ECONOMICAL OPERATION OF THERMAL GENERATOR INVOLVING TRANSMISSION LOSS USING NOVAL CAPRA OPTIMIZATION ALGORITHM

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Abstract
This paper put forward the significance of Novel Capra Optimization Algorithm (NCOA) to solve classical Economic Dispatch (ED) problem. ED is to estimate, the output power of all generating units so that mandatory demands are satisfied at minimum cost, while satisfying diverse methodological constraints. Economic dispatch problem is especially non-linear and complex to solve because of its immense dimension. This paper intend to present the new algorithm to solve ED, which is modeled on the basis of the behavior of an herbivorous species namely Capra and also compares the success of the NCOA with known algorithm in literature. The simulation of the NCOA problem is tested with IEEE standard 3, 6and 15 thermal generating units. The Simulation results of the proposed NCOA approach is better than Neural Network, Evolutionary Programming, Differential Evolution (DE), Self Adaptive Differential Evolution, and other well known algorithms in literature.

Keywords: *Economic Dispatch, Capra Optimization, Multi-objective optimization.*

1. Introduction

Economic dispatch (ED) problem in a power system is to acquit optimal allocation of generating units to meet the power demand while satisfying the operating constraints [1]. Economic dispatch problem is exceedingly non-linear and complex to solve because of its immense dimension. Various researches on ED have been maneuvered till date. Earlier techniques to solve this ED problem classical methods such as lambda iteration, linear programming, dynamic programming and Newton's method were been used. Lambda-iteration method is unsuccessful to apply directly to the ED problem with discontinuous prohibited zones results in oscillatory problems in large-scale mixed generating unit systems [2]. Dynamic programming experiences from the "curse of dimensionality" and does not require any check on fuel cost curve [2]. Linear programming has impotent associated with piece wise linear cost approximation [3]. Newton's method experiences convergence to local optimality [4]. Back propagation algorithm (BPA) based neural network and Hopfield neural network (HNN) has been salutary applied to solve ED problem alternate to traditional techniques [5, 6]. Attributable to improper choice of learning, momentum rates, inappropriate sigmoid function and larger iteration BPA and HNN take additional time to obtain optimal solution.

In bygone years, computation techniques like Genetic algorithm (GA), Evolutionary programming (EP), Simulated annealing (SA), Tabu search algorithm (TSA), Particle swarm optimization (PSO) and Ant colony optimization (ACO) were successfully applied to solve the extremely complicated real world problems. Recent researchers have identified some deficiencies in GA performance which are the premature convergence leads to reducing the searching capability and superior probability towards obtaining a local optimum [7]. SA might prove to be very effective, in practice annealing schedule of SA should be tuned cautiously; otherwise the result accomplish will be local optimum [8]. Improper selection of TSA and ACO factors may increase the computational time for realize optimal solution [9, 10]. PSO algorithm can be effectively applied to many non smooth cost functions; in the study the velocity of each parameter is restricted to a certain value to locate optimal solution [11].

In recent times, several algorithms has been successfully applied to ED problem such as Hybrid EP combined with sequential quadratic programming [12], PSO technique with the SQP [13], Improved GA (IGA) [14], Cauchy based evolution strategy [15], and Adaptive hope field neural network [16] and Improved EP for different economic dispatch problem [17]. Even though, numerous techniques are applied to ED problem. The realistic ED problem involves with valve-point and multi fuel effects are represent as a non smooth optimization problem with equality and inequality constraints, and this put together the problem finding global solution difficult. Complexity to solve ED problem reveals the essential for the improvement of efficient algorithm.

In this paper lavishly enlighten the novel modeling of Capra optimization algorithm to solve such high non linear problem. Moreover the robustness of the NCOA investigates the ED problem. In this paper classical ED problem formation with constraints are formulated in chapter 2. Section 3 provides the modeling of Capra algorithm. The rest of the paper organized with simulation result and discussion at section 3 and conclusion of the proposed work.

