Load Frequency Control for Two Area Using Intelligent Control

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Abstract

The content of our study is to control the loading frequency of two regions using particle swarm optimization (PSO), genetic algorithms (GA), sine cosine algorithms(SCA) and relative integral derivative (PID) algorithms. Thetraditional PID controller is developed using the optimization algorithms we mentioned earlier and has reduced frequency change and has faster response. Integral Time Absolut Error (ITSE) is the function used in all algorithms for error calculation.The results showed that the algorithms had better results than the traditional method, and the SCA algorithm was also the best among them in terms of response speed.

1. Introduction

The safe production and distribution of electrical energy to multiple customers is the main objective of the electrical system.Population growth, the significant economic activity of recent years, and the need for individual electricity to support increased services and electrical gadgets in homes, workplaces, and industries are the three main causes of this increase in the demand for electricity. These factors increased the need for energy, and the rise in demand must be carefully managed somewhere to prevent it from affecting the rest of the electrical grid.Based on the availability of various consumer appliances, consumers can generally be categorized into three groups: residential, industrial, and commercial. The goal of an electric power system is to deliver electricity to every consumer, regardless of their demands, starting with the efficient generation of electricity. Before stepping down at the user end according to requirements, the initially generated high-voltage electrical energy is transferred at an additional high-voltage range through an appropriate step-up mechanism [1–5].

It is difficult to maintain the frequency at its rated value because consumer power demands are unpredictable. Frequency and power signal oscillations are magnified under dynamic demand situations and the power system may experience undesirable instability issues. The stability and dynamic performance of the power system networks can be significantly improved with the right design of the automatic generation control (AGC) system by dampening the variance in frequency/power signals.The AGC system monitors the tie-line power flow and system frequency, calculates the required increase or decrease in power generation based on changes in consumer demand, and modifies the set position of the speed changer in the control area to keep the time average of area control error (ACE) at a minimal value. As a result, AGC controls ACE to zero, which also affects frequency and tie-line power error.Two control actions, referred to as primary control and supplementary control, are used in power systems to achieve AGC. The first frequency adjustment is carried out via the primary control, which also has a steady state error. Only the naturally occurring time lags of the governor, turbine, and the system itself serve as a barrier to the response's rapidity. By using a controller to set the frequency error to zero, the supplementary control adjusts the frequency precisely [6].AGC's main goals are to reduce load variation and maintain preset values for frequency (f) and voltage (V). While the effects of active (P) and reactive (Q) power on frequency and voltage are mixed, the frequency and voltage control problems can be solved individually using the AGC approach [7–11].

Because the electrical grid is interconnected, the (AGC) helps maintain the flow of energy within the boundaries of these interconnection lines. With the shift towards computer-based control systems, a variety of factors can be taken into account, including the majority of economic units, the coordination of unit types, and even device efficiency and network connectivity limitations [12–16].

Various control techniques have been proposed in recent years based on conventional controls to obtain the optimal value of the PID gain. There are many teaching-learning-based optimization (TLBO) methods and techniques for tuning the Fuzzy-PID microcontroller for AGC in multiple regions [17]. PSO has applied for multi-region units from AGC [18]. Improvement of genetic algorithms for AGC in an interconnected energy system [19]. “Bacterial feed (BF) is applied to gain control unit integrated with GRC to improve AGC performance” [20]. “Linear Matrix Inequality (LMI) Control for AGC System” [21]. “Bacterial Foraging (BFA) AGC Algorithm Based on PID” [22]. “Bacterial Feed Optimization Algorithm (BFOA)-An Optimized Fuzzy PI/PID Controller for AGC in Multiple Regions” [23]. AGC using ANN technology [24]. A proportional integral derivative (FP-PID) fuzzy predictive AGC microcontroller [25]. Negative swarm algorithm (SSA) for PID controller tuning [26]. Multi-region AGC plot using FOPID (Fuzzy Optimized PID) controller [27]. Implementation of a fuzzy-ordered PID controller to study AGC [28]. Photoelectric, Thermal and Hydrothermal AGC by Capacitor Energy Storage (CES) and Auxiliary Fuzzy PID with Filter (FPIDF- (1 + PI)) Microcontroller [29]. This work makes a comparison of four PID gain tuning techniques to ensure that the problems of frequency deviation due to load change or sudden lift are solved, and also to maintain the stability of the electrical system to maintain the power flow.

