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Combined Economic Emission Dispatch using Noval Bat Algorithm in Thermal Power Plant

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Abstract:

Now a days the fossil fuels helps for power generation in which it emits contaminants like carbon dioxides and sulphur dioxide in addition to nitrogen oxides in to the air. This makes global warming and environmental contamination. The modern utilities were forced to simultaneously optimize both economy and emission targets because of public awareness environmental protection also due to the enactment of amendments (CAAA) of 1990. This paper deals with the optimization of the electrical power system in which it tend to consider a major emission with the standard constraint and the amount of fuel cost. CEED problem implies to reduce the greenhouse gases emission from the thermal power generating stations. It also tend to minimize the total fuel cost of the thermal generation in solving over all system constraints which makes the multi objective problem. This problem deals with the area of multiple criteria in which multi is converted into single objective problem through the introduction of penalty factor in terms of price, this helps in steady system performance. The solution to the problem is implemented by using "BAT Algorithm". Generating stations with 3 thermal generating units are considered as test systems for this work. The performance of the analyzed method is going to be implemented in MATLAB.

Keywords: *CEED (Combined Economic Emission Dispatch), Bat Algorithm, CAAA (Clean Air Act Amendments), Economic Load Dispatch (ELD), Economic emission dispatch (EED)*

1. INTRODUCTION

The various forms of energies generated, electrical energy is considered, that could be generated, transmitted and distributed at a reasonable cost[1]. The initial objective is to offer reliable and steady power supply to the consumers in a high quality at lowest cost by a proper electrical power generation systems. It can be possible only by a economic dispatch because of an output power optimal combination has taken into an account to lower the total fuel cost and also solving a set of major constraints[2] (equality constraints and inequality constraints).

The conventional economic power dispatch [15],[16],[20]considers only minimizing the total fuel cost and hence it doesn't meet the environmental protection requirements. To achieve an optimal solution between the objectives , considering the electric power system emission and its economics dispatch as a perfect challenging objectives. This formulates the CEED problem with an object which polish off the electric power by bringing into consideration both economic and environmental aspects.

Optimization has been of great interest in engineering[10] and is one of the best methods to use[3]. In order to manage the whole power system, the main decision were made to understand the subject area in a quantitative and precise manner by taking an effective measures for system effectiveness. Also then looking for the most acceptable and suitable criteria for system optimization[9]. Due to wide geographical changes with dispersion, there is a modern generation power systems gives a non linear characteristics[4]. Hence it requires a stable optimization technique for a complex objective function by considering few practical constraints. Hence a whole power system optimization involves with all the maximization or minimization of a certain objective function under some particular conditions.

In general, to control the modern power system, a new strategy needs to be incorporated this aids in gaining maximum benefits through valued performance with reliability[5]. All the power grid networks are examined with traditional techniques also with the cited techniques in order to deliver maximum of power from the thermal plants to the consumers. In order to overcome the major difficulties with the traditional techniques, a proper intelligent techniques[6],[7],[8] has also involved in this research. A technique which involves well-defined objective, constraint functions and their derivatives are produced to achieve a global optimal in the process of power generation management.

1.1 THERMAL POWER PLANT

Energy generation by using fossil fuels is simple, cost effective is plenty, Report from CEA (2013) states that roughly 67% of the electricity. In general India consumes power is usually generated by all the stand alone thermal power plants and the country's commercial energy demand is achieve by coal reserves of India[19] [26].

