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Adaptive Cuckoo Search Algorithm for Economic Emission Load Dispatch Problem

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Abstract

This paper proposes an Adaptive Cuckoo Search Algorithm (ACSA) for solving economic emission dispatch (EELD) problem with quadratic fuel function. The ACSA is developed by performing two adaptive updated step size parameters on conventional CSA in aim to enhance the convergence speed and quality solution of the conventional CSA. In addition to minimizing electricity generation fuel cost, emission released into the air from thermal plants is also another main objective needs to be minimized. In order to test the performance of the proposed ACSA two systems including a three unit system with one load case and a six unit system with three load cases are employed. The obtained result by the ACSA compared to that from other methods has revealed that the proposed ACSA is a very promising meata-heuristic algorithm for solving economic emission load dispatch problem.

Keywords*: Adaptive Cuckoo Search algorithm, economic emission load dispatch, quadratic fuel cost function, two modifications.*

Nomenclature

$a_i,\ b_i,\ c_i$	Cost coefficients of thermal unit i
$d_i,\ e_i,\ f_i$	Emission coefficients of thermal unit i
$B_{ij},\ B_{0i},\ B_{00}$	Transmission loss formula coefficients
N	Number of online generating units
P_D	Total load demand of the system (MW)
P_L	Total network loss of the system (MW)
P_i	Output power of unit i (MW)
$P_{imin},\ P_{imax}$	Lower and upper generation limits of unit i (MW)
w_1, w_2	Weights corresponding to the fuel cost and NOx emission objectives.
$rand$	Uniformly distributed random number in [0, 1]
P_{ds1}	Power output of the slack thermal unit
P_{1max}, P_{1min}	Maximum and minimum power outputs of slack thermal unit 1
$P_s^{\lim}$	Limit for the slack unit 1
$Nogood$	Number of solutions in the good group
$Nobad$	Number of solutions in the bad group
X_{r1}, X_{r2}	Random perturbation for positions of the nests in X_d.
F_j	Value of objective j
F_{jmax}, F_{jmin}	Maximum and minimum values of objective j.
μ^k_D	Cardinal priority of kth non-dominated solution
$\mu(F^k_i)$	Membership function of objective j
N_{obj}	Number of objective functions

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N_S Number of Pareto-optimal solutions.
μ^k_D Membership function

1. Introduction

A power system mainly consists of thermal plants to supply electricity to load. There is the fact that the fuel cost of generating electricity from the thermal plant is so expensive, leading the electricity price that customers uses to be high. Besides, the thermal plants are one of the main resources of polluted emission in to the air, causing hotter temperature and climate change for the earth. Therefore, the main objective of the economic emission dispatch problem is to minimize both electricity generation fuel cost and emission [1].

Over decades, many methods have been applied for solving EELD problem such as Improved Hopfield Neural Network Model (IHNN) [2], Tabu Search (TS) [3], fuzzy logic controlled genetic algorithm (FCGA) [4], the Non-dominated Sorting Genetic Algorithm - II (NSGA-II) [5], Differential Evolution (DE) [6], biogeography-based optimization (BBO) [7], multi-objective differential evolution (MODE) [8], Hybrid Differential volution-sequential quadratic programming (DE-SQP) and Hybrid Particle Swarm optimization- sequential quadratic programming (PSO-SQP) [9], parallel synchronous PSO algorithm (PSPSO) [10], Cuckoo Search Algorithm (CSA) [11]. Among the methods, the application of IHNN to the EELD problem is the most limited because it cannot deal with complicated problem with nonconvex fuel cost function of thermal units. Besides, the IHNN faces to the local optimal solution with high number of iterations for convergence. In [6] and [8], the EELD has been successfully solved by DE algorithm based-methods. DE has been considered a strong tool for solving optimization problem in engineering fields since it could tackle the disadvantage of IHNN, namely considering nonconvex fuel cost function of thermal units; however, the methods requires a careful section of control parameters. Otherwise, the method can fall in the near optimal solution. The difference between DE in [6] and [8] is that MODE in [8] can determine the best compromise solution, which can satisfy both cost and emission minimization requirement without using fuzzy mechanism like DE in [6]. The manner enables MODE to reduce the computing procedure and execution time as well. Two hybrid methods employed in [9], DE-SQP and PSO-SQP, are the combination of two individual methods. The advantage of the methods is that they can take advantage of each individual to enhance the solution approaching the global optimization; however, the methods have to cope with the high number of iterations and longer computational time. BBO has been widely and successfully used for solving the EELD problem and obtained superior results to other methods like NSGA-II and Tabu Search. PSO has become a popular method for over decades in electrical engineering especially power system optimization like load dispatch and optimal power flow. Nevertheless, the method needs more improvement performing on the conventional PSO to achieve higher solution. Compared to other meta-heuristic algorithms, CSA can be considered the most efficient method because it gets 100% convergence rate with higher performance than PSO, DE…

