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Generation Scheduling and Short Term Unit Commitment

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ABSTRACT

The economic load dispatch plays an important role in electric power system. Several different techniques are used to solve the economic load dispatch problem. The economic load dispatch plays an important role in the operation of power system, and several models by using different techniques have been used to solve these problems. Several traditional approaches, like lambda-iteration and gradient method are utilized to find out the optimal solution of non-linear problem. More recently, the soft computing techniques have received more attention and were used in a number of successful and practical applications. The purpose of this work is to find out the advantages of application of the Differential Evolution and Pattern Search in particular to the economic load dispatch problem. Here, an attempt has been made to find out the minimum cost by using DE using the data of three, four, six and fifteen generating units. In this work, data has been taken 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. DE is applied to find out the minimum cost for different power demand which is finally compared with Lambda- iteration method, Cuckoo search, Evolutionary technique and PSO Method.

Keywords: Lambda- iteration method, Cuckoo search, DE Algorithm, MATLAB, PSO Method.

I. INTRODUCTION

Electric power carries vital role in all sphere. The modern industry is totally dependent upon the electricity. This enhances the demand of electricity day by day so number of power station and their capacities increases. Also the cost of power transmission lines raises which connect the generating stations to the load centre. With large interconnection of electric networks, the energy crisis in the world and continuous rises in the prices of energy [3]. It is necessary to reduce the operating cost of electric energy. To get the goal of minimum operating cost, the main problem which comes is the economic load dispatch.

The electric energy is obtained by conversion from fossil fuels, namely coal, oil, natural gas and also from hydro and nuclear sources. Due to burning of these fossil fuels, the contaminant such as CO_2, SO2 and NO_x increases in the atmosphere. According to the increasing concern of environmental pollution, the minimum cost of operating a unit in not only the particular factor for economic load dispatch problem. Therefore for meeting the future energy demand much importance needs to be placed on electricity generation in the best technical, economic and environmental conditions. It can also be stated that, main criteria of economic load dispatch is to apportion the optimal power generation from distinct units at the minimum cost possible along with meeting all the constraints.

There are some modern soft computing techniques like genetic algorithms, Tabu search, fuzzy logic approach, artificial neural networks etc. to solve the unit commitment problem. Various methods like Newton Raphson method, Lambda Iteration method, and Gradient method are used. The Dynamic Programming is to construct a best hybrid technique to get a better outcome than the existing ones. The input/ output characteristics of modern units are highly non-linear. The ordinary techniques are not approved right in solving these kinds of problems. In that way, stochastic search algorithms like genetic algorithm, evolution strategy, evolutionary programming, particle swarm optimization and simulated annealing can be resulted to be very efficient in solving non-linear ELD problems. In modern computer aided power system design, Economic Load Dispatch (ELD) is one of the most prominent optimization problems.

The ELD problem finds the optimum shifting of load among the committed generating units subject to satisfaction of power balance and capacity constraints, such that the total cost of operation is kept at a minimum [1]. In order to generate a significant saving in the operational cost, there are numerous methods and investigations are being obtained.

Conventional techniques like Lambda Iteration method, dynamic programming , mixed integer programming , branch and bound , gradient-based method, and Newton's method were used earlier to obtain optimal dispatch to the ELD problems. In power system, Unit commitment problem is a circuitous decision-making process which includes the arranging of generators over a set of time periods to satisfy system load demand, water demand, system reliability, operational, and security constraints.

Analytically, this is a nonlinear, non-convex, high dimensional and large-scale optimization problem over mixed integer variables. Unit commitment (UC) is the main issue of scheduling of generating units over a given time period so that the total operational cost is minimized and all operational constraints are satisfied. UC involves two decision processes; first, the "economic dispatch" decision, which involves the allocation of the system demand and reserve capacity among the operating units in each specified hour. Second, the "unit scheduling" that actuate on/off status of generating units in each hour of planning horizon subject to system capacity requirements, including the spinning reserve and the constrained on start-up and shut-down of units. For a short-term unit commitment issue like hourly or daily scheduling of generators, the operator first needs to run the model in real-time. The operator should also have critical access to information concerning which units should be operated when emergency situations arise or how to schedule around planned maintenance of units. Modern Soft Computing Techniques is developed to solve the unit commitment problem. Economic Load Dispatch (ELD) problem plays crucial role in power system operation and planning.