2. Formulation of the Problem

The two area thermal-hydro power system biased on "PID- controller to improve the stability.

3. Various Components Mathematical Modelling:

3.1 Generator Model

By applying the swing equation of the small "synchronous machine"

Deviation in speed

$$\frac{d\Delta w}{dt} = \frac{1}{2H}\ (\Delta P_m - \Delta P_e)$$

By taking Laplace to the equation

$$\Delta\Omega = \frac{1}{2H_s}\ [\Delta P_m(s) - \Delta P_e(s)]$$

3.2 Loading Model

Is approximated by:

$$\Delta P_e = \Delta P_L + D\Delta_w$$

Where (ΔP_L)is the change of the frequency insensitive load, and (Δ_w) is the change of the frequency sensitive load. (D) Is expressed as the percentage change in load divided by the percentage change in frequency.

3.3Governor

By shifting the hydraulic booster (ΔP_g) to the position of the steam valve (ΔP_V) we have the following:

$$\Delta \boldsymbol{P_V}(\boldsymbol{s}) = \frac{\mathbf{1}}{\mathbf{1} + \boldsymbol{T_g}} \Delta \boldsymbol{P_g}(\boldsymbol{s})$$

3.4 Turbine Model

There are different types of turbines usedwe remind them:

None reheat turbine

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

Reheat turbines

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

Hydro turbines

The hydro turbine transmission function is:

$$\frac{\Delta P_w(s)}{\Delta P_V(s)} = \frac{1 - s\,T_w}{1 + 0.5\,s\,T_w}$$

4. System Control Equation

$$\frac{\Delta P_w(s)}{\Delta P_V(s)} = \frac{K_D S^2 + K_P S + K_I}{K_D S^2 + S\left(K_P + \frac{f}{R_2}\right) + K_I}$$

The PID Controller has an Area control Error (ACE) inputof the respective regions, the inputs to which they are controlled(u_1,u_2) to factory structure the PID controller as follows:
$ACE_1 = B\Delta f_1 + \Delta P_{tie\,12}(1)$
$ACE_2 = B\Delta f_2 - \Delta P_{tie\,12}(2)$
$u_1 = K_{p1} ACE_1 + K_{i1} \int ACE_1 + K_{d1} \frac{d}{dt}(ACE_1)(3)$

$u_2 = K_{p2}ACE_2 + K_{i2}\int ACE_2 + K_{d2}\frac{d}{dt}(ACE_2)(4)$

The ACE is treated as the output control of the AGC system, which detects any mismatch between the power generation side and the load requirements side.

