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Optimization of LFC using Bacteria Foraging Optimization Algorithm

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Abstract: This Paper tries to explore the potential of using artificial intelligence method in controllers and their advantages over conventional methods. Intelligent control techniques are of great help in implementation of AGC in power systems. Today's power systems are more complex and require operation in uncertain and less structured environment. Consequently, secure, economic and stable operation of a power system requires improved and innovative methods of control. This Paper asserts that the conventional approach of controller tuning is not very efficient due to the presence of non-linearity in the system of the plant. Whereas intelligent control techniques provide a high adaption to changing conditions and have ability to make decisions quickly by processing imprecise information. Some of these techniques are rule based logic programming model based reasoning, computational approaches like fuzzy sets, artificial neural networks, evolutionary programming and genetic algorithms. In this paper work, the bacterial foraging Optimization (BFO) technique has been used for LFC of interconnected power systems.

Keywords: Bacterial Foraging Optimization, Automatic Generation Control, Load Frequency Control, Integral controller, Area Control Error

Nomenclature

Δ	The deviation
S	Laplace domain derivative term
f	Frequency
ω	Angular speed
$K_{p1,2,3}$	Generator Gain Constant
$T_{p1,2,3}$	Generator Time Constant
P_t	Turbine Output Power
T_t	Turbine Time Constant
P_g	Governor Output Power
T_g	Governor Time Constant
T_{ij}	Tie Line Coefficient
$K_{i1,2,3}$	Integral Controller Gains
a_{ij}	Operator
B_i	Bias Factor
P_{ref}	The Output Of ACE
P_l	Electric Load Variations
R	Regulation Parameter
ACE	Area Control Error

I. Introduction

In actual power system operations, the load is changing continuously and randomly. As a result the real and reactive power demands on the power system are never steady, but continuously vary with the rising or falling trend. The real and reactive power generations must change accordingly to match the load perturbations. Load frequency control is essential for successful operation of power systems, especially interconnected power systems [1]. Without it the frequency of power supply may not be able to be controlled within the required limit

band. To accomplish this, it becomes necessary to automatically regulate the operations of main steam valves in accordance with a suitable control strategy, which in turn controls the real power output of electric generators. Thus the main objective of the power system is to maintain continuous supply of power with an acceptable quality, to all the consumers in the system. In case of an interconnected power system having two or more areas connected through tie lines, each area supplies its control area and tie lines allow electric power to flow among the areas. However, a load perturbation in any of the areas affects output frequencies of all the areas as well as the power flow on tie lines. Hence the control system of each area needs information about transient situation in all the other areas to restore the nominal values of area frequencies and tie line powers. The information about each area is found in its output frequency and the information about other areas is in the deviation of tie line powers. For example, for a two area interconnected power system, this information is taken as

$$B_i \Delta f_i + \Delta P_{tie} \dots (i = 1, 2) \quad (1.1)$$

Where, B = tie line frequency bias, f = nominal frequency, P_{tie} = tie line power

Equation 1.1 refers the area control error (ACE) and the same is fed as input to the integral controller of corresponding area. Thus an AGC scheme for an interconnected power system basically incorporates suitable control system, which can bring the area frequencies and tie line powers back to nominal or very close to nominal values effectively after the load perturbations. A lot of literature is available on load frequency control of isolated and interconnected electrical power systems. Literature shows that Concordia et al studied effect of speed governor dead band on tie-line power and frequency control performance [2]. Elgerd and Fosha [3] developed a dynamic system model of the multiarea electric energy system. This system is suitable for the study of the megawatt-frequency control problem. Concordia and Kirchmayer [4],[5],[6] have analyzed the AGC problem of two equal area thermal, hydro and hydro-thermal systems. Bohn and Miniesy [7] have studied the optimum LFC of a two-area interconnected power system by making the use of i) differential approximation and ii) a Luenberger observer and by introducing an adaptive observer for identification of unmeasured states and unknown deterministic demands, respectively. Automatic Generation Control is an ancillary service which plays an important role in the power system. It maintains the tie line power and scheduled system frequency during normal operating condition and also during small perturbation. Also a very effective work is done by Hadi Sadat on LFC and other issues relating to power systems using MATLAB software. The last lap of twentieth century has witnessed many research articles relating to power system control schemes based on intelligent techniques to overcome the drawbacks of the existing schemes.

