ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

Proposed Differential Evolution Technique for Solving the Power System Economic Load Dispatch Problem

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ABSTRACT: Electrical power industry restructuring has created highly vibrant and competitive market that altered many aspects of the power industry. In this changed scenario, scarcity of energy resources, increasing power generation cost, environment concern, ever growing demand for electrical energy necessitate optimal economic dispatch. In This paper presents an application of the Differential Evolution optimization algorithm to power system economic load dispatch problem with ramp rate limit for 15 unit test case system. Power system Economic load dispatch problems are applied and compared its solution quality and computation efficiency to Genetic algorithm (GA) and Differential Evolution optimization algorithm.

KEYWORDS: power system Economic Load Dispatch, Genetic Algorithm, Differential Evolution algorithm,

I. INTRODUCTION

Electric utility system is interconnected to achieve the benefits of minimum production cost, maximum reliability and better operating conditions. The economic scheduling is the on-line economic load dispatch, wherein it is required to distribute the load among the generating units which are actually paralleled with the system, in such a way as to minimize the total operating cost of generating units while satisfying system equality and inequality constraints. For any specified load condition, ELD determines the power output of each plant (and each generating unit within the plant) which will minimize the overall cost of fuel needed to serve the system load. ELD is used in real-time energy management power system control by most programs to allocate the total generation among the available units. ELD focuses upon coordinating the production cost at all power plants operating on the system [1]. Economic Load Dispatch (ELD) is an important optimization problem to schedule the generation among generating units in power system. The main aim of ELD problem is to minimize the operation cost by satisfying the various operational constraints in order meet the load demand. Due to the nonlinear nature of modern generating unit's input-output characteristics and other constraints, the topic of ED problem is still becoming the main research interest in order to find for the better solution [2]. Economic load dispatch (ELD) is the online dispatch which is used for the distribution of load among the generating units. The cost of power generation, particularly in fossil fuel plants, is very high and ELD helps in economy a considerable amount of profits [3]. Non-conventional techniques are evolutionary programming [14][16], genetic algorithm [13], particle swarm optimization [15]is solving non-linear ELD problems. In this paper, Differential Evolution technique is discussed to solve the ED problem by considering the linear equality and inequality constraints for a 15 units system and the results were compared with GA. The algorithm described in this paper is capable of obtaining optimal solutions efficiently.

II. ECONOMIC LOAD DISPATCH - THERMAL STATIONS

Rapid growth in power system size and Electrical power demand, problem of reducing the operating cost has gained importance while maintaining voltage security and thermal limits of transmission line branches. A large number of mathematical programming and Artificial Intelligence Technique have been applied to solve (Economic Load Dispatch) ELD. In most general formulation, the ELD is a nonlinear, non-convex, large scale, static optimization

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problem with both continuous and discrete control variables. Mathematical programming approaches most general formulation, the ELD is a nonlinear, non-convex, large scale, static optimization problem with both continuous and discrete control variables [4].A power system is a mix of different type of generations, out of which thermal, hydro and nuclear power generations contribute the active share. However, economic operation has conveniently been considered by proper scheduling of thermal or hydrogenation only. As for the safety of nuclear station, these types of stations are required to run at its base loads only and there is a little scope for the schedule of nuclear plants in practice. Economy of operation is most significant in case of thermal stations, as the variable costs are much higher compared to other type of generations. This can be considered by looking at various costs of different stations.

Table 1: Various Costs of different Stations

Plant cost	Thermal power plants	Hydro power plants	Nuclear power plants
Fixed cost of plant	20 %	75 %	70 %
Fuel cost of plant	70 %	0 %	20 %
Other operational costs of plant	10 %	25 %	10 %

Obviously the cost of fuel form the major portion of all variable costs and the purpose of economic operation is to reduce the cost of fuel. This is a static optimization problem. This paper deals with the economic load dispatch of the thermal plants [5].

