iJRASET
International Journal For Research in Applied Science and Engineering Technology



# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

**Volume:** 5 **Issue:** XI **Month of publication:** November 2017

**DOI:**

www.ijraset.com

Call: 08813907089 | E-mail ID: ijraset@gmail.com

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
*ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor:6.887*
*Volume 5 Issue XI November 2017- Available at www.ijraset.com*

# Best Compromise Solution of Economic Emission Load Dispatch Using Ant Lion Optimization

Arjun Rathore[1], Nitish Chopra[2]
1,2Assistant Professor, SSIET Galgotia college of Engineering & Technology

***Abstract*: *This paper presents ant lion optimization method for solving multi-objective economic emission load dispatch (EELD) problem in diverse test power systems. NOX emission, power balance and generation limit constraints are considered here. Ant Lion Optimization (ALO) is a novel meta-heuristic motivated by hunting mechanism of ant lions in nature. The proposed technique is applied on different test systems having 3,6,10 and 40 generators have been considered for solving the EELD. Comparison of the obtained results is carried out with other techniques stated in literature which shows that ALO is effective to solveEELD.***

***Keywords: Economic Emission Load Dispatch(EELD); ALO; best compromise solution(BCS)***

## I. INTRODUCTION

The main goal of economic emission load dispatch problem is to get optimum output of thermal generators in power system subjected to several constraints to minimize the operating cost. The thermal power plant operation is dependent upon combustion of fossil fuel which produces SOx, NOx and COx emissions. The increasing pollution is a matter of environmental concern worldwide which has led to formation of international standards for emissions from industries and power plants. Different acts have been made which forces the industries to modify their principles to follow the environment-emission standards strictly. Thus it becomes significant to do emission dispatch or consider emission constraints in economic emission load dispatch. The economic & emission scheduling are contradictory in character and both must be considered together to find optimal scheduling. The problem is put together as a multi objective economic emission load dispatch problem (EELD) problem in which both objectives (emission and economy) have to be minimized.

Earlier traditional methods like Newton's method, gradient approach and linear programming [1] were used for solving economic load scheduling problem. In the last years different techniques have been used for solving EELD. Nanda et al [2] applied goal programming techniques to solve economic emission load dispatch. Song et.al [3] solved environmental/economic dispatch with genetic algorithm controlled by fuzzy logic. Abido [4] used genetic algorithm for the economic emission load dispatch (EELD) to find out pareto-optimal solutions. Ah King [5, 6] applied improved non-dominated sorting genetic algorithm (NSGA-II) for creating pareto-optimal front for EELD. Then mozhi [7] solved EELD using hybrid genetic algorithm. Perez [8] solved environmental/economic dispatch using differential evolution. Hong [9] applied immune genetic algorithm for EELD. Hazra [10] proposed bacteria foraging algorithm for emission constrained economic dispatch. Hemamalini [11] solved non convex EELD by applying particle swarm optimization. Sudhakaran applied refined genetic algorithm[12] and hybrid genetic algorithm[13] for solving EELD problem. Bhattacharya.et.al [14] presented a BBO technique to solve EELD of thermal generators with different emission substances (SOx, NOx, &COx).Niknam [15]proposed teaching learning based algorithm for dynamic EED. Abedinia [16] applied firefly algorithm (FFA) for EELD.

Differential evolution hybridized with biogeography-based optimization [17]is applied to solve EELD problem. Rajasomashekaret al.[18]proposed a new method applying BBO algorithm for getting best compromised solution for EELD problem[18].Opposition based Harmony Search Algorithm [21] is used to solve EELD problems. Güvenç et al.[22]solved EELD using gravitational search algorithm (GSA). Shaw et al. [23]solved EELD by including the opposition based learning scheme of [21] within gravitational search algorithm. Basu [24] applied multi objective differential evolution for solving EELD. Bhattacharjee.et.al.[25] solved EELD using Real Coded Chemical Reaction algorithm.

Harinder.et.al [26] applied particle swarm optimization (PSO) algorithm for solving multi objective load dispatch. Hota et al. [27] proposed fuzzy based bacterial foraging algorithm (MBFA) for solving EELD problem. Similarly there are many other techniques

©IJRASET (UGC Approved Journal): All Rights are Reserved

like artificial neural networks [28], constraint handling PSO [29], artificial bee colony(ABC) algorithm[30],firefly optimization[31], NSGA [32] and SPEA [33]which have been successfully used to solve EELD problem.

Recently, a new optimization technique based on the concept of hunting mechanism of ant lions called antlion optimization (ALO)has been proposed by Seyedali Mirjalili[34].The proposed algorithm has been applied successfully to solve benchmark test functions , classical engineering problems(truss design, gear train design and cantilever beam design) and for optimizing shape of ship propellers. In this paper ALO is applied to find out best compromise solution for EELD problem using the normalized objective function proposed by Rajasomashekar[18].

## II. PROBLEM FORMULATION

### A. *Economic load dispatch (ELD)*

Objective for economic dispatch is to reduce the operating (fuel) cost of thermal generators satisfying some limits. The objective function is given by:

$$C = \sum_{i=1}^{NG}(a_i P_{gi}^2 + b_i P_{gi} + c_i) \quad (1)$$

Where $a_i$, $b_i$, & $c_i$ are the fuel-cost coefficient sand$P_{gi}$is power output for the $i^{th}$ generating unit among *NG* total committed generating units.

The overall fuel cost has to be reduced with the following constraints:

1) *Power balance constraint:* The overall generation by the entire generators should be equal to the sum of whole power demand ($P_D$)& system's real power loss ($P_L$).

$$\sum_{i=1}^{NG} P_{gi} - P_D - P_L \quad (2)$$

The power loss is calculated by using B coefficients and unit power output:

$$P_L = \sum_{i=1}^{NG}\sum_{j=1}^{NG} P_i B_{ij} P_j + \sum_{i=1}^{NG} B_{0i} P_i + B_{00} \quad (3)$$

2) *Generator limit constraint*

Each generator's real power generation is to be controlled within its respective lower operating limits $P_{gi}^{min}$and upper operating limits$P_{gi}^{max}$.

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \quad , i=1, 2\ldots NG \quad (4)$$

### B. *Economic Emission dispatch(EED)*

The objective is to reduce the entire pollution discharge from combustion of coal or gas for producing electricity. The problem of optimum emission dispatch for NOx emission can be defined by as:

$$E_N = \sum_{i=1}^{NG}(d_{iN} P_{gi}^2 + e_{iN} P_{gi} + f_{iN}) \quad (5)$$

Where $E_N$are the total amount of NOx emission from the power plant in kg/hr. $d_{iN}$,$e_{iN}$, $f_{iN}$are the NOx emission coefficients of $i^{th}$generating unit. The power balance & generator limit restrictions are given by Eq. (2 & 4) respectively.

