Weight Pattern Based Cuckoo Search for Unit Commitment Problem

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Abstract: In this paper weight pattern based cuckoo search with Levy Flight algorithm is used for solving unit commitment problem. The basic idea behind this method is that a few cuckoo species rely on other species to raise their eggs in merge with Levy Flight behaviour of a few birds. The weight pattern is used to change the scale to get the more precise and better results for the system. The success of the projected method is analysed on two systems comprising of three and six generating units without and with losses. The comparative analysis of the proposed method is done with some other methods.

Key Words: Unit Commitment, Cuckoo Search, Levy Flight, Weight Pattern.

1. INTRODUCTION

In today's era, the stability of the power system load is very much affected varying from peak value to low value depending on the demand. Unit Commitment (UC) plays a very important role in generation resource management. Its purpose is to turn on and off the generating units over a scheduling sphere so that the related to production of power is minimized depending on the load demand while fulfilling the procedure constraints.

Unit Commitment is the problem of determining the optimal scheduling of electricity generation units within a power system subject to operating constraints. The optimal scheduling guarantees a feasible system operation at minimum operational system cost. The principle method of solving the scheduling problem of generator is to try all the possible combination and the choosing the best solution out of them giving the least operating cost. But this is quite time consuming and it gets difficult with complex large systems, so is applied for simplest cases. Various new optimization techniques are nowadays applied to solve the UC problem like Genetic Algorithm, Particle Swarm Optimization etc.

Nowadays cuckoo search technique has attracted more attention and has been applied in almost every area more precisely in engineering optimization.

2. NOTATION

a_i ,b_i ,c_i cost coefficients for i^{th} unit

$F(P_{gi})$ the total cost of generation

P_{gi} generation of i^{th} plant

P_D the load demand

P_l the power loss

Abbreviation

UC Unit Commitment

HGA Hybrid genetic algorithm

EP Evolutionary programming

SGA Simple genetic algorithm

GA Genetic algorithm

GA-PS Hybrid GA and PS

SADE Self-adaptive differential evolution

ABC Artificial Bee Colony

3. PROBLEM FORMULATION

As the demand of electricity increases during day time and lowers during the late evening and morning, the power system experience cycles. This requires an hourly based plan for the generation of power by utilities companies. The problem is to determine which of the available units needs to b turn on and which units to turn off for particular period of time and then to determine the optimal Economic dispatch schedule of the generating units for unit commitment problem.

At a particular hour for a particular set of units for generation, the total cost of power production is minimized by cost-efficiently dispatching the units scheduled in focus to particular constraints given below as:

