International Journal of Electrical and Electronics Engineers ISSN- 2321-2055 (E)
http://www.arresearchpublication.com IJEEE, Volume 07, Issue 01, Jan- June 2015

STUDY ON COMBINED ECONOMIC-EMISSION DISPATCH OF THERMAL-HYDRO POWER GENERATION SYSTEMS

Rajanish Kumar Kaushal[1], Dr. Tilak Thakur[2], Isarar Ahamad[3]

[1]Ph.D Research Scholar, [2]Associate Professor, Department of Electrical Engineering,
PEC Chandigarh (India)
[3]Assistant Professor, Department of Electrical & Electronics Engineering, IU Lucknow (India)

ABSTRACT

Electric power has been become a primary requirement for present day life and to various economic sectors. To balance the increasing demand for Electric power, the number of generating units, transmission lines and distribution systems is rising steadily. Because of these increasing electric power systems have been become the most complex industrial systems of the modern age and a main source of gaseous emissions and pollutants. Electric power systems must be operated in such a way that the load demand is met reliably, cost-effectively and in an environmentally responsible manner. Two such objectives which are conflicting with each other that are, minimizing the fuel cost and the gaseous emissions need to solve simultaneously. So for multi-objective optimization techniques are employed to obtain trade-off relationships between these conflicting objective functions. This paper presents a study on Combined Economic-Emission Dispatch of Thermal-Hydro Power Generation Systems and various techniques that can be used for these problems with their merits and demerits.

Keywords: Combined Economic-Emission Dispatch, Valve-Point Effects, Short Term Hydrothermal Scheduling, Techniques with Their Merits and Demerits.

I. INTRODUCTION

Economic operation and planning of electrical power systems have always been a primary concern in the electrical power industry. Optimal economic operation of power generation systems is achieved through the efficient use of the available fuel which comes mostly from irreplaceable natural resources. An imperative truth that raises the importance of the optimal economic operations is that the electrical energy cannot be stored in large amounts. In addition, significant reduction in the amount of fuel used and hence in the operating costs can be achieved by a small percent of savings in power generation systems [1]. Operating costs of different generating units are dissimilar due to various reasons such as their characteristics and efficiencies and the distances between their locations and load centres. Consequently, an optimal power generation schedule that determines the generation level of each of the units is essential to meet the load demand at the minimum cost [2]. Furthermore, the operating cost of a specific generating unit is not linearly dependent on the power it produces. In fact, this relationship is a nonlinear and even non-smooth function. Obtaining the optimal economic generation schedule can only be realized by considering various operational constraints and limitations. The load demand, for instance, must be satisfied all the time while including the system losses that are function of the power generation. Other practical issues such as the valve-point effects and reserve margins considered by the generation patterns need to be taken into consideration.

II. THERMAL GENERATION PLANT: OPERATING COST MODELING

The total cost of operating thermal plants includes cost of labour and maintenance in addition to the costs of fuel and other supplies. In general, the economic dispatch process considers the cost of the fuel burnt in the fossil units. This does not mean that the other costs are neglected but they are commonly assumed to be a fixed percentage of the incoming fuel costs [3]. As a result of a mechanical process, energy is produced and transformed into mechanical form through steam or combustion turbines. The electric generator is driven by the turbine and hence, energy is finally transformed into electrical form. The power output of this system is connected to the electric power load. In addition, it supplies the auxiliary power system requirements of the plant itself. Fig.1 is a schematic illustration of a typical turbine-generator unit.

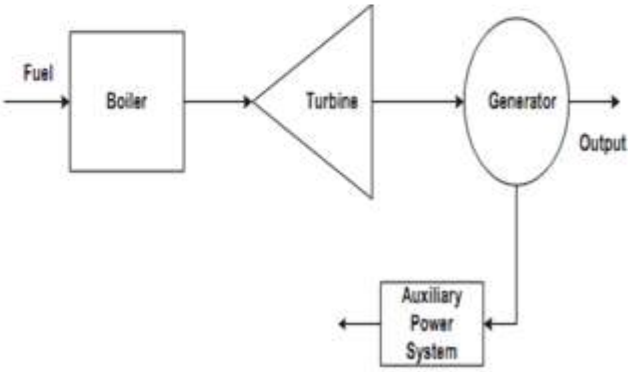

Fig.1: Typical turbine-generator models

The input to the thermal plant is generally measured in MBtu/h and the output power is in MW. The input-output relation of a thermal unit, which is known as “heat-rate” curve, is shown in Fig.2.

