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Implementation of a New Methodology for ELD Problems

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Abstract

Now a day's an electrical utility wants to maximize its profit, the optimization of economic dispatch is of economic value to the network operator. So, our objective is to optimize the total cost of the plant. The ELD problem in a power system to determine the least generation of all the operating generators which will minimizes the total fuel cost of the plant. This paper introduce a bio inspired optimization algorithm called BAT ALGORITHM to solve combined economic dispatch problems is presented and the enhancing the convergence property to obtain results quickly and it is effectively proposed to six unit thermal plant. Here Numerical results show that the proposed method has good convergence property and better in quality of solution than PSO and IWD reported in recent literature.BAT algorithm is easy to implement and priory in terms of accuracy and efficiency compared with other algorithms. In this work, data has been collected from the published work in which loss coefficients are also given with the max-min power limit and cost function. All the techniques are implemented in MATLAB environment. BAT ALOGORITHM is applied to find out the minimum cost for different power demand which is finally compared with both PSO method and IWD method. When the results are compared with the conventional PSO and IWD seems to give a better result with better convergence characteristic.

1 INTRODUCTION

Since an engineer is always concerned with the cost of products and services, the efficient optimum economic operation and planning of electric power generation system have always occupied an important position in the electric power industry. With large interconnection of the electric networks, the energy crisis in the world and continuous rise in prices, it is very essential to reduce the running charges of the electric energy. A saving in the operation of the system of a small percent represents a significant reduction in operating cost as well as in the quantities of fuel consumed. The classic problem is the economic load dispatch of generating systems to achieve minimum operating cost.

This problem has taken a subtle twist as the public has become increasingly concerned with environmental matters, so that economic dispatch now includes the dispatch of systems to minimize pollutants and conserve various forms of fuel, besides achieving minimum cost. In addition there is a need to expand the limited economic optimization problem to incorporate constraints on system operation to ensure the security of the system, thereby preventing the collapse of the system due to unforeseen conditions. However closely associated with this economic dispatch problem is the problem of the proper commitment of any array of units out of a total array of units to serve the expected load demands in an 'optimal' manner. For the purpose of optimum economic operation of this large scale system, modern system theory and optimization techniques are being applied with the expectation of considerable cost savings.

2.1: ECONOMIC LOAD DISPATCH

The Economic Load Dispatch (ELD) can be defined as the process of allocating generation levels to the generating units, so that the system load is supplied entirely and most economically. For an interconnected system, it is necessary to minimize the expenses. The economic load dispatch is used to define the

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production level of each plant, so that the total cost of generation and transmission is minimum for a prescribed schedule of load. The objective of economic load dispatch is to minimise the overall cost of generation. The method of economic load dispatch for generating units at different loads must have total fuel cost at the minimum point.

In a typical power system, multiple generators are implemented to provide enough total output to satisfy a given total consumer demand. Each of these generating stations can, and usually does, have a unique cost-per-hour characteristic for its output operating range. A station has incremental operating costs for fuel and maintenance; and fixed costs associated with the station itself that can be quite considerable in the case of a nuclear power plant, for example. Things get even more complicated when utilities try to account for transmission line losses, and the seasonal changes associated with hydroelectric plants.

There are many conventional methods that are used to solve economic load dispatch problem such as Lagrange multiplier method, Lambda iteration method and Newton- Raphson method. In the conventional methods, it is difficult to solve the optimal economic problem if the load is changed. It needs to compute the economic load dispatch each time which uses a long time in each of computation loops. It is a computational process where the total required generation is distributed among the generation units in operation, by minimizing the selected cost criterion, and subjects it to load and operational constraints as well.

2.1.1 Load Dispatching:

The operation of a modern power system has become very complex. It is necessary to maintain frequency and voltage within limits in addition to ensuring reliability of power supply and for maintaining the frequency and voltage within limits it is essential to match the generation of active and reactive power with the load demand. For ensuring reliability of power system it is necessary to put additional generation capacity into the system in the event of outage of generating equipment at some station. Over and above it is also necessary to ensure the cost of electric supply to the minimum. The total interconnected network is controlled by the load dispatch centre. The load dispatch centre allocates the MW generation to each grid depending upon the prevailing MW demand in that area. Each load dispatch centre controls load and frequency of its own by matching generation in various generating stations with total required MW demand plus MW losses. Therefore, the task of load control centre is to keep the exchange of power between various zones and system frequency at desired values.

