IJASRM
International Journal of Advanced Scientific Research and Management, Volume 4 Issue 4, April 2019
www.ijasrm.com
ISSN 2455-6378

Deregulated Multi-objective Economic Load Dispatch using Cuckoo Search Algorithm with valve point effect consideration

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Abstract

The distributed generation is the need of the world as the power demand increases day by day. But the power generation at the distribution side makes the power system deregulated. The power market has to be redesigned for it. In deregulated environment every distributed generator becomes as one individual seller. So, if the sellers are more, the regulation of power if difficult. For that the problem of economic load dispatch is used here. In this paper valve point effect of distribution generations are considered. And the results are compared with "Particle swarm optimization" (PSO), genetic Algorithm (GA), differential evaluation (DE) and "cuckoo search algorithm" (CSA).

Keywords: *Valve point effect, 3 seller, 8 seller, cuckoo search algorithm, deregulation.*

1. Introduction

Many literatures use GA, PSO, simulated annealing (SA), evolutionary programming (EP), shuffled frog leap algorithm (SFLA), bacterial foraging algorithm (BFA), artificial be colony algorithm (ABC), harmony search algorithm (HSA), firefly algorithm etc., for solving the economic load dispatch.

The hybrid GA with DE is explained in [1], GA including valve point effect is described in [2]. The EP is used in [3] for economic load dispatch. Hybrid PSO-with sequential quadratic programming is used for economic load dispatch in [4]. A hybrid genetic algorithm is used in [5] with value point effect consideration.

The DE is used for solving the deregulated environment in [6]. And the same is used to solve non-smooth and non-convex economic dispatch in [7]. DE and quadratic programing are combined for solving the economic load dispatch with value point effect [8]. And variable scale DE is used for economic load dispatch in [9]. CSA is used for economic load dispatch in [10]. Economic load dispatch is solved using binary BAT algorithm in [14]. For deregulated environment 4 algorithm comparison with success rate is done in [15],[16].

In [11] gives the clear explanation of stochastic algorithms and evolutionary techniques for solution of optimization problems. And the [12] gives the operation and control of economic dispatch equations.

In this paper the valve point effect is included in the economic load dispatch of deregulated power system with 3-seller and 8-seller system are solved using the PSO, GA, DE and CSA algorithms. The comparison of 10 runs is done and the best algorithm for the problem solution is identified.

2. Problem Definition

The seller cost is assumed as thermal power system and the incremental cost function is taken as the bidding cost. So, the bidding cost function can be represented as below [14],

$$F_i(P_{gi}) = a_i + b_i P_{gi} + c_i P_{gi}^2 + |d_i * \sin\{e_i * Pimin - Pi\}. \ldots (1)$$

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Incremental cost is defined of the bidden cost function,

$IC_i(P_{gi}) = b_i + 2c_iP_{gi} + |d_i cos\{e_i * P_{imin} - Pi\}$….(2)

The economic dispatch problem for deregulated environment can be defined as follows,
Cost function,
$F1 = \sum_{i=1}^{n} F_i(P_{gi})$….(3)
Power system load and generation balance
$F2 = \sum_{P_{gi}}^{N_g}(P_{gi} - P_d - P_l)$ …(4)
Multi-objective function,
Minimize F = F1+F2 … (5)

$P_{i\,min} < P_{gi} < P_{i\,max}$, $i \in [1, N_g]$ …..(6)

When $\sum_{i=1}^{N_g} P_{i\,min} > P_d$ $or \sum_{i=1}^{N_g} P_{i\,max} = P_d$, there is no feasible solution,

When $\sum_{i=1}^{N_g} P_{i\,min} = P_d$, each seller is contracted amount is at its capacity lower limit.

When $\sum_{i=1}^{N_g} P_{i\,min} < P_d$ and $\sum_{i=1}^{N_g} P_{i\,min} > P_d$ is a non-trivial case.

