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## Evolutionary Programming Techniques for Solving Non-Convex Economic Load Dispatch Problem with Valve-Point Loading Effect

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Abstract: This paper presents three heuristic optimization techniques algorithms like Particle Swarm Optimization (PSO), Teaching-learning Based Optimization (TLBO) and Differential evolution (DE) for solving economic load dispatch (ELD) problem with non-convex/linear fuel cost curves by considering power balance condition, capacity constraints, and valve-point loading effect. These algorithms are used for finding the optimal solution with minimum fuel cost. In this paper, a methodology is used for solving the economic load dispatch that is a combinational unit of three different test systems cases such as 16, 43, and 56 generating units respectively. The three algorithms are presented and described in detailed in this paper. The optimization has been done considering total fuel cost as the fitness function. The results of the Evolutionary programming techniques were compared in terms of fuel cost. The convergence characteristics for all the cases are analyzed and presented in this paper.

Keywords: Economic Load Dispatch (ELD), Particle Swamp Optimization (PSO), Teaching-Learning Based Optimization (TLBO), and Differential evolution (DE)

I.

#### INTRODUCTION

Economic load dispatch (ELD) problem is one of the basic issues in power system operation due to the improvement of the social and industrial sector. So now a day the electrical power market becomes more competitive. Generally, there are so many sources to generate electric power such as thermal power plant, hydroelectric power plant, nuclear power plant, and renewable energy sources. Thermal power plant takes the main role to satisfy the peak load demand. In the case of thermal power plant the generation cost dependents on the fuel cost. In order to overcome the all those problems, the optimal power generation is required which minimize the fuel cost [1]. The primary objective of the ELD is to minimize the total fuel cost of generation while satisfying the operational constraints. In the traditional ELD problem, the cost function for each generator has been presented by a quadratic function and solved using mathematical programming based optimization techniques such as lambda iteration method [2]. base point and participation and gradient-based method, dynamic programming methods. But in reality the input-output characteristics of modern generators non-linear and highly constraints because of valve point effect, generating unit ramp rate limits and prohibited zones[3-6]. To overcome all limitation of the traditional methods recently, heuristic optimization techniques are used such as genetic algorithm (GA), evolutionary programming (EP), particle swarm optimization (PSO), [7] differential evolution (DE), [8] simulated annealing (SA), ant colony optimization (ACO) and artifical bee colony (ABC), Teaching-Learning Based Optimization[9] (TLBO), and Differential evolution (DE) have been employed to optimize the ELD problem for better global search abilities against numerical optimization methods[10].

In this paper, have presented the three bio-inspired algorithms such as Particle Swamp Optimization (PSO) Teaching-Learning Based Optimization (TLBO) and Differential evolution (DE) algorithms and to solve ELD problems for three different systems, one consisting of 16 generating units and the others consisting of 43, 56 test system which are generated from 3, 13, and 40 standard test systems respectively for a load demand.

#### II. PROBLEM FORMULATION

Generally, non-convex ELD problems should consider different operational constraints such as valve-point effects, prohibited zones, ramp rates and multi-fuel options, and power balance constraints. The following objective and constraints are taken into account in the formulation of the ELD problem.



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1) Objective function

The objective of ELD is to minimize the total fuel cost while satisfying all equality and inequality constraints. Generally, the objective function of ELD can be modeled as a quadratic, which can be represented as below equation.

$$Minimize F_T = \sum_{i=1}^{N} F_i(P_i)$$
(1)

Where  $F_i(p_i) = a_i P_i^2 + b_i P_i + c_i$  without valve point loading effect and

 $F_i(p_i) = a_i P_i^2 + b_i P_i + c_i + |e_i \sin(f_i * (P_i^{min} - p_i)|)$  With valve point loading effect Where

 $F_T$  = total cost fuel cost of power generation,

 $F_i$  =Fuel cost of  $i^{th}$  generator

 $P_i$  =power output of the  $i^{th}$  generator (MW)

 $a_{i}$ ,  $b_i$  and  $c_i$  Are fuel consumption cost coefficients of  $i^{th}$  generator

 $e_i$  and  $f_i$  are fuel cost coefficients of the  $i^{th}$  with valve point loading effect

N=number of generator

 $P_i^{min}$  = minimum power generation limit

The valve-point loading effects will make the cost function non-smooth and increase the number of local optima the fuel cost curve with and without valve-point loading effect which illustrates as in fig1. The minimization of the generation cost is subjected to the following equality and inequality constraints.

