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Performance Analysis of Various Soft Computational Techniques for Economic Load Dispatch

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ABSTRACT: A good practice is the one in which the product cost is minimized without scarifying the quality. The main aim of ELD is to minimize the production cost. Economic operation strategy those are required to maintain the power dispatch economically. Now day's limitation of energy resources, high power generation cost, and increasing demand for electrical energy requires optimal economic dispatch. The main idea is that in order to serve load at 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 MW of energy onto the system. This paper reflects the effectiveness and reliability of Particle Swarn Optimization (PSO) over convectional mathematical model Lamdda Iteration, which has been carried out for 3 bus and 6 bus generator systems. We also have compared the fuel cost (effective) computation with Particle Swarn Optimization (PSO) over Lamdda Iteration and Genetic Algorithm (GA) optimization. The results obtained using Particle Swarn Optimization (PSO) is found to be encouraging over conventional techniques.

I. INTRODUCTION

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 honor 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, recognizing any operational limits of generation and transmission facilities.

The economic load dispatch (ELD) is a vital parameter in power system like unit commitment, Load Forecasting, Available Transfer Capability (ATC) calculation, Security Analysis, Scheduling of fuel purchase etc. A survey on ELD methods gives out numerous mathematical optimization techniques have been demonstrated to approach the ELD .Previously ELD is calculated by traditionally using mathematical programming based on optimization techniques such as lambda iteration, gradient method. Economic load 3 dispatch with piecewise linear cost functions is a highly heuristic, approximate and extremely fast form of economic dispatch. Complex constrained ELD is addressed by intelligent methods. Among these methods, some of them are genetic algorithm (GA), evolutionary programming (EP), dynamic programming (DP), hybrid EP, neural network (NN), adaptive Hopfield neural network (AHNN), particle swarm optimization (PSO) etc. For calculation simplicity, existing methods use second order fuel cost functions which involve approximation and constraints are handled separately, although sometimes valve-point effects are considered. However, the authors propose higher order cost functions for (a) better curve fitting of running cost, (b) less approximation, (c) more practical, accurate and reliable results, and modified particle swarm optimization (MPSO) is introduced to calculate the optimum dispatch of the proposed higher order cost polynomials. Constraint management is incorporated in the MPSO and no extra concentration is needed for the higher order cost functions of single or multiple fuel units in the proposed method. Lambda iteration, gradient method can solve simple ELD calculations and they are not sufficient for real applications in deregulated market. However, they are fast. There are several Intelligent methods among them genetic algorithm applied to solve the real time problem of solving the economic load dispatch problem. Whereas some of the works are done by Evolutionary algorithm. Few other methods like tabu search are applied to solve to solve the problem. Artificial neural network are also used to solve the optimization problem. However many people applied the swarm behavior to the problem of optimum dispatch as well as unit commitment problem are general purpose; however, they have randomness. For a practical problem, like ELD, the intelligent methods should be modified accordingly so that they are suitable to solve economic dispatch with more accurate multiple fuel cost functions and constraints, and they can reduce randomness. Intelligent methods are iterative techniques that can search not only local optimal solutions but also a global optimal solution depending on problem domain and execution time limit. They are general-purpose searching techniques based on principles inspired from the genetic and evolution mechanisms observed in natural systems and populations of living beings. These 4 methods have the advantage of searching the solution space more thoroughly. The main difficulty is their sensitivity to the choice of parameters. Among intelligent methods, PSO is simple and promising. It requires less computation time and memory. It has also standard values for its parameters. In this thesis the Particle Swarm Optimization (PSO) is proposed as a methodology for economic load dispatch. The data of three generating units and six generating units has taken to which PSO with different population is applied and compared. The results are compared with the traditional method i.e. Lambda iteration method and Genetic Algorithm (GA).

II. METHODOLOGY

A. ECONOMIC LOAD DISPATCH PROBLEM

Economic load dispatch problem is the sub problem of optimal power flow (OPF). The main objective of ELD is to minimize the fuel cost while satisfying the load demand with transmission constraints.

B. OBJECTIVE FUNCTION

The classical ELD with power balance and generation limit constraints has been formulated as follows.