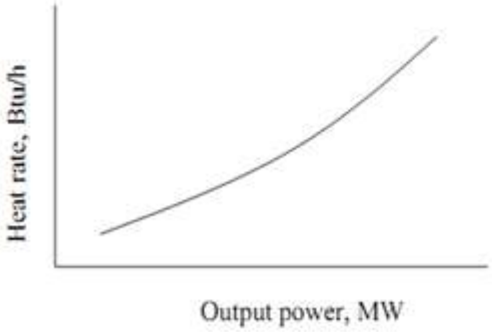

Fig.2: Heat-rate curve

The heat-rate curve is converted to the fuel cost curve representing the relationship of the operating cost of a fossil-fired thermal unit and its output power as shown in Fig.3. This cost is usually approximated as a quadratic function of the real power generation in equation (1).

$$F_i(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i \quad (1)$$

The lower limit of the output power $P_{gi}^{\min}$ is the minimum economical loading limit below which the operation is infeasible technically and/or economically. On the other hand, $P_{gi}^{\max}$ represents the upper limit and the maximum output power.

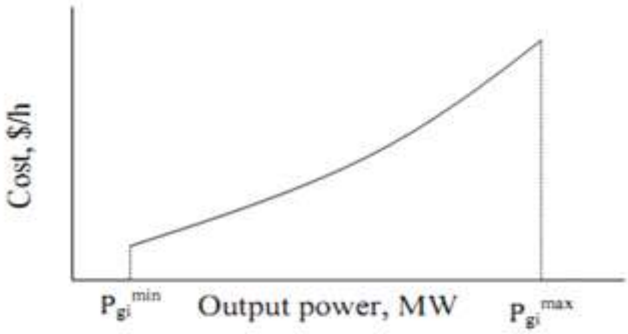

Fig.3: Incremental fuel-cost Curve

The derivative of the fuel cost curve with respect to the active power results in an important characteristic which is a measure of the cost of the next increment of power. This relationship, which is shown in Fig.3, is known as the "incremental fuel-cost" curve.

$$\frac{dF_i(P_{gi})}{dP_{gi}} = 2a_iP_{gi} + b_i \tag{2}$$

III. ECONOMIC DISPATCH PROBLEM

The economic dispatch problem is designed to determine the optimal loading of all committed generating units to minimize the cost function subject to the system constraints [2]. These running generating units are assumed to be known in advance. It is also assumed that the information about the daily load demand is also available. Accordingly, assuming that the number of committed units is Ng and the total load demand isP_D, then the ED problem can be formulated with the following objective function:

$$F_T = \sum_{i=1}^{N_g} F_i(P_{gi}) \tag{3}$$

Minimize

This is subjected to operational equality and inequality constraints as follows:

Load balance equation

$$\sum_{i=1}^{N_g} P_{gi} - P_D = 0$$

Generation unit capacity limits

$$P_{gi}^{\min} \le P_{gi} \le P_{gi}^{\max}$$

IV. OPTIMAL ECONOMIC DISPATCH: TRANSMISSION LOSSES CONSIDERED

In power systems where electrical energy is transmitted using long transmission lines, network losses cannot be neglected as they significantly affect the generation dispatch. In practical systems, it is estimated that the system power losses can be as much as 5% to 10% of the total power generation .The generating units in this system are connected to an equivalent load bus through a transmission network [2]. In the ED problem, the transmission losses are included in the load balance Equation (4). Accordingly, the objective function expressed in Equation (3) is to be minimized while satisfying the following active power balance equation:

$$\sum_{i=1}^{N_g} P_{gi} - P_D - P_L = 0 \tag{4}$$

Where P_L are the active power losses as a function of only the real power generation. The real power transmission losses in power systems are principally computed using the exact power flow equations. However, it is a common practice to express the losses as a quadratic function only in terms of real power generation. This function is referred to as the loss formula and its simplest form is known as George's formula [3].The parameters are called the loss coefficients or B-coefficients. In order to obtain a more accurate loss formula, a linear term and a constant is added to the expression of (5) to form what is referred to as Kron's loss formula [3]:

$$P_L = \sum_{i=1}^{N_g}\sum_{j=1}^{N_g} P_{gi} B_{ij} P_{gj} + \sum_{i=1}^{N_g} B_{i0} P_{gi} + B_{00} \tag{5}$$

$$P_L = [P_{g1} \quad P_{g2} \quad \cdots \quad P_{g3}] \begin{bmatrix} B_{11} & B_{12} & \cdots & B_{1Ng} \\ B_{21} & B_{22} & \cdots & B_{2Ng} \\ \vdots & \vdots & \ddots & \vdots \\ B_{Ng1} & B_{Ng2} & \cdots & B_{gNg} \end{bmatrix} \begin{bmatrix} P_{g1} \\ P_{g2} \\ \vdots \\ P_{gNg} \end{bmatrix}$$

$$+ \begin{bmatrix} P_{g1} & P_{g2} & \cdots & P_{gNg} \end{bmatrix} \begin{bmatrix} B_{01} \\ B_{02} \\ \vdots \\ B_{0Ng} \end{bmatrix} + B_{00}$$

