COMBINED ECONOMIC EMISSION LOAD DISPATCH SOLUTION USING CUCKOO SEARCH ALGORITHM

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ABSTRACT

The Cuckoo Search Algorithm (CSA) has been selected to find the best optimum solution for Combined Economic and Emission Load Dispatch Network (CEELD) problems. The objective, in the (CEELD) Analysis, that operating a generator schedule is necessary with both minimum fuel costs and emission levels, together, while satisfying the load demand and operational limitations. In this paper, the objective of research is oriented to minimize the fuel cost and emission for generation sets. The numerical results captured from the suggested method are compared with other techniques such as the Gravitational Search Method, strength Pareto evolutionary algorithm and nondominated sorting genetic algorithm-II to illustrate the efficiency of suggested method.

Keywords: combined economic and emission load dispatch, cuckoo search method.

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1. INTRODUCTION

The economic Load dispatch (ELD) problem is considered one of the complex problems in the electrical system. Finding the best power generation to match the demand while satisfying all of the system restrictions is a core goal of ELD. Because of its increased knowledge of environmental issues, society needs electricity without pollution. As a result, a new issue with the economic operation of the power system is developed. The CEELD issue is a nonlinear multi-objective optimization problem that essentially aims to find the ideal quantity of energy production from fossil fuels while simultaneously reducing fuel expense and pollution levels [1-3]. The Clean Air Act modifications passed in 1990 and the growing environmental situation has compelled the power utilities to minimize the emission [4].

Therefore, energy generation must be increased with the lowest amount of pollution and at the lowest cost. To keep the atmospheric layers without any change, the pollution must be minimized [5].

In [6], the objective is to reduce the operating cost of thermal plants while adhering to the constraints of both thermal and hydro plants. Installation of post-combustion cleaning equipment is one of them, as it is converting to low-fuels, changing out the old fuel burners for newer, cleaner ones, and dispatching with emission considerations. The Cuckoo bird’s family worked for the optimization model in steps. The invention of this new evolutionary optimization method for dispatch problems was primarily driven by the unique lifestyle of these birds and their traits in egg laying and reproduction. Cuckoo Search Method starts with a starting population, just as other evolutionary techniques. The comparison between the different algorithmic methods helps in investigating the best optimization method [7]. Using biogeography-based optimization, Roy, Ghoshal, and Thakur looked for a solution to the CEELD issue. The electrical systems may contain three, six, and fourteen generating units and are tested to search the suitable algorithm methods [8]. The nondominated sorting genetic algorithm-II (NSGA-II) is considered the suggested algorithm in practice on a ten-unit test system to find the optimum solution [9]. CEELD Study is solved effectively using a lambda-principle with the Evolutionary Programming [10]. The Genetic Algorithm (GA) is used to solve the CEELD problem. On Indian utility-sixty bus networks with nineteen generators and line flow limitations, they tested the proposed algorithm [11]. A Genetic Algorithm (GA) has been effectively employed to address the Economic Load Dispatch (ELD) issue in a power system comprising six units, each subject to various constraints such as real power balance, generator power limits, and ramp rate limits [12]. The particle Swarm Optimization method is selected to decrease Inertia Weight to detect the solution of CEELD problem. They used an IEEE 30-bus system with 6 generating units to test the suggested method using a quadratic programming approach [13]. Particle Swarm Optimization (PSO) has been applied to a 26-bus, 6-unit system, and its performance has been assessed. The outcomes of the proposed method are contrasted with those derived from the conventional lambda iteration method. The findings indicate that the proposed approach is both viable and effective [14]. To showcase the effectiveness of the particle swarm optimization technique, it has been implemented on a test system comprising four hydro units and three thermal units arranged in a multi-chain cascade[15]. Particle Swarm Optimization technique outperforms the Genetic Algorithm in terms of both cost savings and computational time when applied to this problem[16]. The artificial bee colony algorithm, when applied to address the optimal short-term hydrothermal scheduling problem, demonstrates superior performance in

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achieving cost-effective schedules with reduced fuel expenses and faster execution times in comparison to alternative methods [17]. In [18], an Imperialist Competitive Algorithm (ICA) is presented as a solution to the economic dispatch problem. This algorithm aims to distribute the load demand among the existing thermal units in order to minimize operating costs.

Multi-Objective Differential Evolution (MODE) implementation on CEELD has been suggested in [19]. In the literature, it has also been proposed to incorporate the Gravitational Search Method (GSM) [20]. In this study, the Cuckoo Search Method (CSM) was used to address the CEELD problem.

In this paper the aim of CEELD is to operate energy-producing generators in a power plant with the least fuel costs and minimal emissions levels while meeting operational restrictions and load demand. The objective of the CEELD problem is to optimally dispatch the total load demand to the generating units. Heuristic or analytical algorithms have been used in certain investigations to solve the CEELD problem.

2. PROBLEM DESCRIPTION

The objective of the CEELD problem in the electrical power system is to schedule the outputs of committed generating units to satisfy the equality and inequality constraints imposed on the system while meeting the consumer load demand at a minimal operational cost and emmision. A multi-objective mathematical programming problem is used to describe the economic dispatch for the operation of electrical units. This problem involves minimizing the fuel cost function and emission, finding the best generation profile, and ensuring that the load power and operational limits of the groups are satisfied. The multi objective function is transferred to single objective function.

