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Performance Analysis of LFC in Multi Area Power System Using hybrid Firefly Algorithm

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ABSTRACT: In multi area thermal power system, the frequency and tie-line power vary randomly with change in load demand. The interconnected power system holds frequency and desired power output at scheduled values and to control the change in tie-line power flow between control areas is the aim of load frequency control. Reliable controller is used to implement many modern control techniques. The objective can be attained by maintaining both voltage and frequency within allowable range which can produce and deliver reliable power. In multi area system hybrid firefly algorithm is used to explore the design and performance analysis of PI controller. Initially, a three-area thermal system with time delay, reheat turbine, generation rate constraint (GRC) and governor dead band non-linearity are considered and the gains of the fuzzy PI controller are optimized employing fuzzy and firefly optimization technique.

KEYWORDS: PI controller, Load Frequency control, Firefly Algorithm

I.INTRODUCTION

In modern thermal power system, Load Frequency Control (LFC) plays a vital role to maintain the system frequency and tie line power flow at their scheduled values under normal as well as when the system is subjected to small step load perturbation. Load Frequency Control issue in power systems has a long history and its literature is huge. The preliminary LFC schemes have involved over the past decades, and interest continues in proposing new intelligent LFC approaches with an improved ability to maintain tie-line power flow and system frequency close to specific values. It is well known that system frequency depends on the balance between the real power generated and the instant load demand.

Literature study reveals that several control strategies have been proposed by many researchers over the past decades for LFC of power system. Many control and optimization techniques such as conventional, Evolution (DE), optimal control, Differential Fuzzy Logic Controller (FLC), and Artificial Neural Network (ANN), Craziness based Particle Swarm Optimization (CPSO), and Genetic Algorithm (GA) have been proposed for LFC. The design and analysis of hybrid firefly algorithm-pattern search based fuzzy PID controller for LFC of multi area system. In this work, a two-area thermal system with Governor Dead Band (GDB) nonlinearity is considered and the gains of the fuzzy PID controller are optimized employing a hybrid FA and PS (hFA–PS) optimization technique. The advantage of the proposed fuzzy PID controller has been shown by comparing the results with some recently published techniques,

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such as Differential Evolution (DE) and Craziness based Particle Swarm Optimization (CPSO). A firefly algorithm optimized fuzzy PID controller for AGC of multi-area multi-source power systems with UPFC and SMES [3]. In this paper, a two area six units power system is used and the gains of the fuzzy PID controller are optimized employing FA optimization technique using an ITAE criterion. In order to further increase the performance of the controller, a modified objective function is derived using Integral Time multiply Absolute Error (ITAE), damping ratio of dominant eigenvalues, settling times of frequency and peak overshoots with appropriate weight coefficients. In the view of above, the hybrid firefly algorithm optimization technique is applied to tune the inputs and outputs.

II. MULTI AREA POWER SYSTEM MODEL

The three-area power system consists of interconnection of three power systems.The outputs are the generator frequency ΔF and area control error (ACE) given by,

$$ACE = B\Delta F + \Delta PT \quad (1)$$

Where, B is the frequency bias parameter.

Each area of the power system consists of speed governing system, turbine, and generator. Each area has three inputs and two outputs. The important constraints which affect the power system performance are time delay, reheat turbine, Generation Rate Constraint (GRC), and Governor Dead Band (GDB) nonlinearity.