2. ED Problem Formulation

The goal of ED problem is to minimize the total generation cost subject to various equality and inequality constraints, as articulated as follows [6],

$$\min\ f = \sum_{j=1}^{n} F_j(P_j) \tag{1}$$

Where,

f Total generation cost in \$/hr

$F_j(P_j)$ Cost function of j^{th} generator in \$/hr

P_j Electrical power output of j^{th} generator

n number of generators

$j = 1,2,3,.....n$

Quadratic generation cost function as a polynomial as given below,

$$F_j(P_j) = \sum_{j=1}^{n} a_j P_j^{\,2} + b_j P_j + c_j \tag{2}$$

where,

a_j, b_j, c_j Fuel cost coefficients of j^{th} generator

2.1 Equality constraint

$$\sum_{j=1}^{n} P_j = P_D + P_L \tag{3}$$

Where,

P_D Total demand in MW

P_L Transmission loss in MW

The network loss can be formulated using $B_{mn} - loss$ coefficients as given below

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} B_{0i} P_i + B_{00} \tag{4}$$

Where,

B_{ij}, B_{0i}, B_{00} Transmission loss B-coefficients

2.2 Inequality Constraints

2.2.1 Bounded power limits

$$P_j^{\min} \le P_j \le P_j^{\max} \tag{5}$$

Where,

$P_j^{\min}$ Lower limit of j^{th} generator

$P_j^{\max}$ Upper limit of j^{th} generator

2.2.2 Ramp rate Limit

$$\max(P_j^{\min}, P_j^0 - DR_j) \le P_j \le \min(P_i^{\max}, P_j^0 + UR_j) \tag{6}$$

Where,

P_j^0 Previous output power of j^{th} generator

UR_j Up-ramp limit of j^{th} generator

DR_j Down-ramp limit of j^{th} generator

2.2.3 Prohibited operating Zone

$$P_j^{\min} \le P_j \le P_{j,1}^{L} \tag{7}$$

$$P_{j,m-1}^{U} \le P_j \le P_{j,m}^{L} \tag{8}$$

$$P_{j,nzi}^{U} \le P_j \le P_j^{\max} \tag{9}$$

Where,

$P_{j,1}^{L}$ Lower bound of j^{th} prohibited zone

$P_{j,m-1}^{U}$ Upper bound of j^{th} prohibited zone

nzi Number of prohibited zone

m = 1,2,3,4….,nzi

3. Modeling of Capra Optimization

An herbivore genus known as Capra refers to domesticated goat's grazing behavior is modeled as optimizing algorithm to solve ED problems. An herbivore is an animal anatomically and physically gets used to eating plant materials for their diet [18]. Herbivora is derived from Latin word "Herba" meaning a small plant and "vora" means to devour (eat). Herbivores utilize numerous types of feeding strategies such as grazing and browsing [18]. Browsing means feeding on leafs, shoots and twins of shrubs and other high-growing vegetation. Grazing refer to feed on growing grass and pasturage or to small portion of food in the field or meadows [19].

The searching difference between the grazing and browsing behavior of the herbivores makes us to choose the grazing behavior of Capra, an herbivore. Moreover Capra possesses exclusive features which distinguish them from other domestic animals. Capra is more proficient of utilizing natural grazing meadows (land). Capra are capable of covering wide area in search of grazing land [20] this motivates us to model the novel search algorithm.

The novel search algorithm namely Capra optimization algorithms (COA) are modeled as follows,

Capra is an exploring herbivore which is able to cover an ample area in search of grazing. Capra's small mouth and split upper lips allow them to pick small leaves. Thus Capra finding the most nutritious feed available from the grazing land. The total optimal grassing intake of the Capra is modeled as,

$$\lambda_i = \beta_i * l_i \quad (10)$$

λ_i Total optimal grass intake of the i^{th} Capra

β_i Bite rate of the i^{th} Capra

l_i Reachable grazing area of i^{th} Capra

Total optimal grassing intake λ_i of Capra is depends upon the bite rate β_i and reachable grazing area l_i the reachable grazing area is modeled as,

$$l_i = rand(0\, to\, r(\chi(\psi))) \quad (11)$$

χ Grazing land type,

ψ Grazing Area

r Radius of the grazing area ψ

l Reachable area of Capra

3.1 Grazing land

Grazing land of a Capra plays an important role in optimizing the total intake of optimal grazing in the search space. Grazing land χ of Capra can be as mountain, grassland, health land, Rough pasture, Savanna, Potrero, Rangeland, etc.,

