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Research Article

Implementation of Smooth and Non-Smooth Fuel Cost Function for Economic Load Dispatch using Cuckoo Search Method

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Abstract

Economic Load Dispatch (ELD) is an important topic in the operation of power plants which can help to build up effecting generating management plans. The ELD problem has no smooth cost function with equality and inequality constraints which make it difficult to be effectively solved. The paper presents an application of Cuckoo Search Algorithm (CSA) to solve Economic Load Dispatch (ELD) problems with smooth and non-smooth fuel cost objective functions. Main objective of ELD is to determine the most economic generating dispatch required to satisfy the predicted load demands including line losses over a certain period of time while relaxing various equality and inequality constraints. The unit Min/Max operational constraints, effects of valve-point loading ripples and line losses are considered for the practical applications. This paper describes the implementation of smooth and non smooth fuel cost function by CSA Method and its comparison with BAT method. We have used 6 and 12 bus system for calculating their total fuel cost.

Keywords: *Economic Load Dispatch, Equality Constraints, Inequality Constraints, Smooth And Non- Smooth Cost Functions, CSA Method, Bat Algorithm*

Introduction

The sizes of electric power system are increasing rapidly to meet the power demand so it becomes necessary to operate the plant units most economically and with large interconnection of the electric networks, the energy crisis in the world and continuous rise in the prices, it is very essential to reduce the running charges of the electric energy i.e. reduce the fuel consumption for meeting a particular load demand. The main factor controlling the most desirable load allocation between various generating units is the total running cost. The operating cost of a thermal plant is mainly the cost of the fuel. Fuel supplies for thermal can be coal, natural gas, oil, or nuclear fuel. The other costs such as costs of labour, supplies, maintenance, etc. Being difficult to be determined 3wand approximate, are assumed to vary as a fixed percentage of the fuel cost. Therefore, these costs are included in the fuel cost. Thus, the operating cost of a thermal plant, which is mainly the fuel cost, is given as a function of generation. This function is defined as a nonlinear function of plant generation. The cost of generation depends upon the system constraint for a particular load demand it means the cost of generation is not fixed for a particular load demand but depends upon the operating constraint of the sources. The ELD problem has been solved via many traditional optimization methods, including: Gradient-based techniques, Newton methods, linear programming, and quadratic programming. The economic operation of a thermal unit, input-output modelling characteristic is significant.

ELD Problem Formulation ELD is an important function in modern power system to schedule the power generator outputs with respect to the load demands, and to operate the power system most economically, the main objective of economic load dispatch is to allocate the optimal power generation from different units at the lowest possible cost while satisfying the system constraints.

The ELD problem is considered as a general minimization problem with constraints, and can be written in the following form:

Minimize : $f(x)$
Subjected to : $g(x) = 0$
: $h(x) \le 0$

$f(x)$ is the objective function, $g(x)$ and $h(x)$ are respectively the set of equality and inequality constraints.

x is the vector of control and state variables. The control variables are generator active and reactive power outputs, bus voltages, shunt capacitors/reactors

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and transformers tap-setting. The state variables are voltage and angle of load buses.

Equality Constraints

The sum of real power generation of all the various units must always be equal to the total real power demand on the system.

$$\mathbf{Pd = \Sigma_{i=1}^{NG} Pgi}$$

Where Pgi is the total real power generation. Pd is the total real power demand.

Inequality Constraints

Inequality constraints for power generating units are as follows:

$$Pgi^{min} <= Pgi <= Pgi^{max} \quad (i = 1,2,3.......,NG)$$

Where Pgi min, and Pgi max are the minimum and maximum limit of power generation of a i'th plant.

Cost Function

The total cost incurred to generate electrical energy is the sum of the cost of individual generator.

Cost function is given by

$$\mathbf{C = \sum_{i=1}^{n} C_i (P_{gi})}$$

Transmission Loss

The transmission loss can be calculated by the following equations:

$$\mathbf{PL = \Sigma_{i=1}^{NG} \Sigma_{j=1}^{NG} Pgi\ Bji\ Pgj}$$

Where Pgi and Pgj are the real power generations at i'th and j'th buses respectively. Bij are the loss coefficients or B- coefficients.

Load Shaping Techniques

1) **Peak Shaving –** Peak shaving refers to reduction of peak load by switching off unwanted load either manually or through distribution automation software, i.e certain load that increase the active demand such as water heaters.
2) **Valley Filling –** During low demand certain loads are switched on by filling up the valley. Thus the base load line is shifted by valley filling and generations becomes economical.
3) **Load Shifting –** The shifting of certain loads by rescheduling the timings is called load shifting. Through load shifting we can control the switch on and off timings of different loads so that during peak hours the active demand on the power system can be minimised.

