European Journal of Scientific Research
ISSN 1450-216X Vol. 85 No 2 September, 2012, pp. 262 - 270

http://www.europeanjournalofscientificresearch.com

A Modified Shuffled Frog Leaping Algorithm for Solving Combined Economic and Emission Dispatch Problems

H. Vennila
Electrical and electronics Department, Noorul Islam University, Tamilnadu
E-mail: vennilarajesh@yahoo.co.in

T. Ruban Deve Prakash
Electrical and electronics Department, Noorul Islam University, Tamilnadu
E-mail: Mahiruban2006@yahoo.co.in

Abstract

This paper is a discussion on the topic Modified Shuffled Frog Leaping Algorithm (MSFLA) aimed at solving, the combined Economic and Emission dispatch problems. In economic dispatch practices there are many choices for setting the operating points of generators. The target of the economic dispatch is to include variables that affect operational costs, such as the generator distance from the load, type of fuel, load capacity and transmission line losses. These variables are able to perform economic dispatch and interconnect generators, so as to minimize operating cost and functions. The environmental concerns that arise from the emissions(classical economic dispatch) the sole producer being fossil fuelled power plants which has an advantage of minimising the capital cost alone, can no longer be considered. Thus, by environmental dispatch, emissions has to be monitored and minimized to the farthest extent as possible in power generation. To demonstrate the effectiveness of the proposed method Economic & Emission dispatch problems are tested in 6 bus and 10 unit test system and comparisons are made with other optimization techniques.

Keywords: Shuffled Frog Leaping Algorithm, Economic and Emission dispatch.

1. Introduction

Economic Dispatch(ED) problem is an optimization problem which allocates the generation among the generators in a power system so that total cost of generation is minimized maintaining the system operating constraints. Traditional economic dispatch methods [1] minimize the total fuel cost without considering the level of emission. With the increase in environmental awareness and introduction of Kyoto protocol in 1990, operating at minimum cost is no longer the only criterion for dispatching electric power and now emission minimization is also necessary for the generation utilities. The basic Economic dispatch considers the power balance constraint apart from the generating capacity limits. However, a practical ED must take ramp rate limits, prohibited operating zones, valve point effects, and multifuel options into consideration to provide the completeness for the ED formulation. The resulting ED is a non convex optimization problem, which is a challenging one and cannot be solved by the traditional methods. Several classical optimization techniques such as lambda iteration method, gradient method, Newton's method, linear programming[LP],Interior point method and dynamic programming[DP][2] have been used to solve the economic dispatch problem[3].

The Economic and Emission dispatch is a non linear multi-objective optimization problem and is basically used to generate optimal amount of generating power from the fossil fuel based generating units. Recently some modern heuristic techniques such as Genetic Algorithm[GA], GA combined with Simulated Annealing[SA],Evolutionary Programming[EP], Improved Tabu Search[ITS], ant swarm optimization and Particle Swarm Optimization[PSO] have been used to solve the complex non-linear optimization problems[4,5]. When environmental constraints are augmented to the basic economic dispatch problem, ED becomes a multi-objective optimization problem. Various techniques have been proposed to solve this multi- objective optimization problem emphasizing emissions [6,7]. In past decades, the Economic and Emission dispatch problem was converted to a single objective problem by linear combination of different objectives as a weighted sum [8,9].

A modified bacterial foraging algorithm (MBFA) applied for the solution of the economic and emission dispatch problem in [10]. This approach utilizes the natural selection of global optimum bacterium having successful foraging strategies in the fitness function. Fuzzy clustering based particle swarm optimization method is applied on economic emission load dispatch in [11].Various established techniques like PSO,external repository of elite particles, niching, fuzzy based clustering, self adaptive mutation, and fuzzy decision making have been integrated by the authors in that paper.

