Economic Load Dispatch considering Valve Point Loading using Cuckoo Search Algorithm

[1]S. Nagaraju, [2]M.Mani Sankar, [3]G. Ashok, [4]A. Srinivasareddy

[1]Associate Professor, [2,3]Assistant Professor, [4]Professor
[1,2,3]Aditya Institute of Technology & Management, Tekkali
[4]Sir.C.R.Reddy college of Engineering, Eluru.

***Abstract*—This paper presents solution for the Economic Load dispatch (ELD) problem considering valve point loading on fuel cost function using cuckoo search algorithm (CSA). The main objective of the ELD problem is to minimize the fuel cost for meeting the power demand considering valve loading effect, generator limits, Power balance constrain without considering transmission losses. The cuckoo search is heuristic search algorithm which is inspired by the reproduction strategy of cuckoos. The advantage of cuckoo search method is few control parameters, high solution quality and fast computational time.**

Key words: Economic Load Dispatch, cuckoo search method.

I. INTRODUCTION

The Objective of the Economic Load dispatch (ELD) is to distribute the load demand among the generation units in such a way that the overall generation cost is minimized subjected to the constraints. An optimal ELD should meet load demand, subjected to the generation limit, ramp rate, prohibited operating zone, valve loading effect, emission effect etc. considering transmission losses such that the total cost is minimum [1]. While the problem can be solved easily if the incremental cost curves of the generators are assumed to be monotonically increasing piece-wise linear functions, such an approach will not be workable for nonlinear functions in practical systems. In the past decade, conventional optimization techniques such as lambda iterative method, linear programming and quadratic programming have been successfully used to solve power system optimization problems such as Unit commitment, Economic load dispatch etc [1, 2]. If valve-point loading is taken into account, the objective function includes a trigonometric term in addition to the quadratic terms that makes it highly nonlinear. This highly nonlinear equation cannot be directly solved by using conventional methods. For highly non-linear and optimization problems, the conventional methods are facing difficulties to locate the global optimal solution.

Several classical optimization techniques such as the gradient method [3], lambda iteration method [4], linear programming [5], quadratic programming, nonlinear programming [6], Lagrangian relaxation algorithm and dynamic programming [7] are in practice to solve ED problems. Many artificial intelligence methods such as the Genetic algorithm [8], Tabu Search [9], Hopfield neural network [10], ant colony optimization [11], different types of evolutionary programming (EP) techniques [12], bacterial foraging (BF) and hybrid bacterial foraging algorithm particle swarm optimization (BFA-PSO) [13], and so on, have also been proposed to solve ED problems. In this paper, a cuckoo search algorithm (CSA) is proposed for solving the ELD problem considering valve loading effects.

The new meta-heuristic search method CSA developed in 2009 [14] has been widely and successfully applied on engineering optimization problems regarding electrical power system such as economic load dispatch [15], economic emission dispatch [16], and hydrothermal optimal scheduling [16,17]. The proposed CSA method inspired from the reproduction behavior of cuckoo birds has attracted many researchers implementing to engineering optimization problems since it has showed several advantages of few control parameters, high solution quality and fast computational time.

II. ELD PROBLEM FORMULATION

A. Nomenclature and Acronyms

$F_{GenCost}$ – Total power generation cost
N_G - Number of generators in the system
P_{Gi} - Power output of i^{th} generator.
F_i (P_i) - Fuel cost characteristics of the i^{th} generator.
P_D - Total power demand
P_{gi}^{max} - Maximum generation capacity of the i^{th} generator.
P_{gi}^{min} - Minimum generation capacity of the i^{th} generator.
rand ( ), Rand ( ) - Uniform random value in the range [0, 1]
a_i, b_i, c_i - Fuel cost coefficients of the i^{th} generator
e_i, f_i – Fuel cost coefficients of the i^{th} generator with valve point effects
r - the random number in the range [0,1]

B. Objective Function

The objective of ELD problem is to minimize the total cost of generation subject to the equality and inequality constraints.

Fuel cost function:

Main generation is the cost of fuel. Usually, fuel cost of a thermal unit is expressed as a second order approximate function of its output P_i.