Here,

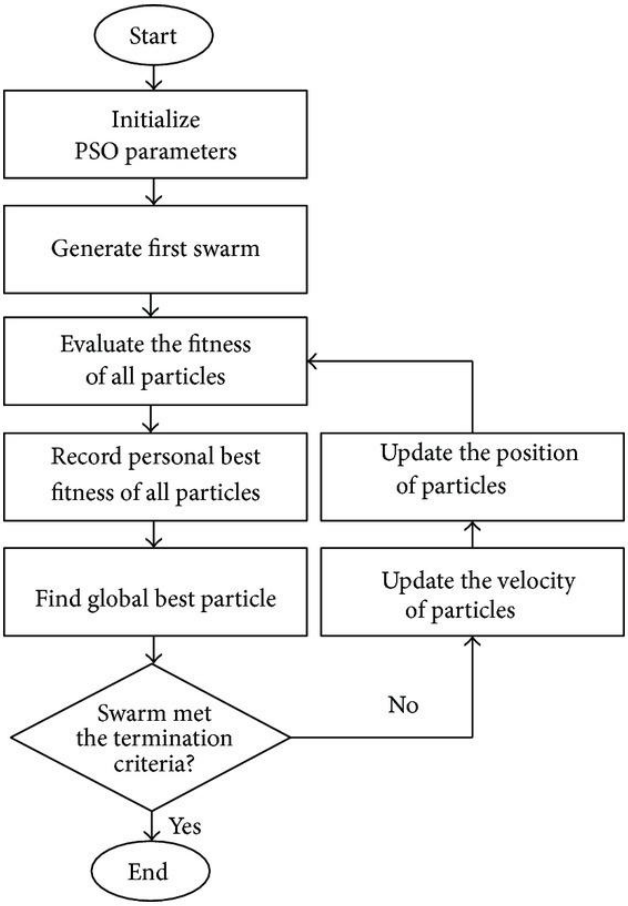
$F_i(P_{gi})$ $- cost\ of\ generator\ i$
P_{gi} $- Power\ in\ MW\ of\ i^{th}\ generator$
a_i, b_i, c_i, d_i, e_i $- constant\ co-ordinate$
$P_{i\,min}, P_{i\,max}$
$- minimum\ and\ maximum\ limits\ of\ i^{th}\ generator$
P_d $- Power\ demand\ in\ MW$
n, N_g $- Number\ of\ generators$
P_l $- Power\ in\ MW\ of\ i^{th}\ generator$

With all the above constraints deregulated power system problem is formulated [6].

3. Solutions Methods Used

3.1 Particle Swarm Optimization (PSO) [12]

Swarm optimization is one of the simple algorithms to implement, which is made of the food searching behavior of the fishes. Algorithm flow is given in the figure.



Velocity equation is given below,
$V_j(i) = V_j(i-1) + c_1r_1[P_{bestj} - X_j(i-1)] + c_2r_2[G_{best} - X_j(i-1)]$ …. (6)

$where, j = 1,2, \dots, N$

$here\ c1, c2\ are\ cognitive\ and\ social\ learning\ rates\ taken\ 2$

$r1, r2\ are\ uniformy\ distributed\ randoms\ in\ range\ 0\ and\ 1$

Position update equation is given below
$X_j(i) = X_j(i-1) + V_j(i)$….(7)

Here the particles (X) are the generator values and the fitness are the equation (1) which is cost

