Advanced Research in Electrical and Electronic Engineering
Print ISSN: 2349-5804; Online ISSN: 2349-5812 Volume 1, Number 3 (2014) pp. 39-45

http://www.krishisanskriti.org/areee.html

Group Search Optimizer for Economic Load Dispatch

Farheen Chishti[1], Arun Kumar Gangwar[2]

[1]*Electrical Engineering Department*
Shri Ram Murti Smarak Women's College of Engineering & Technology, Bareilly, India
[2]*Electrical Engineering Department, Invertis University, Bareilly, India*

Abstract: **The economic load dispatch (ELD) is the process of allocating the forecasted load demand among the committed generating units in electric power system and its primary objective is to minimize the total cost of generation while honoring the operational constraints of the available generation's resource. This paper concerns with the implementation of group search optimizer (GSO) to find the global solution for nonlinear optimization problems while satisfying equality and inequality constraints in the context of time expansive evaluation of functions. GSO technique implements the animal scanning mechanism metamorphically to design optimum searching strategies for solving optimization problems. Group search algorithm employed in this paper is population based algorithm, and resource searching process of animals in nature is analogous to the process of seeking optima in a search space. The promising results on the benchmark function show the applicability of the group search optimizer for solving economic load dispatch problem. The validity of the proposed method has been demonstrated for three, four and six generator electrical power system.**

Keywords: Economic load dispatch, minimize, Group search optimizer, scanning, searching, optima.

1. INTRODUCTION

Economic dispatch is the method of determining the most efficient, low-cost and reliable operation of a power system by dispatching the available electricity generation resources to supply the load on the system. The primary objective of economic load dispatch problem is to minimize the total cost of generation while satisfying the operational constraints of the available generation resources. Traditionally, in economic load dispatch the input–output characteristics (or cost function) of a generator is approximately represented by using a single quadratic function. Practically, operating conditions of many generating units need the cost function to be represented as piecewise quadratic function. However, higher-order nonlinearities and discontinuities are observed in real input–output characteristics due to valve-point loading in fossil fuel burning plants. Furthermore, the operating range for online units is actually restricted by their ramp-rate limits. These and other constraints transform an economic load dispatch problem into a hard non convex optimization problem, with many local optimum solutions and a large number of constraints. Conventional methods have failed to solve such problems as they are sensitive to initial estimation and converge into local optima. GSO is an evolutionary programming technique and provides better solution when compared with the other methods. This paper is a response note on the work of application of population based GSO algorithm to solve various ELD problems.

2. REVIEW OF LITERATURE

Optimization techniques involved in solving ELD using quadratic programming techniques, evolutionary techniques, and population based algorithms are discussed. The latest work is done on economic load dispatch problem by the employment of the population based algorithms as they provide a method that finds the optimum cost accurately. Aoki and Satoh [4] presented and efficient method to solve the economic load dispatch problem with the dc load flow type network security constraints. Chowdhary and Rahman [6] presented a survey of papers and reports which addressed various aspects of economic load dispatch. Walters and Sheble [8] used genetics based algorithm to solve economic dispatch problem for valve-point discontinuities. Dhillon, *et al*. [7] gave the economic emission load dispatch (EELD) problem is a multiple non-commensurable objective problem that minimized both cost and emission together. EELD problem has been formulated with consideration of the uncertainties in the system production cost and nature of the load demand, which is random. Eberhart and Kennedy [9] described the optimization of the nonlinear functions using the particle swarm methodology. Chiang [14] developed a genetic algorithm with multiplier updating (IGAMU) to solve practical power economic load dispatch (PELD). Coelho, et al. [22] proposed a differential evolution (DE) algorithm for solving economic load dispatch problems. Bhattacharya, et al. [24] presented a biogeography-based optimization (BBO) algorithm to solve both convex and non-convex economic load dispatch (ELD) problems of thermal plants. These methods have their own advantages and disadvantages but the group search optimizer being a population based algorithm provides results which are robust and they are successfully tested on the benchmark functions as well as on the three and six generator electrical power system.

3. PROBLEM FORMULATION

3.1 Objective Function

The primary objective of any ELD problem is to reduce the operational cost by fulfilling the load demand within limit of constraints. The various kinds of objective function formulation are given below.