Shuffled frog leaping algorithm (SFLA), developed by Eusuff and Lansey in 2000and is a population based heuristic for combinatorial optimization [12].It attempts to balance between a wide scan of a large solution space and also a deep search of promising locations for a global optimum. In this algorithm evolution of memes is driven by exchange of information among the iterative individuals. The SFLA has been tested on several benchmark functions that present its efficiency to many global optimization problems. A modified shuffled frog-leaping algorithm(MSFLA)[13] with new search –acceleration parameter introduced for applications to protect management and concluded that the MSFLA with an acceleration factor in the range of 1.3 to 2.1, on average, has the best chance of finding the global optimum with the least number of evolutionary iterations.

In this paper, modified Shuffled Frog Leaping Algorithm is used to find the solution of Economic and Emission dispatch problems. It is also used for Electronic design, digital filter optimisation, and Robot control.

2. Problem Formulation

Economic load dispatch pertains to optimum generation scheduling of available generators in an inter connected power system to minimise the cost of generation subject to relevant system constraints.

I. Economic Dispatch

a. Fuel Cost Minimisation

$$\text{Min } C_T = \sum F_i(P_{gi})$$

$$= \sum(a_i P_{g\,i}^{2} + b_i P_{gi} + c_i) \tag{1}$$

Where C_T is the total generation cost($/hr), F_i is the fuel-cost function of generator i($/hr), n is the number of units, P_{gi} is the real power generation of generator i in MW, and a_i,b_i,c_i are the cost coefficients of unit i.

The objective function is subject to equality and inequality constraints such as,

$$\sum P_{gi} = P_D + P_L \tag{2}$$

$$P_{gimin} \leq P_{gi} \leq P_{gimax} \text{ where } i=1,2,....n. \tag{3}$$

P_D=Power demand in MW

P_L=Network loss in MW

P_{gimin}, P_{gimax}= Minimum and Maximum power generation limit of generator i.

b. Objective Function Subject to Ramp Rate Limits

Considering Ramp rate limits , real power generation limits are modified as,

$$\mathrm{Max}(P_{gimin}, P_{g\ i}^{0}-DR_i)\leq P_{gi}\leq \min(P_{gimax}, P_{g\ i}^{0}+UR_i) \text{ where } i=1,2,.......n \quad (4)$$

$P_{g\ i}^{0}$= Previous operating point of generator i

DR_i, UR_i= Down and Up ramp rate limits of the generator i.

II. Considering Valve Point Loading Effect

The objective function is given by

$$F_i(P_{gi})=a_iP_{g\ i}^{2}+b_iP_{gi}+c_i+ | d_i\sin(e_i(P_{gimin} - P_{gi}):) \quad (5)$$

Where, d_i, e_i=Valve point loading constants

Subject to the constraints (2-4).

III. Combined Economic and Emission Dispatch

The amount of emission from a fossil- based thermal generator unit depends on the amount of power generated by the unit. But this emission is not considered in pure ED problem. Considering emission control the objective function is formulated as,

$$E(P_g)=\sum (\alpha_iP_{g\ i}^{2}+\beta_iP_{gi}+\gamma_i)x10^{-2}+x_i\exp(y_iP_{gi}) \quad (6)$$

Where $\alpha_i,\beta_i, \gamma_i, x_i, y_i$= emission coefficients of unit i

Combined economic and emission dispatch problem is formulated as

$$\Psi=\xi_1*F_i(P)+\zeta_2*K*E \quad (7)$$

ξ_1, ξ_2=weight factors.

Subject to constraints (2-4).

3. Modified Shuffled Frog Leaping Algorithm

In this section, a modified shuffled leaping algorithm(MSFLA) is designed based on the same frame work of shuffled frog leaping algorithm(SFLA). MSFLA starts with an initial population of “X” frogs created randomly like other evolutionary algorithms. The whole population of frogs is then partitioned into subsets referred to as memeplexes. The different memeplexes are considered as different cultures of frogs that are located at different places in the solution space. Each culture of frogs performs a deep local search. Within each memeplex, the individual frogs hold information that can be influenced by the information of their frogs within their memeplex, and evolve through a process of change on information among frogs from different memeplexes. After a defined number of evolutionary steps, information is passed among memeplexes in a shuffling process. The local search and the shuffling processes continue until a defined convergence criterion is satisfied.