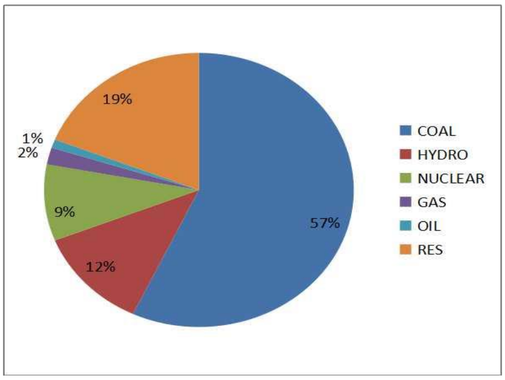

Figure.1 various forms of energy Generation in India

The main fuel source of the thermal power plants are coal, oil and natural gas. Sometimes a combustible material can also be used. Among the fuel source, it is common to change oil plants into gas plants for achieving a cost effectiveness. For a effective electricity production, it is best to use 90% of coal. Also in India, Ember is the main fuel for electrical power generation in order to satisfy the power demand needed by the country. Approximately 57% of the total powers in India which produced in plants are based on the fuel sources like coal and ignite.

The main fuel source coal is classified into anthracite, bituminous and lignite and this can be further classified as semi-anthracite, sub-bituminous and semi-bituminous. Among them Anthracite is the oldest coal which is a hard coal where it contains carbon mainly with very few volatile content. Also it has no moisture. These volatile matter are the particles which vaporize when Anthracite is ignited.

Coals such as bituminous coals and sub-bituminous coals are ideally used in industries. With the help of geological study of India report, the calorific value has been taken in 2019 which is listed in Table 1.

Coal Grade	Calorific Value Range in Kcal/Kg
A	Above 6200

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B	5600 to 6200
C	4940 to 5600
D	4200 to 4940
E	3360 to 4200
F	2400 to 3360
G	1300 to 2400

Table 1: Coal Grade and Coal Calorific Value Range

Here in India D, E and F coal grades are available. The coal combustibility is the main factor for its chemical composition. By the Geological survey of India (GSI) reports, The typical gross value of the coal in India has a less calorific value per Kg when compared with other countries. The Table 2 represents the GVC values.

Parameters (2009 report by Inventory of India's Coal resource)	Lignite (Dry without moisture)	India's Coal	Indonesia's Coal	South Africa's Coal
GCV (Kcal/Kg)	4500	4000	5500	6000

Table 2: Comparisons of Calorific Values

Analysis of coal can be done by two methods. Method one is Ultimate Analysis and the other Method is Proximate Analysis. The method one can be done with citation to the geological survey of India (GSI) in it indicates the percentage by weight of the fixed carbon, ash, volatiles and moisture content.

Parameter(2009 report by Inventory of India's Coal resource)	India's Coal	Indonesia's Coal	South Africa's Coal
Moisture	5.98	9.43	8.50
Volatile matter	20.70	20.79	23.28
Ash	38.63	13.99	17.10
Fixed Carbon	34.69	46.79	51.22

Table 3: Ultimate Analysis of coal

The ultimate analysis denoted in Table 3 is carried out by a skilled chemist in a proper lab while proximate analysis denoted in Table 4 can be defined with apparatus.

Parameters (2009 report by Inventory of India's Coal resource)	Bituminous coal (Sample I)	Bituminous coal (Sample II)	Indonesia's Coal
Moisture in (%)	5.98	4.39	9.43
Mineral matter I in (%)	38.63	47.86	13.99
Carbon in (%)	42.11	36.22	58.96
Hydrogen in (%)	2.76	2.64	4.16
Nitrogen in (%)	1.22	1.09	1.02
Sculpture in (%)	0.41	0.55	0.56
Oxygen in (%)	9.89	7.25	11.88
GCV in (Kcal/Kg)	4000	3500/	5500

Table 4 : Proximate analysis of coal

In India, the quantity of power generation is depend on the variety of fuels[25]. It also extends its zone of production with the help of natural resources. The power generation is also depends on the imported energy and population size as well as

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the electrification rate and the level and speed of development with saving.

