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PERFORMANCE COMPARISON OF INTEGER CODED CUCKOO AND LEVY FLIGHTS ALGORITHM APPLIED TO UNIT-COMMITMENT PROBLEM

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ABSTRACT

Optimal use of generated power using the Unit Commitment (UC) has been a of research interest for decades. Even though there were lots of optimization techniques tested on the Unit Commitment problem in the past the research is still on because of the newer optimization techniques. With this motivation new algorithms like the Cuckoo Search Algorithm (CSA) using Levy Flights Algorithm (LFA) is implemented on the Unit Commitment problem and compared with the Shifted Frog Leap Algorithm (SFLA). The parameters under study for performance comparison are the execution time, speed of convergence, search area and total number of iterations. Matlab™ based UC problem simulation is carried on a ten-unit system for a 24-hour load demand with the SFLA and CSA algorithm and the performance comparison is tabulated. The CSA algorithm gives overall improvement in the performance compared to the SFLA method of UC solution.

Keywords: *Cuckoo Search Algorithm, Unit Commitment, Shuffled Frog Leap Algorithm, Meta-Heuristic Search Algorithms, Optimization techniques*.

1. INTRODUCTION

The fast changing power requirement and power references in the power industry has brought in the problem of Unit commitment (UC) with higher accuracy and dynamics. So, the new techniques are introduced every now and then in order to attain the new accuracy and speed criteria. The techniques that later on were introduced with the deregulation for there were new power references introduced. The criterion of attaining minimum fuel cost is taken and optimized with the newly occurring algorithms to optimize the time, accuracy and computational complexity. The deregulated environment would create a complex situation of power and resource sharing during the peak and the base load conditions. This resource sharing has to occur with the above-discussed criteria considered. The review in of non-classical methods from expert systems to the natural systems implemented on the unit commitment is discussed [1]. The simultaneous solution of two sub-problems, mixed-integer and non-linear programming problem comprises the UC solution [2]. Priority List (PL) method [3], Dynamic Programming (DP) method [4-5], Lagrangian Relaxation (LR) method [6-8],meta-heuristic methods like Genetic Algorithm [9-14], Particle Swarm Optimization (PSO)[15-19] are some of the methods implemented in the previous literatures. In [20] Imperialistic Competition Algorithm (ICA) was implemented on UC problem. The implementation of these methods has brought about different performance and convergence tradeoffs that have to be sorted out. In [21] it is discussed that the DP method come across with more computational complexity and thus it increases the computational time. The dimensionality of the problem would largely affect the DP computation and also the solution. The PL and LR methods having the disadvantage of sub-optimal solution makes it less preferable [1]. The optimization techniques like GA,PSO makes long

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execution time and does not guarantee the optimal solution. PSO having larger search space could exhibits a better performance in optimization than the GA.SFLA has proved itself to be faster and more optimal as compared to LR and GA methods in solving UC problems [2]. In [20] UC problem was solved using the Imperialistic Competitive Algorithm (ICA). The ICA method gave the least cost function as compared to GA, Integer Coded GA, Hybrid PSO(HPSO) and Bacterial Foraging Algorithm(BFA).But when it comes to execution time BFA performed better than the ICA. In [22] a new meta-heuristic algorithm called the Cuckoo Search via Levy Birds (CSA) was introduced as a new bio-inspired technique. This introduces the dynamics of both the brood parasitic behavior of the Cuckoo species with Levy flights behavior of the fruit flies. CSA is a more generic optimization technique, which was used in the economic dispatch problem, which exhibited the least cost of all the previous methods [23].

This paper employs the CSA method to solve the UC problem and compares with the SFLA method's solution previously obtained. Execution time, settling time and maximum number of iterations to solve the UC problem are compared as a measure of superiority between the methods used.

This paper is organized as follows, Section II gives a brief overview about the CSA method, Section III speaks about the problem formulation of UC problem with the constraints, Section IV provides the results and discussion of the two methods applied on the UC problem.