$F_{GenCost} = \sum_{i=1}^{N_G} F_i(P_{Gi})$

Where $F_i(P_i) = a_i P_{Gi}^2 + b_i P_{Gi} + c_i$ i=1,2,3,4…….N_G ………(1)

Where a_i, b_i and c_i are fuel cost coefficients of the i^{th} generation unit.

To take into account of the valve-point effect, sinusoidal functions are added as given below.

$F_i(P_i) = a_i P_{Gi}^2 + b_i P_{Gi} + c_i + \left| d_i \sin\left(e_i\left(P_{Gi}^{min} - P_{Gi}\right)\right)\right|$ ………(2)

Where d_i and e_i are the fuel cost-coefficients of the i_{th} unit with valve-point effects. P_{Gi} is the power generated by the i_{th} unit.

Therefore the objective function of the ELD problem is to minimize $F_{GenCost} = \sum_{i=1}^{N_G} F_i(P_{Gi})$ subjected to the following constraints.

C. Constraints

The constraints that must be satisfied during the solving of ELD optimization are as follows.

1. Power balance

Power generated from the all available units must meet the load demand.

$$\sum_{i=1}^{N_g} P_{Gi} - P_D = 0 \qquad \text{………(3)}$$

2. Generator constraints

For steady operation of generator, the active power, reactive power and voltages must be between theirs lower and upper values as given below.

$$P_{Gi}^{\ min} \leq P_{Gi} \leq P_{Gi}^{\ max} \qquad \text{………(4)}$$

III. PROPOSED METHOD

A. CUCKOO SEARCH ALGORITHM:

The CSA is a new and efficient population-based heuristic evolutionary algorithm[14] for solving optimization problems with the advantages of simple implement and few control parameters. This algorithm is based on the obligate brood parasitic behavior of some cuckoo species combined with the Lévy flight behavior of some birds and fruit flies. There are mainly three principal rules during the search process as follows.

1. Each cuckoo lays one egg (a design solution) at a time and dumps its egg in a randomly chosen nest among the fixed number of available host nests.
2. The best nests with high quality of egg (better solution) will be carried over to the next generation.
3. The number of available host nests is fixed, and a host bird can discover an alien egg with a probability pa 2 [0,1]. In this case, it can either throw the egg away or abandon the nest so as to build a completely new nest in a new location.

As a further approximation, the last assumption can be approximated by a fraction pa of the n host nests are replaced by new nests (with new random solutions). For maximization problems, the quality or fitness of a solution can simply be proportional to the value of the objective function. Other forms of fitness can be defined in a similar way to the fitness function in genetic algorithms.

Generally, the CSA method consists of two important operations including (1) laying egg and (2) destroying and rebuilding nest.

B. Application of cuckoo search algorithm (CSA) to economic dispatch

The step wise implementation of CSA to ELD is given below.

Step-1: Select parameters for CSA including the number of nest N_n, the maximum number of iterations and the probability of discovering an alien egg.

Step-2: In cuckoo search, each egg can be regarded as a solution. In the initial process, each solution is generated randomly. The proposed CSA has N_n host nests representing $X_D = [X_1, X_2, \ldots\ldots, X_N]^T$ where each nest X_D contains power outputs of N_G generation units.

$P_{Gi} = P_{Gi}^{min} + rand*(P_{Gi}^{max} - P_{Gi}^{min})$

Step-3: Calculate the first generator output as

$P_{G1} = P_D - \sum_{i=2}^{N_G} P_{Gi}$

Step-4: Evaluate fitness function to using cost function to determine X_{best} and G_{best}. Set the current iteration Iter = 1.

Step-5: Generate all new nests via Levy flights as
'Generation of new solution via Levy flights'.
$X_d^{new} = Xbest_d + \alpha_1 * rand * \Delta X_d$
α_1 is the updated step size, rand is the random number (0,1)
stepsize=u./abs(v).^(1/β)
u=α*(1-v);
α =(γ(1+ β)*sin(β *pi/2))/(γ ((1+ β)/2)* β *2^((β -1)/2));
Where is β=1.5 (0.3≤ β≤2), v is random number (0,1).
$\Delta X_d^{new} =$ stepsize*(Nest best-Nest$_i$)

Step-6: – Define the new nests in case of violating their limits
Using

$$P_{Gi} \leq \begin{cases} P_{Gi}{}^{min} & if\ P_{Gi} < P_{Gi}{}^{min} \\ P_{Gi}{}^{max} & if\ P_{Gi} > P_{Gi}{}^{max} \\ P_{Gi} & otherwise \end{cases}$$

– Calculate the fitness using equation

$$F_{GenCost} = \sum_{i=1}^{N_G} F_i(P_{Gi})$$

Step-7: Compare each new nest with each old nest to keep the nest owning lower fitness value.