### C. *Multiobjective Economic emission load dispatch (EELD) problem*

The emission and economic dispatch are contradictory in character and they both have to be considered together to find optimal dispatch. The problem is expressed as a multi objective economic emission load dispatch (EELD) problem in which both the objectives (emission and economy) have to be minimized. The objective function is given by:

$$FC\ (C, E_N) \quad (6)$$

Where 'C'denotes fuel cost objective and '$E_N$' denote emission objective.

The multi-objective optimization could be solved using Fuzzy set theory along with any conventional optimization techniques [19], weighted sum method and many other techniques. Again, the multi-objective problem mentioned above could be solved after converting EELD problem to a solo objective optimization problem using cost penalty factors (CPF) [20].The whole objective function may be put together by using PPF and given as:

$$\text{Minimize } FC = \sum_{i=1}^{NG}\{wC_i(P_{gi}) + (1-w)jE_i(P_{gi})\} \quad (7)$$

Here 'j' is the cost penalty factor that combines the emission costs with the usual fuel costs and 'w' is the bargaining parameter varying between [0, 1]. The above equation is reduced subject to power balance and generating limits constraints as mentioned in

©IJRASET (UGC Approved Journal): All Rights are Reserved

(2) and (4). When the value of w is 1 the objective function represents fuel cost of generation function and when w is equal to 0, the objective function represents emission function only. It is very difficult to make a solution that will give the best compromising solution (BCS) which lie nearer to both of the best solution. The fuel cost rises and emission price reduces when w is decreased in steps from 1 to 0. When w is equal to 0,objective function becomes purely EED that curtail only the emissions.

Pareto front based on the non-dominated solution could be founded by resolving the problem a number of times with dissimilar w values. However it might not give the best compromising result, which can be described as the one with equal percent difference from the best solutions resultant to ELD and EED.

Rajasomashekar et al. [18] proposed a method to find the best compromising solution. The drawbacks of the existing approaches is overcome, after expressing bi-objective function of Eq.(7) in a modified way after normalizing the fuel cost and emission components with a view to provide relatively equal significance to both the objectives. The modified overall objective function may be represented as:

$$Minimize\ FC = w\left[\frac{\sum_{i=1}^{NG} C_i(P_{gi}) - C_{min}}{C_{max} - C_{min}}\right] + (1-w)\left[\frac{\sum_{i=1}^{NG} E_i(P_{gi}) - E_{min}}{E_{max} - E_{min}}\right] \quad (8)$$

The required values for $C_{min}$, $C_{max}$, $E_{min}$ and $E_{max}$, canbe obtained through solving Eq.(7)for both economic dispatch and emission dispatch.

The customized normalized depiction of objective function for EELD problem offers best compromising solution (BCS) when w is set to 0.5 [18] and the overall solution process involves only three runs for solution of ELD, EED and EELD problems. But, fuzzy based strategies require several solution runs with different w values. The current methods provide a result in which fuel cost is extremely near to the best fuel cost while restraining the emission far-off from the best emission point and contrariwise. This indicates that the relative importance given to both objectives are unequal. But according to [18], the new problem formulation (8) based optimization process gives approximately the same significance to the fuel cost and emission and get their values to lie in the similar range.

The amount by which best compromising solutions deviate from the global best fuel cost and emissions are calculated using the following indices:

*1)* Fuel Cost Performance Index( FCPI)

$$= \left[\frac{\sum_{i=1}^{NG} C_i(P_{gi}) - C_{min}}{C_{max} - C_{min}}\right] \times 100 \quad (9)$$

*2)* Emission Cost Performance Index( ECPI)

$$= \left[\frac{\sum_{i=1}^{NG} E_i(P_{gi}) - E_{min}}{E_{max} - E_{min}}\right] \times 100 \quad (10)$$

However, the relative significance between fuel cost and emissions can be varied by altering w in between 0 and 1 in the objective function of (8). It permits the operator of system to choose on diverse desires for the objectives according to operating conditions of system.

## III. ANT LION OPTIMIZATION

Ant Lion Optimizer (ALO) [34] is a novel nature-inspired algorithm proposed in 2015 by Seyedali Mirjalili. The ALO algorithm imitates hunting behavior of ant lions in nature. Five major steps of prey hunting such as the arbitrary walk of ants, trap constructing, entrapping of ants in traps, prey grabbing, and trap rebuilding are implemented.

There are two main phases in ant lions lifecycle: larvae and adult. A normal entire lifespan (shown in Fig.1) could be of 3 years, which typically occurs in larvae (maturity period only for 3 to 5 weeks). Ant lions undergo metamorphosis in a cocoon to become adult. They generally hunt in larvae and the adulthood phase is for reproduction. An ant lion larva digs a cone-shaped pit in soil by moving along a round path and flinging out soil with its colossal jaw as shown in Fig. 2(a). After digging the trap, larvae hide at the bottom of the cone and wait for insect (ant) to be trapped in the pit. The verge of the cone is sufficiently sharp for insects to drop to the bottom of the trap easily as illustrated in Fig. 2(d). Once the ant lion realizes that a prey is in the trap, it tries to catch it [34].The steps for ALO algorithm are given Fig.3.

