International Journal of Current Trends in Engineering & Technology
ISSN: 2395-3152
Volume: 01, Issue: 07 (NOV-DEC, 2015)

OPTIMIZATION OF ENVIRONMENTAL EMISSION WITH ED USING NEW EVOLUTIONARY TECHNIQUES

Nagendra Singh
Research Scholar, Department of Electrical Engineering
Mewar University, Chittorgarh, Rajasthan, India
Email: nsingh007@rediffmail.com

Harish Nagar
Professor & Director of Research, Department of Electrical Engineering
Mewar University, Chittorgarh, Rajasthan, India
Email: drharishngr@gmail.com

Yogendra Kumar
Professor, Department of Electrical Engineering
MANIT, Bhopal, MP, India.
Email: ykmact@yahoo.co.in

Abstract: *Evolutionary techniques are very effective, efficient and can obtain the optimum solution of the nonlinear problems. Environmental emission is the biggest issue in this era. An economic load dispatch for a thermal power plant is applied for obtaining the optimal power distribution among the various consumer. If same time we can optimize the generation of power to the use of coal will be minimized and hence emission also minimize. This work proposing the multi-objective ED problem including the environmental emission as constraints. Here considered a test data of 30 EEE bus 6 generating unit systems. Proposed test data are solved by a classical method like Lambda iteration and evolutionary techniques like PSO, CPSO, WIPSO, SOH-TVAC PSO, and MRPSO. The validation of the results obtained by proposed evolutionary techniques is compared with other techniques listed in the literature. It is found that MRPSO gives the best results than the other considered techniques.*

Keywords: Multi-objective problem, optimization, economic dispatch, moderate random search particle swarm optimization.

1. Introduction

Electrical power affects the entire process of development, expansion and continued existence of all living beings. It also plays an important role in the development of the economy of the country and human welfare. Electrical power is a strategic commodity. If any uncertainty arises with this then the functioning of the economy will also affect the same ratio[1]. So achieving electrical power security is an important issue for any of the countries. The most important objective of energy security is to fulfill the demand for power supply, lack of energy and environmental effects of energy growth. Electricity expanded rapidly throughout the world after invention. Electrical power systems in the world have grown at a rapid rate and economically expansive with many interconnections between neighboring systems. The production of electricity in India increases and recorded an impressive rate of economic growth in recent years[2].

The efficient and optimum economic operation of electric power systems has always occupied an important position in the electric power industry. In the recent decade, it becomes important to get max. Utilization of power systems with minimum cost while satisfying their customer demand all the time and trying to make a profit [3]. Since the demand is very large and the power generation is limited so it is required to fulfill the load demand using committed generating units in minimum fuel cost.

The electrical power industry changing rapidly and under the current commercial pressure, determining the operating strategies to meet the demand for electricity, for a specific planning horizon, is one of the most important concerns. Power generation plants consisting of many generating units, having their characteristics and operating parameters, are used to meet the total demand at minimum cost[4]. Generally, the operating cost of these generators cannot be proportional to their output, hence the distribution of the total load among generating units is a challenge for power utilities. It becomes more complex when utilities try to account for the transmission loss and seasonal changes[5].

In literature many classical methods known as deterministic algorithms such as Lagrange multipliers [6], Leaner Programming (LP) [7], Dynamic programming (DP) [8], Quadratic Programming (QP) [9], Improved Quadratic Interior Point [10], Parametric Quadratic Programming [11], Interior Point Methods [12], Harmony Search Method [13], and Pattern Search Programming [14], methods were listed, used for the solution of economic load dispatch problem.

In literature, many heuristic evolutionary algorithms are listed such as Differential Evolution (DE) [15], Simulated Annealing (SA) [16], Genetic Algorithm (GA) [17], Particles Warm Optimization (PSO) [18,24], Tabu

Search (TS) [19], Neural Network [20], Fuzzy Logic system [21], etc. used for solution of ELD problems.

In this work, we are proposing the new PSO technique with a moderate random search strategy. Moderate search strategies help to explore the particles in the search area efficiently and help to evaluate the optimum solution as soon as possible. Also, this PSO technique not required to update the particle position again and again so it gives the optimum solution in very little time.

