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FOUR AREA INTERCONNECTED SYSTEM ON LOAD FREQUENCY CONTROL USING FIREFLY ALGORITHM

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ABSTRACT-- *The paper deals with optimal tuning of a PID controller for a load frequency control of four areas Power system using Firefly algorithm. The proposed approach has superior feature, including easy implementation, stable convergence characteristics and very good computational performances efficiency. The main objective is to obtain a stable, robust and controlled system by tuning the PID controller using Firefly algorithm. The interconnected four area LFC system is modeled and simulated using MATLAB-SIMLINK environment and the PID control parameters are tuned based on FA algorithm. By comparison with the conventional technique, the effectiveness of the anticipated scheme is confirmed. Hence the results establishes that tuning the PID controller using the firefly optimisation technique gives less over shoot, system is less sluggish. Optimization technique finds the best parameters for controller and designed controller are an optimal controller. The simulated results are obtained for different load configurations of the Firefly algorithm based controller and this indicate that the better control performance in terms of overshoot and settling time can be achieved by choosing PID among the other considered classical controllers.*

Keywords: LFC, PID, Power System Control, Firefly algorithm.

I. INTRODUCTION

In a power system, the generating electric power unit must satisfy the load demand to all consumers in the system with desired qualities. The main objective of power ssystem control is to maintain the continuous balance between electrical generation and varying load demand and the associated system losses while system frequency and voltage level are maintained constant. The load variations in the power system affect the quality of power. If the power demand is more than the generated power, system frequency will decrease and if the power demand is lesser than the generated power, system frequency will increase affecting the real power of the system[1]. Hence the balance of the power system gets disturbed. To supply the load demand without giving much constrain to a single system and to improve the reliability, power systems are interconnected and power is exchanged between the systems over the tie-lines by which they are connected. An approach on the "Evolutionary Computation based Four-Area Automatic Generation Control in Restructured Environment"[4]. load frequency control (LFC) is a very important issue in power system operation and control for supplying sufficient and both good quality and reliable power.

A new methodological approach on "Optimizing power flow of AC–DC power systems using artificial bee colony algorithm"[16]. PID controller improves the transient response of a system by reducing the overshoot, and by shortening the settling time of a system. Although new methods are proposed for tuning the PID controller, their usage is limited due to complexities arising at the time of implementation. Since, Firefly Optimization algorithm is an optimization method that finds the best parameters for controller in the uncertainty area of controller parameters and obtained controller is an optimal controller. The objective of this study is to investigate the load frequency control and inter area tie-power control problem for a four-area power system taking into consideration the uncertainties in the parameters of system[1]. An optimal control scheme based firefly Algorithm (FA) method is used for tuning the parameters of this PID controller. The proposed controller is simulated for a four-area power system. To show effectiveness of proposed method and also compare the performance of these four controllers, several changes in demand of the four areas simultaneously are applied. Simulation results indicate that Firefly algorithm based controllers guarantee the good performance under various load conditions.

II.FOUR AREA POWER SYSTEM:

Power systems have variable and complicated characteristics and comprise different control parts and also many of the parts are nonlinear.These parts are connected to each other by tie lines and need controllability of frequency and power flow. Interconnected multiple-area power systems can be depicted by using circles. A simplified four area interconnected power system used in this study is shown in Fig. 1.

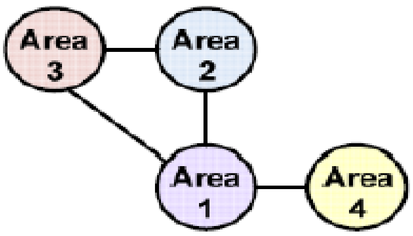

Fig 1.Simplified interconnected power system diagram.

In an interconnected power system, different areas are connected with each other tie-lines. When the frequencies in two areas are different, a power exchange occurs through the tie-line that connected the two areas, where ΔP_{tieij} is tie-line exchange power between areas i and j, and T_{ij} is the tie-line synchronizing torque coefficient between area i and j as shown in fig.2.it can see that the tie-line power error is the integral of the frequency difference between the two areas.

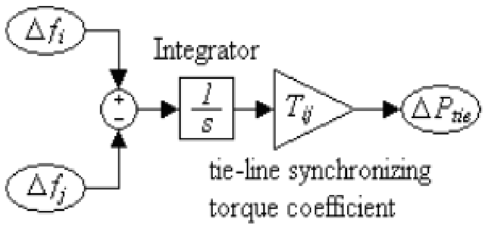

Fig 2.Block diagram of the tie line

Where, Δf_i & Δf_j: are the two areas interconnected.
T_{ij}: the tie line synchronizing torque coefficient
ΔP_{tie} : tie line power exchange between areas I and j.