A. Economic Dispatch
The objective of economic load dispatch of electric power generation is to schedule the committed generating unit outputs so as to meet the load demand at minimum operating cost while satisfying all units and operational constraints of the power system[6]. The economic dispatch problem is a constrained optimization problem and it can be mathematically expressed as follows:

$$\textit{Minimize } F_T = \sum_{n=1}^{n} F_n(P_n) \dots\dots\dots\dots.(1)$$

Where, FT: total generation cost (Rs/hr) n: number of generators Pn : real power generation of nth generator (MW) Fn(Pn) : generation cost for Pn Subject to a number of power systems network equality and inequality constraints. These constraints include:

B. System Active Power Balance For power balance, an equality constraint should be satisfied. The total power generated should be the same as total load demand plus the total line losses

$$P_D + P_L - \sum_{n=1}^{n} P_n = 0 \dots\dots.(2)$$

Where, PD: total system demand (MW) PL: transmission loss of the system (MW)
C. Generation Limits Generation output of each generator should be laid between maximum and minimum limits. The corresponding inequality constraints for each generator are (2.3) Where, Pn, min: minimum power output

$$P_{n,min} \le P_n \le P_{n,max}$$

Where, Pn, min: minimum power output limit of nth generator (MW) Pn,max : maximum power output limit of nth generator (MW) The generation cost function Fn(Pn) is usually expressed as a quadratic polynomial:

$$F_n(P_n) = a_n P_n^2 + b_n P_n + c_n \dots\dots\dots(3)$$

Where, an, bn and cn are fuel cost coefficients.

III. PROPOSED DIFFERENTIAL EVOLUTION ALGORITHM

Differential Evolution is one of the most recent population based stochastic evolutionary optimization techniques. Storn and Price first proposed DE in 1995.DE is used for multidimensional real-valued functions and does not require

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derivatives of the objective function as in classical optimization method. The DE can be used in optimization problems where the objective function is stochastic, non-continuous, noisy, difficult to differentiate, change over time. The candidate solutions in DE are referred as agents. These agents are moved around in solution space to combine the position of existing agents from the population. If the new position of an agent is enrichment, then it is accepted and becomes the part of the population otherwise the new position is rejected [7][8]. In DE algorithm, solutions are represented as chromosomes based on floating-point numbers. In the mutation process of this algorithm, the weighted difference between two randomly selected population members are added to a third member to generate a mutated solution followed by a crossover operator to combine the mutated solution with the target solution so as to generate a trial solution. Then a selection operator is applied to compare the fitness function value of both competing solutions, namely, target and trial solutions to determine who can survive for the next generation. The basic DE algorithm consists of four steps, namely, initialization of population, mutation, crossover and selection [9][10]. Also, it has three control parameter, namely, population size (Np), scaling coefficient (F), and crossover probability (CR).

IV.CONTROL PARAMETER OF DIFFERENTIAL EVOLUTION ALGORITHM

Proper selection of control parameters is very important for algorithm performance and success. The control parameters are problem specific. Therefore, the set of control parameters have to be chosen carefully. Parameter tuning is the most common method to select control parameters. Parameter tuning adjusts the control parameters through testing until the best settings are determined. Typically, the following ranges are good initial estimates: F = [0.5, 0.6], CR = [0.75, 0.90], and NP = [3*D, 8*D]. In order to avoid premature convergence, F or NP should be increased, or CR should be decreased. Larger values of F result in larger perturbations and better probabilities to escape from local optima, while lower CR preserves more diversity in the population thus avoiding local optima.

