Hybrid Optimization For Economic Load Dispatch Problems

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Abstract- *There were large numbers of issues associated with the traditional Economic Load Dispatch techniques due to the simplicity of the models. Power balance equations are used for the modelling of the power system. In order to make power system more effective various models are developed that are capable to make the power generation system more effective but they are really complex and non linear. Economic Load Dispatch has the property that it considers the power balancing instead generating the power up to the capacity limits.*

In order to get better results in difficult optimization problems various developments have done named it as evolutionary algorithms. These algorithms are the best replacement for the global optimal techniques especially in case of non-continuous, non-convex and extremely solution spaces. Various methods implemented to overcome the issues are Genetic Algorithms, Particle Swarm Optimization and Differential Evaluation etc. These algorithms have attained the large scale acceptance as it find the application in the ELD problems.

The solution of economic load dispatch will be done by using the Firefly and Chaos Optimization technique in the projected mechanism. The key advantages are that it can provide very quick convergence at a very initial stage by switching from exploration to exploitation. This makes it an efficient algorithm for applications when a quick solution is needed.

Keywords- Optimum Load Dispatch, Economic Load Dispatch, Power Generation System, Firefly Optimization, Chaos Optimization.

I. INTRODUCTION

ELD is an abbreviation of Economic Load Dispatch. Main objective of LD is to distribute the power among different units so that the load [1] demand can be easily fulfilled. Distribution of power is done in accordance with the least cost expenditure on transmission of energy and consumption of fuel [2]. After going through the economic dispatch, it is determined that in order to provide the power to small units the online power generators can be used. Production cost of power by using the online generator is compared with the output power generated by it [3]. To design the generator which can simplifies the arithmetical formulation various quadratic cost functions can be implemented and conventional optimization methods can be applied to these generators. These techniques describes that the curve showing the fuel cost either increase with the fix rate Such approaches defines that the curve of fuel cost either increase or decrease with the fix rate so that the optimum solution can be obtained [4]. Various methods such as dynamic programming may or may not applicable in large systems as it needs complex computations so that provision of supplementary can be available and steady fallout [5]. With the introduction to different optimization techniques like PSO, evolutionary optimization algorithm in which the simple model is required then in this case different problems can be overcome and these are also able to produce the precise and fast results [6].

In electrical field, main objective is to improve the operational efficiency and reliability of various techniques. Various techniques implemented in the field of power system should be able to reduce the operational cost and also overcome rest of limitations [7]. It is a kind of provision to increase the profit. On the basis of available power and resources, it is required to satisfy the load demand of customers. As a result, to meet the demand of load by the customer end, ELD can be implemented on power generating resources as a scheduling method and this method also decrease the cost of operation [8].

II. PROBLEM FORMULATION

Electrical power industry restructuring has created highly vibrant and competitive market that altered many aspects of the power industry. Economic Load Dispatch (ELD) is one of the important optimization problems in power systems that have the objective of dividing the power demand among the online generators economically while satisfying various constraints. Economic load dispatch problem is the sub problem of optimal power flow (OPF). The economic load dispatch is defined as the process of allocating generation levels to the generating units, so that the system load is supplied entirely and most economically. For the connection between the two systems it is important that the expenses should be minimized. To describe the production level, each unit in the system is defined, so that the total cost of the system is calculated. The expenses should be less. Economic load dispatch problem is the sub problem of optimal power flow (OPF). The main objective of ELD is to minimize the fuel cost while satisfying the load demand with transmission constraints. So main aim of ELD is to minimize the expense of the system. In traditional work the GWO was implemented for optimizing the results. But in GWO, half of the iterations are devoted to exploration and the other half are dedicated to exploitation, overlooking the impact of right balance between these two to guarantee an accurate approximation of global optimum. Hence there is a requirement to develop a system which can overcome this shortcoming of GWO algorithm.

