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Ensemble mutable smart bee algorithm and a robust neural identifier for optimal design of a large scale power system

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ABSTRACT

The aim of the current study is to probe the potentials of ensemble bio-inspired approaches to handle the deficiencies associated with designing large scale power systems. Ensemble computing has been proven to be a very promising paradigm. The fundamental motivation behind designing such bio-inspired optimization models lies in the fact that interactions among different sole optimizers can afford much better income as compared with an individual optimizer. To do so, the authors propose an optimization technique called ensemble mutable smart bee algorithm (E-MSBA) which is based on the aggregation of several independent low-level optimizers. Here, each low-level unit of the proposed ensemble framework uses mutable smart bee algorithm (MSBA) for optimization procedure. The main provocations behind selecting MSBAs of different properties as components of ensemble are twofold. On the one hand, MSBA proved its capability for handling multimodal constraint problems. On the other hand, based on different experiments, it was demonstrated that MSBA can find the optimum solution with a relatively low computational cost. In this study, the authors intend to indicate that the proposed ensemble paradigm can efficiently optimize the operating parameters of a large scale power system which includes different mechanical components. To this end, E-MSBA and some rival methods are taken into account for the optimization procedure. The obtained results reveal that E-MSBA inherits some positive features of the MSBA algorithm. Additionally, it is observed that the ensembling approach enables the proposed method to effectively tackle the flaws associated with optimization of large scale problems.

1. Introduction

Optimal design of practical power systems has been proven to be a very formidable task. There are several practical obstacles that hinder such an optimization procedure. To name only a few, one can mention to the urge for considering several constraints that are often highly non-linear and uncertain, the need for a fast yet robust and reliable optimizer which enables the operator to have a pragmatic insight into the variations in outputs of the power system, balancing the exploration/exploitation of the optimization algorithm in a fashion that it can search for a set of optimal solutions, and etc. The problem even can be much more crucial when the designers deal with several operating parameters which in turn lead to a large scale optimization circumstance. Besides, the experts should be fully aware that a very small deviation over the optimization procedure may lead to impractical results which in turn incur life hazards. To handle the defects associated with optimizing practical power systems, an immense number of methods has been proposed in literature. Those methods address a wide spectrum of intelligent computation principals ranging from designing of efficient bio-inspired optimization approaches to employing machine learning methods to predict the main features of energy systems. Mozaffari et al. [1] developed a synchronous parallel shuffling self-organized Pareto strategy algorithm (SPSSOPSA) and a neural network (NN) to analyze, control and optimize the operating parameters of Damavand power [2] plant as the biggest power plant of Middle East. The obtained results indicated that integration of multi-objective algorithm with neural network aided the authors to capture the nonlinear behavior of the system. Esen et al. [3,4] used several intelligent techniques such as adaptive neuro-fuzzy inference system (ANFIS) and support vector machine (SVM) to investigate the operating characteristics of a ground-coupled heat pump. Gorji-Bandpy and Goodarzian [5] optimized a gas turbine (GT) power plant using a genetic algorithm (GA) and an efficient mathematical model. Gorji-Bandpy et al. [6] engaged a multi-objective neuro-evolutionary algorithm and thermodynamic principals [7] to verify the optimum operating parameters of Mahshahr power plant. Toffolo and Lazzaretto [8] proposed a Pareto

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based evolutionary algorithm (EA) for multi-objective energetic and exergetic optimization of thermal systems. Mozaffari et al. [9] utilized three different bio-inspired methods, i.e. the great salmon run [10], bee algorithm [11] and particle swarm optimization [12], for optimal arrangement of thermo-electric cells to reuse the waste energy in compressors. Valdes et al. [13] applied GA for thermoeconomic optimization of combined cycles in a GT power plant. Xu and Fan [14] studied the application of evolutionary computing techniques for intelligent optimization in power systems. Yao et al. [15] proposed a quantum-inspired particle swarm optimization (QPSO) algorithm for optimal management of power system operations considering wind power uncertainty. Katsigiannis et al. [16] proposed a hybrid bio-inspired algorithm based on integration of simulated annealing (SA) and tabu search (TS) for optimal sizing of autonomous power systems. There also exist a number of approaches that have been proposed in an attempt to address the deficiencies associated with optimization of problems with large number of operating parameters (large scale optimization). Bertsekas et al. [17] proposed a solution methodology based on duality, Lagrangian relaxation and non-differentiable optimization to handle the optimal unit commitment in an electric power system, as a large-scale, mixed integer and dynamic optimization problem. Gan et al. [18] applied tabu search (TS) for large scale variable optimization and planning of a power system. Zhao [19] proposed a hybrid optimization method based on GA and a linear planning methodology for SVC planning in large scale power systems. Nayak and Sharma [50] proposed a hybrid method based on the integration of SA and NN for scheduling the on/off status of power generation units. Wong et al. [51] investigated the performance of an evolving neural network for unit commitment optimization in a large scale power system. Dudek investigated the applicability of different variants of GA for the unit commitment of a large scale power generation system [52–54]. Brzozowski and Warwas [55] proposed a hybrid metaheuristic based on the integration of GA and nelder mead method to ensure the minimal difference between the measured and calculated pressure courses in the cylinder of a large scale power system.