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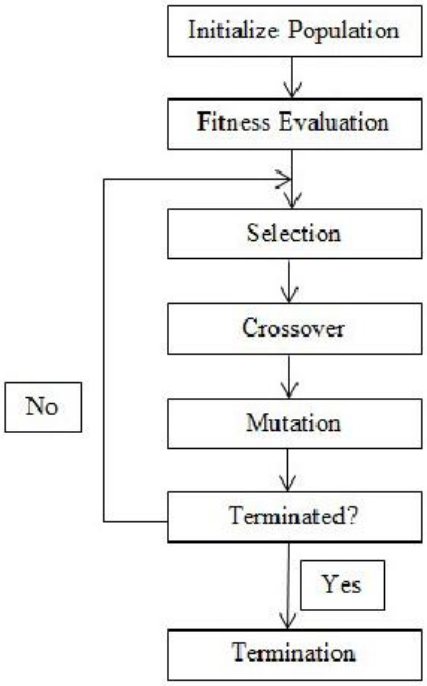
International Journal of Advanced Scientific Research and Management, Volume 4 Issue 4, April 2019
www.ijasrm.com
ISSN 2455-6378

minimization. The global best value is identified using the PSO algorithm

3.2 Genetic Algorithm (GA)

Genetic algorithm is inspired by the human genetic behavior.This is also population based search method like particle swarm optimization. The solution steps are given below [12] in the figure.

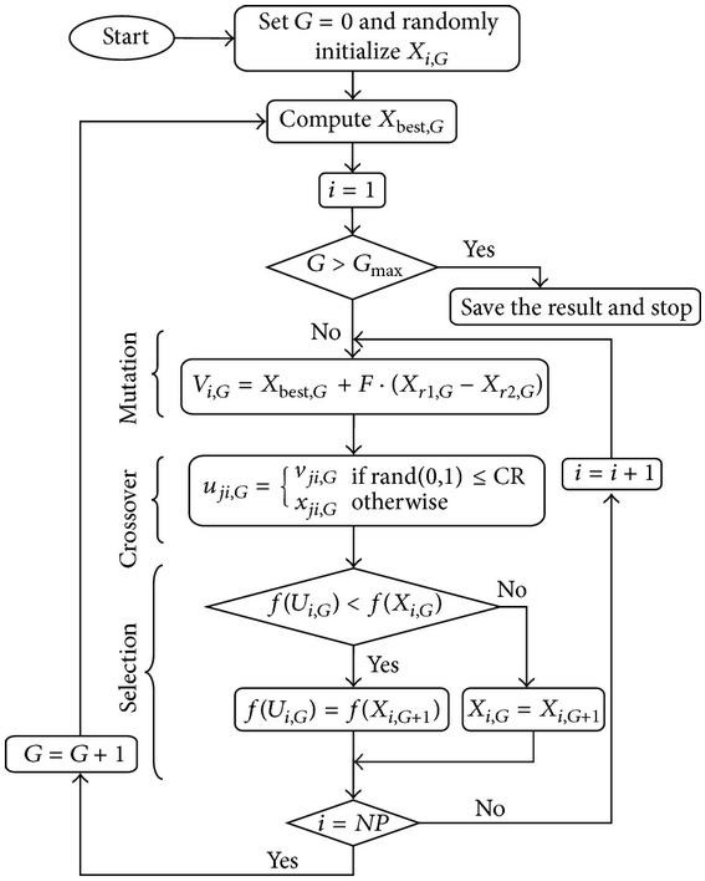


Here also population is the generator values fitness is the equation (1).

3.3 Differential Evolution technique (DE)

The DE algorithm has much similarity with the genetic algorithm.

It is also a stochastic search method for solving complex problems [6].



It is also similar to GA but the mutation, crossover and selection changes according to the differential evolution algorithm. Here also X is the generator values and the ‘f’ is the fitness function equation (1).