III. PROPOSED WORK

The objective of the Economic Dispatch Problems (EDPs) of electric power generation is to schedule the committed generating units outputs so as to meet the required load demand at minimum operating cost while satisfying all units and system equality and inequality constraints. The Economic Dispatch Problem is solved by specialized computer software which should honor the operational and system constraints of the available resources and corresponding transmission capabilities. Recently, global optimization approaches inspired by insects or flies and evolutionary computation approaches have proven to be a potential alternative for the optimization of difficult EDPs.

In the proposed work the solution of economic load dispatch will be done by using the Firefly and Chaos Optimization technique. The key advantages are that it can provide very quick convergence at a very initial stage by switching from exploration to exploitation. This makes it an efficient algorithm for applications when a quick solution is needed.

The proposed technique uses the firefly chaos optimization in order to minimize the cost incurred on power generating and transmission. The methodology of proposed technique is implemented in following steps:

STEP 1: First step is to set power generator parameters. Every generator have its own parameters such amount of generated power, amount of total lost transmission etc. The parameters are generated on the basis of some equations.

STEP 2: After setting the power generator parameters the power requirement or demanded power of various units will be entered.

STEP 3: Now generate random population. In firefly the generation of random population is an important step.

STEP 4: Now calculate the cost incurred on generating the power by using cost characteristic equation**.**

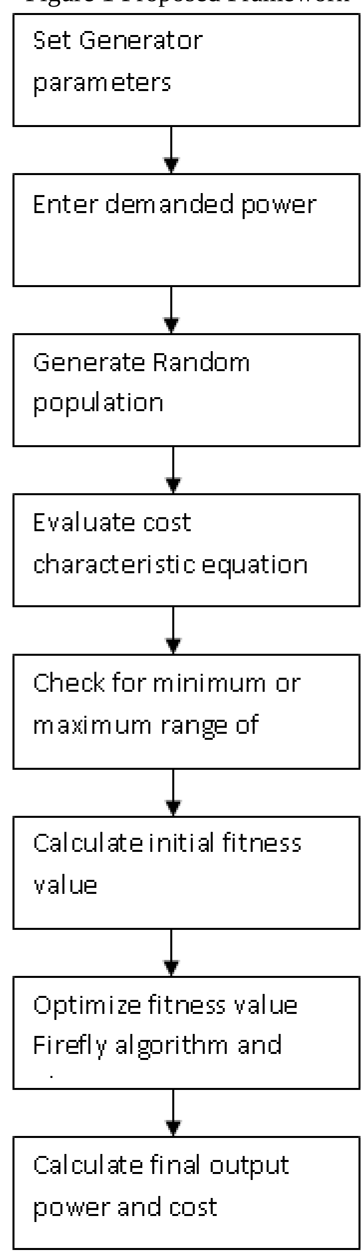
STEP 5: Now evaluate the minimum or maximum range of generated power from the above calculated cost.

STEP 6: Number of iterations will execute in order to find the best fitness value.

STEP 7: Now apply proposed firefly and chaos algorithm for optimizing the fitness value from obtained set of fitness value.

STEP 8: Evaluate the final output and various parameters such as total generated power. Total power loss, total cost incurred.

Figure 1 Proposed Framework



IV. OPTIMIZATION MECHANISM ANALYSIS

In this work, firefly chaos optimization mechanism is applied to optimize the issue of electrical load dispatch. In order to observe the efficiency of firefly chaos optimization over other optimization techniques, an comparative analysis is done and implemented in Matlab. The analysis is done by using uni-modal and multi modal functions.