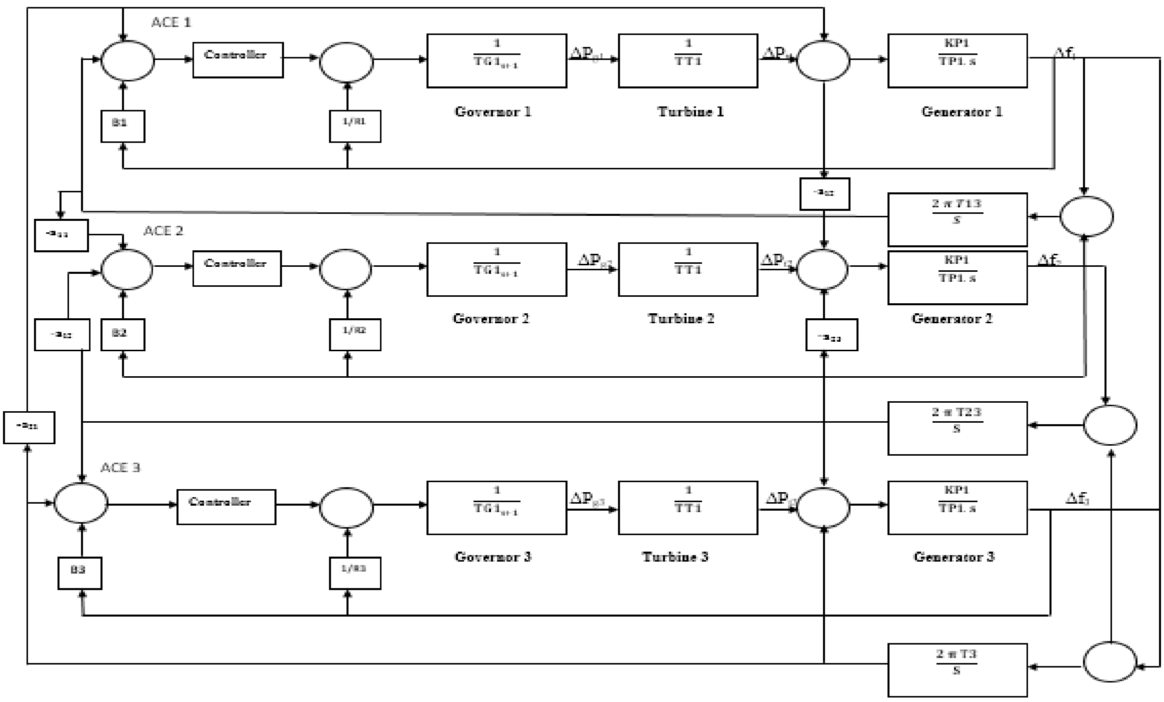

Fig.1 Block Diagram of Multi Area Power System Model

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To get an accurate insight of the LFC problem, it is essential to include the important inherent requirement and the basic physical constraints and include them model. Time delay degrades a systems performance and even cause system instability.Governor dead band non-linearity is the total amount of a continued speed change within which there is no change in valve position. Dead zone is a kind of non-linearity in which the system does not respond to the given input until the input reaches a particular level.

ACE_1, ACE_2 and ACE_3 are area control errors; R_1, R_2 and R_3 are governor speed regulation constants; B_1, B_2 and B_3 are frequency bias factors; u_1, u_2 and u_3 are control inputs to speed governing system coming out of the controllers; Tg_1, Tg_2 and Tg_3 are governor time constants in seconds; ΔPg_1, ΔPg_2 and ΔPg_3 are changes in governor valve positions. Tt1 and Tt2 are turbine time in seconds. ΔK_1, ΔK_2 and ΔK_3 are the parameters which is gain parameters and also constants in seconds; ΔPt1 and ΔPt2 are the changes in turbine output powers; kp_1, kp_2 and kp_3 are the power system gains; Tp_1, Tp_2 and Tp_3 are power system time constants in seconds; ΔPD_1, ΔPD_2 and ΔPD_3 are the changes in the load demands; ΔPTIE is the change in tie-line power; and Δf_1, Δf_2 and Δf_3 are the deviations in the system frequencies.

Controller structure

Fuzzy PI controller method is better method of controlling to the complex and unclear model systems. It can give simple, effective control, robustness, good dynamic response, rising time, overstrike characteristics. Most existing conventional PID controller fails where industrial process having degrees of non-linearity and parameters variability and uncertainty of the mathematical model of the system. However, conventional PID controller algorithm is simple, stable, easy adjustment and high reliability. Tuning parameters of such systems also difficult.

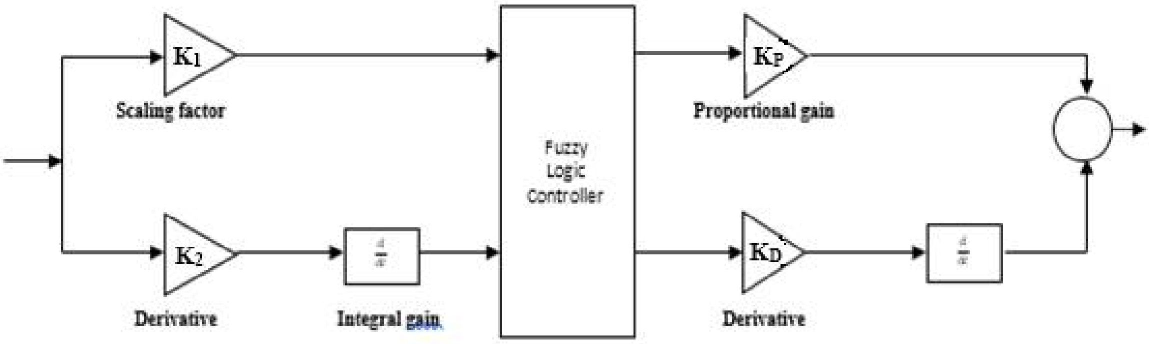

Fig. 2 Structure of PI Controller

The frequency control for fuzzy PI controllers are provided in each area. The error inputs to the controllers are the respective Area Control Errors given by:

