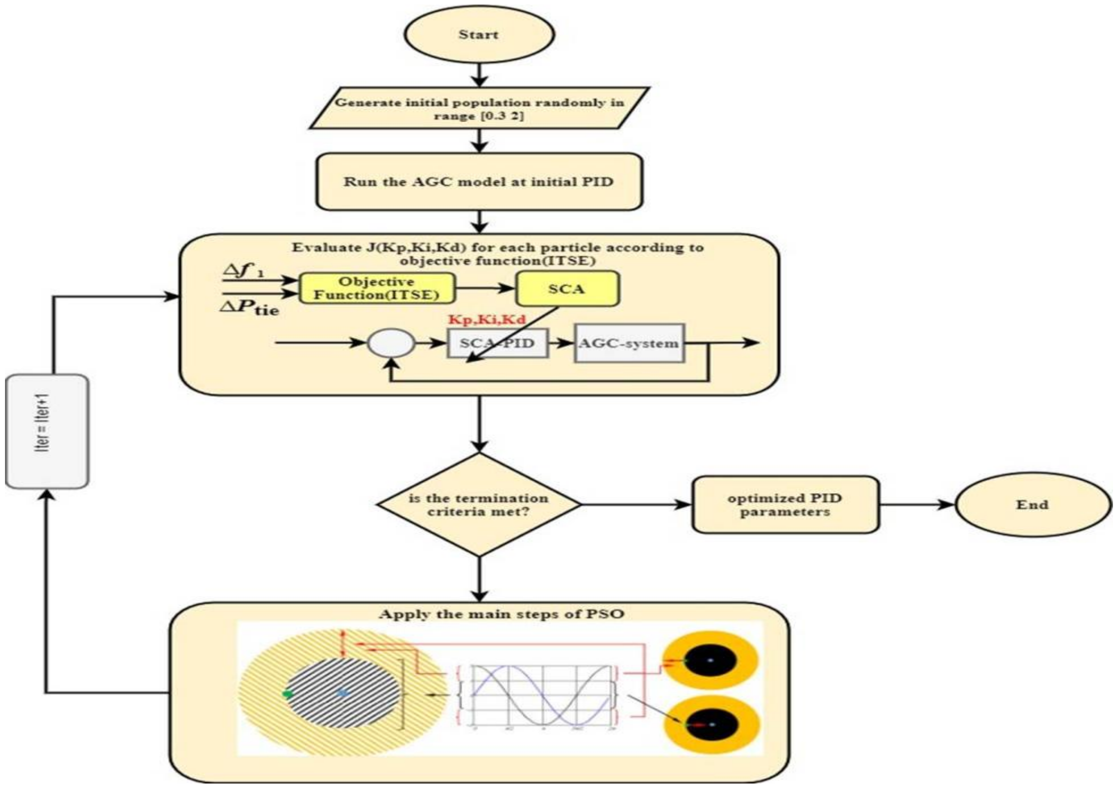

Fig (2) Graphical Illustration the Sine Cosine Algorithm Outline

5.Simulation and Results

In this paper, a three areaspower system was used. The thermal non reheat and reheat and hydraulic generation plants were employing. As the work was designed on the MATLAB program, in which a disturbance in the load was projected on the area in which the thermal reheat is located only.The waves generated in each area are drawn as well as the wave lines connecting the regions.As shown in the fig. from (3-8) and the values were as in Table No. (1-2)

