Kufa Journal of Engineering
Vol. 10, No. 4, October 2019, P.P. 89-105
Received 21 July 2019, accepted 20 October 2019

A REVIEW OF META-HEURISTIC APPROACHES FOR SOLVING OPTIMAL POWER DISPATCH PROBLEMS IN POWER NETWORKS

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http://dx.doi.org/10.30572/2018/kje/100408

ABSTRACT

Increase in geometrical trend in the demand for electrical energy, in addition to large interconnections, has increased the operational and structural complexities of modern power systems. Improved performance in modern power systems as well as enhanced reliability without sacrificing the integrity of the network at a minimum operating cost is, therefore, of great concern to power system utilities researchers and engineers. In addition, there has been a rapid development in the integration of renewable energy sources into the conventional power systems and various hybrid generating plants, in modern power systems, have emerged. In solving the EDP in modern power systems, due to the existence of non-convexity in the problem, the capability derived in the meta-heuristical-based methods have been extensively explored in recent times. This paper, therefore, presents a comprehensive review of various meta-heuristic approaches through which the solution to economic dispatch problems could be effectively provided.

KEYWORDS: Economic dispatch problem, renewable energy sources, meta-heuristic approach, lambda iteration, operating costs.

1. INTRODUCTION

Considering the consistently increasing interest for electrical energy, shortage of energy resources, and expanding fuel costs, ensuring dependable and economical supply of electricity is a developing interest (Abbas *et al.*, 2017; Singh and Sharma, 2017). Electrical power is a distinctive item in that it cannot by and large be stored in huge scale at a reasonable expense (Mehta and Mehta, 2005). So, utility companies operating the transmission grid need to make arrangements and take activities to ensure demand and supply are coordinated progressively. The objective of engineers in power system planning and operation is to give a reliable supply of electrical power at the most conservative expense (Maskar, Thorat and Korachgaon, 2017). Numerous factors, however influence the total generating cost. Fuel costs can vary, particularly amid times of high demand. Also, each power plant has construction, maintenance, and operating costs (Sunny Orike, 2013; Haruna *et al.*, 2017). This challenge of allocating the required load demand between the available generation units such that the cost of operation is at a minimum can however be appropriately addressed by considering Economic Dispatch (ED). Economic Dispatch determines the ideal yield of various generating unit to meet the load demand of the system, at the most minimal possible cost, subject to transmission and operational constraints (Suman *et al.*, 2016; Chauhan, Jain and Verma, 2017). The outputs of all the committed units in the power system are scheduled such that the total cost of generation is minimized while all system equality and inequality constraints imposed are satisfied (Moosavian *et al.*, 2016). To achieve this, Economic Dispatch (ED) submits on-line generators to fulfil power demand at a minimum cost while additionally satisfying all system constraints (Saka *et al.*, 2017; Dash, 2018).

Economic dispatch problem is formulated as a non-linear programming optimization problem in which the fundamental goal is to determine the optimal schedule of online generators in order to satisfy the power demand at least operating cost under different operating constraints and working limitations. The significance of economic dispatch is to get maximum usable power utilizing least resources (Singh and Sharma, 2017). To satisfy the power demand at the very least total cost, economic dispatch ensures an optimum combination of the generators connected to the system with the set of generators having the most minimal operating costs are utilized first. The output power of online generators is varied within the limits and fulfils the load demand with less fuel cost.

Numerous attempts have been made, based on the existing literature, for providing an effective solution to the economic dispatch issues through a few strategies in recent times.

The optimization strategies are classified as classical, meta-heuristic and hybrid techniques. The classical methods are the conventional/traditional approaches to solving economic dispatch problems while the meta-heuristic methods are developed to manage the non-convex and overcome the limitations identified with the traditional approach. The hybrid methods are the combination of the methods from the previous groups which ordinarily perform superior to the individual techniques (Moosavian *et al.*, 2016).

Modern power systems have witnessed rapid development as a result of high penetration of renewable energy sources. Consequently, there has been an increasing interest in meta-heuristic methods in solving EDP within the scientific communities. Most power system researchers have, therefore, shifted their interest from the conventional-based approaches to meta-heuristical-based approaches in providing an effective solution to the EDP.

This paper, therefore, presents a comprehensive review on the patterns in the current trends of the meta-heuristic approaches for resolving various issues on the EDP in power networks. The remainder of the paper is organized as follows: Section 2 presents the mathematical formulations for the problem based on the conventional approach. A comprehensive review of different approaches to ED problems, with the main focus on heuristic-based approaches, is presented in section 3 while the study is concluded in section 4.

2. METHODOLOGY

2.1. Mathematical formulations

Consider an electrical power system network having n number of generators with a given power demand of P_D. For every plant i, the cost C_i in \$/hour is represented as a function of its generation level P_{Gi} (the 3phase power) using its cost-rate curve. The actual power generation P_{Gi} is allotted to generators with the goal that total cost of generation is minimized.