Table 1 Benchmark Functions

Type of Function	Function		Dimensions	Range	f_{min}
Uni-modal Benchmark Function	$F_1(x)$	$\sum_{i=1}^{n} x_i^2$	50	[-100,100]	0
	$F_2(x)$	$\sum_{i=1}^{n-1}[100(x_{i+1}-x_i^2)^2+(x_i-1)^2]$	50	[-30,30]	0
Multi-modal Benchmark Function	$F_3(x)$	$\sum_{i=1}^{n} -x_i sin(\sqrt{\lvert x_i \rvert})$	50	[-500,500]	
	$F_4(x)$	$\sum_{i=1}^{n}[x_i^2-10cos(2\pi x_i)+10]$	50	[-5.12,5.12]	0

Table 2 Results of Uni-modal Benchmark

Function	PFCO	MVO(20)	GWO(16)	GSA(17)	PSO(19)	GA(18)
$F_1(x)$	2	2.08583	2319.19	2983.667	3.552364	27187.58
$F_2(x)$	404	1272.13	3425.462	7582.498	1132.486	65361.62

Table 3 Results of Multi-modal Benchmark Function

Function	PFCO	MVO(20)	GWO(16)	GSA(17)	PSO(19)	GA(18)
$F_3(x)$	-20285.80	-11720.2	-10739.5	-4638.41	-6727.59	-10698.6
$F_4(x)$	7	118.046	89.13475	128.0103	99.83202	273.2519

On the basis of the results that are defined in above tables, it is observed that the PFCO (Proposed Firefly Chaos Optimization outperforms the traditional optimization techniques in both uni-modal and multi-modal benchmark functions.

V. RESULTS AND EXPERIMENTS

In this section the results are described which are obtained after implementing the proposed method i.e. Firefly and Chaos Optimization technique. The proposed technique is implemented on different number of generator units and for each implementation the results are observed and compared with the conventional techniques used for resolving the problems related to ELD.

In figure 2 it is represented that the Firefly and Chaos Optimization technique is implemented on 10 generator units and the generation cost has been observed for 100 iteration cycles. It is observed that the generation cost is reduced with the increase in number of cycles.

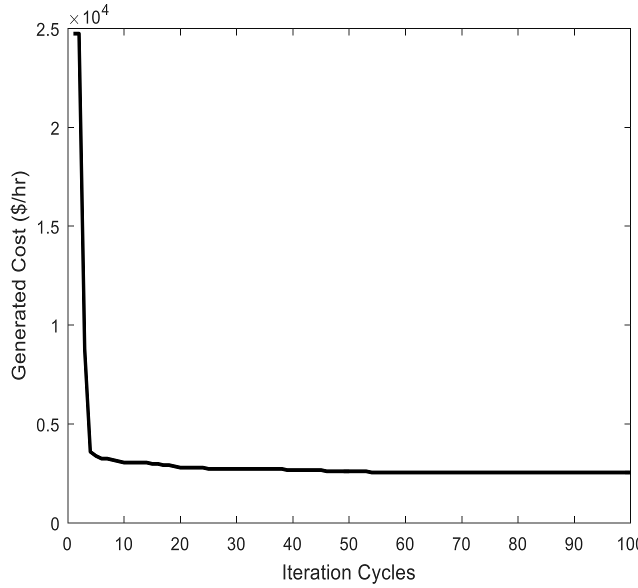


Fig 2: Generated cost of 10 generator units for 100 iteration cycles.

After completion of 100 iteration cycle the total generation cost is observed and that it is565.5244 $/hr. The table 4 shows the generated power of 10 unit generators using proposed algorithm. From table 5 it can be observed that the proposed technique has the optimum results as compare to various other techniques in terms of mean cost, best cost, worst cost, SD and average simulation time.

