Short Term Generation Scheduling of Thermal Units with Emission Limitation in Deregulation Environment

C.Sakthivel[1] , S.Pavithra[2], S .Pradeep kumar[3], R.Guruprasath[4]

1Assistant Professor, Department of EEE, JCT College of Engineering and Technology
2Assistant Professor, Department of EEE, JCT College of Engineering and Technology
3Assistant Professor, Department of EEE, JCT College of Engineering and Technology
4Assistant Professor, Department of EEE, SNS college of Technology, Coimbatore

Abstract -***This paper presents a generation scheduling of thermal units considering startup and shutdown ramp limits by using Shuffled Frog Leaping Algorithm. The Startup and shutdown ramp limits are does not consider in the conventional method of unit commitment (UC). Without considering the ramp limits in generation scheduling problem, solution for large power system does not give practical value. The objective of proposed work is to determine the optimal committed of thermal generating units at minimum operating cost while considering load demand, spinning reserve and other equality and inequality constraints at each hour time interval. The solution obtained from the proposed Shuffled Frog Leaping Algorithm (SFLA) for four unit system is compared with other conventional methods.***

Keywords -*Unit Commitment, Shuffled Frog Leaping Algorithm (SFLA), Startup Ramp limit and Shutdown Ramp limit.*

I. INTRODUCTION

The planning and operation of generation scheduling of thermal units in electric power system is based on the total load demand on the system. The daily load demand of the system varies time to time and hour to hour. So the commitment of thermal units gets important to ON/OFF the thermal generating units [1]. The committed units optimally distribute the forecasted load. Unit commitment is a mixed integer nonlinear optimization problem used to schedule the thermal generating units in order to satisfying the load demand and reserve requirements of minimum cost [2]. The thermal unit commitment problem is solved by various optimization methods [3].The methods are like Priority list (PL), Forward Dynamic programming(FDP), Lagrangian Relaxation (LR), Genetic algorithm(GA), Simulated Annealing (SA), Particle Swarm optimization (PSO) and Ant colony Optimization (ACO).

The priority list method comparatively gives high production cost and high computational time. The dynamic programming method has more mathematical complexity compare to other methods for solving unit commitment problem [4]. The inherence sub optimality is the main drawback in the Lagrangian relaxation based unit commitment problems [5]. In genetic algorithm convergence does not guaranty to produced optimal solution compare to other methods [6]. The simulated annealing also has some mathematical complexity to implement the scheduling problem [7]. Particle swarm Optimization is based on birds flocking behavior which produces the efficient output [8],[9]. In ant colony Optimization, the colony of individuals is adopting by decision making policy [10].

In this paper we propose a integer coded Shuffled Frog Leaping Algorithm (SFLA) for solving the short term thermal generation scheduling problems. The four thermal generating units with eight hour load demand is consider as a case study for our proposed work. The organization of paper is follows. Section I describes the introduction of unit commitment; section II a detailed mathematical formulation of problem with considering the various constraints. The proposed integer coded SFLA with flow chart is explained in section III. Section IV and V gives the result and discussion and conclusion of our proposed work."

II. PROBLEM FORMULATION

The Unit commitment problem can be mathematically formulated by the following equation.

$$OC_T = \sum_{t=1}^{T}\sum_{i=1}^{N} PC_i(P_{i,t}).U_{i,t} + SC_i \qquad (1)$$

$$PC_i(P_{i,t}) = A_i + B_iP_{i,t} + C_iP_{i,t}^2 \qquad (2)$$

$$SC_i = \sum_{i=1}^{N}\sum_{c=2}^{C} H\,(T_i^c).SC_i(-T_i^{c-1}) \qquad (3)$$

$$SC_i(-T_i^{C-1}) = \begin{cases} H_{cost\ i}, & if\,(DT_i - T_i^{C-1}) \le C_{hour\ i} \\ C_{cost\ i}, & if\,(DT_i - T_i^{C-1}) > C_{hour\ i} \end{cases} \qquad (4)$$

The objective function subjected to following constraints.