Step-8: Generate a fraction of new eggs by discovering alien egg and randomizing as in Section 'Alien egg discovery and randomization'.

Step-9: – Define the new nests in case of violating their limits as calculated in step-6.

Step-10: Compare each new nest with each old nest to keep the nest owning lower fitness value.

Step-11: Set each nest to X_{bestd} and one nest corresponding to the lowest fitness value to the global best nest G_{best}.
Step-12: If Iter < Itermax, Iter = Iter + 1 and return to Step 5.
Otherwise, stop the procedure.

IV. NUMERICAL RESULTS

In this paper, cuckoo search methods was implemented in MATLAB 7 computing environment on a Pentium core i3 processor 3.3GHz and 4GB Ram memory. Three test systems with 3,6 and 13 thermal units including valve loading effect are solved to test the algorithm. For the three test systems (3,6 and 13 thermal units) cuckoo search method was run for 10 times for a given demand and stopping criteria was maximum (100) iterations. The parameters of the PSO are: Population size=4, iterations=100, β=1.5, v=rand(1,1) and u=Alpha*(1-v);

A. Test case I - 3 unit system.

In this test system, 3 thermal units are considered with a power demand of 850MW. Table 1 shows the results for 3 thermal units based on cuckoo search algorithm. From Table 1 it can be observed that cuckoo yields better results as compared with the other methods. Also the execution time is less.

TABLE1.
CUCKOO SEARCH METHOD RESULTS FOR 3 UNIT THERMAL PLANTS

Algorithm	Best Result ($/hour)	Mean Result ($/hour)	Best execution time	Mean execution time
CSA	8248.2	8397.16	0.067018	0.077223

TABLE 2.
GENERATION ALLOCATION BETWEEN 3 GENERATION UNITS BASED ON CSA

	CSA based generation allocation
P1/MW	498.62
P2/MW	101.3186
P3/MW	250.0614
Total generation/MW	850
Cost ($/hour)	8248.2
Execution Time	0.078457

B. Test case II- 6 unit system.

In this test case 6 thermal generator units with a load demand of 800MW. Table 4 shows the generation allocation among 6 thermal units based on cuckoo search algorithm. From Table 3 it can be observed that cuckoo yields better results as compared with the other methods. Also the execution time is less.

TABLE3.
CUCKOO SEARCH METHOD RESULTS FOR 6 UNIT THERMAL PLANTS

Algorithm	Best Result ($/hour)	Mean Result ($/hour)	Best execution time	Mean execution time
CSA	10034	10192	0.122176	0.156739

TABLE 4.
GENERATION ALLOCATION BETWEEN 6 GENERATION UNITS BASED ON CSA

	CSA based generation allocation
P1/MW	301.9488
P2/MW	157.9381
P3/MW	147.3459
P4/MW	100.4665
P5/MW	45.2406
P6/MW	47.0602
Total generation/MW	800
Cost ($/hour)	10034
Execution Time	0.161105

C. Test case III- 13 unit system.

In this test case 13 thermal generator units with a load demand of 1800MW. Table 6 shows the generation allocation among 13 thermal units based on cuckoo search algorithm. From

Table 5 it can be observed that cuckoo search method yields better results as comparable with the other methods.