The mathematical unit of the proposed system

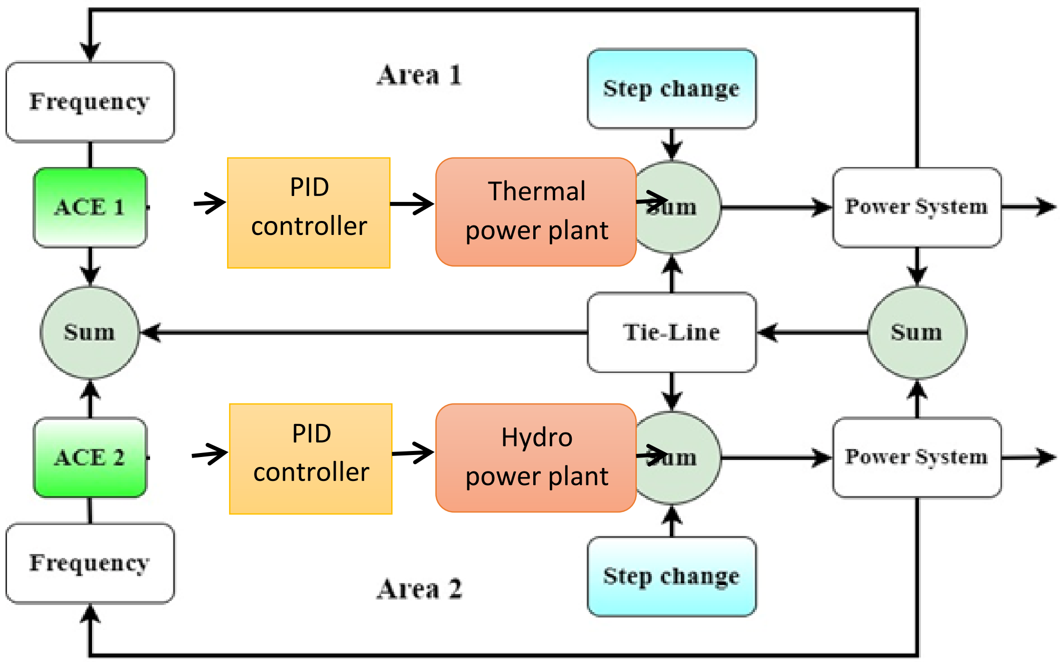

Figure (1) twoareasThermal - Hydropower system

5. Two Area Power System State Space Representations:

State Variables:

$$\Delta x_1 = \frac{1}{1+sT_g}\Delta x_2 = \frac{K_rT_rs+1}{1+sT_r}\Delta x_3 = \frac{1}{1+sT_t}$$

$$\Delta x_4 = \frac{1}{1+sT_1}\Delta x_5 = \frac{1+sT_3}{1+sT_2}\Delta x_6 = \frac{1-s\,T_w}{1+0.5\,s\,T_w}$$

Variable inputs for control:

u_1 And u_2

Input variables for disturbances:

$$d_1 = \Delta P_{L1} d_2 = \Delta P_{L2}$$

The state variable is created for thermal area:

$$\dot{x}_i = A_i x_i + \dot{B}_{1i} w_i + B_{2i} u_i \qquad (5)$$

$$x_1 = [\Delta f_1 \Delta P_{tie12} \quad \Delta E \quad \Delta x_1 \quad \Delta x_2 \quad \Delta x_3]^T$$
$$w_1 = [\Delta P_{L1} \quad \Delta f_2]^T$$
$$U_1 = u_1$$

$$A_1 = \begin{bmatrix} -\frac{1}{T_p} & -\frac{K_p}{T_p} & 0 & 0 & 0 & \frac{K_p}{T_p} \\ 2\pi T_{12} & 0 & 0 & 0 & 0 & 0 \\ \beta_1 & 1 & 0 & 0 & 0 & 0 \\ -\frac{1}{T_g * R_1} & 0 & 0 & -\frac{1}{T_g} & 0 & 0 \\ -\frac{K_r}{T_g * R_1} & 0 & 0 & \frac{1}{T_r} - \frac{K_r}{T_g} & -\frac{1}{T_r} & 0 \\ 0 & 0 & 0 & 0 & \frac{1}{T_t} & -\frac{1}{T_t} \end{bmatrix}$$

$$B_{11} = \begin{bmatrix} 0 & -\frac{K_p}{T_p} \\ -2\pi T_{12} & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} B_{21} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{1}{T_g} \\ \frac{K_r}{T_g} \\ 0 \end{bmatrix}$$

