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# Multi objective load frequency control using hybrid bacterial foraging and particle swarm optimized PI controller

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ABSTRACT

Excessive load demand with reliability in power availability, demands for interconnection of large number of generating units over existing tie lines. Due to sudden change in demand, the power transfer over existing tie lines working close to their thermal limits results in low frequency power oscillations. Thus, in modern power systems the study of mitigation of these frequency oscillations is more involved and formulates the area of Load Frequency Control (LFC). Many conventional and heuristic control techniques have been recently applied to address the issue of LFC. This paper investigates load frequency control of large interconnected power system consisting of conventional and renewable energy sources, using hybrid heuristic approach. The proposed strategy is shown to result in improved system damping resulting in faster mitigation of low frequency oscillations.

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## Introduction

Modern power system involves various types of generation resources; conventional and renewable ones located far apart geographically. This is due to the fact the location of generation resources depends upon the location of natural resources, fossil fuels, availability of wind and tidal power. Further, the deregulated operations of power system demand for transfer of power to large distances over existing transmission lines, due to which these lines are operated close to their thermal limits. The operation of power system over stressed transmission links results in generation of sustained frequency oscillations in light of sudden change in demand or supply. Due to this reason, recent research has been more concentrated over load frequency control apart from voltage stability problem. Abrupt changes in the load demand and subsequent frequency deviation may result into malfunctioning of frequency relays, and thus affects the reliability of the power system [1]. Further, the penetration and interconnection of micro grids (solar, wind and fuel cell) with the conventional main grid (steam and hydro) gives rise to load frequency deviation issues [2–4]. The sudden change in system frequency may also affect generator voltage stability apart from tripping of frequency relays, due to which a particular area of whole of power system may face blackout [5,6]. To mitigate the problem of frequency deviation, the frequency deviation signal may be used for supplementary control called Load Frequency Control (LFC) to aid the primary control loop [7]. The LFC problem has been studied using various conventional and modern control techniques including heuristics based control. Due to complex interconnections of modern power systems, the control loops are based upon their approximate model or behavior. Conventionally tuned PID controllers are employed to address the LFC issues using various tuning methods that include Hit and trail, Ziegler Nichols tuning method, etc. [8–10]. However, improperly tuned PID controller may exhibit poor dynamical response, in addition wrong choice of integral gain may even destabilize the overall system. Conventional tuning is particular suited for simple systems, however fine-tuned heuristics based methods are particularly suited for complex systems e.g. power systems [11,12]. Heuristic search techniques like PSO and GAs. Formulate the controller design problem as multi-objective optimization problem in terms of controller gains. A discrete-time predictive control strategy for supervising load/frequency control problems in a multi area power system subject to coordination constraints was developed [13]. Yazdizadeh and Ramezani [14] proposed a new decentralized robust optimal MISO(multiple input single output) PID controller based on Characteristic Matrix Eigen values and Lyapunov method for load frequency control problem. Dey et al. [15] proposed a delay-dependent two-term H-infinity controller using linear matrix inequalities. Effectiveness of the

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proposed two-term controller was compared with that of existing one-term and two-term controller. Conventional controllers do provide wide range of operation despite ease in design. In addition, the complex interconnections of the power system involving variety of generating units demand for comprehensive control design in coordinated way. Finding analytical control for such complex interconnection is undesirable due to increased complexity of control solution. However, controller have been designed on the basis of artificial intelligence and heuristic based techniques such as neural network [16], particle swarm optimization (PSO) [17], Bacterial foraging algorithm (BFOA) [23], genetic algorithm (GA) [19] and Fuzzy logic based control design [18,20]. The controller designed using such techniques provides nearly optimal solution and automatically coordinate the controller gains for large areas.

A decentralized LFC multi objective optimizing control scheme was proposed by Daneshfar and Bevrani [19], which is based on GA and results have been compared with the conventional method. A new decentralized fuzzy logic-based LFC schemes for successful operation of interconnected power systems in the presence of high-penetration wind power was proposed by Bevrani and Daneshmand [20]. Shabani et al. [21] optimized the controller parameters using imperialist competitive algorithm (ICA) and compared the results with existing results on GA and Neural Network based technique. Sheroei et al. [22] proposed a robust multivariable Model based Predictive Control (MPC) solution for the LFC problem in a multi-area power system. Bacterial Foraging Optimization Algorithm (BFOA) was employed to search for optimal controller gains to minimize the time domain objective function [23]. Differential Evolution (DE) algorithm was applied to Load Frequency Control (LFC) of a multi-source power system [24]. Implemented multi-objective optimization of controller gain using Artificial Bee Colony (ABC) algorithm a two area thermal power system [25]. Sathya and Ansari [26] highlighted dual mode Bat algorithm based scheduling of PI controllers for interconnected power systems. Adaptive indirect adaptive fuzzy control technique for multi-area power system has been recently proposed by Yousef [27]. Here, we propose a hybrid heuristic technique using iterative PSO and BFO steps for optimizing controller gains in multi area system.