2.1 Minimization of Total Fuel Cost

$$F(P_{Gi}) = \sum_{i=1}^{N} [a_i + b_i P_i + c_i P_i^2 + |d_i \sin\{e_i(P_i^{min} - P_i)\}|] \quad (1)$$

$$i = 1, 2, \ldots\ldots\ldots, N \quad (2)$$

where F (P_i) is total fuel cost function, a_i , b_i and c_i are the fuel cost coefficients of the i^{th} generating unit. d_i and e_i coefficients are used only if the valve point effect is taken into consideration.

2.2 Minimization of Emission

$$E(P_i) = \sum_{i=1}^{N} \alpha_i + \beta_i P_i + \gamma_i P_i^2 + \mu_i \exp(\delta_i P_i) \quad (3)$$

$$i = 1, 2, \ldots\ldots\ldots, N \quad (4)$$

where E(P_i) is total NOx emission function and also α_i , β_i , γ_i , δ_i , η_i are the emission coefficients of the ith generating unit, N is the number of generating units in the plant. δ_i and η_i are used only if the valve point effect is taken into account.

2.3 Constraints

i) Power balance constraint:

$$\sum_{i=1}^{N} P_i - P_{id} - P_{loss} = 0, \; i = 1,2, \ldots\ldots, N \quad (5)$$

where P_{loss} is called active transmission line losses, which can be assessed by B matrix and formulated as follows:

$$P_{loss} = \sum_{i=1}^{N} \sum_{j=1}^{N} P_i B_{ij} P_i \quad (6)$$

Where P_i and P_j are the power generation of the i^{th} and j^{th} unit and also B_{ij} is considered the loss coefficient between the ith and the jth generating unit.

ii) Output Generation capacity constraint:

$$P_i^{min} < P < P_i^{max} \quad (7)$$

2.4 CEED Formulation

Minimize FCEED = F + hE

Min (FCEED)

$$= \sum_{i=1}^{N} [a_i + b_i P_i + c_i P_i^2 + |d_i \sin\{e_i(P_i^{min} - P_i)\}|] + h_i(\alpha_i + \beta_i P_i + \gamma_i P_i^2 + \mu_i \exp(\delta_i P_i)) \quad (8)$$

$$i = 1, 2, \ldots\ldots\ldots, N \quad (9)$$

where h_i is the price penalty factor in \$/h. It is the ratio between maximum fuel cost and maximum emission, and is described as follows:

$$\text{hi} = \frac{F(P_i^{max})}{E(P_i^{max})} = \frac{a_i + b_i P_i^{max} + c_i P_i^{max^2} + |d_i \sin\{e_i(P_i^{min} - P_i^{max})\}|}{\alpha_i + \beta_i P_i^{max} + \gamma_i P_i^{max^2} + \mu_i \exp(\delta_i P_i^{max})} \quad (10)$$

3. THE CUCKOO SEARCH ALGORITHM

The cuckoo family of birds, which are known for their distinctive lifestyle and aggressive reproduction tactics, served as the inspiration for Cuckoo Search Algorithm (CSA). Yang and Deb proposed this algorithm [21]. The CSA is an optimization method based on cuckoo species' brood parasitism, in which they lay their eggs in the communal nests of other host birds, albeit they may also remove other host birds' eggs to maximize the likelihood that their own eggs will hatch. Some host birds engage in direct conflict with invaders and do not act amicably towards them. When a host bird realizes the eggs are not her own, she will either discard them or quit the nest and make a new one elsewhere [22]. The following is a description of the CSA rules:

a) Each cuckoo lays one egg at a time, and then drops it into a nest that is selected at random.

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b) The best nests will produce high-quality eggs (solutions) that will be passed down to future generations.

c) A host has a chance of discovering a foreign egg with a set number of possible host nests pa ∈ [0, 1]. The host bird has two options in this situation: either toss the egg out or leave the nest and start a brand-new nest somewhere else.

The ability of the CSA for practical optimization study has been operated on three test cases. The software program is chosen using MATLAB wand the system configuration is CORE i7 processor with 3.00 GHz speed and 8 GB SD RAM.