The B-coefficients mainly depend on the operating condition of the system. They are usually assumed to be constant parameters, unless the system operating state of a new generation scheduling is significantly different from the base case.

V. OPTIMAL ECONOMIC DISPATCH: VALVE-POINT EFFECTS CONSIDERED

The ED problem is approximated by a smooth differentiable quadratic or piecewise quadratic objective function, which is the same approach used by classical optimization methods. However, due to the valve-point effects, the real input-output characteristics contain higher order nonlinearity and discontinuity which results in a non-convex, non-smooth fuel cost function. These discontinuities in the fuel cost curves are caused by sharp increases in throttle losses as a result of the effects of wire drawing at valve points. As a consequence of steadily lifting the valve, the losses decrease until the valve is fully opens [3].

The valve-point effects are represented using two different approaches**.** In the first, the effects are formulated as inequality constraints that represent them as prohibited operating zones [24]. The second approach, which is considered, includes a rectified sinusoidal term in the original objective function to model these effects. Accordingly, the input-output characteristic function of Equation (6) is modified to obtain an accurate cost function model. The valve-point effects are included in the fuel cost function as follows**.**

$$F_i(P_{gi}) = \sum_{i=1}^{N_g} a_i p_{gi}^2 + b_i P_{gi} + c_i + \left| e_i \sin\left(f_i (P_{gi}^{\min} - P_{gi}) \right) \right| \tag{6}$$

The coefficients e_i and f_i are constant fuel cost coefficients for unit i with valve-point effects. The total cost function to be minimized can be expressed as follows:

$$F_T = \sum_{i=1}^{N_g} a_i P_{gi}^2 + b_i P_{gi} + c_i + \left| e_i \sin\left(f_i (P_{gi}^{\min} - P_{gi}) \right) \right| \tag{7}$$

VI. SHORT-TERM HYDRO-THERMAL GENERATION SCHEDULING

The objective of hydro-thermal scheduling is to determine the generation level for each committed hydro and thermal unit in such a way that the total operating cost is minimized while satisfying various operational constraints [2]. In large-scale hydro-thermal generation systems, it is indispensable to operate thermal and hydro plants integrated in the same grid in order to achieve the optimal economic operation. Although the capital cost of hydro-electric plants is high, their operating cost does not depend on the output power. In contrast, the capital cost of the thermal plants is lower but their operating cost varies with the output power. In addition, while the starting and speed of response of thermal units are slow, hydro-electric plants can respond and start quickly and can handle fluctuating loads with high reliability. For these complementary characteristics of thermal and hydro-electric plants, the integrated operation of these plants is both economic and convenient practice. In contrast to thermal power production, there is no fuel cost associated with hydro-electric generation. However, fixed charges are accounted for regardless of the amount of the hydro power produced. Therefore, it is essential to use up the entire amount of water available over a planning period of time. In addition to generating electric power, hydro-electric plants must meet certain obligations as the reservoirs are multipurpose in most cases. A maximum forebay elevation, for instance, must not be exceeded due to the flooding considerations. In addition, to meet irrigational and navigational commitments, a minimum reservoir discharge and spillage must be observed [3].

A wide range of optimization techniques has been applied to solve the STHTS problem. These techniques are principally based on the criterion of local search through the feasible region of solution [3]. Applied optimization methods can be mathematical programming algorithms such as linear and nonlinear programming, dynamic programming and interior point methods**.** Among the other methods are the artificial intelligence techniques including neural networks, fuzzy systems and the evolutionary methods such as genetic algorithms and simulated annealing.