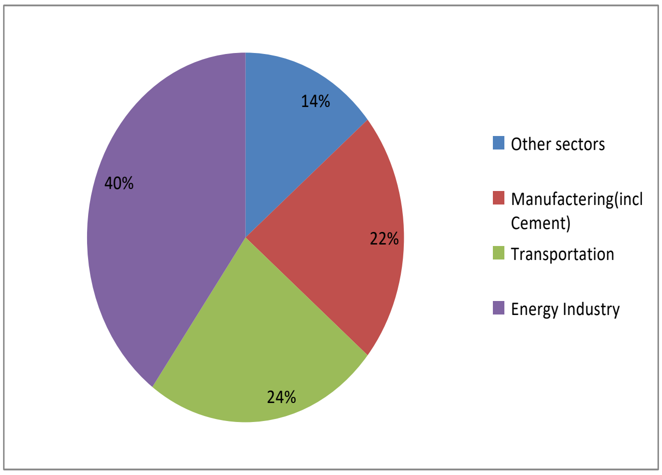

Figure 2 Causes of Environmental Pollution

It is evident that necessary steps shall be taken to reduce

1. Fuel cost of proper dispatch of generating units

2. Emission control the environmental pollution

3. Power loss

1.2 EXHAUSTS OF THERMAL POWER PLANT

In the Thermal power plants, coal's chemical energy is transformed as electric energy. Huge amount of heat, many particulate matters and ash are released when combustion of coal takes place. They are oxides of sulfur (SOx), oxides of nitrogen (NOx), and oxides of carbon (CO, CO2) which leads to emissions of hazardous air which causes pollutions. Oxides of sulfur (SOx) get oxidized to H2S04 and metallic sulfates in the air. The emission that originate through a combustion source are caused by Oxides of nitrogen (nox) which refer to the addition of both the nitric oxide (NO) and nitrogen dioxide (NO2). Most of the NOx produced during the combustion of syngas is the form of NO and it oxidized to NO2 in the air. The fugitive emission through the consequence of incomplete combustion source is caused by Oxides of carbon (Co, Co2),[23][24].

During combustion or gasification, Lead emissions are emitted from coal which are partially volatize and become enriched. Ionic spices, trace elements and organic compounds are hazardous Air Pollution from coal- fueled power plant. These trace substances are released in flue gas and solid effluents, also in aqueous discharges.

2. PROBLEM FORMULATION

The CEED problem does the following:
1. It reduces the computing objective functions (two in number)
2. It reduces the amount of fuel cost
3. It reduces the total amount of emission
4. It also meets the various equality and inequality constraints.

Generally the CEED problem is formulated as follows:

2.1 Objective function of ELD

The method of tracing the optimal output of the generators to solve the load demand in total is defined by ELD. In thermal units, the fuel cost per unit changes with the output power of the unit. The Cost of Fuels are shown in Eq.(1) as a quadratic function of output power[18].

$$F_c = \sum_{i=1}^{NG} (A_i Pg_i^{\,2} + B_i Pg_i + C_i) \qquad \text{-------→ Eq (1)}$$

The whole power generation shown in Eq.(2) should be equal to the demand and the power loss with this the minimization is performed by considering the equality constraints.

$$P_D + P_L = P_{gi} \qquad \text{-------→Eq (2)}$$

where, P_D= Load demand

P_L= Transmission loss

The total transmission loss given in Eq. (3)

$$P_L = \sum_{i=1}^{NG} \sum_{j=1}^{NG} Pg_i B_{ij} Pg_j MW \qquad \text{--------→Eq (3)}$$

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Where, B_{ij}=Loss coefficient, where these coefficients are constant and with the less fault it is acceptable. In Eq.(4), the power limits with the maximum value and minimum value of the generators considering the inequality constraints is shown.

$$Pg_i^{\min} \le Pg_i \le Pg_i^{\max}$$ ------------→ Eq (4)

For the cost function of the generators, the valve point effect[15],[16],[17] is considered with respect to practicality. Because of the wire drawing effects in each of the steam entrance valve, there is an abrupt growth in losses. Also these valve leads to the non-linear rippled input-output curve as depicted. On the basis particular rippled curve, the cost function is formed. Therefore, the cost function of the each one fossil fuel generator is applied as the amount of quadratic and a sinusoidal function [22].

