Journal of Emerging Trends in Economics and Management Sciences (JETEMS) 14(6):266-272

Scholarlinkinstitute.org/jetems

Unit Commitment Using Advanced Three Stage Approach

Anup Shukla, ***Student Member, IEEE*** **and S. N. Singh,** ***Senior Member, IEEE***
Department of Electrical Engineering
Indian Institute of Technology Kanpur, India

Abstract
Daily generation scheduling is a critical task in the modern energy management system. The main task of unit commitment (UC) problem involves scheduling the ON /OFF status of units, as well as the real power output of thermal units to meet the forecasted demand over a short-term period, meeting all kinds of system and unit constraints to minimize the overall production cost. Optimum scheduling of units save significant amount of production cost per year. In this paper, an advanced three-stage (ATHS) approach for solving unit commitment problem is presented. In the proposed approach, the first stage is utilized to get the solution in a feasible duration of time by producing a primal scheduling of unit, based on predefined priority. In the second stage, a pseudo-inspired algorithm is applied to the crazy particle swarm optimization (CPSO) for the economic dispatch of operating units. In spite of the acceptable solutions obtained by these two stages, proposed approach may take another stage called improved solution modification process (ISMP) to reach an optimal solution. The simulation results of the proposed algorithm have been compared with the results of various existing methods. The obtained results show the effectiveness of proposed approach.

Keywords: Priority List, Unit Commitment, Economic Dispatch, Improved Solution Modification Process, Crazy Particle Swarm Optimization

---

INTRODUCTION

Unit commitment plays an important role in power system optimal operation. The primary objective of the UC is to ensure that the demands of the users are met at least cost. This objective explicitly specifies an optimization problem with a cost function to be minimized with various constraints, describing the operating limits (Shahidehpour, et al., 2002).

The UC problem is formulated as a nonlinear, large scale, mixed-integer combinatorial problem. The literature on application of optimization methods for generation scheduling problem is vast. Several methods have been proposed to solve the UC problem such as priority list (PL), it is simple and fast, but quality solution is not guaranteed (Senjyu, et al., 2003), dynamic programming (DP) which is based on priority lists, it is flexible but computationally expensive (Ouyang and Shahidehpour, 1991), and lagrangian relaxation (LR) approach provides a fast solution, but it may suffer from numerical convergence and solution quality problem (Sriyanyong and Song, 2005). These methods are known as classical or numerical optimization techniques.

To mitigate the above limitations, many stochastic search techniques have been proposed by researchers such as genetic algorithm (GA), due to random operation of genetic operator's infeasible solution may be generated. GA requires excessive computational time (Senjyu, et.al, 2003). The evolutionary programing (EP) is similar to GA, but the structure of the optimization program is fixed, while its numerical parameters are allowed to evolve. One disadvantage of EP, in solving some of the high dimensional problems is its slow convergence to a good near-optimum (Juste, et al., 1999). In the Bacteria foraging (BF), due to random generation of tumble angles, useful information can't be shared between bacteria. Secondly, the step size in BF is a constant. If the step size is large at the end stage, it is hard to converge to an optimal point (Passino, 2002; Eslamian, et al., 2009).

In the integer-coded genetic algorithm (ICGA), integer coding of chromosome improves execution time and robustness of algorithm, but suffers from the curse of dimensionality (Damousis, et al., 2004). Compared to other evolutionary techniques, the characteristic of the particle swarm optimization (PSO) is simple to implement to find a number of high quality solutions, and has stable convergence characteristics. PSO is widely used in power systems. A survey of its applications in power systems is presented by Al-Rashidi, et al., 2009. In the past few years, several new improvements such as adaptive particle swarm optimization (APSO), (Pappala, et al., 2008), improved particle swarm optimization (IPSO) (Zhao, et al., 2006), and binary clustered particle swarm optimization

(BCPSO), (Gaing, 2003) etc., have been suggested for getting the better and faster solutions.

Later, efforts have been made to develop hybrid techniques, such as GA based on unit characteristic classification (GA-UC) to obtain a higher quality of UC solution in a shorter time with the help of new genetic operator which is based on characteristic classification of unit and intelligent method for generating initial populations (Senjyu, et al., 2002). Enhanced adaptive lagrangian relaxation (ELR), consisting of adaptive LR (ALR), and heuristic search algorithms was introduced (Ongsakul and Petcharaks, 2004). Three-stage (THS) method involves three different steps, with hybrid serial algorithm of artificial intelligence (AI) including PSO and nelder-mead (NM) algorithm are applied (Khanmohammdi et al. 2010). But these hybrid techniques fail to resolve the problem.