Traditionally, the EDP is usually viewed and formulated as a nonlinear optimization problem. The main aim of providing solution to an EDP is to provide an effective estimation of the optimal operating cost of power generation subjected to various system constraints. The cost function, in terms of the active power, in the network is expressed as

$$C_i(P_{Gi}) = a_i P_{GI}^2 + b_i P_{Gi} + c_i \tag{1}$$

The total system cost is therefore given by

$$C_T = \sum_{i=1}^{n} C_i(P_{Gi}) \tag{2}$$

The fundamental generation dispatch problem can be formulated mathematically as a minimization problem of the total fuel cost of all available and committed plants subject to the constraints. This total fuel cost function in terms of the active power is given in equation (2). Hence, the objective function to be minimized can be restated as

$$Minimize \quad \sum_{i=1}^{n} C_i(P_{Gi}) \tag{3}$$

where $C_i(P_{Gi})$ is the fuel cost expression for the i^{th} generator unit.

The objective function as expressed in equation (3) is usually minimized subject to two main sets of constraints. These constraints are as follows:

i. The power balance equality: In regards to power balance, it must be the case that the total generation equals the total demand P_D plus the total losses P_L.

$$\sum_{i=1}^{n} P_{Gi} = P_D + P_L \tag{4a}$$

The losses P_L depend on the flows in the circuits, and the flows in the circuits depend on the generation dispatch. Therefore we represent this dependency according to the equation below.

$$\sum_{i=1}^{n} P_{Gi} = P_D + P_L\left(P_{G1}, P_{G2}, ..., P_{Gn}\right) \tag{4b}$$

ii. Active power constraints: Generation limits exist as generators cannot operate above their maximum capabilities, represented as $P_{Gi}^{\max}$. And clearly, they cannot operate below their minimum capabilities, represented as $P_{Gi}^{\min}$.

$$P_{Gi}^{\min} \le P_{Gi} \le P_{Gi}^{\max} \quad (i = 1,2,..., n) \tag{5a}$$

$$P_{Gi} = |V_k| \sum_{n=1}^{N} |Y_{kn}||V_n| \cos\left(\theta_{kn} + \partial_n - \partial_k\right) \\ k = 1,2,\ldots, N \tag{5b}$$

The B-coefficients B_{ii} are used to express transmission loss as a function of generators active power. An approximate loss formula is expressed as (Saadat, 2010).

$$P_L = \sum_{i=1}^{n} B_{ii} P_{Gi}^2 \tag{6}$$

3. REVIEW OF SOLUTION APPROACHES TO ECONOMIC DISPATCH PROBLEMS

This section reviews relevant studies as applied to various existing approaches being explored by different researchers in resolving various Economic Dispatch (ED) issues in power system networks. Various optimization approaches to ED problems can be grouped into Classical-based methods, Meta-heuristical-based Method and Hybrid-based technique. Although, the three classifications are considered in this paper, more attention is paid to the use of meta-heuristic approaches as presented in the sub-sections that follow.

3.1. Conventional-based approaches

Many researches have been published on existing approaches for solving optimal dispatch problem and documented in the open literature. For instance, Chauhan, Jain and Verma (2017) tackled the optimal dispatch problem by lambda iteration method using MiPower version 9. A solution based on the Newton's method utilizing a closed form expression for the calculation of the Lambda is presented by Ramanathan (1985). Also, Dike, Adinfono and Ogu (2013) proposed a modified lambda-iteration method. Furthermore, Xing et al. (2017) explored the use of distributed augmented lambda-iteration method. The proposed method when compared with the conventional lambda-iteration method presented a better result as it model avoided unnecessary oscillatory behaviour often exhibited by conventional lambda-iteration method.