1. The total power generation have to be equal to the load demand.

$$\sum_{i=1}^{NG} F(P_{gi}) = Pd \quad \ldots(1)$$

With losses

$$\sum_{i=1}^{NG} F(P_{gi}) = P_d + P_l \quad \ldots(2)$$

2. The power generated by the units must lie between the particular boundary limit (minimum and maximum capacity).

$$P_{gimin} \leq P_{gi} \leq P_{gimax} \quad \ldots(3)$$

The fuel cost function at any time interval of generated power output is

$$F(P_{gi}) = a_i P_{gi}^2 + b_i P_{gi} + c_i \quad \ldots(4)$$

4. CUCKOO SEARCH AND ITS ALGORITHM

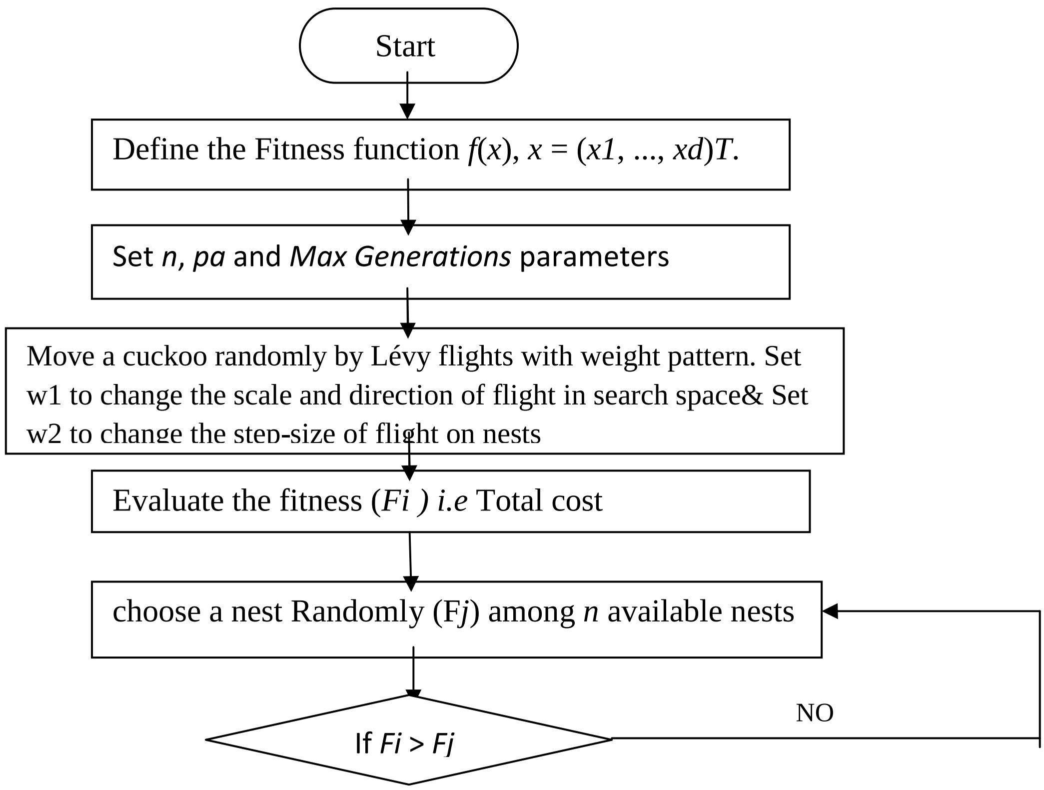
(i). Cuckoo search

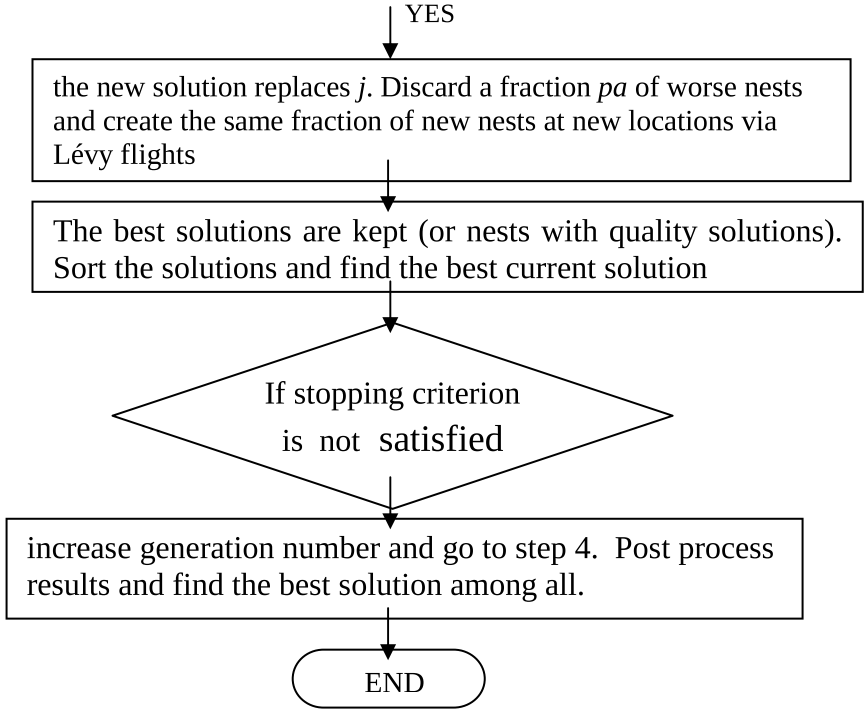
In 2009 Xin-she Yang and Suash Deb introduced a new practice of optimization called Cuckoo search inspired by a process by which some of the varieties of cuckoo lay their eggs in other bird nests of other species as a host. The other species birds comes into direct quarrel with the cuckoos if a host bird finds that the eggs in their nests do not belong to them and it will either dispose of its nest or throw unfamiliar eggs away and build a new nest at new place.