Operating cost of a thermal power plant

The factors influencing power generation are operating efficiencies of generators, fuel cost and transmission losses. The total cost of generation is a function of the individual generation of the sources which can take values within certain constraints. The problem is to determine the generation of different plants such that total operating cost is minimum. The input to the thermal plant is generally measured in Btu/hr and the output power is the active power in MW. A simplified input-output curve of a thermal unit is known as heat rate curve.

Materials and methods

The economic operation of power system

In a practical power system, the power plants are not located at the same distance from the centre of loads and their fuel costs are different. Also, under normal operating conditions, the generation capacity is more than the total load demand and losses. Thus, there are many options for scheduling generation. In an interconnected power system, the objective is to find the real and reactive power scheduling of each power plant in such a way as to minimize the operating cost. This means that the generator's real and reactive powers are allowed to vary within certain limits so as to meet a particular load demand with minimum fuel cost. This is called optimal power flow problem. Economic Load Dispatch (ELD) is the scheduling of generators to minimize total operating cost of generator units subjected to equality constraint of power balance within the minimum and maximum operating limits of the generating units.

Economic load dispatch

Economic dispatch is the short-term determination of the optimal output of a number of electricity generation facilities, to meet the system load, at the lowest possible cost, subject to transmission and operational constraints. The Economic Dispatch Problem is solved by specialized computer software which should satisfy the operational and system constraints of the available resources and corresponding transmission capabilities. In the US Energy Policy Act of 2005, the term is defined as the operation of generation facilities to produce energy at the lowest cost to reliably serve consumers, recognising any operational limits of generation and transmission facilities.

The main idea is that, in order to satisfy the load at a minimum total cost, the set of generators with the lowest marginal costs must be used first, with the marginal cost of the final generator needed to meet load setting the system marginal cost. This is the cost of delivering one additional MWh of energy onto the system. The historic methodology for economic dispatch was developed to manage fossil fuel burning power plants, relying on calculations involving the input/output characteristics of power stations.

There are different methods for solving ELD PROBLEMS. In which conventional ones include the lambda iteration method, gradient search method, linear method etc but all of this are less efficient and does not give accurate solutions to the problem. The newer technology includes new techniques with more accurate results such as PSO, BBO, whale optimization, cuckoo search method, bat algorithm etc.

Optimum load dispatch

The optimum load dispatch problem includes the solution of two different problems. The first of these is unit commitment or pre-dispatch problem wherein it is required to select optimally out of the available generating sources to operate to meet the expected load and provide a specified margin of operating reserve over a specified period. The second aspect of economic dispatch is the line economic dispatch whereas it is required to distribute load among the generating units paralleled with the system in such a manner as to minimize the total cost of supplying the minute to minute requirements of the system.

Generator operating cost

The total cost of operation comprises the fuel cost, cost of labour, supplies and maintenance. Generally, cost of labour, supplies, and maintenance are fixed percentage of incoming fuel costs. The power output of fossil plants is increased consecutively by opening a set of valves to its steam turbine at the inlet. The throttling losses are large when is just opened and small when it is fully opened.

The cost is usually approximated by one or more quadratic segments. For dispatching purposes, this cost is usually approximated by one or more quadratic segments.

Cost Function

Let C_i be the cost, expressed for example in rupees per hour, of producing energy in the generator unit I. The total controllable system production cost therefore will be:

$C= \sum_{i=1}^{N} c(i)$ Rs/ h

the generated real power P_{Gi} accounts for the major influence on C_i. the individual real generation are raised by increasing the prime mover torques, and this requires an increased expenditure of fuel.

The reactive power generation Q_{Gi} do not have any measurable influence on C_i as they can be controlled by controlling the field current. The individual production cost C_i of generators unit I is therefore for all practical purposes a function only of P_{Gi}, and for the overall controllable production cost, thus be:

$C= \sum_{i=1}^{N} c(i)(P_{Gi})$

P When the cost function C can be written as a sum of terms where each term depends only upon one independent variable.

System Constraints

Basically, there are two types of system constraints:

a) Equality constraints:
b) Inequality constraints: inequality constraints are further sub divided in two types:

- Hard type: are those which are definite and specific. Eg, tapping range of transformer.
- Soft type: are those which have some flexibility. Eg, phase angles, nodal voltages.