Within each memeplex, the frogs with the best and the worst fitness are identified as Xb and Xw respectively.Also, the frog with the global fitness is identified as Xg. The position of the worst frog adjusts its position using frog leaping rule in each cycle.

The proposed algorithm is different from SFLA in two aspects in the memetic evolution step as follows

- A new acceleration factor is considered in the frog leaping rule of SFLA algorithm as

$$D=C*rand()*(Xb-Xw) \quad (8)$$

Where C is acceleration factor.

- Censorship step of the SFLA i.e., creation of random frog in place of worst frog will be done after the maximum number of memetic evolutions are completed.

When the difference between the worst frog position i.e., the frog under evolution and the best frog becomes small, the change in frog position is small and thus algorithm may lead to premature convergence and this problem is called as stagnation. To avoid this, a large value of C in the equation (7) is assigned at the beginning of the evolution process, the global search area will be widening due to bigger change in frogs position. Then, as the evolution process continues, the acceleration factor will focus the process on a deeper local search as it allows the frogs to change its position. Due to the shifting of censorship step, MSFLA attempts to balance between wide search of the solution space and a deep search of promising locations that are close to a local optimum.

3.1. MSFLA Algorithm for Economic and Emission Dispatch Problems

In this section , a modified shuffled frog leaping algorithm(MSFLA) is described for solving the Economic and Emission dispatch problems. The search procedures of the MSFLA method were shown below.

Step 1: Specify the generator cost coefficients and emission coefficients, choose number of generator units, specify maximum and minimum capacity constraints of all generators, and load demand.

In implementing the MSFLA, some parameters must be determined in advance like population size P, number of memeplexes m, number of frogs in each memeplexes n such that mxn=P, maximum number of memetic evolutions (IE), maximum step size for each generator unit Dmax=[D_1,max,D2,max,..,D_N,max].In this problem Dmax s taken as 100%. Also set the maximum number of shuffled iterations SI.

Step 2: An initial population of frogs X=[X_1,X_2,...X_P] is created randomly for an n-dimensional problem. A frog i is represented by N decision variables, such as X_i=($x_{1,i}$,$x_{2,i}$,...,$x_{N,i}$).Since the decision variables for the Economic and Emission dispatch problems are real power outputs of generation units, they are used to represent each element of a given population of virtual frogs. The element of the virtual frog's matrix is initialised randomly within the effective real power operating limits. The first element of virtual frog's matrix is taken as P_D-$\sum P_{gi}$. Each frog of the population matrix should satisfy equality constraint.

Step 3: Calculate the fitness value for each population set of the total population. Fitness value represents the total cost of the generators as in the equation (2) for the load demand.

Step 4: Sort the population in descending order of their fitness. Assign the first population as global frog, Xg. Partition the entire population into m memeplexes such that each containing n frogs. For example, m=3, frog ranking 1 goes to memeplex 1, frog ranking 2 goes to memeplex 2, frog ranking 3 goes to memeplex3, frog ranking 4 goes to memeplex 1, and so on.

Step 5: In the memeplex evolution step, the group of frogs in each memeplex acts and evolves as an independent culture.