This paper addresses the design of a load frequency controller for a three area power system model using hybrid BFOA–PSO control technique. The simulations of the considered three area power system model with existing BFOA, PSO and proposed hybrid control technique has been carried in MATLAB–Simulink environment and the results have been compared. The rest of the paper consists of the detailed model of single area power system, the interconnections of three area systems, brief details of existing BFOA and PSO algorithms, proposed hybrid BFOA–PSO based PI control design followed by simulation results and conclusions.

## Single area load frequency model

Large power systems with multiple generation types are modeled as $N$ area power systems, wherein each area can be modeled independently. The overall power system model may be obtained by imposing the constraints in terms of interconnections on such single area models. The block diagram of single area model suited to load frequency studies to be used in $N$ area interconnected power system with primary governor control and secondary supplementary feedback loops, is as shown in Fig. 1.

For $N$ interconnected control areas, the total change in tie-line power between $i^{th}$ and other areas is given as follows [1]:

$$\Delta Ptie,i = \sum_{\substack{j=1\\ j\neq i}}^{N} \Delta P_{tie,ij} = \frac{2\pi}{s}\left[\sum_{\substack{j=1\\ j\neq i}}^{N} T_{ij}\Delta f_i - \sum_{\substack{j=1\\ j\neq i}}^{N} T_{ij}\Delta f_j\right] \tag{1}$$

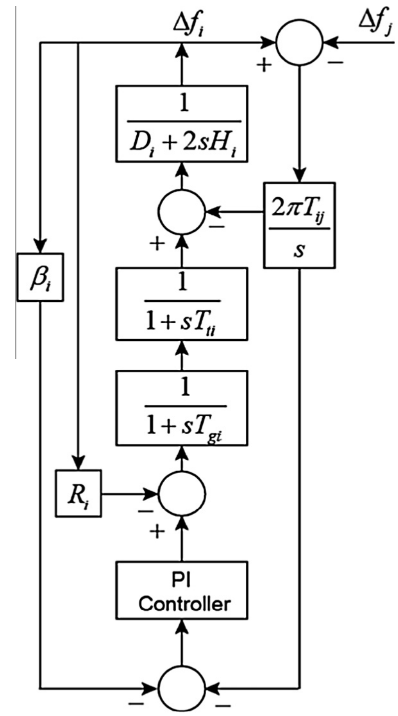


**Fig. 1.** Block diagram of $i^{th}$ area steam power system.

where $\Delta Ptie,i$ tie-line power deviations in $i^{th}$ area, $T_{ij}\Delta f_i$ is the power corresponds to tie-line coefficient $T_{ij}$ and change in frequency after load demand fluctuations. $\Delta f_j$ is the frequency deviations in another $j^{th}$ control area. The output of power system block is change in system frequency $\Delta f_i$ corresponding to frequent load demand and acts as feedback signal. The feedback signal is then compared with tie line power signal to obtain an error signal AFCE (Area Frequency Control Error). This deviation is then used by the controller block to obtain actuation input to the governor block. As per the error signal input, governor valve positions fed steam or water inlet to the turbine to cope up the speed of shaft. The following set of first order of linear equations represents dynamic behavior of $i^{th}$ control area corresponds to load disturbances [1].

$$AFCE_i = \Delta P_{tie,i} + \beta_i \Delta f_i \tag{2}$$

where $\beta_i$ is the frequency bias. The deviation in frequency may be represented as:

$$\Delta\dot{f}_i = \left(\frac{1}{2H_i}\right)\cdot \Delta \mathrm{Pm}_i - \left(\frac{1}{2H_i}\right)\cdot \Delta \mathrm{PL}_i - \left(\frac{D_i}{2H_i}\right)\cdot \Delta \mathrm{f}_i - \left(\frac{1}{2H_i}\right)\cdot \Delta \mathrm{Ptie} \tag{3}$$

and the dynamics of the governor represented by

$$\Delta\dot{P}_{mi} = \left(\frac{1}{T_i}\right)\cdot \Delta \mathrm{Pg}_i - \left(\frac{1}{T_{ti}}\right)\cdot \Delta \mathrm{Pm}_i \tag{4}$$

The overall dynamics of the turbine can be expressed as:

$$\Delta\dot{P}_{gi} = \left(\frac{1}{T_{gi}}\right)\cdot \Delta \mathrm{Pc}_i - \left(\frac{1}{R_i T_{gi}}\right)\cdot \Delta f_i - \left(\frac{1}{T_{gi}}\right)\Delta \mathrm{Pm}_i \tag{5}$$

where

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