2.1.2 Necessity of Generation Scheduling:

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, 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 so as to minimize the operating cost. This means that the generators 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 the “Economic load dispatch” (ELD) problem.

The objective functions, also known as cost functions may present economic cost system security or other objectives. The transmission loss formula can be derived and the economic load dispatch of generation based on the loss formula can also be obtained. The Loss coefficients are known as B-coefficients.

A major challenge for all power utilities is not only to satisfy the consumer demand for power, but to do so at minimal cost. Any given power system can be comprised of multiple generating stations having number of generators and the cost of operating these generators does not usually correlate proportionally with their outputs; therefore the challenge for power utilities is to try to balance the total load among generators that are running as efficiently as possible.

The economic load dispatch (ELD) problem assumes that the amount of power to be supplied by a given set of units is constants for a given interval of time and attempts to minimize cost of supplying this energy subject to constraints of the generating units. Therefore, it is concerned with the minimization of total cost incurred in the system and constraints over the entire dispatch period.

Therefore, the main aim in the economic load dispatch problem is to minimize the total cost of generating real power (production cost) at various stations while satisfying the loads and the losses in the transmission links.

2.2 GENERATOR OPERATING COST

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

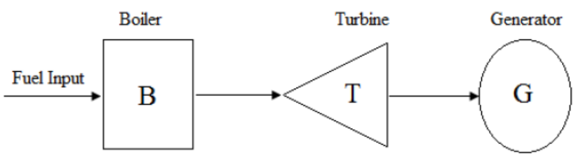

Figure 2.2.1 Simple model of a fossil plant

Figure 2.2.1 shows the simple model of a fossil plant dispatching purposes. The cost is usually approximated by one or more quadratic segments. The operating cost of the plant has the form shown in Figure 2.2. For dispatching purposes, this cost is usually approximated by one or more quadratic segments. So, the fuel cost curve in the active power generation, takes up a quadratic form, given as:

$$F(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i Rs/hr$$

------------------->**(2.1)**

Where

a_i, b_i, c_i are cost coefficients for i^{th} unit

$F(P_{gi})$ is the total cost of generation

P_{gi} is the generation of i^{th} plant

3.1. PARTICLE SWARM OPTIMIZATION

Particle Swarm Optimization (PSO) is one of the modern heuristic algorithms, which can be effectively used to solve nonlinear and non-continuous optimization problems. It is a Population-based search algorithm and searches in parallel using a group of particles similar to other AI-based optimization techniques.

Eberhart and Kennedy suggested a Particle Swarm Optimization (PSO) based on the analogy of swarm of bird and school of fish. In PSO, each individual makes its decision based on its own experience together with other individual's experiences. Particle swarm optimization (PSO) is a population-based stochastic optimization technique, inspired by simulation of a social psychological metaphor instead of the survival of the fittest individual. In PSO, the system (swarm) is initialized with a population of random solutions (particles) and searches for optima using cognitive and social factors by updating generations. The particles are drawn stochastically toward the position of present velocity of each particle, their own previous best performance, and the best previous performance of their neighbours. PSO has been successfully applied to a wide range of applications, mainly in solving continuous nonlinear optimization problems.

PSO is a kind of evolutionary algorithm based on a population of individuals and motivated by the simulation of social behaviour instead of the survival of the fittest individual. It is a population-based evolutionary algorithm. Similar to the other population-based evolutionary algorithms, PSO is initialized with a population of random solutions. Unlike the most of the evolutionary algorithms, each potential solution (individual) in PSO is also associated with a randomized velocity, and the potential solutions, called particles, are then "flown" through the problem space.

The main advantages of the PSO algorithm are summarized as: simple concept, easy Implementation and computational efficiency when compared with mathematical algorithm and other heuristic optimization techniques. The practical ELD problems with valve- point loading effects are represented as a non smooth optimization problem with equality and inequality constraints.

5.1 BAT ALGORITHM:

Bat algorithm is a metaheuristic optimization algorithm developed by Xin-She Yang in 2010. The Bat algorithm based on the echo location behaviour of bats. Bats have the ability to find their prey discriminate different types of insects even in complete darkness.

