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COMBINED ECONOMIC AND EMISSION DISPATCH USING IMPROVED CUCKOO SEARCH

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ABSTRACT
The paper presents the application of an improved Cuckoo Search algorithm (ICSA) for solving combined economic and emission load dispatch (CEED) problems where transmission power losses are considered. The method is developed by modifying the several modifications on the conventional Cuckoo Search algorithm (CCSA) in aim to improve the performance of the original ones. ICSA is tested on two different systems with the transmission power losses. The performance of ICSA is evaluated by comparing obtained results with other existing algorithms available in the study. As a result, it can be concluded that the applied method outperforms others and it is very strong for solving the CEED problem.

Keywords:
Improved Cuckoo Search algorithm, transmission power losses, economic load dispatch, emission dispatch, combined economic and emission dispatch

INTRODUCTION

The main task of the CEED problem is to determine the optimal power output of thermal units so that the fuel cost and emission can be minimized significantly while exactly meeting all constraints from current set of units and power system such as limitations on capacity of thermal units, power balance constraints considering power losses in transmission lines. The fact that fossil fuels will become exhausted in the near future because people have exploited and used the fuels with a large amount yearly. Furthermore, during the process of generating electricity, polluted emissions such as NOx, SO2 and CO2 are released into the air without control. Consequently, the purpose of minimization of both fuel cost and emission has a significantly high role in the power systems. Due to the importance of the problem, a huge number of researchers have been attracted and published a lot of papers so far such as Improved Hopfield Neural Network Model (IHNN) [1], Tabu Search (TS) [2], fuzzy logic controlled genetic algorithm (FCGA) [3], the Non-dominated Sorting Genetic Algorithm - II (NSGA-II) [4], Differential Evolution (DE) [5], Genetic algorithm (GA) [6], Particle swarm optimization (PSO) [6], biogeography-based optimization (BBO) [7], pareto differential evolution (PDE) [8], nondominated sorting genetic algorithm-II (NSGA-II) [8], strength pareto evolutionary algorithm 2 (SPEA 2) [8], Hybrid Differential evolution-sequential quadratic programming (DE-SQP) [8], Hybrid Particle Swarm optimization-sequential quadratic programming (PSO-SQP) [9], parallel synchronous PSO algorithm (PSPSO) [10], ABC_PSO [11], multi-objective cultural algorithm (MOCA) [12], Basic Cuckoo Search Algorithm (CSA) [13], Lambda method (LM) [14], Hopfield Lagrange Network (HNN) [14], and flower pollination algorithm (FPA) [15]. Among these considered methods, IHNN [1], LM [14] and HNN [14] belong to the family of deterministic algorithms where other ones are included in the meta-heuristic algorithms. A big difference between the two ones is the way for optimal solution obtained. In fact, the comer owns only one solution and the solution tends to be improved gradually when the search process goes to the end whereas the latter consists of a set of solutions, which are improved by evaluating fitness function. When the search process of the comer ends, it means that all the constraints can be exactly met; however, the manner is not always true for the latter. The latter's stopping criteria is always based on the maximum number of iterations and all constraints can be exactly satisfied although the search process does not terminate. On the other hand, it can be concluded that the applicability of the meta-heuristic algorithm is more potential than the deterministic ones because the deterministic ones must stop dealing with problems where nonconvex function as well as non-differential functions are included meanwhile the meta-heuristics can solve easily.
Conventional Cuckoo search algorithm (CCSA), a very efficient meta-heuristic algorithm, was developed by Yang and Deb in 2009 [16]. CCSA has just been pointed out by Walton et al. [17] that it also possesses several

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drawbacks including local solution search based on random walk and long execution time. Finally, we suggested an improved version of the CSA (ICSA). To validate the effectiveness and robustness of the applied method, two systems with three units and power losses in transmission lines are employed and the results from the systems are the evidence to be compared. The comparisons among the method with others have indicated that the ICSA method is efficient for CEED problem.

PROBLEM FORMULTATION

Objective function

In the CEED problem, the fuel cost and polluted emission of each generating unit are minimized, thus the objective of the problem is written as:

$$Min\sum_{i=1}^{N}F_i=\sum_{i=1}^{N}\left[w_1F_{1i}(P_i)+w_2.PR.F_{2i}(P_i)\right] \quad (1)$$

Where w_1 and w_2 are weight factor associate with fuel cost and emission; *PR* is the price penalty factor [18]; F_{1i} and F_{1i} are the fuel cost function and emission function.