2. Formulation of Multi-objective ELD problem

Objective I

Economic Cost Function: The main objective of the ELD problem as mentioned in Eqn. (1) is taken as the first objective,

$$\text{Minimize } F_T = \sum_{i=1}^{N} F_i(P_i) \quad (1)$$

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i \quad (2)$$

B. Objective II

Emission objective function: The main objective of this study is to minimize the total environmental emission cost. A typical NO_x emission [17], can be formulated as,

$$\text{Minimize } E_T = \sum_{i=1}^{N} E_i(P_i) \quad (3)$$

Where,

$$E_i(P_i) = (\alpha_i + \beta_i P_i + \gamma_i P_i^2) + \xi_i \sin(\lambda_i P_i) \quad (4)$$

Now both objectives may be combined in a single objective as given in Eqn. (4), (5) and (6). Evaluate the cost of each generator at its maximum output.

$$F_i(P_{i.max}) = (a_i P_{i.max}^2 + b_i P_{i.max} + c_i) \quad (5)$$

Evaluate the NO_x Emission of each generator at its maximum output.

$$E_i(P_{i.max}) = (\alpha_i + \beta_i P_{i.max} + \gamma_i P_{i.max}^2) + \xi_i \sin(\lambda_i P_{i.max}) \quad (6)$$

Divide the cost of each generator by its NO_x emission

$$\frac{F_i(P_{i.max})}{E_i(P_{i.max})} = k_i \quad (7)$$

where, E_T is the total emission for ith generating units, $E_i(P_i)$) is the Emission function for ith generating units, and α_i, β_i, γ_i, ξ_i and λ_i are the environmental emission coefficients.

2.1 Subjected to the following Constraints

Power Balance Constraint

The classical and non-classical models either with smooth or non-smoothed fuel cost functions are subjected to the following equality and inequality constraints.

$$\sum_{i=1}^{n} P_i = P_D + P_L \quad (8)$$

Where,
P_D is the total demand and P_L is the line loss.

Generator Power Limits

Each generator is constrained between its minimum and maximum limits, as shown in Eqn. (8),

$$P_i^{min} \le P_i \le P_i^{max} \quad (9)$$

where, P_i is the output power of i[th] generator; P_i^{min} and P_i^{max} are the min/max power outputs of i[th] generator.

3. Particle Swarm Optimization (PSO)

Implementation of the PSO algorithm for the solution of the ELD problem, each element of the swarm is initialized randomly within the effective real power operating limits of the plant. The particles and velocity of the particles are initialized as follows in terms of generated power limits of thermal generating units.

$$P_{initial} = P_{imin} + rand * (P_{imax} - P_{imin}) \quad (10)$$

$$V_{initial} = V_{imin} + rand * (V_{imax} - V_{imin}) \quad (11)$$

where rand is a random positive number between 0 and 1. This position and velocity initialization scheme guarantees to produce new particles satisfying real power operating limit constraints.

3.1 Selection of Velocity

Maximum velocity is given by

$$V_{max} = (P_i^{Max} - P_i^{Min})/N \text{ , and} \quad (12a)$$

$$V_{min} = -(P_i^{Max} - P_i^{Min})/N \quad (12b)$$

where N is the number of intervals in the d-dimension selected by the user and, are maximum and minimum values found so far by the particles.

3.2 Selection of Acceleration Constants

In literature, the value of acceleration constants c_1 and c_2 are considered between 1.2 to 2.4. A maximum number of authors considered c_1 and c_2 =2. In this work, we have to consider $c_1 = c_2 = 2$ and get an optimum solution to the ELD problem.

3.3 Selection of Inertia Weight

The inertia weight is formulated as follows,

$$W = W_{max} - \frac{W_{max} - W_{min}}{iter_{max}} \times \text{iteration} \quad (13)$$

The higher value of inertia weight is considered $W_{max} = 0.9$ and it is decreased in lower value of $W_{min} = 0.4$.

3.4 Updating the Velocity and Particle Positions

The velocity and the position of the d-dimension of the i[th] particle are updated as follows.

$$V_i^{(K+1)} = WV_i^K + c_1 Rand_1 \times (Pbest_i - S_i^K) + c_2 Rand_2 \times (gbest - S_i^K) \quad (14)$$

$$S_i^{(K+1)} = S_i^K + V_i^{K+1} \quad (15)$$

Where, $V_i^{(K+1)}$ and $S_i^{(K+1)}$ is the new velocity and new positions respectively of the particles.

3.5 Fitness Function

For the optimization of economic load dispatch problem in such a way to get the minimum generation cost of the thermal generating units required a fitness function of the ELD problem. This study considers the fitness function as follows,

$$\text{fitness function} = \frac{(\text{Total Demand} - \text{Total power generation})^2}{2} \quad (16)$$

According to this fitness function, the objective of the proposed problem can be formulated as

$$\text{Objective} = \frac{1}{(1+\text{fitness function})} \quad (17)$$

4. Moderate Random Search Particle Swarm Optimization (MRPSO)

PSO is a very simple and popular optimization tool used for solving the ELD problem but it has some disadvantages also, for example, PSO lacks in global search ability at the last stage of iterations. So it is unable to give the global optimal solution of the ELD problem. In the year of 2011 [22], Gao and Xu first introduced the PSO with a moderate random search strategy called MRPSO.