Table 4: Best solution for proposed system for 10 generator units

Unit No.	Generated power (MW)
1	250
2	230
3	201
4	265
5	470
6	85
7	428
8	265
9	143
10	363

Table 5: Best generation cost comparison for different algorithms applied on 10 generator units

Algorithm	Mean cost	Best cost	Worst cost	Standard deviation	Average simulation time
NPSO(22)	625.2180	624.1624	623.67543	623.67542	NA
PSO(19)	625.5054	624.3045	625.9252	625.9252	NA
GA(18)	624.7419	624.5050	624.8169	624.8169	NA
TSA(18)	635.0623	624.3078	624.8285	624.8285	NA
KHA(15)	605.8043	605.7582	605.9426	605.8426	NA
GWO(16)	605.6818	605.6263	605.7937	605.7937	1.02
Proposed technique	582.01101	565.5244	565.5385	0.00147	0.553

In figure 3 it is represented that the Firefly and Chaos Optimization technique is implemented on 40 generator units and the generation cost has been observed for 100 iteration cycles.

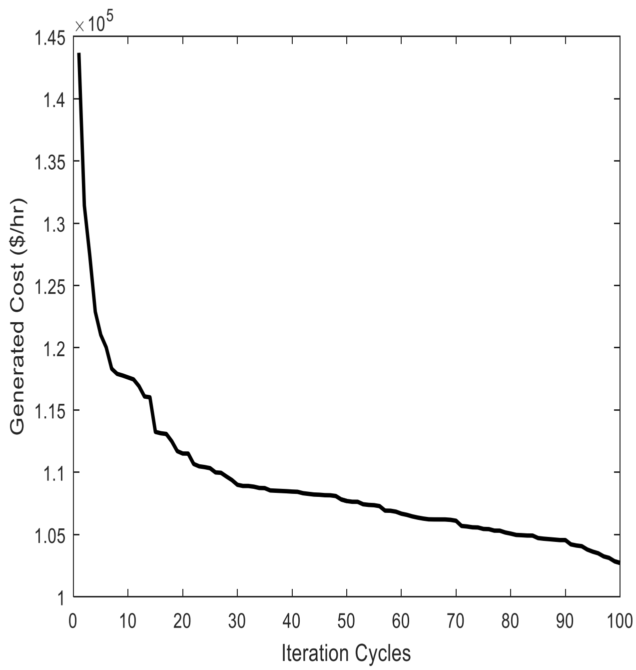


Fig 3: Generated cost of 40 generator units for 100 iteration cycles

During 100 iteration cycles it is seen that with the increase in the iteration the generation cost is also reduced. The total generated Cost after implementation of proposed technique for 40 units is observed as 104677.210 $/hr.

The comparison table for various algorithms showing the best generation cost for 40 generator units is represented below. The table 6 gives the total generated power for 40 unit generators using proposed system. From the table 7 it can be clearly observed that the best generation cost for 40 units is least in comparison table for the proposed technique in terms of different parameters.

Table 6: Best solution for proposed system for 40 generator units

Units	Generated power (MW)
1	114
2	114
3	101
4	190
5	93
6	100
7	284
8	299
9	294
10	148
11	94
12	94
13	148
14	500
15	389
16	445
17	491
18	476
19	532
20	542
21	543
22	463
23	550
24	525
25	550
26	550
27	10
28	11
29	10
30	88
31	181
32	169
33	190
34	90
35	194
36	127
37	110
38	107
39	92
40	492

Table 7 Best generation cost comparison for different algorithms applied on 40 generator unit

Algorithm	Best cost	Mean cost	Worst cost	Standard deviation	Average simulation time
GA-API(18)	139864.96	NA	NA	NA	NA
SDE(21)	138157.46	NA	NA	NA	NA
TLBO(23)	137814.17	NA	NA	NA	4.83
QOTLBO(23)	137329.86	NA	NA	NA	4.58
KHA(15)	136670.37	136671.24	136671.86	NA	NA
GWO(16)	136446.85	136463.96	136492.07	0.098	4.27
Proposed technique	104677.210	108911.82	143729.78	0.03527	9.835

Firefly and Chaos Optimization technique is implemented for 80 generator units and the process is repeated for 100 cycles to take the observation and note down the best generator cost. The observation for 80 unit systems after implementation of the proposed technique is shown in the figure 4 below.