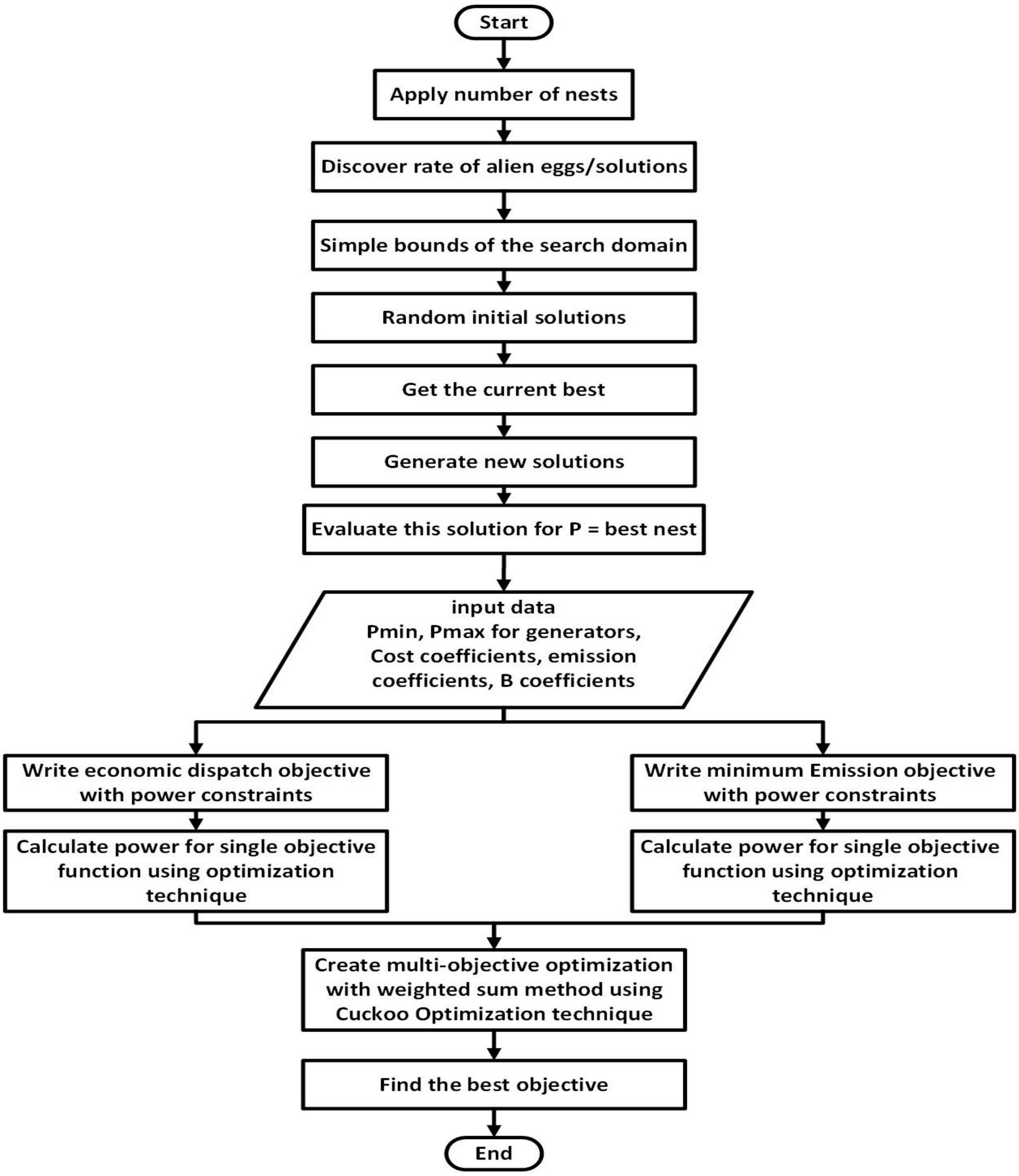

Figure-1. Workflow proposed of suggested Combined by Cuckoo Search Algorithm.

4. CASE STUDY AND NUMERICAL RESULTS

Test System 1: This system consists of six generating units having quadratic cost and emission functions. The input data for the 6-generator system is taken from [13], and the total demand (PD) is set as 1000 MW. In this case study we neglected the transmission losses and power losses and
(d_i - e_i-η_i - δ_i).

Test System 2: This system consists of ten generating units, having the effects of valve-point loading quadratic cost and emission level functions. The input data for testing the 10-generator system are taken from [13], and has a total load of 2000 MW. In this case study we neglected the transmission losses and power losses and.

Test System 3: This test system consists of forty generating units with non-smooth fuel cost and emission

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level functions. The input data for the 40-generators test system are taken from [13], which has a total load of 10,500 MW. In this case study we neglected the transmission losses and power losses and.

Table-1. Six units generator characteristics.

Unit	P_i^{min}	P_i^{max}	a_i ($/h)	b_i ($/MWh)	c_i ($/MW)^{2}h)	α_i (lb/h)	β_i (lb/MWh)	γ_i (lb/MW)^{2}h)
1	10	125	756.7988	38.5390	0.15247	13.8593	0.32767	0.00419
2	10	150	451.3251	46.1591	0.10587	13.8593	0.32767	0.00419
3	35	210	1243.5311	38.3055	0.03546	40.2669	−0.54551	0.00683
4	35	225	1049.9977	40.3965	0.02803	40.2669	−0.54551	0.00683
5	125	315	1356.6592	38.2704	0.01799	42.8955	−0.51116	0.00461
6	130	325	1658.5696	36.3278	0.02111	42.8955	−0.51116	0.00461

Table-2. Comparison for Fuel cost and emission of six units' system 1 (PD = 1000 M).

Unit	GSA [20]	Suggested CSA
P1 (MW)	78.8221	80.896
P2 (MW)	83.0013	79.507
P3 (MW)	164.2907	164.965
P4 (MW)	164.9136	165.952
P5 (MW)	258.1108	252.882
P6 (MW)	250.8619	255.795
Cost ($/h)	51255.7880	50446.684
Emission (kg/h)	827.1380	826.639
CPU time (s)	-	3.01

the results obtained in Table-2 are estimated from applying the CSA for the electrical network with a power demand of 1000 MW in the CEELD problem. The optimization results are compared with the other optimization methods in the literature. It is noticed that for minimization of the CEELD problem, the optimization results are listed in Table-2, the fuel cost is 50446. 684 $/h from the study using CSA which is less than other optimization methods. The emission level is alsom826.639 kg/h less than other optimization techniques. CPU time records 3.01 sec which is less than others.