3.1.1 Generator Operating Cost: The total cost of operation includes the fuel cost, cost of labour, supplies and maintenance. Mathematically it can be represented as a quadratic polynomial of generated power.

$$F_i(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i \quad \text{Rs/h} \qquad (1)$$

where : a_i ,b_i, c_i are the operating cost coefficients. P_{gi} is the real power generation and the decision variable and $F_i(P_{gi})$ is the operating fuel cost of the ith plant.

3.1.2 Objective Function with Valve Point Loading*:* Real input-output characteristics display higher-order nonlinearities and discontinuities due to valve-point loading in fossil fuel burning plant. The valve-point loading effect has been modeled in as a recurring rectified sinusoidal function [10]. Mathematically, operating cost considering valve point loading is defined as:

$$F(P_{gi}) = \sum_{i=1}^{n}(a_i P_{gi}^2 + b_i P_{gi} + c_i) + \left|d_i * \sin\{e_i * (P_{gi}^{min} - P_{gi})\}\right| \qquad (2)$$

where: P_{gi}^{min} is the minimum loading limit below which it is uneconomical to operate the unit and P_{gi}^{max} is the upper permissible limit of real power generation.

3.2 Economic Load Dispatch without Transmission Losses

Suppose there is a station with n generators committed and the active power load P_D is given, the real power generation P_{gi} for each generator has to be allocated so as to minimize the total cost. The optimization problem can be stated as [10]:

$$\text{Minimize: } F(P_{gi}) = \sum_{i=1}^{n} F_i(P_{gi}) \qquad (3)$$

Subjected to:
The energy balance equation

$$\sum_{i=1}^{n} P_{gi} = P_D \qquad (4)$$

The inequality constraints are given

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \; (i = 1,2,\dots,n) \qquad (5)$$

where: n is the number of generating plants.

3.3 Economic Load Dispatch with Transmission Losses

The transmission losses cannot be neglected particularly when long distance transmission of power is involved. While developing the ELD policy, transmission losses P_L are considered. Mathematically, the ELD optimization problem is defined as

$$\text{Minimize: } F(P_{gi}) = \sum_{i=1}^{n} F_i(P_{gi}) \quad \text{Rs/h} \qquad (6)$$

Subjected to:
The energy balance equation

$$\sum_{i=1}^{n} P_{gi} = P_D + P_L \qquad (7)$$

The inequality constraints are given

$$P_{gi}^{min} \le P_{gi} \le P_{gi}^{max} \qquad (i = 1,2,\dots,n) \qquad (8)$$

The transmission loss expression is [17]:

$$P_L = B_{00} + \sum_{i=1}^{n} B_{i0} P_{gi} + \sum_{i=1}^{n}\sum_{j=1}^{n} P_{gi} B_{ij} P_{gj} \; \text{MW} \qquad (9)$$

where P_{gi} and P_{gj} are the real power injections at the ith and the j buses, respectively. B_{00}, B_{i0}, B_{ij} are the loss coefficients which are constant under certain assumed conditions. n is the number of the generation buses.

4. GROUP SEARCH OPTIMIZER

Nature serves as a source for concepts, principles and designing algorithms for solving many complex problems. The most successful algorithms are evolutionary algorithms that are inspired from the concept of natural selection. There are many recently developed algorithms that are being able to resolve many of the highlighted problems. Some of them are genetic algorithm (GA)[8], ant colony algorithm (ACO)[18], particle swarm optimization (PSO)[9][23][26], biogeography based optimization technique (BBO)[24][25], evolutionary programming (EP) and evolutionary strategies (ES)[22].

The group search algorithm is a population based, nature inspired Optimization algorithm, basically inspired from the animal behavior. This animal behavior is the animal searching behavior which is based on the Producer-Scrounger model which assumes that group member search either for finding or for joining opportunities. The finding part is done by the producer (best member with best fitness value) and the joining part is done by the scroungers. Group searching allows the group members to increase patch finding rates as well as to reduce the variance of the search success [27].