5.2 ECHOLOCATION BEHAVIOUR OF BATS

5.2.1 Behaviour of Microbats:

Bats are fascinating animals. They are the only mammals with wings and have the capability of echolocation. Microbats typically have forearm length of about 2.2cm to 11cm. Most microbats are insectivores. Microbats use a type of sonar, called echolocation to detect prey, avoid obstacles and locate their roost in the dark.

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 (FM) signals. The signal bandwidth varies depends on the species, and often increased by using more harmonics.

5.2.2 Acoustics of Echolocation:

The typical range of frequencies for most bat species are from 25KHz to 100KHz, though some species can emit higher frequencies up to 150Khz. Microbats emit about about 10 to 20 sound bursts every second. When hunting for prey, the rate of pulse emission can be increase up to 200 pulses per second, when they fly near their prey.

As the speed of sound in air is typically v = 340 m/s. The wavelength 'λ' of the ultrasonic sound bursts with a constant frequency 'f ' is given by;

$$\lambda = v / f \quad \text{--------------------->(5.1)}$$

Which is in the range from 2mm to 14mm for the typical frequency range from 25KHz to 150KHz.The travelling range of short pulses is typically a few meters, depending on the actual frequencies. 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 will build up the three dimensional scenario of the surrounding. They can detect the distance and orientation of the target, type of the prey and even the moving speed of the prey.

5.3 BAT ALGORITHM

The echolocation behaviour of microbats can be used to optimize an objective function. In this three approximate (or) idealized rules are used:

a) All bats use echolocation to sense distance, and they also know the food/prey and the obstacles, in some magical way.

b) Bats fly randomly with velocity V_i at position X_i with a fixed frequency f_{min} , varying wavelength λ and loudness A_0 to search for prey. They can automatically adjust the wavelength (or frequency) of their emitted pulses and adjust the rate of pulse emission r in the range of [0, 1], depending on the distance of their target.

c) Although the loudness can vary in many ways, we assume that the loudness varies from a large (positive) A_0 to a minimum constant value A_{min}.

In addition to these simplified assumptions, we

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also use the following approximations. In general, the frequency f in a range of [f_{min}, f_{max}] corresponds to a range of wavelengths [λ_{min}, λ_{max}]. For simplicity, we can assume f is within [0, f_{max}]. We know that higher frequencies have shorter wavelengths and travel a shorter distance. The rate of pulse emission can be simplified in the range of [0, 1], where 0 means no pulse at all, and 1 means maximum rate of pulse emission.

5.3.1. Movement of Bats:

The movement of the bats depending upon the velocity changes with respect to time step. The new solutions x_i^t, and velocities v_i^t, at time step t are given by;

$$f_i = f_{min} + (f_{max} - f_{min}) * \beta$$
--------------------->(5.2)

$$v_i^t = v_i^{t-1} + (x_i^t - x_*) * f_i$$
--------------------->(5.3)

$$x_i^t = x_i^{t-1} + v_i^t$$
--------------------->(5.4)

Where, $\beta \in [0, 1]$ is a uniformly distributed random vector. x_* is the current global best location (solution), which is located after comparing all the solutions among all the n bats. We can choose f_{min}, f_{max} depending upon the domain size of the optimization problem. Initially, each bat is randomly assigned a frequency within the range [f_{min}, f_{max}].

For the local search, once a solution is selected among the current best solutions, a new solution for each bat is generated locally using random walk;

$$x_{new} = x_{old} + \varepsilon A^t$$
--------------------->(5.5)

Where, $\varepsilon \in [-1, 1]$ is a random number, while $A^t = \langle A_i^t \rangle$ is the average loudness of all the bats at this time t.

5.3.2. Loudness and Pulse Emission:

The loudness A_i and the rate of pulse emission r_i are updated accordingly as the iterations proceed. Once a bat has found its prey loudness decreases and rate of pulse emission increases. Assume $A_{min} = 0$, means that a bat has just found the prey and temporarily stop emitting any sound.

$$A_i^{t+1} = \alpha A_i^t$$
--------------------->(5.6)

$$r_i^{t+1} = r_i^0 [1 - \exp(-\gamma t)]$$
--------------------->(5.7)

Where, α and γ are constants.

