Optimization of Aninterconnected Hydro Thermal Power System Using Firefly Algorithm For Load Frequency Control

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Abstract- In this paper, a recently proposed optimization method known as Firefly Algorithm (FA) is used to solve the Load Frequency Control (LFC) problem of an interconnected hydro thermal power system. A normal Proportional Integral (PI) controller is used for control purposes in each area of the system. The optimum gain values K_{Pi}, K_{Ii} of the controllers are determined using FA method of optimization. The result obtained using FA is cross verified against the results obtained using BAT algorithm in order to demonstrate that FA suits better for LFC.

Index Terms- BAT Algorithm, Firefly Algorithm, Load frequency Control (LFC), Proportional Integral (PI) controller.

I. INTRODUCTION

Load Frequency Control (LFC) is a control mechanism whose main aim is to maintain the change in frequency and tie line power change to zero. It is considered to be one of the most important ancillary services pertaining to the power system. It also continuously monitors the change in demand and in turn changes the generation to make generation and load demand equal.

Under steady state conditions the aggregate power generated by power stations is equivalent to the load and losses encountered by the system. Because of sudden advancement of generation-load mismatches, the frequency can wander off from itsnominal value and it is called as off-nominal frequency. Off-nominal frequency can specifically have drastic effect on power system operation and system dependability. An extensive frequency deviation can harm equipment, corrupt load performance, cause the transmission lines to be over-burden and can meddle with protection schemes,eventually prompting an unstable condition of power system.

So, whenever there is perturbation i.e. addition of a block of load to a normally operating system, power mismatch is observed in the system. This power mismatch is compensated in initial stages by extracting Kinetic Energy from the system. But, the extraction of Kinetic Energy causes a dip or fall in the system frequency. This is the reason why the ultimate result of load increase is the decline in system frequency.

LFC is not a recently encountered problem. Researchers have been addressing the problem for the past 30 years. But, they found fruitful results only in the past decade. It is because most of the researchers started integrating the LFC problem with optimization techniques in the past decade. Hence, the use of optimization techniques became a necessary thing for LFC.

Several optimization techniques have been proposed over the years for a two area power system. Some of them include Particle Swarm Optimization (PSO) [1], Bacteria Foraging optimization Algorithm (BFOA) [2], Emotional Learning based Intelligent Controller technique [3], Differential Evolution [4], Non-dominated Shorting Genetic Algorithm (NSGA-II) [5], BAT algorithm [6], Gravitational search Algorithm (GSA) [7], Artificial Bee Colony (ABC) [8] and so on. It is observed from the extensive literature review that using new optimization techniques is a default setting to get good outputs for LFC problem.

Firefly Algorithm is a recently proposed meta-heuristic optimization technique which has been developed by Yang [9-10]. It takes its inspiration from the flashing behaviour of fireflies. FA has recently been employed to obtain results for a non-linear and non-convex optimization problem [11-12] and the output of FA to the above problem was found to be better.

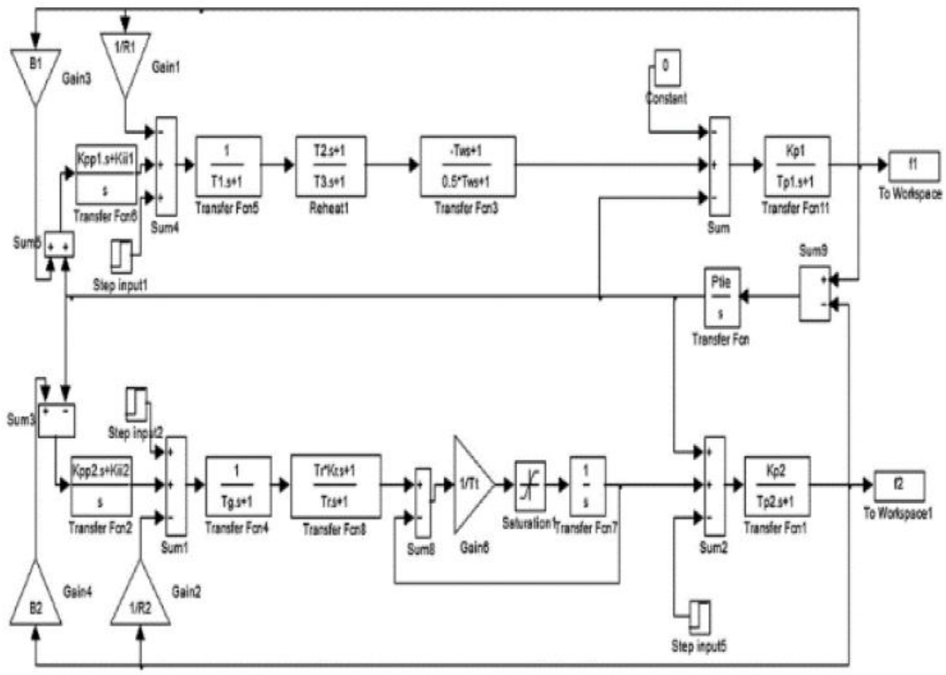

Fig. 1: Block Diagram of aninterconnected hydro thermal power system

Considering all the above discussions, an endeavour has been made in this paper to demonstrate the working of two area thermal power system using FA and show its superiority over BAT algorithm.

