Automatic Generation Control of Two Area Power System using Modified Bacteria Foraging Algorithm

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Abstract –This paper investigates the design, modeling and performance analysis of a proportional integral (PI) controller which is incorporated with a two area power system. This design problem of automatic generation control (AGC) has been formulated in an optimization framework. Modified bacteria foraging algorithm (MBFA) is implemented to find the optimally tuned controller parameter which can accomplish the operational objectives i.e. minimization of settling time, peak overshoot and integral square error (ISE).

Index Terms – Two area power system, AGC, MBFA.

1. INTRODUCTION

Maintaining the power system frequency at a constant value is given utmost importance for the health of power generating equipment and also utilization of equipment at consumer's end. Due to small disturbances like imbalance between generation and load or large disturbance like loss of large generator or load, if the generated active power becomes less than the power demand, the frequency of generating units tends to decrease and vice versa. This results in deviation of system frequency [1] from its nominal value which is undesirable. A substantial drop in system frequency may result in high magnetizing currents in ac motors and transformers. The other problem for interconnected power system is power exchange among control areas which may result in frequency deviation from its nominal one. To damp out the frequency deviation quickly and to keep the tie-line power at its scheduled value, a control mechanism was required. This mechanism should perform a continuous real-time check to adjust the power generation economically with active focus on frequency control. The design of control system for each generating unit must control the system frequency and tie-line power flow between different control areas of an interconnected power system. As power demand cannot be forecasted accurately, hence a power mismatch between generation and load is inherently present in the system. In this context, a control mechanism i.e. AGC [2] was developed which can (i).monitor continuously the power deviation, (ii). take appropriate action to minimize the deviation, (iii). hold the frequency very close to the specified nominal value against any load change and (iv). Maintain the correct value of interchange power between control areas. For achieving these operational objectives, the design and parameter tuning of the controller needs to be done in an intelligent manner. In this context, the present work has demonstrated the implementation of MBFA in obtaining the optimum controller parameter which can operate the two area power system in a frequency secure manner.

2. RELATED WORK

AGC has been the area of exhaustive exploration by researchers across the globe for its efficient execution in ensuring the frequency stability of complex power system infrastructure. An initial attempt in the area of AGC was carried out in controlling the frequency deviation of power system via a flywheel governor/primary control [3] of synchronous machine. Though it is a fast acting controller, still was not sufficient to control the frequency deviation at the instant application of load demand. Therefore, it was apprehended that a supplementary action/secondary controller (i.e. load frequency controller) must be required for achieving the stable speed control mechanism. This concept constitutes the classical approaches to the AGC of power system. The secondary controller makes use of combination of proportional (P), Integral (I) and derivative (D) control action which needs to be intelligently tuned to achieve the desired operational objective. Authors in [4] have implemented jaya algorithm in tuning the controller in a single objective problem using analytic hierarchy process. Application of PI-PD cascade control to multi area interconnected thermal power system using flower pollination algorithm is done in [5]. Investigation of the effect of RF battery in AGC of two area restructured thermal power system has been done by authors in [6]. They have designed an optimal AGC regulator which makes use of performance index minimization approach. In [7], AGC of a two-area multi-source power system interconnected via AC/DC parallel links under restructured power environment is proposed. The design of a novel fuzzy PID controller for AGC of a two unequal area interconnected thermal system using teaching learning based optimization algorithm (TLBO) has been demonstrated in [8].

Application of grey-wolf-optimization (GWO) algorithm to AGC of multi area solar thermal power system [9] is presented by authors. It reveals that, with GWO optimized schedule the system performance is improved in term of less settling time, reduced peak over shoot and reduced oscillations. In order to demonstrate the rapid convergence characteristics, authors in [10] have implemented quasi-oppositional harmony search algorithm to AGC of two area power system.

3. PROPOSED MODELLING

3.1. FITNESS FUNCTION FORMULATION

The considered system is a two unequal area thermal system in which the capacity ratio of area1:area2 is 1:2. Thermal systems are modeled with generation rate constraints (GRC) of 3% per minute. The system is developed with single reheat turbine and integral controllers. The fitness function [9] to be optimized is the ISE . Mathematically it is formulated as

$$F = \int_0^t \{(\Delta f_i)^2 + \left(\Delta P_{tie\ i-j}\right)^2\} dt \quad (1)$$

Where i, j are the area number and i≠j.

Δf_i is the frequency deviation in the area.

ΔP_{tie} is the tie line power deviation between area1 and area2.

Due to the exceptional performance of PI controller even during continuously varying circumstances, in this work it is implemented as a secondary controller.

Area control error (ACE) is the input given to the supplementary controller which is expressed as

$$ACE_1 = B_1 \Delta f_1 + \Delta P_{tie} \quad (2)$$

$$ACE_2 = B_2 \Delta f_2 + \propto_{12} \Delta P_{tie} \quad (3)$$

In the above expression,

B_1, B_2 are the frequency bias factors for area 1 and area 2 respectively.