The population is defined as the group and each individual in the group is termed as the member. There are three types of members in GSO which are defined as [15]:

- Producers
- Scroungers
- Rangers (dispersed members)

Here in this paper it is assumed that at each iteration there is only one producer and the rest members are scroungers and rangers and all the members will join the resource found by the producer. The producer will find the best point with the best fitness value (resource) by employing the scanning mechanism. Only the producer scans the environment to find the optima. The unknown optima are considered as open patches randomly distributed in the search space. All the members search for these patches by moving over the search space. At each iteration, the member which is in the most promising area and granting the best fitness value is chosen as the producer. All the members have the same phenotypic characteristics. So, they can switch between the two roles of producer and scrounger. If the producer fails to find the best point and a scrounger is able to do the same then in the next iteration it will switch to be the producer and the producer of the older iteration with other members of the group will perform the scrounging activity after dispersion from their current positions. This switching helps the group to escape from the entrapments of local minima in the earlier iterations. Some of the dispersed members may perform random walks and systematic search strategies to locate the resource efficiently, and they are referred to rangers. Ranging is an initial phase of the search that starts without cues leading to a specific resource [27].

5. ALGORITHM FORMULATION

5.1 The GSO Algorithm Consists of the Following Steps:

5.1.1 Initialization of population: Initial population is generated by assigning random values to each decision parameter of each individual of the population. In GSO x_{ji} is the decision variable for the population. If the initial solution is available, addition of normally distributed random deviations to the nominal solution often generates the initial population.

$$x_{ji} = x_i^{min} + R(\,)(x_i^{max} - x_i^{min}) \quad (j = 1,2,\dots,NV\,;\, i = 1,2,\dots,NA) \quad (10)$$

where x_{ji} is the initial population of the i^{th} generating unit. x_i^{max} is the lower bounds of the i^{th} generating unit and x_i^{min} is the upper bounds of the i^{th} generating unit. R is the uniformly distributed random number.

5.1.2 Initialization of head angles: The initial head angles are generated using

$$d_{1j} = \cos(\varphi_{1j}) \qquad (j = 1,2\dots,NA) \quad (11)$$

$$d_{ij} = \cos(\varphi_{ij})\prod_{q=i}^{NV-1}\sin(\varphi_{qj}) \quad (j = 1,2\dots.NA\,;\, i = 1,2,\dots,NV) \quad (12)$$

$$d_{NV,j} = \prod_{q=1}^{NV-1}\sin(\varphi_{qj}) \quad (j = 1,2,\dots,NA) \quad (13)$$

With φ_i as the head angle of the i^{th} generating unit and d_i is the search direction unit vector i^{th} generating unit.

The maximum pursuit distance is calculated using:

$$l^{max} = \left\| x_i^{max} - x_i^{min} \right\| \quad (14)$$

5.1.3 Fitness: The objective function is calculated on these parameters and the function value is termed as fitness. So, the fitness is sorted to find the member with best fitness or lowest function value.

5.1.4 Choosing producer: At each iteration, the generating unit in the most promising area and conferring the best fitness value is chosen as the producer. The producer then stops and scans the environment to seek optima or resource.

5.1.5 Producer's action: The producer will scan at zero degree and then laterally scan by randomly sampling three points in the scanning field using

At zero degree:

$$X^z = X_p{}^k + d_j{}^k * R_1 * l^{max} \qquad (j = 1,2,\dots,NA) \quad (15)$$

(R_1 = normally distributed random number)
At right hand side of hypercube:

$$X^r = X_p{}^k + R_1 * l^{max} * d_j{}^k \;;\; \varphi_j = \varphi_j{}^k + \frac{\theta^{max} * R_2}{2} \quad (j = 1,2,\dots,NA) \quad (16)$$

At left hand side of the hypercube:

$$X^l = X_p{}^k + R_1 * l^{max} * d_j{}^k \;;\; \varphi_j - \varphi_j{}^k - \frac{\theta^{max} * R_2}{2} \quad (j = 1,2\dots,NA) \quad (17)$$

(R_2 = uniform distributed random number)

where k is the predefined number of iterations. NV is the number of variables and NA is the number of generating units. x_i^{min} *and* x_i^{max} is the minimum and maximum population and $\varphi_0 = \frac{\pi}{4}$ (Initial angles) and φ_{ij} is the head angles. a is constant, l^{max} is maximum pursuit distance, $\theta^{max} = \frac{\pi}{a^2}$ (maximum pursuit angle) and $\alpha^{max} = \frac{\theta^{max}}{2}$ (maximum turning angle)

The best point with the best resource (fitness value) is found. If the best point has a better resource than its current position, then it will fly to this point. Otherwise it will stay in its current position and turn its head to a new angle using:

$$\varphi_{ij}^{k+1} = \varphi_{ij}^{k} + R_2 * \alpha^{max} \quad (i = 1,2,\dots,NV-1; j = 1,2,\dots,NA) \tag{18}$$

