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Combined Economic Load and Emission Dispatch using Cuckoo Search Algorithm

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Abstract— This paper presents an application of cuckoo search algorithm for multi-objective optimization problem in power system. Considering the environmental impacts that grow from the emissions produced by fossil-fuelled power plant, the economic dispatch that minimizes only the total fuel cost can no longer be considered as single objective. Application of cuckoo Search algorithm in this paper is based on mathematical modelling to solve economic, emission and combined economic and emissions dispatch problems by a single equivalent objective function. cuckoo search algorithm has been applied to two realistic systems at different load condition. Results obtained with proposed method are compared with other techniques presented in literature. Cuckoo Search algorithm is easy to implement and much superior to other algorithms in terms of accuracy and efficiency.

Keywords: **Economic dispatch; Cuckoo Search algorithm; Artificial Bee Colony algorithm; Combined economic and emission dispatch; Mathematical modelling.**

I. INTRODUCTION

This paper introduce the economic dispatch problem in a power system is to determine the optimal combination of power output for all generating units which will minimize the total fuel cost while satisfying load and operational constraints. The economic dispatch problem is very complex to solve because of its colossal dimension, a non-linear objective function, and a large number of constraints. Well known long-established techniques such as integer programming, dynamic programming, and lagarangian relaxation have been used to solve the economic dispatch problem. Recently other optimization methods such as

Simulated Annealing, Genetic Algorithm, Particle Swarm optimization, and Tabu Search Algorithm are presented to solve the economic dispatch problem. This single objective economic dispatch can no longer be considered along due to the environmental concerns that arise from the emission produced by fossil-fuelled electric power plants. Economic and environmental dispatch is a multi-objective problem. Recently, various modern heuristics multiobjective evolutionary algorithms such as Nondominated Sorting Genetic Algorithm- II (NSGAII), Evolutionary Programming algorithm (EP),Strength Pareto Evolutionary Algorithm (SPEA) and Multi-Objective Particle Swam Optimization algorithm (MOPSO) may prove to be efficient in solving EED problem by tackling both two objectives of EED problem simultaneously as competing objectives. But all these methods seem to be lack of ability to find the Pareto-optimal front due to their drawbacks: NSGA-II and SPEA may obtain only near Pareto-optimal front with long simulation time when applied to solve EED problem because of the premature convergence of Genetic Algorithm (GA) which they are based on; EP suffers from the oscillation of the solution, and computational time may be too long when applying EP to solve EED problem; the premature convergence of PSO may lead optimization progresses of MOPSO methods to the local Paretooptimum front, which would degrade their performance in solving EED problem. In [17-18] including emission constrains to the economic dispatch and unit commitment problems have been presented, under cost-minimization environment.

II COMBINED ENVIRONMENTAL ECONOMIC DISPATCH

The traditional economic dispatch problem has been defined as minimizing of an objective function i.e., the generation cost function subject to equality constraints (total power generated should be equal to total system load plus losses for all solutions) and inequality constraints (generations should lie between their respective maximum and minimum specified values). The objective function (1) is minimised subjected to equality constraint (2) and inequality constraints (3).

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Where x is a state variable, Pi is the control variable, i.e., real power setting of □□□ generator and n is the number of units or generators.

$$\varphi(x,P)\varphi_t(P_i)=\sum_{i=1}^{n}\varphi_i(P_i) \quad (1)$$
$$g(x,P)\sum_{i=1}^{n}P_i-P_L-P_D=0 \quad (2)$$
$$H(x,P)\le 0 \quad P_{imin}\le P_i\le P_{imax} \quad (3)$$

There are several ways to include emission into the problem of economic dispatch. Reference [19] summarizes the various algorithms for solving environmental dispatch problem with different constraints. One approach is to include the reduction of emission as an objective. In this work, only □□□ reduction is considered because it is a significant issue at the global level. A price penalty factor (h) is used in the objective function to combine the fuel cost, Rs/hr and emission functions, kg/hr of quadric form.