The state variable is created for hydro area:

$$x_2 = [\Delta f_2 \quad \Delta P_{tie\,12} \quad \Delta E \quad \Delta x_4 \quad \Delta x_5 \quad \Delta x_6]^T$$
$$w_1 = [\Delta P_{L2} \quad \Delta f_1]^T$$
$$U_2 = u_2$$

$$\boldsymbol{A_2} = \begin{bmatrix} -\frac{1}{T_{p2}} & -\frac{K_{p2}}{T_{p2}} & 0 & 0 & 0 & \frac{K_{p2}}{T_{p2}} \\ 2\pi T_{12} & 0 & 0 & 0 & 0 & 0 \\ \beta_2 & -1 & 0 & 0 & 0 & 0 \\ -\frac{1}{T_1 * R_2} & 0 & 0 & -\frac{1}{T_1} & 0 & 0 \\ -\frac{2}{T_3 R_2 T_1} & 0 & 0 & \frac{1}{T_3} - \frac{T_2}{T_3 T_1} & -\frac{1}{T_3} & 0 \\ -\frac{2T_2}{T_3 R_2 T_1} & 0 & 0 & \frac{-2}{T_3} + \frac{2T_2}{T_3 T_1} \frac{2}{T_w} + \frac{2}{T_3} & -\frac{2}{T_w} \end{bmatrix}$$

$$B_{12} = \begin{bmatrix} 0 & -\frac{K_{p2}}{T_{p2}} \\ 2\pi T_{12} & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \\ 0 & 0 \end{bmatrix} B_{22} = \begin{bmatrix} 0 \\ 0 \\ 0 \\ \frac{1}{T_1} \\ \frac{T_2}{T_3 T_1} \\ -\frac{2T_2}{T_3 T_1} \end{bmatrix}$$

6. Control System

In fact, there are many optimization methods used in designing PID controllers for LFC targets.So we will use three different optimization algorithms used in this research which are (PSO), (GA) and (SCA).

6.1 Particle Swarm Optimization (PSO)

Particle swarm optimization (PSO) was originated by James Kennedy and R.C. Eberhard in 1995. It is a stochastic evolutionary computation method. This method is based on the swarm theory, as the bird has always looked for the shortest way to find food. Figure 2 shows the PSO algorithm [30].

