Comparative analysis of Hybrid algorithm in AGC for two area reheat Thermal power system

Ambarish Panda

Department of Electrical and Electronics Engineering
Sambalpur University Institute of Information Technology

Abstract— An attempt has been made in this work to investigates the modeling and performance analysis of a proportional integral (PI) controller which is incorporated with a two area reheat thermal power system. This design problem of automatic generation control (AGC) has been formulated in an optimization framework. Using the concept of hybridization among two intelligent techniques i.e. Modified bacteria foraging algorithm (MBFA) and Genetic Algorithm (GA), the hybridized technique 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). The potential and effectiveness of the Hybrid algorithm is compared with that of differential evolution algorithm (DE) and flower pollination algorithm (FPA).

Keywords— Automatic generation control; load frequency control; Reheat turbine; Hybrid algorithm; Optimization.

I. INTRODUCTION

For stable, efficient and reliable operation of the power system, it is necessary to maintain the system frequency and tie line power deviation at their scheduled values. The main objective of an interconnected electric power system is to generate, transport and distribute electric energy with nominal system frequency and terminal voltage. The values and tolerances of those parameters are classified depending on power quality standards. In accordance with power system control theory, a nominal system frequency depends on the balance between power generation and power demand [1]. The difference between generated power and instantaneous load demand introduces change of nominal system frequency at the normal state. If the amount of power generated becomes less than the demanded amount, speed and frequency of the generator units begin to drop, and vice versa. Hence, the amount of production of the synchronous generators needs to be monitored for minimization of frequency deviations and maintaining a power balance. For this purpose, an automatic generation control concept is used. Automatic monitoring and minimization of these deviations becomes necessary for healthy power system operation. It is extremely difficult to maintain the balances between generation and load without any efficient control mechanism. So, a control system becomes essential to minimize the effects of the random load variations and to keep the frequency at the standard value. The AGC loop continuously regulates the active power output of the generator to match with the randomly varying load. Thus it maintains the system frequency and tie line power exchange at their nominal values and ensures the generation of each unit at their most economic value. Numerous researchers have focused on AGC of interconnected systems using different approaches [1–5].

Controlling the frequency deviation of power system through the flywheel governor of synchronous machine was done by authors in [4]. There were some restrictions to obtain controlled frequency deviation at the instant of application of load, in this approach. Due to this reason, the necessity of having a supplementary control action (i.e. load frequency controller) was realized for
maintaining a steady frequency operation. Author in [5] have proposed the control mechanism with the supplementary controller which was based on tie-line bias control approach. In [6], based on state variables and on some proposals on classical control theory a mechanism was proposed for the design of AGC. The work demonstrates the automatic generation control of an interconnected hydrothermal system in continuous-discrete mode using conventional integral and proportional-integral controllers. Appropriate generation rate constraint has been considered for the thermal and hydro plants. The hydro area is considered with mechanical or electric governor and thermal area is considered with either single or double reheat turbine. Performances of mechanical governor, electric governor, and single stage reheat turbine and two stage reheat turbine on dynamic responses have been explored. Further, in [6] selection of suitable value of speed regulation parameter \( R \) and sampling period has been investigated. As the controller design and its tuning mechanism plays a crucial role in achieving the frequency secure operation, application of evolutionary computational intelligence-based techniques have been employed in the AGC study of power system. The analysis of automatic generation control (AGC) of an interconnected hydrothermal power system in the presence of generation rate constraints (GRCs) is depicted in [7]. The improvement of AGC with the addition of a small capacity superconducting magnetic energy storage (SMES) unit in either, as well as in both the areas is studied. Using time domain simulations, the performance of the power system and control logic was observed. The optimal values of the integral gain settings were obtained using integral square error (ISE) technique by minimising a quadratic performance index. Authors in [8] proposed BFOA based Load Frequency Control (LFC) for the suppression of oscillations in power system. A two area non-reheat thermal system has been considered to be equipped with proportional plus integral (PI) controllers. Here BFOA is employed to search for optimal controller parameters by minimizing the time domain objective function. The performance of the proposed controller has been evaluated with the performance of the conventional PI controller and PI controller tuned by genetic algorithm (GA) in order to demonstrate the superior efficiency of the proposed BFOA in tuning PI controller. A load frequency control (LFC) of a realistic power system with multi-source power generation is presented in [9]. The single area power system includes dynamics of thermal with reheat turbine, hydro and gas power plants. Appropriate generation rate constraints (GRCs) are considered for the thermal and hydro plants. The performances of the proposed controller are compared with the full state feedback controller. The action of this proposed controller has shown satisfactory balance between frequency overshoot and transient oscillations with zero steady state error in the multi-source power system environment. Further the effect of regulation parameter (R) on the frequency deviation response is examined.

In [10], authors have presented a method based on Type-2 Fuzzy System (T2FS) for Load frequency control (LFC) of power systems including Superconducting magnetic energy storage (SMES) units of a two-area interconnected reheat thermal system. They have proposed a Type-2 (T2) fuzzy approach for load frequency control of two-area interconnected reheat thermal power system with the consideration of Generation Rate Constraint (GRC), Boiler Dynamics (BD) and SMES. The salient advantage of this controller is its high insensitivity to large load changes and plant parameter variations even in the presence of non-linearities. The proposed method in [10] is tested on a two-area power system to illustrate its robust performance with various area load changes. In [11] a new population based parameter free optimization algorithm is presented as teaching learning based optimization (TLBO) and its application to automatic load frequency control (ALFC) of multi-source power system having thermal, hydro and gas power plants.