If the producer cannot find a better area after a iterations then it will turn its head back to zero degree using:

$$\varphi_j^{k+a} = \varphi_j^{k} \qquad (j = 1,2,\dots,NA) \tag{19}$$

5.1.6 Perform scrounging: *Randomly select 80% from the rest members to perform scrounging using:*

$$X_j^{k+1} = X_j^{k} + R_3 * (X_p - X_j) \; (j = 1,2,\dots,NA) \tag{20}$$

5.1.7 Perform dispersion: *For the rest members, they will be dispersed from their current positions to perform ranging using:*

Generate the random head angle using Eq.(18)
Choose a random distance l_j from the Gauss Distribution using:

$$l_j = a * R_1 * l^{max} \tag{21}$$

Move to the new point using:

$$X_j^{k+1} = X_j^{k} + l_j * d_j \quad ; d_j = d_j^{k} * \varphi_j^{k+1} \; (j = 1,2,\dots,NA) \tag{22}$$

Now, again the fitness of the current members are calculated and the steps are again performed

5.1.8 Stopping criteria: These steps are continued until a predefined number of iterations are executed. This is mainly the stopping criteria for almost all the population based methods.

6. RESULTS

The group search algorithm is implemented on standard test functions and on the three and six generator electrical power system and the observed results are discussed. The performance is observed through the diversity of the obtained solution.

6.1 Standard Test Functions

Test Function 1:
Minimize:

$$f(z) = -20\exp\left(-0.2\sqrt{\tfrac{1}{n}\sum_{i=1}^{n} z_i^2}\right) - \exp\left(\tfrac{1}{n}\sum_{i=1}^{n} \cos 2\pi z_i\right) + 20 + e$$

where $-32 < z_i < 32$ and $(i = 1,2,\dots,NA)$

The variation of the objective test function value with number of iterations using group search optimizer is depicted in Figure.1.

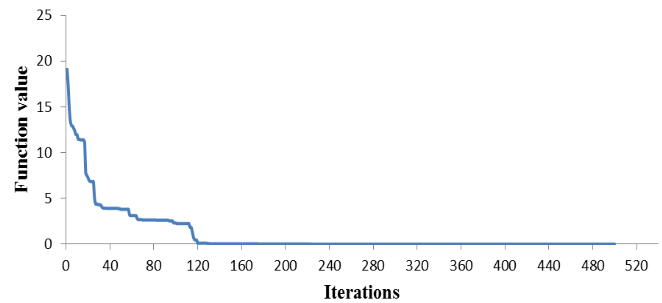

Figure.1. Variation of function value w.r.t. number of iterations

The function value decreased from 20.091760 to 0.00004 in 500 iterations

6.2 Electrical Power System: Three Generator

With Valve Point Loading: For a three generator system, the fuel cost coefficients, operating generator limits are given in Table 1 and the B_{ij}-coefficients for transmission loss are given in Table 2. For a given load demand of 210 MW, the optimum generation schedule is obtained and can be seen from Figure.2.

Table 1: Fuel cost coefficients and operating generator limits for three generator system with valve point loading

Generator i	a_i (Rs/MW²h)	b_i (Rs/MWh)	c_i (Rs/h)	d_i (Rs/h)	e_i (Rs/h)	P_{gi}^{min} (MW)	P_{gi}^{max} (MW)
1	0.006085	10.04025	136.9125	200.0	0.035	5.0	150.0
2	0.005915	9.760576	59.1550	140.0	0.040	15.0	150.0
3	0.005250	8.662500	328.1250	100.0	0.004	50.0	250.0

Table 2: B_{ij}- -coefficients for three generator system (MW-1)

0.0001363	0.0000175	0.0001839
0.0000175	0.0001545	0.0002828
0.0001839	0.0002828	0.0016147

The variation of the cost with number of iterations is shown in Figure.2. The local cost and the global cost are depicted in the same graph and the concluded result is that, in 1000 iterations the lowest cost attained is Rs 2605.0729.