©IJRASET (UGC Approved Journal): All Rights are Reserved

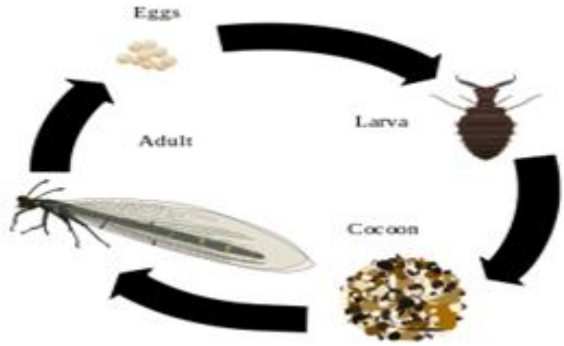



Fig. 1. Lifecycle of Antlion

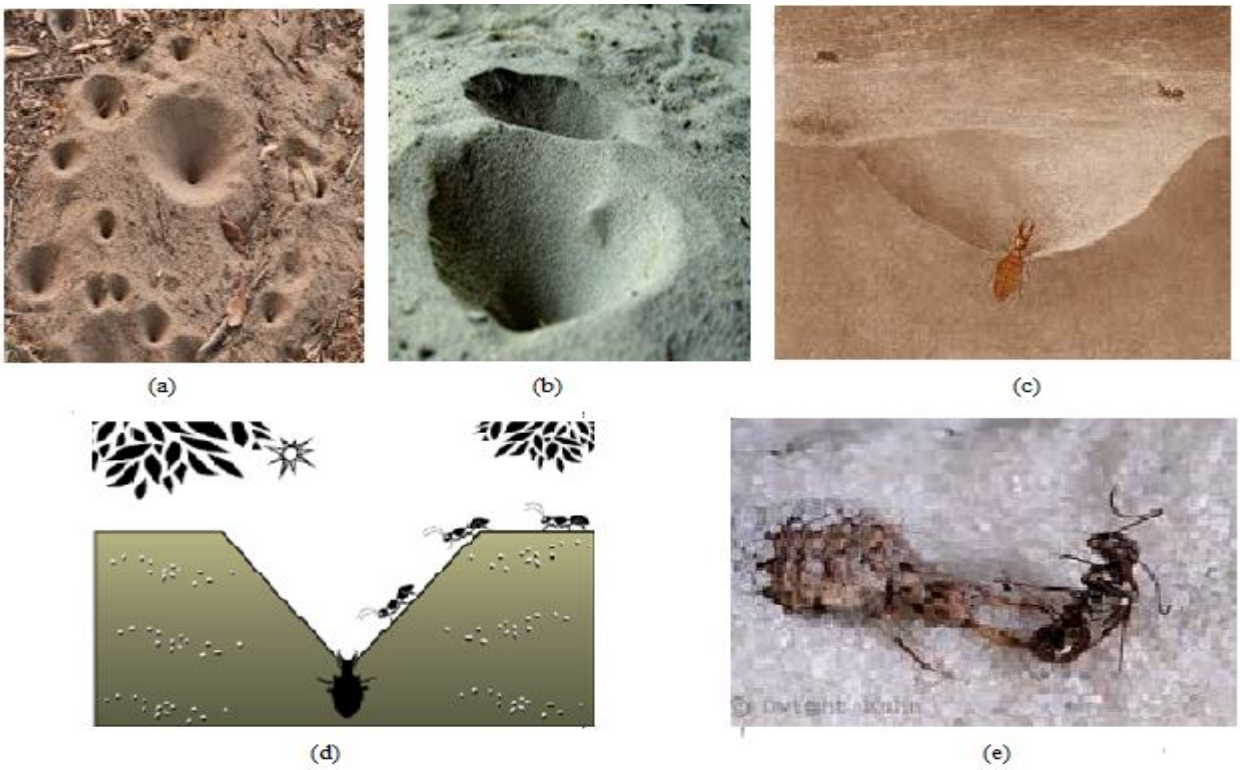



Fig. 2.a–c Trap building of antlions ; d–e prey catching and trap rebuilding [34]

*A. Random Walks of Ants*

Random walks are all based on the equation below:

$$X(t) = [0, cumsum(2r(t_1) - 1), cumsum(2r(t_2) - 1), \dots\dots\dots, cumsum(2r(t_n) - 1)] \quad (11)$$

Where *cumsum* computes the cumulative sum, *n*denotes maximum iterations, *t* shows the arbitrary walk step and *r(t)* is an assumed function stated as :

$$r(t) = \begin{cases} 1 & if\ rand > 0.5 \\ 0 & if\ rand \leq 0.5 \end{cases} \quad (12)$$

To keep the arbitrary walks within the search space, they are normalized using the succeeding equation:

$$X_i^t = \frac{(X_i^t - a_i) \times (d_i - c_i^t)}{(d_i^t - a_i)} + c_i \quad (13)$$

Where $a_i$is the minimum of arbitrary walk of $i^{th}$ variable, $b_i$ is the maximum of arbitrary walk in $i^{th}$ variable, $c_i^t$ is the minima of $i^{th}$ variable at$t^{th}$ iteration, and $d_i^t$indicates the upper limit of $i^{th}$ variable at $t^{th}$ iteration.

©IJRASET (UGC Approved Journal): All Rights are Reserved

*B. Trapping in Antlion's Pits*

Antlions' traps influence the arbitrary walks of ants. To model this assumption mathematically, the equations proposed are:

$c_i^t = Antlion_j^t + c^t$(14)

$d_i^t = Antlion_j^t + d^t$ (15)

where $c^t$ is minima of entire variables at$t^{th}$ iteration, $d^t$ denotes the vector having the maxima of entire variables at $t^{th}$ iteration, $c_j^t$ is the minima of entire variables for i$^{th}$ ant, $d_j^t$ is the maxima of entire variables for $i^{th}$ant, and $Antlion_j^t$ indicates the location of the chosen$j^{th}$antlion at $t^{th}$iteration

*C. Constructing Trap*

To model the hunting ability of antlion, a roulette wheel is used. ALO algorithm needs to use a roulette wheel operator for picking ant lions according to their fitness during optimization [34]. This method gives better probabilities to the fitter ant lions to catch ants.

*D. Sliding ants towards ant lion*

With the method proposed so far, ant lions are capable of constructing traps relative to their fitness and ants are required to move arbitrarily. However, ant lions shoot soil outward the mid of the pit once they understand that an ant is in trap. This conduct slides down the trapped ant that is attempting to escape [34]. To model this mathematically following equations are proposed in this regard:

$$c^t = \frac{c^t}{I} \& d^t = \frac{d^t}{I} \quad (16)$$

Where $c^t$ is the minima of entire variables at $t^{th}$ iteration, and $d^t$ indicates the vector having the maxima of entire variables at $t^{th}$ iteration and '$I$' is a fraction given by:

$$I = 10^w \frac{t}{T} \quad (17)$$

Where $t$ is the iteration in progress, $T$ is the maximum number of iterations, and $w$ is a constant defined based on the current iteration [23].

*E. Catching prey and re-building the pit*

Thelast phase of hunting is when an ant reaches the bottommost of pit and is trapped in the antlion's jaw. After this phase, the antlion jerks the ant inside the soil and eats its body. For imitating this procedure, it is supposed that prey catching occur when ants turn out to be fitter (go inside soil) than its analogous antlion [34]. Then it is essential for antlion to update its position to the newest position of frightened ant

to improve its gamble of catching novel prey. The following equation is offered in this regard:

$$Antlion_j^t = Ant_i^t \ \ if\ f(Ant_i^t) > f(Antlion_j^t) \quad (18)$$

Where $t$ shows the current iteration, $Antlion_j^t$ shows the location of selected $j^{th}$ antlion at $t^{th}$ iteration, and $Ant_i^t$ indicates the location of $i^{th}$ant at $t^{th}$iteration.

*F. Elitism*

It is supposed that each ant arbitrarily walks around a particular antlion by roulette wheel and the elite concurrently as follows:

$$Ant_i^t = \frac{R_A^t + R_E^t}{2} \quad (19)$$

Where $R_A^t$ is the arbitrary walk in the region of the antlion nominated through roulette wheel at $t^{th}$ iteration, $R_E^t$is the arbitrary walk in the region of the elite at$t^{th}$ iteration, and $Ant_i^t$indicates the location of $i^{th}$ ant at $t^{th}$ iteration.