The position of the particles is updated for the ith particle at the (K+1)th iteration as following:

$$S_i^{K+1} = P_d + \alpha\,\lambda\left(m_{besti} - S_i^K\right) \quad (18)$$

Where the value of m_{best} for ith generating unit is given as follows

$$m_{best\,i} = \sum_{i=1}^{N} \frac{P_{best}}{N} \quad (19)$$

where N is the population size.

$$P_d = rand_0\, P_{best} + (1 - rand_0)\, g_{best} \quad (20)$$

And the value of λ is represented as

$$\lambda = \frac{rand_1 - rand_2}{rand_3} \quad (21)$$

4.1 Algorithm of MRPSO for Economic Load Dispatch Problem

In this work, PSO with the moderate random search technique is used to solve the ELD problem. The main objective is to minimize the total generation cost and the second objective is to reduce the environmental emission of the thermal power plant. The following steps are being used to solve the ELD problem by using MRPSO.

Step.1 *Select the constants.*
Step.2 *Initialization of the swarm:- First off all particles are randomly generated for population size in the range 0 and 1, and located between the maximum and the minimum operating limits of the generators.*
Step.3 *Initialize velocity and position for all particles randomly set to within their minimum and maximum limits.*
Step.4 *Set generation counter: counter = counter+1.*
Step.5 *Evaluating the fitness for each particle according to the proposed objective function.*
Step.6 *Compare particle fitness evaluation with its P_{best} and $_{best}$.*
Step.7 *Update the position of particles by using Eqn. (18).*
Step.8 *Apply the stopping criteria. A maximum number of iterations is the stopping criteria taken in this study, which means when the number of iterations will complete the conversion of the algorithm is stopped. A maximum number of iteration is tuned based on trial and error.*

Table 1:Capacity, cost coefficients and environmental emission limits of 6 generator systems.

Gen. Unit	a_i	b_i	c_i	d_i	e_i	f_i	P_i^{min}	P_i^{max}
1	015	38.54	756.8	.0042	.33	13.86	10	125
2	0.11	46.2	451.4	.004	.33	13.9	10	150
3	0.02	40.16	1049.99	.00683	-.55	40.27	35	225
4	0.04	38.31	1234.5	.0068	-.55	40.27	35	210
5	0.02	36.33	1658.6	.0046	-.52	42.7	130	325
6	0.02	38.27	1356.7	.0042	-.52	42.7	125	315

Table 2: Results of 6 generating unit systems for load demand of 700MW.

Output Power	Lambda Iteration [23]	PSO	SOH-TVAC PSO	WIPSO	MRPSO
P1(MW)	46.825	29.5178	28.9413	78.9416	68.6312
P2(MW)	44.6809	89.7406	91.9585	23.0482	14.3395
P3(MW)	159.6223	158.084	108.153	104.028	100.431
P4(MW)	83.8875	116.911	129.8021	195.35	210
P5(MW)	220.0442	145.541	187.287	199.730	130
P6(MW)	191.0025	184.831	179.281	125	202.77
Loss(MW)	46.0624	26.098	25.42	26.179	24.6273
Power output (MW)	746.062	726.098	725.424	726.179	724.627
Fuel cost ($/h)	38345.04	38051.18	38066.86	38058.59	38013.8
Emission (kg/h)	542.1007	516.9762	470.7899	539.927	460.2424
Total cost($/h)	38887.104	38568.08	38537.68	38598.49	38478.01
Computation time(sec)	2.019	0.872	0.840	0.882	0.810

5. TEST CASE AND RESULT ANALYSIS

Here a multi-objective ELD problem is considered. The capacity, cost coefficients and environmental emission limits of 6 generator systems, for the load demand of 700MW, is shown in table 1. Optimum results obtained by PSO, SOH-TVAC PSO, WIPSO, and MRPSO are presented in table 5.14. The obtained results of these evolutionary techniques are compared with Lambda iteration [23], and it is found that the best results are given by the MRPSO algorithm. The fuel cost obtained by MRPSO is 38013.8 $/h, environmental emission obtained by MRPSO is 460.2424 Ton /h and time taken to compute the solution of this problem is 0.8101 second.