2. UNIT COMMITMENT PROBLEM

Like the other meta-heuristic methods CSA is also a population-based method with two sub operations in it .One is the direct search based on Levy Flights and a random search based on the probability for the host bird to discover the alien egg in its nest. As discussed by Xin She Yang et.al ,2009 CSA had a more power search method than other meta-heuristic search methods. This makes the CSA method to be more effective in applying on the UC problem. The steps involved in the CSA method is as defined in the following,

Initialization: The population, that is the number of host nest here in UC problem is the time each of the Generators are ON/OFF considering the unit's minimum downtime and uptime as denoted by MD_i and MU_i respectively. The population is divided into many smaller units of time in integer format until the downtime and the uptime is satisfied for a particular generating unit. The initialization is mathematically formalized as given in [2],

$$T_i^1 = \begin{cases} +Rand(\max(0, MU_i - T_i^0), T), if T_i^0 > 0 \\ -Rand(\max(0, MD_i + T_i^0), T), if T_i^0 < 0 \end{cases} \quad (1)$$

where, T_i^0 is the time that particular generator was ON previously. And it is defined in [2] that,

$$\sum_{c=1}^{C} \left| T_i^c \right| = T$$

where, c denotes in which cycle in the commitment cycle the i^{th} generator. And T is the total scheduling period. For $T_i^{c-1} < 0$ cycle c in ON mode with the period as given below

$$T_i^c = \begin{cases} +Rand(MU_i, RT_i^{c-1}), if (RT_i^{c-1} > MU_i) \\ +RT_i^{c-1}, otherwise. \end{cases} \quad (2)$$

where , RT_i^{c-1} is the residual time after allocating to $c-1$ cycles.

$$RT_i^{c-1} = T - \sum_{p=1}^{c-1} \left| T_i^p \right| \quad (3)$$

Sometimes the scheduling time is satisfied with c cycles itself so the rest the allocation between c +1 to C cycles will be zero. As in these methods the minimum up time and minimum down time are satisfied the penalty function is not need to be added in the objective function. The upper and the lower limits of i^{th} generation unit power is as follows,

$$P_{i\min}^t < P_i^t < P_{i\max}^t \quad (4)$$

where, $P_{i\min}^t$ and $P_{i\max}^t$ are the minimum and the maximum power output of the i^{th} generator at time t. After considering the ramp and down time of the units the power generated are defined as,

$$\begin{aligned} P_{i\max}^t &= \min\{P_{i\max}, P_i^{t-1} + \tau.RU_i\} \\ P_{i\min}^t &= \max\{P_{i\min}, P_i^{t-1} - \tau.RU_i\} \end{aligned} \quad (5)$$

where, τ is equal to 60 minutes which is the UC step time. The Power balance equation of the UC problem can be defined as

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$$\sum_{i=1}^{N} u_i(t).P_i^t = D^t; t = 1,.....T \quad (6)$$

where, $u_i(t)$ is the status of the i^{th} generating unit if 1then it is ON ,OFF if the value is 0. D^t is the load demand of the system. The spinning reserve (10 minutes) of the power system is the excessive load that is pending after all the units have supplied its power, which can be denoted as,

$$\sum_{i=1}^{N} u_i(t).P_{i\max r}^t \geq D^t + R^t; t = 1,...T \quad (7)$$

where, $P_{i\max r}^t$ is the 10 minute maximum response rate constrained power generation of the i^{th} generator which can be defined with equation (5) , R^t is the system reserve at time t with $\tau = 10$.

3. CUCKOO SEARCH ALGORITHM WITH LEVY FLIGHTS

The solution vector is initialized and vector T_i^1 ,where each nest represents the time each units would deliver power to the system denoted by (1) as approached in [2].Then the power demand for each hour is taken as the input and given for the unit commitment problem. The 24-hour data of the power demand is tabulated in Table.1. The initial solution set are checked for the inequality violation of MD_i and MU_i and UC fitness function is calculated using

$$TC = \sum_{t=1}^{T}\sum_{i=1}^{N}(FC_i(P_t^i).u(t)) + SUT + SDT \quad (8)$$

Where, FC_i is the fuel cost of the i^{th} generator, SUT and SDT are startup and shutdown costs respectively, which can be equated as follows.