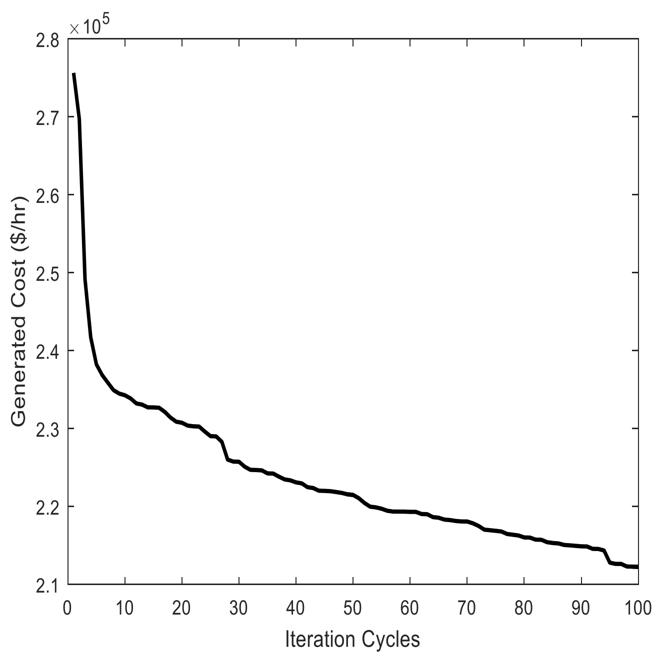


Fig 4 Generated cost of 80 generator units for 100 iteration cycles

The total generated Cost after implementation of proposed technique for 80 units is observed as 216458.8642 $/hr.

The comparison table is also drawn to check the efficiency of proposed method in comparison with the conventional techniques.

Table 8: Best solution for proposed system for 80 generator units

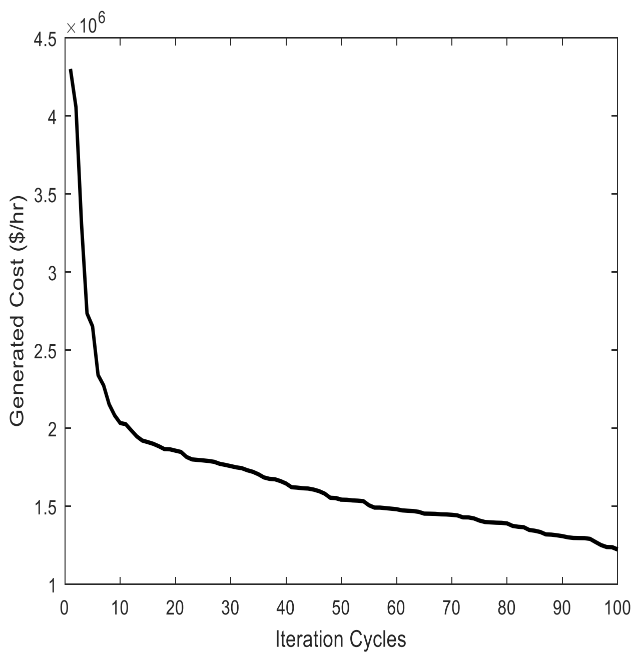
16	450
17	500
18	372
19	550
20	550
21	517
22	542
23	550
24	550
25	521
26	544
27	28
28	10
29	12
30	89
31	176
32	170
33	165
34	200
35	98
36	133
37	55
38	110
39	93
40	424
41	114
42	72
43	105
44	177
45	47
46	140
47	153
48	300
49	251
50	281
51	208
52	149
53	291
54	500
55	496
56	309
57	439
58	472
59	448
60	472
61	496
62	550
63	533
64	524
65	521
66	467
67	28
68	49
69	24
70	97
71	132
72	170
73	190
74	166
75	156
76	200

77	75
78	65
79	110
80	548

Table 9 Best generation cost comparison for different algorithms applied on 80 generator units

