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Multiobjective optimization using weighted sum Artificial Bee Colony algorithm for Load Frequency Control

K. Naidu [a,*], H. Mokhlis [a,b,*], A.H.A. Bakar [b]

[a]Department of Electrical Engineering, Engineering Summit, Faculty of Engineering, University of Malaya, 50603 Kuala Lumpur, Malaysia
[b]UM Power Energy Dedicated Advanced Centre (UMPEDAC), Level 4, Wisma R&D, University of Malaya, Kuala Lumpur, 59990 Malaysia

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ABSTRACT

This paper presents the implementation of multiobjective based optimization of Artificial Bee Colony (ABC) algorithm for Load Frequency Control (LFC) on a two area interconnected reheat thermal power system. The ABC algorithm is currently being applied in many research works due to the local and global search capability of the algorithm. This paper uses the weighted sum approach of the ABC to optimize the PID controller's gains to provide a compromise between the frequency response's settling time and maximum overshoot. The composite objective function comprising both objectives is characterized by the performance criterions – Integral of Time Multiplied Absolute Error (ITAE) and Integral of Time Weighted Squared Error (ITSE). Analysis is carried out to determine the best weightage set for this investigation. A performance index based on Least Average Error (LAE) is formulated to calculate the index of each weightage set. In order to ensure effective compensation in the system output, the PID controllers for both areas are tuned simultaneously. The tuning performance of the algorithm is evaluated by comparing the performance of the proposed controller with conventional PI and PID controller. The robustness of the proposed algorithm is further investigated by evaluating the response of the system under simultaneous step load perturbation (SLP), changing load demand and collectively varying system parameters in the range of ±50%. The simulation result shows the dynamic response of the controller emphasizes on the compromise between the settling time and maximum overshoot of the frequency response. Furthermore, the proposed algorithm is robust enough to operate under different operating conditions and system parameter variations.

1. Introduction

The electrical power system is an interconnection of many important components which ensures successful transmission of power over a certain region or large area. Proper interaction between the generating, transmitting and distributing elements of the system is important in order to ensure successful operation and stability of the interconnected power system. The dynamics of the power system will have a consequence on the resultant transient response. As such, the sudden variation in active power demand will introduce dynamic changes in the system. The system's frequency which depends upon the active power has to be maintained at its nominal value. In an interconnected power system, the Load Frequency Control (LFC) is used to maintain the frequency and inter-area (tie-line) power based on its scheduled value. The frequency of the system is affected when the load generation equilibrium is not maintained. When there is a difference between the generated power and load demand, frequency excursion will occur. If the load demand of the system is greater than the generator's power, the frequency of the system will decrease. Control action has to be initiated as soon as possible to deal with large frequency excursions to prevent system instability. If the maximum frequency overshoot reaches the threshold level, load shedding process will be initiated automatically to maintain the nominal frequency. With respect to that, in order to ensure reliable system operation, the system settling time should be less and the maximum overshoot should be minimum [1].

Analysis on LFC has been extensive and new research are still ongoing on how to further enhance the control approach and operation of the LFC. Physical limitations, dynamic behavior and system non-linearities have spurred researchers to further enhance the modeling and design of LFC [2]. Different methods and strategies have been implemented by researchers to optimize the performance of LFC. The design methods can be categorized as classical methods, adaptive and variable structure methods, robust control approaches, intelligence based algorithms and digital control methods [3]. The classical methods are conventional

* Corresponding author.
E-mail addresses: vkanendra@gmail.com, kanen@siswa.um.edu.my (K. Naidu), hazli@um.edu.my (H. Mokhlis), halim5389@gmail.com, a.halim@um.edu.my (A.H.A. Bakar).

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control strategies which were limited due to their poor performance in dynamic response. Elgerd and Fosha reported that the conventional control strategy which is based upon heuristic knowledge and experience is workable in practice but there might be better strategies available [4]. In the adaptive and variable structure method, fuzzy logic has been commonly used as the gain scheduling algorithm. However the adaptive tuning method requires accurate model design as operating condition parameters have to be monitored before the fuzzy logic rules are implemented [5]. The robust control method which is very suitable for practical application, takes into account uncertainties and disturbance/variations in the system. Wang et al. has designed a robust controller based on the Riccati equation which provides stable performance for all allowable parameter uncertainties [6]. Digital control method deals with the implementation of LFC controller in the discrete mode. Due to the discrete nature of the controller, the trade-off between the system response and sampling rate has to be considered [7].