In this paper, an adaptive cuckoo search algorithm (ACSA) is successfully applied to EELD problem where transmission losses and limitations of thermal unit are taken into account. The performance of the ACSA has been validated by testing on different systems and compared to other methods consisting of Tabu Search (TS) [3], FCGA [4] and CGA [4], [NSGA-II [5], BBO [7], and CSA [11].

2. Problem Formulation

The optimal economic emission dispatch is to determine the power output of each thermal unit so that the both electricity generation fuel cost and released emission are minimized during the optimal horizon.

2.1. Economic Dispatch

At thermal power plants fossil fuel is burned to drive generator and produce electricity. In addition, the fuel is very expensive and becomes exhausted in the near future. Therefore, minimization of the fuel cost, economic dispatch, is one of the objectives during operation of thermal units. The objective is expressed as the following equation.

$$\text{Min } \sum_{i=1}^{N} F_{1i}(P_i) = \sum_{i=1}^{N} (c_i P_i^2 + b_i P_i + a_i) \tag{1}$$

2.2. Emission Objective Function

In addition to minimization of fuel cost, the emission produced from burning the fossil fuel released into the air, one of the factors causing to higher temperature, is also needed to be minimized during the operation. The emission objective is summarized in the following expression.

$$Min \sum_{i=1}^{N} F_{2i}(P_i) = \sum_{i=1}^{N} (f_i P_i^2 + e_i P_i + d_i) \tag{2}$$

2.3. Economic Emission Dispatch

As minimizing both fuel cost and emission, the problem is named economic emission dispatch (EED). The objective of the EED problem is as follows.

$$Min \sum_{i=1}^{N} F_i = \sum_{i=1}^{N} \left(w_1 F_{1i}(P_i) + w_2 F_{2i}(P_i) \right) \tag{3}$$

Subject to:

1. Power balance constraints:

$$\sum_{i=1}^{N} P_i - P_L - P_D = 0 \tag{4}$$

$$P_{Lk} = \sum_{i=1}^{N_1} \sum_{j=1}^{N_1} P_i B_{ij} P_j + \sum_{i=1}^{N} B_{0i} P_i + B_{00} \tag{5}$$

2. Generator operating limits:

$$P_{i\min} \le P_i \le P_{i\max} \tag{6}$$

3. Weight constraint [12]:

$$w_1 + w_2 = 1 \tag{7}$$

3. Cuckoo Search Algorithm for EELD Problem

3.1. Calculation of Generation for Slack Thermal Unit.

In order to satisfy equality constraints, most meta-heuristic algorithms used sack variables and obtained promising results [11]. In the paper, power output of thermal units excluding the first unit is initialized and newly generated whereas the first thermal unit generation is considered as a slack variable. Its value is determined by [11]:

$$P_{s1} = P_D + P_L - \sum_{i=2}^{N} P_i \tag{8}$$

3.2. Adaptive Cuckoo Search Algorithm Implementation for the EED problem

The main steps for the proposed ACSA for solving EELD problem are described as follows:

1) *Initialization:* Similar to other meta-heuristic algorithms, each cuckoo nest in N_p nests is represented by a vector $X_d = [P_{d2}, \ldots\ldots, P_{dN}]$ $(d = 1, \ldots, N_p)$. Certainly, the upper and lower limits of each nest are respectively $X_{dmin}=[P_{imin}]$ *and* $X_{dmax}=[\ P_{imin}]$. Consequently, each nest X_d is randomly initialized within the limits $P_{i,min} \leq P_{i\ d} \leq P_{i,max}$ $(i=2, \ldots, N_1)$ as follows.

$$X_d = X_{d\min} + rand * (X_{d\max} - X_{d\min}) \tag{9}$$

Fitness function is calculated to evaluate the quality of each solution. The value includes objective function value and the penalty value of the slack thermal unit 1. The detail of fitness function is as below.

$$FT_d = \sum_{i=1}^{N} \left(w_1 F_{1i}(P_{id}) + w_2 F_{2i}(P_{id}) \right) + K_s (P_{ds1} - P_{s1}^{\lim})^2 \tag{10}$$

where $P_{s1}^{\lim}$ is obtained by:

$$P_{s1}^{\lim} = \begin{cases} P_{s\max} & if\ P_{ds1} > P_{1\max} \\ P_{s\min} & if\ P_{ds1} < P_{1\min} \\ P_{ds1} & \text{otherwise} \end{cases} \tag{11}$$

The initial population of the host nests is set to best value of each nest $Xbest_d$ ($d = 1, \ldots, N_d$) and the nest corresponding to the best fitness function in (10) is set to the best nest *Gbest* among all nests in the population.

All the solutions are ranged in increasing order of fitness value. It means that the solution with the lowest fitness value is ranged at the first position meanwhile the one with the highest fitness value is located at the end. There is a ratio to divide the number of solutions into two group including good solution group, called X_{dgood} and bad solution group, called X_{dbad}

2) *The first new solution generation* via *Lévy flights*

a. New solution generation for the good egg group

The new solution by each nest is calculated as follows:

$$X_d^{new} = Xbest_d + \alpha_1 \times rand \times \Delta X_{dgood}; d = 1, \ldots, Nogood \tag{12}$$

where $\alpha_1 = 1/\sqrt{G}$ and the increased value ΔX_{dgood} is determined by:

$$\Delta X_{dgood} = \nu \times \frac{\sigma_x(\beta)}{\sigma_y(\beta)} \times \left(Xbest_d - Gbest \right); d = 1, \ldots, Nogood \tag{13}$$

Where $\nu \times \dfrac{\sigma_x(\beta)}{\sigma_y(\beta)}$ is determined as described in detail in [11]

b. New solution generation for the bad egg group

The new solution by each nest is calculated as follows:

$$X_d^{new} = Xbest_d + \alpha_2 \times rand \times \Delta X_{dbad}; d = Nogood + 1, ..., N_P \tag{14}$$

where $\alpha_2 = 1/\text{G}^\wedge 2$ and the increased value ΔX_{dbad} is determined by:

$$\Delta X_{dgood} = \nu \times \frac{\sigma_x(\beta)}{\sigma_y(\beta)} \times \left(Xbest_d - Gbest\right); d = Nogood + 1, ..., N_P \tag{15}$$

For the newly obtained solution, its lower and upper limits should be satisfied according to the generating unit's limits:

$$X_d^{new} = \begin{cases} X_{d\max} & \text{if} \quad X_d^{new} > X_{d\max} \\ X_{d\min} & \text{if} \quad X_d^{new} < X_{d\min} \end{cases} \tag{16}$$

The new solution is evaluated by using eq. (10) above. The fitness function value of the new solutions is compared to that from the old one and better one is kept.

