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Study on Techniques for Combined Economic and Emission Dispatch

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Abstracts - Economic Dispatch (ED) optimization problem is the most important issue which is to be taken into consideration in power systems. The problem of ED in power systems is to plan the power output for each devoted generator unit in such a way that the operating cost is minimized and simultaneously, matching load demand, power operating limits and maintaining stability. This problem becomes more complex in large scale power systems, as it is hard to find out optimal solution because it is nonlinear function and it contains number of local optimal. Various techniques are proposed by the researchers for ED. The main objective of ED techniques is to minimize the total cost of the emission while maintaining stability of the power systems. This paper presents a survey on the existing ED optimizing techniques for power systems with its functionalities, specific features and drawbacks. Moreover, in ED techniques,emission of various pollutants occur which are very harmful and thus to avoid emission a better technique called Combined Economic Emission Dispatch (CEED) is proposed by the researches. This survey will help the researchers for providing better techniques for CEED optimization in power system.

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Study on Techniques for Combined Economic and Emission Dispatch

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Abstract - Economic Dispatch (ED) optimization problem is the most important issue which is to be taken into consideration in power systems. The problem of ED in power systems is to plan the power output for each devoted generator unit in such a way that the operating cost is minimized and simultaneously, matching load demand, power operating limits and maintaining stability. This problem becomes more complex in large scale power systems, as it is hard to find out optimal solution because it is nonlinear function and it contains number of local optimal. Various techniques are proposed by the researchers for ED. The main objective of ED techniques is to minimize the total cost of the emission while maintaining stability of the power systems. This paper presents a survey on the existing ED optimizing techniques for power systems with its functionalities, specific features and drawbacks. Moreover, in ED techniques, emission of various pollutants occur which are very harmful and thus to avoid emission a better technique called Combined Economic Emission Dispatch (CEED) is proposed by the researches. This survey will help the researchers for providing better techniques for CEED optimization in power system.

Keywords : PSO, Economic Dispatch, Emission Dispatch, Genetic Algorithm, Combined Economic Emission Dispatch.

I. Introduction

In recent years, Power systems have become huge and complicated. The problem of adapting the best solution for meeting the varying demand for electricity is one of the major concerns of the electricity generating organizations. Economic load dispatch is the most important functions in electrical power system operation, organization and scheduling [23, 24]. Economy, consistency and stability are the important factors to be considered when carrying out the power dispatching. In general, the main aim of ED is to minimize the total production cost of the generating system while maintaining the required equality and inequality constraints.Due to emerging technology, various techniques have been proposed by several researchers.

To solve the real time economic and emission dispatch problem. Based on convention, electrical power systems are operated based on minimizing operational cost while maintaining the system constraints [1] [2]. The dispatch approaches should consider both economic factors and emission reduction [25]. Though economic and emission dispatch issues have been successfully solved by several existing techniques, the related dispatch programs need to be rerun when the system load changes and thus is unsatisfactory for the Real time dispatch.

Recently, energy sources to generate mechanical power applied to the rotor shaft of generating units are of fossil fuels. This causes a vast amount of carbon dioxide, sulfur dioxide, nitrogen oxides emissions which cause atmospheric pollution. There has been a keen attention for emission control over environmental pollution caused by fossil-fired generating units and the enforcement of environmental regulations. Thus nowadays, the ED optimization technique should also consider this environmental pollution scenario.

However, considering only the operation of minimum environmental impact is impractical due to causing the higher production cost of the system. Alternatively, operating the power system with the minimum of total production cost cannot satisfy the emission requirement. Hence, economic dispatch, emission dispatch or combined economic and emission dispatch have to be considered. To choose the best approach among the three, a good power management policy is required. Various traditional optimization approaches such as lambda iteration, linear programming, non-linear programming, quadratic programming, and interior point method are used for providing solution to various economic dispatch problems and also the unit commitment problems [26]. These approaches are well known for the economic thermal dispatch of generators.

More recently, better optimization and intelligent search techniques like Genetic Algorithm, Evolutionary Programming, Particle Swarm Optimization, etc [27, 28] are also proposed by several researchers. ED problems using GA need a large number of generations when the power generating system has the large number of units. Combined economic and emission dispatch has been proposed which simultaneously reduces both fuel cost and total emissions.