#### A. Equality constraint (power balance equation)

The total generated power should be equal to the sum of the total system demand and transmission loss. The system power balance equation is given a

$$\sum_{i=1}^{N} P_i = P_D + P_L \tag{2}$$

Where  $P_D$  = Total power demand (MW)

 $P_L$  = Transmission losses (MW)

In this paper, the transmission loss  $P_L$  of the network is neglected.

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#### B. Inequality Constraints (Generator Capacity Constraints)

The major considered inequality constraint is maximum and minimum limits for power generation. The generation power of each generator should lie between the maximum limit and minimum limit. That represents as below equation.

$$P_i^{min} \le P_i \le P_i^{max} \tag{3}$$

Where  $P_i^{min}$  and  $P_i^{max}$  are the minimum and maximum limits for power output of generator *i*.

#### III. METHODOLOGY

In this paper, we described three evolutionary algorithms method to solve nonlinear economic load dispatch (ELD) problem with valve-point loading effect. In this section, the basic function of algorithms and the concept behind the algorithms described in detail.

#### A. Particle Swarm Optimization (Pso)

PSO based operators are exploring the search space. In 1995, Kennedy and Eberhart first introduced the particle swarm optimization method, it is a population-based meta-heuristic that simulates the social behavior of organisms such as fish schooling and bird flocking. PSO, as an optimization tool, provides a population-based search procedure in which individuals called particles to change their positions with time. In a PSO system, particles fly around in a multi-dimensional search space. During the process, each particle adjusts its position according to its own experience, and the experience of neighboring particles, making use of the best position encountered by itself and its neighbors. The swarm direction of a particle is defined by the set of particles neighboring the particle and its historical experience. To get the optimal solution, each particle adjusts their positions by using the following updating equations

$$V_{id}^{(t+1)} = w * V_{id}^{(t)} + C_1 * r_1 * \left(pbest_{id} - X_{id}^{(t)}\right) + C_2 * r_2 * \left(gbest_d - X_{id}^{(t)}\right)$$
(4)  
$$X_{id}^{(t+1)} = X_{id}^{(t)} + V_{id}^{(t+1)}$$
(5)

Where  $C_1$ ,  $C_2$  are acceleration coefficients, w is inertia weight,  $r_1$  and  $r_2$  are random numbers in the range of [0,1].  $V_{id}^{(t)}$  And  $X_{id}^{(t)}$  denote the velocity and position of the particle in  $d^{th}$  dimension at  $t^{th}$  iteration.  $pbest_{id}$  is the value in dimension d of the best parameters combination(a particle) found so far by particle.  $pbest_{id} = \langle pbest_{1the}, \dots, pbest_d \rangle$  is called personal best.  $gbest_d$  is the value in dimension d of the best parameters combination (a particle) found so far by particle.  $pbest_{id} = \langle pbest_{1the}, \dots, pbest_d \rangle$  is called personal best.  $gbest_d$  is the value in dimension d of the best parameters combination (a particle) found so far in the swarm.  $gbest_d = \langle gbest_1, \dots, gbest_d \rangle$  is represented as the global best. In the search space, particles track the individual's best values and the best global values. The process is terminated if the number of iteration reaches the pre-determined maximum number of iteration.