The methods considered in this survey can be classified as follows:

- Lagrangian relaxation and Benders decomposition-based methods
- Interior point methods
- Mixed Integer programming
- Dynamic programming
- Evolutionary computing methods
- Artificial intelligence methods
- Optimal control methods

These optimization methods can be generally classified into two main groups: deterministic methods and heuristic methods. Deterministic methods include Lagrangian relaxation and Benders decomposition methods, mixed integer programming, dynamic programming and interior point methods. Genetic algorithms, particle swarm optimization and other evolutionary methods are heuristic. Most of the methods that have been used to solve the STHTS problem are deterministic in nature. However, modern heuristic methods are getting more attention in solving large-scale optimization problems.

To search for the optimal solution, classical deterministic methods, also known as derivative-based optimization methods, apply techniques such as the gradient and Hessian operators. They use single path search methods while heuristic methods use population-based search techniques to search the solution hyperspace. This difference, in fact, is an advantage for the heuristic methods as it helps searching in spaces with non-smooth characteristics. It also improves convergence for heuristic methods and makes it less dependent on the initial solution points. Being derivative-free, modern methods are applicable to any optimization problem regardless of the linearity or nonlinearity of its objective function and constraints. In contrast, different deterministic methods are required for different optimization problems. Another main difference between the two classes is that heuristic methods use stochastic techniques and include randomness in moving from one solution to the next while determinist methods follow deterministic transition rules. This, of course, gives an advantage to heuristic methods in avoiding local minima.

GA was presented in [4] and applied to determine the optimal short-term scheduling of hydro-thermal systems. In this paper, a case study system of chain cascaded hydro units and a number of thermal units was used to evaluate the algorithm where the unit commitment problem was assumed solved while the economic dispatch sub-problem was considered. Many practical constraints were included in the formulation, however, the size of the problem of the case study was small and there was no evidence that the algorithm could be successfully applied to larger size problems. The performance of the algorithm was considered good although no comparison with other approaches was carried out in order to evaluate whether the algorithm was competitive or not. A concurrent solution of the unit commitment and the economic dispatch sub-problems in addition to the STHTS problem using GA was presented in [5].

In [6], SA was implemented to solve the thermal sub-problem while the hydro sub-problem was solved using a peak shaving method in order to find the optimal short-term scheduling for hydro-thermal power systems. The proposed method was tested using a modified version of a realistic power system and was considered robust with good performance and reasonable conversion time although it was not compared to other optimization approaches.

Umayal et al. in [7], presented a PSO application to find the short-term optimal generation schedule as a multi-objective optimization problem. In addition to the minimization of operation costs, the formulation of the objective function had to consider minimizing gaseous emission in order to satisfy environmental constraints. Several practical constraints including emission control and the usual hydro and thermal constraints were considered but some of them such as ramp rates were not accounted for. In order to evaluate the proposed algorithm, two testing systems were employed and good performance results were reported.

An EP algorithm in [8] was applied and compared to a genetic algorithm approach and when tested showed better performance in terms of cost while no details were shown regarding computational time and memory size. A modified differential evolution-based approach was compared to an EP algorithm in [9] when applied to solve the short-term hydro-thermal scheduling problem. Effects of valve-point loading and emission function inclusion were investigated while various thermal and hydro constraints were considered.

In [10, 11] a Lagrangian relaxation-based algorithm and a dynamic programming technique were integrated into an expert system to solve the STHTS problem. Steam and gas turbines were considered as well as many constraints such as the nonlinearity of thermal generation cost, transmission losses and the water discharge rates. The algorithm was reported to reach a feasible solution in an acceptable time although additional iterations were required in some test cases to find the optimal Lagrangian multipliers for the nearest feasible solution.

In [12, 13], a multi-pass dynamic programming was integrated with an evolutionary programming (EP) algorithm in order to obtain an improved solution. Two case studies were presented to implement the approach considering, in addition to thermal and hydro units, pumped storage units which either worked in pumping mode or generation mode with no idle times.

In [14] paper presents a bibliographical survey of the work published on the application of different optimization methods used to solve the short-term hydrothermal coordination problem. Various optimization techniques that tackled the problem are overviewed and classified with their advantages and limitations having been critically discussed. The paper provides a general literature survey and a list of published references on the topic aiming to offer the essential guidelines regarding this active research area.

VII. COMBINED ECONOMIC-EMISSION DISPATCH (CEED)

Wong et al. proposed an SA-based algorithm to solve the multi-objective generation dispatch optimization problem [15]. In addition to fuel and environmental costs, security requirements of the all-thermal system were taken into consideration in the problem formulation. To represent the environmental objective, constant weighting factors were augmented in the pollutant emission objective function. The effectiveness of the method was demonstrated using a single test system assuming the security of supply to be primary concern and neglecting the transmission power losses.