Cuckoo Search follows the following three idealized regulations [6]:

1. The egg laid by Cuckoo should be one at a time and dumps its egg in aimlessly chosen nest.
2. The high and good quality eggs will be carried by the best nest to the next generation.
3. The host nests availability is fixed in numbers and the discovery rate of the cuckoo eggs by host bird lies between probability 0 and 1. In this case host birds throw away the cuckoo eggs or abandon their nest and build their new nest.

(ii). Flow chart of Cuckoo Search with Weight pattern Algorithm





5. SYSTEM MODELLING

WITHOUT LOSSES

(i). *Test system 1*

Table 1 Data [18] for Cost Coefficients and power limits of three units

Unit	Min(MW)	Max(MW)	a	b	c
1	100	600	0.001562	7.92	561
2	100	400	0.001940	7.85	310
3	50	200	0.004820	7.97	78

Table 2 Data [18] showing load pattern for three units

Hour [h]	Load [MW]	Hour [h]	Load [MW]
1	1200	13	500
2	1200	14	500
3	1150	15	600
4	1100	16	800
5	1000	17	850
6	900	18	900
7	800	19	950
8	600	20	1000
9	550	21	1050
10	500	22	1100
11	500	23	1200
12	500	24	1200

Table 3 Unit Commitment using Weight pattern based cuckoo search of three units

HOUR	LOAD	UC	PI	P2	P3	TOTAL COST(Rs/hr)
1	1200	1 1 1	600	400	200	11500.523
2	1200	1 1 1	600	400	200	11500.523
3	1150	1 1 1	570.356	400	179.642	11012.062

4	1100	1 1 1	532.592	400	167.401	10529.921
5	1000	1 1 1	463.610	391.323	145.05	9583.107
6	900	1 1 1	416.05	353.51	129.83	8653.60
7	800	1 1 0	433.18	366.81	0	7735.46
8	600	0 1 1	0	400	200	5625.20
9	550	0 1 1	0	400	150	5142.34
10	500	0 1 1	0	365.38	134.61	4675.49
11	500	0 1 1	0	365.38	134.61	4675.49
12	500	0 1 1	0	365.38	134.61	4675.49
13	500	0 1 1	0	365.38	134.61	4675.49
14	500	0 1 1	0	365.38	134.61	4675.49
15	600	0 1 1	0	400	200	5625.20
16	800	1 1 0	322.38	277.61	0	7735.46
17	850	1 1 1	393.16	334.60	122.22	8194.35
18	900	1 1 1	416.66	353.50	129.83	8653.60
19	950	1 1 1	440.13	372.41	137.44	9116.51
20	1000	1 1 1	463.61	391.32	145.05	9583.10
21	1050	1 1 1	494.82	400	155.17	10053.67
22	1100	1 1 1	532.59	400	167.40	10529.92
23	1200	1 1 1	600	400	200	11500.52
24	1200	1 1 1	600	400	200	11500.52

Total operating cost 197153.39

Table 4 Comparison of simulation result of three methods for three units

METHOD	Total Operating Cost (Rs)
Particle Swarm Optimization [18]	197397.5459
Dynamic Programming [18]	199097.7838
Proposed Method	197153.39

Three units are considered serving a load pattern of 24-h in above system. The data for the three units system and its load pattern [18] is given in table 1 and 2.

Table 3 represents the simulation result for unit commitment problem via weight pattern based cuckoo search algorithm method. Hour is represented by the first column, second column represents the load pattern for each hour, the third column represents the combination of the units in table 3. The fourth column represents the load shared among the units and the last column represents the total cost obtained by committing the units. Table 4 shows comparison of proposed method with other two methods and it is shown that the total cost of operation obtained using Weight pattern based Cuckoo search method is minimum in comparison to other two methods.