Table-3. Ten-unit generator characteristic.

Unit	P_i^{min}	P_i^{max}	a_i ($/h)	b_i ($/MWh)	c_i ($/MW)^{2}h)	d_i ($/h)	e_i (rad/MW)	α_i (lb/h)	β_i(lb /MWh)	γ_i (lb /MW)^{2}h)	η_i (lb/h)	δ_i (1/MW)
1	10	55	1000.403	40.5407	0.12951	33	0.0174	360.0012	−3.9864	0.04702	0.25475	0.01234
2	20	80	950.606	39.5804	0.10908	25	0.0178	350.0056	−3.9524	0.04652	0.04652	0.01234
3	47	120	900.705	36.5104	0.12511	32	0.0162	330.0056	−3.9023	0.04652	0.25163	0.01215
4	20	130	800.705	39.5104	0.12111	30	0.0168	330.0056	−3.9023	0.04652	0.04652	0.01215
5	50	160	756.799	38.5390	0.15247	30	0.0148	13.8593	0.3277	0.00420	0.24970	0.01200
6	70	240	451.325	46.1592	0.10587	20	0.0163	13.8593	0.3277	0.00420	0.24970	0.01200
7	60	300	1243.531	38.3055	0.03546	20	0.0152	40.2669	−0.5455	0.00680	0.24800	0.01290
8	70	340	1049.998	40.3965	0.02803	30	0.0128	40.2669	−0.5455	0.00680	0.24990	0.01203
9	135	470	1658.569	36.3278	0.02111	60	0.0136	42.8955	−0.5112	0.00460	0.25470	0.01234
10	150	470	1356.659	38.2704	0.01799	40	0.0141	42.8955	−0.5112	0.00460	0.25470	0.01234

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Table-4. Comparison for Fuel cost and emission of ten units' system for (PD = 2000 MW).

Unit	MODE [19]	PDE [19]	NSGA-II [19]	SPEA 2 [19]	GSA [20]	CSA
P1 (MW)	54.9487	54.9853	51.9515	52.9761	54.9992	54.031
P2 (MW)	74.5821	79.3803	67.2584	72.8130	79.9586	77.121
P3 (MW)	79.4294	83.9842	73.6879	78.1128	79.4341	82.655
P4 (MW)	80.6875	86.5942	91.3554	83.6088	85.0000	93.778
P5 (MW)	136.8551	144.4386	134.0522	137.2432	142.1063	110.038
P6 (MW)	172.6393	165.7756	174.9504	172.9188	166.5670	114.336
P7 (MW)	283.8233	283.2122	289.4350	287.2023	292.8749	256.339
P8 (MW)	316.3407	312.7709	314.0556	326.4023	313.2387	340.000
P9 (MW)	448.5923	440.1135	455.6978	448.8814	441.1775	404.748
P10 (MW)	436.4287	432.6783	431.8054	423.9025	428.6306	467.046
Cost ($\times 10^5$ \$)	1.1348	1.1351	1.1354	1.1352	1.1349	1.07169
Emission (lb)	4124.9	4111.4	4130.2	4109.1	4111.4	4039.4
CPU time (s)	3.82	4.23	6.02	7.53	-	3.12

the results obtained from the CSA are listed in Table 3 for the power demand network of 2000 MW in the CEELD problem. The optimization results are compared with the other optimization methods in the literature. It is noticed that for minimization of the CEELD problem, the results are illustrated in Table 4. The fuel cost is estimated with 1.07169×10^5 \$ using CSA technique, which is less than the other optimization methods as in Figure-1.

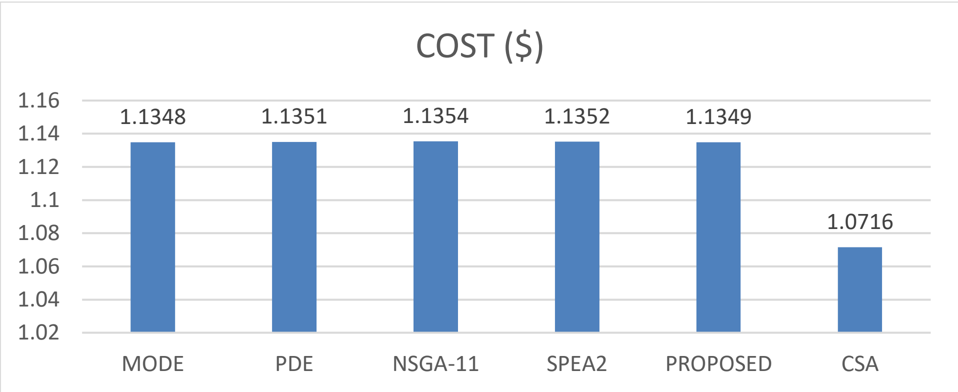

Figure-2. The Fuel Cost of a Ten Unit System using different techniques.

The emission level records 4039.4 lb, which is less than other optimization techniques The CPU time records 3.12 sec which is less than other techniques as in Figure-2.