Laplace transformation of the tie line is given by,

$$\Delta P_{tie12}(s)=2\Pi T^0/s(\Delta f_1(s)-\Delta f_2(s)) \quad \textbf{(1)}$$

The system state-space model can be represented as

$$\dot{x}=Ax+Bu$$
$$y=Cx \quad \textbf{(2)}$$

Where, system matrix A, input matrix B, state matrix x, control matrix u and output matrix C

$$u=[u_1\ u_2\ u_3\ u_4]^T$$
$$y = [y_1\ y_2\ y_3\ y_4]^T=[\Delta f_1\ \Delta f_2\ \Delta f_3\ \Delta f_4]^T$$
$$x = [\Delta_{f1}\ \Delta P_{T1}\ \Delta P_{G1}\ \Delta P_{C1}\ \Delta P_{tie1}$$
$$\Delta_{f2}\ \Delta P_{T2}\ \Delta P_{G2}\ \Delta P_{C2}\ \Delta P_{tie2}$$
$$\Delta_{f3}\ \Delta P_{T3}\ \Delta P_{G3}\ \Delta P_{C3}\ \Delta P_{tie3}$$
$$\Delta_{f4}\ \Delta P_{T4}\ \Delta P_{G4}\ \Delta P_{C4}\ \Delta P_{tie4}]^T \quad \textbf{(3)}$$

For the four area considered in this study, the conventional integral controller was replaced by a PID controller with the following structure.

K(s) = KP +KI / S+ KDS

Where KP is the proportional gain, KI is the integral gain, and KD is the differential gain, respectively. The

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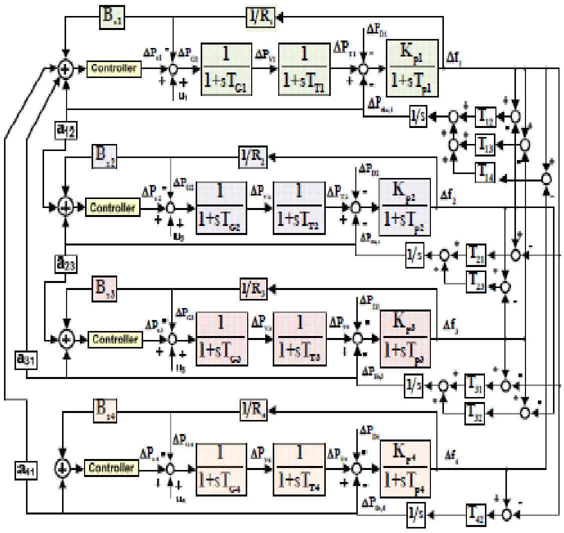

PID controllers in both areas are considered to be identical.

Fig. 3. Block diagram of a four-area power system.

The control signal for PID controller can be given in the following equation.

$$U_i(s) = -k(s)*ACE_i(s) \tag{4}$$

Now a performance index can be defined by adding the sum of squares of cumulative errors in ACE, hence based on area control error a performance index J can be defined as:

$$J=\int_0^\infty (ACE)_i \hat{}2dt \tag{5}$$

Based on this performance index J optimization problem can be stated as: Minimize J subjected to:

$$K_P^{min} \le K_P \le K_P^{max}$$
$$K_I^{min} \le K_I \le K_I^{max}$$
$$K_D^{min} \le K_D \le K_D^{max} \tag{6}$$

IV. METHODOLOGY OF FIREFLY ALGORITHM:

Nature-inspired methodologies are among the most powerful algorithms for optimization problems. Firefly algorithm is a novel nature-inspired algorithm inspired by social behavior of fireflies. Fireflies are one of the most special, captivating and fascinating creature in the nature. There are about two thousand firefly species, and most fireflies produce short and rhythmic flashes. The main part of a firefly's flash is to act as a signal system to attract other fireflies. Firefly-inspired algorithms use the following three idealized rules:

(1) All fireflies are unisex which means that they are attracted to other fireflies regardless of their sex;

(2) the degree of the attractiveness of a firefly is proportion to its brightness, thus for any two flashing fireflies, the less brighter one will move towards the brighter one and the more brightness means the less distance between two fireflies. If there is no brighter one than a particular firefly, it will move randomly;
(3) the brightness of a firefly is determined by the value of the objective function. For a maximization problem, the brightness of each firefly is proportional to the value of the objective function. In case of minimization problem, brightness of each firefly is inversely proportional to the value of the objective function. Based on the effectiveness of the firefly algorithm in optimizing continuous problems, it is predictable that this algorithm can also be modified to solve discrete optimization problems in an effective manner. In general, firefly algorithm incorporates three important strategies which are given as follows.