Selecting an appropriate grazing land χ leads to reduce the forage area of Capra and increasing the optimization process, hence selecting a suitable grazing land is most essential for optimization. In this modeling, forage land of Capra is assumed as $\chi = 1$ as unit circle of searching area. Length of the grazing area of the Capra is the next crucial part of NCOA towards the optimal solution so the calculation of r is modeled in section 3.2.

3.2 Modeling of length grazing area

Consider a fenced circular grazing land χ with known radius R. At the edge of this grazing land χ is a pole with a rope attached to it. At the other end of the rope a Capra has been tied and what length of rope is necessary if we want the Capra to graze over exactly *half* the area of the grazing land? The above situation is described in the fig. 1.

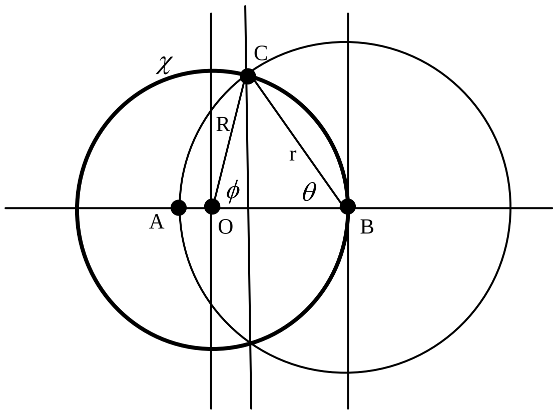

Fig 1. Grazing area of Capra

Fig 1. Describe the grazing land is represented by the circle of radius ψ through B centered at O, and the rope is attached to the fence at point B. The limit of the Capra's tether is the circle of radius r through C centered at B. The upper half of the section accessible by the Capra consists of a portion of the circle of radius r subtended by the angle θ, plus a portion of a unit circle subtended by the angle ϕ, minus the triangular region OCB. Consider a typical reachable area of Capra is equal to some specified fraction ψ (such as one half) of the area of the upper half of the grazing land χ (i.e., the upper half of the unit circle χ =1). Thus we have forgiven any fraction ψ (the fraction of the circular grazing land reachable by the Capra), we can solve this equation (19) for the angle α, and then the length of the rope for Capra (length of the grazing area) is can be written as

$$r(\chi) = \sqrt{2(1+\cos(\alpha))} \quad (12)$$

3.3 Bite Count

In the behavior of herbivorous the bite count also had been an important factor for optimal grazing intake. In study Capra has been restricted to nominal 100-150 bites in order to minimize overlapping bites and the time that belonging between the first and the last bite has been recorded [21]. From the recordings the bite number, bite rate, bite strength, bite depth, bite area, bite volume are calculated using the following formula [21].

$$\beta_i = \frac{Bite\ Count}{Time\,spent\ in\ Biting} * per\ \min. \tag{13}$$

Obvious that the NCOA algorithm has the following control factors: 1) the grazing land of the Capra 2) the maximum and minimum limit of search space of an optimization problem, which is the grazing surface of the Capra 3) the maximum rotation for the optimization termed with respect to the bite count of the Capra. Updating these three parameters towards the most effective values has a higher probability of success than in other competing meta-heuristic methods. The implementation of NCOA to ED problem is as follows:

4. Implementation of NCOAED

4.1 Reachable grazing area of NCOAED

The reachable area of NCOAED from Eq. no (11) is termed as l_{Pi}, which is determined by

$$l_{Pi} = rand(0\,to\,r(\chi(\psi))) \tag{14}$$

Selecting a fraction $\psi \in [0,1]$ (the fraction of the circular grazing land reachable by the Capra) and $\chi = 1$ as unit circle, Therefore by solving the following equation, the length of the grazing area has been calculated for generating the initial population for NCOAED problem.