©IJRASET (UGC Approved Journal): All Rights are Reserved

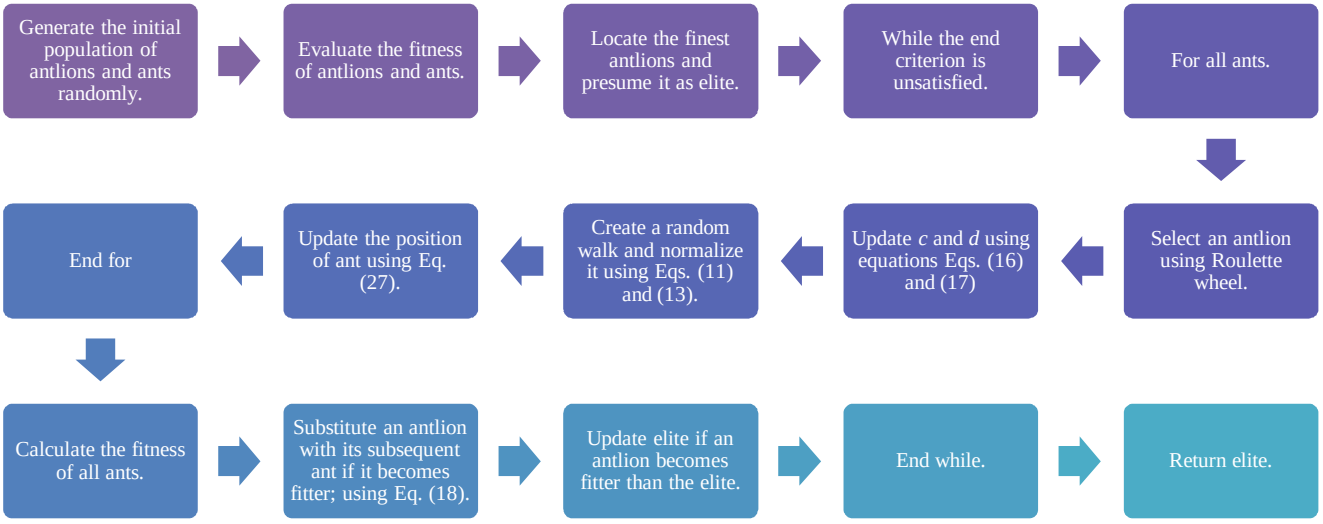



Fig.3. Steps of ALO algorithm [34]

## IV. SIMULATION TESTS & RESULTS

In this paper multi-objective economic emission load dispatch has been solved for three different test systems. In all cases, the constraints of operating limit and power balance are considered. The program was written in MATLAB (R2009b).The population taken in each case was 30 and maximum numbers of iterations performed were 500.

### *A. Test system I*

In this case system having 3 generating units considering NOx emissions is tested with power demand of 700 MW. The inputdata, such as cost & emission coefficients, loss data, generation restrictions, is taken from [30]. The best compromise results achieved from ALO are shown in table 1 and their comparison with conventional method [12], simple genetic algorithm (SGA) [12], refined genetic algorithm (RGA)[12] and FFA[31] is shown in table 2.FCPI and ECPI indices were calculated with respect to ELD and EED results for ALO and small difference of 2.86 between the two indices promises the validity of ALO for finding best compromising solution.

### *B. Test system II*

In this case system having 6 generating units considering NOx emissions is tested with power demand of 1200MW. The input data, such as cost & emission coefficients, loss data, generation restrictions, is taken from [24]. The best compromise results achieved from ALO are shown in table 3 and their comparison with MODE [24], PDE [24], NSGA-II [24], SPEA-2 [24] and PSO [26] is shown in table 4. FCPI and ECPI indices were calculated with respect to ELD and EED results for ALO and small difference of 0.331 between the two indices promises the validity of ALO for finding best compromising solution.

TABLE I. OBTAINED BY ALO FOR TEST SYSTEM I ( $P_D$=700 MW)

| Units | Power output (MW) | | |
|---|---|---|---|
| | ELD | EED | BCS for EELD |
| 1 | 154.725 | 185.818 | 169.764 |
| 2 | 284.518 | 268.748 | 276.879 |
| 3 | 284.516 | 268.725 | 276.872 |
| Power loss (MW) | 23.760 | 23.292 | 23.516 |

©IJRASET (UGC Approved Journal): All Rights are Reserved

| | | | |
|---|---|---|---|
| Fuel Cost (Rs) | 35424.174 | 35472.112 | 35435.510 |
| Emission (kg) | 660.408 | 651.416 | 653.800 |
| FCPI | 0 | 100 | 23.6456 |
| ECPI | 100 | 0 | 26.5079 |
| Difference | 100 | 100 | 2.86 |

TABLE II. COMPARISO OF BEST COMPROMISING SOLUTION FOR TEST SYSTEM I ( $P_D$=700 MW)

| Method | Cost ($/h) | Emission (lb) |
|---|---|---|
| CONVENTIONAL METHOD [12] | 35485.05 | 652.55 |
| SGA [12] | 35478.44 | 652.04 |
| RGA [12] | 35471.4 | 651.60 |
| FFA[31] | 35464 | 651.5 |
| ALO | 35435.510 | 653.800 |

*C. Test system III*

In this case system having 10 generating units considering valve point effects and NOx emissions is tested with power demand of 2000 MW. The input data, such as cost & emission coefficients, loss data, generation restrictions, is taken from [22]. The best compromise results achieved from ALO are shown in table 5 and their comparison with MODE [24], PDE [24], NSGA-II [22],SPEA 2,[22],GSA [22],RCCRO[25] is shown in table 6. FCPI and ECPI indices were calculated with respect to ELD and EED results for ALO and small difference of 2.209 between the two indices promises the validity of ALO for finding best compromising solution. The pictorial comparison of difference between FCPI and ECPI indices obtained by various methods is shown in fig.4.