5.4 FLOWCHART OF MODIFIED BAT ALGORITHM

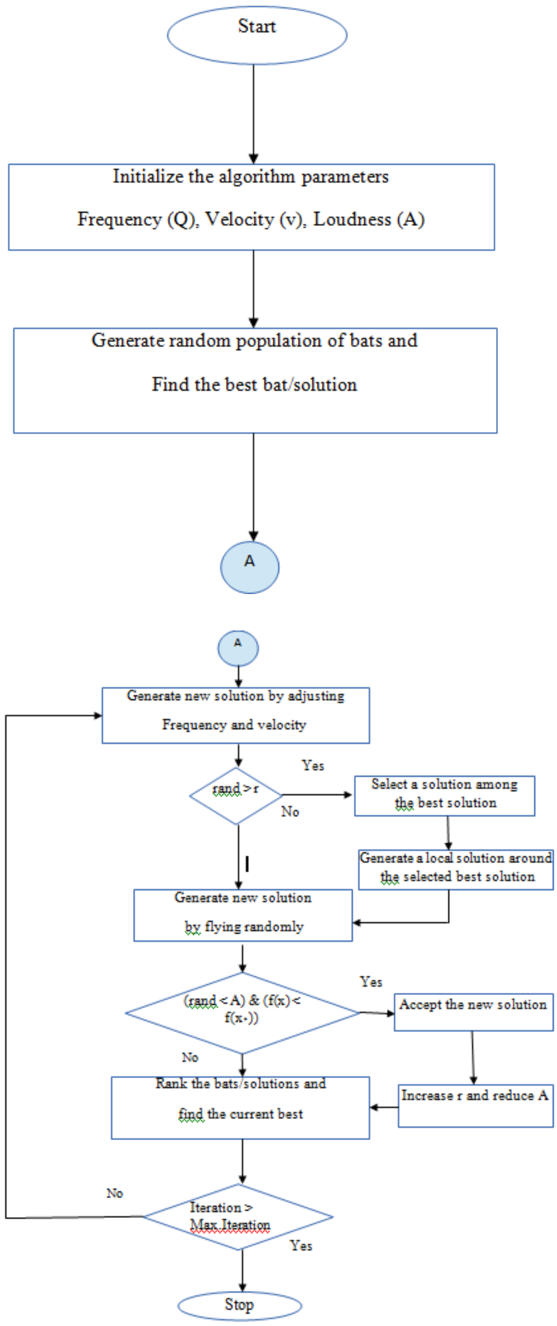

figure 5.2.2.2 Flow chart of modified BAT Algorithm

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5.5. PSEUDO CODE FOR BAT ALGORITHM

BEGIN
Objective function f(x), $x = (x_1, x_2, x_3, \ldots, x_d)^T$
Initialize the bat population x_i, (i = 1, 2, 3, . . ., n) and v_i
Define pulse frequency Q_i at x_i
Initialize pulse rates r_i and loudness A_i
while (t < Max. number of iterations)
Generate new solutions by adjusting frequency $f_i = f_{min} + (f_{max} - f_{min}) * \beta$
and updating velocity $v_i^t = v_i^{t-1} + (x_i^t - x_*) * f_i$
and updating location $x_i^t = x_i^{t-1} + v_i^t$
if (rand > r_i)
Select a solution among the best solutions
Generate a local solution around the selected best solutions
end if
Generate new solutions by flying randomly
if (rand < A_i & $f(x_i) < f(x_*)$)
Accept the new solutions
Increase r_i and decrease A_i
end if
Rank the bats and find the current best x_*
end while
Post process results and visualization
END

6.1 CASE STUDY ON 6 THERMAL UNIT SYSTEMS

The different methods discussed earlier are applied to one six thermal unit system to find out the minimum cost for any demand. Results of BAT Algorithm are compared with the conventional methods Particle Swarm Optimization (PSO) and Intelligent Water Drop (IWD). In this case the transmission losses and prohibited zone constraints are considered. The maximum number of iterations has been taken as 500. All these simulation are done on MATLAB 2011 environment.