The combined economic and emission dispatch problem can be formulated as to minimize

$$\varphi_i=\sum_{i=1}^{n}E_i(P_i)\ Rs/hr \quad (4)$$
$$\varphi_i=\sum_{i=1}^{n}(a_i\,P_i{}^2+b_iP_i+c_i)+h\sum_{i=1}^{n}(d_i\,P_i{}^2+e_iP_i+f_i)Rs/hr \quad (5)$$

Subject to equality and inequality constraint defined by equations (2), (3). Once price penalty factor (h) is known, equation (5) can be rewritten as

$$\varphi_i=\sum_{i=1}^{n}\{(a_i+h\,d_i)P_i{}^2+(b_i+he_i)P_i+(c_i+f_i)\}\ Rs/hr \quad (6)$$

This has the resemblance of the familiar fuel cost equation, once h is determined. A practical way of determining h is discussed by Palanichamy and Srikrishan [8]. Consider that the system is operating with a load of PD MW, it is necessary to evaluate the maximum cost of each generator at its maximum output, i.e.

(i) Evaluate the maximum cost of each generator at its maximum output, i.e.,

$$F_i(P_{imax})=\sum_{i=1}^{n}(a_i\,P_{imax}{}^2+b_{imax}P_i+c_{imax})\ Rs/hr \quad (7)$$

(ii) Evaluate the maximum NO_x emission of each generator at its maximum output, ie,

$$E_i(P_{imax})=\sum_{i=1}^{n}(d_i\,P_{imax}{}^2+e_{imax}P_i+f_{imax})\ kg/hr \quad (8)$$

(iii) Divide the maximum cost of each generator by its maximum NO_x emission, i.e.,

$$\frac{F_i(P_{imax})}{E_i(P_{imax})}=\frac{\sum_{i=1}^{n}(a_i\,P_{imax}{}^2+b_{imax}P_i+c_{imax})}{\sum_{i=1}^{n}(d_i\,P_{imax}{}^2+e_{imax}P_i+f_{imax})}\ Rs/kg \quad (9)$$

Recalling that

$$\frac{F_i(P_{imax})}{E_i(P_{imax})}=h_i\ \text{Rs/kg} \quad (10)$$

(iv) Arrange hi (I = 1,2,......,n) in ascending order.

(v) Add the maximum capacity of each unit, one at a time, starting from the smallest h_i unit until total demand is met as shown below.

$$\sum_{i=1}^{n}P_{imax}\ge P_D \quad (11)$$

At this stage, hi associated with the last unit in the process is the price penalty factor h Rs/Kg for the given load. Arrange hi in ascending order. Let 'h' be a vector having 'h' values in ascending order.

$$h=[h_1,h_2,h_3,\dots,h_n] \quad (12)$$

For a load of PD starting from the lowest hi value unit, maximum capacity of unit is added one by one and when this total equals or exceeds the load, hi associated with the last unit in the process is the price penalty factor for the given PD. Then equation (6) can be solved to obtain environmental economic dispatch using lambda iteration method.

III CUCKOO SEARCH ALGORITHM

The Cuckoo search (CS) [2] algorithm is a Meta heuristic developed by Xin-She yang and Suash Deb in 2009.This algorithm is a nature inspired algorithm which is based on aggressive

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reproduction strategy of fascinating birds, cuckoos. These cuckoos spread their species by replacing other bird's eggs in their nests with cuckoo's eggs to increase the hatching probability. Some bird species are able to discover the alien eggs and they throw off them or build new nests for their own eggs.

Assumptions

Some of the assumptions utilized for describing the Cuckoo Search algorithm are

1. Only one egg is laid at a time by each cuckoo and this egg is dumped in a nest which is chosen randomly.

2. Eggs with high quality in the best nests are carried to next generations.

3. The probability of discovering the cuckoo's eggs by other birds is defined by pa in the range [0, 1] and the number of host nests available is assumed to be constant.