$$e_1(t) = ACE_1 = B_1\Delta F_1 + \Delta P_{Tie} \quad (2)$$

$$e_2(t) = ACE_2 = B2\Delta F_2 - \Delta P_{Tie} \quad (3)$$

Fuzzy controller uses error (e) and derivative of error as input signals. The outputs of the fuzzy controllers u_1 and u_2 are the control inputs of the power system. The input scaling factors are the tunable parameters K_1 and K_2.

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III. PROBLEM FORMULATION

Design of a controller is based upon well-defined objectives meeting the system requirements and constraints. In this paper, the design objectives considered to tune the controller parameters are minimization of the settling times of frequency and tie-line power deviations, ITAE error minimization and reduction in peak overshoots of deviations in system frequency and tie-line power.The first considered objective J1, is the settling time of the deviations in the system frequencies of the two areas, the tie-line power deviations and the ACEs of the respective areas. This objective accounts for maintaining the power exchange between the control areas at its predefined values as soon as possible under any kind of load change or system disturbances. It is represented in the following

$$J_1 = T\Delta F_1 + T\Delta F_2 + T\Delta P_{Tie} + TACE_1 + TACE_2 \quad (4)$$

where, $T\Delta F_1$ and $T\Delta F_2$ are the selling times of the frequency deviations in area 1 and area 2, respectively, $T\Delta P_{Tie}$ is the settling time for the incremental change in tie-line power and $TACE_1$ and $TACE_2$ are the settling times ACEs of area 1 and area 2, respectively.The second objective J2 is considered based on ITAE criterion which is widely chosen design objective. This objective is accountable for maintaining the change in frequency to zero under any load change and minimizing the integral of the change of the frequency. It is formulated as:

$$J2 = \int(|\Delta f| + |\Delta f| + |\Delta PTie| + |ACE1| + |ACE2|)\cdot t\cdot dt \quad (5)$$

where, Ts is the total simulation time.

IV. FIREFLY ALGORITHM

The Firefly Algorithm (FA) is a population-based algorithm developed by Yang. Fireflies are characterized by their flashing light produced by biochemical process bioluminescence. The flashing light may serve as the main courtship signals for mating. It is based on the following three idealized behavior of the flashing characteristics of fireflies.
(a) All fireflies are unisex and are attracted to other fireflies regardless of their sex.
(b) The degree of the attractiveness of a firefly is proportional to its brightness. Their attractiveness is proportional to the light intensity. Thus, for any two flashing fireflies, less bright firefly moves towards the brighter one. As brightness is proportional to distance, more brightness means less distance between two fireflies. If any two flashing fireflies have the same brightness, then they move randomly.
(c) The brightness of a firefly is determined by the objective function to be optimized.
In FA algorithm, there are two important issues: (1) the variation of light intensity; and (2) formulation of attractiveness. However, these parameters are either set constants or fixed empirically in the traditional FA, which may make the algorithm inefficient for the problems with complex landscapes. Researchers have made numerous contributions to the improvement of FA considering the alteration of the control parameters applied to several chaos mechanisms to tune light absorption coefficient and attractiveness coefficient.
Although much progress has been achieved on the FA-based algorithms since 2008, more efforts are required to further improve their performance:
a) Providing the sufficient analysis for the control parameter settings;
b) Efficient strategies or mechanisms for the selections of the control parameters;
c) Employing heterogeneous search rules to enhance the performance of FA.
The light intensity varies with the distance monotonically and exponentially as,

$$I(r) = I_o e^{-\gamma r^2} \quad (6)$$

Where I_o is the original light intensity and γ is the light absorption coefficient.
As the firefly's attractiveness is proportional to the light intensity seen by adjacent fireflies, the attractiveness β of a firefly is defined as,

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$$\beta(r) = \beta_o e^{-\gamma r^2} \tag{7}$$

Where, βo is the attractiveness.