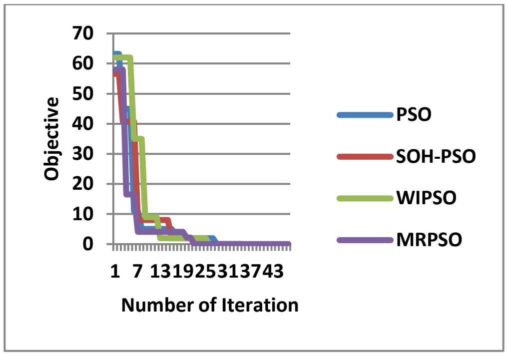

Fig. 1. Characteristic of (a) PSO b) SOH-PSO (c) WIPSO and (d) MRPSO, for 6 Generating units and 700 MW load demand.

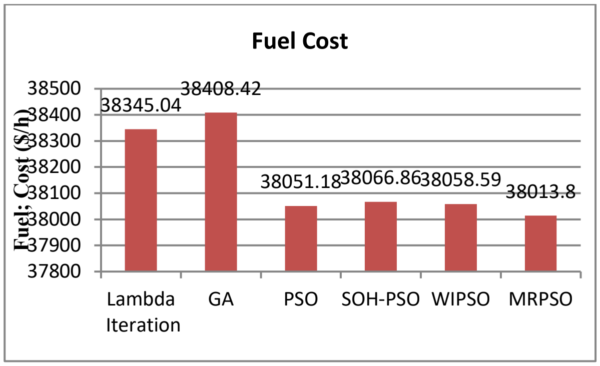

Fig.2. Fuel cost obtained by different techniques for 6 Generating units and 700 MW load demand.

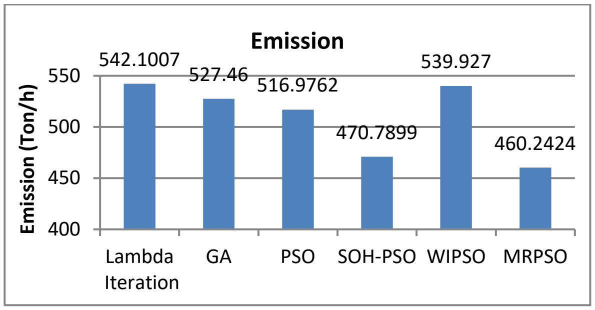

Fig.3. Emission obtained by different techniques for 6 Generating units and 700 MW load demand.

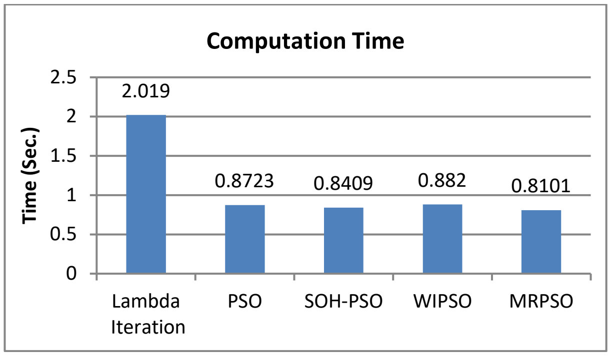

Fig.4. Computational time is taken by different techniques for 6 Generating units; and 700 MW load demand.

6. Conclusions

Results of the test on various IEEE standard data bus systems of the different generating unit systems are represented in this chapter. All test data taken for testing of the proposed evolutionary techniques have their generation limits as well as fuel cost coefficients, environmental effect constants, and constraints limits. All the test data presented over in this chapter are tested by Lambda iteration methods and evolutionary techniques such as PSO, CPSO, WIPSO, SHO-TVAC PSO, and MRPSO. Results obtained by each test data by use of these optimization techniques are represented for the comparative analysis. The convergence characteristic of evolutionary techniques for each test case is also presented in this chapter. Computational time taken by different techniques is presented by the bar chart.

References

[1]. Azami1 Rahmat, Mohammad Sadegh Javadi and Ghasem Hematipour, "Economic load dispatch and dc-optimal power flow problem-PSO versus LR", International journal of multidisciplinary sciences and engineering, vol. 2, no. 9, pp. 8-14, December 2011.

[2]. Batham Rajkumari, Jain Kalpana, and Pandit Manjaree, "Improved particle swarm optimization approach for nonconvex static and dynamic economic power dispatch", International journal of engineering, science, and technology, vol. 3, no. 4, pp. 130-146, 2011.

[3]. Bouktir Tarek, Labdani Rafik, and Slimani Linda, "Economic power dispatch of power system with pollution control using multiobjective particle swarm optimization", University of Sharjah Journal of pure & applied sciences vol. 4, No. 2, pp. 57-77, 2007.