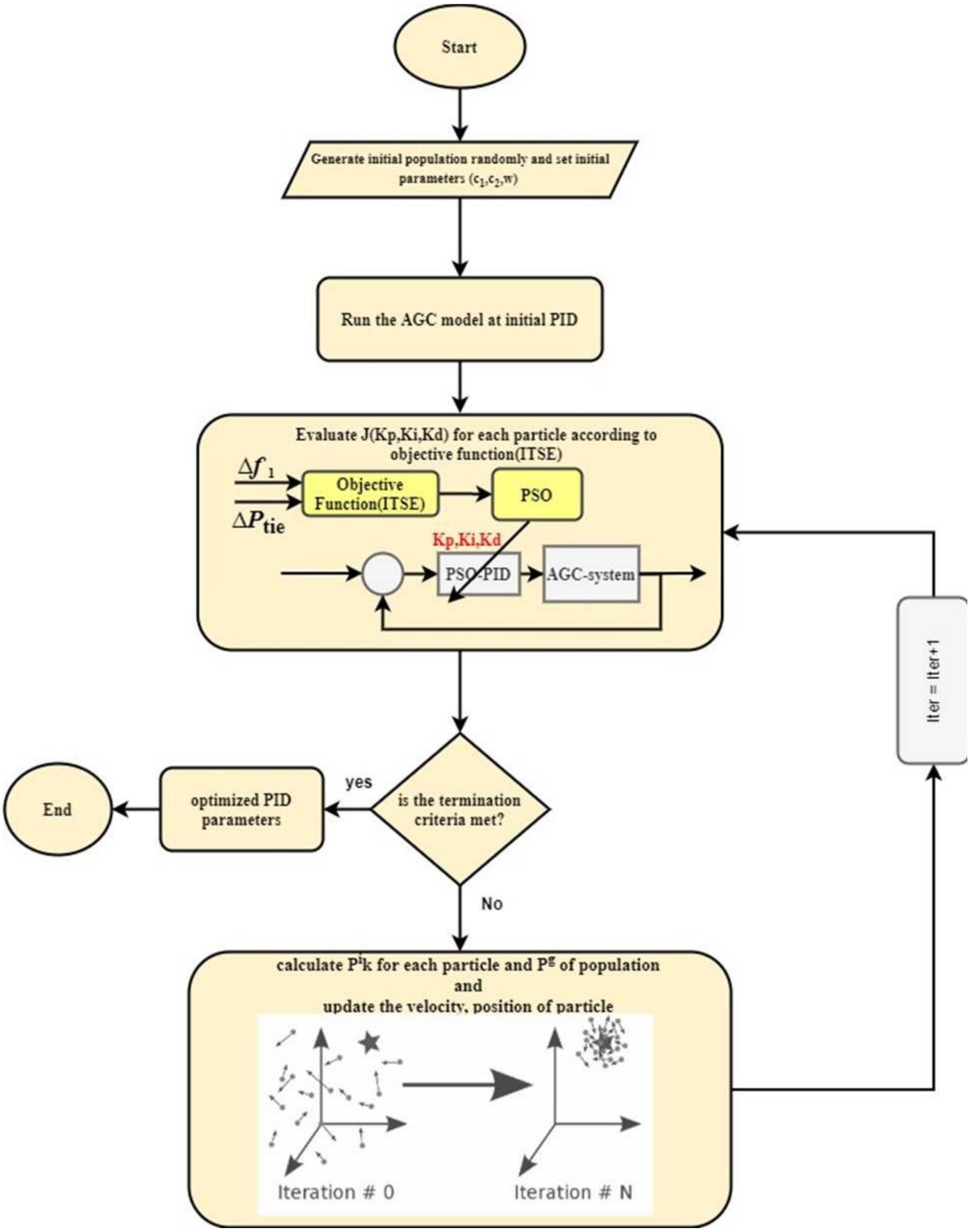

Figure (2)a flow chart showing the particle swarm

6.2 Genetic Algorithms (GA)

Genetic algorithm is an algorithm taken from Darwin's idea in nature. It is a method that starts without clear or complete information, but is based on experience and selectivity. In other words, he selects the best traits from the existing ones and tries to transfer and develop them by finding the species that have the best genes taken. Figure 3 shows the GA algorithm [31].

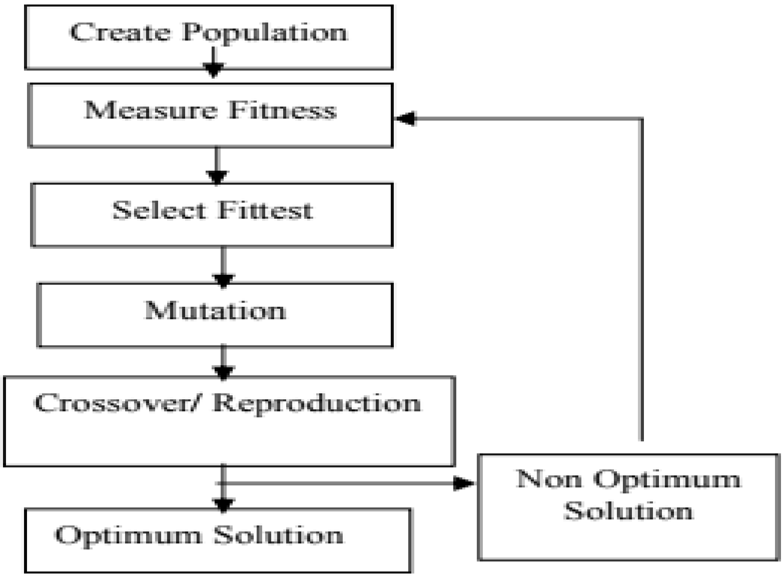

Figure (3) a diagram of the genetic algorithm scheme

6.3Sine Cosine Algorithms

The SCA generates many candidate and re-random initial solutionsthey seek to find the best solutions by using a mathematical model using sine and cosine functions.This algorithm also includes a number of variables that take random values and that can adapt to increase the possibilities and find search places in different stages of optimization. First, the exploration, exploitation, local optimization avoidance, and SCA convergence are tested using a collection of well-known test cases that includes Unimodal, Multimodal, and Composite functions. Second, a number of performance indicators are employed to track and validate the SCA's effectiveness on the transferred 2D test functions, including lookup history, path, average fit of solutions, and best solution during optimization. A demanding case study to verify and perform is optimization of the aircraft wing cross section by SCA [32]. The presentation devil puts this algorithm inthe following update situations are proposed in this work for the two follow-up phases:

