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RESEARCH ARTICLE

OPTIMIZATION OF AN INTERCONNECTED 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.

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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 its nominal 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, over burden the transmission lines 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) (Gozde, 2011), Bacteria Foraging optimization Algorithm (BFOA) (Ali, 2011), Emotional Learning based Intelligent Controller technique (Reza Farhangi, 2012), Differential Evolution (Rout, 2013), Non-dominated Shorting Genetic Algorithm (NSGA-II) (Sidhartha Panda, 2013), BAT algorithm (Ramesh Kumar, 2013), Gravitational search Algorithm (GSA) (Sahu, 2014), Artificial Bee Colony (ABC) (Haluk Gozde, 2012) 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 (Yang, 2008 and Yang, 2009). 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 (Yang, 2010 and Yang, 2012) and the output of FA to the above problem was found to be better. Considering all the above discussions, an endeavour

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has been made in this paper to demonstrate the working of an interconnected hydro thermal power system using FA and showcase its superiority over BAT algorithm.

Based on (2.3), the problem statement can be defined as Minimize J subjected to the constraints:

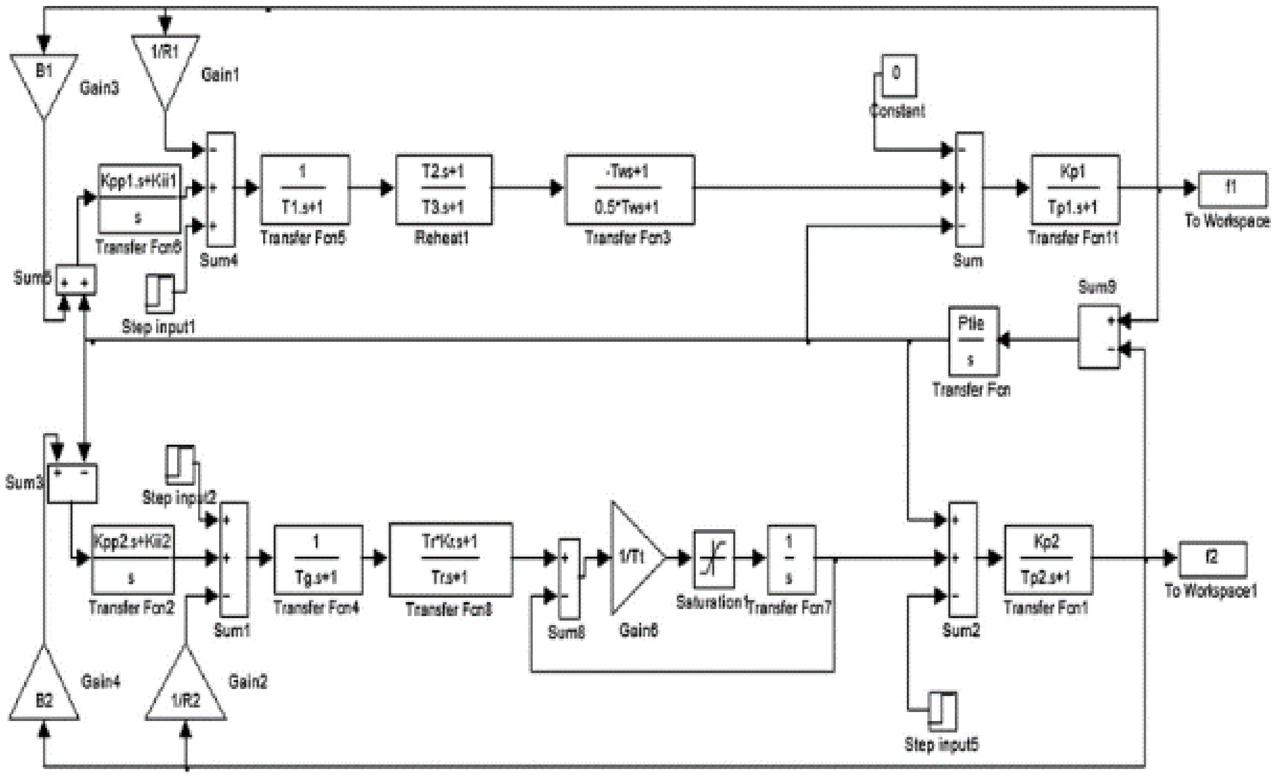

Fig. 1. Block Diagram of an interconnected hydro thermal power system

System under study and proposed approach

All the optimization techniques listed in the introduction (Gozde, 2011; Ali, 2011; Reza Farhangi, 2012; Rout, 2013; Sidhartha Panda, 2013; Ramesh kumar, 2013) 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 (Nanda, 2006), fuzzy logic controller (Sachin Khajuria, 2012) on an interconnected hydro thermal power system. Hence, an interconnected hydro thermal prower system as 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:

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

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

where B_1, B_2 are the bias parameters for frequency, ΔF_1, ΔF_2 are the deviations in frequency and ΔP_{tie} is the tie-line power flow between the areas.

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

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

$$K_p^{min} \le K_p \le K_p^{max}, K_I^{min} \le K_I \le K_I^{max} \quad \text{………..(2.4)}$$

Firefly Algorithm

Firefly Algorithm (FA) is a meta-heuristic optimization technique discovered by Yang (Yang, 2008) Fireflies are portrayed by their glimmering light created by a biochemical process called as bioluminescence. The blazing light may fill in as the fundamental romance sign for mating. It depends on the accompanying three glorified conduct of the blazing qualities of fireflies (Yang, 2009).

1) All fireflies are unisex and different fireflies are pulled nearer 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 value of attractiveness (β). The engaging quality i.e 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 separation r as given below:

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

where I_0 is the original 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:

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

where β_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:

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

where n denotes the dimensionality of the problem.

The movement of the i-th firefly also influences the movement of another more attractive firefly j. 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 parameter α and the randomly created number ε_i from interval [0, 1].

The above development is communicated as:

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

RESULTS AND DISCUSSION

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 1. 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 2. Comparison of settling times

Optimization Method		BAT	FA
Settling times (sec)	ΔF_1	19.59	9.72
	ΔF_2	20.64	13.21
	$\Delta P_{tie\text{-}12}$	20.22	14.95