#### B. Teaching-Learning Based Optimization (TLBO)

TLBO is based on the relationship between teacher and student in the class. It is a population-based method and it uses a population of solutions to get the global solution. In any optimization algorithm, there are numbers of different design variables. In TLBO design variables are subjects offered to learners and result of learners as considered as the fitness of the population. The algorithm contains two parts they are teacher phase and learner phase. Teacher phase means learning from the teacher and learner phase means learning through the interaction between learners in a class. Implementation of TLBO described below.

1) *Teacher phase:* The teacher tries to improve the mean performance of the class to some extent depending on the capability of the learners. The teacher influences the performance of each student in a random manner for each subject. The best solution in each iteration will be chosen as the teacher  $X_{teacher}$ . Teacher phase can be represented as followed for  $i^{th}$  iteration

$$X_{id}^{(t+1)} = X_{id}^{(t)} + rand() * (X_{teacher} - T_F * M_g)$$
(6)

Where  $X_{id}^{(t+1)}$  is the new population and  $X_{id}^{(t)}$  old population.  $X_{teacher}$  is the teacher (best solution), rand () is random number in between 0 and 1.  $T_F$  is teaching factor which shouthe ld be either 1 or 2, that is selected randomly. The mean parameter of each subject in the class at each generation g is given as



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$$M_g = \begin{bmatrix} m_{1g}, m_{2g}, \dots, m_{dg} \end{bmatrix} \tag{7}$$

The  $X_{id}^{(t+1)}$  is found to be better than  $X_{id}^{(t)}$  in  $i^{th}$  generation than it replace on  $X_{id}^{(t)}$  otherwise, it remains the same.

2) Learner Phase: A learner gain knowledge from interaction with some other randomly selected learners, with the help of group discussion, presentation, or some formal communication. Any learner learns from any other learner having better knowledge than him which helps the learner to improve his level of knowledge. For a learner $X_{id}^{(t)}$ , randomly select another learner $X_{rd}^{(t)}$  as

$$i \neq r$$
. The learner phase can be formulated for  $i^{th}$  iteration as followed

$$X_{id}^{(t+1)} = X_{id}^{(t)} + rand() * (X_i^{(t)} - X_r^{(t)}) \quad \text{if } f(X_i^{(t)}) < f(X_r^{(t)})$$

$$X_{id}^{(t+1)} = X_{id}^{(t)} + rand() * (X_r^{(t)} - X_i^{(t)}) \quad \text{if } f(X_i^{(t)}) > f(X_r^{(t)})$$
(8)
(9)

Where rand () denotes a random number in between 0 and 1. The termination condition of algorithm obtained when MAXIT iteration is completed, then the algorithm is stopped, otherwise, repeat from 'Teacher Phase'.

#### C. Differential evolution

The Differential evolution (DE) is a stochastic population-based algorithm that was used for searching the optimum solution of ELD problems. The advantages of DE are simplicity, efficiency, and use of real coding. It starts to explore the search space by randomly choosing the initial candidate solutions within the boundary. Generally, the initialization is performed randomly within constraint boundaries. After initialization DE has three stages to solve the economic load dispatch (ELD) problem such as mutation, crossover, and selection

 Mutation: In mutation each generation and for each individual a donor member using an operator and a donor member is generated by adding a weighted difference of another member. There are several operational strategies for mutation. Commonly used Mutation strategy represented as below

$$V_i^{t+1} = X_{best}^t + F(X_{r1}^t - X_{r2}^t)$$
(10)  
$$i = 1, 2, 3..., N_p$$

Where  $X_{best}^t$  is best among current population vector and r is random numbea r in between 0 to n. F is scaling factor or of mutation vector,  $N_p$  is the population size.