$$r_P(\chi) = \sqrt{2(1+\cos(\alpha))} \tag{15}$$

4.2 Generation of initial population

Initialization of i individual population is key step of NCOAED formulated as,

$$P_{ij} = P_{ij}^{\max} * l_{Pi} \tag{16}$$

P_{ij} is the randomly generated output of the j^{th} generator in i^{th} population and l_{Pi} is a random number in the range of 0 - $r_P(\chi)$. Repeat Eq. (15) i times to create the i uniformly distributed individuals as initial feasible solutions in the search space. The resultant gives the initial population as

$$P_{ij} = \begin{bmatrix} P_{11} & P_{12} & \cdots & \cdots & P_{1j} \\ P_{21} & P_{22} & \cdots & \cdots & P_{2j} \\ \vdots & \vdots & \cdots & \cdots & \vdots \\ \vdots & \vdots & \cdots & \cdots & \vdots \\ P_{i1} & P_{i2} & \cdots & \cdots & P_{ij} \end{bmatrix} \tag{17}$$

4.3 Calculate the objective function

The total fuel cost values of all the generated individuals of Eq. (16) are calculated using Eq. (1). All individual in the population is compared and ranked against all other individuals, then the objective value of chosen individual quantifies as the best optimum solution $Pbest_{ij}$.

4.4 optimal solution: grassing intakes

Optimal solution of NCOAED is obtained from grassing intake of the Capra bite count strategies applied to the $Pbest_{ij}$ of all i individuals as,

$$P_{ij}^{new} = P_{best_{ij}} + \lambda_{Pi} \tag{18}$$

$$\lambda_{Pi} = \beta_i * l_{Pi} \tag{19}$$

Where λ_{Pi} is the optimal intake of the Capra from Eq. (18). P_{ij}^{new} The randomly generated number for the j^{th} generator in i^{th} population λ_{Pi} is a random number in the range of 0 - $r_P(\chi)$ and random bite count of 0 to 150 β_i [21] of percentage of byte count. $Pbest_{ij}$. Best optimum solution for the current bite count is obtained for all individual in the population is compared and ranked against all other individuals.

4.5 Stopping criterion

The algorithm stops when the specific grazing count is reached.

4.6 Algorithm of NCOAED

Step 1 : Read the required initial data fuel cost function constants of j^{th} thermal generating units, a_j , b_j , c_j , boundary conditions $P_j^{\min}$ and $P_j^{\max}$, fuel cost function constants of j^{th} WBG units wc_j , turbulence intensity τ , P_j^{rat} rated power of WBG, $v(\tau)$ Scale coefficient, $k(\tau)$ Index coefficient of WBG, number of generator n, population size i , number of grazing count $k_{\max}$, grazing land χ , Grazing area ψ , Bite count β_i

Step 2: Reachable Grazing area of Capra is calculated using the Eq. (15)

Step 3: Initialization: Initializing the Population P_{ij} is the randomly generated number for the j^{th} generator in i^{th} population by using Eq. (16)

Step4: Evaluate the fitness function for each individual P_{ij} using Eq. (1)

Step 5: Select the best individuals of $Pbest_{ij}$ from step 4.

Step6: Generate $P_{ij}^{\ new}$ randomly selected mutually different integers that are different from the initial population index using Eq. (24) and Eq. (25)

Step 7: Chose the best vector compared with $Pbest_{ij}$ initial vector versus best vector of $Pbest_{ij}^{\ new}$

Step 8: If the $Pbest_{ij}^{\ new}$ is the best individual vector k^{th} grazing count, repeat the step 5 to step 7 else go to step 9.

Step 9: Update the individual bite count β_i and repeat the step 5 to step 9 is repeated till the stopping criterion grazing count $k_{\max}$ is met.

