International Journal of Advanced Research in Biological Sciences
ISSN: 2348-8069
www.ijarbs.com
Coden: IJARQG(USA)

Research Article

SOI: http://s-o-i.org/ 1.15/ijarbs-2-11-29

Economic dispatch using bacterial foraging algorithm (BFO) incorporating time varying particle swarm optimization (PSO-TVAC) and differential evolution (DE) algorithm

Hafiz Tehzeeb Ul Hassan[1], Anum Arif[2], Fariha Durani[3] and Hafiz Ghulam Murtaza Qamar[4]*

[1]Associate Professor, Department of Electrical Engineering, The University of Lahore, Lahore, Pakistan,
Email: tehzibulhassan@gmail.com
[2]Lecturer , Electrical Engineering, The University of Lahore, Lahore, Pakistan, Email: anumarif24@gmail.com
[3]Lab Engineer, Electrical Engineering, The University of South Asia, Lahore, Pakistan.
Email :Fariha.durrani@yahoo.com
[4]Lecturer, Electrical Engineering, The University of Lahore, Lahore, Pakistan,E-mail :ghulam.murtaza@ee.uol.edu.pk
*Corresponding author

Abstract

In this paper Bacterial Foraging Algorithm (BFA), an optimization technique along with Time Varying Particle Swarm Optimization (PSO-TVAC) and Differential Evolution (DE) is adopted to solve the Static Economic Dispatch (SED) and Dynamic Economic Dispatch (DED) problem. The ED problem considered is both convex and non-convex in this paper. This non-convexity of ED problem is due to valve point loading effects and ramp rate limits and prohibited operating zones. The basic BFA has improved its performance benefiting from PSO-TVAC by efficient direction vector calculation. This combination of BFA with PSO-TVAC gives fast convergence towards the optimal solution and DE operator fine tunes the solution obtained from BFA and PSO-TVAC. A3-machine, 5-machine and 6-machine IEEE systems are tested to show the effectiveness of this method.

Keywords: Economic dispatch (ED), valve-point effects, dynamic economic dispatch, bacterial foraging algorithm (BFA), hybrid approach.

1. Introduction

Economic dispatch (ED) is one of the most important concern of electric power utilities for efficient operation of power systems. Economic dispatch is basically the search of the suitable combination of the optimum powers of all the generating units committed in the powersystem. The suitable combination is selected in such a way that overall fuel cost of the generating station is reduced. Several deterministic methods have been applied for solving the ED problem such as lambda- Iteration method [1], gradient-search method and non-linear programming [2].These methods model the economic dispatch problem as convex problem [3-5]. However, practically ED problem is non-convex in nature because of certain non-linearites which arises in generating unit's characteristic curves . These non-linearites are due to limits of ramp-rates, restriction of operating zones and many fuel inlet openings [6-8]. That's why researchers introduced many heuristic techniques such as Genetic Algorithm (GA) [6], Particle swarm optimization (PSO) [8,9] ,Sequential quadratic programming [10] and their hybrids – BFO –Nelder-Mead [11], MBFO – PSO [12], IBFO [13], MBFA [14], BF-MPSO[15], BFPSO-DE[16], MOBCC[17]. These techniques have put a benchmark in optimization problems related to economic dispatch in power system operation and control . Bacterial foraging algorithm (BFA) is the newly introduced technique based upon foraging behavior of E.coli bacterium [18] which lives in human intestine. It has gained much importance among researchers because of its efficiency in solving certain difficult optimization problems. Bacterial foraging optimization algorithm (BFOA) is known for its local search ability but possesses poor convergence characteristics over a large search space [16]. To enhance the performance of BFOA it is essential to utilize those optimization techniques whose global search efficiencies are excellent. PSO and DE are one of those heuristic techniques so the benefit of both the local and global search can be obtained by merging these three optimization techniques. This hybrid technique has been previously implemented by K. Vaisakh [16] for DED problem. It is observed through literature that PSO apart from possessing global search ability, suffers from premature convergence especially where many local optimums are present [19, 20]. That's why in this paper PSO-TVAC is adopted instead of classical PSO along with BFO and DE.. Two acceleration coefficients of PSO-TVAC known as cognitive component C_1 and social component C_2 converges the population in PSO to the most optimum solution. If the coefficients are updated in such a way that initially cognitive component C_1 is increased and C_2 is decreased and in later iterations C_1 decreases gradually and C_2 increases then their will be more potential of exploring the search space and avoids being trapped in local minima [19,21]. The proposed technique is applied for solving both static and dynamic economic dispatch problems on many test systems with valve point effects, ramp rate limits, transmission losses and system constraints. Results obtained affirmed the effectiveness of the approach.