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The present economic and environmental factors increasingly put stress on the existing transmission systems. Modern electric power systems built with nonlinear characteristics are highly interconnected with wide geographical distribution. This demands the optimization of a complex objective function under few practical constraints. Hence power system network optimization involves maximization or minimization of objective function under certain constraints.

Thus, due to the importance of the ED of power system and its influence in the environment, there are several approaches developed by various researchers for the stabilization of the power systems. This paper deals with the analysis of the various existing approaches for the ED optimization of power system.

II. Literature Survey

A novel form of dynamic programming method is proposed by Muralidharan *et al.,* [1]. The main aim of this approach is that cost, emission and loss are combined and moreover the pareto-optimal economic dispatch for emission constrained and loss-restricted case. In this approach, a novel Dynamic Programming (DP) approach replaces the conventional optimization approaches. It's a new recursive technique for recognizing production cost minimization, with an emission constrained and loss reduced condition. DP is a mathematical approach [21, 22] which deals with the optimization of multistage decision process. A final operating condition with minimum production cost at reduced emission rate while maintaining stability leads to a multi-objective problem which is successfully carried out in this approach.

Prasanna *et al.,* [2] proposed Fuzzy-Tabu search algorithm for combined economic and emission dispatch. Recently, with increasing knowledge of environmental pollution due to burning of fossil fuels, emission of pollutants is also a norm for economic dispatch of the plants. The environmental aim of generation dispatch is to reduce the total environmental cost or the total pollutant emission. Fuzzy logic has been combined with Tabu Search (TS) algorithm to solve various power system problems. In order to obtain better convergence in TS, the mutation and recombination processes are enhanced by fuzzy logic approach leading to an enhanced TS approach termed as Fuzzy Guided Tabu Search (FGTS). An effective and simple technique for solving the emission constrained economic dispatch problem using FGTS is proposed in this paper. The convergence and the significance of the proposed approach are illustrated via its application to a test system. From the computational results, it is clearly observed that the proposed technique has excellent convergence characteristics and has the potential to apply to other power system problems. In spite of economic and emission dispatches, the proposed approach can be used in multi constrained Dynamic economic dispatch, co-ordination of various FACTS controllers pertaining to optimal power flow and optimization problems in a deregulated power system. Combined Economic Emission Dispatch (CEED) issue is to schedule the committed generating unit outputs to satisfy the needed load demand at minimum operating cost with minimum emission simultaneously. This multi-objective CEED problem is changed into a single objective function with the help of a price penalty factor. Ugur Guvenc *et al.,* [3] proposed a novel Genetic Algorithm technique based on similarity crossover for solving CEED problem in power systems. In the proposed technique, children are generated by using similarity measurement between mother and father chromosomes relationship. The proposed technique has been tested on a six-generator and eleven generator economic emission load dispatch problems. From the experimental results, it is clear that the proposed technique is very effective in finding higher quality solutions in CEED problems.

The amount paid for one unit power consumption is rising every year. Senthil *et al.,* [4] uses Improved Tabu Search Algorithm (ITS) which minimizes the cost per unit power consumption. The amount spent by the consumer can be minimized to a great extent which can improve the economy of the country significantly. Economic Load Dispatch (ELD) is one of the very important optimization tasks in power system. It is the method of assigning generation among the committed units such that the constraints imposed are satisfied and the energy necessities are reduced. The three criteria for solving the economic load dispatch problem are reducing the total generator operating cost, total emission cost and scheduling the generator units. The proposed ITS approach provides solution to economic dispatch problem and is very significant when addressing heavily constrained optimization problem in terms of solution accuracy. The allocation of generation for each generator unit is optimized by ITS algorithm. The total cost of the power generation in thermal power plants is based upon fuel cost and emission cost. The proposed technique significantly minimizes the total cost for power generation. From the results, it is clearly observed that the proposed approach is more efficient in terms of number of evolution to reach the global optimum point. Moreover, the solution technique is valid for real time applications and it provides challenges and opportunity to the Engineers to enhance the economy of the country.