3.2. Meta-Heuristic-based approaches

Particle swarm optimization (PSO), presented by James Kennedy and Russell Eberhart in the year 1995, is a nature-inspired metaheuristic-based optimization algorithm (Mahor, Prasad and Rangnekar, 2009; Abbas et al., 2017). It was conceptualized by an assortment of creature social conduct like flocking of flying creatures, schooling of fishes, and so on while searching for food. PSO was proposed by Gaing in 2003 for unwinding the issue of economic dispatch (ED) in power systems (Gaing, 2003). Nonlinear characteristics of the generator were seen using the proposed technique in practical generator operation. His results exhibited that the proposed strategy provides for efficient solution to ED problems. Dash (2018) consolidated Moderate Random Search Strategy with Particle Swarm Optimization (MRSPSO) in taking care of ED issue on a six generator system with ramp rate limit requirements and valve point loading impact. The technique is found to create a better outcomes. Another variation based PSO called Time Varying Acceleration Coefficients (TVAC) is applied by Hamed and Mahdad (2012) to tackle economic dispatch problem. A modified PSO algorithm is explored by Rizwana et al. (2015) to oversee economic dispatch problem with transmission losses on a 3-unit generating system. Results obtained showed that power losses are drastically reduced. Jaini et al. (2010) developed PSO with one of the accelerating coefficients being constant to take care of ED problem. The outcomes obtained uncovers that the proposed strategy has the ability in accomplishing optimal solution for tending to the issue. According to the study presented by Jobanputra and Kotwal (2018), a PSO approach is applied to solve the ED problem with a consideration given to transmission line restrains using a system with 10 generating units as a case study. Results obtained demonstrated a decrease in total system losses and decrease in total generation cost with constrained transmission line flow limits. Sarstedt, Garske and Hofmann (2018) also applied the approach of PSO to solve an Economic Optimal Reactive Power Dispatch (EORPD) problem. Thakur et al. (2006) in (Thakur et al., 2006) also employed PSO to tackle Combined Economic and Emission Dispatch (CEED) problem. The results obtained demonstrated that the PSO gives a balanced outcome between emission and cost of generation. Manojkumar and Singh (2018) in (Manojkumar and Singh, 2018) built up a multi-objective particle swarm optimization technique for the solution of CEED problem with thought given to both equality and inequality constraints. Economic dispatch and emission dispatch are treated as conflicting objectives. Results obtained showed a minimize generation cost as well as emission at the same time. Yu and Chung (2011) presented Multiple Particle Swarm Optimization (MPSO) algorithm for solving multi-objective ED problem. Results got outlines that the proposed strategy can provide solutions with reasonable performance. In (Varma, Murthy and Srichandan, 2013), Gaussian PSO technique was presented for solving the CEED problem. The outcomes acquired demonstrated better convergence contrasted with those obtained by general PSO strategy. In (Sharma and Vadhera, 2017), a Particle Swarm Optimization (PSO) method with Gravitational Search Algorithm (GSA) for solution to economic load dispatch problem is presented. GSA showed quicker convergence and better search proficiency when contrasted with PSO. This is makes it an excellent optimization technique in providing an efficient solution to economic load dispatch problem.

Chen and Chang (1995) presented Genetic Approach (GA) to deal with ED problem in large-scale systems. The approach is evaluated on Taipower system and results obtained displayed faster convergence than the traditional lambda-iteration method in large-scale systems. The study presented in (Adhinarayanan and Sydulu, 2008) explored the use of a directional search Genetic Algorithm (GA) approach to deal with ED problem with prohibited operating zones. The methodology was demonstrated using 15-unit and 40-units test cases. Results obtained demonstrated that the strategy yields a genuine optimal solution with no convergence issue. In (Nasiruzzaman and Rabbani, 2008), GA was executed with fuzzy logic for solving economic dispatch problem. The proposed algorithm displayed better results in terms of convergence and computational time contrasted with basic GA based method. Genetic algorithm based optimization approach is utilized in (Khosa, Zia and Bhatti, 2015) for ED issue constrained by stochastic wind power. Result obtained showed stable convergence. The work of Tyagi, Verma and Saxena (2015) presented Gray Coded Genetic Algorithm (GGA) for economic dispatch (ED) problem. It is observed that GGA demonstrated lesser number of fitness function evaluations and better convergence qualities. In (De et al., 2017) a Real Coded Genetic Algorithm (RCGA) for achieving optimal solution in Economic Dispatch (ED) problem is introduced. The optimization problem is developed as a single-objective problem satisfying both equality and inequality constraints. Simulation results demonstrated improved solution by the proposed technique. In (Chellappan and Kavitha, 2017), Genetic Algorithm (GA) was combined with Cuckoo Search Algorithm (CSA) to take care of optimal dispatch problem. Results acquired with these strategies showed quality convergence.

In (Abdullah et al., 2016), Firefly Algorithm (FA) was presented with consideration given to transmission losses. The results of the proposed technique showed better convergence. λ-logic based algorithm was developed in (Adhinarayanan and Sydulu, 2007) with a number of the on-line generator units having constrained operating zones. Results obtained showed that the proposed strategy is proficient for generator units with restricted operating regions and reduced calculation time. In (Bhongade and Agarwal, 2016), Artificial Bee Colony (ABC) is exhibited to solve the Combined Economic and Emission Dispatch (CEED) problem. Results showed that ABC is a powerful algorithm with great convergence characteristics. A novel charged system search algorithm is presented in (Zhang, Chen and Lee, 2018) for solution to optimal reactive power dispatch problem. Results obtained showed that the algorithm provided an answer with fast convergence rate. In (Dasgupta and Banerjee, 2014), Backtracking Search Algorithm (BSA) algorithm was presented on ED problem with Prohibited Zone constraints. Results obtained showed that the technique displayed great tuning characteristics by which it converges to an optimal solution. The work of Sun and Cui

(2014) applied Hysteretic Noisy Chaotic Neural Network (HNCNN) to economically dispatch power within the network. It is shown based on the results obtained that the algorithm is proficient in acquiring optimal solution. Back-propagation neural networks was applied to ED problem in (Panta and Premrudeepreechacham, 2007). The solutions compared with the Lambda iteration method demonstrated better exactness in reduced computation time.