3.4 Cuckoo Search Algorithm (CSA)

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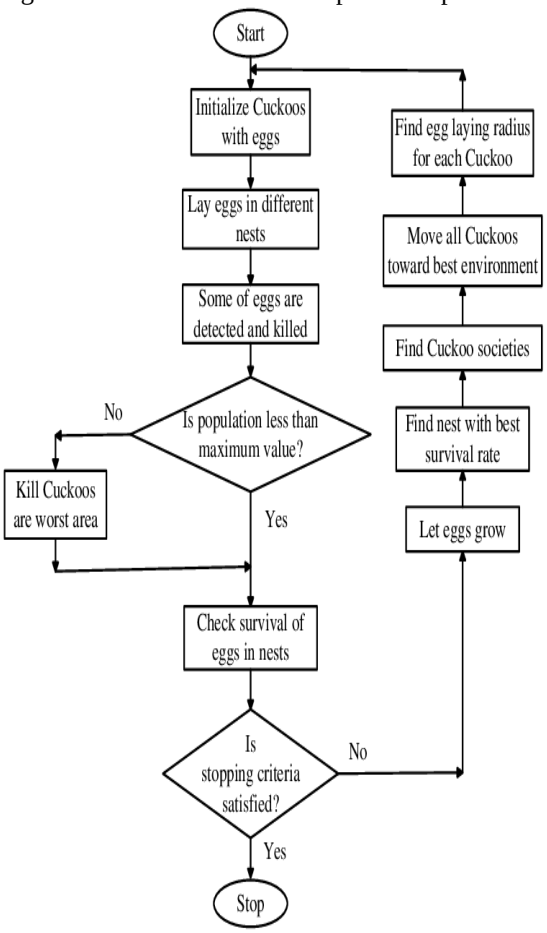
The Cuckoo search algorithm is based on the cuckoo bird on behavior of its breeding. The behavior is given as the algorithm and it is used for the problem specified.



Here the cuckoos with eggs are the generator values and the fitness function is the equation (1).

4. Results and Discussion

The results cases are split as two. Case (i) is with 3 seller system [6] and case (ii) is 8 seller system [6].

Case (i)

The three-seller system is taken as test system in these solution algorithms. The loss formula is used for loss calculation to solve F2 equation. PSO, GA, DE and CSA are chosen for getting the optimal cost value. Fig.1 shows the results of 10 runs with respect to fitness value with PSO. The deviation can be seen in the figure clearly. It deviates from $9310 to 9550. Fig.2 shows the same results of GA there are lesser deviations compared to PSO algorithm. Fig. 3 shows the results of DE. Here its deviation is more compared to GA and lesser compared to PSO. Fig.4 shows the results of CSA. Here comparatively it gives lesser deviation with all the other algorithms. Table 1-4 shows the final generation values (B1 to B3), fitness equations (F1, F2) of each algorithm in all the 10 runs.