Effective and best economic operations of electric power generation systems have always been considered important in the electric power industry. This involves assigning of the total load between the available generating units such that the total cost of

operation is kept at a minimum. Recently, this problem has taken an appropriate twist as the public concern for the environmental matters has increased and thus, economic dispatch now includes the dispatch of systems to reduce pollutants while achieving minimum cost. Lakshmi Devi *et al.,* [5]proposes a lambda based technique for solving the CEED problem using Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) techniques considering the power limits of the generator. The proposed approach determines the global or near-global optimal solution for the Combined Economic and Emission Dispatch (CEED) problem. The main aim of CEED is to reduce both the operating fuel cost and emission level simultaneously while maintaining load demand and operational constraints. This multi-objective CEED problem is converted into a single objective function using a modified price penalty factor technique. The proposed approach is tested with three generating units. The PSO technique has shown to offer accurate and feasible solutions within acceptable computation time.

Lakhwinder Singh *et al.,* [6] deals with the Economic Emission Dispatch (EED) issue involving real and reactive power scheduling of thermal power generating units. The formulated EED problem is solved using weighting technique to generate non-inferior solutions which allows explicit trade-offs between objective levels for each non-inferior solutions. Fuzzy decision making technique is exploited to determine the generation schedule. To access the indifference band, interaction with the decision maker is obtained via Cardinal Priority Ranking (CPR) of the objectives. The Cardinal Priority Ranking is constructed in the functional space and then transformed into the decision space, so the cardinal priority ranking of objectives relate the decision maker's preferences to non-inferior solutions through normalized weights. Regression analysis is performed between the cardinal priority ranking and simulated weights to decide the 'best' compromised solution. Decoupled load flow analysis is performed to find the loss coefficients and transmission losses. The validity of the proposed method is demonstrated on IEEE 11-bus system which comprises 3-generators.

Demirel *et al.,* [7] proposed Economic and minimum emission dispatch with Hopfield Neural Network (HNN) and Lagrange Multiplier (LM) solutions to economic dispatch (ED), NO_x Emission Dispatch (EmD), and Economic-Emission Dispatch (EED) of a sample system which contains six thermal generators are presented. A system consisting of N thermal generating units connected to a transmission network serving a received electrical load P_D [MW] is studied in this paper. The total cost rate of this system is the sum of the cost rate of the individual units. The fuel cost curve is assumed to be approximated by a quadratic function of P_i [MW]. The results of HNN are compared with the results of LM. The paper illustrated that the HNN approach can be applied easily to the economic-emission dispatch problems.

T. Ratniyomchai *et al.,* [8] proposed a demonstration of solving combined economic and emission dispatch problems. The main aim of the combined problem can be expressed by taking both the fuel cost and total emission into consideration with required constraints. Particle Swarm Optimization (PSO) is one of most efficient intelligent search techniques involved in solving economic load dispatch. PSO is exploited in this approach to demonstrate its significance. The two Economic and emission dispatch problems are combined and converted into a single objective function [21, 22] with the help of a price penalty factor h. The converted objective function is minimized based on efficient PSO. A three-unit thermal power plant is used for the simulation test. Sets of suitable dispatch with respect to economic or emission objectives can be efficiently found.

Due to the recent environmental policies and awareness many electric utilities are forced to restructure their operational practices to account for their emission impacts. One way to achieve this is by reformulating the conventional economic dispatch problem such that emission effects are included in the mathematical model. Alrashidi *et al.,* [9] proposed a PSO algorithm to solve the Economic- Emission Dispatch issue (EED) which has recently gained lot of attention due to the deregulation of the power industry and strict environmental regulations. The issue is formulated as a multi-objective one with two competing functions such as economic cost and emission functions, subject to different constraints. The inequality constraints considered are the generating unit capacity limits while the equality constraint is generation-demand balance. A novel equality constraint handling mechanism is proposed in this technique. PSO technique is tested on a 30-bus standard test system. Results obtained reveal that PSO approach is very effective in handling multi-objective optimization problems and is capable of capturing Pareto optimal solution set under different loading conditions.