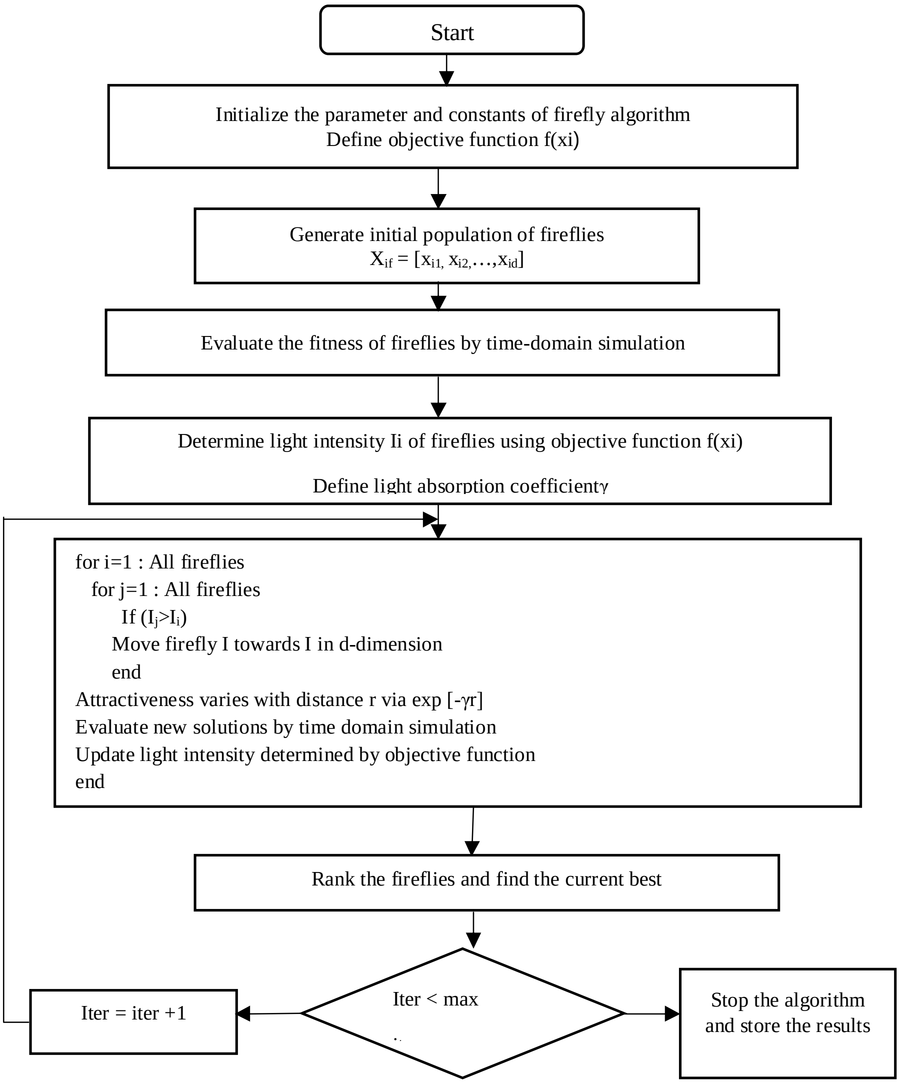

Fig. 3 Flowchart of Firefly Algorithm

The distance between any two fireflies Xi and Xj is expressed as Euclidean distance by the base firefly algorithm as,

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$$r_{ij} = ||x_i - x_j|| = \sqrt{\sum_{d=1}^{D}(x_{i,d} - x_{j,d})^2} \quad (8)$$

Where, d is the dimension of an optimization problem Xi and Xj are the best and current best of the fireflies rij is the randomization of fireflies.

V. RESULT AND DISCUSSION

The performance analysis of hybrid firefly algorithm using fuzzy PID controller is compared and result is discussed below. The simulation results of three area thermal power system is considered. The change infrequency and tie line power deviation in 3 areas thermal power system with respect totime is given. It is observed that hybrid Firefly Algorithm decreases maximum frequency and tie line power deviations. The result for the respective system are discussed below