2) *Crossover:* In crossover stage each member of the population is enabled crossover by mating with donor vector to generate a set of trial vector which is calculated equation (11)

$$U_{i,j}^{t+1} = \begin{cases} V_{i,j}^{t+1}, if \, rand(0,1) \le C_r \\ X_{i,j}^{t+1}, otherwise \end{cases}$$
(11)

Where  $C_r$  is user supplied crossover rate constant  $k \in \{1, 2, ..., N\}$ 

3) Selection: The fitness of each individual is calculated and best fitness value is considered to the next generation to get a best the trial vector  $(X_i^{t+1})$  which is represented as equation (12). The value of the cost function in the point  $u_i^G$  using the below conditions and based on below condition new population solution selected for next generation.

$$X_{i}^{t+1} = \begin{cases} u_{i}^{t} f(u_{i}^{G}) \leq f(X_{i}^{t}) \\ X_{i}^{t} f(u_{i}^{G}) > f(X_{i}^{t}) \end{cases}$$
(12)

This evolutionary process consisting of the mutation, crossover and selection stages is repeated over several iterations until getting the optimal solution.



### D. Parameters Of Algorithms

The performance of the algorithm depends on the control parameters of algorithms. In this algorithms list of control parameters with approximate values listed in below table

Table1 parameters			
Particle Swamp Optimization (PSO), and	$C_1 = 1, C_2 = 1$ ,number of		
	population=30,maximum number of		
	iterations=150		
Teaching-Learning Based Optimization	TF=0.5, number of population=30, maximum		
(TLBO),	number of iterations=150		
Differential evolution (DE)	F=0.9,CR=0.75, number of population=30,		
	maximum number of iterations=150		

#### IV. ALGORITHM STEPS FOR ANALYSIS OF ECONOMIC LOAD DISPATCH (ELD)

In this paper, the three algorithms are applied for solving the nonlinear economic dispatch problem to get optimal power generation. The main steps to calculate the search procedure explained in detailed (consider DE algorithm)

- 1) Step 1: Specify the number of generator units (N), and the generator cost coefficients  $(a_i, b_i, and c_i)$  and valve-point coefficient  $(e_i, and f_i)$ , capacity constraints of all generators  $[P_i^{min}, P_i^{max}]$  and load demand  $P_D$ . Initialize parameters
- 2) Step 2: An initial population of X is created randomly in N-dimensional search space (number of generating units) which can be denoted as

$$X = \begin{bmatrix} X_1 \\ X_2 \\ \vdots \\ X_p \end{bmatrix} = \begin{bmatrix} \begin{pmatrix} x_{1,1} & \cdots & x_{N,1} \\ \vdots & \ddots & \vdots \\ x_{p,1} & \cdots & x_{N,P} \end{bmatrix}$$
(13)

where *i* is represented by N decision variables, such as  $X_i = x_{i,1}x_{i,2} \dots x_{i,N}$ . The decision variables for the ED problems are real power generations, so they are used to represent each element of a given population of individual solutions. The equality constraint of generators must be satisfied by the population matrix. The matrix is initialized randomly within the real power operating limits as

$$X_{i,j} = X_{min,N} + rand() * (X_{max,N} - X_{min,N})$$
(14)

Where  $X_{i,j}$  is the power output i.e.,  $j^{th}$  population  $i^{th}$  generation unit and rand () is a random number between 0 and 1. Each in dividual must be a feasible population solution that satisfies the inequality constraint. Each individual frog undergoes equality constraint handling procedure before evolution.

3) Step 3: power balance violations are eliminated by adding a penalty term in their Fitness function. The fitness function f(X) calculated using equation (15)

$$f(X) = \frac{1}{\mu \left| \sum_{i=1}^{N} (P_i - P_D) \right| + F_T}$$
(15)

Where  $\mu$  is the penalty factor.  $F_T$  is the objective of the economic load dispatch (ELD) which is calculated using equation (1)

- 4) *Step4:* Set ITER = 0 (iteration counter)
- 5) Step 5: Increment the iteration counter i.e., ITER=ITER+1;
- 6) Step 6: Apply the evolution steps of DE, such as mutation, crossover, and selection this is calculated using equations (10) (11) and (12) and new population solution is obtained.
- 7) Step 8: If the maximum number of iterations is not reached, i.e., if,  $ITER \ge SI$  go to the steps 5.
- 8) Step 9: Print the best solution and stop.