(A) Population initialization: (B) Mutation (C) Crossover (D) Selection operate

(A) INITIALIZATION OF DIFFERENTIAL EVOLUTION

At the early stage of DE search, i.e. t = 0 the problem independent variables are initialized somewhere in their feasible numerical range. Therefore, if the jth variable has its lower and upper bounds as x_j^L and x_j^U, respectively, then the jth component of the ith population member may be initialized as: The basic strategy employs the difference of two randomly selected parameter vectors as the source of random variations for a third parameter vector. It can be presented:-

$$P = [Y_1^{(G)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . Y_{NP}^{(G)}] \quad (4)$$

$$Y_i^{(G)} = [X_{1i}^{(G)}, X_{2i}^{(G)} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . Y_{Di}^{(G)}] \quad (5)$$

Where i = 1,2, ……………Np

$$X_{ij\,(0)} = x_j^L + rand(0,1), (x_j^u - x_j^l) \quad (6)$$

Where rand (0, 1) is a uniformly distributed random number between 0 and 1.

(B) MUTATION OF DIFFERENTIAL EVOLUTION

In each generation, a donor vector Vi(t) is created in order to change the population member vector Xi(t). Generally, the method of creating this donor vector demarcates between various DE schemes.

In this mutation strategy, creation of the donor vector, Vi(t) for the ith member Xi passes through the following steps:

1 Three different members Xr1, Xr2, and Xr3, are chosen randomly from the current population and not coinciding with the current member Xi.

1. Next, a scalar number F scales the difference between any two of the chosen members and this scaled difference is added to the third one. Therefore, the jth component of Vi(t) can be expressed as,

$v_{i,j}(t+1) = x_{r1,j}\ (t) + F(x_{r2j}(t) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots x_{r3j}(t))$

This creates the donor vector Vi (t) . Typical value of F is in the range of 0.4-1.0

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Vol. 4, Issue 12, December 2015

(C) CROSSOVER OF DIFFERENTIAL EVOLUTION

To increase the diversity of the population, crossover operation is carried out in which the donor vector exchanges its components with those of the current member Xi(t). Two types of crossover schemes can be used by DE algorithm. These are exponential crossover and binomial crossover. Among these two the binomial variant is much more used in recent applications. Recombination is employed to generate a trial vector by replacing certain parameters of the target vector with the corresponding parameters of a randomly generated donor vector. This is similar to a process known as crossover in Gas and ESs.

(D) SELECTION OF DIFFERENTIAL EVOLUTION

To keep the population size constant over subsequent generations, the selection process is carried out to determine which one of the child and the parent will survive in the next generation , i.e. at time t = t+1. DE actually involves the survival of the fittest principle in its selection process.
The selection process can be expressed as:-

$$x_i(t+1) = \{ U_i\ (t)\ if\ \ f\ (\ U_i(t))\ \le f(x_i\ (t))\ \} \qquad (7)$$
$$\{ x_i\ (t)\ if\ \ f\ (\ x_i(t))\ < f(U\ (t))\ \} \qquad (8)$$

Where f (U(t)) is the function to be minimized. So, if the child yields a better value of the fitness function, it replaces its parent in the next generation; otherwise, the parent is retained in the population. Hence, the population either gets better in terms of the fitness function or remains constant but never deteriorates.

V. RESULT AND DISCUSSION

The 15-generating test system has been taken from [11].The proposed Differential Evolution Algorithm has been implemented successfully to solve the economic load dispatch problem of 15 units. In this paper case studies of effect of different population and compare different optimization technique.

Test Case (A) Population Size based solution

In this test case effect of population size 10, 30.50,70 and 100 in different parameter and used power demand 2630 MW and 2650.There are best trails results minimum cost, mean cost, maximum cost and standard deviation is shown in figure 1 (pop 10), figure 2 (pop 30), figure 3 (pop 50), figure 4 (pop 70), figure 5 (pop 100),table 2 and figure 6 (pop 10), figure 7 (pop 30), figure 8 (pop 50), figure 9 (pop 70), figure 10 (pop 100) & table 3.Proposed Differential Evolution Algorithm achieved quite effective result, It's clear that Pop size increase so system cost and standard deviation of the of the system decreased.