Steps for memeplex evolution

Step 5.1: Set im=0(memeplex counter)

Step 5.2: Increment memeplex counter im=im+1

Step 5.3: Set ie=0(internal evolution counter)

Step 5.4: Increment internal evolution counter ie=ie+1

Step 5.5: Find best and worst frog and worst frog fit Xb and Xw and mwfit. Save the fitness of worst frog in different location owfit=mwfit

Step 5.6: Apply frog leaping rule for the improvement of worst frog position using (8)

Step 5.7: Evaluate the fitness of new position of Xw i.e., nwfit If fitness improves replace the old frogs by new one and mwfit=nwfit and go to step 5.10

Step 5.8: Improvement of worst frog position by replacing Xb by Xg

Step 5.9: Evaluate the fitness of new position of Xw. If fitness improves replace the old frogs by new one and mwfit=nmfit and go to step 5.13

Step 5.10: Check number of internal evolution,i.e., if $ie \leq IE$ go to step 5.4

Step 5.11: If mwfit>owfit go to step 5.13

Step 5.12: The frogs new position is not better than the old position after maximum number internal evolutions using both criteria, the spread of defective meme is stopped by randomly generating a new frog to replace Xw, whose new position was not favourable to progress towards an optimal value.

$x_{ij}=x_{j,min} + rand().(x_{j,max} - x_{j,min})$

Step 5.13: Check number memeplexes, i.e., if $im \leq m$ go to step 5.2. Otherwise go to shuffling operation to form new memeplex sets

Step 6: After IE number of internal evolution within each memeplex the population is shuffled. Periodic shuffling strategy promotes a global change of information among the frogs. The shuffling property helps to concentrate the search direction in a most promising region identified by individual memeplexes.

Step 7: Maximum number of shuffled iterations is reached, the algorithm is terminated. Otherwise, go to step 4.

4. Simulation Results and Discussions

a. Description of the Test Systems

To validate the proposed Modified Shuffled Frog Leap Algorithm, it is tested with two test systems having non convex solution spaces. The first test system consists of six generators with a total load of 1263MW[14].All the generators are having ramp rate limits. The best generation cost reported until now is $15,423/h. The previous best generation cost was $15,450[15].

The second system consists of ten generators with multi fuel options and valve-point effects[16]. The first generator is having two fuel options, and the remaining generators are having three fuel options. The best generation cost reported so far is $624.1273[15].

The combined Economic and Emission dispatch problem was solved for six generator system. The generator emission coefficients are taken from ref[17].

b. Convergence Test

The convergence test is performed in order to find out the effectiveness of the quickness of the Modified Shuffled Frog Leap Algorithm in terms of the number of main PSO iterations .The Proposed Modified Shuffled Frog Leap algorithm is applied in a 6-generator system and the obtained convergence characteristics are given in Fig1 . The output of generation cost is given in Table1 . From the output, it is evident that Modified Shuffled Frog Leap Algorithm is for more superior when compared with PSO and GA algorithms. The worse experience component provides the extra diversification which causes this superiority.

In IGAMU [15], multiple fuel option and valve point loading are combined to resolve the economic dispatch problems. IGAMU is faster and yields quality solutions compared to conventional genetic algorithm with multiplier upgrading[CGAMU][15].The characteristics of solution to the EDVLMF problem using MSFLA and convergence characteristics are compared with that of IGAMU method illustrated in Fig2 and Table[2].

c. Comparisons of the Solutions

By comparing the best power output of the six generator system using SFL algorithm, GA and PSO it is seen that in MSLF algorithm the generation cost is minimum. Thus the MSFL algorithm has multiple advantages of best generation schedule with minimum network loss, keeping generation costs viable.

d. Robustness Test

Multiple iterations with different initializations are required for determining the performance of heuristic algorithms. For these algorithms to be robust, they should give constant results in all iterations.

The results of 50 iterations with the six bus system are compared and shown in Table [3] which clearly highlights the superiority of the Modified Shuffled Frog Leap Algorithm over GA[15]and PSO[15] . The maximum and average values obtained by Modified Shuffled Frog Leap Algorithm have only marginal variations from the minimum value. This reiterates the fact that MSFLA is more sturdy and vigorous.

