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# Economic Load Dispatch Using Cuckoo Search Algorithm

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## ABSTRACT

**Economic Load Dispatch problem (ELD) is one of the most important optimization problems in power system operation and planning. This paper introduces a solution to ELD problem using a new metaheuristic nature-inspired algorithm called Cuckoo Search Algorithm (CSA). The proposed approach has been applied to various systems. This algorithm is based on the obligate brood parasitic behavior of some cuckoo species. The results proved the efficiency of the proposed method when compared with the other optimization algorithms.**

***Keywords*** **-** Cuckoo Search Algorithm (CSA), Economic Load Dispatch (ELD)

## I. Introduction

The economic load dispatch is an important real time problem, in allocating the real power demand among the generating units. The best generation schedule for the generating plants to supply the required demand, plus the transmission loss with the minimum generation cost. Traditional optimization techniques such as gradient method, lambda iteration method, the linear programming method and Newton's method are used to solve the ELD problem with increasing cost function.

Economic dispatch methods require the generator cost curve to be continuous. Hence the operating cost function for each generator has been approximately represented by the quadratic function. It is of great importance to solve this problem quickly and accurately as possible by considering all kind of discontinuity in non-linear space. The conventional methods include the base point and participation factor, lambda-iteration method and gradient method [1]. In these numerical methods, an essential assumption is that the incremental cost curves of the units are increasing.

The input-output characteristics of modern units are highly non-linear. These non-linear characteristics of generating units are due to discontinuous prohibited operating zones, ramp rate limits and cost functions, which are not smooth, thus gives inaccurate results. Therefore more interests have been focused on the application of Artificial Intelligence (AI) technology for solution of these problems. Some of AI methods are Genetic Algorithm, simulated Annealing , Tabu Search, Evolutionary Programming, Ant Colony Optimization, Artificial Neural Networks, Differential Evolution , Harmony search Algorithm, Dynamic Programming and Particle Swarm Optimization [2-11], have been developed and applied successfully to small and large systems to solve ELD problems in order to find better results. Recently, a new metaheuristic search algorithm, called Cuckoo Search (CS) [12-17], has been developed by Yang and Deb. In this paper, Cuckoo Search Algorithm has been used to solve the ELD problem.

## II. Economic Load Dispatch Formulation

### 2.1. Economic Dispatch

The main objective of ELD of electric power generation is to schedule the generating units so as to meet the load demand at minimum operating cost while satisfying all the constraints. The economic load dispatch problem including transmission losses is expressed as

$$\text{Minimize } F_T = \sum_{i=1}^{n} F_i(P_i) \qquad (2.1)$$

Where $F_T$ is the total generation cost in RS/hr, 'i' is the number of generators, $P_i$ is the real power generation of $i^{th}$ generator in MW, $F_i(P_i)$ is the generation cost for $P_i$. Subjected to equality and inequality constraints. These constraints include:

### 2.1.1 Power Balancing Equation

For power balance condition, an equality constraint should be satisfied. The total power generation should be same as total load demand plus the total line losses.

$$P_D + P_L - \sum_{i=1}^{n} P_i = 0 \qquad (2.2)$$

Where $P_D$ is the total demand in MW, $P_L$ is the transmission loss of the system in MW.

### 2.1.2 Generator Limits

The generation output of each generator should lie between minimum and maximum limits. The inequality constraints for each generator are

$$P_{i,\min} \le P_i \le P_{i,\max} \qquad (2.3)$$

Where $P_{i,\min}$ is the Minimum power output limit of $i^{th}$ generator in MW, $P_{i,\max}$ is the Maximum power output limit of $i^{th}$ generator in MW.

The generator cost function $F_i(P_i)$ is usually expressed as a quadratic polynomial (cost-curve equation):

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i \qquad (2.4)$$

Where $a_i$, $b_i$ and $c_i$ are fuel cost coefficients.

### 2.1.3 Transmission Losses

The Transmission losses are taken in to account to achieve true economic load dispatch. It is a function of unit generation. To calculate the transmission losses two methods are there in general. One is the penalty factors method and other is the B-coefficients method. In the B-coefficients method, network losses are expressed as a quadratic function:

$$P_L = \sum_{i=1}^{n} \sum_{j=1}^{m} P_i B_{ij} P_j \qquad (2.5)$$

Where $B_{ij}$ is a constant which is called B-coefficients or loss coefficients.