3) *The second new solution generation via the discovery of alien egg*:

In the strategy of the second new solution, only a fraction of kept solutions above are newly generated using the probability Pa as the following equation.

$$X_d^{dis} = \begin{cases} X_d + rand(X_{r1} - X_{r2}) \text{ if } & rand < Pa \\ X_d & otherwise \end{cases} \tag{17}$$

Similar to the solution obtained via Lévy flights, this new solution is also redefined as in (23), and each nest $Xbest_d$ and the best value of all nests *Gbest* are set based on fitness value obtained from (16).

4) *Stopping Criteria*: The proposed algorithm is terminated when the current iteration is equal to the maximum number of iteration.

4. Best Compromise Solution by Fuzzy-Based Mechanism

In the economic emission load dispatch, there is a difficulty to determine a solution which has acceptable fuel cost and emission values. In fact, as an optimal was solution found out it can certainly satisfy a particular objective due to it simple fitness function. Therefore, there is a set of non-dominated solutions are first found and then the compromise one is determined based on fuzzy satisfying method [13]. The linear membership function of the technique is as follows [13]:

$$\mu(F_j) = \begin{cases} 1 & if \quad F_j \le F_{j\min} \\ \dfrac{F_{j\max} - F_j}{F_{j\max} - F_{j\min}} & if \quad F_{j\min} < F_j < F_{j\max} \\ 0 & if \quad F_j \ge F_{j\max} \end{cases} \tag{18}$$

For each k non-dominated solution, the membership function is normalized as follows [12]:

$$\mu_D^k = \sum_{i=1}^{Nobj} \mu(F_i^k) \Bigg/ \sum_{k=1}^{Np} \sum_{i=1}^{Nobj} \mu(F_i^k) \quad (19)$$

The solution that obtains the maximum membership μ^k_D in the fuzzy set is chosen as the 'best' solution based on cardinal priority ranking:

$$\text{Max } \{\mu^k_D : k = 1, 2, \dots , N_S\} \quad (20)$$

5. Results and Discussions

The proposed ACSA is coded in Matlab 7.2 programming language and run on an Intel 1.8 GHz PC with 4 GB of Ram. The ACSA is tested on two systems where the first is comprised of three and the second consists of six thermal units. The ACSA is run ten independent trials for each case of a set control parameter.

5.1. System I with three thermal units.

In the section, the ACSA is tested on a three unit system considering transmission losses [5]. Three dispatch cases including economic dispatch, emission dispatch and economic emission dispatch are performed as follows.

Case 1: Economic dispatch (w_1=1 and w_2=0)

In this case, the number of nests and the maximum number of iterations are respectively set 12 and 40 whereas the probability is ranged from 0.1 to 0.9 with a step of 0.1. The obtained results in terms of minimum cost, average cost, maximum cost, standard deviation cost and average computational time are given in Table 1. As seen from the table, the best minimum cost, $ 8344.5927 is obtained at the Pa=01-0.9 whereas the best average cost is obtained at Pa=0.3-0.9 and the best maximum cost is obtained at Pa=0.5-0.9. Standard deviation cost is equal to zero at Pa=0.4-0.9. There is a fact that the standard deviation values of obtained results will reveal the solution quality of an optimization algorithm and these values from the ACSA are nearly equal to zero for almost values of probability *Pa*. On the other hand, the same value of the best minimum cost obtained at each Pa has indicated that the value of Pa has tiny impact on the obtained result for the economic dispatch case.

Case 2: Emission dispatch (w_1=0 and w_2=1)

In emission dispatch, the control parameters are set to the same values with those from case 1. The obtained results are summarized in Table 2. It is surprised that all values in the case are the same and the standard deviations are equal to zero. Compared to the economic dispatch, quality of the solution for the emission dispatch is better since the best minimum emission is also obtained at all Pa and the standard deviation cost is zero for all the cases of Pa.