$X_i^{t+1} = X_i^t + r_1 \times \sin(r_2) \times |r_3 P_i^t - X_i^t|$(6)

$X_i^{t+1} = X_i^t + r_1 \times \cos(r_2) \times \left|r_3 P_i^t - X_{i_i}^t\right|$(7)

where P_i is the location of the destination point in the $i-th$ dimension, $X_i^t$is the position of the current solution in the $i-th$ dimension at the $t-th$ iteration, r_1, r_2, and r_3 are random values, and | | denotes the absolute value. The following is how these two equations are combined:

$$X_i^{t+1} = \begin{cases} X_i^{t+1} = X_i^t + r_1 \times sin(r_2) \times |r_3 P_i^t - X_i^t| r_4 < 0.5 \\ X_i^{t+1} = X_i^t + r_1 \times \cos(r_2) \times |r_3 P_i^t - X_i^t| \, r_4 \geq 0.5 \end{cases} \quad (8)$$

Where $r_4$israndom number in [0, 1]

The equations above demonstrate that there are four primary parameters in SCA. The parameter r_1 determines the region of the subsequent location (or the direction of travel, which may be between or outside the solution) as$r_1.r_2.r_3$andr_4. The option provides the $r_2$distance up to or past the animation's finish line. To highlight whether the destination affects distance determination by random (r_3> 1) or de-emphasis (r_3 <1) means, the parameter gives r3a random weight for your destination. Last but not least, the parameter alternates between the sine and cosine parts of the equation. (8).