The main ambition of the Economic Load Dispatch problems is to build the optimal arrangement of power outputs of all generating units so as to assemble the required demand at minimum cost while satisfying the equality and inequality constraints. Normally, the cost function for each unit in Economic Load Dispatch problems has been around defined by a quadratic function and is obtained using MATLAB programming techniques. Normally, these mathematical techniques require some insignificant cost information to get the global optimal solution. Unfortunately, the real-world I/O characteristics of generating units are extremely nonlinear and non-smooth because of banned operating zones, multi-fuel effects and valve point loadings etc. Thus, the practical Economic Load Dispatch problem is re-mentioned as a non-smooth optimization problem with equality and inequality constraints, which cannot be find by the mathematically methods.

II. PREVIOUS WORK

The method by Yu D, et al**.** formulated the hybrid algorithm to decide unit commitment problem that involves the operation of ant colony optimization algorithm and lambda iteration method. Space complication of ACO algorithm for solving UCP is reduced [1]. One more method is given by Chitra N., et al. to selected Ant colony optimization (ACO) is an intelligent searching algorithm, that applied for real time self tuning of control parameter. The simulation result represent that the proposed controller offers an excellent response to satisfy the Power quality improvement. Microgrid is the major spot in research on distributed energy system. This paper focused on Power quality improvement in self-determine microgrid. An optimal power control approach for an autonomous microgrid is achieved in a real time self tuning method. The main parameter which is consider in this work, particularly from grid connected to islanding operation mode are voltage frequency (V_f) regulation and harmonic analysis [2]. Ouiddir R, et al. explored the benefits of genetic algorithm to solve an economic dispatch problem. The chromosome involves only the encoding of a normalized incremental cost system. Therefore, the total number of bits of a chromosome is completely individualistic of the number of units. This method has been applied to the western part of the Algerian power network, and the conclusion have been establish to be sufficient in comparison with other results achieved using classical methods [12].

III. PROBLEM FORMULATION

(A) Single Objective Problem Formulation of UC

Unit commitment also be describe as the action of determining the least production cost, generator turn ON/turn OFF schedule and real power outputs of committed units while meeting the forecasted demand over a scheduled limit. The obtained unit commitment schedule should also satisfy the global constraints i.e. power balance, spinning reserve and environmental and local constraints like operational and physical constraints of every unit. Unit commitment is a complex, non-linear, mixed integer optimization problem.

The main intention of unit commitment is to find the optimal itinerary for operating the available generating units in order to minimize the total operating cost of the power generation. Total operating cost of power generation includes fuel cost, start up and shut down costs. The fuel costs are determined using the data of unit heat rate & fuel price information which is normally a quadratic equation of power output of each generator at each hour determined by Economic Dispatch(ED).

$$F_c\left(P_i\right) = a_i + b_i P_i + c_i P_i^{\,2}$$

where, a_i, b_i, c_i are the cost coefficients. The total fuel cost over the given time period 'T' is

$$TFC = \sum_{t-1}^{T} \sum_{i=1}^{N} F_c P_i * X_i(t)$$

Start up cost is that cost which occurs while bringing the thermal generating unit online. It is expressed in terms of the time (in hours) for which the units have been shut down. On the other hand, shut down cost is a fixed amount for each unit which is shut down. A start up cost can be expressed as

$$SUC_i = \begin{Bmatrix} HSC_i, if MDT_i \le DT_i < MDT_i + CSH_i \\ CSC_i, if DT_i > MDT_i + CSH_i \end{Bmatrix}$$

Where, DT_i - shut down time, MDT_i - Minimum down time, HSC_i - Hot start up cost, CSC_i - Cold start up cost, CSH_i - Cold start hour of i^{th} unit. here, X_i (t) is the position or status of i^{th} unit at t^{th} hour.

(B) Multi objective Formulation of UCP

Since, the plants consume the fossil fuel to generate power and these plants increased the pollution level. we cannot neglect the emission level. This emission involves the gases like Co_2, So_2, No_x, which increases the green house effect into the atmosphere.