(ii). *Test System 2*

Table 5 Data [18] for Cost Coefficients and power limits of six units

Unit	Min(MW)	Max(MW)	a	b	c
1	50	200	0.0037	2.0000	0
2	20	80	0.0175	1.7500	0
3	15	50	0.0625	1.0000	0
4	10	35	0.0083	3.2500	0
5	10	30	0.0250	3.0000	0
6	12	40	0.0250	3.0000	0

Table 6 Unit Commitment result of six units in comparison with two methods

METHOD	**UC SCHEDULE**	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**TOTAL COST(Rs/hr)**
Particle Swarm Optimization [18]	1 1 1 1 0 0	196.19	50.20	19.02	17.90	0	0	769.5164
Dynamic Programming [18]	1 1 1 0 0 0	186.76	46.63	50	0	0	0	828.511
Proposed Method	1 1 1 1 1 1	159.78	41.58	50	10	10	12	689.5147

An IEEE standard 30-bus system comprising of six units is taken [18]. In this results are obtained for 1 hour taking a load of 283.4MW. The data for six unit system is shown in table 5. The results by committing the six unit system is shown in table 6 in comparison with the other two methods. The first column indicates the method used to solve unit commitment problem, second column represents the scheduling of the units , third column represents the allocation of load among various units. The fourth column indicates the total cost attained by committing the units which showing the total operating cost obtained by Weight pattern based Cuckoo search method is minimum in comparison to other two methods.

<u>WITH LOSSES</u>

(iii). *Test system 3*

Table 7 Data [20] for Cost Coefficients and power limits of three units

Unit	**Min(MW)**	**Max(MW)**	**a**	**b**	**c**
1	10	85	0.008	7	200
2	10	80	0.009	6.3	180
3	10	70	0.007	6.8	140

The transmission loss coefficient matrix B for three unit system [20] is specified as

$$B_{ij} = \begin{bmatrix} 0.000218 & 0.000093 & 0.000028 \\ 0.000093 & 0.000228 & 0.000017 \\ 0.000028 & 0.000017 & 0.000179 \end{bmatrix}$$

$$B_{i0} = [0.0003 \quad 0.0032 \quad 0.0015]$$

B_{00}= 0.030523

Table 8 Results for the best simulations with three generating units system.

POWER OUTPUTS	**CUCKOO SEARCH [20]**	**ABC [20]**	**FIREFLY ALGORITHM [20]**	**PROPOSED METHOD**
UNIT 1(MW)	33.490	33.049	32.729	82.73
UNIT 2(MW)	64.116	61.764	63.843	0
UNIT 3(MW)	55.126	57.872	56.151	70
Power Loss(MW)	2.73	2.70	2.72	2.73
Power Demand(MW	150	150	150	150
Power	152.73	152.70	152.72	152.73

Generation(MW)				
Cost(Rs/hr)	1600.46	1600.51	1600.47	1484.16

The three unit system data is given in table 7 and table 8 represents results for the best simulations with three generating units system [20]. In this case the load demand expected is 150 MW.

(iv). *Test System 4*

Table 9 Data [13] for Cost Coefficients and power limits of six units

Unit	Min(MW)	Max(MW)	a	b	c
1	50	200	0.00375	2	0
2	20	80	0.01750	1.75	0
3	15	50	0.06250	1	0
4	10	35	0.00834	3.25	0
5	10	30	0.02500	3	0
6	12	40	0.02500	3	0

Table 10 Data [13] showing Load pattern of six units

Hour [h]	Load [MW]	Hour [h]	Load [MW]
1	166	13	170
2	196	14	185
3	229	15	208
4	267	16	232
5	283.4	17	246
6	272	18	241
7	246	19	236
8	213	20	225
9	192	21	204
10	161	22	182
11	147	23	161
12	160	24	131

The transmission loss coefficient matrix B for six unit [20] system is specified as

$$B_{mn} = \begin{bmatrix} 0.000218\ 0.000103\ 0.000009 - 0.000010\ \ 0.000002\ \ 0.000027 \\ 0.000103\ 0.000181\ 0.000004 - 0.000015\ 0.000002\ \ 0.000030 \\ 0.000009\ 0.000004\ \ 0.000417 - 0.000131 - .000153 - .000107 \\ -.000140 - .000015\ \ - .000131\ \ 0.0000221\ 0.000094\ 0.000050 \\ 0.000002\ \ 0.000002\ \ 0.000153\ \ 0.000094\ \ \ 0.000243\ \ 0.000000 \\ 0.000027\ 0.000030 - .000107\ 0.000050\ 0.000000\ 0.000358 \end{bmatrix}$$