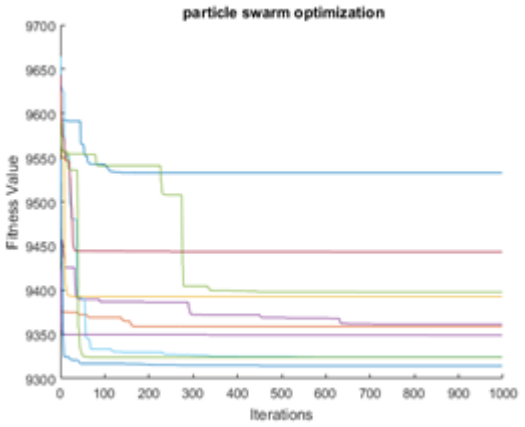


Fig. 1 convergence graph-PSO-3seller

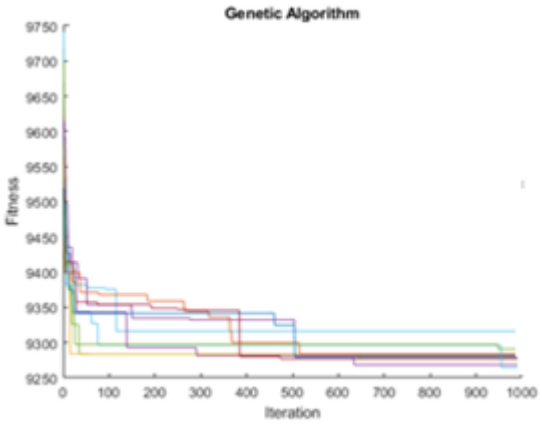


Fig. 2 convergence graph-GA-3seller

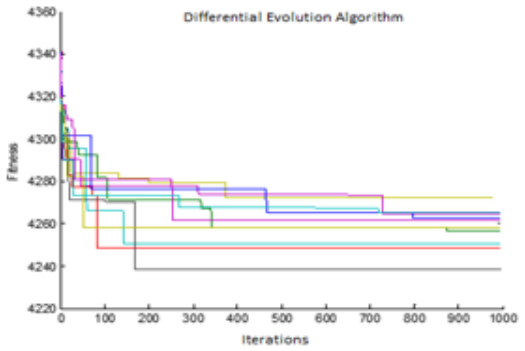


Fig. 3 convergence graph-DE-3seller

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www.ijasrm.com
ISSN 2455-6378

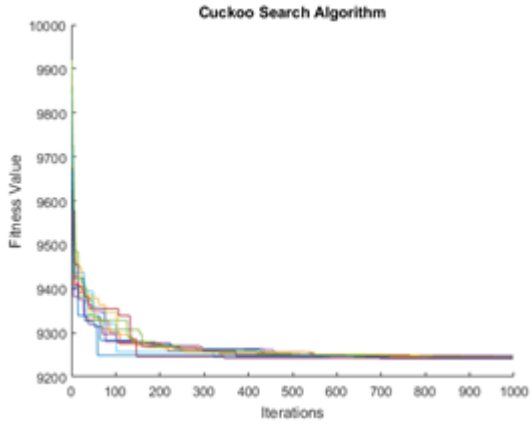

Fig. 4 convergence graph-CSA-3seller

Table 1: 3 seller system comparisons for 10 runs -PSO algorithm

PSO algorithm					
Run	Power in MW			F1	F2
	B1	B2	B3		
1	292.9398	448.7359	212.2024	9361.419	0
2	492.6991	307.5642	163.4412	9532.611	0
3	198.1749	400.9319	340.017	9397.812	0
4	495.7178	249.5996	211.1342	9358.827	0
5	296.3495	371.2238	275.0647	9324.511	0
6	310.9752	449.0659	196.3419	9392.638	0
7	492.6999	180.7033	276.5753	9443.243	0
8	409.0813	345.2596	199.6755	9348.907	0
9	300.5284	449.0659	205.3449	9314.28	0
10	296.3495	371.3179	274.9821	9323.981	0

Table 2: 3 seller system comparisons for 10 runs -GA algorithm

Genetic algorithm					
Run	Power in MW			F1	F2
	B1	B2	B3		
1	297.57725	448.47411	208.36467	9316.1127	0.019914
2	394.9969	352.90354	205.27454	9283.571	0.2622888
3	400.57866	350.28308	202.57129	9268.4526	0.0455564
4	396.10345	358.45639	199.3904	9277.7292	0.0413252
5	394.62844	348.46256	208.62936	9284.1227	0.3957929
6	399.32102	348.11241	205.35418	9279.753	0.0609103
7	396.40362	351.20524	205.47721	9276.9341	0.2100647
8	395.59364	349.95891	207.16864	9264.4528	0.1643918
9	393.468	353.96819	205.06945	9290.8995	0.261209
10	393.70274	348.90348	209.69969	9281.5851	0.1976903

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www.ijasrm.com
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Table 3: 3 seller system comparisons for 10 runs -DE algorithm