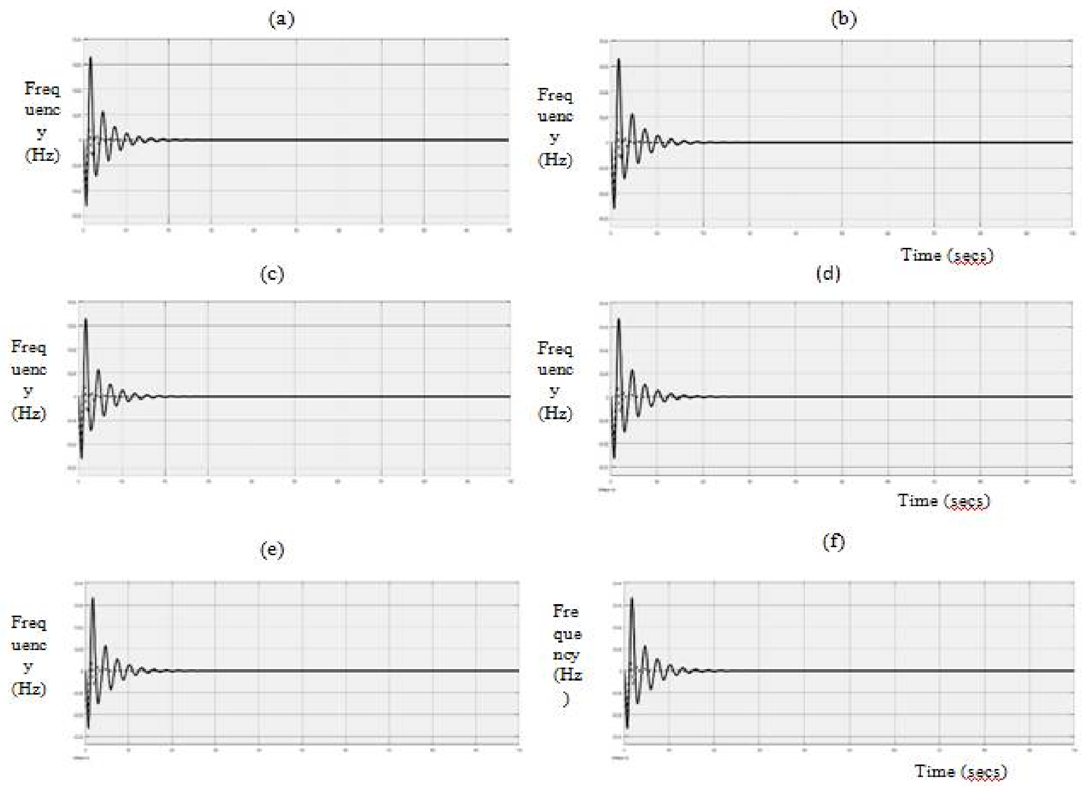

Fig. no. 3. Frequency and Tie line power deviation for (a) Area 1, (b) Area 2, (b) Area 3 without hybrid firefly algorithm and (d) Area 1, (e) Area 2, (f) Area 3 with hybrid firefly algorithm

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VI. TABULATION

From the given comparisons, it is observed that performance of change in frequency and tie line power deviation response of hybrid firefly algorithm gives better result compared with other algorithms. The tabulation for frequency and tie-line power deviations are given as follows,

Table. 1 Steady State Analysis of With and Without Firefly Algorithm

PARAMETER	WITHOUT FIREFLY ALGORITHM						WITH FIREFLY ALGORITHM					
	FREQUENCY			**TIE-LINE**			**FREQUENCY**			**TIE-LINE**		
	AREA 1	**AREA 2**	**AREA 3**	**AREA 1**	**AREA 2**	**AREA 3**	**AREA 1**	**AREA 2**	**AREA 3**	**AREA 1**	**AREA 2**	**AREA 3**
Peak under shoot	-0.026	-0.028	-0.028	-0.019	-0.019	-0.019	-0.026	-0.026	-0.026	-0.019	-0.019	-0.019
Settling time	36sec	34sec	31sec	19sec	22sec	29sec	26sec	24sec	27sec	9sec	11sec	10sec
Steady state error	-0.035	-0.037	-0.037	-0.003	-0.003	-0.003	-0.035	-0.035	-0.035	-0.002	-0.002	-0.002

VI. CONCLUSION

It is recognized that the load frequency control of multi area thermal power system results in maintaining frequency and tie line power deviation. Load Frequency control is a system to maintain reasonably uniform frequency, to divide the load between the generators and to control the tie line interchange schedules. The important constraints which affect the power system performance are time delay, reheat turbine, Generation Rate Constraint, and Governor Dead Band nonlinearity. The formulation of load frequency control in multi area system has been discussed and the solution

is obtained. An algorithm based on hybrid firefly algorithm optimization, which is a population-based optimization technique has been tested on multi area thermal power system for frequency and tie line power deviation. From the results obtained, it is observed that hybrid Firefly Algorithm achieves maximum frequency and tie line power deviation compared to other optimization techniques. It is found that result obtained from multi area power system using hybrid firefly algorithm gives better solution and it achieves 10 seconds.

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