II. PROPOSED MODELLING

2.1. 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 additional reheater unit. The system is...
developed with single reheat turbine and integral controllers. The fitness function [13] to be optimized is the ISE. Mathematically it is formulated as

$$F = \int_{0}^{t} \left( (\Delta f_i)^2 + (\Delta P_{tie i-j})^2 \right) dt$$  \hspace{1cm} (1)

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

$\Delta f_i$ is the frequency deviation in the area.

$\Delta P_{tie}$ 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

$$ACE_1 = B_1 \Delta f_1 + \Delta P_{tie}$$  \hspace{1cm} (2)

$$ACE_2 = B_2 \Delta f_2 + \alpha_{12} \Delta P_{tie}$$  \hspace{1cm} (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.

### III. IMPLEMENTATION OF OPTIMIZATION TECHNIQUES.

#### 3.1. Flower Pollination Algorithm (FPA)

FPA proposed by X. S. Yang is based on survival of the fittest member and the optimal reproduction of plants in terms of numbers as well as the fittest one. There are two key steps in this algorithm; namely global pollination and local pollination. The different stages of FPA may be summarized as follows

1.) Global pollination may be represented by biotic cross-pollination, and movement of pollen-carrying pollinators is done according to Lévy flight.

2.) Local pollination is realised by abiotic and self-pollination.

3.) Pollinators can extend flower constancy, which is comparable to the probability of reproduction that is proportional to the resemblance of two flowers concerned.

4.) A switch probability $p \in [0, 1]$ may control the interaction of local pollination and global pollination. Procedural details of FPA may be referred from [19-20].

#### 3.2. Differential Evolution Algorithm (DE)

DE is a floating-point encoding evolutionary algorithm for global optimization over continuous spaces, which can work with discrete variables. Using the differential operator, DE creates new candidate solutions by combining the parent individual and many other individuals of the same population. A candidate replaces the parent only if it has better fitness value. The important attributes of DE are (i). Amplification factor of the difference vector denoted as ‘F’, (ii) crossover parameter ‘C’, and (iii) population size ‘N’.

The important sequence of steps of DE algorithm are:

(a) Set the parameters: F, C, N, and initialize the generation counter “g” = 1.

(b) Random generation of initial population : $X_{i0}$, for $i = 1, 2, ..., N$ from solution space.

(c) While (stopping criterion is not satisfied).

(d) For each vector $x_{i,g} = \{x_{1,i,g}, x_{2,i,g}, ..., x_{D,i,g}\}$, $i = 1, 2, ..., N$.

A detail description of the algorithm may be obtained from [21].
3.3. Hybrid Algorithm (HA)
The Hybrid Algorithm (HA) is synthesized by implementing the mutation strategies of GA along with a modified strategy of BFA that was first proposed in [14] and then applied in [15-17], so that the optimization efficiencies of both the algorithms may be further improved in some specific problems. The original version of BFA may be referred from [14]. The modified improved version of BFA is similar to the original algorithm, except some modifications, which are elaborated in [15]. The exhaustively explained steps involved in HA can be followed from [18]. In [18], a comparative analysis between HA and PSO has been done to demonstrate the effectiveness of HA. In a similar manner the competency of HA is tested with DE and FPA in this work to further analyze the behavior in meeting the operational objectives as depicted in (1).

IV. SIMULATION RESULTS AND DISCUSSION
The objective function as mentioned in (1) is subjected to optimization with three above mentioned optimization techniques. The best set of operating scenarios in terms of achieving the operational economy, superior voltage profile and faster operation is compared among the three techniques. 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 HA, FPA and DE is presented in Fig.3. From these, the superiority of HA in terms of getting a faster response, less settling time and less overshoot as compared to FPA, DE 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-1 and area-2 using HA is settled after 10 seconds each while that using FPA and DE has taken 13 sec and 16 sec respectively.
- From Fig.1 and Fig.2, the peak overshoots area-1 and area-2 using HA is found to be 0.0066Hz and 0.0034 Hz respectively while that using FPA and DE is found to be (0.0082 Hz, 0.0113 Hz) and (0.014 Hz, 0.034 Hz) respectively.
- From Fig-3, it may be depicted that the tie line power deviation using HA reached to steady state value after 9 sec while that with FPA and DE has settled approximately after 14 sec and 16 sec respectively.

All these details clearly demonstrate the supremacy of HA compared to FPA and DE in achieving the different operational objectives.
V. CONCLUSION

In this work the tuning of PI controller for AGC of two area power system using HA is depicted. To test the effectiveness and supremacy of the optimization technique, it is compared with competent meta-heuristics techniques i.e. FPA and DE. In this context, the performance parameters associated with individual areas and the line joining both the area are evaluated and compared. An integral time absolute error of the frequency deviation of both areas and tie line power is taken as the objective function to improve the system response in terms of settling time and overshoots. Simulation results emphasis that the proposed TLBO tuned PID controller is robust in its operation and gives a excellent damping performance for frequency as compared to other efficient intelligent techniques. From this a notion may be drawn that due to the simple concept and robust architecture of proposed controller which is tuned by HA, it can be used as a decision sustaining contrivance for operational analysis of real time power system.

Fig.2. Frequency deviation in area 2 versus time.

Fig.3. Deviation in tie line power connecting area 1 and area 2 versus time.
REFERENCES