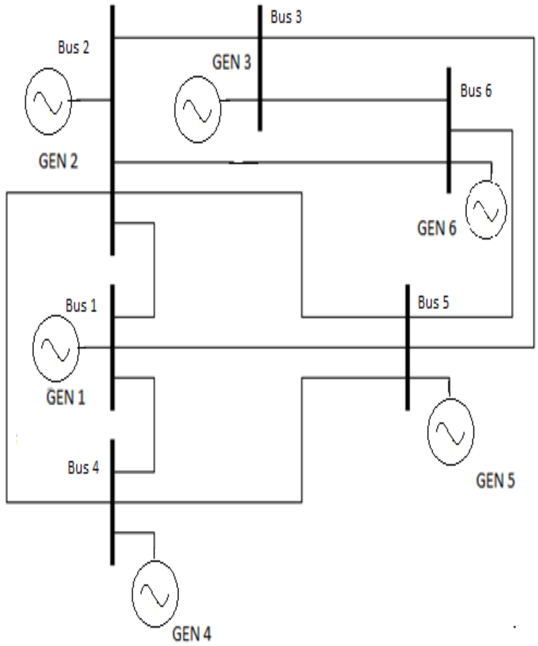

Figure 6.1.1 Single line diagram of 6-unit thermal plant

The system consists of six thermal units .the parameters of all thermal units are tabulated below. The convergence characteristics and results have been shown in fig and table.The validity of the proposed method is illustrated on a sample system comprising six thermal generating units. MATLAB code is developed to perform entire calculations and to generate the table. A program has been developed in MATLAB platform based upon the proposed algorithm.

Table 6.1: Capacity and coefficeient data of six unit thermal system

Unit	P_{gmax} (MW)	P_{gmin} (MW)	a_i RS/MWh^2	b_i RS/MWh	c_i MW
1	500	100	0.0070	7	240
2	150	50	0.0090	11	200
3	200	50	0.0080	10.5	220
4	120	50	0.0075	12	120
5	300	80	0.0090	8.5	220
6	200	50	0.0095	10	200

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Table 6.2 : Prohibited zone limits of six unit system

Unit	Zone-1	Zone-2
1	210-240	350-380
2	80-90	110-120
3	90-110	140-150
4	75-85	100-105
5	150-170	210-240
6	90-110	140-160

The Six generating units considered are having different characteristic. Their cost function characteristics are given by following equations:

$F1 = 0.0070\ P1^2 + 7\ P1 + 240$ RS/Hr

$F2 = 0.0090\ P2^2 + 11\ P2 + 200$ RS/Hr

$F3 = 0.0080\ P3^2 + 10.5\ P3 + 220$ RS/Hr

$F4 = 0.0075\ P4^2 + 12\ P4 + 120$ RS/Hr

$F5 = 0.0090\ P5^2 + 8.5\ P5 + 220$ RS/Hr

$F6 = 0.0095\ P6^2 + 10\ P6 + 200$ RS/Hr

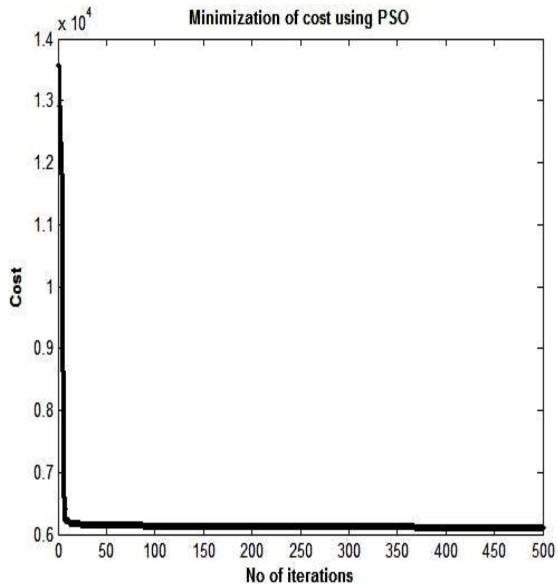
6.2 RESULTS DISCUSSION

6.2.1 PSO method:

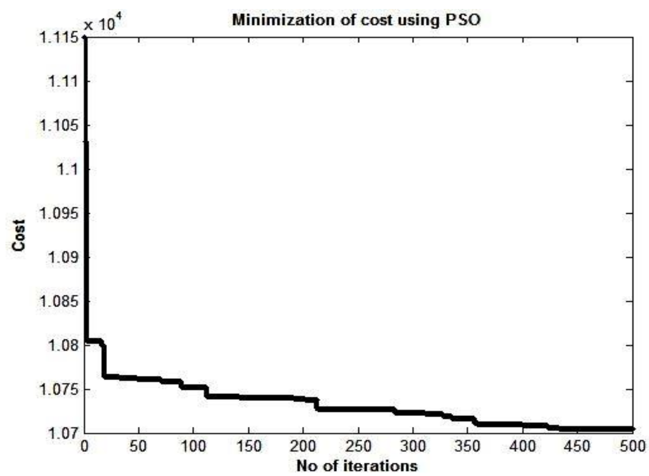
In this method the initial particles are randomly generated within the feasible range. The Parameters c1, c2 and inertia weight are selected for best convergence characteristic. Here, c1 = 2.0 and c2 = 2.0 Here the maximum value of w is chosen 0.9 and minimum value is chosen 0.4.the velocity limits are selected as $V_{max} = 0.5 * P_{max}$ and the minimum velocity is selected as $V_{min} = -\ 0.5 * P_{min}$. There are 100 no of particles are selected in the population. For different value of c1 and c2 the cost curve converges in the different region. So, the best value is taken for the minimum cost of the problem. If the no of particles are increased then cost curve converges faster. It can be observed the loss has no effect on the cost characteristic.

Table 6.3: Six unit system by PSO method

Power demand (MW)	P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	Total Gen cost (RS/Hr)	Power Loss (MW)	Elapsed time (sec)
500	223.75	50	50	50	80.055	50	6114.8	3.80	10.057
900	355.56	67.768	136.91	50.117	203.19	95.385	10709	8.94	10.048
1100	411.99	88.237	171.28	57.403	255.24	129.41	13268	13.56	10.408
1236	473.97	117.23	181.74	64.419	287.83	157.02	15477	19.21	10.520



6.2.1.2 Cost curve of 500MW demand by PSO method



6.2.2.2 Cost curve of 900MW demand by PSO method

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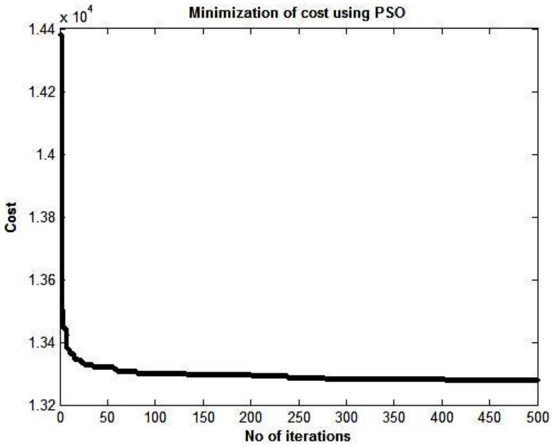
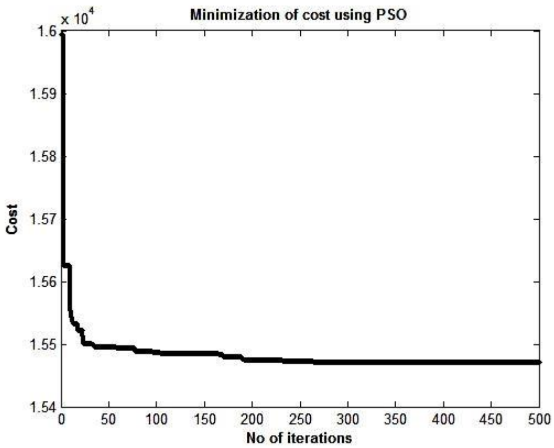


6.2.1.3 Cost curve of 1100MW demand by PSO

method



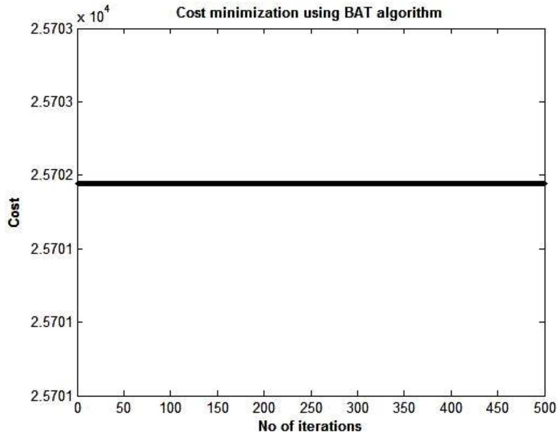
6.2.1.4 Cost curve of 1263 MW demand by PSO method