II. Bacteria Foraging Optimization

As other swarm intelligence algorithms, Bacteria Foraging Optimization Algorithm (BFOA) is based on social and cooperative behaviors found in nature. The Bacterial Foraging Technique proposed by K.M. Passino [8]. This technique is based on the foraging behavior of the e.coli bacteria. The e.coli bacteria present in the human intestine. In fact, the way Bacteria look for regions of high levels of nutrients can be seen as an optimization process. Bacteria search for nutrients in a manner to maximize energy obtained per unit time. Individual bacterium also communicates with others by sending signals. A bacterium takes foraging decisions after considering two previous factors. The process, in which a bacterium moves by taking small steps while searching for nutrients, is called chemo taxis and key idea of BFOA is mimicking chemo tactic movement of virtual bacteria in the problem search space. They perform different functions such as chemo taxis, swarming, reproduction, and elimination and dispersal. In the chemo taxis a tumble followed by swim. Initially the e.coli bacteria measure the food concentration and then tumble to take a random direction and swim for a fixed distance. One step of chemo taxis is the combination of tumble and swim. Swarming means to work in a group. When one e.coli bacterium search nutrients, it can tell others in the group where the nutrients are. In reproduction stage least healthy bacteria will die out and the other healthiest bacteria will split into two bacteria. The no. of population is same in whole process. Furthermore, in elimination and dispersal step, events can occur such that all the bacteria in a region are killed or a group is dispersed into a new part of the environment.

A. Algorithm of Bacterial Foraging

Step 1 Initialization

1. Number of parameters (p) to be optimized;
2. Number of bacteria (S) to be used for searching the total region;
3. Swimming length (N_s) after which tumbling of bacteria will be undertaking in a chemo tactic loop;
4. N_c the number of iterations to be undertaken in a chemo tactic loop ($N_c > N_s$)
5. N_{re} the maximum number of reproduction to be undertaken;
6. N_{ed} the maximum number of elimination and dispersal events to be imposed over the bacteria;
7. P_{ed} the probability with which the elimination and dispersal will continue;

8. The location of each bacterium $P(1-p, 1-S, 1)$ which is specified by random numbers on $[1, 1]$;
9. The value of $C(i)$ which is assumed to be constant in our case for all of the bacteria to simplify the design strategy the values of $d_{attract}$, $w_{attract}$, $h_{repellent}$ and $w_{repellent}$.

Step 2 Iterative Algorithms for Optimization

This section models the bacterial population chemo taxis, swarming, reproduction, elimination, and dispersal (initially, $j = k = l = 0$). For the algorithms, updating θ^i automatic results in updating "P".

Step 1) Elimination -dispersal loop $l = l + 1$.

Step 2) Reproduction loop $k = k + 1$.

Step 3) Chemo taxis loop $j = j + 1$.

a) For $i = 1, 2, \dots, S$, calculate the cost function value for each bacterium as follows:

- Compute the value of cost function $J(i, j, k, l)$.

Let $J_{sw}(i, j, k, l) = J(i, j, k, l) + J_{cc}(\theta^i(j, k, l), P(j, k, l))$ (i.e., add on the cell-to-cell attractant effect for swarming behavior).

- Let $J_{last} = J_{sw}(i, j, k, l)$ to save this value since we may find a better cost via a run.

- End of for loop

b) For $i = 1, 2, \dots, S$, take the tumbling/swimming decision

- Tumble: Generate a random vector $\Delta(i) \in \mathbb{R}^p$ with each element $\Delta_m(i)$ $m = 1, 2, \dots, p$, a random number on $[1, 1]$.