II.1. **Equality Constraints**:

A. Power Balance Constraint

$$\sum_{t=1}^{T}\sum_{i=1}^{N} P_{i,t}U_{i,t} = PD_t \;;\; t = 1,2,3 \ldots T \qquad (5)$$

II.2. **Inequality Constraints**:

A. Generation limit constraint

$$P_{i,min} \le P_{i,t} \le P_{i,max} \qquad (6)$$

B. Reserve limit constraint

$$0 \le R_{i,t} \le P_{i,max} \le P_{i,t} \qquad (7)$$

C. Minimum up time constraint

$$T_i^{ON} \ge UT_i \qquad (8)$$

D. Minimum down time constraint

$$T_i^{OFF} \ge DT_i \qquad (9)$$

E. Spinning reserve constraints

$$\sum_{t=1}^{T}\sum_{i=1}^{N} P_{i,t}\,U_{i,t} \ge PD_t + SR_t \qquad (10)$$

F. Ramp up & down constraint

$$P_{i,t} - P_{i,t-1} \le K.UR_i \qquad (11)$$

$$P_{i,t-1} - P_{i,t} \le K.DR_i \qquad (12)$$

Where, K=60 min is the UC scheduling time step.

G. Startup Time Ramp limit constraint

$$P_{iF} - P_{io} \le K.P_{i,min} \qquad (13)$$

H. Shut down Time Ramp limit constraint

$$P_{iL} - P_{i,min} \le 0 \qquad (14)$$

The following Fig. 1 shows the time duration curve with startup ramp limit (SR_u) and shutdown ramp limit (SR_D).

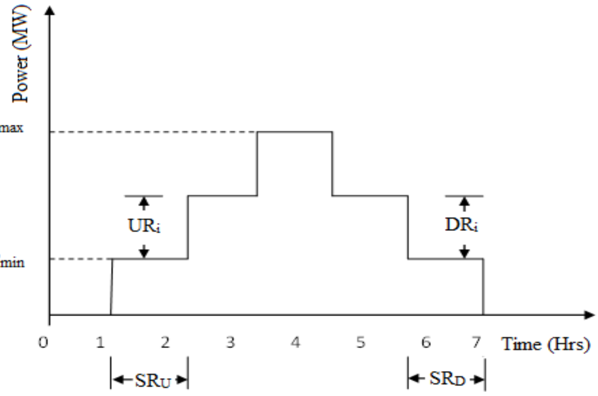

Fig. 1 Time duration curve

III. Shuffled Frog Leaping Algorithm:

The Shuffled Frog Leaping Algorithm is one of the Meta heuristic optimization methods to find a solution of combinational optimization problem [11]. It is Developed B.Y. Ensuff and Lansey in 2003. SFLA is based on the behavior of group of frogs searching for the maximum amount of available food location. The population of group of frogs is partitioned into several parallel communities called memeplex. Within each memeplex each frog holding some idea and it can be influenced by the other frog's idea. The ideas are passed between the parallel communities in a shuffling process[12]-[15].

The local search and the shuffling process are continuing up to the convergence criteria of the tolerance value or number of total iterations met. The shuffling enhances the quality of mems after being infected frogs from all memeplexes. In the proposed method initially P numbers of populations are created randomly and it's divided by number of memeplexes. The worst frog position is updated by the following two equations. The shuffling processes of frogs in memeplexes are continued until the convergence criteria's are satisfied [16],[17].

(i) The specified no of shuffling process is reached.
(ii) The relative change in output in the two shuffling is less than the specified tolerance value.

$$D_i = rand.(X_b - X_w) \qquad (15)$$

$$X_W^{new} = X_W^{current} + D_i, \; (D_{i\,min} < D_i < D_{i\,max}) \qquad (16)$$

Table. I : Unit operator data of a 4-unit base problem

Unit no.	Pmax (MW)	Pmin (MW)	Fuel cost			UT_i (hr)	DT_i (hr)	Ramp Limit (MW/hr)	Shut Down cost ($/hr)	Hot Start Up cost ($/hr)	Cold Start Up cost ($/hr)	Cold Start Time (hr)	Unit Condition (hr)
			a_i	b_i	c_i								
1	80	25	25	1.5	0.00396	4	2	16	80	150	350	4	-5
2	250	60	75	1.35	0.00261	5	3	50	110	170	400	5	8
3	300	75	49	1.2643	0.00289	5	1	60	300	500	1100	5	8
4	60	20	15	1.4	0.0051	1	1	12	0	0	0.02	0	-6