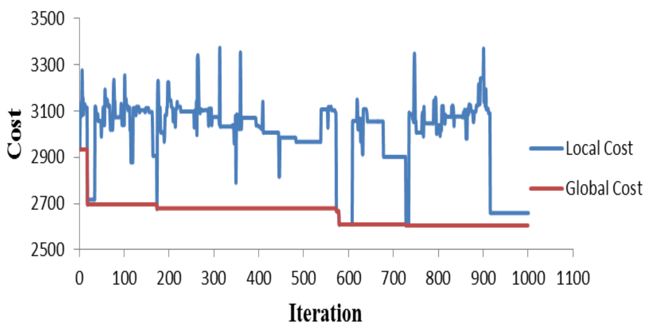

Figure.2. Variation of Cost w.r.t. number of iterations: Three generator system with valve point loading

Without Valve Point Loading: The fuel cost coefficients of three generator electrical power system are given in Table 3 and coefficients for transmission loss are given in Table 4. The optimal generation schedule has been calculated for loads 160 MW and 210 MW and is shown in Figure.3 and Figure.4.

Table 3 Fuel cost coefficients and operating generator limits for three generator system

Generator i	a_i (Rs/MW²h)	b_i (Rs/MWh)	c_i (Rs/h)	P_{gi}^{min} (MW)	P_{gi}^{max} (MW)
1	0.006085	10.04025	136.9125	5.0	150.0
2	0.005915	9.760576	59.1550	15.0	150.0
3	0.005250	8.662500	328.1250	50.0	250.0

Table 4 B_{ij}-coefficients for three generator system (MW-1)

0.0001363	0.0000175	0.0001839
0.0000175	0.0001545	0.0002828
0.0001839	0.0002828	0.0016147

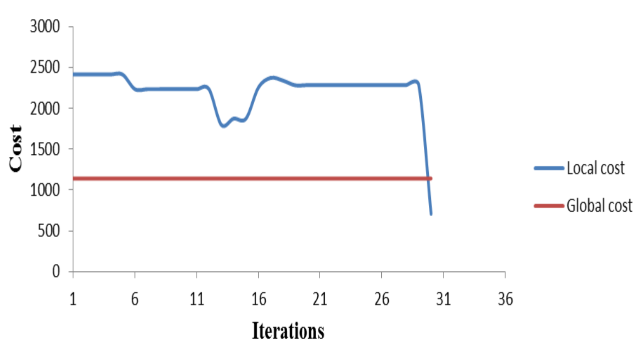

Figure.3. Variation of cost w.r.t. number of iterations: Three generator system with 160 load demand

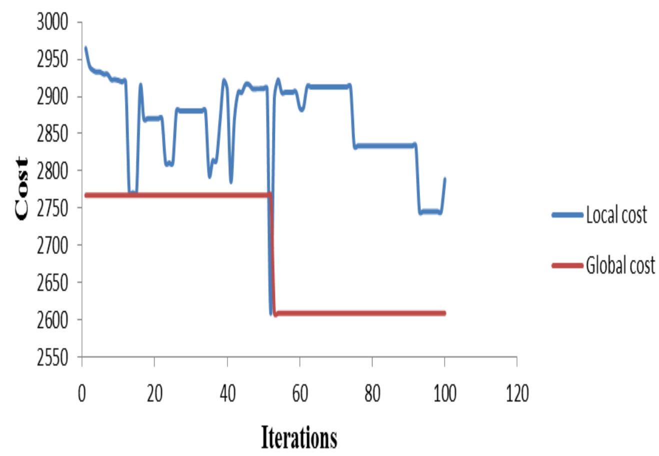

Figure.4. Variation of cost w.r.t. number of iterations: Three generator system with 210 load demand

The results obtained by GSO method for three generator electrical power system without the consideration of the valve point loading are more robust in comparison to the results obtained by steepest descent method [28], conjugate gradient method [28] and Newton-Raphson method [10]. The comparison of the results is shown in Table 5.

Table 5 Comparison of results for three generator system

Load Demand(MW)	Method	P_{g1} (MW)	P_{g2} (MW)	P_{g3} (MW)	F (Rs/h)	P_L (MW)
160	Steepest descent method	58.9287	62.5528	41.4465	2163.73	2.92800
	Conjugate gradient method	55.14402	55.12446	54.7345	2150.07	5.002980
	Newton Raphson method	57.5577	70.5238	37.9172	2176.023	5.99864
	Group search optimizer	60.4691	49.8426	53.0164	1140.811	3.3281
210	Steepest descent method	78.1483	78.9839	62.5287	2747.11	9.66090
	Conjugate gradient method	73.99728	73.93189	72.93531	2716.88	10.86448
	Newton Raphson method	83.4010	95.6169	39.4862	2741.473	8.503935
	Group search optimizer	70.4523	63.2396	112.0366	2608.962	35.728

6.3 Electrical Power System: Six Generator

6.3.1 With Valve Point Loading: The local cost and the global cost are depicted in the same graph and the concluded result is that, in 1000 iterations the lowest cost attained is Rs.2105.671 and is shown in Figure.5.