In [16,] two proposed algorithms were basically a combination of GA and SA techniques. Using relative weighting factors, the total emission of various pollutants were combined into a single objective before obtaining the trade-off curves between total fuel cost and emission. A 10-unit all-thermal generation system with its emission included three pollutants; NOx, SO_2 and CO_2, was utilized to demonstrate the performance of the two hybrid algorithms. In addition, the impact of fuel type switching and hence heat-rate characteristics of generators were also considered in the simulation results.

In [17] both deterministic and stochastic models are first formulated, and then an improved particle swarm optimization (PSO) method is developed to deal with the economic load dispatch while simultaneously considering the environmental impact. Comparative studies are carried out to examine the effectiveness of the proposed approach. First, a comparison is made between the proposed PSO approach and other approaches including weighted aggregation and evolutionary optimization. Then, based on the proposed PSO, the impacts of different problem formulations including stochastic and deterministic models on power dispatch results are investigated and analyzed.

In [18], a decision making technique was proposed to determine the multi-objective function optimization. The economic dispatch and environmental marginal cost are optimized using Powell's method while the Goal programming was utilized for the trade-off between the conflicting objectives. No more than one generation system with 5 thermal generating units was employed to test the method and demonstrate its performance.

A multi-objective function was treated in [19] to find the optimal scheduling for all-thermal power generation systems. The multi-objective function did not only consider cost and emission minimization but also security and reliability aspects. An expert fuzzy set system was proposed to find the optimal solution for a dynamic generation dispatch problem. The multi-objective problem was transformed into a single objective to obtain

Pareto optimal solutions using fuzzy logic. The technique was tested using a moderately sized system and the performance was assessed using various membership functions.

An improved bacterial foraging algorithm is presented [20] in this paper and applied to solve the short-term hydro-thermal scheduling problem considering the environmental aspects. The proposed algorithm is a modified bacterial foraging technique which applies a dynamic deceasing function for updating the solution vector and improving the convergence characteristics of the algorithm. The objective function of the optimization problem considered minimizing the NOx emission in addition to the fuel cost. Simulation results have shown the effectiveness the algorithm in finding the optimum or near optimum solutions and capturing the cost-emission trade-off relationship.

Security issues were considered as a third objective in the multi-objective economic emission dispatch problem presented in [21]. The GA applied in this work was hybridized with an SA technique to perform the selection operation of the algorithm. The proposed hybrid algorithm was tested using two standard systems and a Pareto optimal set of solutions was provided in form of trade-off curves in addition to some statistical data on the convergence property. However, no information was revealed regarding the computation time although it was mentioned that reducing search time was one of the advantages of the algorithm.

The hydro-thermal scheduling problem was treated in [22] to minimize both cost and emission. A simplified direct method was proposed to minimize these two non-commensurable objectives considering various water availability constraints. A single example of a hydro-thermal generation system which included 4 thermal and 2 hydro units was employed to test the proposed method without considering the transmission losses. Although no information regarding the execution time was mentioned in the paper, the proposed algorithm was claimed to be fast and potentially applicable for real time operations. The multi-objective economic-emission load dispatch formulated in [23] considered line flow constraints by expressing them in terms of active power generation using distribution factors. Although transmission losses were considered in the power balance equation, some other practical constraints were not included.

VIII. CONCLUSION

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 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.

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), Artificial Bee Algorithm can be used for the significant performance of the power system.

REFERENCES

[1] D.J. Kothari and J.S. Dhillon, Power System Optimization, New Delhi, India: Prentice-Hall of India Pvt.Ltd, 2004, pp. 572.

[2] A.J. Wood and B.F. Wollenberg, Power Generation Operation and Control, New York, USA: John Wiley & Sons, Inc., 1996, pp. 592.

[3] M.E. El-Hawary and G.S. Christensen, Optimal Economic Operation of Electric Power Systems, New York: Academic Press, 1979, pp. 278.

[4] S.O. Orero and M.R. Irving, "A genetic algorithm modeling framework and solution technique for short term optimal hydrothermal scheduling," Power Systems, IEEE Transactions on, vol. 13, pp. 501-518, 1998.

[5] E. Gil, J. Bustos and H. Rudnick, "Short-term hydrothermal generation scheduling model using a genetic algorithm,"IEEE Transactions on Power Systems, vol. 18, pp. 1256-1264, 2003.

[6] D.N. Simopoulos, S.D. Kavatza and C.D. Vournas, "An enhanced peak shaving method for short term hydrothermal scheduling," Energy Conversion and Management, vol. 48, pp. 3018-3024, 11. 2007.