6.2.2 BAT Algorithm method:

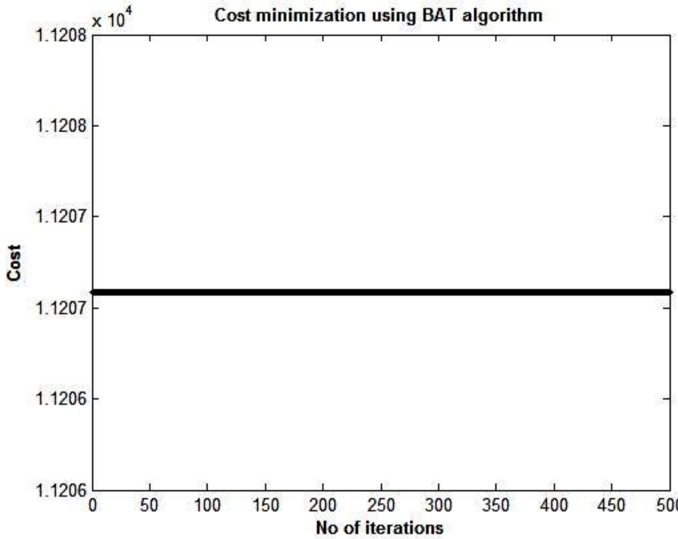
In this method the bats are fly's randomly and automatically adjust wave length(frequency) of emitted signals and adjust the rate of emission r in the range of [0,1] depend their proximity of target.. The parameters of algorithm used for simulation are selected for best convergence characteristic. Here, *n = 100* (size of population), *N_gen=500* (no of iterations), *A= 0.9*(loudness), *r= 0.1*(rate of pulse emission), $Q_{min} = 0$ and $Q_{max} = 2$(frequency) .There are 100 no of bats are selected in the population. For different value of *n* and *N_gen*, the cost curve converges in the different region. So, the best value is taken for the minimum cost of the problem. If the no of bats are increased in population then cost curve converges faster. It can be observed the loss has no effect on the cost characteristic.

Table 6.4: Six unit system by BAT method

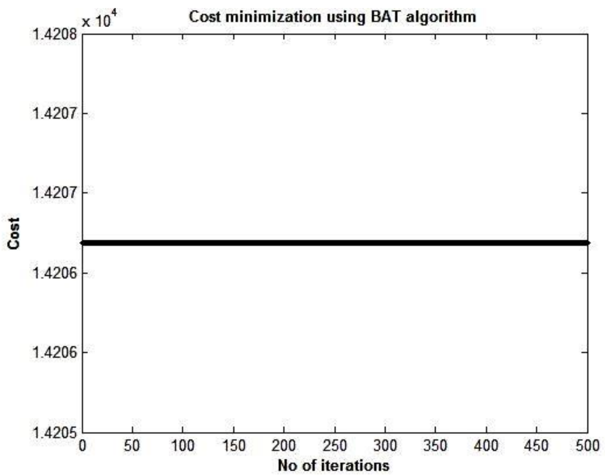
Power demand (MW)	P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	Total Gen cost (RS/Hr)	Power Loss (MW)	Elapsed time (sec)
500	139.14	69.67	52.228	133.94	86.649	142.08	24431	13.15	7.68
900	265.91	61.513	57.666	163.26	219.47	151.31	11186	19.78	7.65
1100	475.81	110.07	120.97	153.34	155.49	105.8	13609	21.05	7.96
1236	500	150	200	164.54	80	200	15472	31.30	8.15



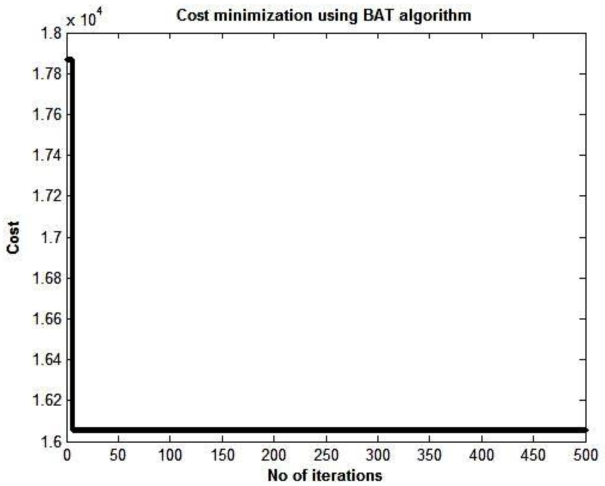
6.2.2.1 Cost curve of 500MW demand by BAT ALOGRITHM method