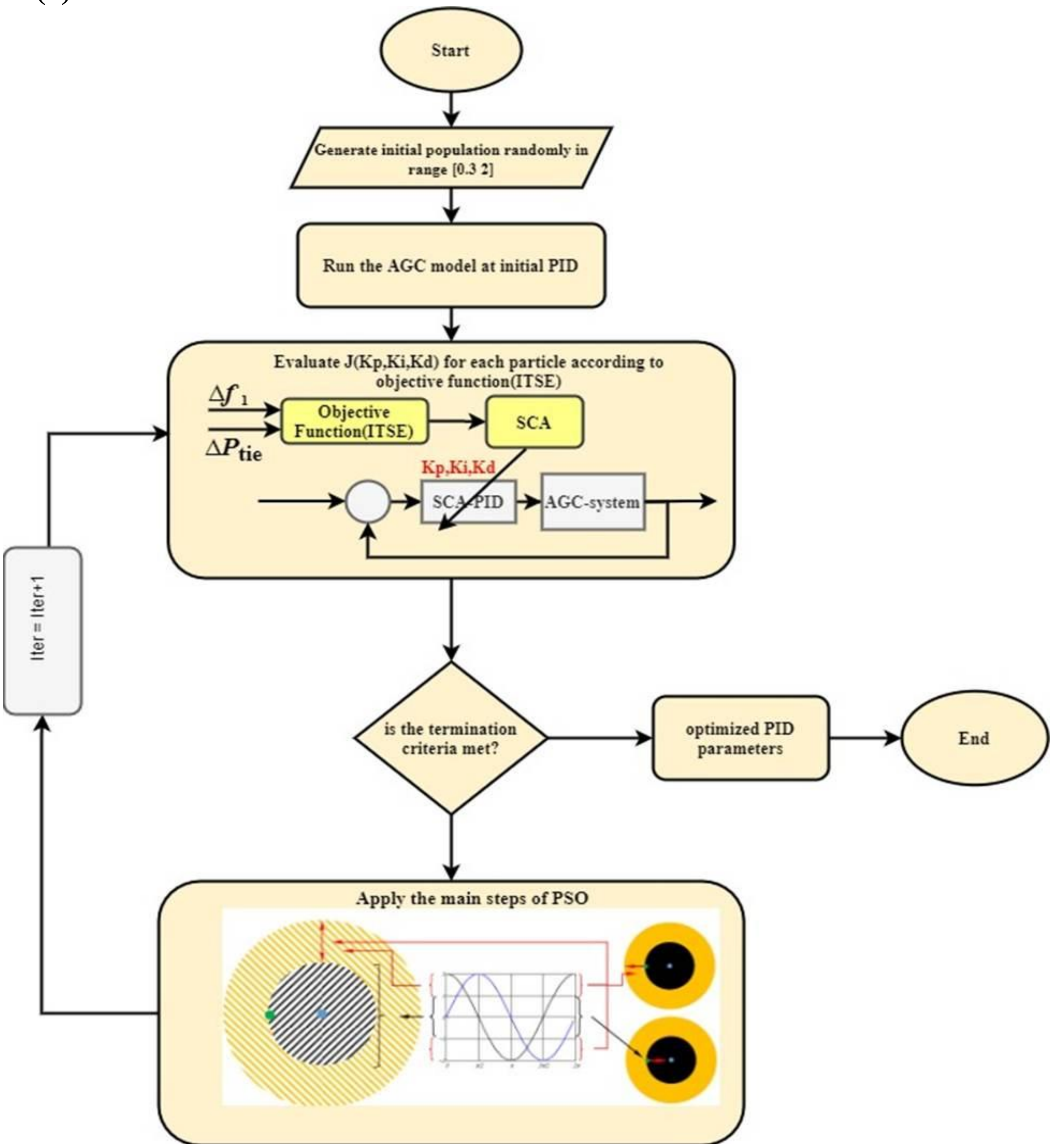

Figure (4) a schematic diagram of the cosine algorithm

7. Simulations and Results

In this paper, a two area energy system was used. Hydraulic and thermal power plants were used.Where the work was designed on the MATLAB program, where the disturbance of the load was displayed on the region in which the thermal reheating is located only, and the waves generated in each region were drawn, as well as generated on the line connecting the two regions, as shown in the figure. From (5-7) the values were as shown in Table No. (1).