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#### V. SIMULATION RESULTS AND ANALYSIS

In this paper we use three cases of the combinational test system of three; thirteen and forty have been analyzed, to find the optimal solution with lowest fuel cost with valve-point loading effect. Each case is analysis with three algorithms and results are compared to each other.

#### A. Case 1: System Consisting Of 16 Thermal Generating Units

In this case, sixteen thermal units with the quadratic cost function are generated by combining three and thirteen unit test system. The expected load demand to meet by all generation units is 2650MW. The system data can be found in the appendix in below which is taken from the [11]. The optimal solution for this test system is reported as 26,302.89 \$/hr. The dispatch results are compared with PSO, TLBO, and DE which is listed in table1 below and cost convergence characteristics is as shown fig2

1 d0102	TO-Onit test system outpe	it values with valve plit load	ng	
POWER	PSO	TLBO	DE	
GENERATION(MW)				
$P_{g1}$	292.180	598.79	119.04	
$P_{g2}$	100.535	500.00	50.000	
$P_{g3}$	337.208	100.00	100.00	
$P_{g4}$	452.381	361.20	527.47	
P <sub>g5</sub>	128.809	360.00	260.84	
$P_{g6}$	301.591	360.00 360.00		
P <sub>g7</sub>	89.7640	60.000	124.01	
$P_{g8}$	134.119	60.000	159.94	
$P_{g9}$	127.841	60.000	161.45	
P <sub>g10</sub>	121.592	60.000	150.89	
P <sub>g11</sub>	118.411	60.000	163.15	
P <sub>g12</sub>	137.451	60.000	147.94	
P <sub>g13</sub>	56.5756	40.000	89.730	
P <sub>g14</sub>	66.2286	40.000	42.720	
P <sub>g15</sub>	89.5046	55.000	95.760	
P <sub>g16</sub>	95.7391	55.000	97.000	
Power demand(MW)	2650	2650	2650	
Total fuel cost (Rs/hr)	26,290.156	26,547.9416	27,065.5482	

Table2 16-Unit test system output values with valve pint loading

#### B. Case 2: System Consisting Of 43 Thermal Generating Units

In this case, forty-three units with the quadratic cost function are generated by combining three and forty unit test system. The expected load demand to meet by all generation units is 11350MW. The system data can be found in the appendix in below which is taken from [11]. The optimal solution for this test system is reported as 1,38,730.7919 \$/hr. The dispatch results are compared with PSO, TLBO, and DE which is listed in table 3 below and cost convergence characteristics is as shown fig3







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#### C. Case 2: System Consisting Of 43 Thermal Generating Units

In this case, forty-three units with the quadratic cost function are generated by combining three and forty unit test system. The expected load demand to meet by all generation units is 11350MW. The system data can be found in the appendix in below which is taken from [11]. The optimal solution for this test system is reported as 1,38,730.7919 \$/hr. The dispatch results are compared with PSO, TLBO, and DE which is listed in table 3 below and cost convergence characteristics is as shown fig3