Minimize $F_t = \sum_{i=1}^{d} F_1(P_1)$

Where F_t is the total fuel cost of generation,

$F_1(P_1)$is the fuel cost function of i[th] generator,

a_1, b_1, c_1 are the cost coefficients of i[th] generator,

P_1 is the real power generation of ith generator,

d represents the number of generators connected in the network.

The minimum value of the above objective function has to be found by satisfying the following constraints.

The power balance constraint is given as

$$\sum_{i-1}^{d} P_1 = P_D + P_L$$

Where P_D is the total load of the system and

P_L is the transmission losses of the system.

The total transmission loss is given as

$$\sum_{m}\sum_{n} \boldsymbol{P_{1,m} B_{mn} P_{1,n}}$$

Where $P_{1,m}$ and $P_{1,n}$ are the real power injections at m[th] and n[th] buses and

B_{mn} are the B-coefficients of transmission loss formula.

The inequality constraint on real power generation P, for each generator is

$$\boldsymbol{P_1^{mn} \le P_1 \le P_1^{max}}$$

Where $P_1^{mn}$and P_1^{max} are, respectively, minimum and maximum values **of** real power allowed at generator.

C. COST FUNCTION

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

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

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 generations Q_{Gi} do not have any measurable influence on C_i because they are controlled by controlling by 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, we thus have

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

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

D.PARTICLE SWARM OPTIMIZATION (PSO)

Particle swarm optimization was first introduced by Kennedy and Eberhart in the year 1995. It is an exciting new methodology in evolutionary computation and a population-based optimization tool like GA. PSO is motivated from the simulation of the behaviour of social systems such as fish schooling and birds flocking**.** The PSO algorithm requires less computation time and less memory because of its inherent simplicity.

E. ALGORITHM OF PSO

The search procedure for calculating the optimal generation quantity of each unit is summarized as follows:

1. In the ELD problems the number of online generating units is the 'dimension' of this problem.

The particles are randomly generated between the maximum and the minimum operating limits of the generators and represented using equation (2.10).

2. To each individual of the population calculate the dependent unit output **Pd.** Fem. the power balance equation and employ the B-coefficient loss formula to calculate the transmission loss P1,using constraint satisfaction techniqu

3. Calculate the evaluation value of each individual p, in the population using the evaluation function f, given by equation (2.1 1).

4. Compare each individual's evaluation value with its p best. The best evaluation value among the p best is identified as g best.

5. Modify the member velocity V of each individual P8, according to the following equation.

$V_{id}^{(t+1)}$=W $V_i^{(t)}$+c, $Rand_1$( )**x(** $pbest_{id}$ –$P_{gid}^{(t)}$)+c_2Rand_2( )x($gbest_d$ – $P_{gid}^{(t)}$)

i = 1,2,…..n, d = 1,2,….m

where n is the population size, m is the generator units.

6. Check the velocity constraints of the members of each individual from the following conditions:

If $V_{id}^{(t+1)} > V_d^{max}$, then $V_{id} = V_d^{max}$,

If $\mathbf{v_{id}^{(t+1)}} < V_d$. then $V_{id}^{(t+1)} = V_d^{min}$,

Where $V_d^{min} = -0.5\ P_d^{min}$

$V_d^{max} = +0.5\ P_d^{max}$

7. Modify the member position of each individual $\mathbf{P_{gi}}$**,** according to the equation

$\mathbf{P_{gid}^{(t+1)}} = P_{gid}^{(t)} + V_{id}^{(t+1)}$

$\mathbf{P_{gid}^{(t+1)}}$ must satisfy the constraints, namely the generating limits, described by equation. If $P_{gid}^{(t+1)}$ violates the constraints, then $P_{gid}^{(t+1)}$ must be modified towards the nearest margin of the feasible solution.

8. If the evaluation value of each individual is better than previous pbest, the current value is set to be pbest. If the best pbest is better than gbest, the best pbest is set to be gbest.

9. If the number of iterations reaches the maximum, then go to step 10. Otherwise, go to step2.

10. The individual that generates the latest gbest is the optimal generation power of each unit with the minimum total generation cost.

F. GENETIC ALGORITHM

Genetic algorithm (GAs) were invented by John Holland in the 1960s and were developed with his students and colleagues at the University of Michigan in the! (70s. Holland’s original goal was to investigate the mechanisms of adaptation in nature to develop methods in which these mechanisms could be imported into computer systems.