Table 1: Simulation parameters of MSFL Algorithm

MSFLA Parameters	Value
Population size (*P*)	30
Max. no. of generations (*SI*)	150
Number of memeplexes (*m*)	4
Number of frogs per memeplex (*n*)	5
Maximum iterations per memeplex (*IE*)	2
Acceleration factor (*C*)	2

Table 2: Output for Six Generator System

Generator Power Output in MW	Methods		
	MSFLA	PSO	GA
P1	445.163	447.497	474.8066
P2	173.052	173.3221	178.6363
P3	263.0645	263.4745	262.2089
P4	138.8094	139.0594	.2826
P5	165.275	165.4761	151.9039
P6	87.074	87.128	74.1812
Total Power(MW)	**1272.4379**	**1275.957**	**1276.0195**
Generation Cost($/h)	**15,416**	**15,450**	**15, 459**

Table 3: Output for Ten Generator System

Units	MSFLA	IGAMU
	PG(MW)	PG(MW)
1.	218.9506	210.1261
2.	211.1237	211.1645
3.	280.8615	280.6572
4.	237.432	238.4770
5.	276.9606	276.4176
6.	241.0572	240.4672
7.	287.6519	287.7399
8.	240.0904	240.7614
9.	430.18	429.3370
10.	275.6798	275.8518
Total Power (MW)	**2700**	**2700**
Total Cost($)	**622.9412**	**624.5178**

Table 4: Cost Comparison after 50 trials

Total Generation Cost($/h)	Methods		
	GA	**PSO**	**MSFLA**
Minimum	15459	15450	15422
Maximum	15524	15492	15424
Average	**15469**	**15454**	**15423**

Table 5: Results of best fuel cost for the SFLA and 3 approaches

Unit	MSFLA	[17]	[18]	[19]
1.	0.0865	0.1281	0.1086	0.1168
2.	0.2354	0.2702	0.3056	0.3165
3.	0.2285	0.5552	0.5818	0.5441
4.	0.9553	1.0053	0.9846	0.9447
5.	0.4604	0.4544	0.5288	0.5498
6.	0.3325	0.4453	0.3584	0.3964
Best Cost	**597.94**	606.66	607.807	608.245
Emission	0.2203	0.2207	0.22015	**0.21554**

Table 6: Results of best emission for SFLA and 3 approaches

Unit	MSFLA	[17]	[18]	[19]
1.	0.3752	0.3713	0.4043	0.4113
2.	0.4139	0.4665	0.4525	0.4591
3.	0.5067	0.5642	0.5525	0.5117
4.	0.2793	0.3650	0.4079	0.3724
5.	0.5018	0.5223	0.5468	0.5810
6.	0.5326	0.5783	0.5005	0.5304
Cost	**639.36**	648.01	642.603	647.251
Best Emission	**0.1936**	0.1945	0.1942	0.1943