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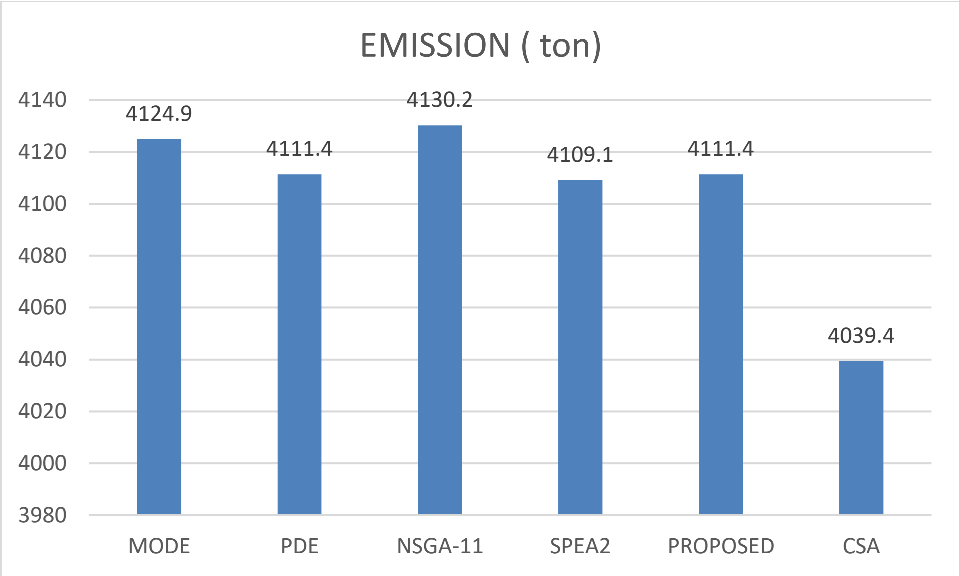

Figure-3. The Emission of ten units System using different techniques.

The Cuko Search Algorithm is applied to forty units Network to estimate the optimum solution of CEELD and get the total fuel cost and emission and compared with the other optimization search methods. The parameters and factors of generation units are written in Table-5.

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Table-5. Forty units station generation parameters.

Unit	P_i^{min}	P_i^{max}	a_i ($\$/h$)	b_i ($\$/MWh$)	c_i ($\$/MW)^2h$	di ($/h)	e_i (rad/MW)	α_i (lb/h)	β_i (lb/MWh)	γ_i (lb/MW)^2h	η_i (lb/h)	δ_i (1/MW)
1	36	114	94.705	6.73	0.00690	100	0.084	60	−2.22	0.0480	1.3100	0.05690
2	36	114	94.705	6.73	0.00690	100	0.084	60	−2.22	0.0480	1.3100	0.05690
3	60	120	309.540	7.07	0.02028	100	0.084	100	−2.36	0.0762	1.3100	0.05690
4	80	190	369.030	8.18	0.00942	150	0.063	120	−3.14	0.0540	0.9142	0.04540
5	47	97	148.890	5.35	0.01140	120	0.077	50	−1.89	0.0850	0.9936	0.04060
6	68	140	222.330	8.05	0.01142	100	0.084	80	−3.08	0.0854	1.3100	0.05690
7	110	300	287.710	8.03	0.00357	200	0.042	100	−3.06	0.0242	0.6550	0.02846
8	135	300	391.980	6.99	0.00492	200	0.042	130	−2.32	0.0310	0.6550	0.02846
9	135	300	455.760	6.60	0.00573	200	0.042	150	−2.11	0.0335	0.6550	0.02846
10	130	300	722.820	12.9	0.00605	200	0.042	280	−4.34	0.4250	0.6550	0.02846
11	94	375	635.200	12.9	0.00515	200	0.042	220	−4.34	0.0322	0.6550	0.02846
12	94	375	654.690	12.8	0.00569	200	0.042	225	−4.28	0.0338	0.6550	0.02846
13	125	500	913.400	12.5	0.00421	300	0.035	300	−4.18	0.0296	0.5035	0.02075
14	125	500	1760.400	8.84	0.00752	300	0.035	520	−3.34	0.0512	0.5035	0.02075
15	125	500	1760.400	8.84	0.00752	300	0.035	510	−3.55	0.0496	0.5035	0.02075
16	125	500	1760.400	8.84	0.00752	300	0.035	510	−3.55	0.0496	0.5035	0.02075
17	220	500	647.850	7.97	0.00313	300	0.035	220	−2.68	0.0151	0.5035	0.02075
18	220	500	649.690	7.95	0.00313	300	0.035	222	−2.66	0.0151	0.5035	0.02075
19	242	550	647.830	7.97	0.00313	300	0.035	220	−2.68	0.0151	0.5035	0.02075
20	242	550	647.810	7.97	0.00313	300	0.035	220	−2.68	0.0151	0.5035	0.02075
21	254	550	785.960	6.63	0.00298	300	0.035	290	−2.22	0.0145	0.5035	0.02075
22	254	550	785.960	6.63	0.00298	300	0.035	285	−2.22	0.0145	0.5035	0.02075
23	254	550	794.530	6.66	0.00284	300	0.035	295	−2.26	0.0138	0.5035	0.02075
24	254	550	794.530	6.66	0.00284	300	0.035	295	−2.26	0.0138	0.5035	0.02075
25	254	550	801.320	7.10	0.00277	300	0.035	310	−2.42	0.0132	0.5035	0.02075
26	254	550	801.320	7.10	0.00277	300	0.035	310	−2.42	0.0132	0.5035	0.02075
27	10	150	1055.100	3.33	0.52124	120	0.077	360	−1.11	1.8420	0.9936	0.04060
28	10	150	1055.100	3.33	0.52124	120	0.077	360	−1.11	1.8420	0.9936	0.04060
29	10	150	1055.100	3.33	0.52124	120	0.077	360	−1.11	1.8420	0.9936	0.04060
30	47	97	148.890	5.35	0.01140	120	0.077	50	−1.89	0.0850	0.9936	0.04060
31	60	190	222.920	6.43	0.00160	150	0.063	80	−2.08	0.0121	0.9142	0.04540
32	60	190	222.920	6.43	0.00160	150	0.063	80	−2.08	0.0121	0.9142	0.04540
33	60	190	222.920	6.43	0.00160	150	0.063	80	−2.08	0.0121	0.9142	0.04540
34	90	200	107.870	8.95	0.00010	200	0.042	65	−3.48	0.0012	0.6550	0.02846
35	90	200	116.580	8.62	0.00010	200	0.042	70	−3.24	0.0012	0.6550	0.02846
36	90	200	116.580	8.62	0.00010	200	0.042	70	−3.24	0.0012	0.6550	0.02846
37	25	110	307.450	5.88	0.01610	80	0.098	100	−1.98	0.0950	1.4200	0.06770
38	25	110	307.450	5.88	0.01610	80	0.098	100	−1.98	0.0950	1.4200	0.06770
39	25	110	307.450	5.88	0.01610	80	0.098	100	−1.98	0.0950	1.4200	0.06770
40	242	550	647.830	7.97	0.00313	300	0.035	220	−2.68	0.0151	0.5035	0.02075