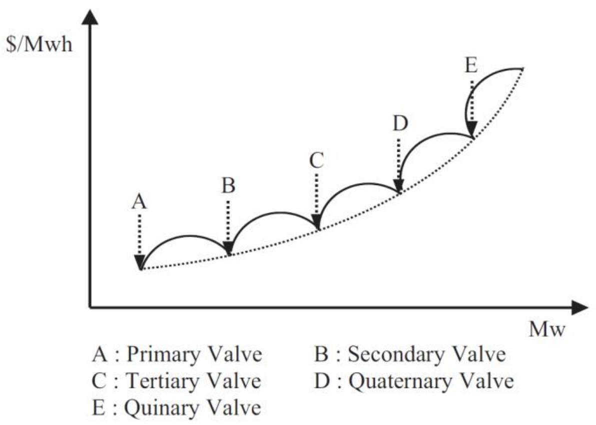

Figure 3: Valve point effect

2.1.1 Objective function of EED:

Economic emission dispatch (EED) means reduces[21] the emission content form the fossil fuel power plants like "Thermal power plants". In Economic Emission Dispatch the total emission is given by Eq. (5)

$$E_C = \sum_{i=1}^{NG} (D_i Pg_i 2 + E_i Pg_i + F_i)$$ -----------→Eq (5)

2.1.2 Objective function of CEED

Both ELD and EED are contrasting to one another. On an account that ELD minimize the fuel price by increasing the pollutants. On the other hand, the EED minimize the emission of pollutants by increasing the fuel cost. So here we need to analysis an operating point to rise a balance between fuel cost and emission rate of pollutants[9],[10]. This balance can be achieved by CEED. The CEED shown in Eq.(6) can be formulated by combining ELD and EED with the price penalty factor (*hi)* :

$$F_T = \sum_{i=1}^{NG} ((A_i Pg_i^{\,2} + B_i Pg_i + C_i) + h_i (D_i Pg_i^{\,2} + E_i Pg_i + F_i))$$ ----------→Eq (6)

The price penalty factor (hi) is the proportion between the maximum fuel cost and emission with respect to the corresponding generator in $/kg.

$$h_i = \frac{A_i Pg_i^{\,2} + B_i Pg_i + C_i}{D_i Pg_i^{\,2} + EiPg_i + F_i}$$ ---------→Eq. (7)

Steps to find Price Penalty Factor (hi) with the particular load demand:

Step 1: Find the ratio between maximum fuel cost and emission of each of the generator.

Step 2: Values should be arranged in ascending order.

Step 3: Sum up the maximum capacity of each unit of the generator *Pimax* one at a time, initiating from the smallest *hi*.

$$\sum P_i^{\max} \geqslant P_D.$$ -------→Eq. (8)

Here the price penalty factor is associated with the final unit is the approximate hi value for the used load. Hence a Price penalty factor (hi) is find the correct value for the given load demand where it interpolating the value of the price penalty factor with their load demand.

3. METHODOLOGY

BASICS OF BAT ALGORITHM

The algorithm which is proposed for optimization called as NBA which denotes a Novel Bat Algorithm. This focuses on the mimicking of the bats behavior and in the biological view, bat algorithms is improved. In this paper, basic BA incorporates with bats habitat selection and the compensation of self-adaptive for the Doppler Effect [11],[12],[13],[14].

Between the behaviors like quantum and mechanical, the bats habitat selection has been chosen and modeled. In NBA, the echo location characteristics of bats is stimulated by considering the bats self-adaptive compensation for the echoes of Doppler Effect. In NBA, a self-adaptive local search has been embedded with it. A four real-world design has demonstrate the strength, stability and efficiency of NBA has compared with simulation also comparison has been done with twenty benchmark problems of NBA to the basic BA. Some of the well-known and analyzed algorithm has been implemented to improve stability based on the biological solution with the real effective.