Table 2 Result of different population size on 15 unit systems (2630)

Population	Minimum Cost	Mean Cost	Maximum Cost	SD
10 Population	3.256.9e+004	3.4016e+004	4.2178e+004	1127.812
30 Population	3.2520e+004	3.3015e+004	3.3927e+004	683.7184
50 Population	3.2460e+004	3.2912e+004	3.3364e+004	307.6190
70 Population	3.2269e+004	3.2824e+004	3.3370e+004	183.2916
100 Population	3.2263e+004	3.2772e+004	3.3237e+004	116.6825

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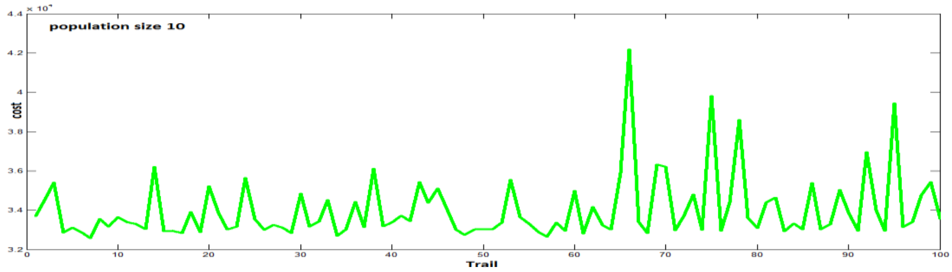

Figure 1 Population size 10 out of 100 trials (PD=2630MW)

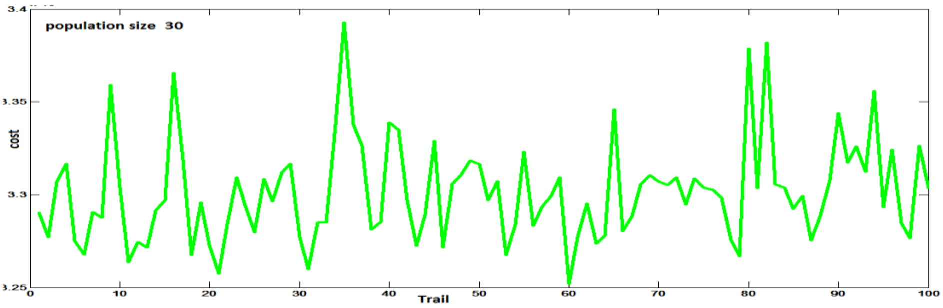

Figure 2 Population size 30 out of 100 trials (PD=2630MW)

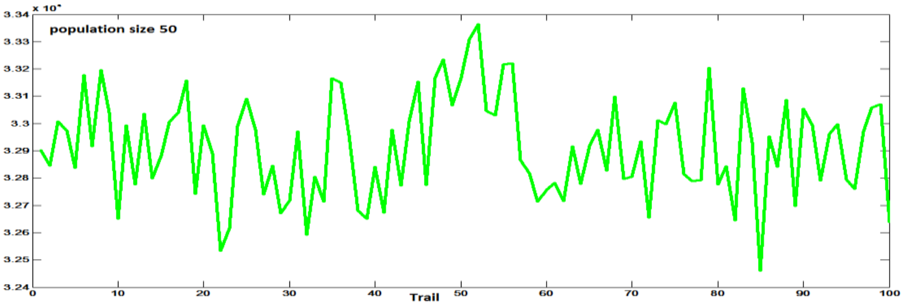

Figure 3 Population size 50 out of 100 trials (PD=2630MW)

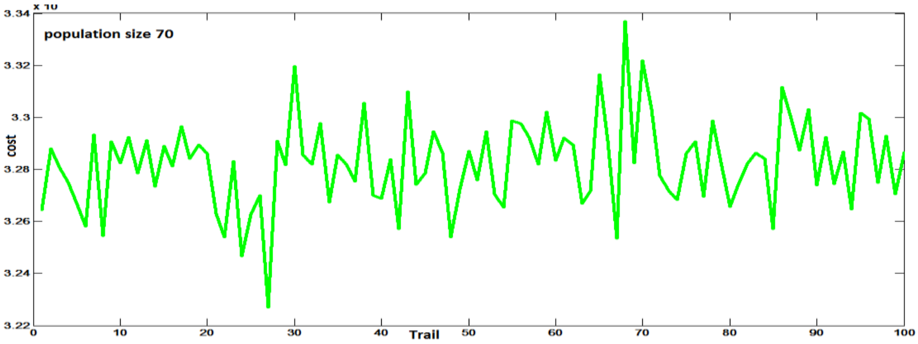

Figure 4 Population size 70 out of 100 trials (PD=2630MW)