Because of the recent environmental concern and consideration, operation of the power systems at absolute minimum cost can no longer be the only measure for dispatching electric power. The environmentally constrained economic dispatch problem which accounts for minimization of both cost and emission is a multiple objective function problem. Yalcınoz *et al.,* [10] presented an approach for the environmentally constrained economic dispatch problem using improved Hopfield Neural Network. The the NO_x emission dispatch and the emission classical economic dispatch, the SO_2 emission dispatch, proposed approach has been effectively applied to the

constrained economic dispatch. The energy function of the Hopfield NN consists of three functions which are the production cost and emissions functions. The proposed method has been tested on a 3-unit system and a 10-unit system. From the results, it is clearly observed that the proposed approach can be very effectively applied to the environmentally economic dispatch problem.

Recently, global warming has been a great concern throughout the world. Global warming is mainly due to the increasing of thermal power plants air pollution and concentration of carbon dioxide emission. It is very important to solve this global warming problem by taking necessary steps. This paper deals with issue of solving the economic dispatch problem includes the dispatch of systems to the minimize carbon dioxide emissions, and also to achieve the minimum fuel cost. Senthil [11] proposed a lambda based approach for solving the Combined Economic and Emission Dispatch (CEED) problem using Evolutionary programming (EP) approach which considers the power limits. EP Technique also reduces the fuel cost and emission of the plant to prevent the global warming. CEED is to minimize both the operating fuel cost and emission level simultaneously while maintaining the load demand and operational constraints. The sample test system of three and six generator system solves the CEED problem for various load demands. EP is an efficient tool for the economic scheduling for generating units with the given generator constraints. The performance and applicability of the proposed approach is shown by the numerical results.

Dieu *et al.,* [12] proposes an Augmented Lagrange Hopfield Network (ALHN) for solving economic dispatch (ED) problem with ramp rate, emission and transmission constraints. The proposed ALHN technique is the continuous Hopfield Neural Network with its energy function based on Augmented Lagrangian function. In ALHN, the energy function is augmented by Hopfield terms from Hopfield Neural Network and penalty factors from augmented Lagrangian function to damp out oscillation of the Hopfield network during its convergence. For the implementation of the ALHN, the augmented Lagrangian function for the problem is firstly formulated, and then energy function of the ALHN is generated depending on the founded augmented Lagrangian function with augmentation of Hopfield terms. Accordingly, ALHN is more effective and it overcomes the limitations of the traditional Hopfield network due to its simplicity, better optimal solution and faster computing time. In the proposed ALHN technique, equality and inequality constraints can be easily handled by augmented Lagrangian function while variables limits are effectively handled by sigmoid function from Hopfield network. Moreover, in this paper, the power flow in transmission lines is calculated using DC power load flow approach which focuses only on real power flow supposing that the voltage at each bus is equal to 1 pu and resistance of transmission lines is negligible. The Generalized Generation Distribution Factor (GGDF) [19] is used for calculating power flow in transmission constraint based on Generation Shift Distribution Factor (GSDF) which is based on DC power flow [20].The proposed approach has been tested on large-scale systems up to 1,200 units and the New England 39-bus system and the obtained results are compared to other methods available in the literature. From the test results, it is clearly observed that the proposed technique is very efficient than the others for less total costs and faster computational times.

Genetic Algorithm (GA) has been used by Ozyon *et al.,* [13] to solve the environmental economic power dispatch problem in hydrothermal power systems. In the process of solution, the use of the demanded amount of water by each of the hydraulic units has been provided as well as the minimization of total thermal cost and total NO_x emission. In order to convert the environmental economic power dispatch problem, which is one of the multi-objective optimization problems; into a single objective optimization problem Weighted Sum Method (WSM) has been used. Genetic Algorithm (GA) technique has been applied to single objective optimization problem for the solution. As an example, the solution of a lossy system with 16 buses consisting of thermal and hydraulic generation units has been given. Considering the one-day operation period of the sample system, solutions have been obtained for various values of weight factor w and the obtained total thermal cost and total NO_x emission values (pareto optimal results) have been evaluated.

Combined Economic Emission Dispatch (CEED) engages the concurrent optimization of fuel cost and emission control that are contradictory ones. The bi-objective CEED is modified into a single optimization problem with the help of Price Penalty Factor (PPF). Gonggui Chen [14] presented a novel technique called Shuffled Frog Leaping Algorithm (SFLA) based reserve constrained CEED. The algorithm to solve the reserve constrained CEED problem is presented in the paper. The performance of the proposed technique is evaluated using a 15-unit system. The evaluation result indicates that the proposed technique is efficient and has a convinced practicality.