The use of Simulated Annealing (SA) technique for solution to ED problem with multi-objective functions is demonstrated and presented in (Avinaash et al., 2013). Results achieved demonstrated that SA is an effective evolutionary based meta-heuristic approach to handle multi-objective ED problem. Vanitha and Thanushkodi (2012) presented Efficient Hybrid Simulated Annealing (EHSA) algorithm to tackle non-convex economic load dispatch (ELD) problem. The proposed methodology was executed considering constraints such as generator constraints, transmission loss, ramp rate limits and prohibited operating zones. The results obtained showed minimal operating cost with minimum transmission loss and better convergence speed. Chanda, Maity and Banerjee (2017) employed Biogeography Based Optimization (BBO) in providing solution to economic dispatch problem with thought given to linear and non-linear constraints. BBO algorithms showed superior convergence characteristics in comparison with other techniques. In (Chandram, Subrahmanyam and Sydulu, 2008), Brent technique which includes the selection of incremental fuel costs is utilized in taking care of ED problem with transmission losses. Results obtained demonstrated that the proposed technique gives quality solution with less computational time compare to the lambda iterative method. The study presented in (Dhivya and Vigneswaran, 2013) tackled ED problem using Primal-Dual Interior Point Algorithm (PDIP). The outcomes got showed fast over lambda iterative method. A Differential Evolution programming based on lambda iterative approach to obtain economic scheduling is also proposed by Visali, Reddy and Reddy (2014). The analysis is carried out with the inclusion of transmission losses and the results indicated reduced generation cost.

The work of Ghosh et al. (2018) documented in (Ghosh et al., 2018) developed Teaching Learning Based Optimization (TLBO) technique to handle linear and non-linear constraints. The outcomes of the study showed good convergence characteristics. In (Guang, 2018), Fruit Fly Optimization Algorithm (FOA), for optimal economic dispatch of generators, is presented. The results demonstrated the effectiveness of the proposed methodology in resolving ED issues. Model Predictive Control (MPC) method has also been proposed by Gui, Kim and Chung (2013) to solve economic dispatch problem. Results obtained showed that the proposed method is effective in providing optimal solution to ED problems. In (Zhang et al., 2005), Weighted Ideal point Method (WIM) is proposed to solve the ED problem. Experimental results demonstrate that the proposed technique is efficient in solving ED problem. Furthermore, Kumar et al. (2017) presented Bat Algorithm as a solution to ED problem. The proposed algorithm minimized both fuel cost and emission simultaneously. In (Liang et al., 2017), Bat Algorithm and chaotic map approach were combined to handle multi-objective ED problem. Simulation results obtained indicated good characteristic of the hybrid optimization technique. Authors of Mostafa, Abdel-nasser and Mahmoud (2018) presented Grey Wolf Optimization (GWO) technique with mutation operators to provide an optimal solution for ED problem. In (Mohamed et al., 2018), Stochastic Whale Optimization (SWO) method is proposed to solve the economic dispatch problem. The obtained simulation results demonstrate the high efficiency compared with the GWO. Pandi and Abraham (2009) presented Improved Harmony Search (IHS) algorithm. The methodology takes care of equality and inequality constraints. The results obtained showed the efficiency of the algorithms over other reported methods. In (Rahmat, Musirin and Othman, 2012), Differential Evolution Ant Colony Optimization (DEACO) was presented to solve ED problem. Several parameters including the number of ants and nodes were manipulated to investigate the behaviour of the algorithm. The algorithm demonstrated quicker convergence.

3.3. Hybrid-based approaches

In (Santra et al., 2015), Particle Swarm Optimization (PSO) is combined with Ant Colony Optimization (ACO) as PSO-ACO, to solve the economic load dispatch problem. The hybrid method showed improved results. Sen and Mathur (2016) proposed an amalgamation of three meta-heuristic algorithms – the Ant Colony Optimization (ACO), Artificial Bee Colony (ABC) and Harmonic Search (HS) algorithms, and hence the name ACO-ABC-HS algorithm, for solving the ED problem. The technique provides an alternative solution in addition to other beneficial highlights like quick convergence rate and capacity to handle discontinuous cost functions. Hybrid Particle Swarm Optimization Combined Simulated Annealing Method (HPSAO) is presented in (Wang et al., 2010) to take care of ED problem. The methodology was tried on three Gorges hydroelectric plant. Results acquired demonstrated that HPSAO has quicker convergence capacity. In (Vanitha and Thanushkodi, 2013) Efficient Biogeography Based Optimization (EBBO) algorithm, which is a blend of PSO, DE and Biogeography Based Optimization (BBO), is proposed. The combined methodology is applied to a test system with 40 thermal units. Results obtained demonstrated the capability of the technique in providing a solution with better convergence speed as compared with individual methodology. Chiang (2017) proposed a Cuckoo Search Algorithm with Multiplier Updating Technique (CSA-MUT) to deal with ED problem of power system. Results obtained showed that the suggested approach has improved optimal characteristic. In (Ding et al., 2014), Mixed Integer Quadratic Programming (MIQP) method was applied to ED problem with disjoint prohibited zones. The results obtained from the numerical illustration of the approach showed that the proposed strategy provides a simple and significant computational improvement over the existing methods. MIQP is further improved in (Pourakbari-kasmaei et al., 2015) to Unambiguous Distance-Based Mixed-Integer Quadratic Programming (UDB-MIQP) model for solving ED problem. The methodology displayed reduced computational time and lesser difficulty. In 2017, Bratati et al. (Bratati et al., 2017) presented Krill Herd optimization technique to take care of ED problems having valve-point loading effect. Results obtained showed a significant improvement in the solution for practical situations.