Xing-She Yang has developed BA in the year 2010. He considered the main characteristics are based on the echolocation behavior of microbes in the BA. Here BA uses frequency tuning which is in the fact of the initial algorithm in the forms of optimization and computational intelligence. In this each of the bat is encoded with a velocity named v_i^t at location x_i^t in an iteration *t* with *d*-dimensional search or solution space. The solution vector has considered the position to the problem of interest. In the population of n bats, the best solution has be found and can be archived during the process of iterative search.

The paper proposed by Yang deprecates the following mathematical functional equation with the updated locations x_i^t and v_i^t velocities can be shown as follows:

$$f_i = f_{\min} + \left(f_{\max} - f_{\min}\right)\beta$$ ----------→Eq. (9)

$$v_i^t = v_i^{t-1} + \left(x_i^{t-1} - x_*\right)f_i$$ ------------→ Eq. (10)

$$x_i^t = x_i^{t-1} + v_i^t$$ -----------→ Eq. (11)

Where $\beta \in [0, 1]$ represents the random vector which is identified from a uniform distribution.

The pulse emission rates can be varied and also the loudness will be varied in respect to the iterations. The equation for the varying of pulse emission rate and varying loudness is represented as shown below:

$$A_i^{t+1} = \alpha \; A_i^t$$ -----------→Eq. (12)

$$r_i^{t+1} = r_i^0\left[1 - \exp(-\gamma t)\right],$$ -----------→ Eq. (13)

Here the constants are considered to be $0 < \alpha < 1$ and $\gamma > 0$.

The summarization of the main parameters of BA are shown as below:

Step 1 : In this Initialization for the lines 1 -3 has been done means the parameters of the algorithm are initialized. Also evaluation of the population is done to determine the best solution among the population.

Step 2: Here, generation of new solution happens where the bats that are virtual has been moved according to the updating rules of BA in the search space

Step 3: This is for Local search step in lines 7 to 9. This gives the best solution which is improved by random walks.

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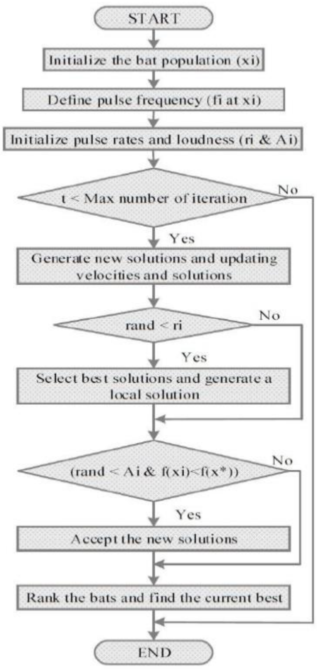
Step 4: Here, we evaluating the new solution in line 10.

Step 5: At last here we save the best solution in lines 12 to 14, where the best solution takes place with conditional archiving.

Step 6: Finding the best solution in line 25 means updating the current best solution.



The exploration and exploitation as well as genetic operators with the help of this study can be made with the fuctional primary elements with respect to BA standard as a global context. The solutions are varied locally due to the mutation's act. If the mutation become very large then it leads to global search. Because of the usage of best solution (x*) found, there will be a certain selection is under taken by using a selection pressure which are relatively constant. It shows that there is no explicit crossover when compared with genetic algorithms even though the mutation varies with respect to the variations of loud and pulse discharge. This variation provide an auto zooming ability which exploits and become intensive as a global optimal search. Therefore in an automatic manner, the phase is switched from explorative phase to an exploitative phase.

4. SIMULATION TEST RESULTS

The model which is proposed for investigating the CEED problem for three generating units.