POWER GENERATION(MW)	PSO	TLBO DE		
P <sub>g1</sub>	600.000	600.000 600.000		
P <sub>g2</sub>	75.2613	99.1790	200.000	
P <sub>g3</sub>	400.000	400.000	400.000	
P <sub>g4</sub>	84.8213	144.000	114.000	
P <sub>g5</sub>	114.000	114.000 144.000		
P <sub>g6</sub>	61.5507	120.000	120.000	
P <sub>g7</sub>	80.2448	190.000	190.000	
$P_{g8}$	79.3870	97.000	97.0000	
P <sub>g9</sub>	69.8664	140.000	140.000	
$P_{g10}$	300.000	144.159	300.000	
$P_{g11}$	210.081	139.919	300.000	
$P_{g12}$	300.000	149.919	300.000	
P <sub>g13</sub>	300.000	259.438	300.000	
$P_{g14}$	248.979	98.9419	110.016	
P <sub>g15</sub>	164.166	375.000	265.712	
$P_{g16}$	287.009	500.000	128.500	
$P_{g17}$	349.952	500.000	130.139	
P <sub>g18</sub>	375.184	500.000	131.245	
P <sub>g19</sub>	500.000	494.182	137.374	
P <sub>g20</sub>	500.000	477.670	130.139	
P <sub>g21</sub>	500.000	477.670	500.000	
P <sub>g22</sub>	539.310	550.000	500.000	
P <sub>g23</sub>	442.851	527.2588	550.000	
P <sub>g24</sub>	426.675	453.8577	467.9039	
P <sub>g25</sub>	55.000	258.9199	259.1394	
P <sub>g26</sub>	543.015	258.9199	550.0000	
P <sub>g27</sub>	55.000	258.9199	550.0000	
$P_{g28}$	55.000	519.7911	550.0000	
P <sub>g29</sub>	357.631 534.8905		550.0000	
$P_{g30}$	16.5256	5256 16.22255 550		
$P_{g31}$	10.5765	14.91999	26.05000	
$P_{g32}$	10.1186	45.16000	21.06900	
P <sub>g33</sub> 48.1708		97.0000	30.94750	
P <sub>g34</sub> 190.000		190.000	97.00000	
$P_{g35}$	186.158	163.8433	190.0000	
$P_{g36}$	60.5331	67.1178	190.0000	
$P_{g37}$	91.8540	200.000	190.0000	
$P_{g38}$	151.522	200.000	200.0000	
$P_{g39}$	175.858	200.000	200.0000	
$P_{g40}$	110.000	32.1178	200.0000	
$P_{g41}$	96.6910	110.000	110.0000	
$P_{g42}$	110.000	110.000	110.0000	
$P_{g43}$	550.000	550.000	550.0000	
POWER DEMAND (MW)	11350.00	11350.00	11350.00	
COST (Rs/Hr)	138730.79	144389.0381	136573.0503	

Table3 43-Unit test system output values with valve pint loading





Fig3 Cost convergence characteristics of 43 Unit test system

#### D. Case 3: System Consisting Of 56 Thermal Generating Units

In this case, fifty-six three units with the quadratic cost function are generated by combining three, thirteen and forty unit test system The expected load demand to meet by all generation units is 11350MW. The system data can be found in the appendix in below which is taken from[11]. The optimal solution for this test system is reported as 1,52,033.60677 \$/hr. The dispatch results are compared with PSO, TLBO, and DE which is listed in table4 below and cost convergence characteristics is as shown fig4

Table4 56-Unit test system output values with valve pint loading

Table4 50-Onit lest system output values with valve phit loading							
UNIT	PSO	TLBO	DE				
P <sub>g1</sub>	370.7682	600.0000	600.0000				
P <sub>g2</sub>	94.3090	102.8526	200.0000				
P <sub>g3</sub>	400.0000	398.6841	400.0000				
P <sub>g4</sub>	680.0000	665.4527	680.0000				
P <sub>g5</sub>	360.0000	360.0000	360.0000				
P <sub>g6</sub>	360.0000	360.0000	360.0000				
P <sub>g7</sub>	180.0000	180.0000	180.0000				
$P_{g8}$	80.6973	180.0000	180.0000				
P <sub>g9</sub>	61.7646	180.0000	180.0000				
P <sub>g10</sub>	180.0000	180.0000	180.0000				
P <sub>g11</sub>	60.0000	180.0000	180.0000				
P <sub>g12</sub>	140.4116	180.0000	180.0000				
P <sub>g13</sub>	130.9342	120.0000	120.0000				
$P_{g14}$	73.7083	120.0000	106.5500				
$P_{g15}$	86.0890	120.0000	120.0000				
P <sub>g16</sub>	55.0000	120.0000	91.0940				
$P_{g17}$	36.0000	114.0000	114.0000				
$P_{g18}$	36.0000	114.0000	98.0909				
$P_{g19}$	60.0000	120.0000	120.0000				
$P_{g20}$	166.8223	190.0000	174.2069				
P <sub>g21</sub>	57.3665	97.000	60.0000				
P <sub>g22</sub>	103.1561	140.0000	140.000				
P <sub>g23</sub>	246.7134	257.5224	212.1483				
P <sub>g24</sub>	285.6071	209.9285	294.0311				
P <sub>g25</sub>	300.0000	273.4410	300.0000				