3.4. Comparison of approaches

Based on the comprehensive review of the relevant literature studies in the areas of EDP, carried out in this paper, it can be concluded that various efficient techniques have been presented in open literature. Most of these methods compare well with each other. For example, Back Propagation Neural Network (BPNN) method compares well with Lambda iteration method in solving ED problem. Though, the results obtained through BPNN are more accurate the disparity in the accuracy is not significant and therefore can be ignored. The study carried out by the authors of (Alayande, Olowolaju and Okakwu, 2019) has also presented a comparison of results obtained based on Lambda iteration and PSO technique. From the results obtained, both methods are seen to be cost effective with the PSO demonstrating high convergence characteristics. Authors of (Çam, Eke and Arıkan, 2018) proposed Genetic Algorithm to be better than Artificial Bee Colony Algorithm in terms of emission output for solving ED problem. It can therefore be concluded that each of the approaches has its merits and demerits in providing solution to the EDP within modern power systems.

4. CONCLUSION

In this paper, a comprehensive review of studies, on various approaches for resolving economic dispatch problems in power systems, has been presented. Different approaches have been considered in this paper. The approaches considered are sectioned into Classical approaches, Meta-Heuristic approaches and Hybrid approaches with the main focus being on the Meta-heuristic approaches.

5. REFERENCES

Abbas, G. *et al.* (2017) 'Solution of an Economic Dispatch Problem through Particle Swarm Optimization : A Detailed Survey – Part I', *IEEE Access*, 5, pp. 15105–15141. doi: 10.1109/ACCESS.2017.2723862.

Abdullah, M. N. *et al.* (2016) 'Firefly Algorithm for Solving Non-Convex Economic Load Dispatch Problem', in *4th IET Clean Energy and Technology Conference (CEAT 2016)*. Kuala Lumpur, Malaysia.

Adhinarayanan, T. and Sydulu, M. (2007) 'Reserve Constrained Economic Dispatch with Prohibited operating zones using " λ -logic " based Algorithm', in *2007 IEEE Power Engineering Society General Meeting*. Tampa, FL, USA.

Adhinarayanan, T. and Sydulu, M. (2008) 'A Directional Search Genetic Algorithm to the Economic Dispatch Problem with', in *2008 IEEE/PES Transmission and Distribution Conference and Exposition*. Chicago, IL, USA: IEEE.

Alayande, A. S., Olowolaju, J. T. and Okakwu, I. K. (2019) 'Solving Optimal Generation Dispatch Problem In Power Networks Through PSO AND Lambda Iteration Techniques', *Nigerian Journal of Technology (NIJOTECH)*, 38(1), pp. 165–176.

Avinaash, R. *et al.* (2013) 'Simulated Annealing Approach to Solution of Multi-Objective Optimal Economic Dispatch', in *2013 7th International Conference on Intelligent Systems and Control (ISCO)*. Coimbatore, India: IEEE.

Bhongade, S. and Agarwal, S. (2016) 'An Optimal Solution for Combined Economic and Emission Dispatch problem using Artificial Bee Department of Electrical Engineering', in *2016 Biennial International Conference on Power and Energy Systems:Towards Sustainable Energy (PESTSE)*.

Bratati, G. *et al.* (2017) 'Krill Herd Algorithm Solution for the Economic Emission Load Dispatch in Power System Operations', in *7th International Conference on Power Systems (ICPS)*. Pume, India: IEEE, pp. 737–742.

Çam, E., Eke, İ. and Arıkan, Y. (2018) 'New Optimization Algorithms for Application to Environmental Economic Load Dispatch in Power Systems', *Electrica*, 18(2), pp. 133–142. doi: 10.5152/iujeee.2018.1825.

Chanda, C. K., Maity, D. and Banerjee, S. (2017) ‘Economic Dispatch Solution for Cogeneration Unit Assisted By Biogeography Based Optimization Algorithm in Competitive Environment’, in *2017 Australasian Universities Power Engineering Conference (AUPEC)*. IEEE.

Chandram, K., Subrahmanyam, N. and Sydulu, M. (2008) ‘Brent method for Dynamic Economic Dispatch with Transmission Losses’, in *2008 IEEE/PES Transmission and Distribution Conference and Exposition*. Chicago, IL, USA: IEEE.