Table 11 Combination of units using Weight pattern based cuckoo search of six units

HOUR	LOAD	P1	P2	P3	P4	P5	P6
1	166	1	1	1	0	0	0
2	196	1	1	1	0	0	0
3	229	1	1	1	0	1	0
4	267	1	1	1	1	1	1
5	283.4	1	1	1	1	1	1

6	272	1	1	1	1	1	1
7	246	1	1	1	0	1	0
8	213	1	1	1	0	1	0
9	192	1	1	1	0	0	0
10	161	1	1	1	0	0	0
11	147	1	1	1	0	0	0
12	160	1	1	1	0	0	0
13	170	1	1	1	0	0	0
14	185	1	1	1	0	0	0
15	208	1	1	1	0	0	0
16	232	1	1	1	0	1	01
17	246	1	1	1	0	1	0
18	241	1	1	1	0	0	0
19	236	1	1	1	0	0	0
20	225	1	1	1	0	0	0
21	204	1	1	1	0	0	0
22	182	1	1	1	0	0	0
23	161	1	1	1	0	0	0
24	131	1	1	1	0	0	0

Table 12 Unit Commitment using Weight pattern based cuckoo search of six units

HOUR	**P1**	**P2**	**P3**	**P4**	**P5**	**P6**	**Total Cost (Rs/hr)**
1	119.92	32,84	15.19	0	0	0	399.7511
2	144.82	38.17	16.68	0	0	0	494.7128
3	163.83	42.25	17.83	0	10	0	603.7186
4	177.07	45.10	18.59	10	10	12	731.6289
5	189.78	47.78	19.41	10.98	10	12	789.8940
6	180.84	45.90	18.80	10	10	12	747.8024
7	176.92	45.05	18.61	0	10	0	658.3603
8	150.33	39.35	17.01	0	10	0	549.0228
9	141.77	37.52	16.50	0	0	0	482.7521
10	117.95	32.41	15.07	0	0	0	392.4921
11	105.87	29.83	15	0	0	0	350.6366
12	117.16	32.25	15.03	0	0	0	389.6104
13	125.50	34.03	15.53	0	0	0	420.5148
14	138.06	36.72	16.28	0	0	0	468.3589
15	157.48	40.88	17.44	0	0	0	545.2585
16	168.24	43.19	18.09	0	10	0	621.9248
17	178.83	45.46	18.73	0	10	0	666.4955
18	175.20	44.68	18.51	0	10	0	651.1217
19	170.34	43.64	18.22	0	10	0	630.6876
20	169.25	43.41	18.15	0	0	0	593.6374
21	151.73	39.65	17.10	0	0	0	522.1305
22	133.75	35.80	16.02	0	0	0	451.7527
23	116.67	32.14	15	0	0	0	387.7979
24	91.88	26.83	15	0	0	0	304.0565

Table 13 Comparison of simulation results of six unit with other mehods

TECHNIQUE	FUEL COST	TOTAL POWER (MW)	POWER LOSS
HGA [13]	802.465	292.9150	9.5105
EP [13]	802.404	292.8791	9.4791
SGA [13]	799.384	292.6801	9.6825

GA [13]	803.699	292.917	9.5177
GA-PS [13]	802.0138	292.7287	9.3286
GA-SADE [13]	798.02	289.97	6.57
PROPOSED	789.8940	289.97	6.57

In test system 4 six units are to be considered serving a load pattern of 24-h with transmission losses. The data for the six units system and its load pattern [13] is given in table 9 and 10.

Table 11 represents the combination of the units via weight pattern based cuckoo search algorithm method for six units. The first, second, third column in table 11 represents the hour, the load corresponding particular hour, the combination of six units In table 12 simulation results is represented representing the first column as hour, second column as the allocation of load among six units and the last column as the total cost obtained by committing six units. In table 13 comparison of proposed method is done with other methods

6. CONCLUSION

A new Weight pattern based Cuckoo search method applied to unit commitment problems in power systems is presented in this paper. The results for various test systems without and with losses are obtained via simulation and are compared with other methods. The results reveal that the total operating cost using Weight pattern based Cuckoo search method is minimum for various test systems compared to other methods which shows that the proposed technique is quite competitive to other techniques for solving large-scale unit commitment problems.

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