$\Delta f_1, \Delta f_2$ are the frequency deviation in area 1 and area 2 respectively.

3.2. IMPLEMENTATION OF OPTIMIZATION TECHNIQUES.

3.2.1. Modified Bacteria Foraging Algorithm.(MBFA)

Bacteria Foraging Algorithm,(BFA) is based on the searching of nutrient rich locations in human intestines by *E. coli* bacteria. The algorithm is based on the principle that natural selection tends to eliminate animals with poor foraging strategies compared to others and favour those having flourishing foraging strategies. During the process of evolution, bacteria having poor foraging strategies are either eliminated or mutated into better ones. The foraging strategy of *E. coli* bacterium is governed by four processes, namely, chemotaxis, swarming, reproduction, and elimination-dispersal. Some modifications are introduced inside the chemotaxis and swarming stages which considerably improves the performance of BFA. Those can be defined as follows.

For a minimization problem, MBFA avoids taking average of all the chemotactic stage cost functions during the chemotactic stage. Instead, the minimum value of cost function obtained for each bacterium during this stage, is retained before sorting is done for reproduction.

For swarming, the distances of all the bacteria in a new chemotactic stage is evaluated from the optimum bacterium till that point of solution and not by considering the distances of all the bacteria from rest others as suggested in.

With these modifications, MBFA has been developed. Procedural details of MBFA may be referred from [11-13].

3.2.2. Ant Colony Optimization Algorithm (ACO)

ACO is an evolutionary meta-heuristic algorithm [14] inspired by the foraging behaviour of ants. The principal inspiration of ACO is to mould the problem as the search for a minimum cost passageway in a graph. Artificial ants move all the way through this graph and stumble on good paths. Better paths are obtained as the sprouting outcome of the global cooperation among ants in the colony. Naturally, an ant deposits pheromone while walking. It probabilistically prefers to follow a direction which enhances pheromone. This behavior can be explained as finding of the shortest path by the ants. More specifically an ACO algorithm is the interaction of three procedures: Construction of ants' solutions, updating of pheromones, and daemon actions. The main procedure of the ACO manages the scheduling of these three above-mentioned components of ACO algorithms via the Schedule Activities construct: i.e. (a) Management of the ants' activity, (b) pheromone updating, and (c) daemon actions. The pseudo code and the details of the techniques may be obtained from [14].

4. RESULTS AND DISCUSSIONS

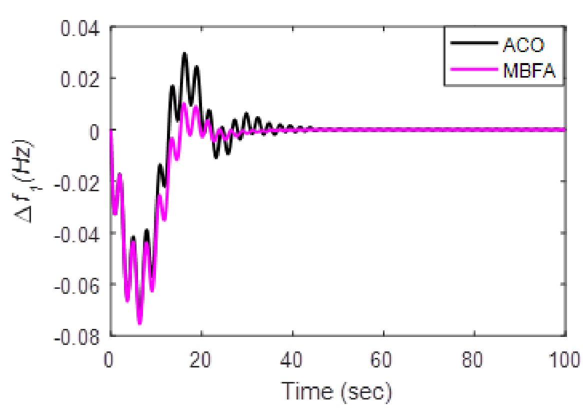

Fig.1. Frequency deviation in area 1 versus time

The block diagram representation of two area power system considered in the work is given in the Appendix.

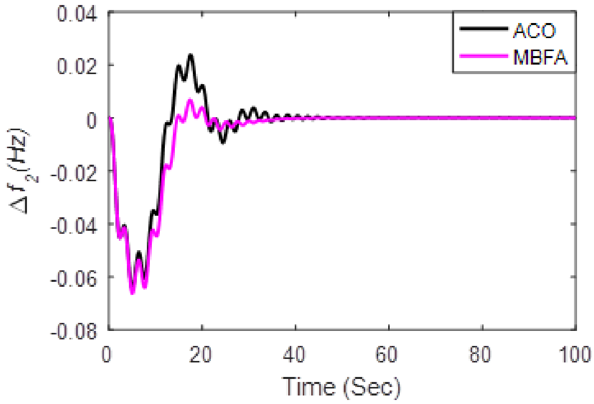

Fig.2. Frequency deviation in area 2 versus time

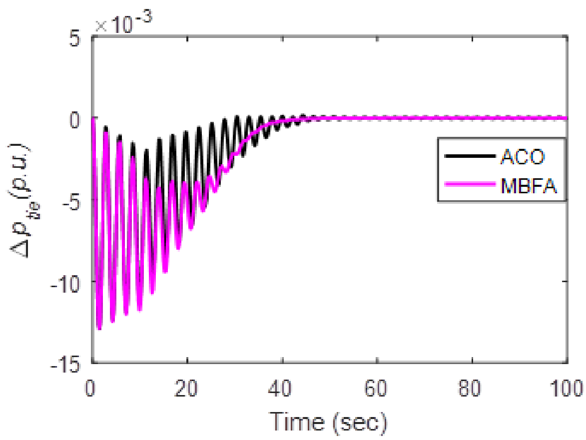

Fig.3. Deviation in tie line power connecting area1 and area2 versus time

The frequency deviation in area-1 and area-2 are shown in fig.1 and fig.2 respectively. Similarly, the tie-line power deviation using MBFA and ACO is presented in Fig.3. From these, the superiority of MBFA in terms of getting a faster response, less settling time and less overshoot as compared to ACO is demonstrated. The numerical analysis of the above results may be portrayed as below..