2. Problem formation for Economic Dispatch problem

The main purpose of ED is to minimize the total fuel cost function while satisfying the constraints imposed on the system [22].

Minimize : $F_T = \sum_{i=1}^{N_g} F_i\left(P_{gi}\right)$ (1)

F_i is fuel cost ith generating unit, P_{gi} is the power output of i^{th} generating unit ,F_T represents the total fuel cost , Ng is total no. of generating units

The Operating cost of fossil fired thermal unit know as fuel cost of thermal power plant is expressed as [23]

$$F_i\left(P_{gi}\right) = a_i + b_i \times P_{gi} + C_i \times P^2{}_{gi} \quad (2)$$

Due to valve point effect an extra sinusoidal term representing the rippling effect is added to the above described quadratic cost function [24] :

$$F_i\left(P_{gi}\right) = a_i + b_i \times P_{gi} + C_i \times P^2{}_{gi} + \left|e_i \sin\left(f_i\left(P_{gi}{}^{min} - P_{gi}\right)\right)\right| \quad (3)$$

Where a_i ,b_i, ci ,ei and fi are fuel cost coefficients of i^{th} generating units

The system is subjected to following constraints while minimizing the generation cost

- Load balance Equation

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

$P_D$is the total load demand, P_L represents the power losses.

- kron's loss formula for power losses[23]

$$P_L = \sum_{i=1}^{N_g} \sum_{j=1}^{N_g} P_{gi} B_{ij} P_{gj} \sum_{i=0}^{N_g} B_{i0} P_{gi} + B_{00} \quad (5)$$

- Generating unit capacity limits

$$P_{gi}{}^{min} \leq P_{gi} \leq P_{gi}{}^{max} , i = 1 ,2 ,\ldots\ldots, N_g \quad (6)$$

Where P_{gi}min and P_{gi} max are limits of minimum and maximum power outputs.

- Ramp – rate limits

$$P_{it} - P_{i(t-1)} \leq UR_i \quad (7)$$
$$P_{i(t-1)} - P_{it} \leq DR_i$$

Where i= 1, 2, 3………………Ng. Ramp –up and down rate of the ith generator is represented by UR_i and DR_i. Thus unit capacity limits modified as :

$$\max\left(P_{gi}^{min}, P_{i(t-1)} - D \leq \min\left(P_{gi}^{max}, P_{i(t-1)} U\right.\right.$$

(8)

3.Handling of Constraints

- In this proposed technique constraints are handled in

Such a way that boundary conditions are satisfied as:

If $P_{it} > P_{it,max}$ then$P_{it} = P_{it,max}$(9)

If$P_{it} < P_{it,min}$then$P_{it} = P_{it,min}$

- Penalty function

$$\sum_{i=1}^{N_g} \mu_1 \times \left|P_{it} - P_{it}^{lim}\right| + \mu_2 \times \left|\sum_{i=1}^{N_g} P_{it} - P_D\right| \quad (10)$$

Where P_{it}^{lim} is

$$P_{it}^{lim} = \begin{cases} P_{it,max} & , \quad if P_{it} > P_{it,max} \\ P_{it,min} & , \quad if P_{it} < P_{it,min} \end{cases} \tag{11}$$

4.Over view of BFO/PSO-TVAC/ DE Algorithms

4.1. Bacterial foraging Optimization

BFO consists of random no. of bacterial population, living in human intestine. The survival of bacteria depends upon food searching strategies and locomotion for accomplishing the search. The whole process is based upon three steps. The first one is Chemotactic which describes the motile behavior of E.coli bacteria. Swimming and tumbling are its two modes of locomotion for its entire life time. If θ(i) is any bacterium position and C(i) is the step size in a random direction D(i)specified by tumble [16]:

$$\theta(i) = \theta(i) + C(i) \times D(i) \tag{12}$$

$$D(i) = \frac{\Delta(i)}{\sqrt{\Delta^T(i).\Delta(i)}} \tag{13}$$

Here Δ is a unit length vector in random direction. In the reproduction step the bacteria who acquire high fitness value are likely to reproduce and contribute their genes to even produce better next generation. In the step of Elimination and dispersal, the unhealthy bacteria which are unlikely to reproduce are discarded or it may place near richer nutrient environment to start search again.