The fuel cost function and emission function are represented by.

$$F_i(P_i)=a_i+b_iP_i+c_iP_i^2 \quad (2)$$

$$F_{2i}=\sum_{i=1}^{N}(\mathrm{a}_{ei}\,P_i^2+b_{ei}P_i\;+c_{ei}) \quad (3)$$

Where N is the number of generators; P_i is real power output of generator i; $P_{i,min}$ is minimum power output of unit i; a_i, b_i, c_i *and* a_{ei}, b_{ei}, c_{ei} are fuel cost and emission coefficients of unit i, respectively.

Constraints

Real power balance: the total real power output of generating units satisfies total load demand plus system power losses.

$$\sum_{i=1}^{N}P_i=P_D+P_L \quad (4)$$

where P_D is total system load demand; P_L is total transmissin loss.

Generator capacity limits: the real power output os geerating units should be limited between theris upper anh lower bounds represented by:

$$\sum_{i=1}^{N}P_i=P_D+P_L \quad (5)$$

where $P_{i,min}$ and $P_{i,max}$ are maximum and minimum power outputs of unit i.

IMPROVED CUKOO SEARCH ALGORITHM

Conventional cuckoo search algorithm

Lévy flights random walk

The Lévy flights random walk plays a very important role for obtaining the high quality solution by their random steps drawn from a Lévy stable distribution via the power law of index β [16]. When a new solution at the current iteration G for nest d, $X_d^{(G)}$ is generated the Lévy flights random walk is performed:

$$X_d^{(G)}=X_d^{(G-1)}+\alpha\oplus L\acute{e}vy(\beta) \quad (6)$$

where $\alpha > 0$ is the step size for updating the new solution.

Selective Random Walk

The selective random walk is employed to generate new solutions by using an updated step-size which is obtained by two random old solutions. However, only a fraction of control variables in the old solution is replaced by comparison between a random value and a predetermined value, called probability of alien eggs to be abandoned. The detail of the selective random walk is summarized by the following expression.

$$X_{d,new}=\begin{cases}X_d+rand.(X_{randper1}-X_{ranper2})\ if\ \ RN<P_a\\ X_d \qquad\qquad\qquad\qquad\qquad otherwise\end{cases} \quad (7)$$

Where P_a is the probability that alien eggs are identified by host birds.

Selection Operation

In the CCSA, solutions are newly generated two times based on the two random walk techniques described above. In fact, it is not assured that all new solutions are always better than all the previous ones, so each new solution and each previous solution at the same nest are compared in terms of fitness function value to retain a better one.

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$$X_d^{retained} = \begin{cases} X_d^{new} & if\ Fitness(X_d^{new}) < Fitness(X_d^{old}) \\ X_d^{old} & otherwise \end{cases}, d = 1,...., NP \quad (8)$$

Improved Cuckoo Search Algorithm.

The update step-size in eq. (7) is called two points-based factor, which aim to create new solution by exchanging information between two current solutions; however, if X_{randper1} X_{randper2} ar close, New solutions will be very like or a little bit different the old ones, leading to falling into local optimum. To overcome the mentioned circumstances, a new equation is proposed as

$$X_{d,new} = X_d + rand(X_{randper1} - X_{randper2} + X_{randper3} - X_{randper4}) \quad (9)$$

To combine the two ways for generating new solutions by (7) and (10), a new criterion based on FDR is proposed in eq. (10) in which FT_{d} and FT_{best} are the fitness of solution d and the best solution among the population, respectively.

$$FDR_d = \frac{FT_d - FT_{best}}{FT_{best}} \quad (10)$$

To choose either eq. (7) or eq. (9) will be applied for producing new solutions, a predetermined threshold ε is regarded as a criterion. If FDR_d is less than ε, eq. (9) will be employed. Otherwise, eq. (7) is chosen.

Implementation of the applied method for CEED problem

Initialization

A population of N_P nests or N_P particle is represented by X_d (d = 1, ..., N_p) where each solution corresponding to each egg or each particle's position given by $X_d = [P_{2,d}, P_{3,d}, ..., P_{N,d}]$. The power outputs are randomly initialized satisfying the limitation, $P_{i,min} \le P_{i,d} \le P_{i,max}$

The fitness function of each solution for the considered problem is calculated as [13]:

$$FT_d = \sum_{i=1}^{N} [w_1 F_{1i}(P_i) + w_2.PR.F_{2i}(P_i)] + K_s \times \left(P_{1,d} - P_1^{\lim}\right)^2 \quad (11)$$

Where K_s is the penalty factors; and $P_{1,d}$ is the power output of slack thermal unit 1 [14] and obtained by using eq. (4).

The limit for slack thermal unit 1 in (11) is determined as follows:

$$P_1^{\lim} = \begin{cases} P_{1,\max} & if\ P_{1,d} > P_{1,\max} \\ P_{1,\min} & if\ P_{1,d} < P_{1,\min} \\ P_{1,d} & \text{otherwise} \end{cases} \quad (12)$$

Where $P_{1,\max}$ and $P_{1,\min}$ are the maximum and minimum power outputs of slack thermal unit 1, respectively.