Figure 1: Cost comparison between three algorithms for six generator system

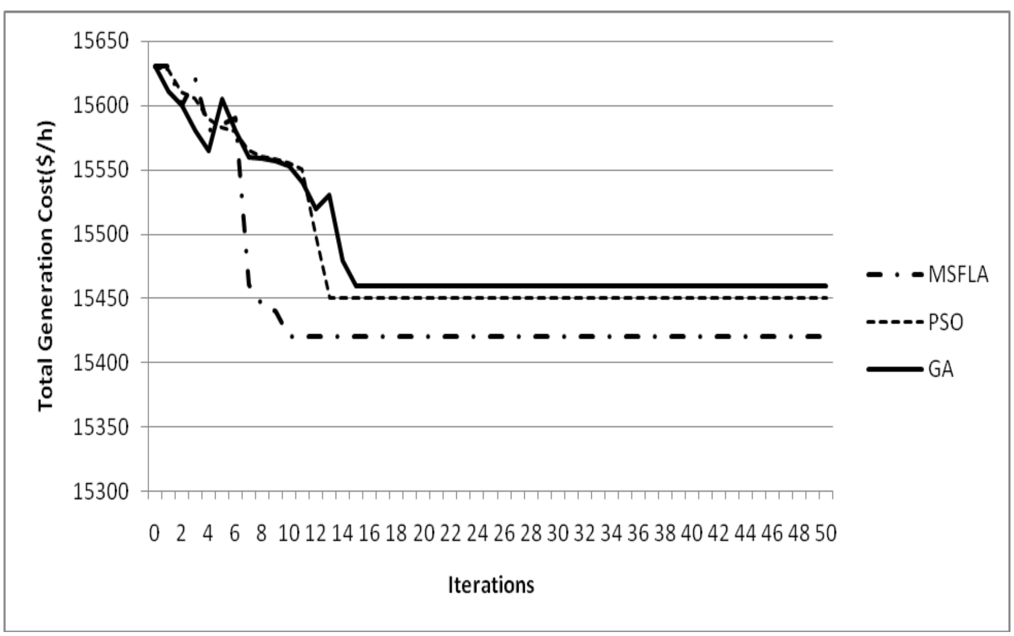
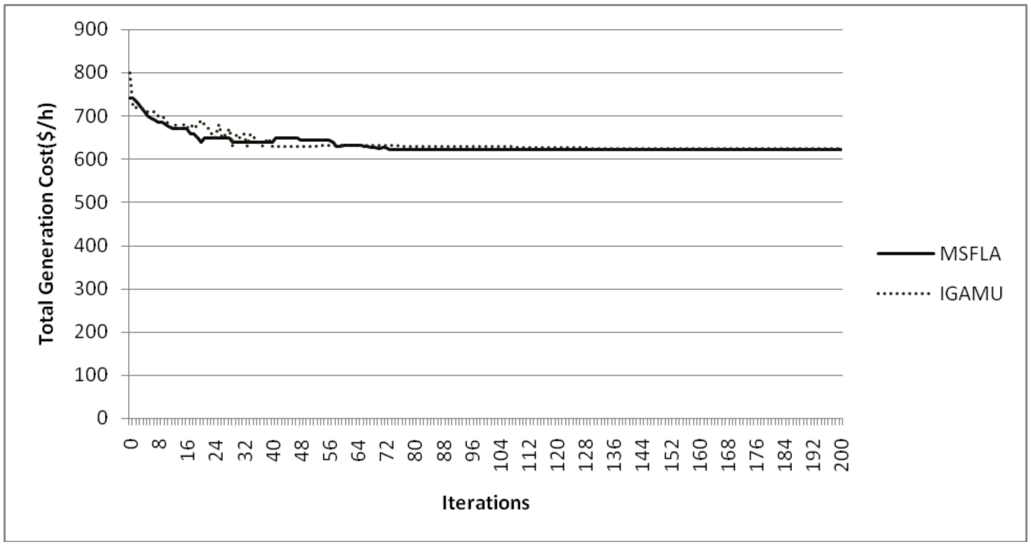


Figure 2: Cost comparison between HB and IGAMU for ten generator system.



V. Conclusion

A new optimisation algorithm has been described to solve the ED problem. The performance has been demonstrated for a 6 bus and10 unit test system, by the proposed MSFL algorithm, it outclassed those techniques prevailing in the same field and is justified, by comparing the accuracy of the results so obtained. The SFL algorithm found many trade off solutions. Wrapping up we can state The MSFL Algorithm as a computationally fast multi objective optimiser tool for complex engineering optimisation problems without any special domain information, apart from that needed to compute objective functions.

References

[1] B.H.Chowdhury and S.Rahman, "A review of recent advances in economic dispatch", IEEE Trans.Power Syst., vol.5, no.4, pp 1248-1259, Nov.1990.

[2] Z.X .Liang and J.D.Glover, " A zoom feature for a dynamic programming solution to economic dispatch including transmission losses," IEEE Trans.Power Syst., vol.7, no.2, pp.544-550, May 1992.