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Table-6. Comparison for Fuel cost and emission of Forty units' system for (PD = 10, 500 MW).

Unit	MODE[19]	PDE [19]	NSGA-II [19]	SPEA 2 [19]	GSA [20]	CSA
P1 (MW)	113.5295	112.1549	113.8685	113.9694	113.9989	113.849
P2 (MW)	114.0000	113.9431	113.6381	114.0000	113.9896	113.961
P3 (MW)	120.0000	120.0000	120.0000	119.8719	119.9995	119.964
P4 (MW)	179.8015	180.2647	180.7887	179.9284	179.7857	179.904
P5 (MW)	96.7716	97.0000	97.0000	97.0000	97.0000	97
P6 (MW)	139.2760	140.0000	140.0000	139.2721	139.0128	139.999
P7 (MW)	300.0000	299.8829	300.0000	300.0000	299.9885	298.945
P8 (MW)	298.9193	300.0000	299.0084	298.2706	300.0000	300
P9 (MW)	290.7737	289.8915	288.8890	290.5228	296.2025	299.931
P10 (MW)	130.9025	130.5725	131.6132	131.4832	130.3850	131.007
P11 (MW)	244.7349	244.1003	246.5128	244.6704	245.4775	318.308
P12 (MW)	317.8218	318.2840	318.8748	317.2003	318.2101	248.941
P13 (MW)	395.3846	394.7833	395.7224	394.7357	394.6257	394.638
P14 (MW)	394.4692	394.2187	394.1369	394.6223	395.2016	395.973
P15 (MW)	305.8104	305.9616	305.5781	304.7271	306.0014	308.957
P16 (MW)	394.8229	394.1321	394.6968	394.7289	395.1005	394.492
P17 (MW)	487.9872	489.3040	489.4234	489.4234	489.2569	489.779
P18 (MW)	489.1751	489.6419	488.2701	488.5321	488.7598	489.261
P19 (MW)	500.5265	499.9835	500.8000	501.1683	499.2320	445.281
P20 (MW)	457.0072	455.4160	455.2006	456.4324	455.2821	454.669
P21 (MW)	434.6068	435.2845	434.6639	434.7887	433.4520	436.084
P22 (MW)	434.5310	433.7311	434.1500	434.3937	433.8125	444.448
P23 (MW)	444.6732	446.2496	445.8385	445.0772	445.5136	434.885
P24 (MW)	452.0332	451.8828	450.7509	451.8970	452.0547	446.236
P25 (MW)	492.7831	493.2259	491.2745	492.3946	492.8864	491.869
P26 (MW)	436.3347	434.7492	436.3418	436.9926	433.3695	445.763
P27 (MW)	10.0000	11.8064	11.2457	10.7784	10.0026	12.014
P28 (MW)	10.3901	10.7536	10.0000	10.2955	10.0246	10.997
P29 (MW)	12.3149	10.3053	12.0714	13.7018	10.0125	12
P30 (MW)	96.9050	97.0000	97.0000	96.2431	96.9125	96.908
P31 (MW)	189.7727	190.0000	189.4826	190.0000	189.9689	200
P32 (MW)	174.2324	175.3065	174.7971	174.2163	175.0000	200
P33 (MW)	190.0000	190.0000	189.2845	190.0000	189.0181	190.884
P34 (MW)	199.6506	200.0000	200.0000	200.0000	200.0000	198.991
P35 (MW)	199.8662	200.0000	199.9138	200.0000	200.0000	200
P36 (MW)	200.0000	200.0000	199.5066	200.0000	199.9978	193.081
P37 (MW)	110.0000	109.9412	108.3061	110.0000	109.9969	110
P38 (MW)	109.9454	109.8823	110.0000	109.6912	109.0126	108.431
P39 (MW)	108.1786	108.9686	109.7899	108.5560	109.4560	109.991
P40 (MW)	422.0682	421.3778	421.5609	421.8521	421.9987	422.546
Cost (×105 $)	1.2579	1.2573	1.2583	1.2581	1.2578	1.2257
Emission (×105 ton)	2.1119	2.1177	2.1095	2.1110	2.1093	2.0773
CPU time (s)	5.39	6.15	7.32	8.57	-	4.20