Table II : Proposed method output with and without considering startup, shutdown ramp limit

S. No	Load (MW)	Without considering Reserve & Ramp constraint							With considering Reserve constraint						
		Power Generation of Units(MW)				Fuel Cost ($)	Startup Cost ($)	Total Production Cost ($)	Power Generation of Units(MW)				Fuel Cost ($)	Startup Cost ($)	Total Production Cost ($)
		1	2	3	4				1	2	3	4			
1	410	0	110	300	0	940.47	0	940.47	0	110	300	0	940.471	0	940.471
2	500	0	200	300	0	1134.7	0	1134.7	0	200	300	0	1134.79	0	1134.79
3	575	80	225	210	60	1237.5	350.02	1587.5	80	195	250	50	1248.28	350.02	1598.30
4	620	80	245	245	50	1359.7	0	1359.7	80	240	250	50	1360.13	0	1360.13
5	555	80	205	210	60	1188.9	0	1188.0	80	165	250	60	1199.21	0	1199.21
6	450	80	150	220	0	970.91	0	970.59	0	150	300	0	1021.61	0	1021.61
7	400	80	100	220	0	870.46	0	870.46	0	100	300	0	921.49	0	921.49
8	445	80	145	220	0	959.99	0	959.99	0	145	300	0	1011.01	0	1011.01
9	535	80	235	220	0	1170.7	0	1170.7	0	210	265	60	1174.95	0.02	1174.97
10	600	80	250	220	50	1307.7	0.02	1307.7	80	190	300	30	1343.04	150	1493.0
11	540	80	240	220	0	1183.7	0	1183.7	80	185	250	25	1180.30	0	1180.30
12	495	80	195	220	0	1071.8	0	1071.8	80	165	250	0	1081.85	0	1081.85
13	450	80	150	220	0	970.59	0	970.59	60	150	240	0	981.377	0	981.377
14	576	60	216	300	0	1303.0	350	1653.0	20	216	300	40	1309.50	0.02	1309.52
15	585	80	205	300	0	1317.1	0	1317.1	20	230	300	35	1335.79	0	1335.79
16	625	80	195	300	50	1390.9	0.02	1390.9	25	250	300	50	1423.74	0	1423.74
17	530	0	230	300	0	1208.9	0	1208.9	20	210	300	0	1215.57	0	1215.57
18	465	0	165	300	0	1054.1	0	1054.1	20	145	300	0	1067.59	0	1067.59
19	405	0	105	300	0	930.91	0	930.91	20	105	280	0	928.689	0	928.68
20	492	0	192	300	0	1115.8	0	1115.8	20	172	300	0	1126.38	0	1126.38
21	568	0	208	300	60	1271.4	0.02	1271.4	25	243	300	0	1307.53	0	1307.53
22 s	483	0	183	300	0	1094.8	0	1094.8	0	183	300	0	1094.84	0	1094.84
Total						27693.07	700.08	28393	Total				28058.97	500.08	28559

Table.III : Optimal solutions of the proposed method for considering ramp and startup, shutdown ramp limit