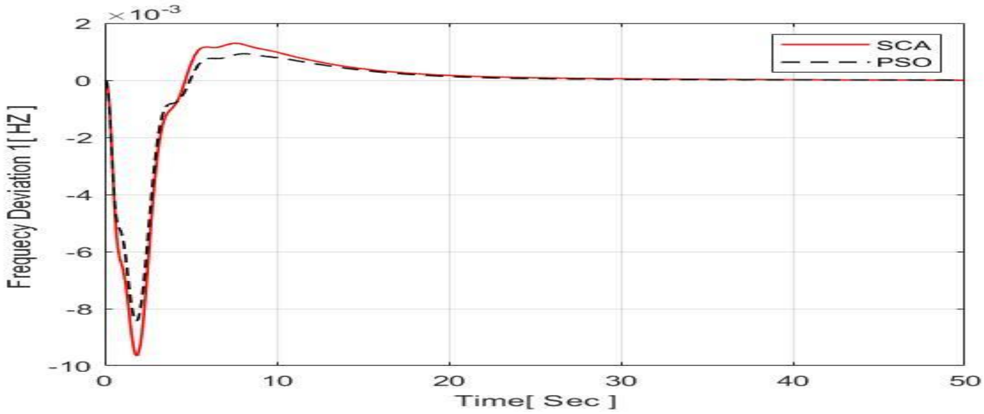

Figure (3) Frequency deviations for region 1

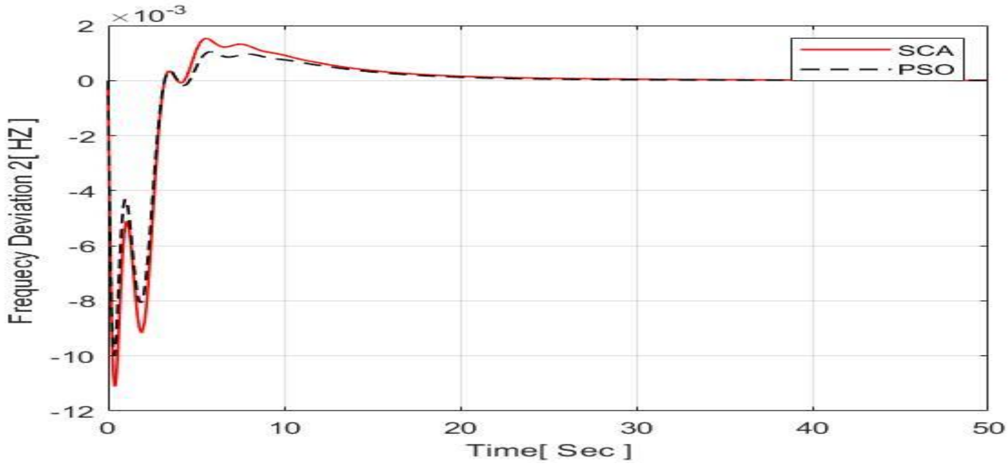

Figure (4) Frequency deviations for region 2

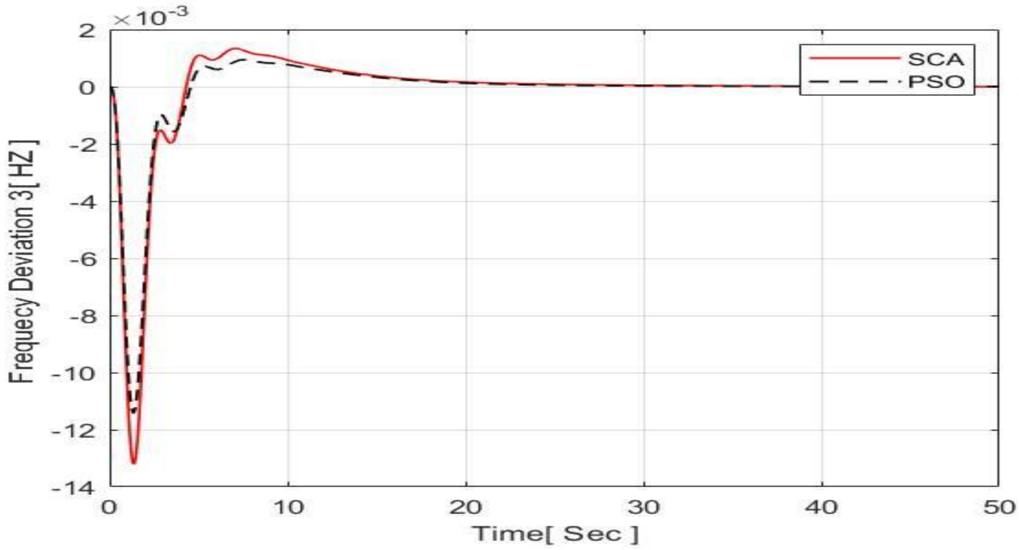

Figure (5) Frequency deviations for region 3

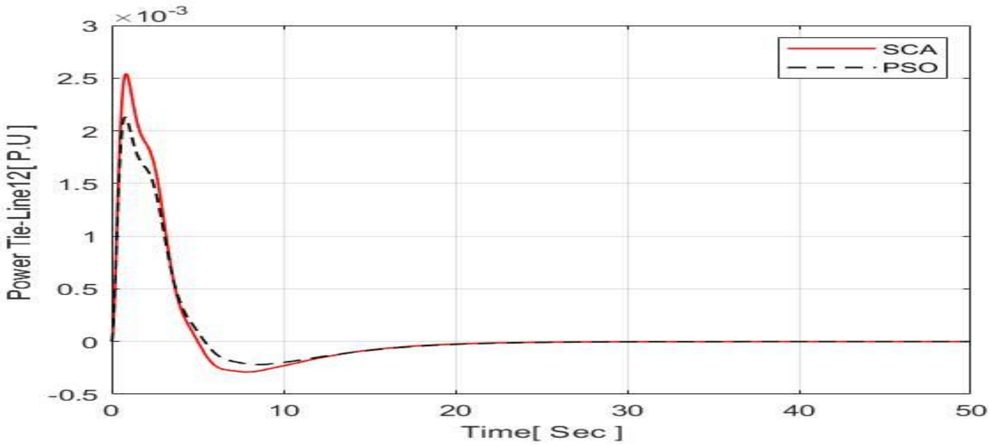

Figure (6) Power deviations for Tie-Line12