For further simplification of the algorithm, each egg in a nest is treated as one solution and cuckoo egg is treated as a new solution. The fitness is determined by the difference in solutions based on the rate of discovery of alien eggs by other birds. Solutions with best fitness replace the existing solutions. Before the initialization of the number of nests, both upper Ub and lower Lb bounds for each egg. Once initialization bounds have been specified, each egg of every nest is assigned a value from within the prescribed range by a random generator as shown in equation.

$$\text{Nest}(i,:)=Lb+(Ub-Lb).*\text{rand}(\text{size}(Lb)) \quad (13)$$

The fitness of the solutions is determined and the current best solution is stored. New solutions are generated based on step size chosen randomly by keeping the current best using the equations (14) and (15)

$$\text{stepsize}=\text{rand}*(\text{nest}(\text{rand}(n),:)-\text{nest}(\text{rand}(n),:)) \quad (14)$$

$$s=s+\text{stepsize}.*\text{randn}(\text{size}(s)) \quad (15)$$

where n is the number of nests and s represents the new solutions Probability of discovery of eggs is defined by pa chosen randomly and the next set of new nests is generated using equations (16) and (17).

$$K=\text{rand}(\text{size}(\text{nest}))>pa \quad (16)$$

$$\text{new\_nest}=\text{nest}+\text{stepsize}.*K \quad (17)$$

IV RESULTS

The applicability and efficiency of cuckoo search algorithm for practical applications has been tested on two test cases. The programs are developed using MATLAB. The Parameters for cuckoo search algorithm considered here are: n=20; Pa=0.25. Test case 1: The system consists of three thermal units. The parameters of all thermal units are presented in reference [7].

Table: 1 Comparison of test results for Three Generating units

Load demand	h, Rs/kg	Performance	Conventional Method [7]	SGA [7]	RGA [7]	ABC	Proposed Method
400	44.788	Fuel cost, Rs/hr	20898.83	20831.54	20801.81	20838.729	208378.27
		Emission, kg/hr	201.5	201.35	201.21	200.198	200.21
		Power loss, MW	7.41	7.69	7.39	7.403120	7.4014
		Total cost, Rs/hr	29922	29820	29812	29805.615	29804.905
500	44.788	Fuel cost, Rs/hr	25486.64	25474.56	25491.64	25494.904	254939.128
		Emission, kg/hr	312.0	311.89	311.33	311.125	311.133
		Power loss, MW	11.88	11.80	11.70	11.679210	11.676
		Total cost, Rs/hr	39458	39441	39433	39429.646	39429.04
700	47.82	Fuel cost, Rs/hr	35485.05	35478.44	35471.4	35462.826	35462.5
		Emission, kg/hr	652.55	652.04	651.60	354.628	651.51
		Power loss, MW	23.37	23.29	23.28	23.334221	23.33
		Total cost, Rs/hr	66690	66659	66631	66617.903	66617.51

Table: 1 shows the summarized result of CEED problem for load demand of 400MW, 500MW and 700MW are obtained by the proposed cuckoo search algorithm with stopping criteria based on maximum-generation=100. Form Table: 1, it is clear that cuckoo search algorithm gives optimum result in terms of minimum fuel cost, emission level and the total operating cost.

Table: 2 gives the best optimum power output of generators for CEED problem using ABC algorithm for load demand 400MW, 500MW and 700MW. Table: 2 Optimum Power dispatch Results by ABC, Proposed cuckoo search method for three units system.

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Load demand, MW	Algorithm	P1	P2	P3	Iterations
400	ABC	102.5546	152.7996	152.0485	29
	cuckoo search	102.5589	153.7197	151.1228	8
500	ABC	128.8494	191.4610	191.3687	56
	cuckoo search	128.8501	192.5603	190.2657	18
700	ABC	182.6259	270.3542	270.3541	44
	cuckoo search	182.6477	271.2397	269.4426	7

The convergence tendency of proposed cuckoo search algorithm based strategy for power demand of 400MW, 500MW and 700 MW is plotted in figure: 1. It shows that the technique converges in relatively fewer cycles thereby possessing good convergence property and resulting in low operating cost.