4.2. PSO-TVAC

PSO-TVAC is the advanced form of simple PSO with only difference of dynamically varying acceleration coefficients throughout its search rather than the static constants observed in classical PSO. PSO-TVAC like PSO is inspired by birds flocking behavior [25], consist of arbitrary particle's population. Each individual member position and velocity are represented by vectors as follows and the movement is guided by its personal best(P_{best}) and group best (g_{best}) experience.

$$Vel_{ij}(it+1) = w \times Vel_{ij}(it) + C_1 \times rand_1 \times \left(Pbest_{ij} - X_{ij}(it)\right) + C_2 \times rand_2 \times \left(gbest_i - X_{ij}(it)\right) \tag{14}$$

$$X_{ij}(it+1) = X_{ij}(it) + Vel_{ij}(it+1) \tag{15}$$

Here $X_{ij}(it)$ and $V_{ij}(it)$ are initial position and velocity of ith particle , C1 and C2 are cognitive and social components respectively and W is the inertia weighting factor can be calculated from eq(18)[26] . By experimentation it is observed that in order to get high quality solution these components are adjusted in such a way that C_1 component is decreased and C_2 is increased as iteration proceeds [27]. These components are updated as:

$$C_1(j) = C_{1i} + (C_{1f} - C_{1i}) \times \frac{j}{j_{max}} \tag{16}$$

$$C_2(j) = C_{2i} + (C_{2f} - C_{2i}) \times \frac{j}{j_{max}} \tag{17}$$

$$w^j = w_{max} - \left(\frac{W_{max} - W_{min}}{j_{max}}\right) \times j \tag{18}$$

$$j = 1, 2, \ldots .iter_{max}$$

Where,

W_{max} and W_{min} = final and initial inertia weights

j_{max} = maximum iteration number

4.3. Differential Evolution:

DE is an evolutionary global optimization population-based technique [28], produces off-spring through mutation as :

$$V_{ij}(G+1) = X_{r_j}(G) + sf \times \left(X_{r2j}(G) - X_{r3j}(G)\right) \tag{19}$$

Trial vector is generated by taking difference of randomly selected parameter vectors scaled by mutation factor usually in the range of 0.1 to 1 and then add to third vector. Trial vector is also generated by recombination process by replacing certain target parameters with the randomly selected donor vector, Range [0, 1] is selected for cross over constant.

$$u_{ij}(G+1) = v_{ij}(G+1) if rand(0,1) < CR \tag{20}$$

$$u_{ij}(G+1) = X_{ij}(G) otherwise \tag{21}$$

5. Hybrid Method (BFPSO-TVAC-DE)

ED problem is solved by using this hybrid approach in this research work. This approach replaces the D (i) of bacterial foraging algorithm with the velocity vector of PSO-TVAC, i.e

$$Vel_{ij}(it+1) = D(i) \tag{22}$$

The fitness function of BFPSO-TVAC-DE is calculated using the following equation [16].

$$JF = \frac{1}{j + penaltyfunction} \qquad (23)$$

Here,

$$j = F_i(P_{gi})$$

(24)

Initially real power outputs are generated randomly and in the next step of swimming and tumbling operation the new real power outputs are generated by changing the position of generation as:

$$C(i) = rand \times K_d$$

(25)

$$P(i) = P(i) + C(i) \times D(i) \qquad (26)$$

DE operator is used to generate new bacterial population after the maximum movement of each of the member and it is represented by the equation as:

$$Pdef = P(i) + sf * |P(r_2) - P(r_3)| \qquad (27)$$

The bacterial population real power outputs of generator) got from differential evolution (DE) is compared against the population obtained from BFPSO-TVAC. Both the fitness functions JF and JFdef are compared for each bacterium and the best value is saved in the fitness function. The best fitness value and generation cost are updated as pbest and gbest for a specified time interval. After the execution of specified Hemotoxic steps, reproduction process starts where healthy bacteria having high fitness value are duplicated and least healthy are discarded and at the last the elimination-dispersal events take place which disperse bacterial population to any random location if probability Ped is greater or equal to the generated random number.