Equality Constraints

These are the basic load flow equations and given as,

$$\mathbf{P_p = \sum^{n}_{q=1}\{ e_p(e_qG_{pq} + \mathit{f}_qB_{pq}) + \mathit{f}_p (\mathit{f}_qG_{pq} - e_qB_{pq})\}}$$
$$\mathbf{Q_p = \sum^{n}_{q=1}\{ f_p(e_qG_{pq} + \mathit{f}_qB_{pq}) - e_p(\mathit{f}_pG_{pq} - e_qB_{pq})\}}$$

P= 1,2,3…………., n

Where e_p and f_p are real and imaginary components of voltage at the p^{th} node and G_{pq} and Bpq are nodal conductance and suseptance between *p*th and *q*th node.

Inequality Constraints

a) Generator Constraints
b) Voltage Constraints
c) Running Spare Capacity Constraints
d) Transformer Constraints
e) Transmission Line Constraints

Cuckoo search algorithm

Cuckoo Search (CS) is a stochastic global search algorithm formulated by Yang and Deb. It is inspired from the breeding strategy of some cuckoo species by laying their eggs in the nest of host birds. Cuckoo bird searches for a nest where they could lay their eggs. As cuckoo eggs would hatch earlier as those of host birds, so they choose a nest where host bird has just laid its eggs. When a cuckoo egg is hatched, it instantly expels the host bird's eggs so as to receive all the food brought in. If host bird discovers cuckoo egg then either it throw away those alien eggs or abandon its nest or build a new nest somewhere. Some breeds of cuckoos have adapted to lay their eggs which mimic the eggs of host birds. This characteristic decreases the probability of their eggs being abandoned and thus increases their reproductivity. In simulation, each nest represents a potential solution. CS idealized this breeding behaviour of cuckoo species for various optimization problems in three steps:

1. Each cuckoo lays only one egg in the randomly chosen nest.
2. The best nests with better proficiency will carry to the next generation.
3. Here the availability of host nests is fixed and probability pa ϵ [0, 1] represents the possibility of alien egg to be discovered by host bird.

The new nest i.e. new solutions x_i^{t+1} are generated by the host by the Lévy flight method.

$$X_i^{t+1} = x_i^t + \alpha * levy(\beta)$$

where α> 0, represents the step size of the concern problem.

The product * means entry wise multiplications.

$$\alpha = \alpha_0 \ (x_j^t - x_i^t)$$

where α_0 is constant, while the term in the bracket represent the difference of two random solutions. This mimics that fact that similar eggs are less likely to be discovered and thus new solutions are generated by the proportionality of their difference. Normally, Lévy flights represent a random way of food searching used by birds and animals. It is suggested that the step size should be L/100, where L is the size of space to be searched. Selection of larger step size would lead new solutions to go out of search space. The generation of random walks by Lévy flights can be achieved either by randomization through Lévy distribution or by normal distribution. By Lévy distribution, the step length can be derived as:

Lévy ~ u = t1-β (0<β<2)

which has an infinite variance and infinite mean. Here, β=1.5.

A fraction of worse nests can be thrown away with probability (pa) so that new nests can be built by random walk or mixing. The mixing of eggs can be performed by random permutation according to the similarity/difference of the host.

Implementation of cuckoo search algorithm for ED problem

The proposed Cuckoo Search Algorithm (CSA) is a population based method similar to other meta-heuristic methods. The structure of CSA includes two main operations including a direct search based on Levy flights and a random search based on the probability for a host bird to discover an alien egg in its nest. With the combination of two operations, the proposed CSA becomes a more powerful search method than other meta-heuristic search methods for complex and large-scale optimization problems. Therefore, the proposed CSA is very effective for solving non-convex and large-scale ED problems. In the proposed CSA method, each nest represents a solution and a population of nest is used for finding the best solution of the problem. The main steps of the proposed CSA method are described below:

Step1: **Initialization**

A population of N_P host nests is represented by $X= [X1,X2,.,X_{NP}]^T$ where each nest Xi= $[Pi1,Pi2,.,P_{ij},.,P_{in}]$ represents power output of units. The power output of unit is initialized by:

$$P_{ij} = {}_j^{pmin} + rand_1 * (pmax_j - pmin_j)$$

where rand1 is a uniformly distributed random number between 0 and 1.

Step 2: Generation Of New Solution Via Levy Flights

The new solution is calculated based on the previous best nests via Levy flights. In the proposed method, the optimal path for the Levy flights is calculated by Mantegna's algorithm The new solution for each nest is calculated as follows:

$$X_i^{new} = Xbest_{\ 1} + a * rand_2 * \Delta X_i^{new}$$

where a > 0 is the updated step size and rand2 is a normally distributed stochastic number

Step3: Alien Egg Discovery and Randomization

The action of discovery of an alien egg in a nest of a host bird with the probability of pa also creates a new solution for the problem similar to the Levy flights. The new solution due to this action can be found out in the following way:

$$X_i^{dis} = Xbest_i + K * \Delta X_i^{dis}$$

where K is the updated coefficient determined based on the probability of a host bird to discover an alien egg in its nest:

$$K = \begin{cases} 1 \text{ if } rand_3 < p_a \\ 0 \text{ otherwise} \end{cases}$$

where rand3 is the distributed random number in [0,1].