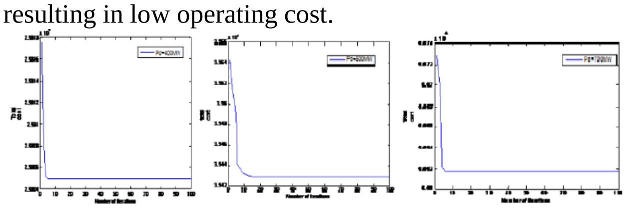

Figure: 1 convergence of Three generating units system for load demand values 400MW, 500MW & 700MW.

Test case II: The system consists of six thermal units. The parameters of all thermal units are presented in reference [9]. The summarized result of CEED problem for load demand of 500MW and 900MW are obtained by the proposed cuckoo search algorithm with stopping criteria based on maximum-generation=100 is presented in Table: 3.

Table: 3 comparison of test Results for six generating unit system

Load demand	h, Rs/kg	Performance	Conventional Method [9]	RGA [9]	Hybrid GA [9]	Hybrid GTA [9]	ABC	Proposed Method
500	43.89	Fuel cost, Rs/hr	27638.300	27692.1	27695	27613.4	27613.247	27613
		Emission, kg/hr	262.454	263.472	263.37	263.00	263.013	263
		Power loss, MW	8.830	10.172	10.135	8.93	8.934145	8.93
		Total cost, Rs/hr	39159.500	39258.10	39257.5	39158.9	39158.9	39158
900	47.82	Fuel cost, Rs/hr	48892.900	48567.7	48567.5	48360.9	48350.683	48350.1
		Emission, kg/hr	701.428	694.169	694.172	693.570	693.788	693.7
		Power loss, MW	35.230	29.725	29.718	28.004	28.009673	28.008
		Total cost, Rs/hr	82436.580	81764.5	81764.4	81529.1	81529.00	81527.7

Form Table: 3, it is clear that cuckoo search algorithm gives the optimum result in terms of minimum fuel cost, emission level and the total operating cost.

Table: 4 gives the best optimum power output of generators for CEED problem using ABC, cuckoo search algorithms for load demand 500MW and 900MW.

Table: 4 Optimum Power dispatch results by ABC Approach for six unit system

Load demand, MW	Algorithm	P1	P2	P3	P4	P5	P6	Iterations
500	ABC	33.2733	26.8554	89.9135	90.4852	135.6435	132.7631	120
	cuckoo search	33.2703	26.85061	89.91347	90.48638	135.6411	132.762	18
900	ABC	92.3297	98.3912	150.1948	148.5588	220.4043	218.1307	132
	cuckoo search	92.3288	98.3910	150.1132	148.5586	220.4007	218.1267	25

The convergence tendency of proposed ABC based strategy for power demand of 500MW and 900 MW is plotted in figure:2. It shows that the technique converges in relatively fewer cycles thereby possessing good convergence property and resulting in low operating cost.

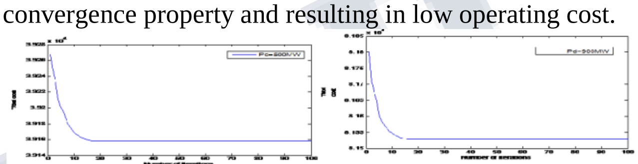

Figure: 2 convergence of six generating unit system for load demand values of 500MW and 900MW.

V CONCLUSION

In this paper, a new optimization of cuckoo search algorithm has been proposed. In order to prove the effectiveness of algorithm it is applied to CEED problem with three and six generating unit. The results obtained by proposed method were compared to those obtained conventional method, RGA and SGA and Hybrid GA and ABC. The comparison shows that cuckoo search algorithm performs better than above mentioned methods. The cuckoo search algorithm has superior features, including quality of solution, stable convergence characteristics and good computational efficiency. Therefore, this results shows that cuckoo search optimization is a promising technique for solving complicated problems in power system.

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