Table 1: summary of results for case study 1 (SED)

Power Dispatch	**Methods**			
	SQP [33]	**GA [32]**	**PS [33]**	**BFPSO-TVAC-DE**
P_{g1}(MW)	399.20	300.00	300.30	298.8935
P_{g2}(MW)	400.00	400.00	400.00	399.3037
P_{g3}(MW)	50.80	150.00	149.70	151.9269
Cost($/h)	8241.60	8237.60	8234.10	8234.92

Results and Discussion

The validity of the proposed hybrid technique is tested on different test systems for optimal Economic dispatch including both static (SED) and dynamic (DED) problems. The hybrid method is implemented in Matlab software 7.10b and at least 50 independents runs are carried out for each test system to check the consistency of proposed algorithm. The adopted BFPSO-TVAC-DE parameters are normally adaptive as they are problem dependent. Appropriate tuning of parameters is done by using hit and trial values after experimentation.

6.1.Static Economic Dispatch(SED) results

The standard IEEE systems are selected in order to check the efficiency of proposed BFPSO-TVAC-DE technique and results are compared with those presented in literature

6.1.1 Case study 1

A 3-generator system with total load demand 850MW is selected for Optimal Economic dispatch. The system data is provided in [1]. Table 1 shows the results acquired from the implemented method and its comparison with other methods the Lambda Iteration Method (LIM) [1], Particle Swarm Optimization (PSO) [29], Genetic Algorithm[30], the Pattern Search (PS) approach [31] showed that the hybrid BFPSO-TVAC-DE method provides a lower cost than other methods.

6.1.2 Case study 2

A 3-generator system with load demand of 850MW is selected. In this system valve-point effects are considered. The system data is given in[32].The hybrid algorithm isapplied on this test system and the results are compared with the SQP[33], the PS [33] and the GA [32].Compared to GA[32] and SQP[33] , the total fuel cost obtained by BFO-PSO-TVAC is significantly lower while the cost is slightly higher than that of PS[33] deterministic method. The results summary for 200 runs is tabulated in Table 2

Table 2: Generators power and cost for case study 2 (SED)

Power Dispatch	**Methods**				
	LIM [1]	**PSO [29]**	**GA [30]**	**PS [31]**	**BFPSO-TVAC-DE**
P_{g1}(MW)	393.20	391.80	349.4938	393.20	440.7862
P_{g2}(MW)	334.60	338.20	399.258	334.60	316.4616
P_{g3}(MW)	122.20	120.00	99.924	122.20	91.2113
Cost($/h)	8194.36	8194.98	8194.36	8194.36	8189.07

6.1.3. Case study 3

The same test system 2 is considered here with taking into account the system losses. The B-coefficients are given in vector notation in [33]. The BPSO-TVAC-DE is successfully applied to solve this ED problem with its results compared to those of the methods listed in the last test system and the results showed the most optimized solution obtained with BFPSO-TVAC-DE. The result summary for 50 runs is shown in Table 3.

Table 3: summary of result for case study 3 (SED)

6.1.4. Case study 4

This case study is on IEEE30-bus system with 6 generators and a total load demand of 1800 MW and the fuel cost characteristics are given in [31, 33]. Results obtained by the BFPSO-TVAC-DE are compared with those of the Surrogate Worth Trade-off with Newton-Raphson (SWT-NR) approach used in [31], the Sequential Quadratic Programming (SQP) method, and PS [33]. The results for 600 runs and comparison are presented in Table 4 shows that the BFPSO-TVAC-DE method gives better results than previous methods reported.

Table 4: results for 6 unit system for case study 4(SED)

6.2.Dynamic Economic dispatch (DED)

The proposed technique is also verified for DED problem on two standard IEEE test systems .