- Move: let $\theta^i(j+1, k, l) = \theta^i(j, k, l) + C(i) \frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}}$, the fixed step size in the direction of tumble for

bacterium is considered.

- Compute $J(i, j+1, k, l)$ and then let $J_{sw}(i, j+1, k, l) = J(i, j+1, k, l) + J_{cc}(\theta^i(j+1, k, l), P(j+1, k, l))$

- Swim:

(i) let $m = 0$; (counter for swim length);

(ii) While $m < N_s$ (have not climbed down too long).

- let $m = m + 1$

- If $J_{sw}(i, j+1, k, l) < J_{last}$ (if doing better), let $J_{last} = J_{sw}(i, j+1, k, l)$ and let

$\theta^i(j+1, k, l) = \theta^i(j, k, l) + C(i) \frac{\Delta(i)}{\sqrt{\Delta^T(i)\Delta(i)}}$ and use this $\theta^i(j+1, k, l)$ to compute the new

$J(i, j+1, k, l)$.

- Else, let $m = N_s$. This is the end of the while statement.

c) go to the next bacterium $(i+1)$ if $i \neq S$ (i.e., go to b) to process the next bacterium.

Step 4) If $j < N_c$, go to Step 3). In this case, continue chemo taxis since the life of the bacteria is not over.

Step 5) Reproduction

a) For the given k and l , and for each $i = 1, 2, \dots, S$, let $J_{health}^i = \min_{j \in \{1 \dots N_c\}} \{J_{sw}(i, j, k, l)\}$ be the health of the bacterium i (a measure of how many nutrients it received over its lifetime and how successful it is at avoiding noxious substances). Sort bacteria in order of ascending cost J_{health} (higher cost means lower health).

b) The $S_r = S/2$ bacteria with the highest J_{health} values die and other S_r bacteria with the best value split (and the copies that are made are placed at the same location as their parent).

Step 6) If $k < N_{re}$, go to 2. In this case, we have not reached the number of specified reproduction steps, so we start the next generation in the chemo tactic loop.

Step 7) Elimination dispersal: For $i = 1, 2, \dots, S$, with probability P_{ed} , eliminate and disperse each bacterium (this keeps the number of bacteria in the population constant) to a random location on the optimization domain.

III. Problem Statement of the work

The objective in this paper is to find a systematic tuning procedure using BFO for load frequency control. The large-scale power systems are normally composed of control areas (*i.e. multi-area*) or regions representing coherent groups of generators. The various areas are interconnected through tie-lines. The tie-lines are utilized for contractual energy exchange between areas and provide inter-area support in case of abnormal conditions. Without loss of generality we shall consider a two-area case connected by a single line as illustrated in Figure 2. The concepts and theory of two-area power system is also applicable to other multi-area power systems *i.e.* three-area, four-area, five-area etc.

Figure 2 Two interconnected control areas (single tie line)

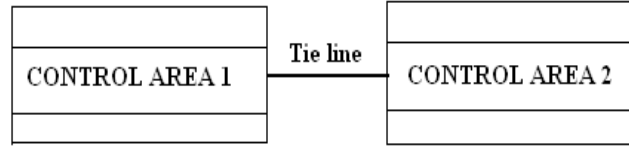
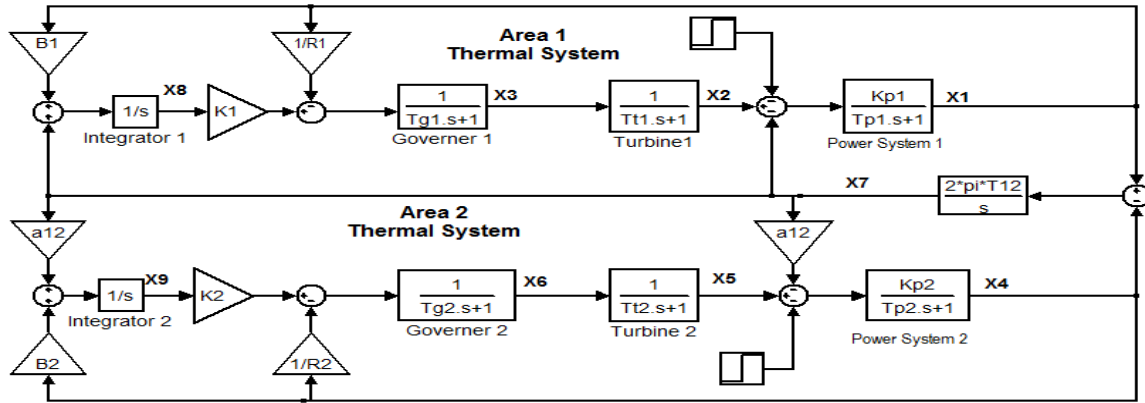