the results obtained from the CSA are applied for a power demand of 10,500 MW in the CEELD problem. The optimization results are compared with the other optimization methods in the literature. It is seen that for minimization of fuel cost and emission for the CEELD problem, the results are listed in Table-6.

The fuel cost is 1.2257×10^5 $ when Appling the CSA on Forty units Network, which is smaller than the other optimization methods as 1.2573×10^5 $ for PDE method as in Figure-4.

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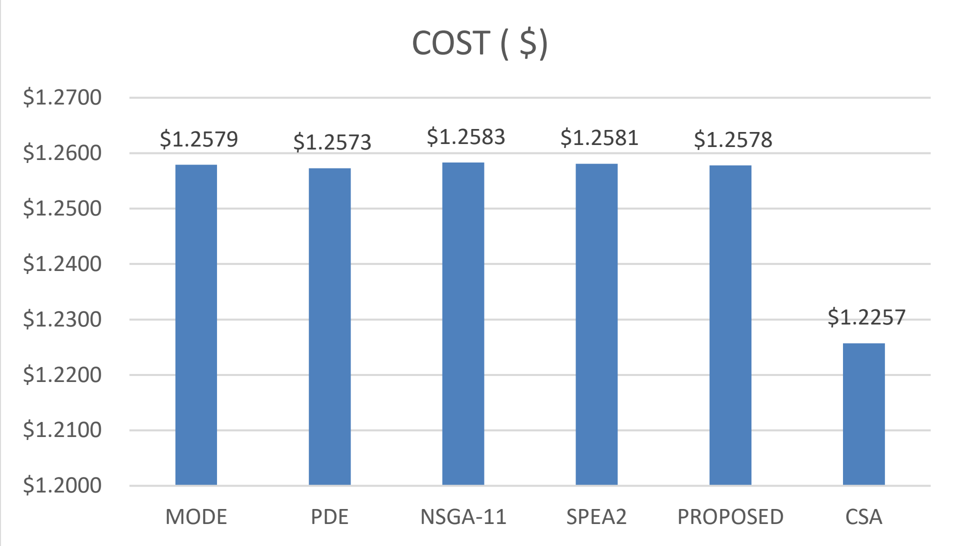

Figure-4. The Fuel Cost of Forty Units System using different techniques.

The emission level is 1.9355×10^5 ton, which less than other optimization techniques and the CPU time processing 4.20 Sec which is less than other optimization techniques as in Figure-5.

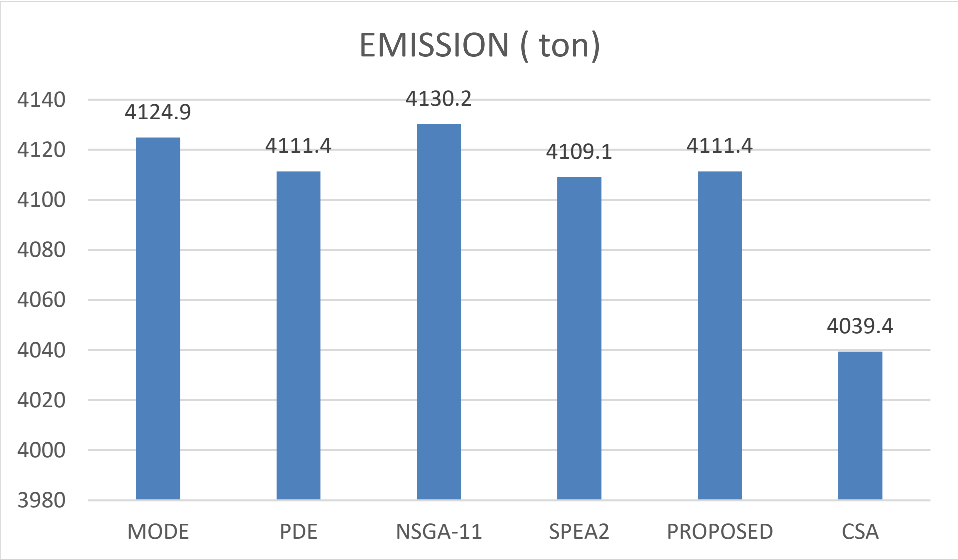

Figure-5. The Emission of Forty Units System using different techniques.