6.2.1. Case Study 1

The test system considered for DED problem is 5-unit system with valve-point loading effects, ramp-rate limits and transmission loss effects. Unit data and load patternfor case 1 and transmission loss coefficients are adapted from [35].The load pattern is presented in 24 hr dispatch intervals consisting of each one hour, shown in table 9.

6.2.2.Dynamic Economic dispatch Case 2

The test system considered for case 2 is 26-bus, 46 transmission lines and 6-unit system [16] with ramp-rate limits , prohibited operating zones and security constraints. The dispatch horizon is is chosen as one day with 24 dispatch intervals of each one hour. The power demand during the dispatch period and prohibited operating zones are given in the table 10 and 11.

6.Nomenclature and BFPSO-TVAC-DE parameters selection:

The proper tuning of control parameters of proposed technique has a significant effect on the solution quality. As the proposed technique is a hybrid of 3-individual techniques so tuning of each technique parameters cast a considerable effect on another technique used in hybrid algorithm. So it is essential to adopt suitable combination of all control parameters in order to get the most optimized solution for Economic dispatch. Generally the parameters are adaptive as they are problem dependent. By experimenting a lot of hit and trail values, Optimal results are found in this research by using range of following control parameters and for multiple no. of runs.

7.1.Basic Bacterial Foraging Algorithm Parameters

N_b (number of bacterial population) =16 ~ 720
N_c (number of chemotactic steps) = 10 ~ 35
N_s (number of swimming steps) = 4 ~ 20
N_{re} (number of reproduction steps) = 2 ~6
P_{ed} (Probability of elimination & dispersal) = 0.2~1
K_d (maximum step size of one bacterium) = 2.9 ~5

7.2.Time Varying Acceleration coefficients Particle swarm Optimization Parameters

C_{1i} (initial cognitive component)=0.6 ~ 2.5
C_{1f} (final cognitive component)=0.02 ~ 0.40
C_{2i} (initial social component)=0.02 ~ 0.40
C_{2f} (final social component)=0.6 ~ 2.5
W_{min} (weighting factor minimum value)=0.4
W_{max} (weighting factor maximum value)=0.9

7.3.Differential Evolution parameters

CR (cross over constant) = 0.7 , 0.8
Sf (scaling factor) = 0.7,0.9

Table 5 : Best scheduling for 5 unit system for DED

Hour	**P1 (MW)**	**P2 (MW)**	**P3 (MW)**	**P4 (MW)**	**P5 (MW)**	**Ploss (MW)**
1	14.6331	101.4452	45.0002	40.7733	212.1756	3.9926
2	31.3305	106.3188	38.4858	45.0266	218.2052	4.4762
3	47.8599	78.3846	44.8517	84.4407	224.4802	5.0953
4	71.3174	97.2639	37.1569	93.2355	237.5715	6.4144
5	60.8597	122.0901	39.119	119.1376	223.737	7.041
6	35.2783	121.469	74.1966	144.7621	240.3012	8.1491
7	29.964	113.1852	109.506	126.063	255.612	8.4827
8	16.1018	120.9256	112.1751	158.0308	256.1899	9.2993
9	37.6311	124.4868	145.5697	178.4299	214.0298	10.0532
10	18.5278	107.784	168.2658	176.0745	243.9881	10.4626
11	33.1722	101.758	145.6759	203.3147	247.2454	10.9824
12	37.0389	119.8228	152.1526	224.8762	217.5608	11.6095
13	50.6541	120.5672	114.782	196.909	231.907	10.61
14	30.0879	118.8108	119.3646	216.6485	215.5135	10.2482
15	20.0988	109.2245	98.9852	219.8849	215.3278	9.3483
16	27.491	109.8637	74.3951	174.1775	201.2609	7.3612
17	42.965	123.4467	80.7153	129.4311	188.1585	6.7318
18	27.6813	108.5374	86.9794	173.2014	219.8068	8.0363
19	49.8052	95.1959	125.101	187.41	205.5789	8.9972
20	22.9491	90.7898	131.3055	215.4991	253.8465	10.6035
21	34.197	100.6941	153.1086	177.6143	224.1344	9.6936
22	30.4805	95.2794	143.9628	148.8198	194.2053	7.6351
23	28.2855	100.1552	105.7858	134.8131	163.6797	5.8483
24	27.81	87.6437	106.6644	106.2734	139.1891	4.4659