DE algorithm					
Run	Power in MW			F1	F2
	B1	B2	B3		
1	393.31868	346.53376	211.97749	9315.6739	0.1341027
2	394.52611	356.32753	203.34372	9353.581	0.7804593
3	400.16597	351.96801	200.455	9336.4899	0.8762599
4	396.67586	354.28602	201.51712	9324.2351	0.7851982
5	400.54553	352.21345	200.07857	9327.8317	0.7424759
6	402.14258	348.01837	203.10751	9287.6802	0.0241159
7	400.93389	353.10401	199.72735	9279.9014	0.0908635
8	311.89611	349.58614	280.14252	9359.6212	0.0276979
9	395.65023	356.63113	201.37874	9275.9348	0.0981821
10	287.48844	298.08986	349.73746	9345.9478	0.0013807

Table 4: 3 seller system comparisons for 10 runs -CSA algorithm

Cuckoo Search algorithm					
Run	Power in MW			F1	F2
	B1	B2	B3		
1	394.6979	351.1491	206.755	9248.648	0.026908
2	394.8115	350.109	207.5104	9242.689	0.004151
3	395.0803	349.371	207.9571	9245.049	0.035113
4	394.4355	349.2561	208.5851	9243.974	0.023215
5	394.4882	350.2346	207.6786	9242.417	0.001598
6	395.2267	349.2094	207.9456	9244.602	0.012065
7	394.6049	349.6217	208.0673	9242.59	0.033243
8	394.595	349.2154	208.4543	9241.064	0.00445
9	395.1072	350.3369	207.0723	9244.253	0.000416
10	395.4533	349.9173	207.1167	9245.565	0.018905

Case (ii)

The eight-seller system is taken as test system in these solution algorithms. PSO, GA, DE and CSA are chosen for getting the optimal cost value. As the control variable increases the deviation increases in the entire algorithms. Fig.5 shows the results of 10 runs with respect to fitness value with PSO. The deviation can be seen in the figure clearly. It deviates from $5110 to 5390. Fig.6 shows the same results of GA; there are lesser deviations compared to PSO algorithm. Fig. 7 shows the results of DE. Here its deviation is more compared to GA and PSO. Fig.8 shows the results of CSA. Here comparatively it gives lesser deviation with all the other algorithms. So even though control variables are more it gives better results. Table 5-8 shows the final generation values (B1 to B8), fitness equations (F1, F2) of each algorithm in all the 10 runs.