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Vol. 4, Issue 12, December 2015

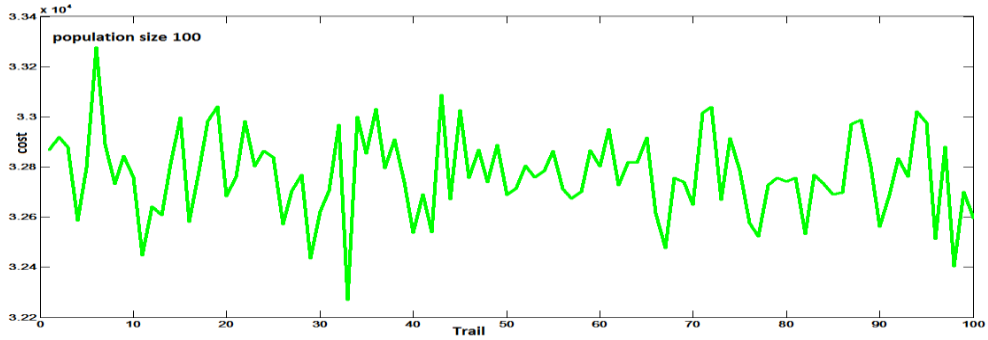

Figure 5 Population size 100 out of 100 trials (PD=2630MW)

Table 3 Result of different population size on 15 unit systems (PD=2650)

Population	Minimum Cost	Mean Cost	Maximum Cost	SD
10 Population	3.2796e+004	3.4221e+004	4.0954e+004	1149.5
30 Population	3.2728e+004	3.3206e+004	3.5500e+004	679.2795
50 Population	3.2708e+004	3.3116e+004	3.3791e+004	380.6569
70 Population	3.2700e+004	3.3061e+004	3.3700e+004	195.1419
100 Population	3.2566e+004	3.2970e+004	3.3429e+004	125.1444

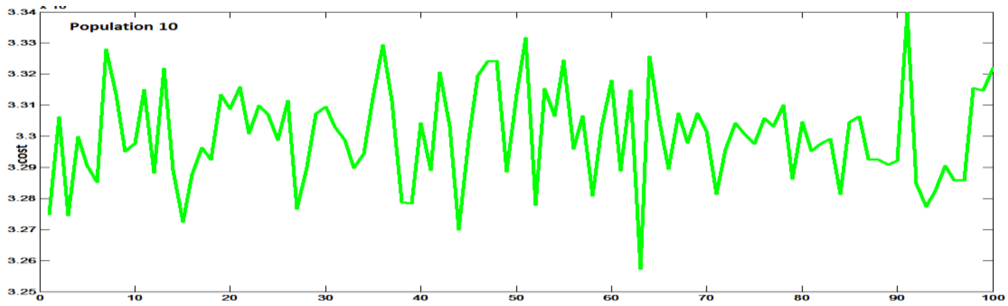

Figure 6 Population size 10 out of 100 trials (PD=2650MW)