A.*ATTRACTIVENESS:*

In the firefly algorithm, the main form of attractiveness function β(r) can be any monotonically decreasing functions such as the following generalized form:

$$\beta(r)=\beta_0 e^{-\gamma r m} , m \geq 1 \quad \textbf{(7)}$$

where r is the distance between two fireflies, β_0 is the initial attractiveness of firefly and γ is a absorption coefficient.

B. *DISTANCE BETWEEN FIREFLIES:*

The distance between any two fireflies p and q at positions xp and xq respectively, can be defined as a Cartesian or Euclidean distance as follows:

$$r_{pq}=||Xp-Xq||=\sqrt{\sum_{k-1}^{d}(X_{p,s}-Xq.s)^2} \quad \textbf{(8)}$$

where $x_{p,s}$ is the sth component of the spatial coordinate of the pth firefly and d is the total number of dimensions. Also q ε {1,2,. . . ,Fn} is randomly chosen index. Although q is determined randomly, it has to be different from p. Here F_n is the number of fireflies. For other applications such as scheduling, the distance can be any of the suitable forms, not necessarily the Cartesian distance.

C. *MOVEMENT OF FIREFLY:*

The movement of a firefly p, when attracted to another more attractive (brighter) firefly q, is determined by

$$X^1=Xp+\beta(r)^{\times}(X_p-X_s)+\alpha(rand-1\backslash 2\ ) \quad \textbf{(9)}$$

The third term introduces randomization with 'α' being the randomization parameter and ''rand'' is a random number generated uniformly distributed between 0 and 1.

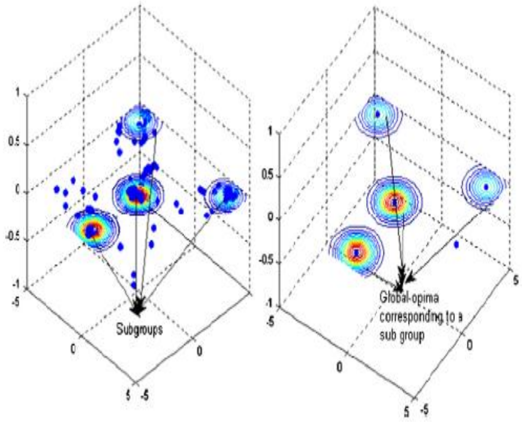

Fig 4 .Firefly behaviour

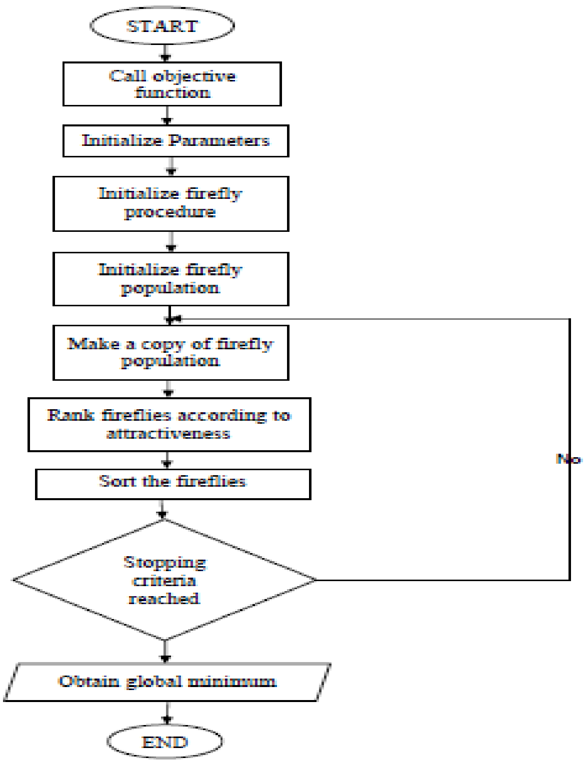

Fig 5.Flowchart of firefly algorithm

V.ALGORITHM

In the firefly algorithm, the optimization process depends on the brightness of the fireflies and the movement of fireflies towards their brighter counterparts. Every firefly is attracted to the other depending on brightness because the fireflies are all unisexual according to the first assumption about artificial fireflies. The following section describes the pseudo code.

Step 1:Define an initialize objective function $f(x)$, $x = (x1,..xd)$
Step 2:Generate initial population of fireflies xi (i = 1, 2, ..., n)
Step 3:Determine light intensity for xi by calculating $f(xi)$
Step 4:Define light absorption coefficient γ
While t < Maximum Generation
Make a copy of the generated firefly population for move function
For $i = 1 : n$ all n fireflies
For $j = 1 : i$ all n fireflies
If ($Ij > Ii$),
Move fireflies i and j according to attractiveness
Evaluating new solutions and updating light intensity for next iteration
End if
End for j
End for i
Sorting the fireflies to find the present best
End while
Begin post process on best results obtained

During the iterative process, the brightness of one firefly is compared with the others in the swarm and the difference in the brightness triggers the movement. The distance travelled depends on the attractiveness between the fireflies. During the iterative process the best solution thus far is continuously updated and the process goes on until certain stopping conditions are satisfied. After the iterative process comes to a halt the best solution of the evaluation is determined and the post process is initiated to obtain the results. The flowchart diagram is shown in Figure 5.