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P <sub>g26</sub>	294.5018	263.6534	212.0322	
P <sub>g27</sub>	375.0000 94.9484		130.5631	
P <sub>g28</sub>	333.7189	97.3848	97.2834	
P <sub>g29</sub>	142.5782	131.6347	145.4148	
$P_{g30}$	500.0000	149.3549	128.0568	
$P_{g31}$	356.7579	222.5020	194.1654	
P <sub>g32</sub>	205.4976	253.4946	142.9923	
P <sub>g33</sub>	409.8413	461.0768	494.5036	
$P_{g34}$	293.5827	432.5063	500.0000	
P <sub>g35</sub>	542.8281	424.5633	500.0000	
P <sub>g36</sub>	468.1670	540.1180	452.5749	
P <sub>g37</sub>	495.8552	442.1932	257.2834	
P <sub>g38</sub>	411.0000	261.9778	257.2834	
P <sub>g39</sub>	546.1186	496.1674	550.0000	
P <sub>g40</sub>	550.0000	421.2119	550.0000	
P <sub>g41</sub>	550.0000	466.1607	550.0000	
P <sub>g42</sub>	550.0000	465.3966	361.6186	
P <sub>g43</sub>	21.6468	34.5292	13.2834	
$P_{g44}$	10.0000	32.8170	13.2834	
$P_{g45}$	10.0000	10.9484	31.8487	
P <sub>g46</sub>	47.0000	97.0000	97.0000	
P <sub>g47</sub>	190.000	190.0000	190.000	
$P_{g48}$	141.9280	190.0000	169.6512	
P <sub>g49</sub>	81.4377	190.0000	187.0850	
P <sub>g50</sub>	142.1179	200.0000	200.0000	
P <sub>g51</sub>	186.0013	200.0000	200.0000	
P <sub>g52</sub>	138.9260	200.0000	145.4258	
P <sub>g53</sub>	41.8278	110.0000	105.5019	
P <sub>g54</sub>	67.9885	110.0000	99.9214	
P <sub>g55</sub>	84.9826	110.0000	110.000	
P <sub>g56</sub>	382.3487	287.4788	382.9154	
POWER DEMAND (MW)	13150.000	13150.000	13150.000	
COST (Rs/Hr)	157711.3452	154193.6778	152033.60677	







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#### VI. CONCLUSION

In this paper economic load dispatched problem has been solved using three algorithms Particle Swarm optimization (PSO), Teaching-Learning Based Optimization (TLBO), Differential evolution (DE) The study has been done for three different combinational systems, one consists of 16 generating units, and the others consisting of 43 and 56, respective for different load demand. The performance analysis has been carried out when transmission losses have been neglected. In this paper we present, analysis using PSO, TLBO, and DE for economic load dispatch solution for all the three systems under consideration for different load demand has been obtained. The results three cases Generating units systems then compared with one other. So, by observing the result obtained using PSO, TLBO, and DE algorithms. DE gives better results compared to the remaining two algorithms. So, finally, it can be analyzed that applying PSO, TLBO, and DE to economic load dispatch solution optimal and reliable result are obtained.