6.2.2.2 Cost curve of 900MW demand by BAT ALGORTHIM method



6.2.2.3Cost curve of 1100MW demand by BAT ALGORITHM method

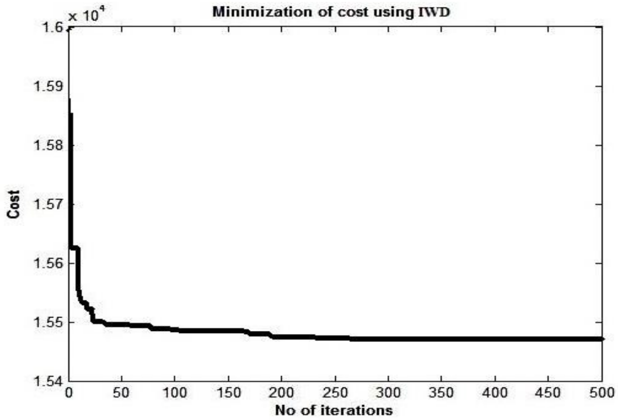


6.2.2.4 Cost curve of 1263MW demand by BAT ALGORITHM method

6.2.3 IWD method:

Table 6. 5: six unit system by IWD method

Power demand (MW)	P1 (MW)	P2 (MW)	P3 (MW)	P4 (MW)	P5 (MW)	P6 (MW)	Total Gen cost (RS/Hr)	Power Loss (MW)	Elapsed time (sec)
1236	447.49	173.32	263.47	139.09	165.47	87.12	15450	12.98	10.79



6.2.3.1 Cost curve of 1263MW demand by IWD method

6.3 COMPARISON OF METHODS

Table 6.6: Comparison of three different methods

S.no	Unit output (MW)	BAT	PSO	IWD
1	P1	500	473.97	447.49
2	P2	150	117.23	173.32
3	P3	200	181.74	263.47
4	P4	164.54	64.419	139.09
5	P5	80	287.83	165.47
6	P6	200	157.02	87.12
7	Total output	1294.54	1282.209	1275.96
8	Power loss	31.30	19.21	12.98
9	Total Generation cost (RS/Hr)	16012	15477	15450
10	Convergence time (sec)	8.15	10.520	10.79

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It has been observed that based on results obtained from table 6 , The BAT algorithm is very efficient and takes very less time to convergence around 8.15 sec where as in PSO takes around 10.52 sec to converge. Bat algorithm has been compared with the PSO, IWD algorithms and it has been found that, it gives minimum cost of 16,012 Rs/hrs with minimum loss of 31.30 MW at 1263 power demand. The convergence characteristic of the BAT method for 6-unit system is shown in Figs (6.2.2.1- 6.2.2.4).

All the methods give the minimum cost are not always equal. The performance depends on randomly generated particle in PSO, The static and dynamic parameters in IWD and bats movements in BAT ALGORITHM .Sometimes PSO gives better result and sometimes BAT gives better result. But convergence is good in BAT ALGOITHM compare to remaining exist methods.

7.1 CONCLUSION

The most economical operation of modern power systems is allocate the optimal power generation from different units at the lowest cost possible while meeting all system constraints. Economic Load Dispatch (ELD) is a method to schedule the power generator outputs with respect to the load demands. Economic Load dispatch problem here solved for a six thermal unit system with only transmission losses considered. The three different methods are performing in the MATLAB environment. Before this thesis draws to a close, major literatures are reported in work and the general conclusions that emerge out from this work are highlighted. The conclusions are arrived at based on the performance and the capabilities of the PSO and IWD application presented here. This finally leads to an outline of the future directions for research and development efforts in this area.

The problem of six units system when transmission losses are solved by three different methods. In conventional methods better cost is obtained but the problem converges when parameters varied randomly. The cost characteristic takes many numbers of iterations to converge. In BAT ALGORITHM the cost characteristic converges in less elapsed time when compared with PSO and IWD methods. In BAT ALGORITHM the selection of parameters are very important. The best results were obtained when number of population is decreased.

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