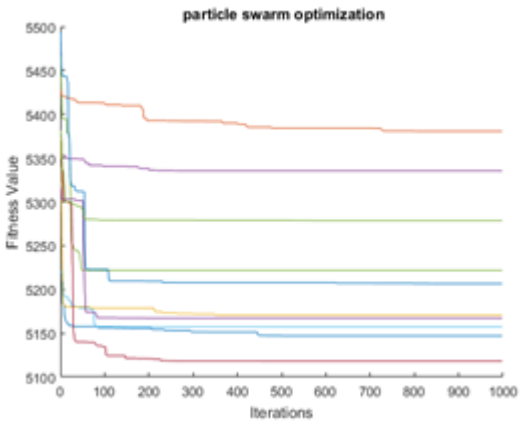

Fig.5 Convergence graph-PSO 8 seller

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ISSN 2455-6378

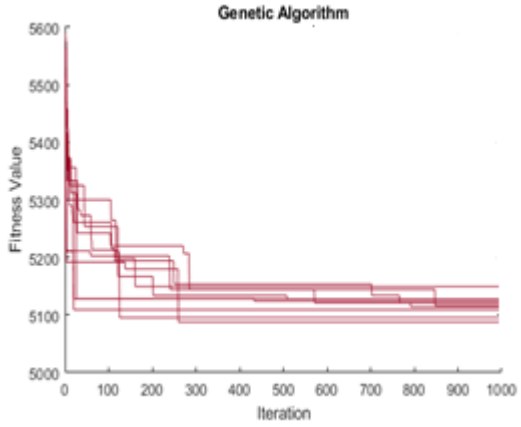

Fig.6 Convergence graph-GA 8 seller

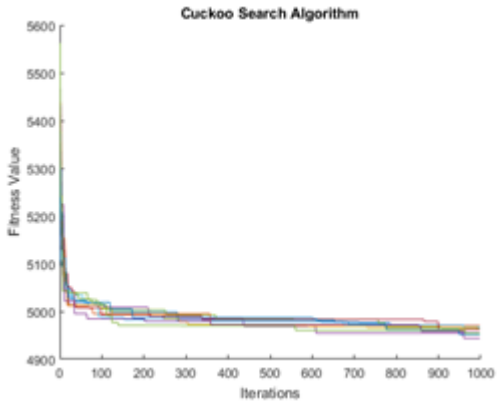

Fig.8 Convergence graph-CSA 8 seller

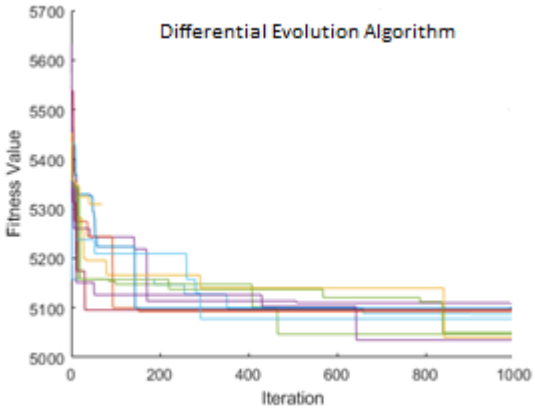

Fig.7 Convergence graph-DE 8 seller

Table 5: 8 seller system comparisons for 10 runs-GA algorithm

Genetic algorithm										
Run	Power in MW								F1	F2
	B1	B2	B3	B4	B5	B6	B7	B8		
1	26.9441	95.0301	93.441	39.0213	94.8078	27.4769	29.1521	97.3483	5149.36	0.54083
2	82.7693	95.2437	20.0851	81.3374	21.1814	95.6289	82.6184	23.5599	5095.49	0.25633
3	99.1456	92.3747	26.7487	21.0312	35.5412	98.5042	99.3751	29.8824	5116.46	0.07743
4	21.1852	24.3909	97.2631	95.7565	53.716	91.2192	20.8319	97.512	5124.27	0.80578
5	40.3194	92.1234	36.9209	95.9597	25.9447	94.3831	95.4957	21.4697	5109.32	0.0638
6	24.267	93.0783	20.7369	95.5126	96.5883	47.0026	26.1481	99.0727	5087.95	0.27401
7	91.8559	25.7724	23.1268	43.6687	96.5724	95.38	29.201	97.2315	5114.2	0.12818
8	88.4508	21.054	60.5743	23.5679	95.5637	98.9996	92.8428	22.0478	5128.03	0.42036
9	21.7858	89.1536	86.3576	73.6625	22.3782	91.8926	94.6611	23.1892	5121.04	0.40007
10	99.5156	90.4379	38.9919	97.476	96.6794	22.2904	36.7605	20.5296	5127.93	0.00063

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www.ijasrm.com
ISSN 2455-6378

Table 6: 8 seller system comparisons for 10 runs-PSO algorithm

PSO algorithm										
Run	Power in MW								F1	F2
	B1	B2	B3	B4	B5	B6	B7	B8		
1	86.8266	95.724	97.5185	20	78.6507	27.1908	37.4225	59.3474	5335.38	0
2	99.4837	78.9994	17.4801	20	25.4837	95.9163	77.3507	87.9666	5146.96	1.14E-13
3	76.9062	94.9092	20	21.2348	28.1519	87.856	71.2087	102.414	5221.65	0
4	72.2036	19.9998	22.555	93.2443	47.1846	100.869	44.4815	102.142	5380.67	0
5	87.1844	106.853	96.7503	20.7719	20	100.092	53.2301	17.7984	5157.24	1.14E-13
6	93.2065	75.7909	69.6122	23.618	97.9481	24.3358	20.0001	98.169	5170.61	0
7	93.8497	93.2612	3.75357	94.7998	84.3267	15.0963	29.3041	88.2892	5118.12	0
8	29.3619	92.2553	90.0214	102.647	23.6097	20	100.341	44.4437	5167.18	0
9	94.7731	99.0084	4.47373	61.5215	18.218	96.545	94.6888	33.452	5206.5	0
10	20.0001	79.1276	19.9344	60.1241	38.8394	96.8251	89.249	98.5808	5278.6	0