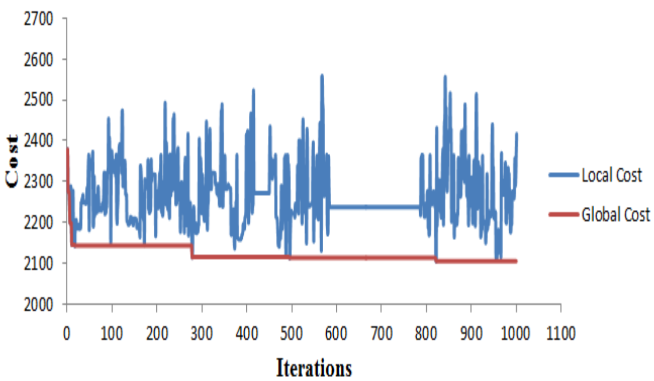

Figure.5. Variation of cost w.r.t. number of iterations: Six generator system with valve point loading

6.3.2 Without Valve Point Loading: Comparison of results obtained for load demand 1800MW for six generator power system by implementation of group search optimizer with the results obtained by steepest descent method [44], conjugate gradient method [44] and newton raphson method [17] are presented in Table 6 and Figure.6.

Table 6 Comparison of results for six generator system

Method	P_{g1} (MW)	P_{g2} (MW)	P_{g3} (MW)	P_{g4} (MW)	P_{g5} (MW)	P_{g6} (MW)	F (Rs/h)	P_L (MW)
Steepest descent method	268.23	276.53	502.77	373.47	306.33	196.47	18639.40	123.83
Conjugate gradient method	194.42	371.07	412.84	330.49	407.17	206.99	18523.80	123.02
Newton Raphson method	251.69	303.77	503.48	372.32	301.46	301.46	18721.39	130.15
Group search optimizer	187.20	267.38	454.97	387.82	342.91	161.231	12279.365	1.525

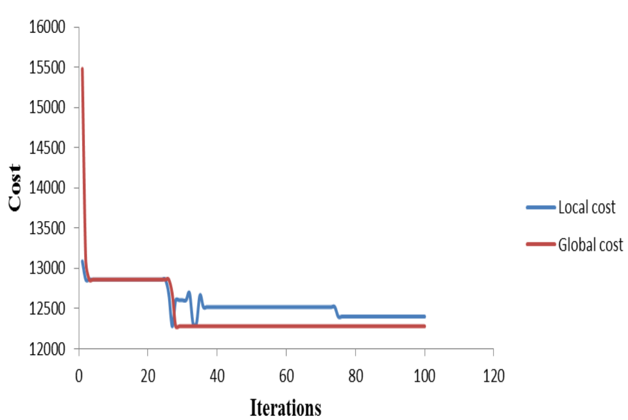

Figure.6. Variation of function w.r.t. number of iterations: Six generator system with 1800 load demand

7. COMPARATIVE STUDY

The group search optimizer provides better solution for the three generator electrical power system with load demand of 160 MW and 210 MW and for six generator system with load of 1800 MW. The following figures depict the comparative operating costs of the steepest descent method [28], conjugate gradient method [28], newton raphson method [10] and group search optimizer method. On analyzing the results it is seen that the cost is reduced effectively without violating any of the constraints.