$$SUT = \sum_{i=1}^{N}\sum_{c=2}^{C} H(T_i^c).SU_i(-T_i^{c-1}) \quad (9)$$

$$SDT = \sum_{i=1}^{N}\sum_{c=2}^{C} [1 - H(T_i^c)].SD_i \quad (10)$$

Where, SU_i and SD_i is the startup and shutdown cost of i^{th} unit respectively, H is the unit step function. The start up cost depends on the time when the unit has been . switched OFF before being started up.

$$SU_i(-T_i^{c-1}) = \begin{cases} H_{\cos t_i}, if(MD_i - T_i^{c-1}) \leq Chour_i \\ C_{\cos t_i}, if(MD_i - T_i^{c-1}) > Chour_i \end{cases} \quad (11)$$

where, $H_{\cos t_i}$ and $C_{\cos t_i}$ are hot and cold start cost respectively, $Chour_i$ is the cold start hour of i^{th} unit. The operator data for the ten generator system taken in this UC problem is as given in Table.2. The algorithm for the CSA with Levy Flights which has two searching methodology in it which includes direct search using Levy Flights and random search using probability for the host bird to find the alien egg in its nest is as given below,

1.The population of the time taken by each unit is randomly generated using the equation (1) which we could call it as nests.

2.The fitness function value in equation (8) is calculated for every population generated from the equation (1) .Where the fuel cost function is defined as below,

$$FC_i(P_i^t) = A_i + B_i.P_i^t + C_i.(P_i^t)^2 \quad (12)$$

where A_i, B_i and C_i are the coefficients of the fuel cost function as given in table.2.

3.The best T_{ibest} value is choosen, which provides the least total cost value as given in equation (8) for each nest and $Gbest$ among all nests in the population.

3.The maximum number of iteration , α -the updated step size, β-the distribution factor, $\Gamma(.)$-the gamma distribution factor are initialized for Levy Flights.

4. The new nest by using the new Levy flights is found using the Mantegna's algorithm [23].

$$T_{inew} = T_{ibest} + \alpha \times rand_2 \times \Delta T_{inew} \quad (13)$$

where, $\alpha > 0$, $rand_2$ is a normally distributed stochastic number ,and the increased value ΔT_{inew} is determined by

$$\Delta T_{inew} = v \times \frac{\sigma_x(\beta)}{\sigma_y(\beta)} \times (T_{ibest} - Gbest) \quad (14)$$

$$v = \frac{rand_x}{|rand_y|^{1/\beta}} \quad (15)$$

where $rand_x$ and $rand_y$ are two normally distributed stochastic variables with standard deviation $\sigma_x(\beta)$

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and $\sigma_y(\beta)$ given by,

$$\sigma_x(\beta)=\left[\frac{\Gamma(1+\beta)\times\sin((\pi\beta)/2)}{\Gamma((1+\beta)/2)\times 2^{((\beta-1)/2)}}\right]^{1/\beta} \quad (16)$$

$$\sigma_y(\beta)=1 \quad (17)$$

where , β is between $(0.3\le\beta\le 1.99)$.

With the new generated nest values the fitness function is re-evaluated and the newly determined best value of each nest T_{ibest} and best nest of all nests $Gbest$ is logged. The next action is the alien egg determination and randomization. The probability P_a of a host bird to determine the alien egg in its nest will create a new solution for the UC problem [23]. The new value of T_i is determined as follows

$$T_i^{dis}=T_{ibest}+K+\Delta T_i^{dis} \quad (18)$$

Where K is the updated coefficient which depends on the probability of the host bird to realize the alien egg in its nest.

$$K=\begin{cases}1, if(rand_3<P_a)\\0, otherwise\end{cases} \quad (19)$$

and the gradient value ΔT_i^{dis} is determined by,

$$\Delta T_i^{dis}=rand_4\times\left[rand_{p1}(T_{ibest})-rand_{p2}(T_{ibest})\right] \quad (20)$$