Figure 3: Transfer function model of two-area Thermal-Thermal system



Simulations Model performed with no controller, with integral controller. BF based integral controller is applied to two-area electrical power system by applying 0.01 p.u. step load disturbance to area 1. Figure 3 to Figure 5 show the dynamic responses of frequency deviations in two areas (*i.e.*, Δf_1 and Δf_2) and the tie line power deviation (ΔP_{tie}) for the two area Thermal-Thermal power system for sample values of area load disturbances ($d1 = 0.01$ p.u.). These figures show the performance of BF based integral controller trained with full state feedback in comparison with open loop and integral controllers on same scale.

Figure 3: Shows Δf_1 of two-area Thermal-Thermal Power System with Open loop, with conventional controller and With BF based integral controller

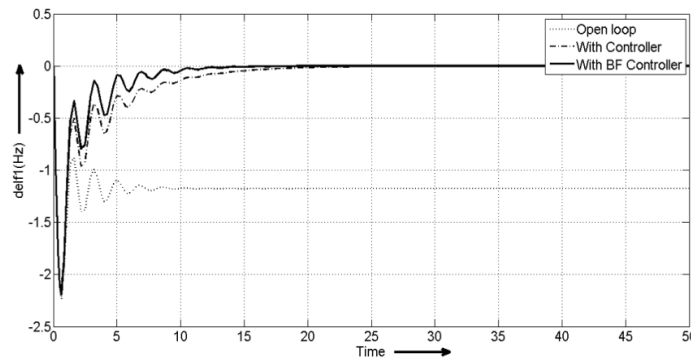


Figure 4: Shows Δf_2 of two-area Thermal-Thermal Power System with Open loop, with conventional controller and With BF based integral controller

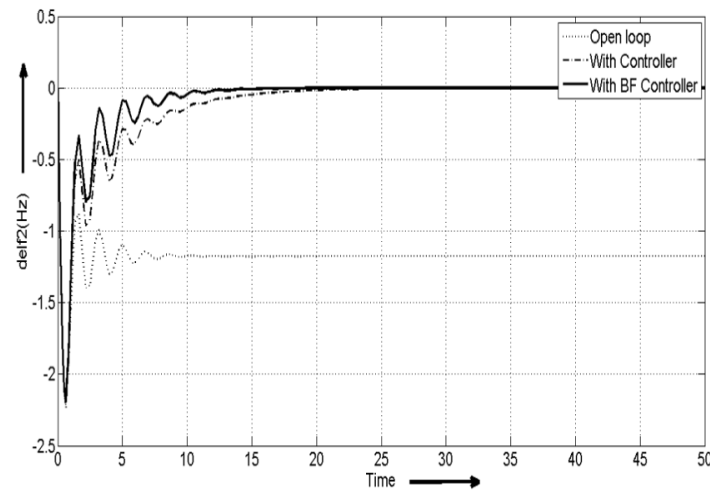


Figure5: Shows ΔP_{tie1-2} of two-area Thermal-Thermal Power System with Open loop, with conventional controller and With BF based integral controller