PD = 400 MW

Hm =43.5598

P [1] = 92.5038 MW

P [2] = 162.7604MW

P [3] = 152.2252MW

Ploss = 7.4894MW

Fuel Cost = 20820.1438Rs/hr

Emission = 201.8421

Total Cost = 29863.9399Rs/hr

Generator	A Rs/MW^2 hr	B Rs/MW hr	C Rs/hr	P min in MW	P max in MW
1	0.03546	38.30553	1243.5311	90	100
2	0.02111	36.32782	1658.6592	150	170
3	0.01799	38.27041	1356.6592	140	160

Table 5 : Fuel Cost Coefficients for Three-Generator units

Generator	D lb/MW^{2}hr	E lb/MW hr	F lb/hr
1	0.00683	-0.54551	40.2669
2	0.00461	-0.5116	42.89553
3	0.00461	-0.5116	42.89553

Table 6 : Emission coefficients for Three-Generator units

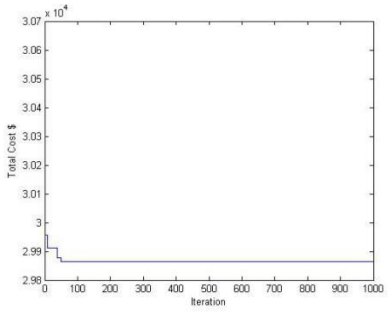


Figure 4: MATLAB output for 3-generating units

Load Demand	H_i	Performance	PSO	GA	NBA
10500	0.3185	Fuel cost, $/hr	122953.4562	122942.4367	122941.7872
		Emission, Kg/hr	195213.1394	195212.7832	195211.7507
		Power loss, MW	9.3642	9.8967	8.75318
		Total cost, $/hr	185113.8231	185108.8743	185108.2271

Table 7: Comparison of different algorithms with NBA for Three-Generating units

Load Demand	H_i	Performance	PSO	GA	NBA
400 MW	43.5598	Fuel cost, Rs/hr	20838.7291	20831.5443	20820.1438
		Emission, Kg/hr	202.1981	201.9562	201.8421
		Power loss, MW	7.503120	7.5632	7.4894
		Total cost, Rs/hr	29864.615	29864.346	29863.9399

Table 8: Comparison of different algorithms with NBA for Three-Generating units

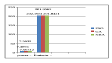


Figure 5: Comparison of power loss (MW) &Emission (Kg/hr)

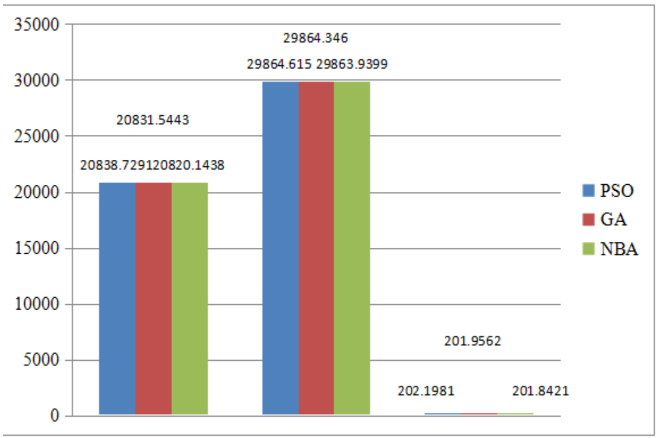


Figure 6: Comparison of Fuel cost (Rs/hr) , Total cost (Rs/hr) and Emission kg/hr

5. Conclusion

In the recent years power systems has become complex and vast. The major complexity of the electricity generating organizations is to determine a perfect solution for changing demand of electricity. To defeat the above challenge, this research study concentrates on solving the CEED problem in Power system using Novel BAT Algorithm is most important consideration in this study. Because of the drawbacks of the existing optimization techniques, there is a need for a unique, simple, effective and economical approach

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for attaining optimal solution to the power system problems.