Hour	**P1 (MW)**	**P2 (MW)**	**P3 (MW)**	**P4 (MW)**	**P5 (MW)**	**P6 (MW)**	**Ploss(MW)**
1	349.7531	160.0521	186.2818	104.3431	88.45327	73.61689	7.500787
2	410.0536	112.9839	149.8832	120.0738	89.99575	66.18659	7.176639
3	347.2105	117.6817	183.601	121.0003	113.5834	58.98265	7.059761
4	382.442	120.7854	185.3518	60.18078	137.5775	51.72231	8.062725
5	383.8011	116.0687	198.5073	62.38767	118.6015	63.56374	7.930011
6	397.5882	128.9066	209.8431	79.61363	89.84003	65.33472	8.12633
7	384.273	121.5888	245.2646	63.75952	115.4559	67.55127	8.892638
8	387.0688	125.8765	207.2482	91.19725	128.5301	92.06491	8.985872
9	417.5366	160.225	209.7456	126.3139	150.3784	72.16589	10.36538
10	412.4301	191.3325	245.618	103.4703	139.0515	69.24553	11.14789
11	451.6324	139.917	255.0384	128.3416	151.3354	86.56762	11.8329
12	437.8237	180.9083	255.4579	145.0696	139.8427	87.99401	12.09622
13	447.212	171.4384	252.6236	109.9972	152.3503	68.34906	11.97041
14	437.7509	163.7337	270.9959	146.8332	158.4416	85.80201	12.55742
15	466.2068	171.1505	278.1704	131.1369	156.9903	72.51037	13.16531
16	430.5479	171.2203	271.8064	125.4023	157.6465	106.2751	12.89866
17	460.9556	165.98	260.4352	138.0539	134.7555	72.85971	12.03989
18	439.5373	170.7854	263.4396	130.3306	136.0632	73.61164	11.76775
19	430.1093	176.1094	246.0943	109.7942	138.5083	69.62561	11.24118
20	419.1336	139.9132	243.4789	108.3209	123.4828	67.66332	9.992768
21	397.045	89.97879	240.4542	120.9432	124.5824	58.69397	8.697506
22	380.5042	88.98261	243.6214	109.6328	110.1151	59.31291	8.169062
23	393.4387	116.4351	240.4533	78.04834	89.22497	65.85938	8.459702
24	389.342	116.8698	207.7355	122.705	72.36496	58.58444	7.601909

Table 6 : Best scheduling for 6 unit system for DED

Time (hr)	**Load (MW)**	**Time (hr)**	**Load (MW)**
1	410	13	704
2	435	14	690
3	475	15	654
4	530	16	580
5	558	17	558
6	608	18	608
7	626	19	654
8	654	20	704
9	690	21	680
10	704	22	605
11	720	23	527
12	740	24	463

Table 8 : 6 unit system Cost Comparison

Method	**Cost($/24h)**
PSO	50124.0000
BFPSO-TVAC-DE	50112.8552

Table 9 Load pattern for 5 unit system

Method	**Cost($/24h)**
PSO	314351.5
BFOA	314081.7
DE	314162.6
BFPSO-TVAC-DE	314022.08

Table 10: Load pattern for 6 unit system

Time (hr)	**Load (MW)**	**Time (hr)**	**Load (MW)**
1	955	13	1190
2	942	14	1251
3	935	15	1263
4	930	16	1250
5	935	17	1221
6	963	18	1202
7	989	19	1159
8	1023	20	1092
9	1126	21	1023
10	1150	22	984
11	1201	23	975
12	1235	24	960

Table 11: Prohibited operating zones for 6 unit system

Unit	Prohibited zones
1	[210 240] [350 380]
2	[90 110] [140 160]
3	[150 170] [210 240]
4	[80 90] [110 120]
5	[90 110] [140 150]
6	[75 85] [100 105]