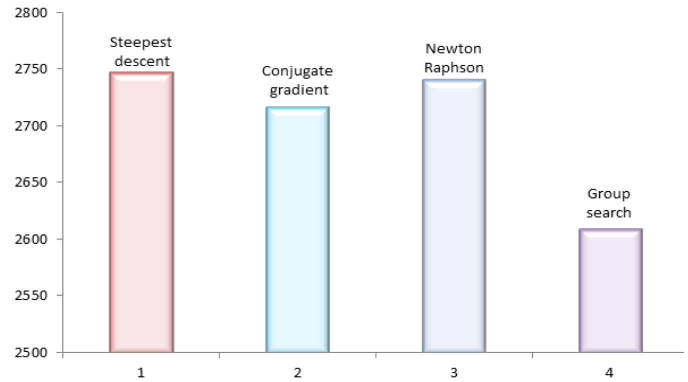

Figure.7. Operating cost comparison for load demand 160 MW

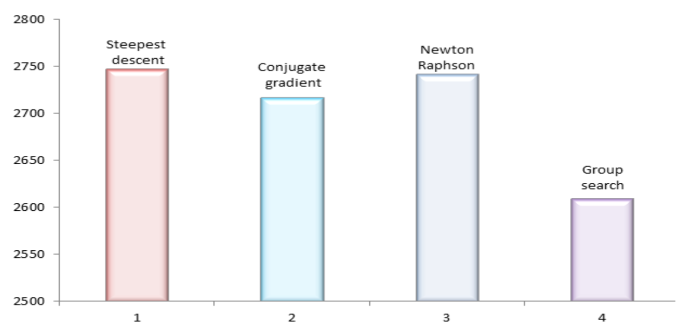

Figure.8. Operating cost comparison for load demand 210 MW

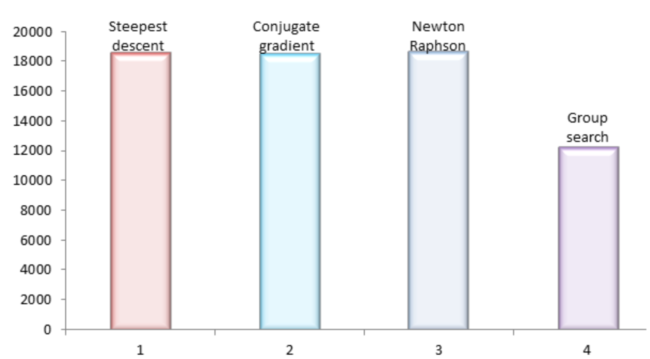

Figure.9. Operating cost comparison for load demand 1800 MW

8. CONCLUSION

Group search optimizer is a stochastic Evolutionary optimization algorithm that mimics the foraging behavior of animals. In order to accomplish the foraging task in GSO algorithm the producer-scrounger strategy is employed. Foragers in the Producer–Scrounger model are assumed to use producing or joining strategies exclusively. Many evolutionary algorithms have been employed but the convergence speed is not satisfactory. But GSO algorithm is found to be efficient and produces better convergence speeds. The effectiveness of the developed program is tested for test function and for different generator set systems i.e. for 3-generator and 6-generator electrical power system. The electrical power systems were taken considering valve point loading and without valve point loading. It is found that GSO gives better solution on comparison with the steepest descent method, conjugate gradient and newton raphson method.

9. ACKNOWLEDGEMENT

The authors gratefully acknowledge the support of Dr.J.S.Dhillon, Professor, Instrumentation and control engineering department, Sant Longowal Institute of Engineering and technology, Punjab, India for providing his support to carry out this work.