Hour (h)	Demand(MW)
1	700
2	750
3	850
4	950
5	1000
6	1100
7	1150
8	1200
9	1300
10	1400
11	1450
12	1500
13	1400
14	1300
15	1200
16	1050
17	1000
18	1100
19	1200
20	1400
21	1300
22	1100
23	900
24	800

Table 1. Load Demand For 24 Hours

Every time T_i^{dis} and T_{inew} is determined it is taken care that it is within the upper and the lower limits between MU_i and MD_i. And the fitness function is re-evaluated for the new values of T_i^{dis} and T_{inew} until the maximum number of iteration is attained. The $Gbest$ for each of the generators are found are tabulated.Similar implementation for the SFLA algorithm is applied and compared in this paper.

4. SIMULATION RESULTS & DISCUSSIONS

The SFLA and CSA method of UC problem solution has been applied on the above mentioned 10-unit system and the 24-hour load demand shown in fig.5. Matlab based simulation is carried out with the following parameters of optimization.

Cuckoo Search Algorithm (CSA) Parameters:
Population Size: 25
Maximum number of Iterations: 2000
P_a(Probability of worst nest)=-0.25

Shuffled Frog's Leaping Algorithm:
Population Size: 200
Number of memeplexes: 20
Number of Frogs in each memeplexs=10
Number of evolutions (N_e) =100
Number of Shuffling Steps (N_s)=300
Total Number of Iterations= N_eX N_s

For the system configuration given below

Intel I3 Processor,
2.6GHz,
8GB RAM

The overall performance of the Cuckoo Search Algorithm has been good in terms of execution time and speed of convergence. The percentage of convergence in CSA has been high compared to SFLA .

The performance comparison of both SFLA and

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CSA algorithm is given as below in Table.3

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10
$P'_{i\max}$	455	455	130	130	162	80	85	55	55	55
$P'_{i\min}$	150	150	20	20	25	20	25	10	10	10
A_i	1000	970	700	680	450	370	480	660	665	670
B_i	16.19	17.26	16.60	16.50	19.70	22.26	27.74	25.92	27.27	27.79
C_i	0.00048	0.00031	.002	.00211	.00398	.00712	.00079	.00413	.00222	.00173
MU_i	8	8	5	5	6	3	3	1	1	1
MD_i	8	8	5	5	6	3	3	1	1	1
H_{cost_i}	4500	5000	550	560	900	170	260	30	30	30
C_{cost_i}	9000	10000	1100	1120	1800	340	520	60	60	60
$Chour_i$	5	5	4	4	4	2	2	0	0	0
ini state	8	8	-5	-5	-6	-3	-3	-1	-1	-1

Table 2. Operator Data for Ten Unit System

S. no	Performance Comparison	
	SFLA	**CSA**
1	Execution time is more to obtain the same results as compared to CSA (10942.14 secs)	Execution time is less Compared to SFLA (1080.58 secs)
2	Number of iterations required to obtain the same result as that of CSA is more (Total cost converges in 3000 (300*100) iterations	Less number of iterations are required. (Total cost converges in 2000 iterations)
3	More Number of population size is required	Less number of population size is required
4	Slow convergence	Fast convergence
5	Search area is less	Search area is more

Table.3 Performance Comparison between SFLA and CSA

The graphs obtained with the number of vector moment of each of the algorithm versus the cost function is generated. The graphs for SFLA and CSA are plotted in the Figure .1 and Figure .2

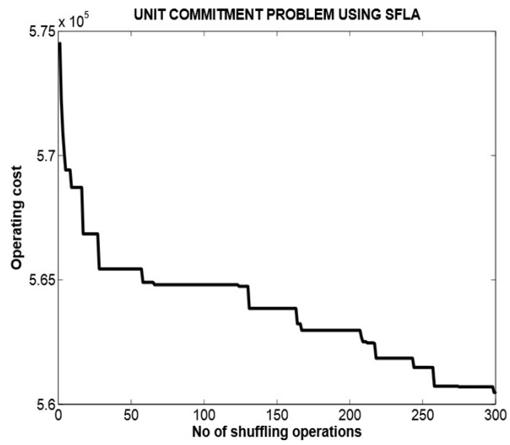

Fig. 1. Cost Function Vs Number Of Shuffling (SFLA)