Consider a power system having N generating units each loaded to P_i MW. The generating units should be loaded in such a way that minimizes the total fuel cost while satisfying the power balance and other constraints. The economic emission dispatch problem is an optimization problem that determines the power output of each online generator that will result in a least cost system operating state with minimum emission.

The total system cost is the sum of the cost function of each generator and emission.
Multiobjective problem in ELD is a combination of both economic and environmental dispatches that individually make up different single problem. The total fuel cost is given by:

$$FC_T = \sum_{i=1}^{N} (a_i P_i^2 + b_i P_i + c_i) + h_i (d_i P_i^2 + e_i P_i + f_i)$$

- **Constraints**

Minimum up Time

If the units have already been shut down, there will be a minimum time before they can be restarted [1, 2]. This constraint in given as:

$$T_{on_i} \ge T_{up_i}$$

Minimum down Time

Once the unit is decommitted, there is a minimum time before it can be recommitted [1, 2]. This constraint is given as:

$$T_{off_i} \ge T_{down_i}$$

Maximum and Minimum Power Limits

Each unit has its own limits of generating power. These limits are bound in the levels of maximum and minimum power generation, below and beyond which the generating unit cannot generate power.

$$P_{i\min} \le P_i^t \le P_{i\max}$$

IV. TECHNIQUE USED

(A) Differential Evolution

Differential Evolution (DE) is a population based optimization method used to discover the arbitrarily produced beginning population to a last solution. DE is a stochastic search algorithm that was initially inspired by the systems of natural selection. DE is exceptionally viable for taking care of optimization problems with non smooth objective functions, since it doesn't require derivative data. The DE algorithm was initially presented by Storn and Price in 1995 [4] and was effectively implemented in the optimization of some well-known nonlinear,non-differentiable and non-convex functions by Storn

DE is a population based on optimization algorithm. The optimization process in DE is characterized with four essential operations in particular, Initialization, Mutation, Crossover and Selection. Through Initialization operation new population is produced and the individual are known as target vectors. New parameters are brought by the mutation operation into the population and make a mutant vector. The crossover operation creates trial vectors by combining the parameter of the mutant vectors with the objective vectors. selection is the procedure in which next generation population vector is created by comparing the fitness of target vector and trial vector.

For a system with NG generators, the population is signified as a vector of length NG. If there are L members in the population ,the whole population is characterized as a matrix.

Initialize a population according to following equation

$$X_{ij} = X_j^{min} + F(X_j^{max} - X_j^{min})$$
$$i=1,2,\ldots\ldots\ldots\ldots N,\ j=1,2,\ldots\ldots\ldots\ldots D''$$

Where X_j^{min} and X_j^{max} are respectively , the minimum and maximum limits of the decision parameter D. The mutation vector F is a user selected parameter utilized to control the perturbation size in the mutation operator. The parameters of mutant vectors and the target vectors are mixed to generate trail vector and this operation is known as crossover operation.

The selection of the vector is done by keeping one vectors among two for given vector when the trial vector is generated. the basic criterion is to keep the vector with improved fitness values and further we can conclude, the target vector will survive if the trail vector has proper fitness. The following step of the algorithm calls for determination to figure out if the trail vector get by to the next generation. Consequently, if f means the fitness function under optimization, then

$$X_i^{(G+1)} = \begin{cases} X_i^{'(G)} & \text{if } X_i^{'(G)} \leq f(Xi^{(G)}) \\ X_i^{(G)} & \text{Otherwise} \end{cases}$$

Differential Evolution is a better type of GA.DE uses the identical operators: mutation, crossover and selection. The fundamental distinction in making better solution is that GA's depend on crossover while DE depends on mutation operation. The different variations are characterized by taking after notation: DE/α/β/∂, where α demonstrates the technique for selecting the parent chromosome that will form the base of the mutated vector, β shows the quantity of distinction vectors used to perturb the base chromosome and ∂ shows the recombination mechanism used to make the offspring population. The bin acronym shows that the recombination is controlled by a series of independent binomial experiments.