G. ALGORITHM OF GA

III. RESULT AND DISCUSSION

A. LAMBDA ITERATION METHOD

In Lambda Iteration method initial value of lambda is assumed that can be calculated from derivative of the cost function. The delta lambda value is assumed small. It is selected as 0.0001 and maintaining a condition that lambda value is selected near to the optimum value. It is seen that minimum cost curve converges after so many iterations than in the no loss case. The cost curve converges within the range of 2000 to 5000 iterations. The lambda selection is vital for convergence of cost curve.

B. Table: Lambda Iteration Method

S. NO.	Power demand (MW)	P_1 (MW)	P_2 (MW)	P_3 (MW)	F_t Rs/Hr
1	400	184.8	198.36	68.16	4665.1
2	650	289.2	304.02	110.13	6872.2
3	850	372.22	389.39	144.01	8711.81

C. PSO METHOD

In Particle Swarn Optimization we have selected the initial particle randomly generated within the range. For best convergence characteristic c1, c2 and inertia weight are selected. Here, c1 = 1.99 and c2 = 1.99 Here the maximum value of w = 0.9 and minimum value is taken as 0.4. The velocity limits are selected as V_{max}= 0.5*P_{max} and V_{min}= -0.5*P_{min}. Selected particle in the population are 10 in numbers. 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 we increase the number of particles then cost curve converges faster. It can be clearly analyzed that the loss does not have any effect on the cost characteristic

C. Table: PSO Method

S.NO	Power Demand	P_1 MW	P_2 MW	P_3 MW	Cost
1	400	181.96	167.6	51.6	4236.25
2	650	299.32	266.4	87.4	6421.67
3	850	393.55	345.57	115.5	8237.15

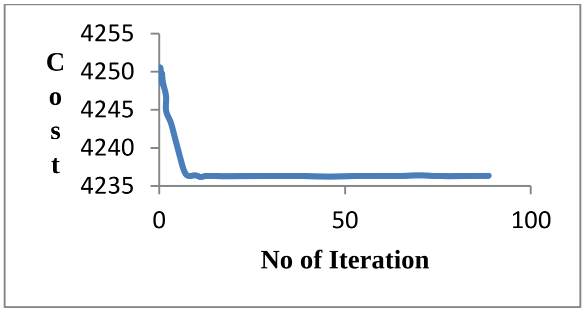

Fig:Cost curve of 400 MW for 3 Bus System for PSO

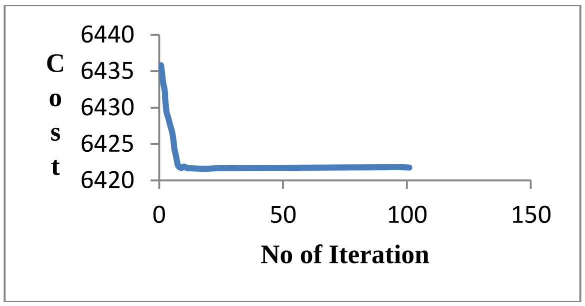

Fig:Cost curve of 650 MW for 3 Bus System for PSO

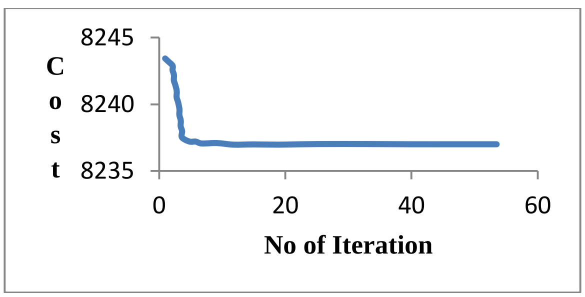

Fig:Cost curve of 850 MW for 3 Bus System for PSO

D. GA METHOD

In GA method for solving the problem of ELD, the number of chromosomes is selected as 10. The length of the string is taken as equivalent to the number of chromosomes i.e 10. Probability of selection for the cross over operation is chosen. In the crossover operation one point crossover method is applied. It is seen that the minimum cost curve convergence is not different when transmission line losses are neglected as we found in conventional method.