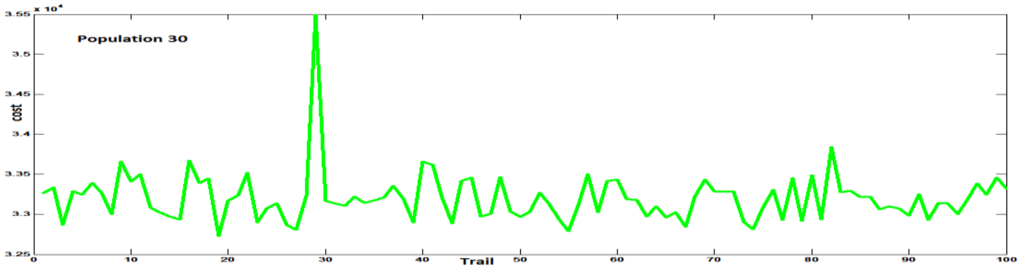

Figure 7 Population size 30 out of 100 trials (PD=2650MW)

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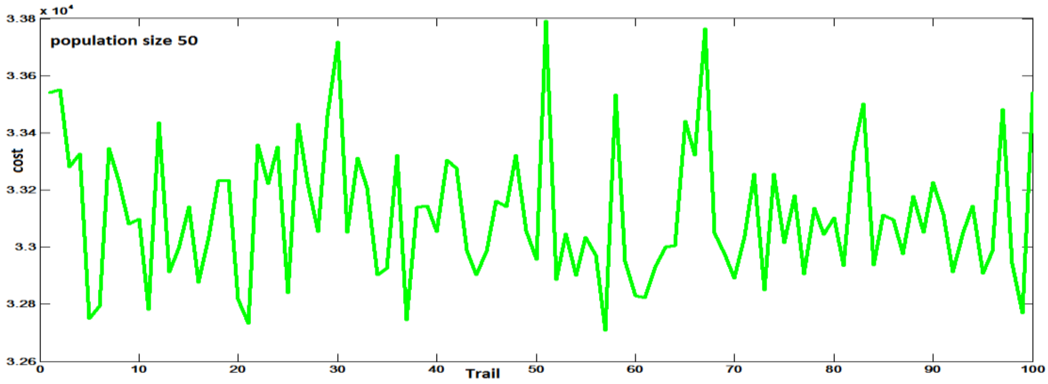

Figure 8 Population size 50 out of 100 trials (PD=2650MW)

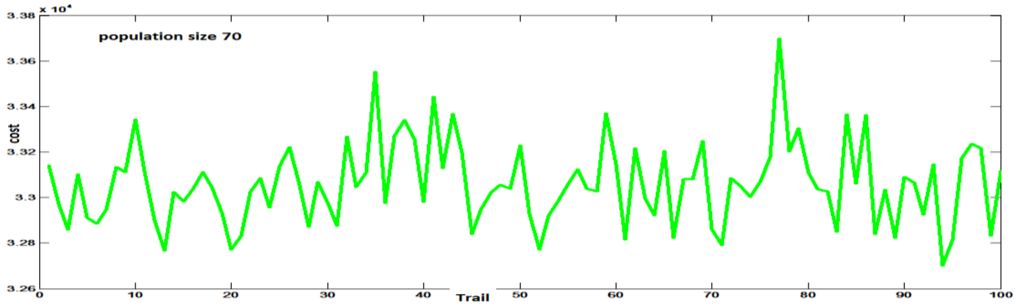

Figure 9 Population size 70 out of 100 trials (PD=2650MW)

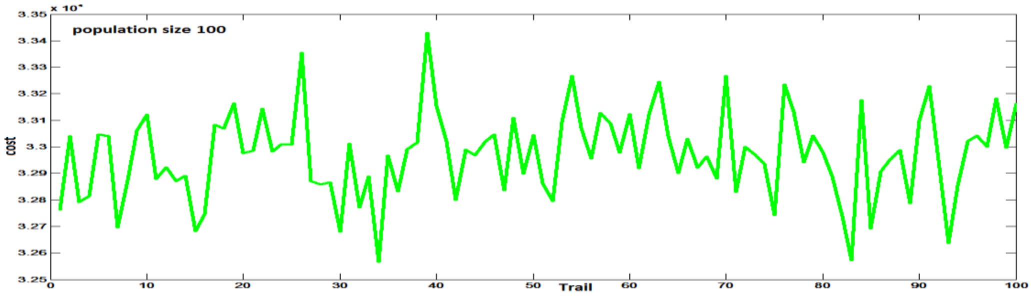

Figure 10 Population size 100 out of 100 trials (PD=2650MW

Test case (B): Comparers of 15- unit system between Genetic algorithm and Proposed Differential Evolution Algorithm