In spite of fruitful researches, there exist rare reports in literature that address the application of intelligent techniques for optimizing the performance of mechanical components of large scale power systems. However, it is highly important to engineers and industrialists to determine the optimum values and qualities of operating parameters of power systems. Therefore, it would be a deliberate choice to experts to seek for some novel bio-inspired and machine learning approaches capable of handling a large number of operating parameters.

The main contribution of the current investigation lies on its attempt to tackle the deficiencies associated with optimal design of a real-world large scale power generating system. Here, the authors intend to take the advantages of aggregated computing and robust neural modeling to capture the uncertainties of the operating parameters and investigate the characteristics of the operating parameters of power plant. To this end, an efficient aggregated bio-inspired model called ensemble mutable smart bee algorithm (E-MSBA) is proposed. A thorough discussion is provided to endorse the authenticity of E-MSBA for large scale optimization tasks. Thereafter, the method is used to derive some operating policies for the current case study.

The rest of the paper is organized as follows. In Section 2, the authors present their novel ensemble bio-inspired optimizer. Besides, they try to make a thorough discussion by using some rival bio-inspired methods to disclose the main advantageous features of E-MSBA. In Section 3, the authors take the advantages of a robust neural network (NN) to overcome the uncertainties of the power plant. Section 4 is devoted to the result and discussions. Finally, some concluding remarks are presented in Section 5.

2. Ensemble mutable smart bee algorithm

2.1. Bee-inspired optimization algorithms

Over the last few years, proposing natural-inspired metaheuristic methods based on the social behavior of honey bees has attracted an increasing interest of researchers [38]. So far, bee-inspired metaheuristic techniques have been applied to a wide range of engineering optimization problems [39]. Akay and Karaboga [40] used artificial bee colony algorithm (ABC) for large scale and constraint engineering problems. To elaborate on the performance of ABC, a set of well-known state-of-the-art metaheuristics have been taken into account. The numerical experiments indicated that ABC can successfully handle different types of engineering optimization problems. Moradi et al. [41] investigated the efficacy of bee algorithm (BA) for finite element (FE) model updating of structures. To demonstrate the authenticity of the proposed approach, the authors applied it to a piping system. Based on numerical results, the authors reported that BA can successfully update several physical parameters of the developed FE model. Kang et al. [42] proposed a bee-inspired memetic algorithm (MA) called Rosenbrock artificial bee colony (RABC) for accurate global optimization of challenging numerical functions. The proposed method was exposed to a wide range of optimization problems. Based on a rigor comparative study, it was observed that RABC can outperform other metaheuristics in terms of convergence speed, success rate and accuracy. Gao et al. [33] proposed an opposition-based chaotic embedded artificial bee colony algorithm (known as IABC) to improve the exploration/exploitation capabilities of the standard ABC. IABC was applied to a large-scale multimodal engineering problem, i.e. control and synchronization of discrete chaotic systems. Based on the numerical simulations, the authors proved that IABC is a robust and effective optimization technique. Cuevas et al. [43] utilized ABC to develop an automatic thresholding mechanism for optimum image segmentation. Through a comparative experimental analysis, it was demonstrated that ABC is able to outperform gradient-based methods in terms of computational complexity, segmentation accuracy and robustness. Besides, it was reported that ABC shows a fast convergence speed and low sensitivity to initial conditions for image segmentation problems.

As it can be inferred, bee-inspired metaheuristics can be reliably used for optimizing complex engineering systems. Therefore, investigations into the practical and theoretical characteristics of bee-inspired methods are still welcome.

In previous studies on the exploration, exploitation, convergence and divergence characteristics of MSBA, the authors achieved some interesting conclusions. It has been observed that the structure of MSBA provides it to be applied to constraint optimization tasks [20]. Likewise, MSBA has been proven to be a fast and accurate optimization model [20]. This is because the authors devised the method in a fashion that it hires low amount of heuristic agents for optimization task. Such a policy obliges the method to conduct a fast process which in turn could be beneficial for practical engineering and industrial optimization. However, the less the number of heuristic agents is, the weaker the algorithm tends to be. In other words, by using a low number of heuristic agents, the metaheuristic fails to reach a logical exploration/exploitation proportion among intelligent individuals. To cope with aforementioned flaw, the authors follow an interesting policy. In [21], MSBA was equipped with an adaptive mutation operator which attempted to reconcile the exploration/exploitation behavior of the heuristic agents to the demands of the problem being optimized. Through a rigor numerical and experimental study, the authors came to the fact that the use of an adaptive mutation operator can be very promising. Taking the advantages of the adaptive version of MSBA, it has been applied to a number of real-world engineering problems. Gorji-Bandpy et al.