Arias *et al.,* [15] provides a model for power systems operation planning that intends to enhance the voltage stability boundary and also the economic dispatch which is prepared as a Bilevel Programming Problem (BPP). The aim is to produce a result for the network operation planning that considers both technical and economical issues. The bilevel model permits system operators to describe various objective

functions for enhancing the voltage stability boundary and intended for an optimum economic dispatch. Also focuses on allowing the imposition of constraints to both the variables of the inner and outer difficulties. The BPP is minimized to a single level optimization problem by substituting the inner optimization problem by its Karush-Kuhn-Tucker optimality conditions. Mixed-integer programming is not necessary for this technique. Additionally, BPP formulation is easier than other formulations, and it is also highly flexible to support the variables and control parameters.

To overcome the economic dispatch difficulty in power system, Peng Chen *et al.,* [16] proposed the floating point representation to the Genetic Particle Swarm Optimization (GPSO). GPSO was derivative of the Standard Particle Swarm Optimization (SPSO) and combined with the genetic reproduction techniques called crossover and mutation. An altered heuristic crossover was developed that was obtained from the differential evolution and genetic algorithm together with the technique of GPSO. The presented technique was implemented to four well-known benchmark functions, and typical constraint sets were provided according to the evaluation outcome. Additionally, MGPSO was utilized to a practical system, and by assessment with the other PSO techniques, MGPSO has resulted better solution.

Ravikumar Pandi *et al.,* [17] proposed a new optimization technique with the help of Improved Harmony Search (IHS) technique in order to answer economic power dispatch problem. The presented technique without difficulty takes care of various equality and inequality constraints of the power dispatch problem to determine the optimal solution. To prove the effectiveness, the presented technique is applied to single area and multi area system of four areas that has 16 units with and without Prohibited Operating Zones (POZ). The outcome is compared with other conventional related techniques. The outcome resulted by using the presented technique ensures the robustness and efficiency of the algorithms over other reported techniques.

The Harmony Search (HS) technique was initially conceptualized with the help of the musical improvisation method of searching for a perfect state of harmony. The HS technique utilizes a random search that is based on random selection, memory consideration and pitch adjusting. Dos Santos Coelho *et al.,* [18] provides a modified HS technique incorporated with differential evolution and chaotic sequences to resolve the economic load dispatch difficulty of thermal generators with the valve-point effect. The provided modified HS algorithm was validated in a power economic problem that consists of 10 generating units with valve-point effects and multiple fuels for a load demand of 2500 MW. Experimental results indicate that the modified HS algorithm resulted in satisfied outcome when compared with outcome of other optimization techniques.

APPROACH	FUNCTIONALITIES
[1]	A novel Dynamic Programming (DP) approach for recognizing production cost minimization, with an emission constrained and loss reduced condition.
[2]	Fuzzy-Tabu search algorithm for combined economic and emission dispatch.
[3]	A novel Genetic Algorithm technique based on similarity crossover for solving CEED problem in power systems
[4]	Improved Tabu Search Algorithm (ITS) which minimizes the cost per unit power consumption.
[5]	A lambda based technique for solving the CEED problem using Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) techniques considering the power limits of the generator.
[7]	Economic and minimum emission dispatch with Hopfield Neural Network (HNN) and Lagrange Multiplier (LM) solutions to economic dispatch (ED), NO_x Emission Dispatch (EmD), and Economic-Emission Dispatch (EED).
[8]	A demonstration of solving combined economic and emission dispatch problems through PSO
[9]	A PSO algorithm is used to solve the Economic- Emission Dispatch issue (EED)
[10]	An approach for the environmentally constrained economic dispatch problem using improved Hopfield Neural Network
[11]	lambda based approach for solving the Combined Economic and Emission Dispatch (CEED) problem
[12]	An Augmented Lagrange Hopfield Network (ALHN) for solving economic dispatch (ED) problem with ramp rate, emission and transmission constraints.
[13]	Genetic Algorithm (GA) has been to solve the environmental economic power dispatch problem in hydrothermal power systems

III. Problems and Directions

Several conventional optimization approaches have been proposed in the literature to solve ECED problem. The conventional approaches for solving economic dispatch problems such as lambda-iteration

and gradient approach requires the unit input-output curves of generators. But, these curves do not increase monotonically due to operating zones of the approaches. Thus, the conventional dispatch algorithms cannot be directly used to optimize such non-linear cost function. In most of the conventional techniques, the Emission-Economic Dispatch (EED) problem was tackled considering only one loading condition for a given system. The impact of different loading conditions on the shape of Pareto optimal set was not addressed in the most of the traditional methods.