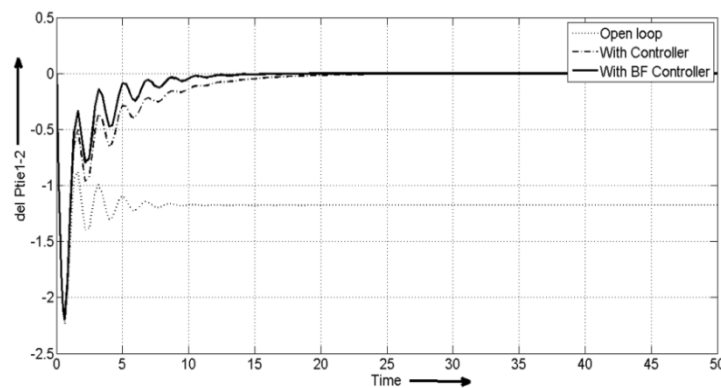


Figure 3 to Figure 5 shows the dynamic responses of two-area Thermal-Thermal system. Three graphs are showing in one graph, without controller, with controller and with BF based integral controller. These graph concluded that BF based integral controller give less settling time and low peak overshoot.

The overall results without controller, with integral controller and with BF based integral controllers applied to two-area Thermal-Thermal power system are summarized in Table-1. It shows that the settling time (T_s) in case of BF based integral controller is better than the conventional integral controller

Table-1: Settling Time and Peak Overshoot of Two-area Thermal-Thermal system

	Settling Time			Peak Overshoot		
	delf1	delf2	Ptie 12	delf1	delf2	Ptie 12
With controller	20s	20s	23s	-1.65438 s	-1.65438 s	-1.65438 s
With BF controller	14s	14s	14s	-1.64024 s	-1.64024 s	-1.64024 s

IV. CONCLUSIONS

BFO Algorithm emerged as a possible solution for many search and optimization problems. BFO may be viewed as an evolutionary process where in the population of feasible solutions to the optimization problem

evolves over a sequence of iterations. Today several papers have been written on the applications of BFO. It is a true metaheuristic, with dozens of application areas. It can be well applied for getting optimized value of K_p , K_i & K_d which provide good tuning of controllers. Simulation are carried out using MATLAB to get the output response of the system. In the proposed method, As graph shows Bacterial Foraging Controller gives better result as compare to conventional controller. Our goal in the end is to design a control system that serves the power network for better performance and better power services in terms of consumption and supplement.

V. FUTURE SCOPE

Bacterial Foraging Algorithms are little understood because the iterations through generation are difficult to model by known analytical techniques. Although some probabilistic analyses were made and theoretical literatures were proposed to explain the optimization formulation process, no clear and insightful analytical techniques yet exist that can explain rigorously the convergence of Bacterial Foraging optimization algorithms or how many iterations are required to obtain the optimal solution or a solution within some predefined infinitesimally close range of globally solution. Bacterial Foraging optimization algorithms have been used successfully to solve numerous different problems. In future, BFOs will prove to be a general purpose powerful heuristic method for solving a wider class of engineering and scientific problems. Bacterial Foraging optimization has captured the imagination by showing how complex behavior can arise from simple deterministic equations.

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Biography



Rita Saini born in Ambala Cantt in India, September 6th, 1982. She completed her Diploma in Electronics and Communication from Government Polytechnic For Women, Sirsa, Haryana (India) in 2002. She graduated (B. Tech.) in Electronics and Communication from Haryana Engineering College, Jagadhri, Haryana (India) in 2005. She completed Post Graduation (M. E.) in Instrumentation & Control from Deenbandhu Chhotu Ram University of Science & Technology (DCRUST), Murthal, Haryana (India) in 2008. She is pursuing research in the field of Intelligent Control from Rajasthan Technical University, Kota, Rajasthan (India). Presently, she is working as Lecturer in the Department of Electronics & communication Engineering at S.D. Institute of Technology & Management, Israna, Haryana (India). Her field of interest includes in Soft-Computing, Intelligent Control Techniques.



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