Case 3: Economic Emission dispatch

In the economic emission dispatch, the value of number of nests and maximum number of iterations are also fixed at 12 and 40 whereas the Pa is fixed at 0.9 and the w_1 and w_2 are set to from 0 to 1 with the relation of (w_2=1-w_1). The manner to obtain the optimal solution for the compromise case is different from two dispatch cases above. Due to the many cases of Pa the best cost and emission for each value of w_1 and w_2 are shown only for the best Pa. As a result, the obtained results consisting of the best cost, the best emission and the value of μ^k_D which is determined as described in section 4 are given in Table 3. The Pareto-optimal front for cost and emission depicted by using the non-dominated solutions is shown in Figure 1.

The comparison of result obtained by ACSA and other methods including Tabu Search (TS) [3], FCGA [4] and CGA [4], [NSGA-II [5], BBO [7], and CSA [11] are reported in Table 4. Obviously, the ACSA obtains approximate or better solution than other methods. On the other hand, the execution time form ACSA for searching optimal solution is fast less than 0.1 second although the execution time comparison cannot be carried out because other methods did not report their time. As compared to CSA, the ACSA is about two times faster.

Table 1. Obtained Results for Economic Load Dispatch for System 1

p_a	Min. cost ($/h)	Average cost ($/h)	Max. cost($/h)	Std. dev. ($/h)	CPU time (s)
0.1	8344.5927	8344.5961	8344.6234	0.009107	0.04
0.2	8344.5927	8344.5929	8344.5934	0.000219	0.036
0.3	8344.5927	8344.5927	8344.5929	4.19E-05	0.041
0.4	8344.5927	8344.5927	8344.5928	0	0.042
0.5	8344.5927	8344.5927	8344.5927	0	0.039
0.6	8344.5927	8344.5927	8344.5927	0	0.038
0.7	8344.5927	8344.5927	8344.5927	0	0.039
0.8	8344.5927	8344.5927	8344.5927	0	0.04
0.9	8344.5927	8344.5927	8344.5927	0	0.042

Table 2. Obtained Results for Emission Dispatch for System 1

p_a	Min. cost ($/h)	Average cost ($/h)	Max. cost($/h)	Std. dev. ($/h)	CPU time (s)
0.1	0.095924	0.095924	0.095924	0	0.038
0.2	0.095924	0.095924	0.095924	0	0.037
0.3	0.095924	0.095924	0.095924	0	0.04
0.4	0.095924	0.095924	0.095924	0	0.041
0.5	0.095924	0.095924	0.095924	0	0.039
0.6	0.095924	0.095924	0.095924	0	0.037
0.7	0.095924	0.095924	0.095924	0	0.038
0.8	0.095924	0.095924	0.095924	0	0.041
0.9	0.095924	0.095924	0.095924	0	0.041

Table 3. Obtained Results for Economic Emission Dispatch for System 1

w_1	Cost ($/h)	Emission (kg/h)	μ^k_D
1	8344.59272	0.0986863	0.0611
0.5	8344.59272	0.0986849	0.0611
0.1	8344.59276	0.0986770	0.0613
0.05	8344.59289	0.0986678	0.0615
0.01	8344.59727	0.0985930	0.0631
0.005	8344.61115	0.0985008	0.0651

0.0025	8344.65885	0.0983420	0.0685
0.0015	8344.75665	0.0981573	0.0723
0.001	8344.92246	0.0979569	0.0762
0.0005	8345.43731	0.0975848	0.0829
0.0003	8346.54103	0.0971443	0.0894
0.000124	**8349.72083**	**0.0965377**	**0.0933**
0.000036	8356.72607	0.0960499	0.0832
0	8365.11365	0.0959239	0.0611