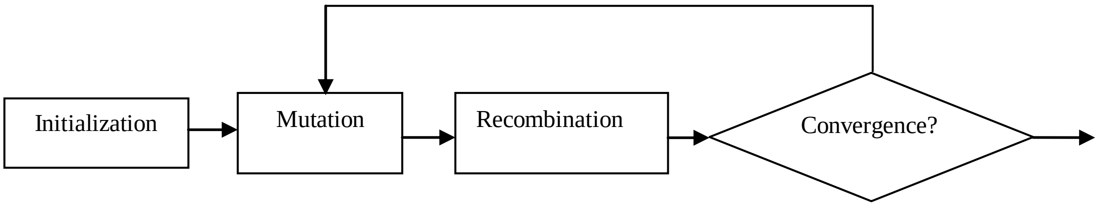


Fig. 1 Representation of DE

- **STEPS FOR DE ALGORITHM**

The algorithm begins with the objective function to be most reduced and initialize the input parameter i.e. population size, boundary constraints of optimization variables (M), mutation factor (f_m), crossover rate (CR), and the stopping criterion (t_{max}).

1. Initialization
2. Create an initial population.
3. Calculate every individual in the population.
4. Get the vector with minimum cost.
5. While the termination criterion not reached do
6.
    a. Mutation
    b. Crossover
    c. Selection
    d. Calculate the new individuals
7. Return
   Output
   END Algorithm