TABLE III. RESULTS OBTAINED BY ALO FOR TEST SYSTEM II ( $P_D$=1200 MW)

| Units | Power output (MW) | | |
|---|---|---|---|
| | ELD | EED | BCS for EELD |
| 1 | 80.695 | 124.931 | 104.461 |
| 2 | 87.566 | 150 | 118.094 |
| 3 | 225 | 205.652 | 210.234 |
| 4 | 210 | 201.789 | 203.9678 |
| 5 | 325 | 283.770 | 308.998 |
| 6 | 325 | 283.840 | 305.872 |
| Power loss (MW) | 53.26 | 49.98 | 51.629 |
| Fuel Cost (Rs) | 63964.041 | 66004.790 | 64783.992 |
| Emission (kg) | 1359.879 | 1241.000 | 1288.366 |
| FCPI | 0 | 100 | 40.1789 |
| ECPI | 100 | 0 | 39.8457 |
| Difference | 100 | 100 | 0.3331 |

©IJRASET (UGC Approved Journal): All Rights are Reserved

TABLE IV. COMPARISO OF BEST COMPROMISING SOLUTION FOR TEST SYSTEM II ( $P_D$=1200 MW)

| Method | Cost ($/h) | Emission (lb) |
|---|---|---|
| MODE[24] | 64843.00 | 1286.00 |
| PDE[24] | 64920.00 | 1281.00 |
| NSGA-II[24] | 64962.00 | 1281.00 |
| SPEA-II[24] | 64884.00 | 1285.00 |
| PSO [26] | 64887.88 | 1283.40 |
| ALO | 64783.99 | 1288.366 |

*D. Test system IV*

In this case system having 40 generating units considering valve point effects and NOx emissions is tested with power demand of 10500 MW. The input data, such as cost & emission coefficients is taken from [22]. The best compromise results achieved from ALO are shown in table 7 and their comparison with MBFA [27] is shown in table 8. FCPI and ECPI indices were calculated with respect to ELD and EED results for ALO and small difference of 4.30078 between the two indices promises the validity of ALO for finding best compromising solution. The pictorial comparison of difference between FCPI and ECPI indices obtained by ALO and MFBA [27] is shown in fig.5.

TABLE V. RESULTS OBTAINED BY ALO FOR TEST SYSTEM III ( $P_D$=2000 MW)

| Units | Power output (MW) | | |
|---|---|---|---|
| | ELD | EED | BCS for EELD |
| 1 | 54.980 | 54.966 | 54.986 |
| 2 | 79.956 | 79.042 | 79.942 |
| 3 | 105.265 | 80.630 | 82.355 |
| 4 | 100.306 | 82.613 | 84.021 |
| 5 | 82.915 | 160 | 135.191 |
| 6 | 83.624 | 240 | 156.177 |
| 7 | 299.982 | 297.052 | 298.707 |
| 8 | 340 | 299.305 | 316.477 |
| 9 | 470 | 391.990 | 437.905 |
| 10 | 470 | 395.928 | 438.608 |
| Power loss (MW) | 87.030 | 81.529 | 84.375 |
| Fuel Cost ($/h) | 111498.783 | 116432.038 | 113099.329 |
| Emission (lb) | 4562.541 | 3932.814 | 4151.034 |
| FCPI | 0 | 100 | 32.444 |
| ECPI | 100 | 0 | 34.653 |
| Difference | 100 | 100 | 2.209 |

©IJRASET (UGC Approved Journal): All Rights are Reserved

TABLE VI. COMPARISO OF BEST COMPROMISING SOLUTION FOR TEST SYSTEM III ( $P_D$=2000 MW)

| Units | MODE [24] | PDE [24] | NSGA-II [22] | SPEA 2 [22] | GSA [22] | RCCRO[25] | ALO |
|---|---|---|---|---|---|---|---|
| P1 (MW) | 54.9487 | 54.9853 | 51.9515 | 52.9761 | 54.9992 | 55.0000 | 54.986 |
| P2 (MW) | 74.5821 | 79.3803 | 67.2584 | 72.8130 | 79.9586 | 80.0000 | 79.942 |
| P3 (MW) | 79.4294 | 83.9842 | 73.6879 | 78.1128 | 79.4341 | 85.6453 | 82.355 |
| P4 (MW) | 80.6875 | 86.5942 | 91.3554 | 83.6088 | 85.0000 | 84.1259 | 84.021 |
| P5 (MW) | 136.8551 | 144.4386 | 134.0522 | 137.2432 | 142.1063 | 136.5034 | 135.191 |
| P6 (MW) | 172.6393 | 165.7756 | 174.9504 | 172.9188 | 166.5670 | 155.5801 | 156.177 |
| P7 (MW) | 283.8233 | 283.2122 | 289.4350 | 287.2023 | 292.8749 | 300.0000 | 298.707 |
| P8 (MW) | 316.3407 | 312.7709 | 314.0556 | 326.4023 | 313.2387 | 316.6746 | 316.477 |
| P9 (MW) | 448.5923 | 440.1135 | 455.6978 | 448.8814 | 441.1775 | 434.1252 | 437.905 |
| P10 (MW) | 436.4287 | 432.6783 | 431.8054 | 423.9025 | 428.6306 | 436.5724 | 438.608 |
| Cost ($/h) | 11.348 * 10^5 | 1.1351 * 10^5 | 1.1354 * 10^5 | 1.1352 * 10^5 | 1.1349 * 10^5 | 113355.7454 | 113099.329 |
| Emission (lb) | 4124.9 | 4111.4 | 4130.2 | 4109.1 | 4111.4 | 4121.0684 | 4151.034 |
| FCPI | 40.33 | 40.94 | 41.56 | 41.15 | 40.54 | 37.81 | 32.444 |
| ECPI | 30.12 | 28.01 | 30.94 | 27.65 | 28.01 | 29.52 | 34.653 |
| Difference | 10.21 | 12.93 | 10.62 | 13.50 | 12.53 | 08.29 | 2.209 |

TABLE VII. RESULTS OBTAINED BY ALO FOR TEST SYSTEM IV (PD = 10500 MW).