E. Table: GA Method

S.NO	Power Demand	P_1 MW	P_2 MW	P_3 MW	COST
1	400	180.53	168.71	51.28	4230.59
2	650	298.48	267.085	87.55	6421.66
3	850	392.92	346.51	115.79	8642.25

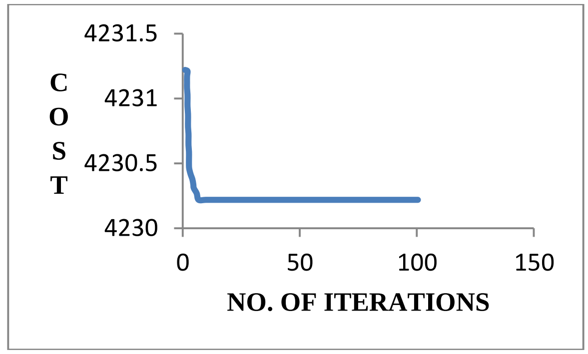

Fig: Cost curve of 400 MW for 3 Bus System for GA

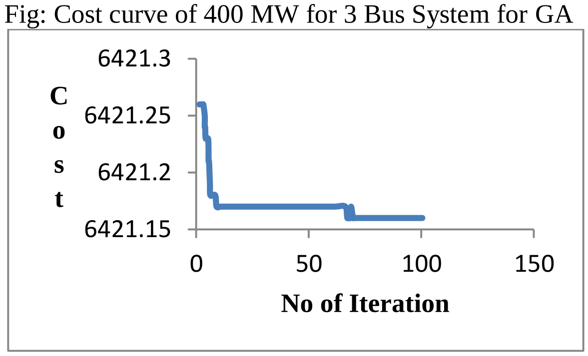

Fig:Cost curve of 650 MW for 3 Bus System for GA

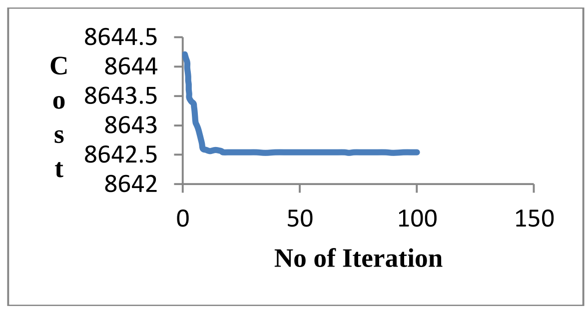

Fig: Cost curve of 850 MW for 3 Bus System for GA

E. COMPARISON OF COST OF 3 UNIT SYSTEM

It has been observed that the minimum cost we found in the PSO and GA method are less than the conventional method. But both the methods PSO and GA gives the minimum cost nearly equal

F. Table: Comparison of cost

S.NO	Power Demand	LIT	PSO	GA
1	400	4665.1	4236.25	4230.59
2	650	6872.2	6421.67	6421.66
3	850	8711.81	8237.15	8642.25

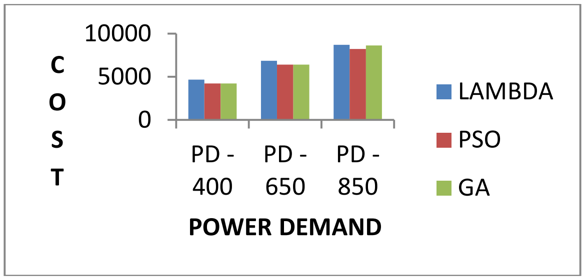

Fig: Comparison of 3 unit system

G. SIX BUS SYSTEM

LAMBDA ITERATION

The initial value of lambda is guessed in the feasible reason that can be calculated from derivative of the cost function. For the convergence of the problem the delta lambda should be selected small. Here delta lambda is selected 0.0001 and the value of lambda must be chosen near the optimum point. In this case also the convergence is largely affected by selection of lambda value and delta lambda.

H. Table: LAMBDA ITERATION

Power Demand	P_1 MW	P_2 MW	P_3 MW	P_4 MW	P_5 MW	P_6 MW	cost
650	24.97	10	102.664	110.63	232.67	219.05	36003.5
750	28.75	10	123.23	126.9	259.99	251.1	40676.1
850	32.51	10.61	143.68	143.06	287.14	282.97	45464.1

I. PSO METHOD

In Particle Swarn Optimization we have selected the initial particle randomly generated within the range. For best convergence characteristic c1, c2 and inertia weight are selected. Here, c1 = 1.99 and c2 = 1.99 Here the maximum value of w = 0.9 and minimum value is taken as 0.4. The velocity limits are selected as V_{max}= 0.5*P_{max} and V_{min}= -0.5*P_{min}. Selected particle in the population are 10 in numbers.