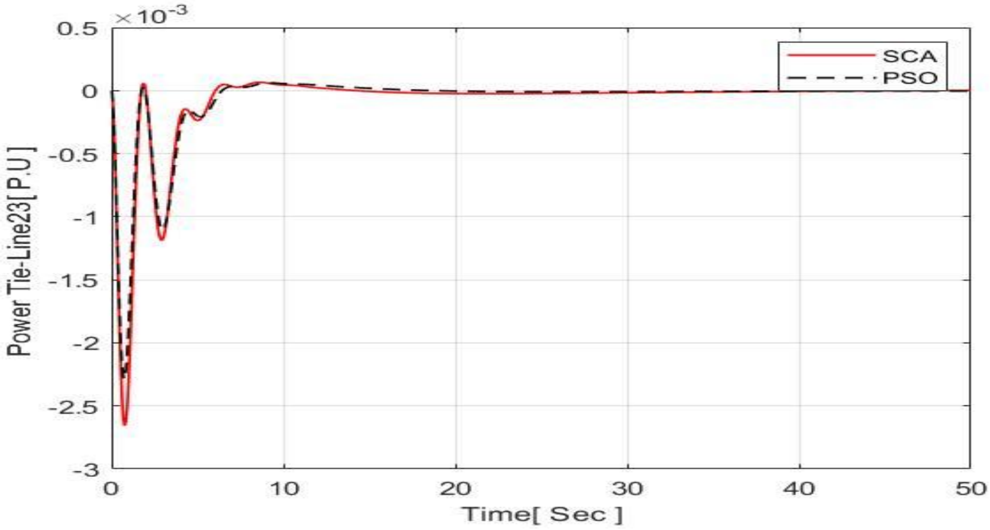

Figure (7) Power deviations for Tie-Line23

Table NO. (1) Comparative performance of overshoot.

Controllers	Overshoot				
	ΔF_1	ΔF_2	ΔF_3	ΔP_{tie12}	ΔP_{tie23}
SCA	0.001293	0.001532	0.001336	0.002544	0.00006613
PSO	0.0009285	0,0010 46	0.0009420	0.002133	0.00006171

Table No. (2) Comparative performance of setting time.