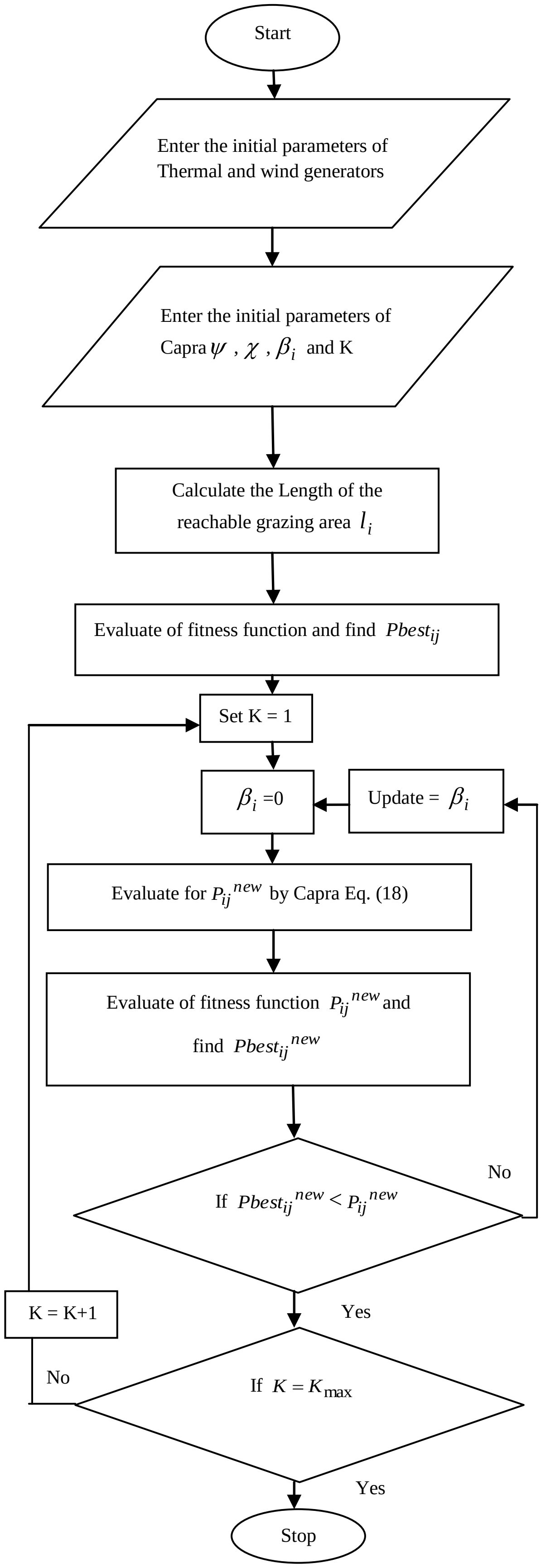

Fig 2. Flow chart of COAED

5. Numerical results and Discussions

In this section, demonstrates the robustness of the proposed NCOAED method. The proposed algorithm has been applied to solve ED problem of standard three test cases. The three different test cases: Case 1 comprises of standard 3, generating units. Case 2 and case 3 comprises of 6 and 15 generating units respectively. The proposed algorithm is carried out on a Matlab 7.0 version, Pentium P4, Core 2 duo, 2.4 GHz personal computer with 1 GB RAM memory. In this simulation, though NCOAED method tunes the sensitive parameters such as Grazing land χ , Grazing Area ψ . Initial values are assigned as,

- Grazing land $\chi = 1$ [25]
- ψ Grazing Area ψ = 0.5
- Time spent in grazing of Capra 1 minutes
- β_i Bite Count varies from 0 to 100 %. [21]
- Total number of Grazing count $K_{\max}$ = 500

ψ = 0.5 (i.e., the Capra can reach half of the grazing land), and with this value of ψ equation (1) implies that α = 1.9056957. Length of the rope is $r_p(\chi)$ = 1.1587285 times the radius of the grazing land.