| Units | ELD | | EED | | BCS for EELD | |
|---|---|---|---|---|---|---|
| | MBFA [27] | ALO | MBFA [27] | ALO | MBFA [27] | ALO |
| 1 | 114.0000 | 112.3215159 | 114.0000 | 113.7901571 | – | 113.6650901 |
| 2 | 110.8035 | 113.4247916 | 114.0000 | 113.8942034 | – | 111.3219521 |
| 3 | 97.4002 | 100.5697446 | 120.0000 | 119.7159511 | – | 99.41236768 |
| 4 | 179.7333 | 131.5182381 | 169.3671 | 175.7333282 | – | 180.7215271 |
| 5 | 87.8072 | 89.35228422 | 97.0000 | 96.93064366 | – | 87.36721866 |
| 6 | 140.0000 | 114.7613699 | 124.2630 | 122.6306849 | – | 106.94894 |
| 7 | 259.6004 | 297.2870638 | 299.6931 | 294.2575497 | – | 275.1213922 |
| 8 | 284.6002 | 299.9440429 | 297.9093 | 293.6042562 | – | 293.1532851 |
| 9 | 284.6006 | 287.0497722 | 297.2578 | 287.639498 | – | 288.9386537 |
| 10 | 130.0000 | 139.0494733 | 130.0007 | 153.7915638 | – | 132.4513295 |
| 11 | 168.7999 | 98.24985186 | 298.4210 | 296.0180853 | – | 244.6069906 |
| 12 | 168.7998 | 168.8810585 | 298.0264 | 299.6681256 | – | 243.9528083 |
| 13 | 214.7598 | 304.629644 | 433.5590 | 433.5063754 | – | 394.355992 |
| 14 | 304.5195 | 394.3024487 | 421.7360 | 421.5400279 | – | 394.7416178 |
| 15 | 394.2794 | 304.534581 | 422.7884 | 423.6487236 | – | 394.1624837 |
| 16 | 394.2794 | 305.2867349 | 422.7841 | 423.3030886 | – | 394.3357374 |
| 17 | 489.2794 | 490.3691148 | 439.4078 | 438.3566651 | – | 487.9795599 |
| 18 | 489.2794 | 489.5036818 | 439.4132 | 439.7283053 | – | 489.2258923 |
| 19 | 511.2795 | 511.7451751 | 439.4111 | 441.3131258 | – | 509.5198803 |
| 20 | 511.2795 | 511.3866797 | 439.4155 | 440.9302873 | – | 424.3372814 |
| 21 | 523.2794 | 523.7526806 | 439.4421 | 432.7498843 | – | 444.6752248 |
| 22 | 523.2794 | 546.4490405 | 439.4587 | 437.9981222 | – | 498.1749219 |
| 23 | 523.2796 | 524.5335111 | 439.7822 | 436.3860074 | – | 518.8884704 |
| 24 | 523.2794 | 524.3520391 | 439.7697 | 438.764263 | – | 461.4264655 |

©IJRASET (UGC Approved Journal): All Rights are Reserved

| | | | | | | |
|---|---|---|---|---|---|---|
| 25 | 523.2795 | 526.0300827 | 440.1191 | 440.5317634 | – | 433.7498497 |
| 26 | 523.2796 | 523.6386784 | 440.1219 | 440.2191136 | – | 503.3093562 |
| 27 | 10.0001 | 10.53824559 | 28.9738 | 24.16349618 | – | 11.00102962 |
| 28 | 10.0002 | 10.3420627 | 29.0007 | 48.41126024 | – | 16.56165106 |
| 29 | 10.0002 | 10.92134498 | 28.9828 | 30.7785289 | – | 13.95256909 |
| 30 | 89.5070 | 94.02741173 | 97.0000 | 95.82240167 | – | 96.3499386 |
| 31 | 190.0000 | 189.4857853 | 172.3348 | 172.5764043 | – | 188.984363 |
| 32 | 190.0000 | 190 | 172.3327 | 170.1042776 | – | 189.0600581 |
| 33 | 190.0000 | 188.8414191 | 172.3262 | 173.2868247 | – | 172.3326822 |
| 34 | 164.8026 | 168.7137325 | 200.0000 | 199.8494977 | – | 199.2972466 |
| 35 | 164.8035 | 190.3635298 | 200.0000 | 200 | – | 169.5882049 |
| 36 | 164.8292 | 199.1141077 | 200.0000 | 200 | – | 199.9560462 |
| 37 | 110.0000 | 89.15280064 | 100.8441 | 96.57168146 | – | 96.01766374 |
| 38 | 110.0000 | 103.4431437 | 100.8346 | 105.9796775 | – | 108.4345129 |
| 39 | 110.0000 | 109.9597579 | 100.8362 | 82.96801795 | – | 89.737272 |
| 40 | 511.2795 | 512.1733591 | 439.3868 | 442.8381317 | – | 422.1824737 |
| Total generation | 10500.00 | 10500.00 | 10500.00 | 10500.00 | 10500.00 | 10500.00 |
| Fuel cost ($/h) | 121415.653 | 122310.1012 | 129995.000 | 130503.4665 | 123638.00 | 125084.5385 |
| Emission (Ton/h) | 356424.497 | 368903.5705 | 176682.269 | 179062.812 | 188963.00 | 235182.0535 |
| FCPI | 0 | 0 | 100 | 100 | 25.9034 | 33.862 |
| ECPI | 100 | 100 | 0 | 0 | 6.8324 | 29.5612 |
| Difference | 100 | 100 | 100 | 100 | 19.0710 | 4.30078 |