[4]. Chakraborty S., Senjyu T., Yona A., Saber A.Y. and Funabashi T., "Solving economic load dispatch problem with valve-point effects using a hybrid quantum mechanics inspired particle swarm optimization", IET generation transmission distribution, vol. 5, Iss.10, pp. 1042–1052, 2011.

[5]. Chen C.H. & Yeh S.N., "PSO for economic power dispatch with valve point effects," IEEE PES transmission & distribution conference and exposition Latin America, Venezuela, 2006.

[6]. Aoki K. and Satoh T., "Robust algorithm for economic dispatch of interconnected systems", IEEE transactions on power apparatus and systems, vol. PAS-104, no. 2, pp. 266-272, February 1985.

[7]. Kyoung-Shin Kim and Un-Chul Moon, "Security constrained economic dispatch using interior point method", International conference on power system technology, pp. 1-6, 2006.

[8]. Travers Dean L. and Kaye R. John, "Dynamic dispatch by constructive dynamic programming", IEEE Transactions on power systems, vol.13, no. 1, pp. 72-78, February 1998.

[9]. Aoki K. and Satoh T., "Economic dispatch with network security constraints using parametric quadratic programming", IEEE transactions on power apparatus and systems, vol. pas-101, no. 12, December 1982.

[10]. Momoh J. A. and Zhu J.Z., "Improved interior point method for OPF problems", IEEE transactions on power systems, vol.14, no.3, pp. 1114-1120, August 1999.

[11]. Aoki K. and Satoh T., "New algorithms for classic economic load dispatch", IEEE transactions on power apparatus and systems, vol. pas-103, no. 6, pp. 1223-1231, June 1984.

[12]. Irisarri G., Kimball L. M., Clements A., Bagchi A., and W. Davis, "Economic dispatch with network and ramping constraints via Interior point methods", IEEE transactions on power systems, vol. 13, no. 1, pp. 236-242, February 1998.

[13]. Arul R., G. Ravi, and Velusami S., "Non-convex economic dispatch with heuristic load patterns using harmony search algorithm", International Journal of computer applications, vol. 16, no.1, pp. 26-34, February 2011.

[14]. Al-Summit J.S., Al-Othman A.K. and. Sykulski J.K, " Application of pattern search method to power system valve point economic load dispatch," Electrical power energy system, vol.29, no.10, pp. 720-730, 2007.

[15]. Coelho Leandro dos Santos and Mariani Viviana Cocco, "Combining of chaotic differential evolution and quadratic programming for economic dispatch optimization with valve-point effect", IEEE transactions on power systems, vol. 21, no. 2, pp. 989-996, May 2006.

[16]. Mantawy A. H., Abdel-Magid Youssef L., and Seliin Shokri, "A simulated annealing algorithm for unit commitment", IEEE transactions on power systems, vol. 13, no.1, pp. 197-204, February 1998.

[17]. Attia A. El-Fergany, "Solution of economic load dispatch problem with smooth and non-smooth fuel cost functions including line losses using genetic algorithm", International Journal of computer and electrical engineering, vol. 3, no. 5, pp. 706-710, October 2011.

[18]. Rashidi M. R., AlHajri M. F., and El-Hawary M. E., "Enhanced particle swarm optimization approach for solving the non-convex optimal power flow", World Academy of science, engineering and technology 62, pp. 651-655, 2010.

[19]. Senthil K. and Manikandan K., "Improved Tabu search algorithm to economic emission dispatch with transmission line constraint", International journal of computer science & communication vol. 1, no. 2, pp. 145-149, July-December 2010.

[20]. Chaturvedi Krishna Teerth, Srivastava Laxmi and Pandit Manjaree "Levenberg Marquardt algorithm based economic load dispatch", IEEE conference, pp. 1-7, 2006.

[21]. Dutta Papiya and Sinha A.K., "Environmental economic dispatch constrained by voltage stability using PSO", IEEE conference, pp.1879-1884, 2006.

[22]. Hao Gao and Wenbo Xu, "A new particle swarm algorithm and its globally convergent modifications," IEEE transactions on systems, man, and cybernetics—Part B: cybernetics, vol. 41, no. 5, pp.1334-1351, October 2011.

[23]. Senthil K. and Manikandan K., "Economic thermal power dispatch with emission constraint and valve point effect loading using improved Tabu search algorithm", International journal of computer applications, vol.3, no.9, pp. 6-11, July 2010.

[24]. Bikash Das; T. K. Sengupta, "Economic load dispatch using PSO and TLBO", Michael Faraday IET International Summit 12-13 Sept. 2015