5.1 Case 1

Case 1 comprises of 3, generators having quadratic cost function with valve point loadings. Maximum load demand is 300 MW.. The data for 3 generating units are taken from [2]. The transmission losses, valve point loadings and prohibited operating zones are considered for 3 generating units. The simulation result obtained by NCOAED is tabulated in Tables 2. Analyzing the data from table 2 is clearly shows that NCOAED method is effective in finding a best solution. The above statement is also confirmed by table 1 which summarizes the minimum cost, average cost and maximum cost obtained by other well-known algorithm. The minimum cost obtained by NCOAED for 3 generating units is 3609.215 which is the best cost found so far.

The analysis of table 1 comparative result demonstrates that the proposed NCOAED shows superior performance when compared to other methods reported in the literature. Table 1 lists the comparison of 3 generating units results obtained from NCOAED with recent different well-known algorithm such as T-NN [14], SARGA [22], BBO [13], and DE/BBO [13]. Test system 3 generating units consider 2 and 5 prohibited zones. The optimal cost obtained by NCOAED is 3609.215 $ which is the best optimal cost for 3 generating units found so far.

Table 1: Comparison of proposed NCOAED with different methods for 3 generating units

Method	Minimum cost ($/h)	Average cost ($/h)	Maximum cost ($/h)
T-NN[14].	3652.6000	NA	NA
SARGA [22].	3627.7100	NA	NA
BBO[13].	3620.1748	NA	NA
DE/BBO[13].	3619.7565	NA	NA
NCOAED	**3609.2150**	3609.2150	3609.2150

Table 2: The simulation result of proposed NCOAED with different methods for 3 generating units

Units	SARGA [22]	BBO [13].	NCOAED
1	192.90	207.99	214.6086
2	85.01	86.01	78.6255
3	34.08	16.07	15.9334
Total Power Output (MW)	311.99	310.07	309.1676
Transmission Loss (MW)	11.99	10.07	9.1676
Total cost ($/h)	3627.21	3620.17	**3609.215**

The convergence characteristics of NCOAED for 3 generating units are represented in fig.3 Convergence diagram clearly shows for 50 generation; Convergence graph of NCOAED has faster and superior convergence rate. Case 1 test studies proves NCOAED algorithm provides globally optimal cost, significantly enhance the searching ability, ensures the quality of average solution moreover, effectively manages the system constraints.

5.2 Case 2

Case 2 comprises of 6, generators having quadratic cost function with valve point loadings. Maximum load demand is 1263 MW. The data for 6 generating units are taken from [22]. The transmission losses, valve point loadings and prohibited operating zones are considered for 6 generating units. The simulation result obtained by NCOAED is tabulated in Tables 4. Analyzing the data from table 3 is clearly shows that NCOAED method is effective in finding a best solution. The above statement is also confirmed by table 3 which summarizes the minimum cost, average cost and maximum cost obtained by other well-known algorithm. The minimum cost obtained by NCOAED for 6 generating units is 15443.32 which is the best cost found so far.

Ttable 5 shows simulation output of 6 generating units of the proposed NCOAED shows superior performance when compared to other methods reported in the literature. Table 3 lists the comparison of 6 generating units results obtained from NCOAED with recent different well-known algorithm such as GA [24], LAM-CON[25], PSO[23], LAM-ITR[1], MPSO[26],[28] . Test system 6 generating units consider all 6generators with prohibited zones. The optimal cost obtained by NCOAED is 15443.32$ which is the best optimal cost for 6 generating units found so far.

The convergence characteristics of NCOAED for 6 generating units are represented in fig.4 Convergence diagram clearly shows for 50 generation; Convergence graph of NCOAED has faster and superior convergence rate. Case 2 test studies proves NCOAED algorithm provides globally optimal cost, significantly enhance the searching ability, ensures the quality of average solution moreover, effectively manages the system constraints.

Table 3: Comparison of proposed NCOAED with different methods for 6 generating units.