Step4: Stopping Criteria

The above algorithm is stopped when the number of iterations reaches the predefined value.

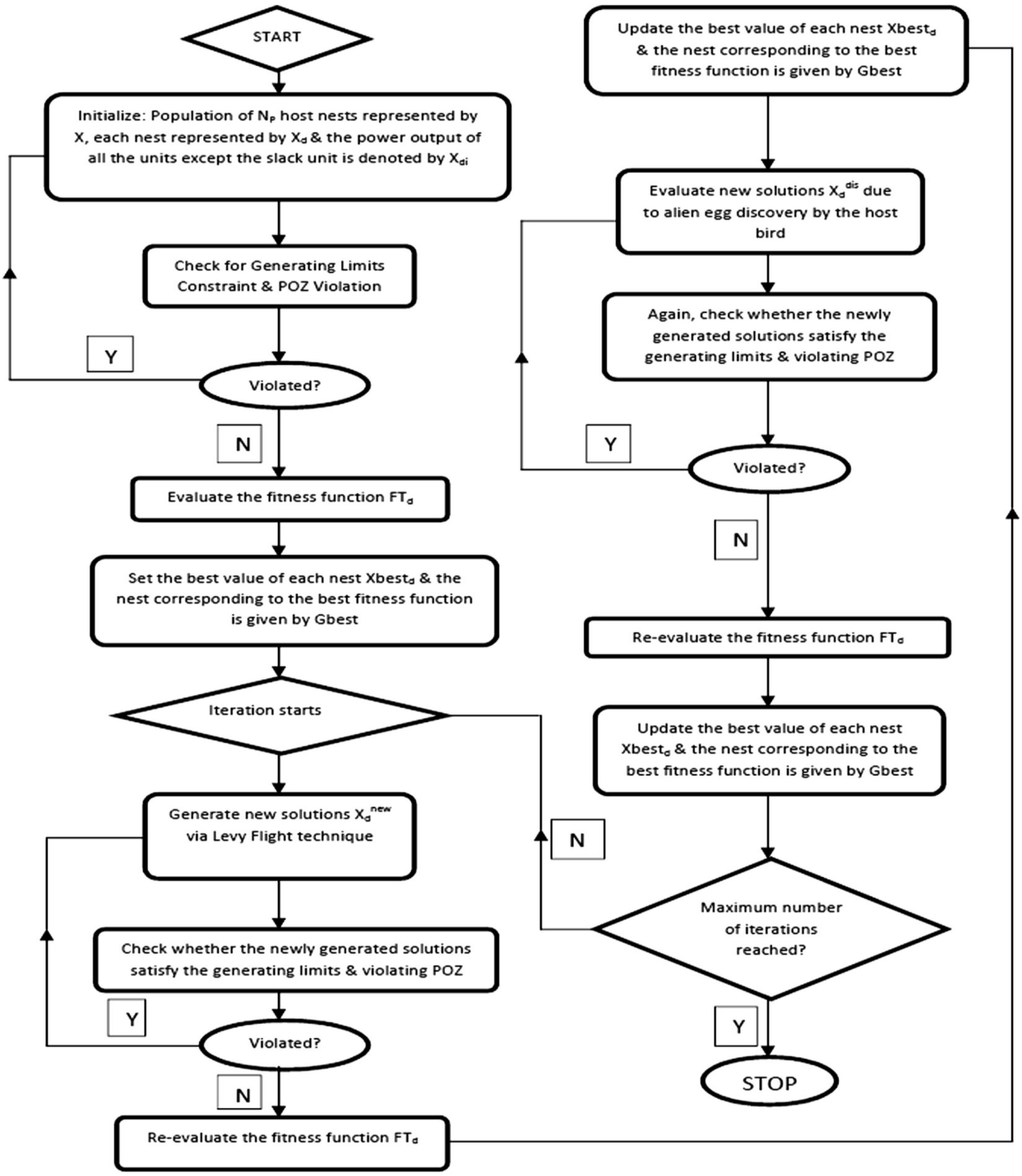


Figure 1: Flow chart of CSA algorithm

Application of cuckoo search algorithm

CS has been applied as optimization algorithm for various tasks including finding optimal features, optimizing the job scheduling, find optimal path and many more in the different domains including industry, health sector, wireless sensor network, image processing. The applications of Cuckoo in the various domains are briefed below:

1. They have used Feature Weighted Support Vector Machines (FW-SVMs) and Modified CS (MCS). First the Diabetes data is collected and Principal Component Analysis (PCA) is applied as a feature selection strategy. PCA reduces the dimension of Diabetes disease dataset form 8 to 4 features.
2. Thresholding is one of the simplest techniques for performing image segmentation that has many applications in image processing, including segmentation, classification, clustering and object discrimination.
3. Sensor node in Wireless Sensor Networks (WSNs) is a tiny device that includes three basic components: a sensing subsystem for data

acquisition from the physical surrounding environment, a processing subsystem for local data processing and storage, and a wireless communication subsystem for data transmission. Energy is the major issue for these nodes as these nodes usually deployed in the remote areas.