Table 7: 8 seller system comparisons for 10 runs-DE algorithm

DE algorithm										
Run	Power in MW								F1	F2
	B1	B2	B3	B4	B5	B6	B7	B8		
1	14.8275	20.4764	86.1483	18.6397	77.3102	12.56	24.8306	248.154	5087	0.2667
2	16.0602	89.5144	89.2138	173.444	22.0849	17.3172	94.6278	0.50989	5046.68	0.09198
3	83.4614	91.3999	90.4951	21.4118	5.13265	92.3508	96.9701	20.7571	5109.68	0.70179
4	255.885	20.5824	20.6337	94.4769	20.0211	35.3792	21.8328	34.1288	5040.05	0.25965
5	245.299	32.3057	24.3727	20.9597	22.1635	98.5583	18.0736	41.4543	5092.97	0.50588
6	93.8164	18.4709	23.7116	89.9277	89.7295	166.155	3.63633	18.1224	5099.68	0.88896
7	26.9766	18.8827	93.4673	17.6549	89.8622	13.2694	165.864	77.0074	5095.27	0.30427
8	24.5373	20.7466	91.4837	172.083	85.9004	2.67168	15.6438	89.58	5077.65	0.03381
9	88.0833	18.8534	93.8572	7.50629	90.6632	9.64258	169.892	24.3925	5049.77	0.20988
10	17.5437	96.6026	19.9832	68.5251	21.012	94.7713	86.8163	97.3451	5034.72	0.08125

Table 8: 8 seller system comparisons for 10 runs-CSA algorithm

Cuckoo Search algorithm										
Run	Power in MW								F1	F2
	B1	B2	B3	B4	B5	B6	B7	B8		
1	20	94.4194	68.4127	20	90.1694	20	95.6318	94.0166	4954.54	0.03057
2	60.4896	94.1031	23.7245	20	20.0857	94.6105	93.9893	95.6875	4970.4	0.00954
3	58.6017	20	94.53	20	95.2904	95.3993	95.956	22.9262	4964.94	0.02307
4	21.817	94.9611	94.4773	91.3618	20.0151	20.0016	64.4851	95.6219	4970.25	0.06031
5	94.7696	93.5097	95.4465	20.0016	93.3869	20	65.2193	20.0002	4966.81	0.34674
6	20	70.9806	92.2271	89.1596	20.0001	94.8086	20.4401	95.0439	4962.15	0.02049
7	95.2996	20.0165	97.9353	94.3739	59.2595	20.0137	94.858	20.8847	4961.89	0.03923
8	20	94.9306	20	69.193	94.7153	89.8246	94.0092	20	4944.01	0.00788
9	68.2723	20.1164	94.1217	20	91.7187	94.7394	93.8471	20	4952.39	0.13504
10	93.4772	20.0005	96.8385	93.4315	20.0055	64.8562	20.0016	94.0794	4954.18	0.0099

5. Conclusions

The Matlab based simulation is carried out using the objective function including the valve point effect included in the economic load dispatch implementation. Multiple meta heuristic methods are implemented including PSO, GA, DE and CSA and their performance measures are calculated. The performance evaluation of these meta heuristic algorithms have proved that the Cuckoo Search Algorithm (CSA) has provided a better convergence compared all the three algorithms. The Cuckoo search algorithm is taking lesser number of iteration to reach convergence.

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