- From Fig.1 and Fig.2, the frequency variation in area-1and area-2 using MBFA is settled after 40 seconds each while that using ACO has taken 55 sec and 58 sec respectively.
- From Fig.1 and Fig.2, the peak overshoot area-1and area-2 using MBFA is found to be 0.0101Hz and0.0068 Hz respectively while that using ACO is found to be 0.0296 Hz and 0.0237 Hz respectively.
- From Fig-3, it may be depicted that the tie line power deviation using MBFA reached to steady state value after 48 sec while that with ACO has settled nearly at 60 sec.

All these details clearly demonstrate the efficacy of MBFA compared to ACO in achieving the different operational objectives.

5. CONCLUSION

In this work the tuning of PI controller for AGC of two area power system using MBFA is depicted. To test the effectiveness and supremacy of the optimization technique, it is compared with an competent meta- heuristics technique .i.e. ACO. In this context, the performance parameters associated with individual areas and the line joining both the area are evaluated and compared. In all these results, the superiority of MBFA was observed. From this a notion may be drawn that MBFA can be used as a decision supporting tool for operational analysis of real time interconnected power system.

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APPENDIX.

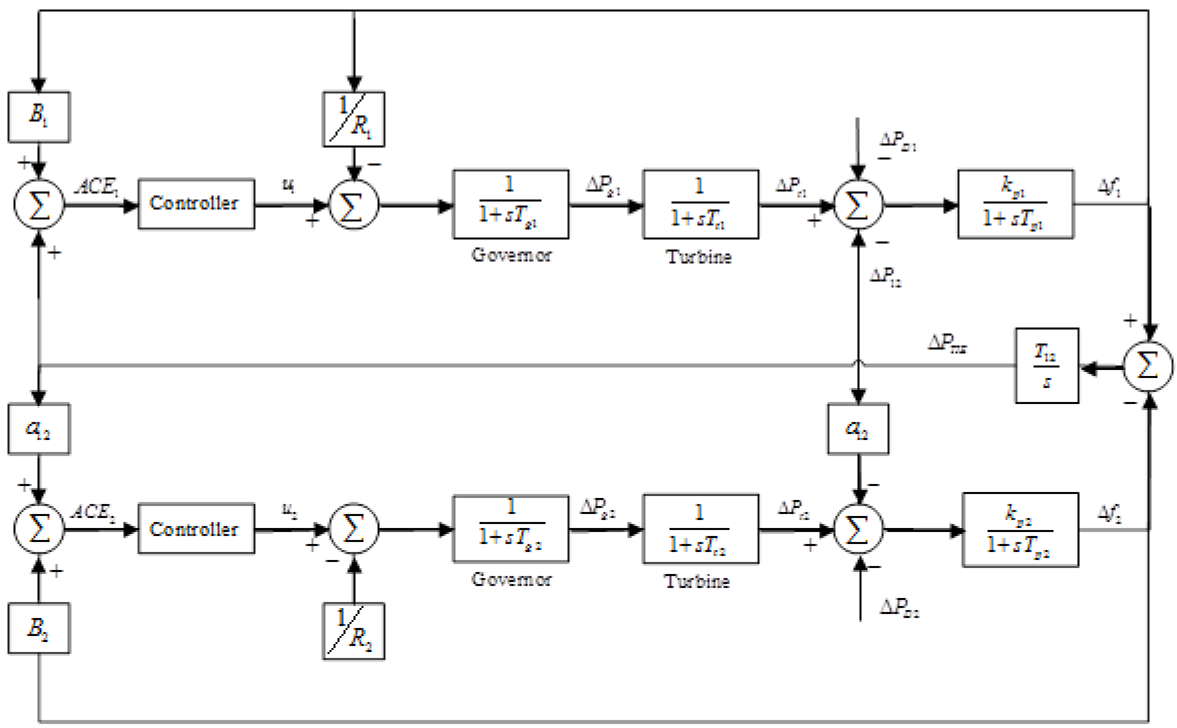

Figure.A.1. Block diagram representation of two area interconnected power system

Parameters Used.

Power rating of the system *Pr* = 2000 MW;

Nominal loading *Pl* = 1000 MW;

System frequency *f* = 60 Hz;

B_1, B_2 = 0.045 MW/Hz ;

R_1, R_2 = 2.4 Hz/p.u.;

Tg_1, Tg_2=0.08 s;

Tt_1, Tt_2=0.3 s;

Kp_1, Kp_2 = 120 Hz/p.u. MW;

Tp_1, Tp_2=20 s;

T_{12} = 0.545 p.u.;

$a_{12} = -1$.