## III. Cuckoo Search

### 3.1. Cuckoo Behavior

Cuckoos are the fascinating birds, not only because of their beautiful sounds they make, but also because of their reproduction strategy. Some species such as the *ani* and *Guira* cuckoos lay their eggs in nests, though they may remove other's eggs to increase the hatching probability of their eggs. A number of species engage the brood parasitism by laying their eggs in the nest of other host birds [12]. There are three basic types of brood parasitism: intra-specific brood parasitism, co-operative breeding, and nest take-over. Some host birds can engage direct conflict with the intruding cuckoos. If a host bird discovers the eggs are not their own, they will either throw these alien eggs away or simply abandon its nest and build a new nest elsewhere. Some cuckoo species such as the New World brood-parasitic *Tapera* have evolved in such a way that female parasitic cuckoos are often very specialized in the mimicry in color a pattern of the eggs of a few chosen host species. This reduces the probability of their reproductivity [13].

### 3.2 Levy Flights

In nature, animals search for food in a random or quasi-random manner. In general, the foraging path of an animal is electively a random walk because the next move is based on the current location/state and the transition probability to the next location [14].

### 3.3 Cuckoo Search

In describing our new Cuckoo Search, we now use the following three idealized rules:

i. Each cuckoo lays one egg at a time, and dump its egg in randomly chosen nest;
ii. The best nests with high quality of eggs will carry over the next generations;
iii. The number of available host nests is fixed, and the egg laid by a cuckoo is discovered by the host bird with a *probability* $P_a$ ε [0. 1].

In this case, the host bird can either throw the egg away or abandon the nest, and build a completely new nest. For simplicity, this last assumption can be approximated by the fraction $P_a$ of the *n* nests are replaced by new nests.

For maximization problem, the quality or fitness of a solution can simply be proportional to the value of the objective function. Other forms of fitness function in genetic algorithms [15]. For simplicity, we can use the following simple representations that each egg in a nest represents a solution, and a cuckoo egg represents a new solution. When generating new solutions $x^{(t+1)}$ for, say, a Cuckoo i, a Levy flight is performed

$$x_i^{(t+1)} = x_i^{(t)} + \alpha \oplus Levy(\lambda) \qquad (3.1)$$

where $\alpha > 0$ is the step size which should be related to the scales of the problem of interests. In most cases, we can use $\alpha = 1$ [16]. The product $\oplus$ means entry wise multiplications. This entry wise product is similar to those used in PSO.

The Levy flight essentially provides a random walk while the random step length is drawn from a Levy distribution

$$Levy \sim u = t^{-\lambda}, \ (1 < \lambda \le 3) \qquad (3.2)$$

which has an infinite variance with an infinite mean. Levy walk around the best solution obtained so far, this will speed up the local search [17].

## IV. Cuckoo Search Algorithm

**Step 1:** Read the system data which consists of fuel cost coefficients, minimum and maximum power limits of all generating units, power demand and B-coefficients.

**Step 2:** Initialize the parameters and constants of Cuckoo Algorithm. They are "**non**", $P_a$, beta, itermax.

**Step 3:** Generate "**non**" number of nests randomly between $\lambda_{\min}$ and $\lambda_{\max}$

**Step 4:** Set iteration count to 1.

**Step 5:** Calculate the fitness value corresponding to "**non**" number of cuckoos.

**Step 6:** Obtain the best fitness value Gbest by comparing all the fitness values and also obtain the best nests corresponding to the best fitness value Gbest.

**Step 7:** Determine sigma value using the following equation:

$$\sigma_u = \left\{ \frac{\Gamma(1+\beta)\sin(\Pi\beta/2)}{\Gamma*[(1+\beta)/2]\beta*2^{(\beta-1)/2}} \right\}^{1/\beta}$$

**Step 8:** Find **newnest** by using **stepsize** between the $\lambda_{\min}$ and $\lambda_{\max}$ limits.

**Step 9:** Find the fitness value, **if tfitness** > **fitness** value then send the nest values to **newnest**. Next update **Gbest** by comparing fitness values.

**Step 10: New solution by Random Walk**

In this if **random value** > **pa** then find the **stepsize1** between any two nests. Then find **newnest1,** where **newnesst1 = nest + stepsize1**, the **newnest1** must be with in the limits. Again update the **Gbest** by comparing fitness values. If this condition violates then go to step 5 and repeat this procedure.