J. Table: PSO METHOD

Power Demand	P_1 MW	P_2 MW	P_3 MW	P_4 MW	P_5 MW	P_6 MW	cost
650	22.96	10.83	88.98	103.66	221.54	201.93	33707.98
750	27.26	10	118.19	119.98	241.65	233.51	38445.50
850	33.19	13.08	197.5	144.67	216.6	243.67	43056.20

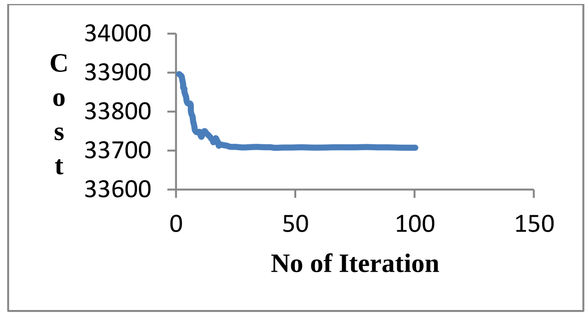

Fig:Cost curve of 650 MW for 6 Bus System for PSO

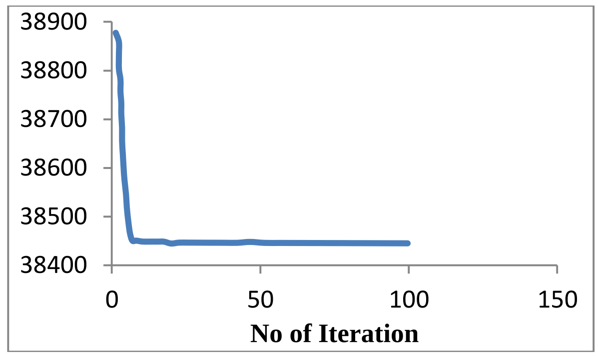

Fig:Cost curve of 750MW for 6 bus system for PSO

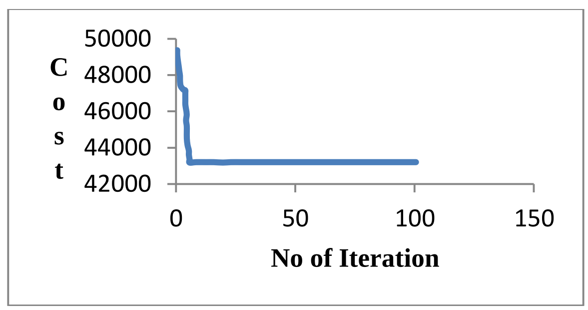

Fig:Cost curve of 850 MW for 6 Bus System for PSO

K. GA METHOD

In GA method for solving the problem of ELD, the number of chromosomes is selected as 10. The length of the string is taken as equivalent to the number of chromosomes i.e 10. Probability of selection for the cross over operation is chosen. In the crossover operation one point crossover method is applied.

L. Table: GA METHOD

Power Demand	P_1 MW	P_2 MW	P_3 MW	P_4 MW	P_5 MW	P_6 MW	cost
650	25.18	10.83	79.43	104.73	225.87	203.89	33715.35
750	27.33	10	118.12	110.53	246.9	237.67	38451.63
850	32.24	10	132.27	132.62	273.38	269.0	43062.30