Bat Algorithm

Behaviour of Microbats

Bats are fascinating animals. They are the only mammals with wings and they also have advanced capability of echolocation. It is estimated that there are about 1000 different species which account for up to 20% of all mammal species. Their size ranges from tiny bumblebee bats(of about 1.5 to 2 g) to giant bats with a wingspan of about 2 man weight up to about1kg. Micro bats typically have a fore arm length of about 2.2 to 11 cm. Most bats uses echolocation to a certain degree; among all the species, microbats are a famous example as microbats use echolocation extensively, while mega bats do not. Most microbats are insectivores. Microbats use a type of sonar, called echolocation, to detect prey, avoid obstacles, and locate their roosting crevices in the dark. These bats emit a very loud sound pulse and listen for the echo that bounces back from the surrounding objects. Their pulses vary in properties and can be correlated with their hunting strategies, depending on the species. Most bats use short, frequency-modulated signals to sweep through about an octave, while others more often use constant-frequency signals for echolocation. The bandwidth of echolocation signals varies with species, and often increases by using more harmonics. Studies show that microbats use the time delay from the emission and detection of the echo, the time difference between their two ears, and the loudness variations of the echoes to build up three-dimensional scenario of the surrounding. They can detect the distance and orientation of the target, the type of prey, and even the moving speed of the prey such as small insects. Indeed, studies suggested that bats seem to be able to discriminate targets by the variations of the Doppler effect induced by the wing-flutter rates of the target insects.

Acoustics of Echolocation

Though each pulse only last safe with thousand second (uptoabout8to10ms), however, it has a constant frequency which is usually in theregionof25 kHz to 150 kHz.Thetypicalrangeoffrequenciesformostbatspeciesar eintheregionbetween 25 kHz and 100 kHz, though some species can emit higher frequencies up to 150 kHz. Each ultrasonic burst may last typically 5 to 20 ms, and microbats emit about 10 to 20 such sound bursts every second. When hunting for prey, the rate of pulse emission can be sped up to about 200 pulses per second when they fly near their prey. Such short sound bursts imply the fantastic ability of the signal processing power of bats. In fact, studies show the integration time of the bat ear is typically about 300 to 400 μ s. As the speed of sound in air is typically v = 340 m/s at room temperature, the wavelength λ of the ultrasonic sound bursts with a constant frequency f is given by

$$\lambda = v f$$

which is in the range of 2 mm to 14 mm for the typical frequency range from 25 kHz to 150 kHz. Such wavelengths are in the same order of their prey sizes. Amazingly, the emitted pulse could be as loud as 110 dB, and, fortunately, they are in the ultrasonic region. The loudness also varies from the loudest when searching for prey and to a quieter base when homing towards the prey. The travelling range of such short pulses are typically a few metres, depending on the actual frequencies. Microbats can manage to avoid obstacles as small as thin human hairs. Obviously, some bats have good eyesight, and most bats also have very sensitive smell sense. In reality, they will use all the senses as a combination to maximize the efficient detection of prey and smooth navigation.

If we idealize some of the echolocation characteristics of microbats, we can develop various bat-inspired algorithms or bat algorithm. For simplicity, we now use the following approximate or idealized rules:

1. All bats use echolocation to sense distance, and they also 'know' the difference between food/prey and background barriers; 2. Bats fly randomly with velocity vi at position xi with a fixed frequency f min (or wavelength λ), varying wavelength λ (or frequency f) andloudnessA0 to search for prey. They can automatically adjust the wavelength (or frequency) of their emitted pulses and adjust the rate of pulse emission r∈[0,1], depending on the proximity.
Although the loudness can vary in many ways, we assume that the loudness varies from a large (positive) A0 to a minimum value Amin.

Another obvious simplification is that no ray tracing is used in estimating the time delay and three dimensional topography. Though this might be a good feature for the application in computational geometry; however, we will not use this, as it is more computationally extensive in multidimensional cases.