Controllers	Setting Time				
	ΔF_1	ΔF_2	ΔF_3	ΔP_{tie12}	ΔP_{tie23}
SCA	27.720	25.589	26.655	13.024	43.535
PSO	26.056	24.981	25.715	13.799	48

6. Conclusions

To solve the LFC problem, two distinct optimization strategies are used to determine the best PID controller values. PSO and SCA are the implemented algorithms for the three systems of turbines. For designing the PID controller parameters, the ITSE is used as an objective function, and it has also been used to solve LFC problems. The algorithms deliver close results and perform well when compared to traditional PID controllers. SCA responds more quickly in tie lines than PSO does in rural areas. PSO also outperforms SCA in terms of overshoot values.

REFERENCES

[1] P.Kundur.1994.Power System Stability and Control.McGraw Hill, New York.pp. 1-1196.

[2] HasanBevrani, TakashiHiyama, "Intelligent Automatic Generation Control", Book, Taylor and Francis Group (2011).

[3] Yao Zang, "Load Frequency Control of Multiple-Area Power System "Tsinghua University July, 2007 Master of Science Engineering. in Electrical

[4] D. Das. 2006. Electrical Power System. New Age International (P)Ltd. New Delhi. pp. 1-1196.

[5] Hadi Saddat. 1999. Power System Analysis. McGraw Hill, New York. pp. Springer.

[6] Kothari DP, Nagrath IJ. Modern Power System analysis. 4th ed. New Delhi: Tata McGraw Hill; 2011.

[7] Bevrani H. Robust power system frequency control. New York: Springer; 2009.

[8] Ibrahim, Kumar P, Kothari DP. 2005. Recent Philosophies of automatic generation control strategies in power system. IEEE.Transactions on Power Systems. 20(1): 346-457.

[9] H. Shayeghi, H. A. Shayanfar, and A. Jalili, "Load frequency Control strategies: A state-of-the-art survey for the researcher," Energy Convers. Manage vol. 50, pp. 344-353, 2009.

[10] Talaq J., Fadel A.l., Basri, 1999. Adaptive Fuzzy gain scheduling for Load Frequency Control, IEEE Transaction on Power System, Vol. 14. No.1, pp.145-150.

[11] Nanda J., Kakkarum J.S. 2003. Automatic Generation Control with Fuzzy logic controllers considering generation constraints, in Proceeding of 6th Int Conf on Advances in Power System Contro Operation and managements" Hong Kong.

[12] Farhangi R., M. Boroushaki, and S. H .Hosseini. 2012. Load–frequency control of interconnected power system using emotional learning-based intelligent controller. International Journal of Electrical Power and Energy Systems. 36(1): 76-83.

[13] Khuntia SR, Panda S. 2012. Simulation study for automaticgeneration control of a multi -area power system by ANFIS approach. Applied Soft Computing 12(1):333-341.

[14] Sudha K.R. and R. VijayaSanthi. 2011. Robust decentralizedload frequency control of interconnected power system with Generation Rate Constraint using Type-2 fuzzy approach. Electrical Power and Energy Systems. 33(3): 699-707.

[15] Zribi M, M. Al – Rasheed and M. Alrifai. 2005. Adaptive decentralized load frequency control of multi – area power system. Electrical Power and Energy Systems. 27(8):575-583.

[16] Dorrigo M and Birattari M and Stutzle T. 2007. Ant Colony Optimization: artificial ants as a computational intelligence. IEEE Computational Intelligence Magazine. 1 (4): 28 – 29.

[17] D. Rerkpreedapong, A. Hasanovic , and A. Filipacchi , “Robust Load Frequency Control Using Genetic Algorithms and Linear Matrix Inequalities,” IEEE Transactions on Power Systems, vol. 18, no. 2, pp. 855–861, May 2003.

[18] Ashok Mohan Jadhav and Dr. K. Vadirajacharya. Performance Verification of PID Controller in an Interconnected Power System Using Particle Swarm Optimization. Energy Procedia, 2012; 14:2075-2080.

[19] Mirjalili, Seyedali. "SCA: a sine cosine algorithm for solving optimization problems." Knowledge-based systems 96 (2016): 120- 133.

.