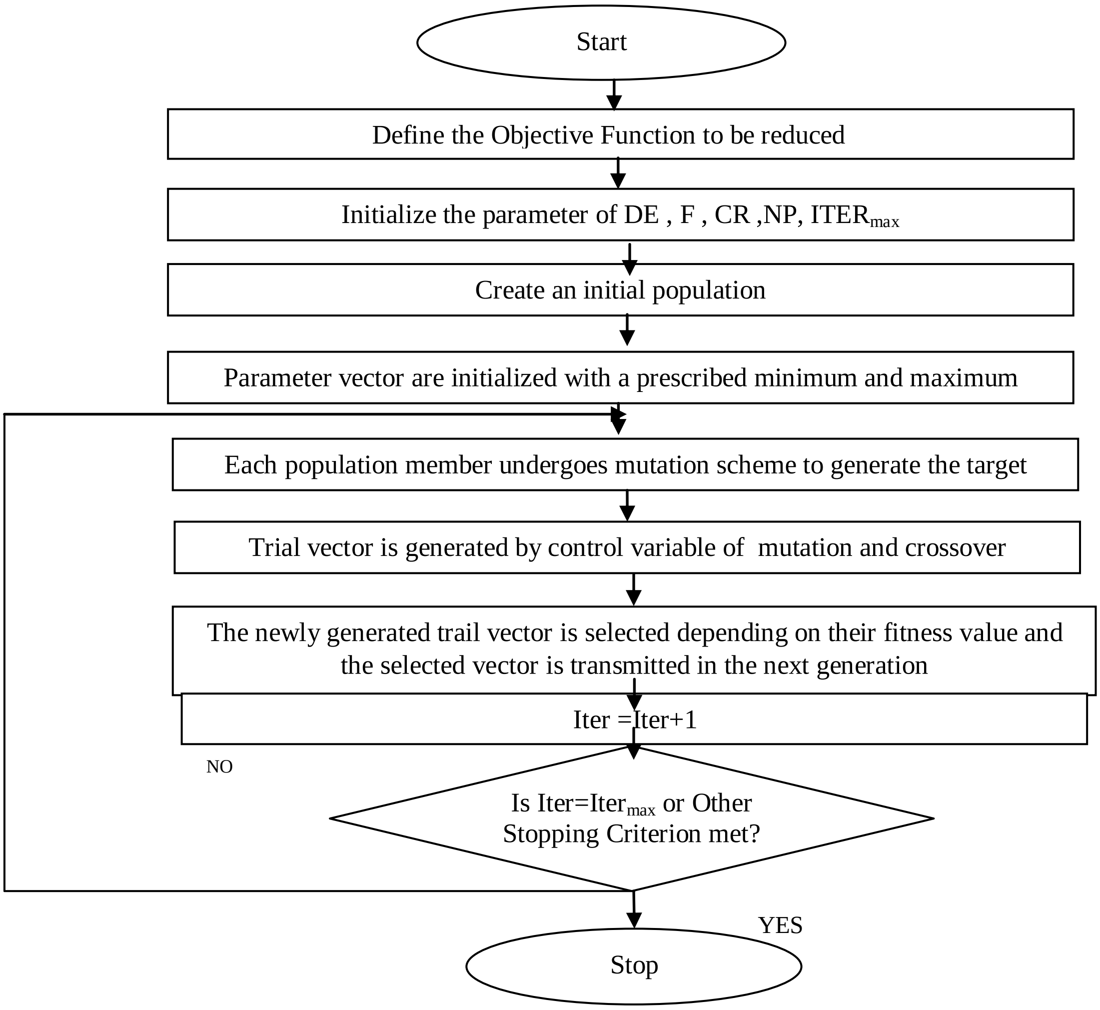


Figure 2: Flow Diagram of DE Algorithm

V. RESULT AND DISCUSSION

In order to show the effectiveness of the DE Algorithm for Economic Load Dispatch Problem, four different types of test systems have been taken into consideration. The corresponding results has been obtained using Differential Evolution Algorithm. The MATLAB Simulation software R2013a(8.1.0.)is used to obtain the corresponding results. For power transmission loss, George's Formula using B-coefficients is taken into consideration. The effectiveness of proposed algorithm is verified by comparing the results of DE algorithm with lambda iteration method and cuckoo search techniques

Table 1 Generator characteristics of 3-Unit Test System

No. of Generating Units	Real Powers (MW)		Cost Coefficients		
	P_{max}	P_{min}	A	B	C
1	210	35	0.003546	38.30533	1243.531
2	325	130	0.0211	36.32782	1658.57
3	315	125	0.01799	38.27041	1356.659

The loss coefficient matrix for 3-unit system:

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

Table 2 Results of 3-Unit System for different Load Demand

S. NO.	POWER DEMAND(MW)	FUEL COST(RS./h)		
		Lambda Iteration Method	Cuckoo Search Algorithm	Differential Evolution Method
1	350	18570.7	18564.5	18564.225
2	400	20817.4	20812.3	20811.970
3	450	23146.8	23112.4	23111.969
4	500	25495.2	25465.5	25464.995
5	550	27899.3	27872.4	27871.844
6	600	30359.3	30334.0	30333.330
7	650	32875.0	32851.0	32850.288
8	700	35446.3	35424.4	35423.573

Table 3 Generator Characteristics for 4 unit Test system

No. of Generating Units	Real Powers (MW)		Cost Coefficients		
	P_{max}	P_{min}	A	B	C
1	300	50	40.0	1.8	0.0015
2	125	20	60.0	1.8	0.0030
3	175	30	100.0	2.1	0.0012
4	250	40	120.0	2.0	0.001

Table 4 Generator characteristics of 6-Unit test System

No. of Generating Units	Real Powers (MW)		Cost Coefficients		
	P_{max}	P_{min}	A	B	C
1	125	10	0.15240	38.53973	756.79886
2	150	10	0.10587	46.15916	451.32513
3	225	35	0.02803	40.39655	1049.9977
4	210	35	0.03546	38.30533	1243.5311
5	325	130	0.02111	36.32782	1658.5596
6	315	125	0.01799	38.27041	1356.6592

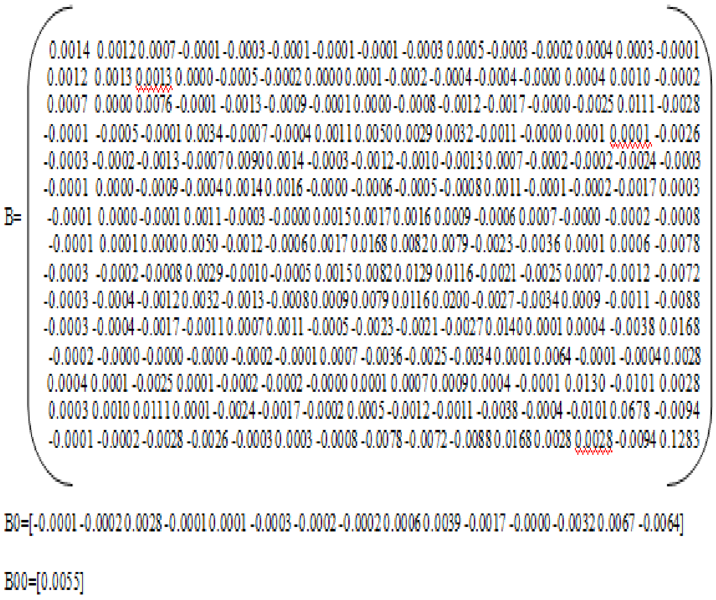
The loss coefficient matrix for 6-unit system:

$$B = \begin{pmatrix} 0.000022 & 0.000020 & 0.000019 & 0.000025 & 0.000032 & 0.000085 \\ 0.000026 & 0.000015 & 0.000024 & 0.000030 & 0.000069 & 0.000032 \\ 0.000019 & 0.000016 & 0.000017 & 0.000071 & 0.000030 & 0.000025 \\ 0.000015 & 0.000013 & 0.000065 & 0.000017 & 0.000024 & 0.000019 \\ 0.000017 & 0.000060 & 0.000013 & 0.000016 & 0.000015 & 0.000020 \\ 0.000014 & 0.000017 & 0.000015 & 0.000019 & 0.000026 & 0.000022 \end{pmatrix}$$

Table 5 Generator characteristics of 15-Unit test System

No. of Generating Units	Real Powers (MW)		Cost Coefficients		
	P_{max}	P_{min}	A	B	C
1	455	150	0.000299	10.1	671
2	455	150	0.000183	10.2	574
3	130	20	0.001126	8.8	374
4	130	20	0.001126	8.8	374
5	470	150	0.000205	10.4	461
6	460	135	0.000301	10.1	630
7	465	135	0.000364	9.8	548
8	300	60	0.000338	11.2	227
9	162	25	0.000807	11.2	173
10	160	25	0.001203	10.7	175
11	80	20	0.003586	10.2	186
12	80	20	0.005513	9.9	230
13	85	25	0.000371	13.1	225
14	55	15	0.001929	12.1	309
15	55	15	0.00447	12.4	323

The loss coefficient matrix for 15-unit system



$$B= \begin{pmatrix} 0.0014 & 0.0012 & 0.0007 & -0.0001 & -0.0003 & -0.0001 & -0.0001 & -0.0001 & -0.0003 & 0.0005 & -0.0003 & -0.0002 & 0.0004 & 0.0003 & -0.0001 \\ 0.0012 & 0.0013 & 0.0013 & 0.0000 & -0.0005 & -0.0002 & 0.0000 & 0.0001 & -0.0002 & -0.0004 & -0.0004 & -0.0000 & 0.0004 & 0.0010 & -0.0002 \\ 0.0007 & 0.0000 & 0.0076 & -0.0001 & -0.0013 & -0.0009 & -0.0001 & 0.0000 & -0.0008 & -0.0012 & -0.0017 & -0.0000 & -0.0025 & 0.0111 & -0.0028 \\ -0.0001 & -0.0005 & -0.0001 & 0.0034 & -0.0007 & -0.0004 & 0.0011 & 0.0050 & 0.0029 & 0.0032 & -0.0011 & -0.0000 & 0.0001 & 0.0001 & -0.0026 \\ -0.0003 & -0.0002 & -0.0013 & -0.0007 & 0.0090 & 0.0014 & -0.0003 & -0.0012 & -0.0010 & -0.0013 & 0.0007 & -0.0002 & -0.0002 & -0.0024 & -0.0003 \\ -0.0001 & 0.0000 & -0.0009 & -0.0004 & 0.0014 & 0.0016 & -0.0000 & -0.0006 & -0.0005 & -0.0008 & 0.0011 & -0.0001 & -0.0002 & -0.0017 & 0.0003 \\ -0.0001 & 0.0000 & -0.0001 & 0.0011 & -0.0003 & -0.0000 & 0.0015 & 0.0017 & 0.0016 & 0.0009 & -0.0006 & 0.0007 & -0.0000 & -0.0002 & -0.0008 \\ -0.0001 & 0.0001 & 0.0000 & 0.0050 & -0.0012 & -0.0006 & 0.0017 & 0.0168 & 0.0082 & 0.0079 & -0.0023 & -0.0036 & 0.0001 & 0.0006 & -0.0078 \\ -0.0003 & -0.0002 & -0.0008 & 0.0029 & -0.0010 & -0.0005 & 0.0015 & 0.0082 & 0.0129 & 0.0116 & -0.0021 & -0.0025 & 0.0007 & -0.0012 & -0.0072 \\ -0.0003 & -0.0004 & -0.0012 & 0.0032 & -0.0013 & -0.0008 & 0.0009 & 0.0079 & 0.0116 & 0.0200 & -0.0027 & -0.0034 & 0.0009 & -0.0011 & -0.0088 \\ -0.0003 & -0.0004 & -0.0017 & -0.0011 & 0.0007 & 0.0011 & -0.0005 & -0.0023 & -0.0021 & -0.0027 & 0.0140 & 0.0001 & 0.0004 & -0.0038 & 0.0168 \\ -0.0002 & -0.0000 & -0.0000 & -0.0000 & -0.0002 & -0.0001 & 0.0007 & -0.0036 & -0.0025 & -0.0034 & 0.0001 & 0.0064 & -0.0001 & -0.0004 & 0.0028 \\ 0.0004 & 0.0001 & -0.0025 & 0.0001 & -0.0002 & -0.0002 & -0.0000 & 0.0001 & 0.0007 & 0.0009 & 0.0004 & -0.0001 & 0.0130 & -0.0101 & 0.0028 \\ 0.0003 & 0.0010 & 0.0111 & 0.0001 & -0.0024 & -0.0017 & -0.0002 & 0.0005 & -0.0012 & -0.0011 & -0.0038 & -0.0004 & -0.0101 & 0.0678 & -0.0094 \\ -0.0001 & -0.0002 & -0.0028 & -0.0026 & -0.0003 & 0.0003 & -0.0008 & -0.0078 & -0.0072 & -0.0088 & 0.0168 & 0.0028 & 0.0028 & -0.0094 & 0.1283 \end{pmatrix}$$