II. SYSTEM UNDER STUDY AND PROPOSED APPROACH

All the optimization techniques listed in the introduction [1-8] are used on power system consisting of two thermal areas with either a reheat turbine or a non-reheat turbine. None of the above mentioned optimization techniques have been implemented on an interconnected hydro thermal power system. Literature consists of only the use of Conventional controller [13], fuzzy logic controller [14] on an interconnected hydro thermal power system. Hence, the system shown in Fig.1 is considered as the system under study.

A normal PI controller is used for control purposes. The inputs to the controllers are the Area Control Errors (ACE) of each area and it is given as shown below:

$e_1(t) = ACE_1 = B_1 \Delta f_1 + \Delta P_{tie}$ (2.1)

$e_2(t) = ACE_2 = B_2 \Delta f_2 - \Delta P_{tie}$ (2.2)

whereB_1,$B_2$are the bias parameters for frequency, ΔF_1, $\Delta F_2$are the deviations in frequency and ΔP_{tie} is the tie-line power flow between the areas.

Integral of Time multiply Absolute Error (ITAE) is considered as the objective function. It is given as:

$J = ITAE = \int_0^{\infty} t(|\Delta f_1| + |\Delta f_2| + |\Delta P_{tie}|)dt$ (2.3)

Based on (2.3), the problem statement can be defined as minimize Jsubjected to the constraints:

$K_p^{min} \leq K_p \leq K_p^{max}, K_I^{min} \leq K_I \leq K_I^{max}$ (2.4)

III. FIREFLY ALGORITHM

Firefly Algorithm (FA) is a meta-heuristic optimization technique discovered by Yang [9]. Fireflies are portrayed by their glimmering light created by biochemical process called as bioluminescence. The blazing light may fill in as the fundamental romance signs for mating. It depends on the accompanying three glorified conduct of the blazing qualities of fireflies[10]:

1) All fireflies are unisex and are pulled in to different fireflies paying little mind to their sex.

2) The level of the attractiveness of a firefly is relative to its brightness. Their engaging quality is corresponding to their light intensity. In this way for any two glimmering fireflies, less bright firefly moves towards the brighter one. As brightness is relative to separation, more shine means less separation between two fireflies. On the off chance that any two glimmering fireflies have a similar shine, then they move arbitrarily.

3) The brightness of a firefly is controlled by the objective function to be optimized.

For appropriate outline of FA, two vital issues should be characterized: the change in light intensity (I) and the plan of attractiveness (β). The engaging qualities the attractiveness of a firefly is controlled by its light intensity or brightness and the brightness is related to the objective function. The light intensity I(r)shifts with the separationr as given below:

$I(r) = I_0 e^{-\gamma r}$ (3.1)

whereI_0 is the original is light intensity and γ is the light absorption coefficient.

As a firefly's engaging quality is corresponding to the light intensity seen by neighboring fireflies, the attractiveness of a firefly is characterized as:

$$\beta = \beta_0 e^{-\gamma r^2} \qquad (3.2)$$

where$\beta_0$is the attractiveness at r = 0.

The distance between any two fireflies $S_i$and $S_j$is defined as Euclidean distance and is given as:

$$r_{ij} = \|S_i - S_j\| = \sqrt{\sum_{k=1}^{k=n}(S_{ik} - S_{jk})^2} \qquad (3.3)$$

wheren denotes the dimensionality of the problem.

The movement of the i-th firefly also influences the movement of another more attractive fireflyj. The developments of fireflies comprise of three terms: the present position of i-th firefly, fascination in another more attractive firefly in order to facilitate the mating, and an arbitrary random walk.This random walk comprises of a randomization parameterα and the randomlyε_i created number from interval [0; 1].

Theabove development is communicated as:

$$S_i = S_i + \beta_0 e^{-\gamma r_{ij}^2}(S_i - S_j) + \alpha\varepsilon_i (3.4)$$

IV. SIMULATION RESULTS AND DISCUSIONS

Simulations were run using a computer with Intel 3rd generation i-5 processor with processing speed of 2.8 GHz and 4 GB RAM. The MATLAB software version used was R2015a. The controller values were finalized to lie in the range of -1.0 to 1.0. 5% step load was considered in both the areas while running both BAT algorithm and FA. The optimization was repeated 10 times for both the cases and the average of 10 controller values were chosen to be the best controller values. These values are as given in Table 1.