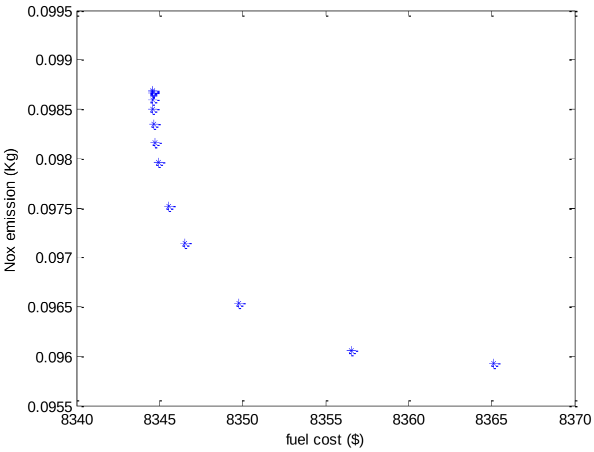

Figure 1. Pareto-optimal Front for Fuel Cost and Emission for System I

Table 4. Result Comparisons for System 1

Dispatch	Method	Tabu Search [3]	NSGA-II [5]	BBO [7]	CSA [11]	ACSA
Economic dispatch	Cost ($/h)	8344.60	8344.60	8344.59	8344.59	8344.5927
	Cpu (s)	-	-	-	0.09	0.036
Emission dispatch	Emission (kg/h)	0.0958	0.09593	0.09592	0.09592	0.095924
	Cpu (s)	-	-	-	0.07	0.037
Economic emission dispatch	Cost ($/h)	-	8349.72		8349.722	8349.72083
	Emission (kg/h)	-	0.09654		0.09654	0.0965377
	Cpu (s)	-	-		0.09	0.038

5.2. System II with six thermal units

In the section, a six-unit system without transmission losses and three load demand cases of 800, 1200 and 1800 MW is considered. The data of fuel cost and emission is respectively taken from [4] and [5]. The control parameters are set to 12 for number of nests, 60 for maximum iterations and from 0.1 to 0.9 for the probability of alien eggs to be abandoned. The results obtained for economic dispatch corresponding to load demand of 800 MW are given in Table 5. It is clearly observed from the Table, the best minimum cost is obtained at Pa=0.8. Similarly, the best solutions obtained by the ACSA for economic dispatch, emission dispatch and economic emission dispatch are compared to those from other methods. The comparisons for three load cases of 800, 1200 and 1800 MW are respectively given in Tables 6, 7 and 8. It is clearly observed from the tables that the ACSA obtains better solution and shorter computational time than CGA and FCGA in [4] for three load cases for economic dispatch whereas the ACSA and CSA [11] obtain approximate cost and emission as well as execution time for all cases.

The optimal solution obtained by ACSA is given in tables 9, 10, 11 and 12.

Table 5. Obtained Results for Economic Load Dispatch for System 2 with Load of 800 MW

p_a	Min. cost ($/h)	Average cost ($/h)	Max. cost($/h)	Std. dev. ($/h)	CPU time (s)
0.1	8227.826	8232.024	8247.314	5.529089	0.035
0.2	8227.158	8228.937	8235.713	2.670165	0.034
0.3	8227.128	8228.842	8239.885	3.757748	0.04
0.4	8228.242	8240.888	8344.593	34.7285	0.035
0.5	8227.143	8227.707	8228.912	0.50765	0.036
0.6	8227.132	8227.596	8230.015	0.84121	0.039
0.7	8227.122	8227.254	8227.503	0.125628	0.038
0.8	8227.099	8238.977	8344.593	35.20566	0.037
0.9	8227.105	8227.17	8227.444	0.095439	0.04

Table 6. Result Comparisons for System 2 for 800 MW Load

Dispatch	Method	CGAs [4]	FCGAs [4]	CSA [11]	ACSA
Economic dispatch	Cost ($/h)	8232.89	8231.03	8227.1	8227.099
	Cpu (s)	14.46	5.62	0.031	0.037
Emission dispatch	Emission (kg/h)	-	-	526.3901	526.3901
	Cpu (s)	-	-	0.03	0.036
Economic emission dispatch	Cost ($/h)	-	-	8269.5117	8253.6208
	Emission (kg/h)	-	-	568.8394	598.7095
	Cpu (s)	-	-	0.032	0.035