5. CONCLUSIONS

CSA is one of the recent heuristic algorithms improved for solving optimization problems. In this paper, CSA is successfully applied to solve a (CEELD) dispatch problem. The problem has been formulated as multi-objective optimization problem with competing fuel cost and emission objectives. The proposed approach is tested on three different test systems. Firstly, CSA is tested on six and Ten-generators, with a quadratic cost function for (CEELD) problems. Secondly, the suggested method is applied to Six, Ten and Forty generators for different network, with a non-smooth cost and emission function for CEELD problems. The simulation results demonstrate the effectiveness and robustness of the proposed approach in solving the CEELD problem under various test systems. Moreover, the results of the suggested CSA technique have been compared to those techniques published in the literature. In comparison to previous stochastic search algorithms in the literature, the suggested approach can offer best results. It is seen from the comparison that the proposed method confirms the effective high-quality solution for CEELD problems.

REFERENCES

[1] Lin W. M., Cheng F. S. and Tsay M. T. 2002. An improved tabu search for economic dispatch with multiple minima. IEEE Transaction on Power Systems. 17(1): 108-112.

[2] M. A. Ayoub, H. A. Henry, S. M. Abdelmaksoud and M. M. Salama. 2021. Short-Term Hydrothermal Scheduling using Imperialist Competitive Algorithm. ELEKTRIKA-Journal of Electrical Engineering. 20(1): 15-20.

[3] Yang H. T., Yang P. C. and Huang C. L. 1996. Evolutionary programming based economic dispatch using with non-smooth fuel cost functions. IEEE Transaction on Power Systems. 11(1): 112-118.

[4] Gaing Z. L. 2003.Particle swarm optimization to solving the economic dispatch considering the generator constraints. IEEE Transaction on Power Systems. 18(3): 1187-1195.

[5] 1995. IEEE Current Operating Problems Working Group, in: Potential impacts of clean air regulations on system operations. IEEE Trans. Power Syst. 10: 647-653.

[6] W. M. Mansour, M. M. Salama, S. M. Abdelmaksoud, H. A. Henry. 2013. Dynamic Economic Load Dispatch of Thermal Power System Using Genetic Algorithm. IRACST-Eng Sci Technol: An Int J (ESTIJ). 3(2).

[7] J. H. Talaq, F. El-Hawary, M. E. El-Hawary. 1994. A summary of environmental/economic dispatch algorithms. IEEE Trans. Power Syst. 9(August): 1508-1516.

[8] Ramin R. 2011. Cuckoo Optimization Algorithm. ELSEVIER. 11(8): 5508-5518.

[9] Roy P.K., Ghoshal S.P. and Thakur S.S. 2010. Combined economic and emission dispatch problems using biogeography-based optimization. Electrical Engineering. 92(4-5): 173-184.

[10] Basu M. 2008. Dynamic economic emission dispatch using nondominated sorting genetic algorithm-II. Electrical Power and Energy Systems. 30, pp. 140-149.

[11] Senthil M. E. K. 2010. Combined economic emission dispatch using evolutionary programming technique. IJCA Special Issue on Evolutionary Computation for Optimization Techniques. pp. 62-66.

[12] W.M. Mansour, M. M. Salama, S. M. Abdelmaksoud, H. A. Henry. 2012. Dynamic Economic Load Dispatch of Thermal Power System Using Particle Swarm Optimization Technique. in The International Conference on Electrical Engineering. Military Technical College.

[13] Koridak L. A, Rahli M. and Younes M. 2008. Hybrid optimization of the emission and economic dispatch by the genetic algorithm. Leonardo Journal of Sciences. 14, pp. 193-203.

[14] M. M. Salama, M. M. Elgazar, S. M. Abdelmaksoud, H. A. Henry. 2013. Short term optimal generation scheduling of multi-chain hydrothermal system using constriction factor-based particle swarm optimization technique. Int. J. Sci. Res. Publication. 3(4): 01-09

[15] M. M. Salama, M. M. Elgazar, S. M. Abdelmaksoud, H. A. Henry. 2014. Short term pumped storage scheduling using two proposed techniques. Int. J. Energy Environ. (IJEE). 5: 219-238.

[16] M. A. Ayoub, H. A. Henry, S. M. Abdelmaksoud and M. M. Salama. 2015. Solving short term hydrothermal generation scheduling by artificial bee colony algorithm. Int. Electr. Eng. J. 6(7): 1973-1987.

[17] M. A. Ayoub, H. A. Henry, S. M. Abdelmaksoud and M. M. Salama. 2019. Solving economic load dispatch problem by Imperialist Competitive Algorithm. in 2019 21st International Middle East Power Systems Conference (MEPCON). IEEE

[18] Danaraj R. M. S. and Gajendran F. 2005. Quadratic programming solution to emission and economic dispatch problems. IE (I) Journal-EL. 86, pp. 129-132.

[19] M. Basu. 2011. Economic environmental dispatch using mutli-objective differential evolution. Applied Soft Computing. 11, pp. 2845-2853.

[20] U. Guvenc, Y. Sonmez, S. Duman, N. Yorukeren. 2012. Combined economic and emission dispatch solution using gravitational search algorithm. Scientia Iranica D. 19(6): 1754-1762.

[21] L. Benasla, A. Belmadani, M. Rahli. 2014. Spiral Optimization Algorithm for Solving Combined Economic and Emission Dispatch. Electrical Power and Energy Systems. 62, pp. 163-174.

[22] R. Balamurugan, S. Subramanian. 2008. A Simplified recursive approach to combined economic emission dispatch. Electric Power Components and Systems. 36(1): 17-27.