In addition to these simplified assumptions, we also, for simplicity. In general the frequency f in a range [f min, f max] corresponds to a range of wavelengths [λ min, λ max]. For example, a frequency range of [20 kHz, 500 kHz] corresponds to a range of wavelengths from 0.7 mm to 17 mm. For a given problem, we can also use any wavelength for the ease of implementation. In the actual implementation, we can adjust the range by adjusting the frequencies (or wavelengths). The detectable range (or the largest wavelength) should be chosen such that it is comparable to the size of the domain of interest, and then toning down to smaller ranges. Furthermore, we do not necessarily have to use the wavelengths themselves at all, instead, we can also vary the frequency while fixing the wavelength λ . This is because λ and f are related, as λ f is constant. We will use this later approach in our implementation. For simplicity, we can assume f ∈[0, f max]. We know that higher frequencies have short wave lengths and travel a shorter distance. For bats, the typical ranges are a few metres. The rate of pulse can simply be in the range of [0,1] where 0 means no pulses at all, and 1 means the maximum rate of pulse emission. Based on the above approximations and idealization, the basic steps of the Bat Algorithm (BA) can be summarized as the pseudo code.

Algorithm for bat method

Step 1: Initialize a population of n bats xi (i=1,2,...,n) and vi
Step 2: Initialize frequencies fi, pulse rates ri and the loudness Ai
while (t <Max number of iterations)
Step 3: Generate new solutions by adjusting frequency, and updating velocities and locations/solutions
if (rand > ri)
Step 4: Select a solution among the best solutions
Step 5: Generate a local solution around the selected best solution
end if
Step 6: Generate a new solution by flying randomly
if (rand < Ai &f (xi) < f(x∗))
Step 7: Accept the new solutions
Increase ri and reduce Ai
end if
Step 7 : Rank the bats and find the current best x∗
end while

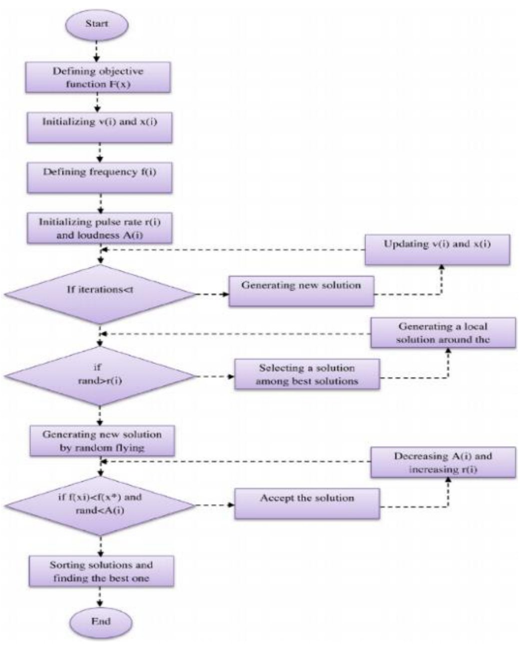


Figure 2: Flow chart of bat algorithm

Application of bat algorithm

The standard bat algorithm and its many variants mean that the applications are also very diverse. In fact, since the original bat algorithm has been developed (Yang, 2010), Bat algorithms have been applied in almost every area of optimization, classifications, image processing, feature selection, scheduling, data mining and others.

1. **Continuous Optimization:** Among the first set of applications of bat algorithm, continuous optimization in the context of engineering design optimization has been extensively studied, which demonstrated that BA can deal with highly nonlinear problem efficiently and can find the optimal solutions accurately.
2. **Combinatorial Optimization and Scheduling:** From computational complexity point of view, continuous optimization problems can be considered as easy, though it may be still very challenging to solve. However, combinatorial problems can be really hard, often non-deterministic polynomial time hard.
3. **Inverse Problems and Parameter Estimation:** Many use the bat algorithm to study topological shape optimization in microelectronic applications so that materials of different thermal properties can be placed in such a way that the heat transfer is most efficient under stringent constraints. It can also be applied to carry out parameter estimation as an inverse problem. If an inverse problem can be properly formulated, then bat algorithm can provide better results than least-squares methods and regularization methods. It can be also used for **image processing, clustering data mining etc.**

Results and discussion

Operating cost of a thermal power plant

The factors influencing power generation are operating efficiencies of generators, fuel cost and transmission losses. The total cost of generation is a function of the individual generation of the sources which can take values within certain constraints. The problem is to determine the generation of different plants such that total operating cost is minimum. The inut to the thermal plant is generally measured in Btu/hr and the output power is the active power in MW. A simplified input-output curve of a thermal unit is known as heat rate curve.

The result for this is divided into two parts , the first case is representing the 6 bus system and the second case is representing the 12 bus system.