Table 7. Result Comparisons for System 2 for 1200 MW Load

Dispatch	Method	CGAs [4]	FCGAs [4]	CSA [11]	ACSA
Economic dispatch	Cost ($/h)	11493.74	11480.03	11477.09	11477.09
	Cpu (s)	17.83	7.43	0.031	0.037
Emission dispatch	Emission (kg/h)	-	-	1113.3005	1113.3005
	Cpu (s)			0.04	0.038
Economic emission dispatch	Cost ($/h)	-	-	11517.493	11517.493
	Emission (kg/h)	-	-	1306.6945	1306.6913
	Cpu (s)	-	-	0.032	0.04

Table 8. Result Comparisons for System 2 for 1800 MW Load

Dispatch	Method	CGAs [4]	FCGAs [4]	CSA [11]	ACSA
Economic dispatch	Cost ($/h)	16589.05	16585.85	16579.33	16579.33
	Cpu (s)	19.66	10.44	0.062	0.045
Emission dispatch	Emission (kg/h)	-	-	2511.9957	2511.9957
	Cpu (s)	-	-	0.03	0.041
Economic emission dispatch	Cost ($/h)	-	-	16641.901	16641.904
	Emission (kg/h)	-	-	2790.9434	2790.9343
	Cpu (s)	-	-	0.034	0.035

Table 9. Optimal Generations for System 1

Generation (MW)	Economic dispatch	Emission dispatch	Economic emission dispatch
P_1	435.1898	508.5939	471.0515
P_2	299.9670	250.4231	280.6460
P_3	130.6724	105.7284	113.5962

Table 10. Optimal Solution for Economic Dispatch for System 2

Generation (MW)	PD=800 (MW)	PD=1200 (MW)	PD=1800 (MW)
P_1	100.0232	124.1875	247.9194
P_2	100	117.925	217.6632
P_3	50	50	75.24467
P_4	305.9481	448.4557	588.1708
P_5	123.048	229.9844	335.4557
P_6	120.9807	229.4474	335.5463

Table 11. Optimal Solution for Emission Dispatch for System 2

Generation (MW)	PD=800 (MW)	PD=1200 (MW)	PD=1800 (MW)
P_1	100.006	176.4025	305.5977
P_2	100	176.5268	305.6227
P_3	117.925	172.1998	200
P_4	140	172.1031	251.4394
P_5	170.8814	251.4258	368.6209
P_6	171.1876	251.3419	368.7193

Table 12. Optimal Solution for Economic Emission Dispatch for System 2

Generation (MW)	PD=800 (MW)	PD=1200 (MW)	PD=1800 (MW)
P_1	100	159.9928	283.4531
P_2	100	151.4750	259.3118
P_3	53.2154	76.8542	126.2125
P_4	200.8903	308.8495	412.8607
P_5	172.9473	251.4262	359.0891
P_6	172.9471	251.4022	359.0727

6. Conclusion and Future Work

In this paper, an adaptive Cuckoo Search Algorithm has been successfully applied for solving economic emission dispatch. The ACSA is an improved version of original CSA in which all eggs in a group are evaluated and classified into two groups including good and bad groups. Each egg in the groups is newly generated by a random walk which is created by an adaptive updated size at each iteration. The manner is considered as an advantage of the ACSA over the conventional CSA since the difficulty of setting parameter is ignored. The obtained result comparison have shown that the ACSA is very efficient as applied to the economic emission dispatch because it can obtain better solution and faster simulation time than others.

In practical systems, a set of huge number of thermal units are operating to supply electricity to load. In addition, the pollutants produced at thermal plant include NOx, CO2 and SO2. Therefore, the method will be applied to economic emission dispatch where multi-thermal units and multi-pollutants are considered.

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