TABLE5.
CUCKOO SEARCH METHOD RESULTS FOR 13 THERMAL PLANT UNITS

Algorithm	Best Result ($/hour)	Mean Result ($/hour)	Best execution time	Mean execution time
CSA	18809	18900	0.202105	0.255432

TABLE 6.
GENERATION ALLOCATION BETWEEN 13 GENERATION UNITS BASED ON CSA

	CSA based generation allocation
P1/MW	369.0548
P2/MW	227.7351
P3/MW	62.1765
P4/MW	108.7713
P5/MW	107.4378
P6/MW	120
P7/MW	163.7386
P8/MW	156.2434
P9/MW	138.6708
P10/MW	108.8067
P11/MW	115.7574
P12/MW	62.2591
P13/MW	59.3485

Total generation/MW	1800
Cost ($/hour)	18809
Execution Time	0.202105

V. CONCLUSION

In this paper, the cuckoo search algorithm method was employed to solve the ELD problem with valve point loading effect for 3, 6 and 13 generator units. Many non-linear characteristics of the generators can be handled efficiently by the proposed method. Therefore the cuckoo search method will be a very efficient and robust method for solving complex ELD problems.

REFERENCES

[1] A. J. Wood and B. F. Wollenberg, “Power generation, operation, and control,” 2nd ed., New York: John Wiley and Sons, 1996.

[2] D. C.Walters and G. B. Sheble, “Genetic algorithm solution of economic dispatch with valve point loading”, IEEE Trans. on Power Systems, vol.10, No.8, pp. 1325-1332, Aug. 1993.

[3] Dodu J C, Martin P, Merlin A, Pouget J. An optimal formulation and solution of short-range operating problems for a power system with flow constraints. Proceedings of the IEEE, 1972, 60(1): 54–63

[4] Chen C L, Wang S C. Branch-and-bound scheduling for thermal generating units. IEEE Transactions on Energy Conversion, 1993, 8(2): 184–189

[5] Parikh J, Chattopadhyay D. A multi-area linear programming approach for analysis of economic operation of the Indian power system. IEEE Transactions on Power Systems, 1996, 11(1): 52–58.

[6] Nabona N, Freris L L. Optimisation of economic dispatch through quadratic and linear programming. Proceedings of the Institution of Electrical Engineers, 1973, 120(5): 574–580

[7] Liang Z X, Glover J D. A zoom feature for a dynamic programming solution to economic dispatch including transmission losses. IEEE Transactions on Power Systems, 1992, 7(2): 544–550

[8] Kumar S, Naresh R. Nonconvex economic load dispatch using an efficient real-coded genetic algorithm. Applied Soft Computing, 2009, 9(1): 321–329

[9] Sa-ngiamvibool W, Pothiya S, Ngamroo I. Multiple tabu search algorithm for economic dispatch problem considering valve-point effects. International Journal of Electrical Power & Energy Systems, 2011, 33(4): 846–854

[10] Su C T, Lin C T. New approach with a Hopfield modeling framework to economic dispatch. IEEE Transactions on Power Systems, 2000, 15(2): 541–545

[11] Pothiya S, Ngamroo I, Kongprawechnon W. Ant colony optimization for economic dispatch problem with non-smooth cost environment. Energy Conversion and Management, 2005, 46(17): 2689–2696

[12] Sinha N, Chakrabarti R, Chattopadhyay P. Evolutionary programming techniques for economic load dispatch. IEEE Transactions on Evolutionary Computation, 2003, 7(1): 83–94

[13] Jayabarathi T, Bahl P, Ohri H, Yazdani A, Ramesh V. A hybrid BFA-PSO algorithm for economic dispatch with valve-point effects. Frontiers in Energy, 2012, 6(2): 155–163

[14] Yang XS, Deb S. Cuckoo search via Lévy flights. In: Proc. World congress on nature & biologically inspired computing (NaBIC 2009), India. p. 210–4.

[15] Dieu VN, Schegner P, Ongsakul W. Cuckoo search algorithm for non-convex economic dispatch. IET Gen Transm Distrib 2013;7:645–54.

[16] Thao NTP, Thang NT. Environmental economic load dispatch with quadratic fuel cost function using Cuckoo search algorithm. Int J u- and e- Serv Sci Technol 2014;7:199–210.

[17] Thang NT, Dieu VN, Anh TV. Cuckoo search algorithm for short-term hydrothermal scheduling. Appl Energy 2014;132:276–87.

[18] Thang NT, Dieu VN. Modified Cuckoo search algorithm for short-term hydrothermal scheduling. Electr Pow Energy Syst 2015;65:271–81.

[19] Mantegna RN. Fast, accurate algorithm for numerical simulation of Levy stable stochastic processes. Phys Rev E 1994;49:4677–83.