Chauhan, G., Jain, A. and Verma, N. (2017) ‘Solving economic dispatch problem using mipower by lambda iteration method’, in *Proceedings - 1st International Conference on Intelligent Systems and Information Management, ICISIM 2017*. Aurangabad, India: IEEE, pp. 95–99. doi: 10.1109/ICISIM.2017.8122155.

Chellappan, R. and Kavitha, D. (2017) ‘Economic and Emission Load Dispatch using CUCKOO Search Algorithm’, in *International Conference on Innovations in Power and Advanced Computing Technologies [i-PACT2017]*.

Chen, P. H. and Chang, H. C. (1995) ‘Large-scale economic dispatch by genetic algorithm’, *IEEE Transactions on Power Systems*, 10(4), pp. 1919–1926. doi: 10.1109/59.476058.

Chiang, C. (2017) ‘Power Economic / Eenvironmental Dispatch Problem Using Cuckoo Search Algorithm’, in IEEE (ed.) *2017 4th International Conference on Systems and Informatics (ICASAI)*. Hangzhou, China, pp. 397–400.

Dasgupta, K. and Banerjee, S. (2014) ‘An Analysis of Economic Load Dispatch using Different Algorithms’, in *Proceedings of 2014 1st International Conference on Non Conventional Energy (ICONCE 2014)*. Kalyani, WB, India: IEEE, pp. 216–219.

Dash, P. M. (2018) ‘Economic Load Dispatch using Moderate Random Search PSO with Ramp Rate Limit Constraints’, *2018 Technologies for Smart-City Energy Security and Power (ICSESP)*. IEEE, pp. 1–4.

De, D. *et al.* (2017) ‘Economic Load Dispatch By Optimal Scheduling of Generating Units using Improved Real Coded Genetic Algorithm’, in *2017 8th Annual Industrial Automation and Electromechanical Engineering Conference (IEMECON)*. Bangkok, Thailand: IEEE, pp. 305–308.

Dhivya, S. and Vigneswaran, T. (2013) 'Primal Dual Interior Point Algorithm for Constrained Economic Load Dispatch and Optimal Power Flow', in *2013 International Conference on Power, Energy and Control (ICPEC)*, pp. 360–365.

Dike, D. O., Adinfono, M. I. and Ogu, G. (2013) 'Economic Dispatch of Generated Power Using Modified Lambda- Iteration Method', *IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)*, 7(1), pp. 49–54.

Ding, T. *et al.* (2014) 'Big-M Based MIQP Method for Economic Dispatch With Disjoint Prohibited Zones', *IEEE Transactions on Smart Grid*, 29(2), pp. 976–977.

Gaing, Z. L. (2003) 'Particle swarm optimization to solving the economic dispatch considering the generator constraints', *IEEE Transactions on Power Systems*, 18(3), pp. 1187–1195. doi: 10.1109/TPWRS.2003.814889.

Ghosh, A. *et al.* (2018) 'Economic Dispatch Solution for Cogeneration Unit Assisted By Bare Bones Teaching Learning Optimization Technique', in *2018 National Power Engineering Conference (NPEC)*. IEEE.

Guang, C. (2018) 'Optimal sitting and parameter selection for fault current limiters considering optimal economic dispatch of generators', in *2018 13th IEEE Conference on Industrial Electronics and Applications (ICIEA)*. IEEE, pp. 2084–2088.

Gui, Y., Kim, C. and Chung, C. C. (2013) 'Economic Dispatch for Wind Farm Using Model Predictive Control Method', in *2013 13th International Conference on Control, Automation and Systems (ICCAS 2013)*. Gwangju, Korea, pp. 1836–1839.

Hamed, M. and Mahdad, B. (2012) 'Solving Combined Economic Emission Dispatch Problem Using Time Varying Acceleration Based PSO', in *2012 11th International Conference on Environment and Electrical Enginering*. Venice, Italy: IEEE.

Haruna, Y. S. *et al.* (2017) 'Optimal Economic Load Dispatch of the Nigerian Thermal Power Stations Using Particle Swarm Optimization (PSO)', *The International Journal Of Engineering And Science (IJES)*, 6(1), pp. 17–23.

Jaini, A. *et al.* (2010) 'Particle Swarm Optimization (PSO) Technique in Economic Power Dispatch Problems', in *2010 4th International Power Engineering and Optimization Conference. (PEOCO)*. Shah Alam, Malaysia: IEEE.

Jobanputra, J. and Kotwal, C. (2018) ‘Optimal Power Dispatch using Particle Swarm Optimization’, in *2018 International Conference on Smart Electric Drives and Power System (ICSEDPS)*. Nagpur, India: IEEE, pp. 157–161.

Khosa, F. K., Zia, M. F. and Bhatti, A. A. (2015) ‘Genetic Algorithm Based Optimization of Economic Load Dispatch Constrained by Stochastic Wind Power’, in *2015 International Conference on Open Source Systems and Technologies (ICOSST*, pp. 36–40.