**Step 11:** Finally Gbest gives the optimal solution of the Economic Load Dispatch problem and the results are printed.

## V. Search Results

The proposed Cuckoo Search Algorithm has been implemented successfully to solve the ELD problem of units. Cuckoo method is tested with three generating unit system and six generating unit system. The problem is solved by Lambda iterative and the Cuckoo Search methods optimize the problem.

The economic load dispatch problem requires the loss coefficient matrix for calculating transmission line losses and also satisfying the power balancing equation and also the operational constraints. The Cuckoo program is written in MATLAB software package.

### 5.1 Three-Unit System

The loss coefficient matrix or B-coefficient matrix of three unit system are given below in table 5.1. Economic Load Dispatch for three unit system is solved by Lambda iteration method and Cuckoo search method. The results of Cuckoo search method are given in below table 5.2. Comparison of Lambda iteration method and Cuckoo search method results are tabulated in below table 5.3.

The loss coefficient matrix of 3-Unit System

$$B_{ij} = \begin{bmatrix} 0.000071 & 0.000030 & 0.000025 \\ 0.000030 & 0.000069 & 0.000032 \\ 0.000025 & 0.000032 & 0.000080 \end{bmatrix}$$

### 5.2 Six-Unit System

The loss coefficient matrix or B-coefficient matrix of six unit system are given below in table 5.4. Economic Load Dispatch for six unit system is solved by Lambda iteration method and Cuckoo search algorithm method. The results of Cuckoo search method are given in below table 5.5. Comparison of Lambda iteration method and Cuckoo search method results are tabulated in below table 5.6.

The loss coefficient matrix of 6-Unit System

$$B_{ij} = \begin{bmatrix} 0.000014 & 0.000017 & 0.000015 & 0.000019 & 0.000026 & 0.000022 \\ 0.000017 & 0.000060 & 0.000013 & 0.000016 & 0.000015 & 0.000020 \\ 0.000015 & 0.000013 & 0.000065 & 0.000017 & 0.000024 & 0.000019 \\ 0.000019 & 0.000016 & 0.000017 & 0.000072 & 0.000030 & 0.000025 \\ 0.000026 & 0.000015 & 0.000024 & 0.000030 & 0.000069 & 0.000032 \\ 0.000022 & 0.000020 & 0.000019 & 0.000025 & 0.000032 & 0.000085 \end{bmatrix}$$

## VI. Conclusion

Economic Load Dispatch problem is solved by using Lambda iteration and Cuckoo search methods. The Results of Lambda iteration method and Cuckoo search algorithm are compared for three generating unit and six generating unit systems. The program is written in MATLAB software package. The Economic Load Dispatch has to meet the load demand at minimum operating cost while satisfying the constraints of power system of all units.

Table 5.1 Cost of power generation and power limits of 3-Uint System

| Units | $a_n$ | $b_n$ | $c_n$ | $P_{n,min}$ | $P_{n,max}$ |
|---|---|---|---|---|---|
| 1 | 1243.5311 | 38.30553 | 0.03546 | 35 | 210 |
| 2 | 1658.5696 | 36.32782 | 002111 | 130 | 325 |
| 3 | 1356.6592 | 38.27041 | 0.01799 | 125 | 315 |

Table 5.2 Cuckoo Search Results for 3-Unit system

| SI.No | Power Demand (MW) | λ | $P_1$ (MW) | $P_2$ (MW) | $P_3$ (MW) | $P_{loss}$ (MW) | Fuel Cost (Rs/hr) |
|---|---|---|---|---|---|---|---|
| 1 | 350 | 44.4387 | 70.3012 | 156.267 | 129.208 | 5.77698 | 18564.5 |
| 2 | 400 | 45.4762 | 82.0784 | 174.994 | 150.496 | 7.56813 | 20812.3 |
| 3 | 450 | 46.5291 | 93.9374 | 193.814 | 171.862 | 9.61271 | 23112.4 |
| 4 | 500 | 47.5977 | 105.88 | 212.728 | 193.306 | 11.9144 | 25465.5 |
| 5 | 550 | 48.6824 | 117.907 | 231.738 | 214.831 | 14.4769 | 27872.4 |
| 6 | 600 | 49.7836 | 130.021 | 250.846 | 236.437 | 17.3040 | 30334.0 |
| 7 | 650 | 50.9017 | 142.223 | 270.053 | 258.124 | 20.3997 | 32851.0 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 8 | 700 | 52.0371 | 154.514 | 289.360 | 279.894 | 23.7680 | 35424.4 |