Conclusion

In this paper, a hybrid bacterial foraging algorithm (BFPSO-TVAC-DE) has been implemented and validated using both Static Economic dispatch (SED) and Dynamic Economic Dispatch (DED) problem considering various practical operational constraints, handled by using penalty factors in the fitness function. The ED problem has been solved considering transmission power losses in some cases and valve-point effects in other cases. The performance of basic bacterial foraging (BFO) algorithm is enhanced by using PSO-TVAC and DE parameters, helping to converge to global optimal solutions robustly. A wide range of case studies have been selected for testing the performance of proposed technique. Simulation results are obtained for multiple number of runs and by using adaptive parameters for BFPSO-TVAC-DE, the proposed technique. Result analysis showed the effectiveness of the approach by successfully achieving the lower fuel cost as compared to previous heuristic techniques reported in literature.

References

1. A.J. Wood, and B.F.Wollenberg. Power generation operation and control. 2nd ed. New York: John Wiley & Sons; 1996.
2. J. Nanda, H. Lakshman, M. Kothari. Economic emission load dispatch with line flow constraints using a classical technique. IEE Proc Generat Transm Distrib 1994;141:1–10.
3. X. S.Han, H.B.Gooi and S.Kirschen Daniel. Dynamic economic dispatch: feasible and optimal solutions. IEEE Trans Power Syst 2001;16(1):22–8.
4. P.Granelli, P.Marannino, M.Montagna and A.Silvestri. Fast and efficient gradient projection algorithm for dynamic generation dispatching. Proc Inst Elect Eng Gener Transm Distrib 1989;136(5):295–302.
5. K.S. Hindi, M.R.Ab Ghani. Dynamic economic dispatch for large scale power systems: a Lagrangian relaxation approach. Int J Electr Power Energy1991;13(1):51–6.
6. D.C. Walters, G.B.Sheble. Genetic algorithm solution of economic dispatch withvalve point loadings. IEEE Trans Power Syst 1993;8(3):1325–31.
7. T.Jayabharathi, K.Jayaprakash, N.Jeyakumar, T. Raghunathan .Evolutionary programming techniques for different kinds of economic dispatch problems.Elect Power Syst Res 2005; 73(2):169–76.
8. Zwe-Lee. Gaing. Particle swarm optimization to solving the economic dispatch considering the generator constraints. IEEE Trans Power Syst 2003;18(3):1187–95.
9. B.K.Panigrahi, V.Ravikumar Pandi, Sanjoy Das. Adaptive particle swarm optimization approach for static and dynamic economic load dispatch Energy Convers Manage 2008; 49:1407–15.
10. F.J. Yuan, Z. Lan. Real-time economic dispatch with line flow and emission constraints using quadratic programming. IEEE Trans Power Syst1998; 13:320–6.
11. A. Y. Saber and G. K. Venayagamoorthy. Economic load dispatch using bacterial foraging technique with particle swarm optimization biased evolution, in *Swarm Intelligence Symposium*, 2008. SIS 2008. IEEE, 2008, pp.1-8.
12. K. Vaisakh, P. Praveena, and S. Rama Mohana Rao. DEPSO and Bacterial Foraging optimization based Dynamic Economic Dispatch with non-smooth fuel cost functions, in *Nature & Biologically Inspired Computing*, 2009. NaBIC 2009. World Congress on, 2009, pp. 152-157.
13. P. K. Hota, A. K. Barisal, and R. Chakrabarti. Economic emission load dispatch through fuzzy based bacterial foraging algorithm. International Journal of *Electrical Power & Energy Systems*, vol. 32, pp. 794-803, 2010.