Method	Minimum cost ($/h)	Average cost ($/h)	Maximum cost ($/h)
MPSO[28]	15570.1900	NA	NA
GA[24].	15459.0000	NA	NA
LAM-CON[25].	15452.0900	NA	NA
PSO[23].	15450.0000	15454.000	15462
LAM-ITR[1].	15449.9000	NA	NA
MPSO[26].	15447.0000	15449.000	15458
NCOAED	**15443.3200**	15443.1900	15443.32

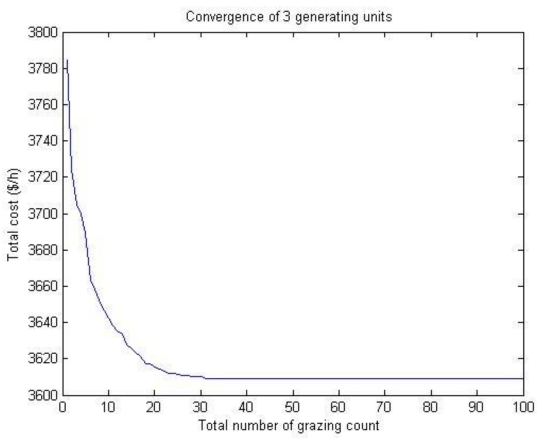

Fig 3. Flow chart of COAED

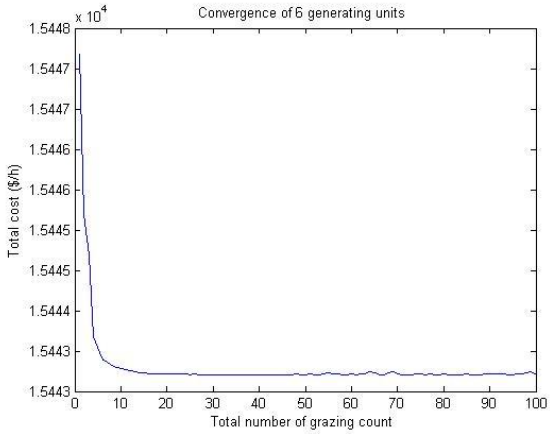

Fig 4. Flow chart of COAED

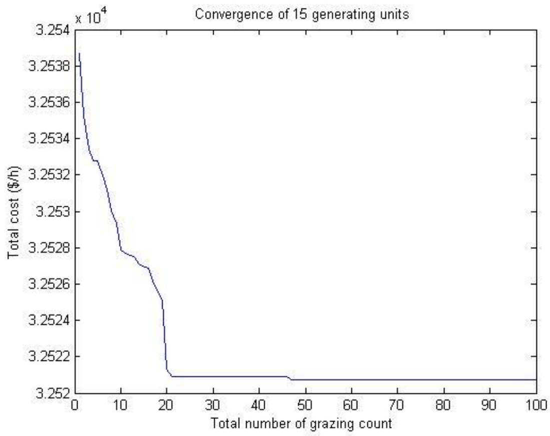

Fig 5. Flow chart of COAED

5.3 Case 3

Case 3 comprises of 15, generators having quadratic cost function with valve point loadings. Maximum load demand is 2630 MW. The data for 15 generating units are taken from [23]. The transmission losses, valve point loadings and prohibited operating zones are considered for 6 generating units. The simulation result obtained by NCOAED is tabulated in Tables 6.

Analyzing the data from table 6 is clearly shows that NCOAED method is effective in finding a best solution. The above statement is also confirmed by table 4 which summarizes the minimum cost, average cost and maximum cost obtained by other well-known algorithm. The minimum cost obtained by NCOAED for 6 generating units is 32520.7200$ which is the best cost found so far. The analysis of table 4 comparative result demonstrates that the proposed NCOAED shows superior performance when compared to other methods reported in the literature.

Table 4 lists the comparison of 15 generating units

Method	Minimum cost ($/h)	Average cost ($/h)	Maximum cost ($/h)
GA[23].	33113.0000	33228.0000	33337.0000
PSO[23].	32858.8800	33039.0000	33331.0000
SARGA[22].	32709.6300	32730.7900	32829.2300
MPSO[26].	32708.0000	32747.0000	32807.0000
ES[27].	32568.5400	32620.0000	32710.0000
LAM-CON[25].	32568.0600	NA	NA
LAM-ITR[1].	32546.2500	NA	NA
HNN[29]	32542.3000	NA	NA
NCOAED	32520.7200	32517.21	32521.52

The results obtained from NCOAED with recent different well-known algorithm such as GA [23], PSO[23], SARGA[22], MPSO[26] ES[27], LAM-CON[25], LAN-ITR[1]. Test system 15 generating units consider 2, 5, 6 and 12 prohibited zones. The optimal cost obtained by NCOAED is 32520.720$ which is the best optimal cost for 15 generating units found so far.