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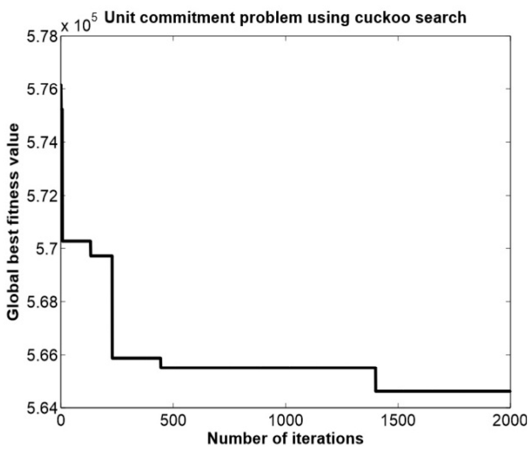

Fig. 2. Cost Function Vs Number Of Iterations(CSA)

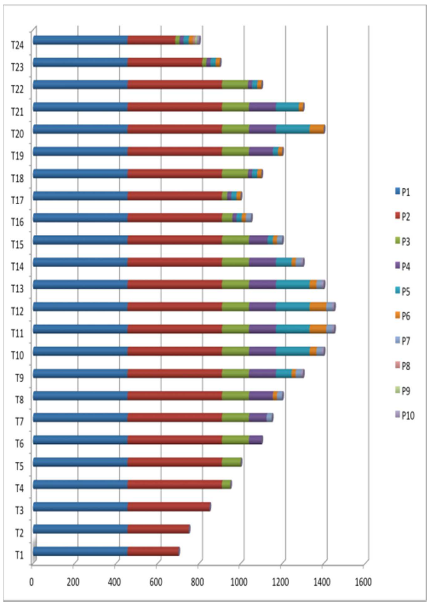

Fig.3(A). Generation In 24-Hour By 10-Generator System (SFLA)

The plots from Fig.1 and Fig. 2 shows that the number of iterations consumed by the SFLA algorithm is 30000 iteration and for CSA it is 2000 iterations to attain the convergence of the UC problem. The cost obtained from the CSA method is less than that obtained from SFLA method. Table.3 also confirms that the execution time taken by the CSA is less than that of the SFLA method, less population size defined in CSA and more search ability and fast convergence compared to SFLA method. The fig.3(a) shows the 24-hour schedule of 10-generator system for the load demand shown in fig.5 using SFLA. Fig.4(a) shows the schedule of 10-generator system using cuckoo search

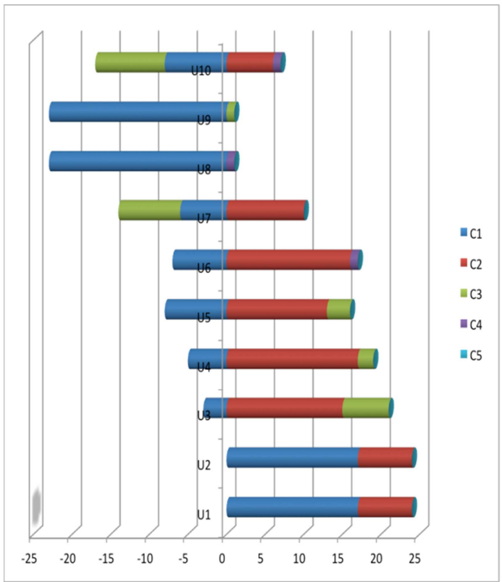

Fig.3(B). Scheduling In Cycles (SFLA)(Negative Indicates Shutdown Time And Positive Indicates On Time)