Kumar, G. R. *et al.* (2017) ‘Multi-Objective Optimal Economic Emission Power Dispatch using Bat Algorithm’, in *International Conference on Innovations in Power and Advanced Computing Technologies [i-PACT2017]*.

Liang, H. *et al.* (2017) ‘A Multiobjective Chaotic Bat Algorithm for Economic and Emission Dispatch’, in *2017 Chinese Automation Congress (CAC)*. Jinan, China: IEEE.

Mahor, A., Prasad, V. and Rangnekar, S. (2009) ‘Economic dispatch using particle swarm optimization : A review’, 13, pp. 2134–2141. doi: 10.1016/j.rser.2009.03.007.

Manojkumar, T. and Singh, N. A. (2018) ‘Solution of Environmental / Economic (EED) Power Dispatch problem using Particle Swarm Optimization Technique’, *2018 International Conference on Control, Power, Communication and Computing Technologies (ICCPCCT)*. IEEE, pp. 347–351.

Maskar, M. B., Thorat, A. R. and Korachgaon, I. (2017) ‘and solution methodologies’, in *2017 International Conference on Data Management, Analytics and Innovation (ICDMAI)*. Pune, India: IEEE, pp. 64–70.

Mehta, V. K. and Mehta, R. (2005) *Principles of power system : (including generation, transmission, distribution, switchgear and protection)*. S. Chand.

Mohamed, F. *et al.* (2018) ‘Economic dispatch using stochastic whale optimization algorithm’, in *2018 International Conference on Innovative Trends in Computer Engineering (ITCE 2018)*. Aswan, Egypt: IEEE, pp. 19–24.

Moosavian, S. M. *et al.* (2016) ‘Solution Techniques for Optimal Power Dispatch Problems-A Review’, in *4th IET Clean Energy and Technology Conference (CEAT 2016)*. Kuala Lumpur, Malaysia: IET, pp. 1–7.

Mostafa, E., Abdel-nasser, M. and Mahmoud, K. (2018) ‘Application of mutation operators to grey wolf optimizer for solving emission-economic dispatch problem’, in *2018 International*

Conference on Innovative Trends in Computer Engineering (ITCE). Aswan, Egypt: IEEE, pp. 278–282.

Nasiruzzaman, A. B. M. and Rabbani, M. G. (2008) ‘Implementation of Genetic Algorithm and Fuzzy Logic in Economic Dispatch Problem’, in *5th International Conference on Electrical and Computer Engineering ICECE 2008*. Dhaka, Bangladesh.

Pandi, V. R. and Abraham, A. (2009) ‘Improved Harmony Search for Economic Power Dispatch’, in *2009 Ninth International Conference on Hybrid Intelligent Systems*. Shenyang, China: IEEE, pp. 403–408. doi: 10.1109/HIS.2009.294.

Panta, S. and Premrudeepreechacham, S. (2007) ‘Economic Dispatch for Power Generation Using Artificial Neural Network’, in *The 7th International Conference on Power Electronics (ICPE’07)*. Daegu, Korea, pp. 558–562.

Pourakbari-kasmaei, M. *et al.* (2015) ‘An Unambiguous Distance-Based MIQP Model to Solve Economic Dispatch Problems with Disjoint Operating Zones’, *IEEE Transactions on Power Systems*, 31(1), pp. 1–2.

Rahmat, N. A., Musirin, I. and Othman, Z. (2012) ‘Effect of Ant Parameters on DEACO in Economic Load Dispatch Problem’, in *2012 IEEE International Conference on Power and Energy (PECon)*. Kota Kinabalu, Malaysia: IEEE.

Ramanathan, R. (1985) ‘Fast Economic Dispatch Based on the Penalty Factors From Newton’S Method.’, *IEEE transactions on power apparatus and systems*, PAS-104(7), pp. 1624–1629. doi: 10.1109/TPAS.1985.319191.

Rizwana, J. *et al.* (2015) ‘Minimization of Fuel Cost in Solving the Power Economic Dispatch Problem including Transmission Losses by using Modified Particle Swarm Optimization’, in *2015 IEEE International Conference on Computational Intelligence and Computing Research (ICCIC)*. Madurai, India: IEEE.

Saadat, H. (2010) ‘Power System analysis’, *Power system analysis*, pp. 353–381.

Saka, M. *et al.* (2017) ‘Economic Load Dispatch Using Vortex Search Algorithm’, *2017 4th International Conference on Electrical and Electronics Engineering*, (2), pp. 77–81.

Santra, D. *et al.* (2015) ‘Hybrid PSO - ACO technique to solve economic load dispatch problem’, in *2015 IEEE International Conference on Research in Computational Intelligence and Communication Networks, ICRCICN 2015*. Kolkata, India: IEEE, pp. 187–191. doi: 10.1109/ICRCICN.2015.7434233.