The CEED problem has been invented with the plan as a multi objective optimization problem by taking fuel cost and emission objective saw by meeting equality and inequality constraints.

The proposed research work for finding the solution to CEED problem using optimization techniques has been simulated using MATLAB. The suggested approaches for solving CEED have been examined on three generator systems.Performance parameters taken for evaluation are fuel cost (Rs/hr), emission output (lb/hr), power loss (MW), number of iterations and commutation time (Sec)

Results retrieved from the proposed NBA have been compared with existing techniques viz. GA and PSO. By considering the overall results, it is evident that the usage of proposed technique minimizes the fuel cost as well as the emission output

The proposed NBA approach outperforms the other two proposed approaches, namely GA and PSO in terms of emission output, fuel cost,force loss, number of iterations and computation time.

Ultimately, the aim of significance for the country`s economy and environmental pollution may be accomplished with the supporter of proposed intelligent techniques for the CEED problem.

6. SCOPE FOR FUTURE WORK

In improver to the various findings and conclusions the following are some important suggestions and key recommendations for future inquiry

The further enhancement of this research work would be to increase the optimizing ability of the heuristic algorithms. The future work lies in incorporating hybrid optimization approaches

Power system optimization problem shall be considering with power system loss minimization by introducing reactive power compensation techniques. To receive a safer performance and restraint of power system, CEED problem also be regarded with the stableness of the power scheme.

Emission dispatch results shall be classified according to the pollutants and each pollutant shall be checked with allowable limits prescribed by environmental authorities.

An intensive research can be thought of in regard to the emission reduction methodologies that can be utilized to the thermal power system, to reduce CO2, sulfur dioxide and nitrogen oxides emissions.

References

[1] U. Güvença, Y. Sönmezb, S. Dumanc, N. Yörükerend, "Combined economic and emission dispatch solution using gravitational search algorithm". Applied Soft Computing , vol : 8 2008, pp- 1428–1438.

[2] Yun-Chia Liang ⇑, Josue Rodolfo Cuevas Juarez, "A normalization method for solving the combined economical and emission dispatch problem with meta-heuristic algorithms", Electrical Power and Energy Systems, vol : 54, 2014, pp – 163-186.

[3] HadiHamedi,"Solving the combined economic load and emission dispatch problems using new heuristic algorithm",Electrical Power and Energy Systems, vol : 46, 2013, pp – 10-16.

[4] Binod Shaw a,⇑, V. Mukherjee b, S.P. Ghoshalc. A novel opposition-based gravitational search algorithm for combined economic and emission dispatch problems of power systems. Electrical Power and Energy System, vol: 55(1), 2014, pp- 29-40

[5] M. Dorigo and M. Birattari.Ant colony optimization. In Encyclopedia of Machine Learning, pages 36–39. Springer, 2010

[6] Karaboga and B. Basturk. A powerful and efficient algorithm for numerical function optimization: artificial bee colony (abc) algorithm. Journal of global optimization, vol:39(3), 2007, pp-459–471.

[7] I. J. Fister, D. Fister, and I. Fister. A comprehensive review of cuckoo search: variants and hybrids. International Journal of Mathematical Modelling and Numerical

May – June 2020
ISSN: 0193-4120 Page No. 1918 - 1927

Optimisation, vol:4(4), 2013,pp- 387–409.

[8] I. Fister, I. FisterJr, X.-S. Yang, and J. Brest. A comprehensive review of firefly algorithms. Swarm and Evolutionary Computation, vol :13, 2013, pp- 34–46, 2013.

[9] J. Kennedy and R. Eberhart,"Particle swarm optimization.In Neural Networks, 1995.Proceedings., IEEE International Conference on, vol 4, 1995, pp- 1942–1948.

[10] T. Back. Evolutionary algorithms in theory and practice.Oxford Univ. Press, 1996.