Table 5.3 Comparison results of Lambda iteration method and Cuckoo search method for 3-Unit System

| SI. No | Power Demand (MW) | Fuel Cost (Rs/hr) | |
|---|---|---|---|
| | | Lambda Iteration Method | Cuckoo Search Algorithm |
| 1 | 350 | 18570.7 | 18564.5 |
| 2 | 400 | 20817.4 | 20812.3 |
| 3 | 450 | 23146.8 | 23112.4 |
| 4 | 500 | 25495.2 | 25465.5 |
| 5 | 550 | 27899.3 | 27872.4 |
| 6 | 600 | 30359.3 | 30334.0 |
| 7 | 650 | 32875.0 | 32851.0 |
| 8 | 700 | 35446.3 | 35424.4 |

Table 5.4 Cost of power generation and power limits of 6-Uint System

| Unit | $a_n$ | $b_n$ | $c_n$ | $P_{n,min}$ | $P_{n,max}$ |
|---|---|---|---|---|---|
| 1 | 756.79886 | 38.53 | 0.15240 | 10 | 125 |
| 2 | 451.32513 | 46.15916 | 0.10587 | 10 | 150 |
| 3 | 1049.9977 | 40.39655 | 0.02803 | 35 | 225 |
| 4 | 1242.5311 | 38.30443 | 0.03546 | 35 | 210 |
| 5 | 1658.5696 | 36.32782 | 0.02111 | 130 | 325 |
| 6 | 1356.6592 | 38.27041 | 0.01799 | 125 | 315 |

Table 5.5 Cuckoo Search Results for 6-Unit system

| SI.No | Power Demand (MW) | λ | $P_1$ (MW) | $P_2$ (MW) | $P_3$ (MW) | $P_4$ (MW) | $P_5$ (MW) | $P_6$ (MW) | $P_{loss}$ (MW) | Fuel Cost (Rs/hr) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 500 | 45.7091 | 19.4904 | 10 | 72.5904 | 82.9315 | 175.082 | 149.791 | 9.88519 | 27442.5 |
| 2 | 600 | 47.3419 | 238.603 | 10 | 95.6389 | 100.708 | 202.832 | 181.198 | 14.2374 | 32094.7 |
| 3 | 650 | 48.1731 | 26.0679 | 10 | 107.264 | 109.668 | 216.775 | 196.954 | 16.7281 | 34482.6 |
| 4 | 700 | 49.0146 | 28.2908 | 10 | 118.958 | 118.675 | 230.763 | 212.745 | 19.4319 | 36912.2 |
| 5 | 750 | 49.8451 | 30.4756 | 11.2265 | 130.446 | 127.515 | 244.466 | 228.182 | 22.3108 | 39384.0 |
| 6 | 800 | 50.6612 | 32.5861 | 14.4843 | 141.548 | 136`045 | 257.664 | 243.009 | 25.3309 | 41896.7 |
| 7 | 850 | 51.4839 | 34.7102 | 17.7675 | 152.708 | 144.614 | 270.897 | 257.859 | 28.556 | 44450.3 |
| 8 | 900 | 52.3162 | 36.8481 | 21.0775 | 163.93 | 153.227 | 284.17 | 272.737 | 31.9881 | 47045.3 |
| 9 | 950 | 53.1585 | 38.9998 | 24.4145 | 175.214 | 161.882 | 297.481 | 287.64 | 35.6295 | 49682.1 |

Table 5.6 Comparison results of Lambda iteration method and Cuckoo search method for 6-Unit system

| SI. No | Power Demand (MW) | Fuel Cost (Rs/hr) | |
|---|---|---|---|
| | | Lambda Iteration Method | Cuckoo Search Algorithm |
| 1 | 600 | 32129.8 | 32094.7 |
| 2 | 650 | 34531.7 | 34482.6 |
| 3 | 700 | 36946.4 | 36912.2 |
| 4 | 750 | 39422.1 | 39384.0 |
| 5 | 800 | 41959.0 | 41896.9 |
| 6 | 850 | 44508.1 | 44450.3 |
| 7 | 900 | 47118.2 | 47045.3 |
| 8 | 950 | 49747.4 | 49682.1 |

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