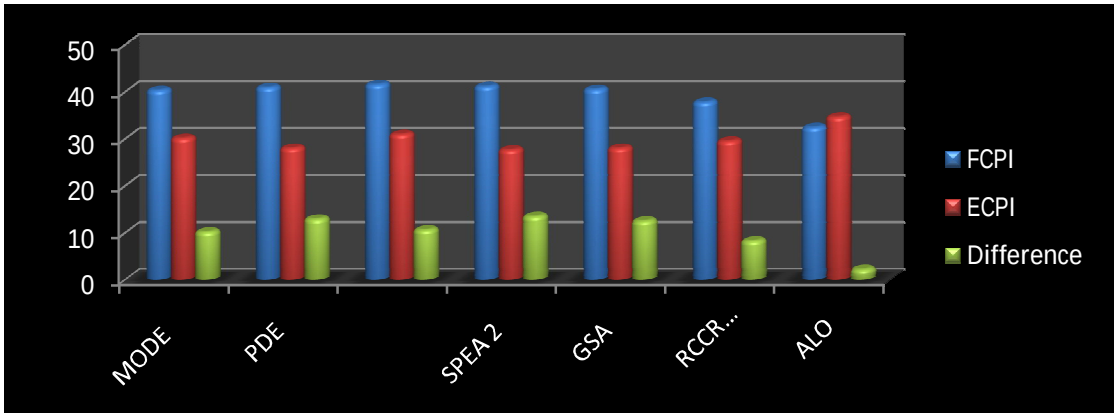



Fig.4. Comparison of the performances for Test case III

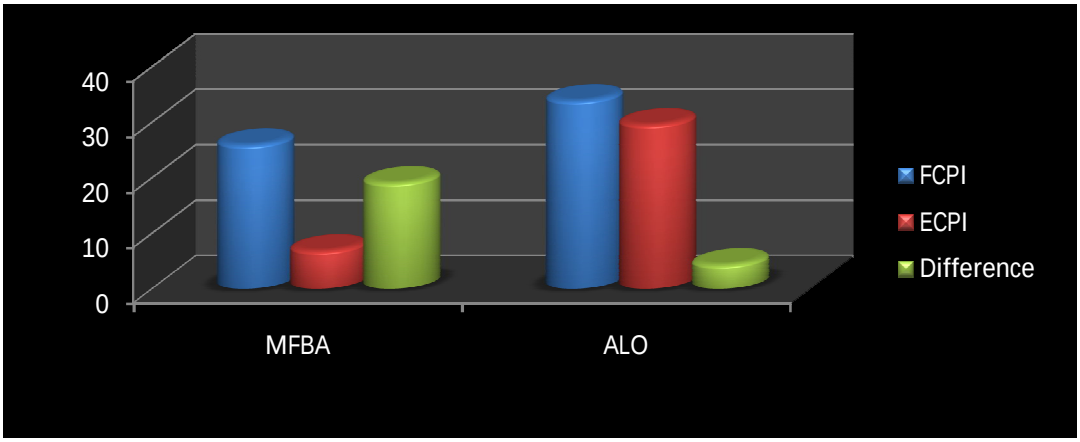



Fig.5. Comparison of the performances for Test case IV

©IJRASET (UGC Approved Journal): All Rights are Reserved

## IV. CONCLUSION

The ALO algorithm is efficiently applied for solving multi-objective EELD problem. The obtained results shows that the proposed ALO algorithm can evade the deficiency of early convergence of the genetic algorithm and particle swarm optimization methods to get superior solutions. The results confirmed that ALO was able to give competitive results in comparison to GA, hybrid GA, PSO, FFA, MFBA, MODE, NSGA-II, GSA and RCCRO. The novel probabilistic model of trap constructing, entrapping of ants in traps, prey grabbing, and trap rebuilding handle the trouble of early convergence. Because of simplicity and effectiveness of the ALO method, it can be useful for searching better results in difficult power system problems in future.