Algorithm	Best cost	Mean cost	Worst cost	Standard deviation	Average simulation time
NPSO(22)	242844.1172	NA	NA	NA	NA
FAPSO (22)	244273.5429	NA	NA	NA	NA
PSO(19)	249248.3751	NA	NA	NA	NA
GWO(16)	242825.4799	242829.8192	242837.1303	0.093	5.27
Proposed technique	216458.8642	224709.2192	279726.3022	0.0149	3.587

Firefly and Chaos Optimization technique is implemented for 140 generator units and the process is repeated for 100 cycles to take the observation and note down the best generator cost. The observation for 140 unit systems after implementation of the proposed technique is shown in the figure 5 .



The total generated Cost after implementation of proposed technique for 140 units is observed as 1506098.39 $/hr. The below shown table 10 gives the generated power of 140 units using proposed system. The comparison table 11 is also drawn to check the efficiency of proposed method in comparison with the conventional techniques.

Table 10 Best solution for proposed system for 140 generator units

Units	Generated power (MW)
1	75
2	159
3	190
4	125
5	190
6	185
7	425
8	485
9	437
10	480
11	440
12	414
13	506
14	458
15	429
16	485
17	409
18	454
19	505
20	492
21	505
22	473
23	501
24	373
25	468
26	537
27	443
28	424

29	491
30	501
31	506
32	506
33	470
34	506
35	458
36	410
37	193
38	194
39	774
40	762
41	19
42	28
43	160
44	164
45	186
46	169
47	167
48	160
49	244
50	178
51	211
52	165
53	186
54	165
55	193
56	180
57	127
58	146
59	153
60	163
61	124
62	166
63	180
64	211
65	211
66	286
67	280
68	153
69	432
70	147
71	191
72	198
73	209
74	182
75	175
76	205
77	330
78	233
79	160
80	219
81	118
82	141
83	141
84	121
85	207
86	207
87	175
88	203
89	175
90	175
91	175
92	580
93	645
94	930
94	930
95	968
96	636
97	712
98	612
99	720
100	885
101	951
102	1007
103	874
104	944
105	971
106	893
107	884
108	1006
109	1013
110	984
111	1000
112	94
113	94
114	122
115	244
116	255
117	247
118	98
119	112
120	116
121	267
122	19
123	25
124	15
125	50
126	37
127	34
128	112
129	20
130	7
131	17
132	71
133	5
134	74
135	42
136	41
137	33
138	7
139	7
140	29

Table 11 Best generation cost comparison for different algorithms applied on 140 generator units

Algorithm	Best cost	Mean cost	Worst cost	Standard deviation	Average simulation time
SDE(21)	1560236.85	NA	NA	NA	NA
GWO(16)	1559953.18	1560132.93	1560228.40	1.024	8.93
Proposed technique	1506098.39	1554019.22	1553980.902	0.249	4.45

VI. CONCLUSION

Term Economic Load Dispatch (ELD) may be described as a phenomenon in which the load is distributed in such a way generation cost of the power system should be least but at the same time it is required to meet the demand of the consumer. Therefore Firefly and Chaos Optimization technique has been proposed for Economic load Dispatch (ELD) to balance the generation cost and consumer demand. Proposed algorithm has been implemented for appropriate distribution of load over the power systems and the results were analyzed by doing the simulation on the MATLAB software. The proposed technique is implemented for different number of generator units such as for 10 units, 40 units, 80 units and 140 units and for each the results were obtained and the comparison was done with various other convention techniques in terms of the best generation cost for the power system. After doing the comparison it is observed that the proposed Firefly and Chaos Optimization technique has shown better results.

For future implementation and enhancement various changes can be done in the Firefly and Chaos optimization method. The amendments can be done by applying the artificial intelligence mechanism such as ANN (Artificial Neural network) After doing the amendments, this technique can be used to solve various other optimization issues in power generation system. This method provides an aid to consider various other cases also.

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