$$B0=[-0.0001\ -0.0002\ 0.0028\ -0.0001\ 0.0001\ -0.0003\ -0.0002\ -0.0002\ 0.0006\ 0.0039\ -0.0017\ -0.0000\ -0.0032\ 0.0067\ -0.0064]$$

$$B00=[0.0055]$$

Table 6 Results of 10-Unit System for 1036 MW Load Demand

Unit Output	**DE Results**				
Power Demand	**350**	**450**	**500**	**600**	**700**
P1(MW)	253.166	169.221	150.000	257.013	320.383
P2(MW)	150.000	237.875	387.790	150.000	150.000
P3(MW)	96.948	91.957	22.139	82.643	111.744
P4(MW)	38.967	42.684	130.000	20.007	42.740
P5(MW)	150.000	179.542	150.001	150.000	150.000
P6(MW)	174.420	136.725	159.798	244.865	323.237
P7(MW)	135.000	135.000	135.041	302.801	233.655
P8(MW)	113.202	60.000	73.891	60.000	60.000
P9(MW)	25.011	25.000	54.885	25.000	25.000
P10(MW)	84.989	64.361	73.396	25.000	25.000
P11(MW)	29.738	45.837	35.613	42.929	40.046
P12(MW)	80.000	34.634	20.000	66.473	80.000
P13(MW)	25.000	59.919	43.727	79.776	53.698
P14(MW)	15.000	15.000	15.000	36.205	15.000
P15(MW)	17.051	21.524	15.000	15.000	15.000
Total Generating Capacity(MW)	1388.492	1319.279	1466.281	1557.712	1645.503
Ploss	1038.496	869.281	1216.280	957.712	1001.416
Fuel Cost(RS./h)	19794.0513	19129.9682	20608.5757	21621.7586	78276.6781
Elapsed Time	1.274344	1.417245	1.294366	1.283363	1.306282

CONCLUSION

In this paper, researchers have presented an effective Differential Evolution algorithm for economic load dispatch problem. The results for standard 3-unit, 4- unit, 6-unit and 15-units Generating model has been successfully evaluated using DE. The effectiveness of proposed algorithm is verified with lambda iteration method, cuckoo search algorithm , PSO and self adaptive differential evolution algorithm.

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