[7] S.P. Umayal and N. Kamaraj, "Stochastic Multi Objective Short Term Hydrothermal Scheduling Using Particle Swarm Optimization," INDICON, 2005 Annual IEEE, pp. 497-501, 2005.

[8] B.N.S. Rahimullah and T.K.A. Rahman, "Short-term Hydrothermal Generation Scheduling Using Evolutionary Computing Technique," Research and Development, 2006. SCOReD 2006. 4th Student Conference on, pp. 220-223, 2006.

[9] L. Lakshminarasimman and S. Subramanian, "Short-term scheduling of hydrothermal power system with cascaded reservoirs by using modified differential evolution," Generation, Transmission and Distribution, IEE Proceedings-, vol. 153, pp. 693-700, 2006.

[10] S. Salam, K.M. Nor and A.R. Hamdan, "Comprehensive algorithm for hydrothermal coordination," Generation, Transmission and Distribution, IEE Proceedings-, vol. 144, pp. 482-488, 1997.

[11] M.S. Salam, K.M. Nor and A.R. Hamdam, "Hydrothermal scheduling based Lagrangian relaxation approach to hydrothermal coordination," Power Systems, IEEE Transactions on, vol. 13, pp. 226-235, 1998.

[12] S. N. Yu, "Using Hybrid EP and Multi-Pass Dynamic Programming for Hydrothermal Coordination Considering Reasonable Spinning Reserve," Transmission and Distribution Conference and Exhibition, 2005/2006 IEEE PES, pp. 903-908, 2006.

[13] R.E. Perez-Guerrero and J.R. Cedeno-Maldonado, "Differential evolution based economic environmental power dispatch," Power Symposium, 2005. Proceedings of the 37th Annual North American, pp. 191-197, 2005.

[14] I.A. Farhat, M.E. El-Hawary, "Optimization methods applied for solving the short-term hydro thermal coordination problem," Electric Power Systems Research, pp.1308-1320, 2009.

[15] Kit Po Wong, Bei Fan, C.S. Chang and A.C. Liew, "Multi-objective generation dispatch using bi-criterion global optimization," Power Systems, IEEE Transactions on, vol. 10, pp. 1813-1819, 1995.

[16] E. Tsoi, Kit Po Wong and Chun Che Fung, "Hybrid GA/SA algorithms for evaluating trade-off between economic cost and environmental impact in generation dispatch," Evolutionary Computation, 1995., IEEE International Conference on, vol. 1; 1, pp. 132, 1995.

[17] D.B. Das and C. Patvardhan, “A new approach for security constrained economic emission dispatch,” TENCON '98. 1998 IEEE Region 10 International Conference on Global Connectivity in Energy, Computer, Communication and Control, vol. 2; 2, pp. 470-473 vol.2, 1998.

[18] L. Wang and C. Singh, “Stochastic economic emission load dispatch through a Modified particle Swarm optimization algorithm,” Electric Power Systems Research, pp.1466-1476, 2008.

[19] B.S. Kermanshahi, Y. Wu, K. Yasuda and R. Yokoyama, “Environmental marginal cost evaluation by non-inferiority surface [power systems],” Power Systems, IEEE Transactions on, vol. 5; 5, pp. 1151-1159, 1990.

[20] D. Srinivasan, C.S. Chang and A.C. Liew, “Multiobjective generation scheduling using fuzzy optimal search technique,” Generation, Transmission and Distribution, IEE Proceedings, vol. 141; 141, pp. 233-242, 1994.

[21] N. A. Khan, Ahmed, B. Awan and A. Mahmood, “Combined emission economic dispatch of power system including solar photo voltaic generation,” Energy Conversion and Management, pp.82-91, 2015.

[22] M.L. Chanana and A. Kumar, “Multiobjective Hydro Thermal Scheduling,” TENCON '91.1991 IEEE Region 10 International Conference on EC3-Energy, Computer, Communication and Control Systems, vol. 1; 1, pp. 391-395, 1991.

[23] J. Nanda, L. Hari and M.L. Kothari, “Economic emission load dispatch with line flow constraints using a classical technique,” Generation, Transmission and Distribution, IEE Proceedings-, vol. 141; 141, pp. 1-10, 1994.

[24] T.A.A. Victoire and A.E. Jeyakumar, "Reserve Constrained Dynamic Dispatch of Units With Valve-Point Effects," Power Systems, IEEE Transactions on, vol. 20, pp. 1273-1282, 2005.