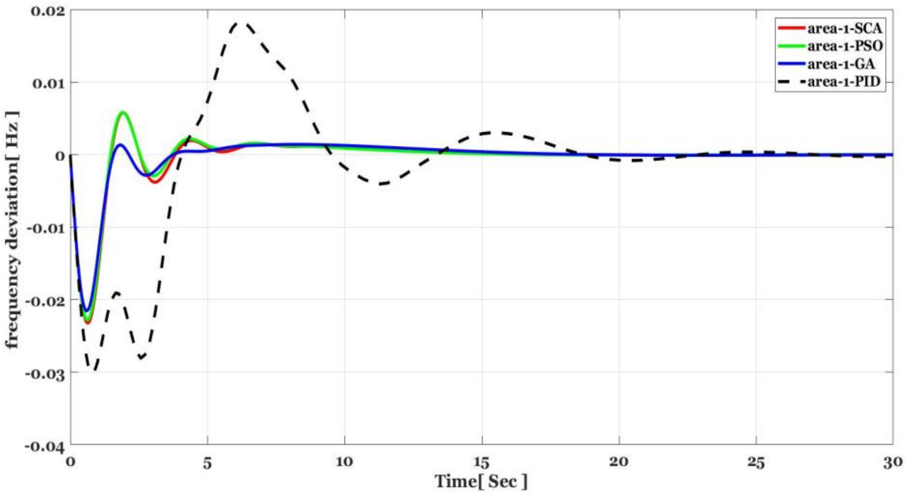

Figure (5) Frequency deviations for region 1

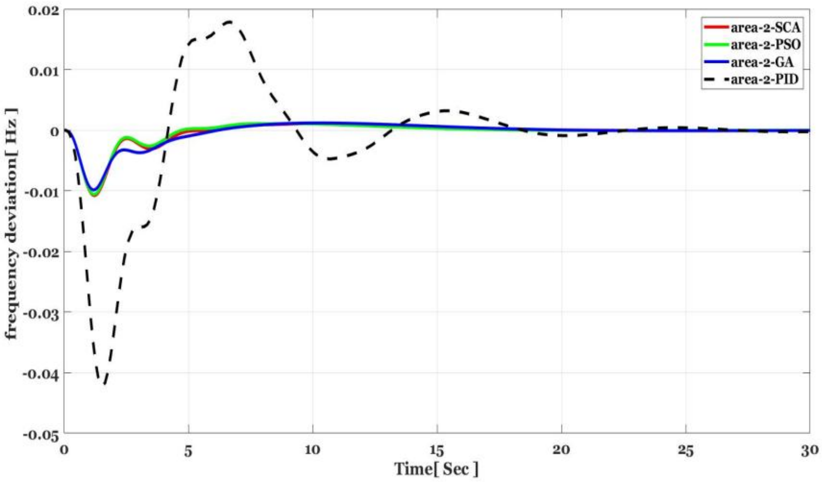

Figure (6) Frequency deviations for region 2

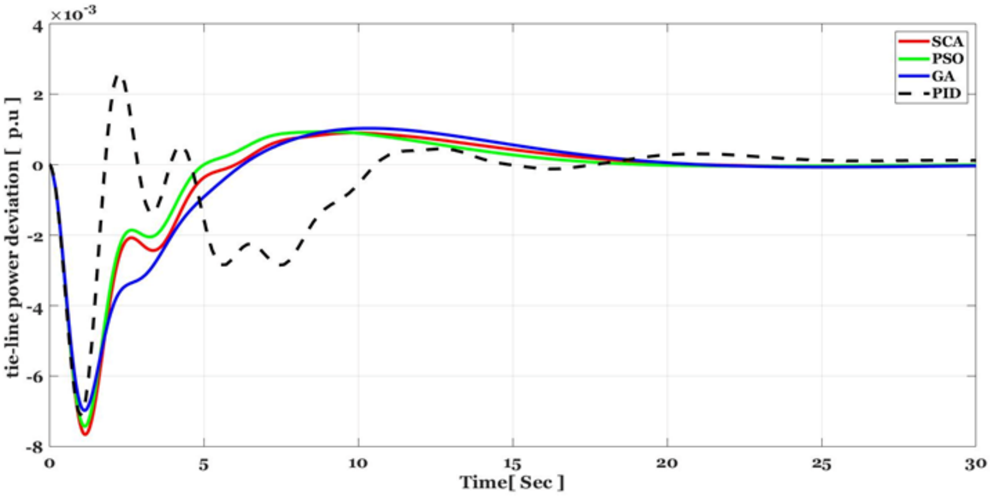

Figure (7) Deviations of the frequency of the tie line

Table No. (1) Comparative performance of time control and goal deficit

control	settling time			Overshoot		
	ΔF_1	ΔF_2	Δ_{tie} f	ΔF_1	ΔF_2	Δ_{tie} f
PID	17,845	20,401	24,712	0.01832	0.01786	0.002582
GA	17.77	18,831	19,977	0.00140	0.001197	0.001027
SCA	11,870	16,974	17,262	0.007238	0.001109	0.001446
PSO	12,971	17,953	13,559	0.00651	0.001013	0.009387

8. Conclusions

In this paper, three different algorithms have been used in addition to the traditional method to obtain the best PID coefficients to solve the frequency perturbation problem. The algorithms applied are SCA, PSO and GA on a two-zone system. By observing the table of results we got from the graphics (5-7) we found that there is a high convergencebetween theSCA and PSO algorithms. For a comparison of the best of all, we found the SCA algorithm to be the fastest way to reach stability.

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