The intelligence based methods have gained much interest from researchers due to the capability of the search mechanism that tunes the controller based on the evaluated fitness function. The PID controller is commonly used due to its simple and efficient characteristics [8]. The selection process of the controller's gain is done without the knowledge of the system parameters. The performance indices are used as the selection criteria in the search process. The common performance indices used by the PID controllers are the Integral of Absolute Error (IAE), Integral of Squared Error (ISE), Integral of Time Multiplied Absolute Error (ITAE) and Integral of Time Weighted Squared Error (ITSE) [9]. In recent literatures regarding the implementation of artificial intelligence in LFC, researchers have used different algorithms to tune the controller's (PI and PID) gains. In 2008, Pothiya and Ngamroo proposed a fuzzy logic based PID controller for LFC. In order to tune the PID gains, the multiple tabu search (MTS) was utilized [10]. Shayeghi designed a multi stage fuzzy controller based on particle swarm optimization (PSO) [11]. Both researchers considered the ITAE cost function. Nanda et al. in 2009 highlighted the application of bacterial foraging (BF) in optimizing several control parameters for an interconnected three area thermal system with unequal generating parameters [12]. The ISE cost function was used. In 2010, Gautam and Goyal presented the implementation of improved PSO (IPSO) to optimize the parameters of the PI controller based on the ISE cost function [13]. Ali and Abd-Elazim in 2011 investigated the application of BF in optimizing the PI controller by using the ITAE cost function [14]. In 2012, Gozde et al. used the Artificial Bee Colony (ABC) algorithm to tune PI and PID controller by investigating the controller's performance on each criterion – IAE, ISE, ITAE and ITSE [15]. Daneshfar and Bevrani introduced a multiobjective optimization method using Genetic Algorithm (GA) to tune the PI controllers [16]. The objective function for the multi area system is based upon the absolute value of Area Control Error (ACE) at the particular time frame. In order to select the fitness function, a vector evaluated objective function is calculated and selection is done based on this vector valued cost function.

Based on the previous work [9–14], it can be evaluated that only a single criterion (settling time or maximum overshoot) is used for optimizing the controller's parameters. Thus, with single objective optimization, only one criterion will be optimized in the expense of other criterion. Different than the previous work, the main objective of this paper is to implement multiobjective optimization in order to obtain a good compromise between the settling time and maximum overshoot in the frequency deviation step response.

The ABC algorithm which was developed by Karaboga is based on the foraging behavior of honey bees. It is a simple and robust algorithm which is capable of solving even complex combinatorial optimization problems [17]. The ABC algorithm has a robust searching capability which incorporates the exploitation and exploration of the search space [18]. The exploitation process is represented by the employed and onlooker bee phase and the exploration process is represented by the scout bee phase. The triple search capability of the ABC algorithm based on the search phases of the three groups of bees prevents stalling of solution and further enhances the search process in finding the optimum value [19]. As such, the multiobjective optimization using weighted sum ABC algorithm is investigated in this study. A performance index based on Least Average Error is formulated to evaluate the tuning performance of each weightage set. This paper also discusses how the PID controller gains for both areas are tuned simultaneously based on the objective function. The robustness of the proposed algorithm is investigated by applying simultaneous

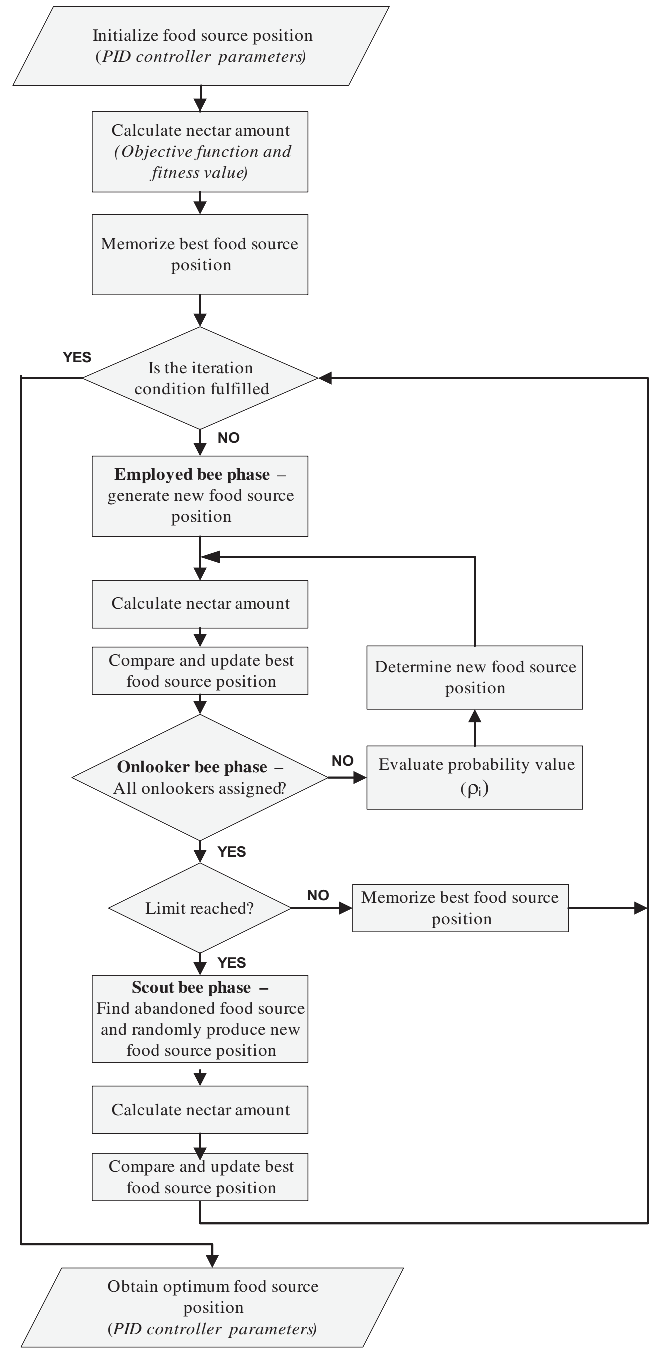

Fig. 1. ABC optimization process flowchart.