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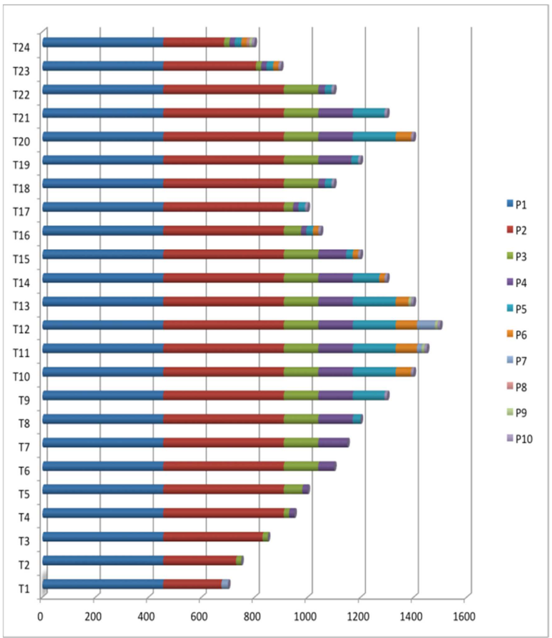

Fig.4(A). Generation In 24-Hour By 10-Generator System (CSA)

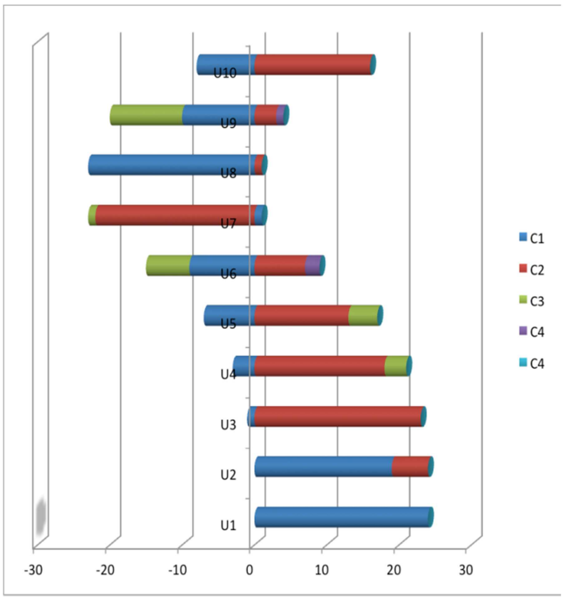

Fig. 4(B). Scheduling In Cycles (CSA)(Negative Indicates Shutdown Time And Positive Indicates On Time)

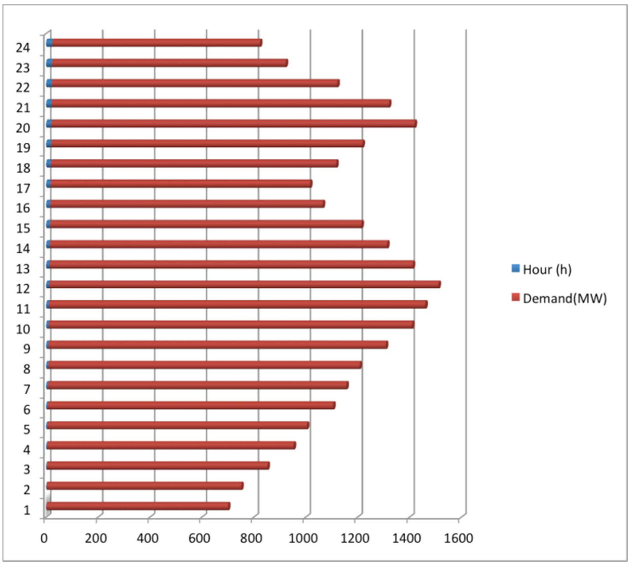

Fig. 5. 24-Hour Load Data

5. CONCLUSIONS

This paper has attempted the performance comparison of the SFLA and the CSA method when applied on UC problem .A Matlab™ based simulation was carried out and the results were tabulated.The results thus obtained conclude that SFLA consumes more number of iterations for convergence as compared to CSA. The success rate of convergence for CSA was 100% which is better as compared to SFLA which gave the 97% success rate of convergence when tried for 10,000 runs. Thus the CSA had provided a overall improvement in the implementation of UC problem.The CSA has been faster in convergence and also the execution time.

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