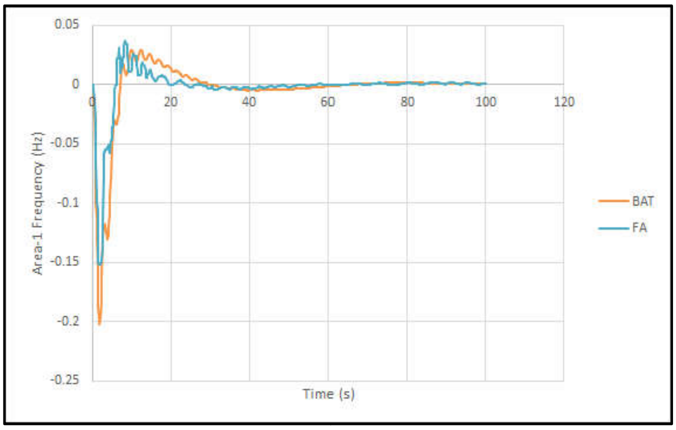

Fig. 2. Frequency deviation of Area-1

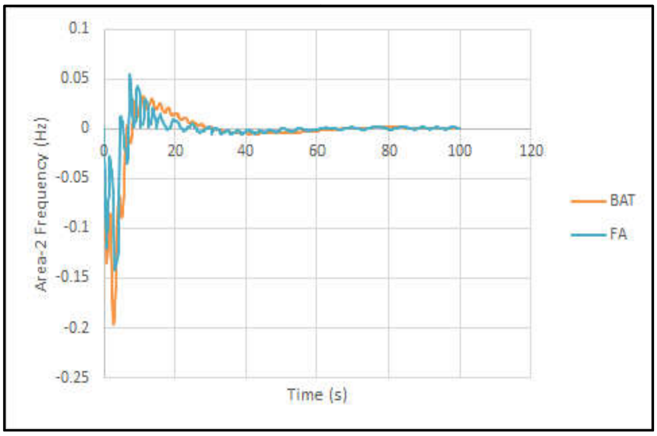

Fig. 3. Frequency deviation of Area-2

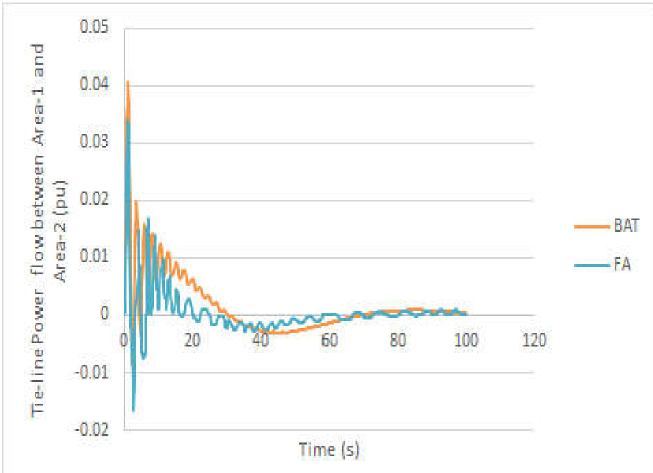

Fig. 4. Tie line power deviation between area 1 and area 2

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.

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 line power 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 are shown 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; Max generation = 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.

REFERENCES

Ali, E.S. and S.M. Abd-Elazim, 2011. "Bacteria foraging optimization algorithm based load frequency controller for interconnected power system", *Electrical Power and Energy Systems* 33. 633–638.

Gozde, H. and M. C. Taplamacioglu, 2011. "Automatic generation control application with craziness based particle swarm optimization in a thermal power system," *Int. J. Elect. Power & Energy Systems*, vol. 33, pp. 8-16.

Haluk Gozde, M. Cengiz Taplamacioglu, and Ilhan Kocaarslan, 2012. "Comparative performance analysis of Artificial Bee Colony algorithm in automatic generation control for interconnected reheat thermal power system", *Electrical Power and Energy Systems,* 42. 167–178.

Nanda, J. Mangla, A. and Suri, S. 2006. "Some findings on automatic generation control of an interconnected hydrothermal system with conventional controllers," *IEEE Trans. Energy Conversion*, vol. 21, pp. 187-193.

Ramesh Kumar, S., Ganapathy, S. 2013. "Design of Load Frequency Controllers for Interconnected Power Systems with Superconducting Magnetic Energy Storage Units using Bat Algorithm", *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, Volume 6, Issue 4 (Jul. - Aug), PP 42-47.

Reza Farhangi, Mehrdad Boroushaki, Seyed Hamid Hosseini, 2012. "Load–frequency control of interconnected power system using emotional learning-based intelligent controller", *Electrical Power and Energy Systems* 36 76–83.

Rout, U. K., Sahu, R. K. and Panda, S. 2013. "Design and analysis of differential evolution algorithm based automatic generation control for interconnected power system," *Ain Shams Engineering Journal*, vol. 4, pp. 409-421.

Sachin Khajuria, Jaspreet Kaur, "Load Frequency Control of Interconnected Hydro-Thermal Power System Using Fuzzy and Conventional PI Controller", *International Journal of Advanced Research in Computer Engineering & Technology (IJARCET)* Volume 1, Issue 8, October 2012.

Sahu, R. K., Panda, S. and Padhan, S. 2014. "Optimal gravitational search algorithm for automatic generation control of interconnected power systems," *Ain Shams Engineering Journal*, vol. 5, pp. 721-733.

Sidhartha Panda, Narendra Kumar Yegireddy, 2013. "Automatic generation control of multi-area power system using multi-objective non-dominated sorting genetic algorithm-II", *Electrical Power and Energy Systems* 53 54–63.

Yang, X. S. 2008. *Nature-Inspired Metaheuristic Algorithms,* Luniver Press, UK.

Yang, X. S. 2009. "Firefly algorithms for multimodal optimization, in: stochastic algorithms: foundations and applications," *Lecture Notes in Computer Sciences,* vol. 5792, pp. 169-178.

Yang, X. S. 2010. "Firefly algorithm, stochastic test functions and design optimization," *International Journal of Bio-inspired Computation,* vol. 2, pp. 78-84.

Yang, X. S., Hosseini, S. S. S. and Gandomi, A. H. 2012. "Firefly algorithm for solving non-convex economic dispatch problems with valve loading effect," *Applied Soft Computing,* vol. 12, pp. 1180-1186.

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