[3] A.J.Wood and B.F.Wollenberg, Power generation operation and control. John Willy and sons, 2nd Ed,pp.39-43,1996.

[4] Srinivasan D, Tettamanzi A. An evolutionary algorithm for evaluation of emission compliance options in view of the clean air act amendments. IEEE Transactions on Power system, vol.12, No.1,Feb.1997, pp.152-168.

[5] Das DB, Patvardhan C. New multi-objective stochastic search technique for economic load dispatch. IEE Proc-Generation Transmission Distribution, vol.145,no.6, Nov.1998,pp.747-752.

[6] EI-Keib A.A., Ma H., Hart J.L. "Economic Dispatch in view of the Clean Air Act of 1990", IEEE Transactions on Power Systems, vol.9,No.2, May 1994,pp.972-979.

[7] Talaq JH, EI-Hawary F, EI-Hawary ME. " a SUMMARY OF Environmental/Economic Dispatch Algorithms", IEEE Transactions on power system, vol.9, no.3,Aug.1994,pp.1508-1514.

[8] Dhillon JS, Parti SC, Kothari DP, "Stochastic economic emission load dispatch", Electric Power System Research, vol.26,No.3,Apr.1993,pp.179-186.

[9] Chang CS,Wong KP, Fan B. “ Security-Constrained multiobjective generation dispatch using bicriterion global optimization” IEE Proceeding- Generation, Transmission Distribution, vol.142, No.4, Jul.1995, pp.406-414.

[10] P.K.Hota, A.K.Barisal, R.Chakrabarti, “ Economic emission load dispatch through fuzzy based bacterial foraging algorithm,” Electrical Power and Energy Systems, vol.32,No.7,Sept.2010,pp.794-803

[11] Agrawal S, Panigrahi BK, Tiwari MK. “ Multiobjective particle swarm algorithm with fuzzy clustering for electrical power dispatch” IEEE Transactions on Evolutionary Computation,vol.12, No.5, Oct.2008 pp.529-541.

[12] Eusuff M.M., Lansey K.E., Pasha F., “Shuffled Frog Leaping Algorithm: A Memetic Meta-heuristic for Discrete Optimization”, Engineering Optimization vol.38, No.2, Mar.2006,pp.129-154.

[13] Emad Elbeltagi, Track Hegazy And Donald Grierson, “ A modified shuffled frog-leaping optimization algorithm: applications to protect management”, Structure and Infrastructure Engineering, vol.3, No.1, Mar.2007, pp.53-60.

[14] J.Nanda, D.P.Kothari,K.S.Lingamurthy,”Economic Emission load dispatch through goal programming technigue, IEEE Trans, Energy Conversion, Vol.3,no.1,pp.26-32, March 1988.

[15] K.Thanuskodi,”A New Particle Swarm Optimization Solution to Nonconvex Economic Dispatch Problems,” IEEE Trans.Power Syst., vol.22,no.1.Feb2007.

[16] N.Sinha,R.Chakrabarti, and P.K.Chattopadhyay,”Evolutionary programming technicques for economic load dispatch.”IEEE Trans.Evol.Comput.,vol.7,no.1,pp.83-94,Feb.2003.

[17] Hemamalini, Sishaj P.Simon,” Emision constrained economic with valve point effect using Particle Swarm Optimisation,” TENCON 2008.IEEE REGON 10.Conference, 19-21 November 2008 page(s): 1-6.

[18] M.Abido,” Environmental/Economic Power dispatch using multi objective evolutionary algorithms,”IEEE Trans.Power Syst., Vol.18, no.4,pp.1529-1537, Nov 2003.

[19] M.A.Abido,” Anovel multi objective evolutionary algorithm for environmental/economic power dispatch,” Electric power system,”Electric Power System Research., vol.65,pp.71-81,2003.