The convergence characteristics of NCOAED for 15 generating units are represented in fig.5 Convergence diagram clearly shows for 50 generation; Convergence graph of NCOAED has faster and superior convergence rate. Case 3 test studies proves NCOAED algorithm provides globally optimal cost, significantly enhance the searching ability, ensures the quality of average solution moreover, effectively manages the system constraints.

Table 5: The simulation result of proposed NCOAED with different methods for 6 generating units

Units	HNN[28]	LAM-CON[23]	PSO[22]	LAM-ITR[23]	MPSO[25]	NCOAED
1	395.620	449.3094	447.4970	447.5040	446.7100	443.8920
2	196.345	173.1754	173.3221	173.3183	173.0100	173.7806
3	291.857	266.1296	263.4745	263.4629	265.0000	265.6556
4	149.473	127.4070	139.0594	139.0655	139.0000	139.2175
5	181.385	174.3958	165.4761	165.4733	165.2300	165.9441
6	110.318	86.02210	87.1280	87.1346	86.7800	86.96697
Total Power Output (MW)		1276.27	1276.01	1275.96	1275.70	1275.46
Transmission Loss (MW)	9.5381	13.27	12.95	12.96	12.733	12.4598
Total cost ($/h)	15570.19	15452.09	15450.00	15449.90	15447.00	**15443.32**

Table 6: Comparison of proposed NCOAED with different methods for case3.

Units	MPSO[25]	ES[27]	LAM-CON[23]	LAM-ITR[1]	HNN[29]	SANSDE
1	455.0000	455.0000	455.0000	455.0000	455.0000	454.9139
2	380.0000	380.0000	455.0000	455.0000	455.0000	454.9139
3	130.0000	130.0000	130.0000	130.0000	130.0000	129.9139
4	130.0000	150.0000	130.0000	130.0000	130.0000	129.9139
5	170.0000	168.9200	298.2294	245.2997	317.8331	234.7583
6	460.0000	459.3400	460.0000	460.0000	460.0000	459.9139
7	430.0000	430.0000	465.0000	465.0000	465.0000	464.9139
8	60.0000	97.4200	60.0000	60.0000	60.0000	59.99865
9	71.0500	30.6100	25.0000	25.0000	25.0000	24.99865
10	159.8900	142.5600	25.0000	25.0000	20.0000	25.10149
11	80.0000	80.0000	44.9350	71.6400	20.0000	79.91388
12	80.0000	85.0000	56.4370	80.0000	87.1659	79.91388
13	25.0000	15.0000	25.0000	25.0000	25.0000	24.99865
14	15.000	15.0000	15.0000	15.0000	15.0000	14.99865
15	15.000	15.0000	15.0000	15.0000	15.0000	15.10149
Total Power Output (MW)	2660.9	2653.85	2659.60	2656.94	265000	2654.267
Transmission Loss (MW)	30.908	23.85	29.60	27.62	00.00	24.26686
Total cost ($/h)	32708.00	32568.54	32568.06	32546.25	32542.30	32520.72

6. Conclusion:

In this paper, NCOAED algorithm viably applied to standard 3, 6 and 15 generating units. The proposed algorithm has provided the best solution satisfying the constraints with good feasibility for the ED problems with transmission losses, ramp rate limits and prohibited operating zones. In addition to facilitate NCOAED being superior to the other past algorithms, the performance estimation schemes are performed such as solution quality, dynamic convergence behavior of all individual population during evolution process, computational efficiencies. It is crystal clear that the result shows the proposed algorithm is capable of obtaining more potent and standard solutions for conventional ED problems with non-linear characteristics of generators.

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