S. No	Load (MW)	With considering Reserve &normal Ramp constraint							With considering Start up and Shut down Ramp limit						
		Power Generation of Units(MW)				Fuel Cost ($)	Startup Cost ($)	Total Production Cost ($)	Power Generation of Units(MW)				Fuel Cost ($)	Startup Cost ($)	Total Production Cost ($)
		1	2	3	4				1	2	3	4			
1	410	0	110	300	0	940.47	0	940.47	0	130	280	0	921.18	0	921.18
2	500	0	160	300	40	1122.36	0.02	1122.38	0	180	300	20	1132.99	0.02	1133.01
3	575	25	205	300	45	1300.13	350	1650.12	25	218	300	32	1308.72	350	1658.72
4	620	25	245	300	50	1410.53	0	1410.53	31	245	300	44	1409.58	0	1409.58
5	555	25	195	297	38	1254.45	0	1254.45	25	195	297	38	1254.45	0	1254.45
6	450	0	150	300	0	1021.61	0	1021.61	0	150	280	20	1007.84	0	1007.84
7	400	0	100	300	0	921.49	0	921.49	0	100	300	0	921.49	0	921.49
8	445	0	145	300	0	1011.01	0	1011.01	0	150	295	0	1006.69	0	1006.69
9	535	0	195	300	40	1202.04	0.02	1202.06	25	200	290	20	1215.11	150.02	1365.13
10	600	25	245	295	35	1368.11	150	1518.10	25	245	298	32	1371.81	0	1371.81
11	540	25	215	275	25	1216.31	0	1216.29	25	215	275	25	1216.29	0	1216.29
12	495	25	195	275	0	1114.71	0	1114.71	0	195	280	20	1109.11	0	1109.11
13	450	25	150	275	0	1013.44	0	1013.44	0	157	261	32	989.15	0	989.15
14	576	25	200	295	56	1294.24	0.02	1294.25	25	207	300	44	1303.12	150.02	1453.15
15	585	25	220	295	45	1322.09	0	1322.09	25	220	295	45	1322.09	0	1322.73
16	625	25	250	300	50	1423.74	0	1423.74	40	250	300	35	1422.59	0	1422.85
17	530	30	200	300	0	1208.35	0	1208.35	43	200	262	25	1175.03	0	1175.73
18	465	25	150	290	0	1056.8	0	1056.8	25	150	270	20	1044.2	0	1044.2
19	405	25	150	230	0	890.8	0	890.87	25	150	230	0	890.8	0	890.8
20	492	25	200	267	0	1103.9	0	1103.96	25	200	267	0	1103.9	0	1103.9
21	568	25	243	300	0	1307.5	0	1307.5	25	243	300	0	1307.5	0	1307.5
22	610	25	258	295	32	1397.5	0.02	1397.5	40	250	300	20	1397.3	0.02	1397.4
23	550	0	230	300	20	1253.9	0	1253.9	25	225	300	0	1261.2	0	1261.2
24	483	0	183	300	0	1094.8	0	1094.8	0	183	300	0	1094.8	0	1094.8
Total						28250.7	500.08	28750.7	Total				28187.4	650.08	28837.5

Table IV : Load demand of the 4-unit base problem

HOUR	1	2	3	4	5	6	7	8	9	10	11	12
LOAD	410	500	575	620	555	450	400	445	535	600	540	495
HOUR	13	14	15	16	17	18	19	20	21	22	23	24
LOAD	450	516	585	625	530	465	405	492	568	610	550	483

Table V : Comparison of simulation results

S.No.	Method	Constraints Taken	Total operating cost ($ / day)	Total operating cost ($ / year)
1.	DP	Without Ramp & Reserve	28884.6	10542879
2.	SFLA	Without Ramp & Reserve	28393.15	10363500
		With Reserve	28559.05	10424053
		With normal Ramp & Reserve	28750.794	10494040
		With Startup and Shutdown Ramp	28837.554	10525707

IV. Result and Discussion

The proposed method has been applied to four unit system over a scheduling period of 24 hour. Table I shows the operator data for 4 unit system. The table IV shows the load demand value for 24 hour scheduling horizon. The initial population of hundred frogs are divided into twenty parallel combination are taken as an input parameters.

The shuffled Frog Leaping Algorithm (SFLA) is implemented using MATLAB 7.1.0 software package and the system configuration is Intel core i3 with 2.7GHZ speed and 4GB RAM. The spinning reserve is assumed to be 10% of the systems load demand of that hour. The proposed method is tested with three different set of instances. Table II shows the proposed method output with and without considering startup, shutdown ramp limit. The normal ramp limit constraint and startup, shutdown ramp limit considered output is given in table III. Finally the comparison results of the various set of instances are given in table V.

V. Conclusion

This paper has proposed a new integer coded Shuffled Frog Leaping Algorithm for the solution of unit commitment problem with startup and shutdown ramp limits. Four unit systems are considered to give the effectiveness of the proposed Shuffled Frog Leaping Algorithm and simulation results were compared with results obtained by conventional dynamic programming method.