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Generator 3 unit $P_{min}(MW)$ $P_{max}(MW)$ a         b           1         100         600         0.001562         7.92         5	c e f \$) (MW) 61 300 0.0315 78 150 0.063
3 unit         (\$/MW         (\$/MW)         ((           1         100         600         0.001562         7.92         5	\$) (MW) 61 300 0.0315 78 150 0.063
(\$/MW)         (\$/MW)         ((\$/1           1         100         600         0.001562         7.92         5	\$)         (MW)           61         300         0.0315           78         150         0.063
1 100 600 0.001562 7.92 5	61         300         0.0315           78         150         0.063
	78 150 0.063
2 50 200 0.004820 7.97 7	
3 100 400 0.001940 7.85 3	10 200 0.042
13 unit $P_{min}(MW)$ $P_{max}(MW)$ a b	c e f
4 00 680 0.00028 8.10 5	50 300 0.035
5 00 360 0.00056 8.10 3	09 200 0.042
6         00         360         0.00056         8.10         3	07 200 0.042
7 60 180 0.00324 7.74 2	40 150 0.063
8 60 180 0.00324 7.74 2	40 150 0.063
9 60 180 0.00324 7.74 2	40 150 0.063
10 60 180 0.00324 7.74 2	40 150 0.063
11 60 180 0.00324 7.74 2	40 150 0.063
12 60 180 0.00324 7.74 2	40 150 0.063
13 40 120 0.00284 8.6 1	26 100 0.084
14         40         120         0.00284         8.6         1	26 100 0.084
15 55 120 0.00284 8.6 1	26 100 0.084
16         55         120         0.00284         8.6         1	26 100 0.084
40 unit $P_{min}(MW)$ $P_{max}(MW)$ a b	c e f
17 36 114 0.00690 6.73 94.	705 100 0.084
18         36         114         0.00690         6.73         94.	705 100 0.084

APPENDIX



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19	60	120	0.02028	7.07	309.54	100	0.084
20	80	190	0.00942	8.18	369.03	150	0.063
21	47	97	0.0114	5.35	148.89	120	0.077
22	68	140	0.01142	8.05	222.33	100	0.084
23	110	300	0.0035.7	8.03	287.71	200	0.042
24	135	300	0.00492	6.99	391.98	200	0.042
25	135	300	0.00573	6.60	455.76	200	0.042
26	130	300	0.00605	12.9	722.82	200	0.042
27	94	375	0.00515	12.9	635.20	200	0.042
28	94	375	0.00569	12.8	654.69	200	0.042
29	125	500	0.00421	12.5	913.40	300	0.035
30	125	500	0.00752	8.84	1760.4	300	0.035
31	125	500	0.00708	9.15	1728.3	300	0.035
32	125	500	0.00708	9.15	1728.3	300	0.035
33	220	500	0.00313	7.97	647.85	300	0.035
34	220	500	0.00313	7.95	649.69	300	0.035
35	242	550	0.00313	7.97	647.83	300	0.035
36	242	550	0.00313	7.97	647.81	300	0.035
37	254	550	0.00298	6.63	785.96	300	0.035
38	254	550	0.00298	6.63	785.96	300	0.035
39	254	550	0.00284	6.66	794.53	300	0.035
40	254	550	0.00284	6.66	794.53	300	0.035
41	254	550	0.00277	7.10	801.32	300	0.035
42	254	550	0.00277	7.10	801.32	300	0.035
43	10	150	0.52124	3.33	1055.1	120	0.077
44	10	150	0.52124	3.33	1055.1	120	0.077
45	10	150	0.52124	3.33	1055.1	120	0.077
46	47	97	0.01140	5.35	148.89	120	0.077
47	60	190	0.00160	6.43	222.92	150	0.063
48	60	190	0.00160	6.43	222.92	150	0.063
49	60	190	0.00160	6.43	222.92	150	0.063
50	90	200	0.0001	8.95	107.87	200	0.042
51	90	200	0.0001	8.62	116.58	200	0.042
52	90	200	0.0001	8.62	116.58	200	0.042
53	25	110	0.0161	5.88	307.45	80	0.098
54	25	110	0.0161	5.88	307.45	80	0.098
55	25	110	0.0161	5.88	307.45	80	0.098
56	242	550	0.00313	7.97	647.83	300	0.035











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