Proposed Differential Evolution Algorithm achieved quite effective result. A parameter tuning was done to find optimal values of F 0.9 & C 0.9, NP 1000 and number of Iteration used 1000 for 15 unit ELD problem, Results obtained from Proposed Differential Evolution Algorithm have been compared with Genetic algorithm [11]. Comparison the best results of GA and DE are shown in Table 4 and fig 11 & fig 12. The proposed DE algorithm provided better results compared to GA evolutionary techniques.

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International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

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Table 4 Comparison Genetic algorithm and Proposed Differential Evolution Algorithm

GENERATION `MW	PD=2630 MW	PD=2650 MW	PD=2630 MW	PD=2650 MW
	GA	GA	DE	DE
PG1	415.31	452.4	415.835089	442.189348
PG2	359.72	455	415.981556	256.426834
PG3	104.42	130.963	129.970223	120.000000
PG4	74.98	129.1	130.000000	125.000000
PG5	380.28	337.1	209.722250	187.480724
PG6	426.79	428.5	450.914159	481.037504
PG7	341.31	466.4	447.831304	400.000000
PG8	124.78	60	230.000000	260.000000
PG9	133.14	27.6	45.000000	25.000000
PG10	89.25	27.1	20.018658	140.000000
PG11	60.5	25.7	26.203213	53.194286
PG12	49.99	54	43.495679	49.247280
PG13	38.77	25	25.000000	50.000000
PG14	41.94	15	25.026455	15.000000
PG15	22.64	15	15.000000	45.000000
Minimum Fuel Cost ($/Hr)	**32517 ($/Hr)**	**33113 ($/Hr)**	**32206 ($/Hr)**	**32432 ($/Hr)**

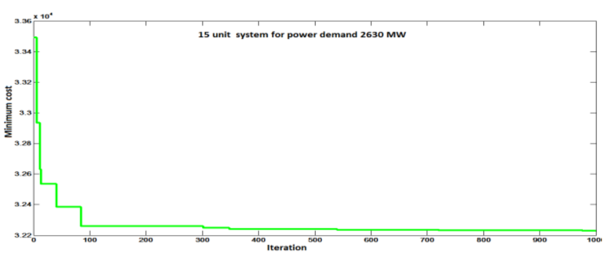

Figure 11 Convergence characteristics of 15 unit (PD=2630 MW)

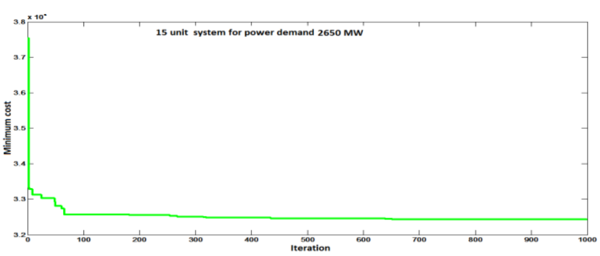

Figure 12 Convergence characteristics of 15 unit (PD=2650 MW)

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 4, Issue 12, December 2015

VI. CONCLUSION

In this paper, authors have successfully introduced Differential Evolution optimization algorithm to solve power system Economic load dispatch problem and compared its results to those of other well established algorithms. It is observed that the Proposed Differential Evolution Algorithm exhibits a comparative performance with respect to other population based techniques. It clearly shows that the figure 11 and figure 12 Differential Evolution optimization algorithms is converging to a better quality near-optimal solution, better computation time and more stable characteristics convergence.

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BIOGRAPHY

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