In the conventional economic dispatch problem, the cost function for each generator has been approximately represented by a single quadratic function. But, the characteristics of generating units are highly nonlinear inherently, because of the constraints power system and emission.

More recently, improved heuristic techniques like Non Genetic algorithm, Evolutionary Programming (EP), Tabu Search (TS) and neural networks are being used to find global or near global optimal solution of simple ED.

Optimization techniques provide better solution for the ED problem. Better optimization approaches can be used for providing promising results especially in cases where the processes are too complex to be analyzed by conventional techniques.

IV. Conclusion

Economic and emission dispatch problems are combined and converted into a single objective function. The converted objective function is minimized based on efficient Particle Swarm Optimization (PSO). The results showed that sets of suitable dispatch with respect to economic or emission objectives can be efficiently found.

This review is undertaken to explore and analyze the existing Economic and emission Dispatch techniques present in the literature which is very much required to minimize the operating cost while maintaining system stability and consistency and provide better performance. This paper present major studies of power system ED techniques, such as NN, fuzzy logic, Genetic Algorithm and other optimization techniques which is available in the literature. These conventional power system stabilization techniques form the basis for the new innovation of the effective power system stabilization approaches. Most of the ED approaches available in the literature cannot be directly used to optimize such non-linear cost function. By contrast, the merits of PSO algorithm convinced and encouraged various researchers to utilize this algorithm for solving the stabilization issue of power system control. Moreover, the cost function for each generator has been approximately represented by a single quadratic function in the conventional approaches. From the literature, it is clearly observed that PSO provides better performance than other conventional techniques. Other modern optimization techniques like Ant Colony Optimization (ACO) can be used for the significant performance of the power system.

References Références Referencias

1. S. Muralidharan, K. Srikrishna, and S. Subramanian, "A Novel Pareto-Optimal Solution for Multi-Objective Economic Dispatch Problem", Iranian Journal of Electrical and Computer Engineering, Vol. 6, No. 2, 2007.
2. Prasanna. T.S. and Somasundaram. P., "Fuzzy - Tabu Search Algorithm for Combined Economic and Emission Dispatch", National Systems Conference, NSC, pages 17-19, 2008.
3. Ugur Guvenc, "Combined economic emission dispatch solution using genetic algorithm based on similarity crossover", Scientific Research and Essays, Vol. 5, No.17, pages 2451-2456, 2010.
4. K. Senthil and K. Manikandan, 'Improved Tabu Search Algorithm to Economic Emission Dispatch with Transmission Line Constraint", International Journal of Computer Science & Communication, Vol. 1, No.2, pages 145-149, 2010.
5. Lakshmi Devi and O. Vamsi Krishna, "Combined Economic And Emission Dispatch Using Evolutionary Algorithms-A Case Study", ARPN Journal of Engineering and Applied Sciences, Vol. 3, No. 6, 2008.
6. Lakhwinder Singh and J.S. Dhillon, "Cardinal priority ranking based decision making for economic-emission dispatch problem", International Journal of Engineering, Science and Technology Vol. 1, No. 1, pages 272-282, 2009.
7. Y. Demirel and A. Demiroren, "Economic and Minimum Emission Dispatch", WSEAS Transactions on Systems, Vol. 3, No. 4, pages 800-804, 2004.
8. T. Ratniyomchai, A. Oonsivilai, P. Pao¯la¯or, and T. Kulworawanichpong, "Particle Swarm Optimization for Solving Combined Economic and Emission Dispatch Problems", Recent Advances in Energy & Environment, 2010.
9. M. R. Alrashidi, and M. E. El-Hawary, "Impact of Loading Conditions on the Emission- Economic Dispatch", World Academy of Science, Engineering and Technology, 2008.
10. T. Yalcınoz, H. Altun and U. Hasan, "Environmentally Constrained Economic Dispatch Via Neural Networks", 2009.
11. K. Senthil, "Combined Economic Emission Dispatch using Evolutionary Programming Technique", IJCA Special Issue on "Evolutionary Computation for Optimization Techniques, ECOT, 2010.