The simulation results show that the proposed work has less conventional time and production cost compare to other conventional methods. The results achieved in proposed method for solving unit commitment problem is quit engaging compare to other methods

REFERENCES

[1] *J. Wood and B. F. Wollenberg, Power Generation Operation and Control. New York: Wiley, 1984.*

[2] *S.M. Shahidehpour, H.Y. Yamin, Z. Li, Market Operations in Electric Power Systems, John Wiley and Sons, 2002.*

[3] *N. P. Padhy, "Unit commitment—A bibliographical survey," IEEE Trans. Power Syst., vol. 19, no. 2, 2004, pp. 1196–1205.*

[4] *C. S. Boopathi, SubhransuSekhar Dash, K. Selvakumar, A. Venkadesan, C. Subramani and D. VamsiKrishna,"Unit Commitment Problem with POZ Constraint Using Dynamic Programming Method", International Review of Electrical Engineering (IREE) Vol.9 Issue.1. Pp.218-225, July-August 2014.*

[5] *C.-P. Cheng, C.-W. Liu, and C.-C. Liu, "Unit commitment by Lagrangian Relaxation and genetic algorithm," IEEE Trans. Power Syst., vol. 15, pp. 707–714, May 2000.*

[6] *K. S. Swarup and S. Yamashiro, "Unit commitment solution methodology using genetic algorithm," IEEE Trans. Power Syst., vol. 17, pp. 87–91, Feb. 2002.*

[7] *K. P.Wong and Y.W.Wong, "Short term hydro thermal scheduling part I: simmulated annealing approach," Proc. Inst. Elect. Eng., Gen. Transm. Dist., vol. 141, pp. 497–501, 1994.*

[8] *A.Y. Saber, T. Senjyu, N. Urasaki, and T. Funabashi, "Unit commitment computation—A novel fuzzy adaptive particle swarm optimization approach," in Proc. IEEE PSCE, Nov. 2006, pp.1820–1828*

[9] *T. O. Ting, M. V. C. Rao, and C. K. Loo, "A novel approach for unit commitment problem via an effective hybrid particle swarm optimization,"IEEE Trans. Power Syst., vol. 21, no. 1, pp. 411–418, Feb. 2006.*

[10] *Sureshkumar. C, Selvakumar. K and Santhoshkumar. G, "Unitcommitment problem solved by Ant colony search algorithm", IJAIR, Vol.1, No.7, pp. 299-304, 2012.*

[11] *Javad Ebrahi , Seyed Hossein Hosseinian, and Gevorg B. Gharehpetian, "UC Problem Solution Using Shuffled FrogLeaping Algorithm, "IEEE Trans. Power Syst., vol. 26, no. 2, pp. 573-581. May 2011.*

[12] *M.M.Eusuff, K.E.Lansey, and F.Pasha, "Shuffled Frog-Leaping Algorithm: A Memetic Meta-Heuristic For Discrete Optimization" Eng.Optimiz, Vol.38, No.2, Pp.129-154, 2006.*

[13] *Selvakumar.K, Vignesh.R.S and Vijayabalan.R, "shuffled frog leaping algorithm for solving Profit Based Unit Commitment problem", in proc. IEEE ICCCA, pp.1-6, 2012.*

[14] *Selvakumar.K, Venkatesan.T and Sanavullah.M.Y., "Price Based Unit Commitment problem solution using shuffled frog leaping algorithm", in proc. IEEE ICAESM, pp.794-799, 2012.*

[15] *M.M.Eusuff and K.E.Lansey, "Optimization of water distribution network design using the shuffled frog leaping algorithm," J. Water Resources Planning &Management, vol.129,no.3,pp.210-225,2003*

[16] *T. Venkatesan and M.Y. Sanavullah, "Shuffled Frog Leaping Algorithm Based Solution to the Profit Based Unit Commitment Problem," Archives Des Sciences, Vol. 65, No. 4, pp. 52-63, Apr 2012.*

[17] *E.Ebeltagi,T.Hegazy,andD.Grierson, "Comparison among five evolutionary–based optimization algorithms," Adv.*