Sarstedt, M., Garske, S. and Hofmann, L. (2018) 'Application of PSO-Methods for the Solution of the economic Optimal Reactive Power Dispatch Problem', *2018 IEEE Electronic Power Grid (eGrid)*. IEEE, (2), pp. 1–6.

Sen, T. and Mathur, H. D. (2016) 'A new approach to solve Economic Dispatch problem using a Hybrid ACO-ABC-HS optimization algorithm', *International Journal of Electrical Power and Energy Systems*. Elsevier Ltd, 78, pp. 735–744. doi: 10.1016/j.ijepes.2015.11.121.

Sharma, A. and Vadhera, S. (2017) 'Comparative Analysis of Economic Load Dispatch Using Evolutionary and Nature based Algorithms', in *2017 International Conference on Power and Embedded Drive Control*. Chennai, India: IEEE, pp. 296–300.

Singh, E. M. and Sharma, E. N. (2017) 'A Review on Economic Load Dispatch using Optimization Techniques', *International Journal of Advance Research in Science and Engineering*, 6(12), pp. 1481–1488.

Suman, M. *et al.* (2016) 'Solution of Economic Load Dispatch problem in Power System using Lambda Iteration and Back Propagation Neural Network Methods', *International Journal on Electrical Engineering and Informatics*, 8(2), pp. 347–355. doi: 10.15676/ijeei.2016.8.2.8.

Sun, M. and Cui, S. (2014) 'Economic Load Dispatch of Power Systems Based on Hysteretic Noisy Chaotic', in *2014 IEEE Workshop on Advanced Research and Technology in Industry Applications (WARTIA)*, pp. 820–823.

Sunny Orike, D. W. C. (2013) 'Constrained Elitist Genetic Algorithm for Economic Load Dispatch : Case Study on Nigerian Power System', *International Journal of Computer Applications*, 76(5), pp. 27–33.

Thakur, T. *et al.* (2006) 'A Particle Swarm Optimization Solution to NO2 and SO2 Emissions for Environmentally Constrained Economic Dispatch Problem', in *2006 IEEE/PES Transmission & Distribution Conference and Exposition: Latin America*. Caracas, Venezuela: IEEE.

Tyagi, A., Verma, A. and Saxena, A. (2015) 'Optimal Economic Dispatch Considering Wind Energy Conversion Systems Using Gray Coded Genetic Algorithm', in *2015 Annual IEEE India Conference (INDICON)*. New Delhi, India: IEEE, pp. 1–5.

Vanitha, M. and Thanushkodi, K. (2012) 'Solving Non-Convex Economic Load Dispatch Problem by Efficient Hybrid Simulated Annealing Algorithm', in *2012 IEEE International*

Conference on Advanced Communication Control and Computing Technologies (ICACCCT). IEEE, pp. 362–365.

Vanitha, M. and Thanushkodi, K. (2013) 'Non Convex Economic Load Dispatch Problem By Efficient Biogeography Based Optimization Algorithm', in *International Conference on Current Trends in Engineering and Technology (ICCTET),* pp. 127–130.

Varma, S. C., Murthy, K. S. L. and Srichandan, K. (2013) 'Gaussian Particle Swarm Optimization for Combined Economic Emission Dispatch', in *2013 International Conference on Energy Efficient Technologies for Sustainability*. Nagercoil, India: IEEE, pp. 1336–1340.

Visali, N., Reddy, S. M. and Reddy, S. K. (2014) 'Economic Load Dispatch of Thermal Power Plants Using Evolution Technique including Transmission Losses', in *2014 International Conference on Advances in Electrical Engineering (ICAEE)*. Vellore, India: IEEE.

Wang, Y. *et al.* (2010) 'Economic load dispatch of hydroelectric plant using a hybrid particle swarm optimization combined simulation annealing algorithm', in *2010 Second WRI Global Congress on Intelligent Systems*. Wuhan, China: IEEE, pp. 231–234. doi: 10.1109/GCIS.2010.79.

Xing, H. *et al.* (2017) 'Distributed Augmented Lambda-iteration Method For Economic Dispatch in Smart Grid', in *2017 Chinese Automation Congress (CAC)*. Jinan, China: IEEE.

Yu, S. and Chung, W.-H. (2011) 'Optimal Economic Dispatch with Environmental Consideration by MPSO Method', in *2011 International Conference on Consumer Electronics, Communications and Networks (CECNet)*. XianNing, China: IEEE, pp. 4235–4238.

Zhang, G.-L. *et al.* (2005) 'Environmental / Economic Load Dispatch Based on Weighted Ideal Point and Hybrid Evolutionary Algorithm', in *2015 International Conference on Machine Learning and Cybernetics*. Guangzhou, China.

Zhang, Y., Chen, C. and Lee, C. (2018) 'Solution of the Optimal Reactive Power Dispatch for Power Systems by Using Novel Charged System Search Algorithm', in *2018 7th International Symposium on Next Generation Electronics (ISNE)*. IEEE.