Case1: 6 Unit Bus System

For this system considering loads of 600mw, 700mw, 800mw, 900mw, 1100mw Cuckoo Search Method (CSA) And BAT Algorithm is applied to obtain the economic load dispatch. The fuel cost (Rs/hr) is being calculated. Then finally the comparison is being made between the two method to show that which gives lower fuel cost for the system.

- **Fuel Cost Modeling**

The fuel cost curve for thermal generating unit (i) can be modeled by a second order polynomial function that relates its fuel cost to its real power output as:

$$F_i(P_{ti}) = a_{0i} + a_{1i} P_{ti} + a_{2i} P^2_{ti} + r_i$$

Where
Fi is the fuel cost function of the ith generating unit
Pti is the power generated by the ith thermal generating unit
aoi, a1i, and a2i are the curve constants of the ith generating unit.
ri is the error associated with the ith equation

Cuckoo Search Method

Table 1: CSA Method For 6 Bus System

Unit Power Output (MW)	Load Demand (MW)				
	600	700	800	900	1100
P_1	37.39861	47.84760	58.84201	69.75570	92.36278
P_2	25.86138	39.08190	53.00908	66.70854	94.91109
P_3	103.28325	118.98162	134.53739	150.04468	180.74842
P_4	105.03321	119.95601	134.75949	149.55722	178.94189
P_5	166.52026	188.99292	210.95699	233.14380	277.02662
P_6	161.90328	185.13996	207.89504	230.79004	276.00921
Fuel Cost (Rs/hr)	31625.26	36307.25	41143.62	46121.69	56539.68

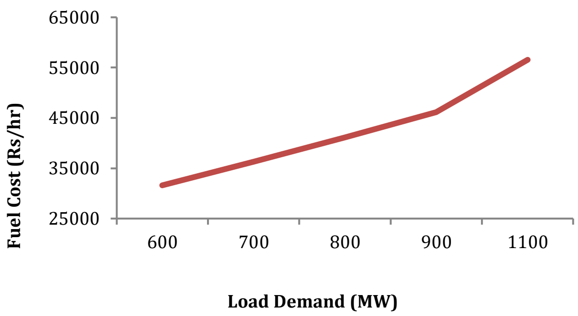


Figure 3: Fuel Cost of CSA Method for 600,700,800,900and 1100M

BAT algorithm

Table 2: BAT method for 6 bus system

Unit Power Output (MW)	Load Demand (MW)				
	600	700	800	900	1100
P_1	23.8587	28.2911	32.5877	36.8470	69.0000
P_2	10.0000	10.0000	14.4827	21.0780	49.4149
P_3	95.6376	118.9568	141.5491	163.9343	198.2179
P_4	100.7030	118.6753	136.0426	153.2216	196.8868
P_5	202.8428	230.7668	257.6603	284.1710	297.4793
P_6	181.1953	212.7419	243.0085	272.7362	296.6303
Fuel Cost (Rs/hr)	31626.79	36310.80	41144.47	46124.54	56542.01

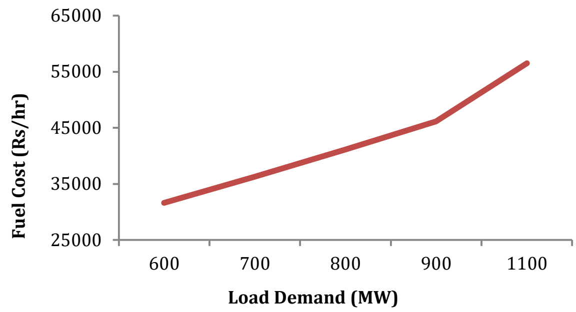


Figure 4. Fuel Cost for Bat Algorithm using 600, 700, 800, 900, And 1100 MW

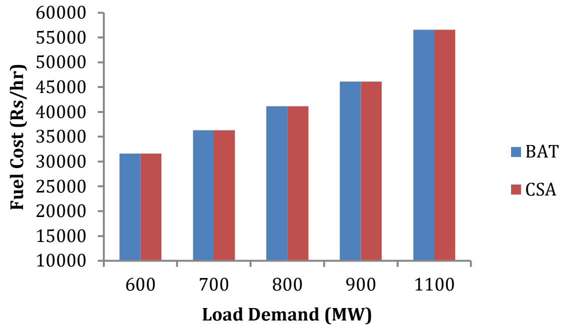


Figure 5: Comparison for CSA Method and Bat Algorithm by 6bus System

Case 2: 12 Bus System

For this 12 bus system considering load of 1500 MW, 1800MW, AND 2000MW CSA method and Bat algorithm method are applied to obtain the economic load dispatch. The fuel cost (Rs/hr) is being calculated:

CSA 12 Bus System

Table 3: CSA method for 12 bus system

Unit Power Output (MW)	Load Demand (MW)		
	1500	1800	2000
P_1	59.393	61.162	67.168
P_2	42.000	46.000	53.101
P_3	42.145	46.628	58.525
P_4	68.377	78.737	92.008
P_5	95.369	103.468	117.671
P_6	96.519	106.972	120.361
P_7	108.969	127.635	140.755
P_8	71.651	74.013	85.406
P_9	104.758	107.153	122.248
P_{10}	202.973	231.813	244.103
P_{11}	206.239	237.309	250.649
P_{12}	401.602	579.105	648.153
Fuel Cost (Rs/hr)	9733.22	17951.30	24040.84

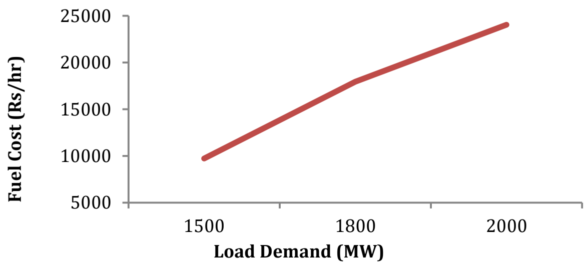


Figure 6: Fuel cost curve for 12 bus system using CSA method

BAT 12 Bus System

Table 4: BAT method for 12 bus system

Unit Power Output (MW)	Load Demand (MW)		
	1500	1800	2000
P_1	70.927	71.315	83.030
P_2	43.073	46.172	60.886
P_3	73.321	76.437	88.549
P_4	74.478	78.058	90.520
P_5	64.417	73.759	93.415
P_6	90.838	98.449	114.967
P_7	68.767	90.703	99.010
P_8	117.964	120.686	145.162
P_9	100.389	102.507	124.317
P_{10}	176.127	181.292	194.181
P_{11}	189.694	191.155	205.961
P_{12}	430.145	669.463	690.256
Fuel Cost (Rs/hr)	9767.99	17976.13	24077.01

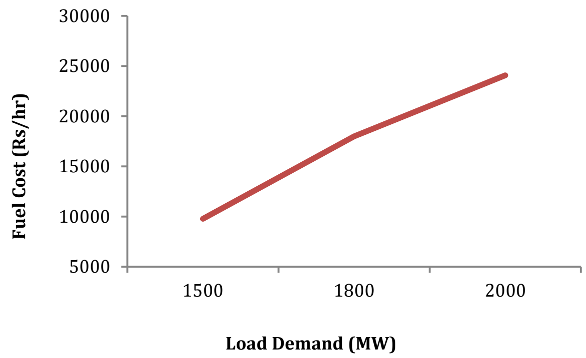
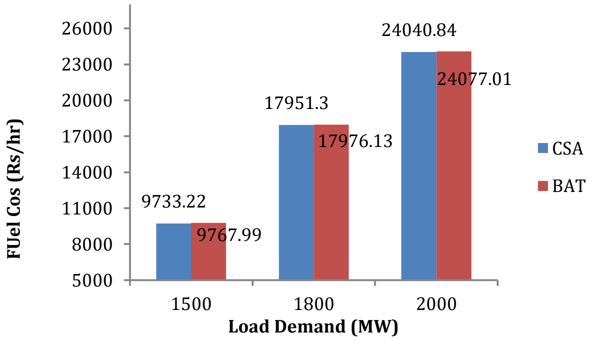


Figure 7: Cost curve for 12bus system using bat algorithm

Comparison of fuel cost using CSA and BAT Method for 12 Bus System



By calculating the fuel cost for 6 bus and 12 bus system by both CSA and BAT Algorithm method we can see that the CSA method gives better results in both the cases for 6 and 12 bus system. The total operated fuel cost comes quite lesser for cuckoo search method than bat algorithm method.

Conclusion and future prospects

Economic Load Dispatch (ELD) is an important topic in the operation of power plants which can help to build up effecting generating management plans. The ELD problem has non smooth cost function with equality and inequality constraints which make it difficult to be effectively solved. The main objective of the ELD problems is to determine the optimal combination of power outputs of all generating units so as to meet the required demand at minimum cost while satisfying the constraints.

CS is a powerful search algorithm that it inspired by the breeding behaviour of cuckoos. CS algorithm in the various domains including Industry, Image processing, wireless sensor networks, flood forecasting, document clustering, speaker recognition, shortest path in distributed system, classification task in health sector, job scheduling. The comparison of CSA Technique gives better output results than BAT technique which proves to it to be modern optimization technique for solving fuel cost function for economic load dispatch problem. The future can be assumed that some hybrid version of cuckoo method can be implemented for obtaining better and efficient results.

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