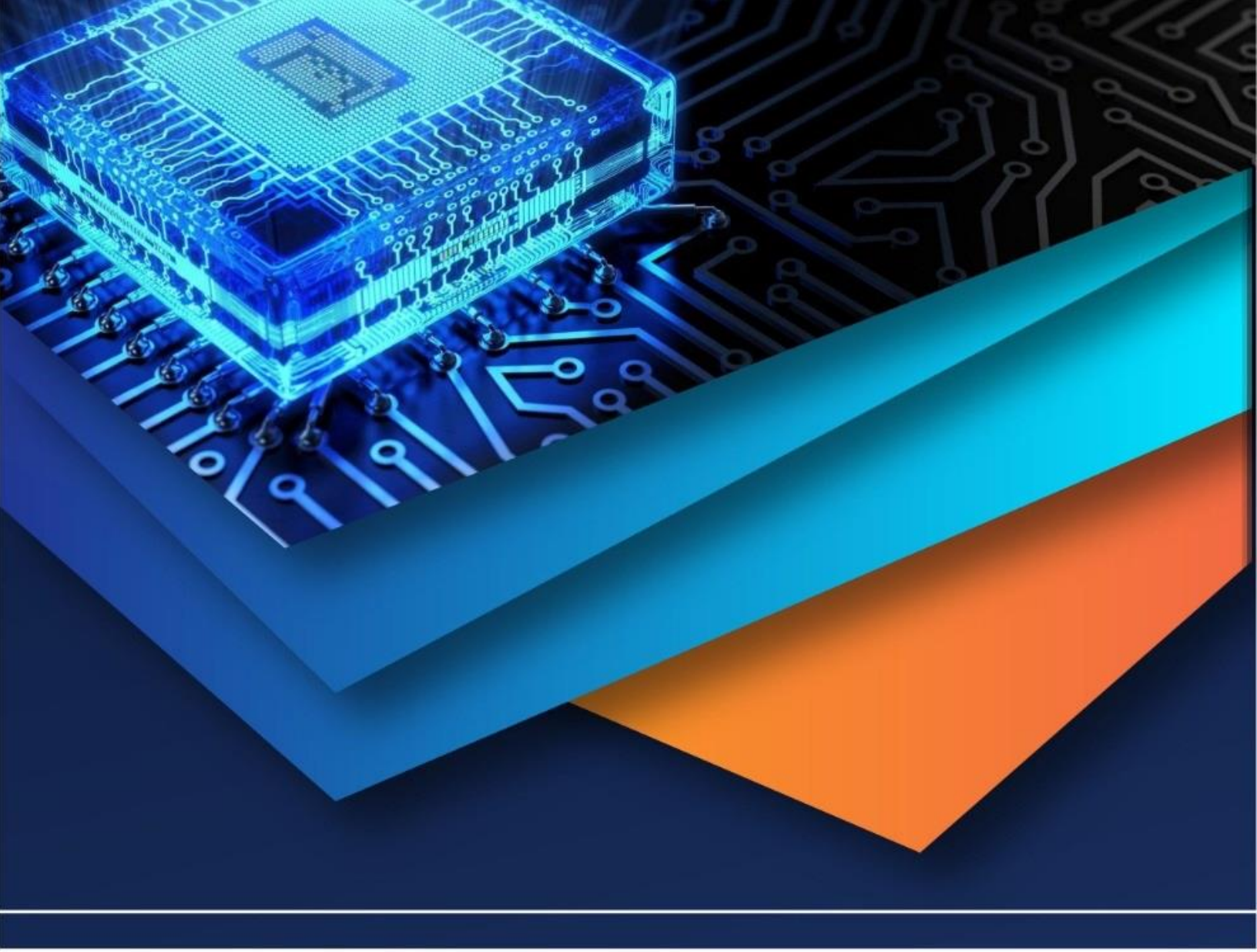
## REFERENCES

[1] Wood, A. J. and Wollenberg, B. F., Power Generation, Operation, and Control, 1996, Wiley, New York, 2nd Ed.
[2] Nanda, J., Khotari, D. P., and Lingamurthy, K. S., “Economic-emission load dispatch through goal programming techniques,” IEEE Trans. Energy Conversion, Vol. 3, No. 1, pp. 26–32, March 1988.
[3] Song, Y. H., Wang, G. S., Wang, P. Y., and Johns, A. T., “Environmental/economic dispatch using fuzzy logic controlled genetic algorithms,” IEE Proc. Generat. Transm. Distrib., Vol. 144, No. 4, pp. 377–382, July 1997.
[4] Abido, M. A., “A niched Pareto genetic algorithm for multi-objective environmental/economic dispatch,” Elect. Power Energy Syst., Vol. 25, No. 2, pp. 79–105, February 2003
[5] Rughooputh, H.C.S.; Ah King, R.T.F., "Environmental/economic dispatch of thermal units using an elitist multiobjective evolutionary algorithm," Industrial Technology, 2003 IEEE International Conference on , vol.1, no., pp.48,53 Vol.1, 10-12 Dec. 2003
[6] R. T. F. Ah King and H. C. S. Rughooputh, “Elitist Multi-objective Evolutionary Algorithm for Environmental/Economic Dispatch,”Congress on Evolutionary computation, vol. 2, pp. 1108-14, 8-12 Dec.2003.
[7] N.; Mary, D., "Economic emission load dispatch using hybrid genetic algorithm," TENCON 2004. 2004 IEEE Region 10 Conference, vol.C, no., pp.476,479 Vol. 3, 21-24 Nov. 2004 doi: 10.1109/TENCON.2004.1414811
[8] Perez-Guerrero, R.E.; Cedeno-Maldonado, J.R., "Differential evolution based economic environmental power dispatch," Power Symposium, 2005. Proceedings of the 37th Annual North American , vol., no., pp.191,197, 23-25 Oct. 2005
[9] Hong-da Liu; Zhong-li Ma; Sheng Liu; HaiLan, "A New Solution to Economic Emission Load Dispatch Using Immune Genetic Algorithm," Cybernetics and Intelligent Systems, 2006 IEEE Conference on , vol., no., pp.1,6, 7-9 June 2006
[10] Hazra, J.; Sinha, A.K., "Environmental Constrained Economic Dispatch using Bacteria Foraging Optimization," Power System Technology and IEEE Power India Conference, 2008. POWERCON 2008. Joint International Conference on , vol., no., pp.1,6, 12-15 Oct. 2008
[11] Hemamalini, S.; Simon, S.P., "Emission constrained economic dispatch with valve-point effect using particle swarm optimization," TENCON 2008 - 2008 IEEE Region 10 Conference , vol., no., pp.1,6, 19-21 Nov. 2008
[12] M. Sudhakaran, S.M.R Slochanal, R. Sreeram and N Chandrasekhar, “Application of Refined genetic Algorithm to Combined Economic and Emission Dispatch” J. Institute Of Engg. (India) volume-85, Sep. 2004pp. 115-119.
[13] M. Sudhakaran and S.M.R Slochanal, “Integrating Genetic Algorithm and Tabu Search for Emission and Economic Dispatch Problem” J. Institute of Engg. (India) volume-86, June.2005, pp-22-27.
[14] Bhattacharya, Aniruddha, and P. K. Chattopadhyay. "Application of biogeography-based optimization for solving multi-objective economic emission load dispatch problems." Electric Power Components and Systems 38, no. 3 (2010): 340-365.
[15] Niknam, T.; Golestaneh, F.; Sadeghi, M.S., " -Multiobjective Teaching–Learning-Based Optimization for Dynamic Economic Emission Dispatch," Systems Journal, IEEE , vol.6, no.2, pp.341,352, June 2012
[16] Abedinia, O.; Amjady, N.; Naderi, M.S., "Multi-objective Environmental/Economic Dispatch using firefly technique," Environment and Electrical Engineering (EEEIC), 2012 11th International Conference on , vol., no., pp.461,466, 18-25 May 201
[17] A, Chattopadhyay PK. Solving economic emission load dispatchproblems using hybrid differential evolution. Appl Soft Comput (Elsevier)2011;11(2):2526–37.
[18] Rajasomashekar S, Aravindhababu P. Biogeography based optimizationtechnique for best compromise solution of economic emission dispatch.Swarm Evol Comput 2012;7:47–57.
[19] Hota PK, Barisal AK, Chakrabarti R. Economic emission load dispatch throughfuzzy based bacterial foraging algorithm. Int J Electr Power Energy Syst2010;32(7):794–803.
[20] Kumarappan N, Mohan MR, Murugappan S. ANN approach applied tocombined economic and emission dispatch for large scale system. In:Proceedings of the 2002 international joint conference on neural networks,IJCNN, vol. 02, no. 1; 2002. p. 323–7.
[21] Chatterjee A, Ghoshal SP, Mukherjee V. Solution of combined economic and emission dispatch problems of power systems by an opposition-basedharmony search algorithm. Electr Power Energy Syst 2012;39(1):9–20.
[22] Güvenç U, Sönmez Y, Duman S, Yörükeren N. Combined economic andemission dispatch solution using gravitational search algorithm. Orig ResArticle Sci Iran 2012;19(6):1754–62.
[23] B, Mukherjee V, Ghoshal SP. A novel opposition-based gravitational search algorithm for combined economic and emission dispatch problems of power systems. Electr Power Energy Syst 2012;35(1):21–33
[24] Basu, M. ‘‘Economic environmental dispatch using multi-objective differential evolution’’, Applied Soft Computing, 11, pp. 2845–2853 (2011).
[25] systems by Real Coded Chemical Reaction algorithm”, Electrical Power and Energy Systems 59 (2014) 176–187
[26] Singh, H.P.; Brar, Y.S.; Kothari, D.P., "Multiobjective load dispatch using Particle Swarm Optimization," in Industrial Electronics and Applications (ICIEA), 2013 8th IEEE Conference on , vol., no., pp.272-277, 19-21 June 2013

©IJRASET (UGC Approved Journal): All Rights are Reserved

[27] Hota PK, Barisal AK, Chakrabarti R. Economic emission load dispatch through fuzzy based bacterial foraging algorithm. Int J Electr Power Energy Syst 2010;32(7):794–803.
[28] Kumarappan, N.; Mohan, M.R.; Murugappan, S., "ANN approach applied to combined economic and emission dispatch for large-scale system," Neural Networks, 2002. IJCNN '02. Proceedings of the 2002 International Joint Conference on , vol.1, no., pp.323,327, 200
[29] AlRashidi, M. R., and El-Hawary, M. E., "Emission-economic dispatch using a novel constraint handling particle warm optimization strategy," Canadian Conference on Electrical and Computer Engineering 2006, pp. 664–669, Ottawa, Canada, 7–10 May 2006.
[30] Gaurav Prasad Dixit, Hari Mohan Dubey, ManjareePandit, B. K. Panigrahi, "Artificial Bee Colony Optimization for Combined Economic Load and Emission Dispatch", International Conference on Sustainable Energy and Intelligent System (SEISCON 2011) ,Dr.M.G.R. University, Maduravoyal, Chennai, Tamil Nadu, India. July.20-22, 2011.
[31] Dinakara Prasad Reddy P, J N Chandra Sekhar ,"Application of Firefly Algorithm for Combined Economic Load and Emission Dispatch" International Journal on Recent and Innovation Trends in Computing and Communication, Vol.2 , No.8(2014):2448-2452
[32] Abido MA. A novel multiobjective evolutionary algorithm for environmental economic power dispatch. Electr Power Syst Res 2003;65(1):71–81.
[33] Abido MA. Environmental/economic power dispatch using multiobjective evolutionary algorithms. IEEE Trans Power Syst 2003;18(4):1529–37
[34] Mirjalili, Seyedali. "The ant lion optimizer." Advances in Engineering Software 83 (2015): 80-98.

©IJRASET (UGC Approved Journal): All Rights are Reserved



10.22214/IJRASET

45.98

IMPACT FACTOR: 7.129

IMPACT FACTOR: 7.429

# INTERNATIONAL JOURNAL FOR RESEARCH

IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Call : 08813907089 (24*7 Support on Whatsapp)