TABLE I. OPTIMIZED CONTROLLER GAINS

Controller	Controller gains
BAT Algorithm based PI Controller	K_{P1}= 0.512, K_{P2}= 0.124 K_{I1}= -0.164, K_{I2}= -0.15
FA Based PI controller	K_{P1}= -0.1310, K_{P2}= -0.3760 K_{I1}= -0.3730, K_{I2}= -0.3892

The better working of FA over BAT algorithm is shown by comparing the settling time of frequency of both the areas and tie line power flow between the areas for both the methods. This comparison is shown in Table 2.

TABLE II. COMPARISON OF SETTLING TIMES

Optimization Method		BAT	FA
Settling times (sec)	ΔF_1	19.59	9.72
	ΔF_2	20.64	13.21
	ΔP_{tie-12}	20.22	14.95

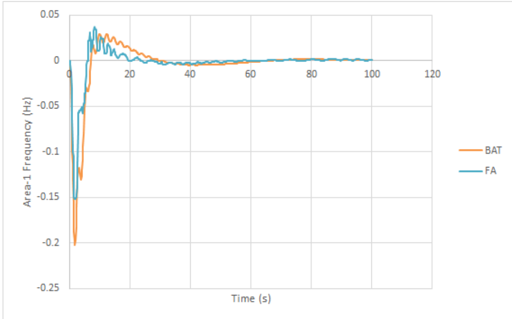

Fig. 2: Frequency deviation of Area-1

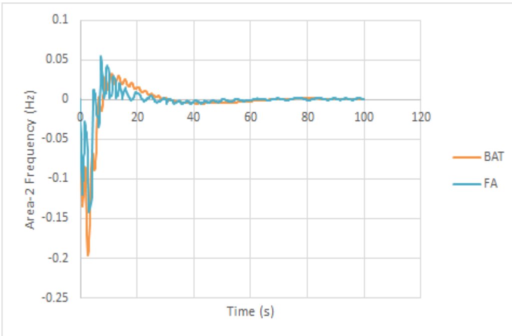

Fig. 3: Frequency deviation of Area-2

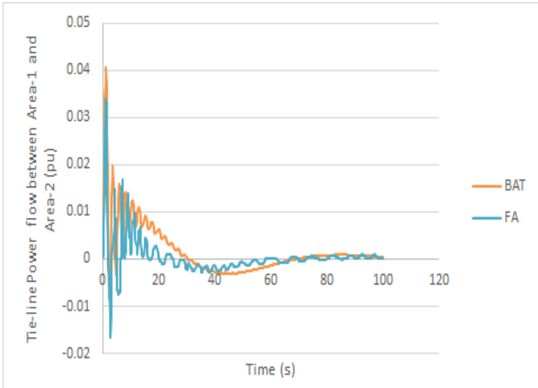

Fig. 4: Tie line power deviation between area 1 and area 2

From Fig. 2, Fig. 3 and Fig. 4, it can be inferred that FA has the capability to settle down faster than BAT algorithm. Not only that, the undershoot and overshoot in case of FA appears to be less than the BAT algorithm. Also, the ripples produced during settling in case of FA is comparitively less than that of BAT algorithm. Considered all of the above, it can be said that FA is better than BAT algorithm.

V. CONCLUSION

The performance of FA for an interconnected hydro thermal power system is presented in this paper. The integral of time multiplied absolute error of the frequency of both areas and tie linepower are taken as the objective function.Simulation results show that FA outperforms BAT algorithm. It also shows that FA has the ability to cope up with the system under study even with different controller parameters and physical constraints. The results of settling time obtained using

FA itself speaks for its robustness and better system performance. Besides its simple architecture, it has the potentiality of implementation in real time environment.

APPENDIX

The typical values of parameters of system under study areshown below:

T_1 = 0.6 s; T_2 =5s; T_3 =32s; T_W =1s;B_1 = 0.383 Pu MW/Hz; B_2 = 0.425 Pu MW/Hz; T_{P1} = 3.76 s;T_{P2} =20s; K_{P1} = 20 HZ/Pu MW; K_{P2} = 120 HZ/Pu MW; T_r =10s;T_g = 0.08 s; K_r = 0.5 Pu MW; R_1 = 3 Hz/Pu MW; R_2 = 2.4 Hz/Pu MW.

The parameters of BAT search algorithm are as follows:

β=γ=0.9; Maxgeneration= 100; Population size = 50;L_{min}= 0; L_0= 1; F_{min}= 0; F_{max}= 100.

The parameters of FA are as follows:

γ = 0.7; β = 0.9; γ =0.5; number of fireflies=5; maximum generation=100.

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