[11] I. FisterJr, X.-S. Yang, I. Fister, J. Brest, and D. Fister.A brief review of nature-inspired algorithms for optimization.Elektrotehniskivestnik, 80(3):116–122, 2013.

[12] X.-S. Yang and X. He. Bat algorithm: literature review and applications. International Journal of Bio-Inspired Computation,vol: 5(3), 2013, pp - 141–149.

[13] X.-S. Yang. Bat algorithm for multi-objective optimisation. International Journal of Bio-Inspired Computation, vol:3(5), 2011,pp-:267–274.

[14] X.-S. Yang and A. H. Gandomi. Bat algorithm: a novel approach for global engineering optimization. Engineering Computations, vol: 29(5), 2012, pp-464–483.

[15] Celal Y., Serdar O, " A new hybrid approach for nonconvex economic dispatch problem with valve-point effect", Energy, vol:36, 2011, pp. 5838-5845.

[16] Srinivasa Reddy A, Vaisakh K, "Shuffled differential evolution for economic dispatch with valve point loading effects", Electrical Power and Energy Systems,vol: 46, 2013, pp. 342-352.

[17] Chatterjee A., Ghoshal S.P., Mukherjee V.**Solution of combined economic and emission dispatch problems of power systems by an opposition-based harmony search algorithm,** Electrical Power and Energy Systems, vol:39, 2012, pp. 9-20.

[18] Adarsh B.R., Raghunathan T., Jayabarathi T., Xin-She Y.**Economic dispatch using chaotic bat algorithm",** Energy,vol: 96, 2016, pp. 666-675.

[19] Sudhir Y, Rajiv P,"**Status and Environmental Impact of Emissions from Thermal Power Plants in India",** Environmental Forensics,vol: 15,2014, pp. 219-222.

[20] Lin C.E., Chen S.T., Huang C.L,"**A Direct Newton-Raphson Economic Dispatch",** IEEE Transactions on Power Systems, 7 (3) (1992), pp. 1149-1154

[21] Kulkarni P.S., Kothari A.G., Kothari D.P,"**Combined Economic and Emission Dispatch Using Improved Backpropagation Neural Network",** In: Taylor & Francis, Electric Machines & Power Systems, vol: 28 (1), 2010, pp. 31-44.

[22] Al-Sumait J.S., AL-Othman A.K., Sykulski J.K,"Application of pattern search method to power system valve-point economic load dispatch, Electrical Power and Energy Systems, vol:29, 2007, pp. 720-730.

[23] TIANCAI WANG, XING HE,TINGWEN HUANG, CHUANDONG LI,"WEI ZHANGCOLLECTIVE NEURODYNAMIC OPTIMIZATION FOR ECONOMIC EMISSION DISPATCH PROBLEM CONSIDERING VALVE POINT EFFECT IN MICROGRID ", INTERNATIONAL JOURNAL ON NEURAL NETWORKS , VOL:93, 2017, PP 126-136.

[24] IMRAN rAHMAN, Junitha mohamed-salesh,''Hybrid bio-Inspired computational intelligence techniques for solving power system optimization problems: A comprehensive survey", Applied soft computing, vol: 69, 2018, pp 72-130

[25] Hamid Rezaie, M.H. Kazemi-Rahbar, Behrooz Vahidi, Hasan Rastegar ,"Solution of combined economic and emission dispatch problem using a novel chaotic improved harmony search algorithm" , *Journal of Computational Design and Engineering*, Volume 6, Issue 3, July 2019, Pages 447–46.

[26] SRIKANTH REDDY K, LOKESH KUMAR GRAHI B K RAJESH KUMAR, AMEENA ALSUMAITI , "BINARY GREY WOLF OPTIMIZER MODELS FOR PROFIT BASED UNIT COMMITMENT OF PRICE-TAKING GENCO IN ELECTRICITY MARKET", SWARM AND EVOLUTIONARY COMPUTATION, VOL 44, 2019,PP 957-971.