The termination criterion of the search process

The search process will be terminating when the current iteration is equal to the maximum number of iterations.

NUMERICAL RESULT

The applied ICSA is tested on two systems with three units and power losses in transmission lines. The proposed algorithm is coded in Matlab platform and run 50 independent trials for each case on a 2.4 GHz PC with 4 GB of RAM.

Study Cases1: Three-unit system considering transmission power losses and with load demand of 850 MW.

In this study case 1, three dispatch case including economic dispatch, emission dispatch and combined economic and emission dispatch are considered. The data of the system are from [4]. For implementation of the method to the cases, the population size and the maximum number of iterations are respectively set to 10 and 30. In addition, CCSA has been applied in [13]. The resulst from the applied method compared to those from other for the three cases are presented in the table 1.

Table 1. Comparisons of result for case 1

Dispatch	Method	TS [2]	NSGA-II [4]	BBO [7]	CSA [13]	ICSA

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Eco.	Cost ($)	8344.6	8344.6	8344.59	8344.59	8344.59
	Cpu (s)	-	-	-	0.09	0.05
Em.	Em. (kg)	0.0958	0.09593	0.09592	0.09592	0.09592
	Cpu (s)	-	-	-	0.07	0.048
CEED	Cost ($)	-	8349.72		8349.722	8349.248
	Em. (kg)	-	0.09654		0.09654	0.0966
	Cpu (s)	-	-	-	0.09	0.04

It is clear from the table that ICSA is also better than CCSA for the first two cases in terms of execution time due to a low value of population size and iterations. Compared to others, ICSA obtains the same quality of solution as them except Tabu search for the emission dispatch case; however, ICSA is very fast when compared to others, which have been reported execution time. Clearly, the improved versions of CSA is very efficient for the study case.

Case 2: Three-unit system considering transmission power losses and with load demand of 400 MW

In the case, a three-unit system supplying to load demand of 400 MW via transmission lines considering power losses is employed. The data of the system are taken from [6]. For implementation of the method to the cases, the population size and the maximum number of iterations are respectively set to 10 and 30. In addition, CCSA is also implemented by setting the same values of control parameters for validating the superiority of ICSA. Table 2 presents the obtained fuel cost and emission from CCSA, ICSA and others methods in [6] and [15]. As observed from the cost and emission, ICSA obtain the same cost and emission but those from them are less than those from CCSA. However, the execution time from the applied method is very fast compared to other ones. In conclusion, it is stated that the ICSA is superior to CCSA and ICSA is a promising method for solving the CEED problem.

Table 2. Comparison of result for case 2

Method	GA [6]	PSO [6]	FPA [15]	CCSA	ICSA
Cost ($)	20840.1	20838.3	20838.1	20848.11	20848.0957
Em.(Kg)	200.256	200.221	200.2238	200.171	200.170
CPU (s)	0.282	0.235	0.175	0.05	0.05

CONCLUSION

In this paper, ICSA method has been applied for finding the optimal solutions for CEED problem where both fuel cost, emission and power losses in transmission lines are considered. The ICSA have been constructed by doing several improvements on the conventional method in aim to enhance the optimal solution quality and speed up convergence. The method has been tested on two three-unit systems with different load and data. Comparisons between ICSA and CCSA have shown that ICSA is better than CCSA for quality of solutions. In addition, the comparisons among the applied method and other ones have indicated that ICSA is very promising for solving the problem and it will be successfully applied for solving the problems with larger scale and more complex.

Nomenclature

F_{1i}	Fuel Cost function of thermal unit *i* in $/h
F_{2i}	Emission function of thermal unit *i* in kg/h
w_1, w_2	Weights corresponding to the fuel cost and emission objectives.
a_i, b_i, c_i, e_i, f_i	Fuel cost coefficients of thermal plant *i*;
α_i, β_i, γ_i	Emission coefficients of thermal unit *i*.
N	Number of thermal units
P_D	Load demand of the system in MW
P_L	Total network loss of the system in MW
P_i	Output power of unit *i* in MW
B_{ij}, B_{0i}, B_{00}	Transmission loss formula coefficients
P_{imin}, P_{imax}	Lower and upper generation limits of unit *i* in MW
rand	Uniformly distributed random number in [0, 1]

P_{1d}	Power output of the slack thermal unit 1 of nest *d* in MW
P_{1max}, P_{1min}	Maximum and minimum power outputs of slack thermal unit 1 in MW
$P_s^{\lim}$	Limit for the slack unit 1 in MW
N_P	Number of population

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