12. Vo Ngoc Dieu, Weerakorn Ongsakul, "Economic Dispatch With Emission And Transmission Constraints By Augmented Lagrange Hopfield Network", Transaction in Power System Optimization (GJOT), Vol.1, 2010.
13. Ozyon, S.; Yasar, C.; Aslan, Y.; Temurtas, H.; "Solution to environmental economic power dispatch problems in hydrothermal power systems by using genetic algorithm", International Conference on Electrical and Electronics Engineering (ELECO), pages 387-391, 2009.
14. Gonggui Chen, "Combined Economic Emission Dispatch Using SFLA", International Conference on Information Engineering and Computer Science (ICIECS), pages 1 – 4, 2009.
15. rias, D.A.; Mota, A.A.; Mota, L.; Castro, C.A.; "A bilevel programming approach for power system operation planning considering voltage stability and economic dispatch", Transmission and Distribution Conference and Exposition: Latin America, 2008 IEEE/PES, pages 1-6, 2008.
16. Peng Chen; Chunhua Zhao; Jian Li; Zhiming Liu; "Solving the Economic Dispatch in Power System via a Modified Genetic Particle Swarm Optimization", International Joint Conference on Computational Sciences and Optimization (CSO), Volume: 1, Page(s): 201 – 204, 2009.
17. Ravikumar Pandi, V.; Panigrahi, B.K.; Mallick, M.K.; Abraham, A.; Das, S.; "Improved Harmony Search for Economic Power Dispatch", Ninth International Conference on Hybrid Intelligent Systems (HIS '09), Vol. 3, pages 403-408, 2009.
18. Dos Santos Coelho, L.; de Andrade Bernert, D.L.; Mariani, V.C.; "Chaotic differential Harmony Search algorithm applied to power economic dispatch of generators with multiple fuel options", IEEE Congress on Evolutionary Computation (CEC), pages 1 – 5, 2010.
19. W. Y. Ng, "Generalized generation distribution factors for power system security evaluations," IEEE Trans. Power Systems, Vol. PAS-100, No. 3, pages. 1001-1005, 1981.
20. A.J. Wood, B. F. Wollenberg, Power generation, operation and control, 2nd edn. New York: John Wiley & Sons, 1996.
21. C.Palanichamy and N. S. Babu, Analytical solution for combined economic and emissions dispatch, *Electric Power Systems Research*, Vol. 78, pages 1129–1137, 2008.
22. P. Venkatesh, R. Gnanadass, and N. P. Padhy, Comparison and Application of Evolutionary Programming Techniques to Combined Economic Emission Dispatch With Line Flow Constraints, IEEE Trans. Power Syst., vol. 18, pages 688-697, 2003.
23. P. Venkatesh, K. Y. Lee, "Multi-Objective Evolutionary Programming for Economic Emission Dispatch problem", Power and Energy Society General Meeting-Conversion and Delivery of Electrical Energy in the 21st Century, pages 1-8, 2008.
24. A.J. Wood and B.F. Wollenberg, Power Generation, Operation and Control, New York, Wiley, 1984.
25. Kulkarni, P.S., Kothari,A.G., and Kothari, D.P., "Combined Economic and Emission Dispatch Using Improved Backpropagation Neural Network", Electric Machines and Power Systems, Vol.28, pages 31-44, 2000.
26. C.-L. Chiang, "Optimal economic emission dispatch of hydrothermal power systems, Electrical Power and Energy Systems", Vol.29, pages 462–469, 2007.
27. M. Basu, "A simulated annealing-based goal attainment method for economic emission load dispatch of fixed head hydrothermal power systems", Electrical Power and Energy Systems, Vol. 27, pages 147–153, 2005.
28. L. Wang, C. Singh, Reserve-constrained multiarea environmental/ economic dispatch based on particle swarm optimization with local search, Engineering Applications of Artificial Intelligence, Vol. 22, pages 298–307, 2009.

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