14. B. K. Panigrahi, V. Ravikumar Pandi, S. Das, and S. Das. Multiobjective fuzzy dominance based bacterial foraging algorithm to solve economic emission dispatch problem. *Energy*, vol. 35, pp. 4761-4770, 2010.
15. A. Y. Saber. Economic dispatch using particle swarm optimization with bacterial foraging effect. *International Journal of Electrical Power & Energy Systems*, vol. 34, pp. 38-46, 2012.
16. K. Vaisakh, P. Praveena, S. Rama Mohana Rao, and K. Meah. Solving dynamic economic dispatch problem with security constraints using bacterial foraging PSO-DE algorithm. *International Journal of Electrical Power & Energy Systems*, vol. 39, pp. 56-67, 2012.
17. R. Azizipanah-Abarghooee. A new hybrid bacterial foraging and simplified swarm optimization algorithm for practical optimal dynamic load dispatch. *International Journal of Electrical Power & Energy Systems*, vol. 49, pp. 414-429, 2013.
18. K..M. Passino. Biomimicry of bacterial foraging for distributed optimization and control. IEEE Contr Syst Mag 2002;22:52–67.
19. A. Ratnaweera, S.K. Halgamuge, H. Watson .Self-organizing hierarchical particle swarm optimizer with time varying acceleration coefficients. IEEE Trans Evol Comput 2004;8(3):240–55.
20. K. Chaturvedi, M. Pandit, L. Srivastava. Self-organizing hierarchical particle swarm optimization for non convex economic dispatch. IEEE Trans Power Syst2008;23:1079-87.
21. A.Safari, H. Shayeghi. Iteration particle swarm optimization procedure for economic load dispatch with generator constraints. Expert SystAppl2011;38:6043–8.
22. A.J. Wood and B.F. Wollenberg. Power Generation Operation and Control, New York, USA: John Wiley & Sons, Inc., 1996, pp. 592.
23. M.E. El-Hawary and G.S. Christensen. *Optimal Economic Operation of Electric Power Systems*. New York: Academic Press, 1979, pp. 278.
24. C. Chao-Lung. Improved genetic algorithm for power economic dispatch of units with valve-point effects and multiple fuels. *IEEE Transaction on Power Systems*, vol. 20, pp. 1690-9, 2005.
25. R. Kenned , J. Eberhart. Particle swarm optimization. In proceedings of the IEEE international conference on neural networks; 1995. Perth, Australia. p.1942–8.
26. P. Jong-Bae, L. Ki-Song, S. Joong-Rin, K.Y.Lee. A particle swarm optimization for economic dispatc h with nonsmooth cost functions. IEEE Transactions on Power Systems. 2005;20:34-42.
27. B. Mohammadi-Ivatloo, A. Rabiee , A. Soroudi , M. Ehsan. Iteration PSO with time varying acceleration coefficients for solving non-convex economic dispatch problems. *International Journal of Electrical Power & Energy Systems*, vol. 42, pp. 508-516, 2012.
28. R. Storn, K. Price. Differential evolution – a simple and efficient heuristic for global optimization over continuous space. J Global Optim 1997;11:341–59.
29. A.I. El-Gallad, M. El-Hawary, A.A. Sallam and A. Kalas. Swarm intelligence for hybrid cost dispatch problem. *Electrical and Computer Engineering*, 2001. Canadian Conference on, vol. 2, pp. 753-757 vol.2, 2001.
30. R. Vijay. Intelligent Bacterial Foraging Optimization technique to Economic Load Dispatch Problem. *International Journal of Soft Computing and Engineering (IJSCE)*, vol. 2, p. 5, May 2012 2012.
31. M.F. AlHajri and M.E. El-Hawary. Pattern search optimization applied to convex and non-convex economic dispatch. *Systems, Man and Cybernetics, 2007. ISIC. IEEE International Conference on*, pp. 2674-2678, 2007.
32. J.S. Dhillon and D.P. Kothari. The surrogate worth trade-off approach for multiobjective thermal power dispatch problem. *Electr.Power Syst.Res.*, vol. 56, pp. 103-110, 11/1. 2000.
33. N. Sinha, R. Chakrabarti and P.K. Chattopadhyay. Evolutionary programming techniques for economic load dispatch. *Evolutionary Computation, IEEE Transactions on* vol. 7, pp. 83-94, 2003.
34. C. K. Panigrahi, , P. K. Chattopadhyay, R. N. Chakrabarti, and M. Basu. Simulated annealing technique for dynamic economic dispatch. *Electric Power Components and Systems*, vol. 34, pp. 577-586, 2006.
35. A.J.Wood and B.F.Wollenberg. Power Generation, Operation and Control. New York: John Wiley & Sons,1996.PP.592