VI. RESULTS AND SIMULATIONS:

In this section different comparative cases are examined to show the effectiveness of the proposed FA method for optimizing Controller parameters. table 1 gives the optimum values of the overshoot, Table 2 gives the values of the under shoot and the table 3 gives the values of the settling time. The simulation results are shown in Figs. 6,7 in
this study.

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Table 1: comparison of PID and optimisation of the four area power system for overshoot

AREA	OVER SHOOT (HZ)	
	PID	FIREFLY
Area 1	0.005	0.0055
Area 2	0.013	0.005
Area 3	0.013	0.003
Area 4	0.006	0.01

Table 2: comparison of PID and optimisation of the four area power system for undershoot

AREA	UNDER SHOOT (HZ)	
	PID	FIREFLY
Area 1	-0.021	-0.012
Area 2	-0.023	-0.012
Area 3	-0.023	-0.013
Area 4	-0.032	-0.031

Table 3: comparison of PID and optimisation of the four area power system for Settling time

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AREA	SETTLING TIME (SEC)	
	PID	FIREFLY
Area 1	45	36
Area 2	66	50
Area 3	63	46
Area 4	52	37

The four area system can be simulated using the MATLAB-SIMULINK environment. The simulation results shown in Figs. 4 and 5 gives the frequency response and step load change using PID controller and the firefly algorithm based optimisation technique. Thus the simulation results shows the following,

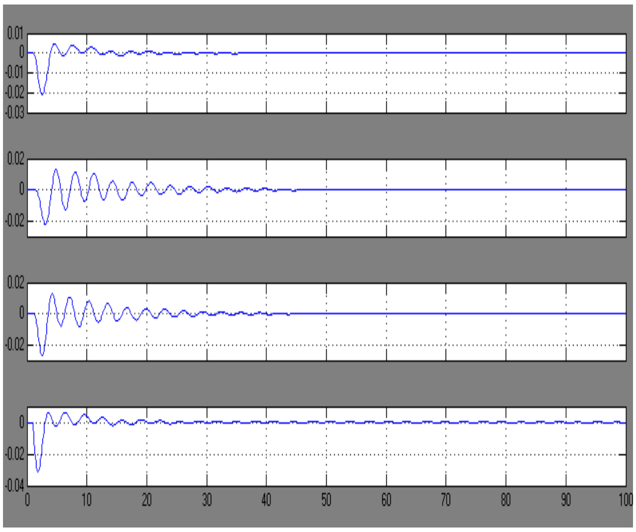

Fig 6: Frequency response and step load change of four area system with PID controller

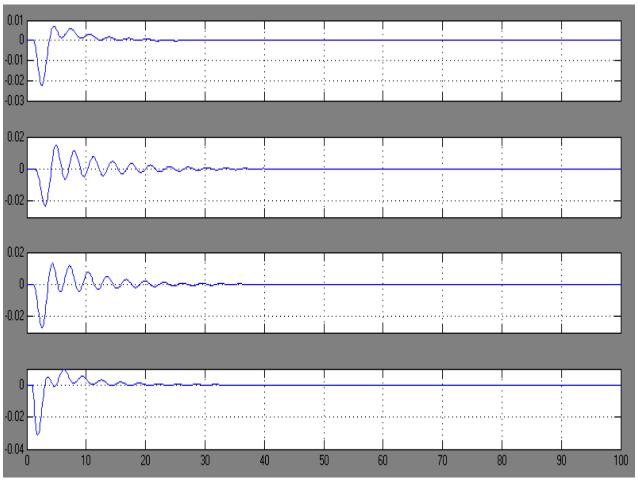

Fig 7.Frequency response and step load change of four area system using optimisation technique

CONCLUSION:

Firefly algorithm is proposed in this four area power system to tune the parameters of PID for LFC. Optimisation -PID controller is suggested to generate good quality and reliable electric energy. Simulation results emphasis that the designed FA tuning PID controller is robust in its operation and gives a good damping performance both for frequency and tie line power deviation compared to conventional controller. Also, these controllers have a simple architecture and the potentiality of implementation in real time environment.

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APPENDIX

AREA 1,2,3&4 Tp1=20sec, Kp1=120, TT1=0.3sec, TG1=0.08sec, R1=2.4
T12=T13=T14=T21=T23=T31=T32=T41=0.545 T24=T34=T42=T43=0,BS1=BS2=BS3=BS4=0.425: a12=a41=a23=a31=-1