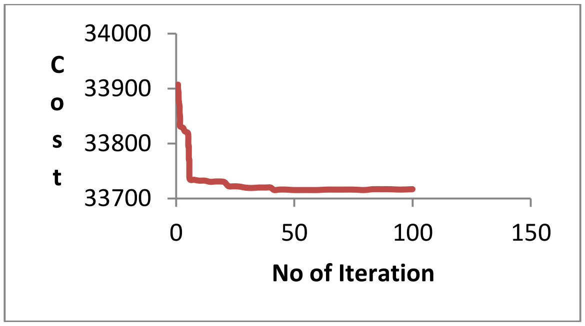

Fig: Cost curve of 650MW for 6 Bus System for GA

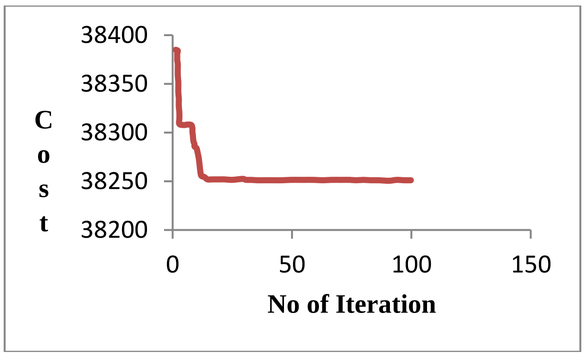

Fig: Cost curve of 750MW for 6 Bus System for GA

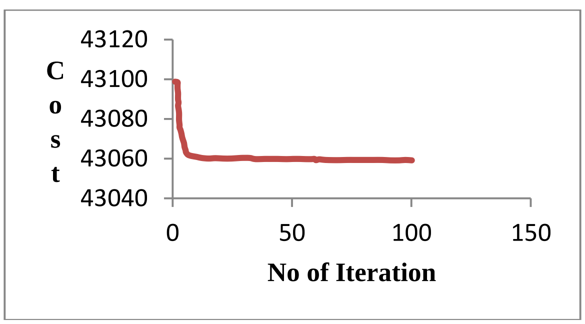

Fig: Cost curve of 850MW for 6 Bus System for GA

M. COMPARISON OF COST OF 6 UNIT SYSTEM

It has been observed that when the numbers of units are increased the minimum cost we found in the PSO and GA method are less than or nearly equal to the conventional method. But both the methods PSO and GA give the minimum cost are not always equal. The performance depends on randomly generated particle in PSO and strings in GA. Sometimes PSO gives better result and sometimes GA gives better result.

N. Table: Comparison of Cost

S.NO	Power Demand	LIT	PSO	GA
1	650	36003.5	33707.98	33715.35
2	750	40676.1	38445.50	38451.63
3	850	45464.1	43056.20	43062.30

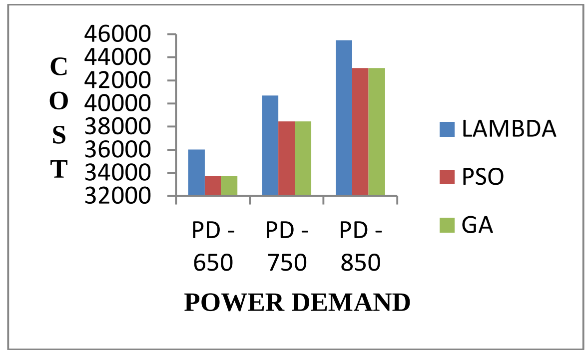

Fig: Comparison of 6 unit system

IV. CONCLUSION

Particle Swarn Optimization (PSO) and Genetic Algorithm (GA) are specifically used to rectify the problem of economic load dispatch. During optimization of Genetic Algorithm for optimum setting there are certain difficulties which hinders the progress but where as far as Particle Swarn Optimization (PSO) is concerned it is effective and very much progressive. Particle Swarn Optimization (PSO) has memory which Genetic Algorithm (GA) does not have. The computed results obtained from 3 and 6 bus system (generator unit) for Particle Swarn Optimization (PSO) is better as compared with Genetic Algorithm (GA). Particle Swarn Optimization (PSO) is cost effective which is a major conclusion regarding the economic load dispatch. The fuel cost obtained with Particle Swarn Optimization (PSO) is lesser than Genetic Algorithm (GA). The fuel cost obtained with PSO and GA are much lesser as compared with Lambda Iteration method, and as we can see in the comparison chart between three PSO and GA has somewhat similar values for lower demand and as we increase the demand PSO illustrates superiority with lower fuel cost as compared with GA. So the result clearly demonstrates that Particle Swarn Optimization (PSO) is better optimization technique as compared to Genetic Algorithm.

V. FUTURE SCOPE

Economic Load Dispatch problem can be examined for large number of units Bat Algorithm and Cuckoo Search Algorithm (CSA) optimization can also be employed for economic load dispatch solution.

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