REFERENCES

[1] Ried G.F. and Hasdroff L., "Economic dispatch using quadratic programming", IEEE Transaction on Power Apparatus and Systems, 1973, Vol. 92, No. 4, pp. 2015-2023.
[2] Happ H.H. ,"Optimal power dispatch– A comprehensive survey", IEEE Transaction on Power Apparatus and Systems, 1977, Vol. 96, No. 3, pp. 1309-1320.
[3] Ross D.W. and Kim S., "Dynamic economic dispatch of generation", IEEE Transaction on Power Apparatus and Systems, 1980, Vol. 99, No. 6, pp. 2060-2068.
[4] Aoki K. and Satoh T., "Economic dispatch with network security constraints using parametric quadratic programming", IEEE Transaction on Power Apparatus and Systems,1982, Vol. 101, No. 12.
[5] Ramanathan R., "Fast economic dispatch based on the penalty factors based on Newton's method", IEEE Transaction on Power Apparatus and Systems,1985, Vol. 104, No. 7.
[6] Chowdhury B.H. and Rahman S., "A review of recent advances in economic dispatch", IEEE Trans. Power System, 1990, Vol. 5, No. 4, pp. 1248–1259.
[7] Dhillon J.S., Parti S.C. and Kothari D.P., "Stochastic economic emission load dispatch", Electric Power Systems Research,1993, Vol. 26, No. 3, pp. 179-186.
[8] Walters D. C. and Sheble G. B., "Genetic algorithm solution of economic dispatch with valve-point loading", IEEE Transactions on Power System, 1993, Vol. 8, No. 3.
[9] Eberhart R.C. and Kennedy J., "A new optimizer using particle swarm theory", Proceedings of the 6th International Symposium on Micro Machine and Human Science", 1995, pp. 39-43.
[10] Kothari D.P. and Dhillon J.S., "Power Systems Optimization", 2011, 2nd edition. Prentice-Hall of India.
[11] Deb, K., "Optimization for Engineering Design - Algorithms and Examples", 2006, Prentice-Hall of India.
[12] Wadhwa C.L., "Electrical Power System", 2009, New Age publishers.
[13] Madouh J.Y. and El-Hawary M.E., "Economic dispatch of all thermal systems with fuzzy load", Large Engineering System Conference on Power Engineering (LESCPE), 2004, pp. 7-18.
[14] Chiang C.L.,"Genetic based algorithm for power economic load dispatch problem", IET Generation, Transmission and Distribution, 2007, Vol. 1, No. 2, pp. 261-269.
[15] Zare K., Haque M.T., and Davoodi E., "Solving non-convex economic dispatch problem with valve point effects using modified group search optimizer method", Electric Power Systems Research, 2012, Vol. 84, pp. 83– 89.
[16] Rao S.S., "Engineering Optimization Theory and Practice", 1999, 3rd edition, New Age International (P) Limited, Publishers.
[17] Rao S.S., "Optimization Theory and Applications", 2003, 5th edition, Willy Eastern Limited, Publishers.
[18] Abd El-Wahed W.F.,Mousa A.A. and Elsisy M.A., "Solving economic emissions load dispatch problem by using Hybrid ACO-MSM Approach", The Online Journal on Power and Energy Engineering (OJPEE), Vol. 1, No. 1.
[19] Sreenivasan G., Saibabu C.H. and Sivanagaraju S., "Solution of dynamic economic load dispatch (DELD) problem with valve point loading effects and ramp rate limits using PSO", International Journal of Electrical and Computer Engineering, 2011, Vol. 1, No. 1, pp. 2088-8708.
[20] Pandian S.M.V and Thanushkodi K., "Solving economic load dispatch problem considering transmission losses by a hybrid EP-EPSO algorithm for solving both smooth and non-smooth cost function", International Journal of Computer and Electrical Engineering, 2010, Vol. 2, No. 3, pp.1793-8163.
[21] Kumar C. and Alwarsamy T., "Dynamic economic dispatch – a review of solution methodologies", European Journal of Scientific Research, 2011, Vol. 64 No.4, pp. 517-537
[22] Coelho L.D.S. and Mariani V.V., "Improved differential evolution algorithms for handling economic dispatch optimization with generator constraints", Energy Conversion and Management, 2007, Vol. 4, No. 8, pp. 1631–1639.
[23] Coelho L.D.S., and Lee C.S., "Solving economic load dispatch problems in power systems using chaotic and Gaussian particle swarm optimization approaches", Electrical Power and Energy Systems, 2008, Vol. 30 , pp. 297–307.
[24] Bhattacharya A. and Chattopadhyay P.K., "Biogeography-based optimization for different economic load dispatch problems", IEEE Transactions on Power Systems, 2010, Vol. 25, No. 2.
[25] Sudhan K.J.V., Kumar R.S.S. and Monica A.R.G., "Economic load dispatch problem based biogeography algorithm", Undergraduate Academic Research Journal (UARJ) , 2012, Vol. 1, No. 1, pp. 2278 – 1129
[26] Sharma J. and Mahor A., "Particle Swarm Optimization approach for economic load dispatch: a review", International Journal of Engineering Research And Applications, 2013, Vol. 3, No. 1, pp.013-022.
[27] He S., Wu Q.H.and Saunders J.R., "Group Search Optimizer: An Optimization Algorithm Inspired by Animal Searching Behavior", IEEE Transactions on evolutionary computation, 2009, Vol. 13, No. 5.
[28] Varshney A., "Gradient based methods for optimization problem", 2010, Thesis, Sant Longowal Institute of Engineering and Technology.