CONCEPT AND MOTIVATION OF THE STUDY

The concept of unit commitment has been part of the focus of international discussion since 60s. According to (Kerr, et al. 1966), unit commitment depends on many variables including the characteristics of the generating units, magnitude of load, and amount of interchange etc. Generally, two basic decisions are involved in solving the UC problem, i.e. the "unit commitment" decision and "economic dispatch (ED)" decision. The UC in a power system involves determining a start-up and shut-down schedule of units to meet the forecasted demand, over a short-term period. In the economic load dispatch, the generator's real and reactive power is allowed to vary within certain limits, so as to meet a particular load demand including the reserves such that the total system operational cost over the scheduled horizon is minimized, subjected to system and generator operational constraints (Wood, et al., 1984). Over the past few years, due to rapid industrialization and domestic consumer needs, power demand (load) has been increasing globally. Major problem to power system operators is load variation during a scheduling interval. For a particular load pattern, system exhibits large difference between maximum and minimum demands. To ensure that the system remains secure and that power is reliably delivered requires optimum and careful planning. Optimum scheduling of units can save millions of dollars per year and it enables the system operators to evaluate these savings against intangibles such as system reliability.

In this paper, advanced three-stage (ATHS) algorithm is developed for unit commitment problem. The proposed approach utilizes three advanced stage. In the first stage, primal configuration of all units is obtained based on a predefined priority. In the second stage, a pseudo-inspired algorithm is applied to the crazy particle swarm optimization (CPSO) for the economic dispatch of operating units. In CPSO, velocity of particles is randomized with certain probability to mend the premature convergence of PSO. In spite of the acceptable solutions obtained by these two stages, the presented approach takes another step called the improved solution modification process (ISMP), to optimize the solution within the reasonable time. The simulation results obtained from proposed ATHS approach provide much better results compared to THS proposed by Khanmohammdi et al. (2010) and with other existing methods.

PROBLEM FORMULATION

The objective of the UC problem is to minimize the total operating cost subjected to a set of system and unit constraints over given scheduling interval. The problem does not consider system configuration and line impedances. To do this, the study period is divided into *T* time intervals and the short-term generation scheduling problem is formulated as follows:

$$Min\ TOC_T = \sum_{t=1}^{T}\sum_{i=1}^{N}[F_i\left(P_i(t)\right)+(1-U_i(t-1)\times STC_i(t)]\times U_i(t) \quad (1)$$

The fuel cost function for the unit *i*, at any given time interval, is assumed as quadratic function of the generator power output, $P_i(t)$:

$$F_i\left(P_i(t)\right)=\alpha_i\times\left(P_i(t)\right)^2+\beta_i\times P_i(t)+\lambda_i \quad (2)$$

subjected to the following constraints:

Power balance constraint

$$\sum_{i=1}^{N}U_i(t)\times P_i(t)=D_L(t)+P_{Loss}(t) \quad (3)$$

Assumed network power losses $P_{Loss}(t)=0$.

Thermal constraints:

Generator limit constraint

$$P_{min,i}(t)\times U_i(t)\le P_i(t)\le P_{\max,i}(t)\times U_i(t) \quad (4)$$

Spinning reserve constraint

$$\sum_{i=1}^{NT}U_i(t)\times P_i(t)\ge\ D_L(t)+P_{Loss}(t)+R(t) \quad (5)$$

Minimum up and down time constraint

$$[t_{on,i}(t-1)-T_{ON,i}]\times[U_i(t-1)-U_i(t)]\ge 0 \quad (6)$$

$$[t_{off,i}(t-1)-T_{OFF,i}]\times[U_i(t)-U_i(t-1)]\ge 0 \quad (7)$$

Startup cost

$$STC_{i,t} = \begin{cases} HSC_i & T_{OFF,i} \le t_{off,i}(t) \le T_{OFF,i} + CSC_i \\ CSC_i & t_{off,i}(t) > T_{OFF,i} + CSC_i \end{cases} \quad (8)$$

GENERATION SCHEDULING USING PROPOSED APPROACH

The time horizon is divided into smaller time stages of one hour each. The proposed advanced three stage algorithm for thermal scheduling is explained as follows:

Stage 1: Primary Scheduling of units

Priority list

The priority list is created on the basis of maximum power output and minimum per unit cost. The best per unit cost of units is a function of fuel cost coefficients (2). The per unit fuel cost of an i^{th} unit is derived as follows:

$$\frac{F_i}{P_i} = \alpha_i P_i + \beta_i + \frac{\lambda_i}{P_i}$$

For minimum per unit cost, first derivative of (9) is equated to zero. Hence,

From (9) and (10), the minimum per unit cost would be,

$$= 2\sqrt{\lambda_i \alpha_i} + \beta_i \quad (11)$$

Therefore, Priority list

$$= 2\sqrt{\lambda_i \alpha_i} + \beta_i / P_{max,i}. \quad (12)$$

Primal configuration of all units is decided on a rule that, till the spinning reserve has not been satisfied, all the allowable units for any hour of scheduling are turned ON according to predefined priority given by (12). The obtained unit schedule may not always satisfy the minimum up and down time constraints. To address any violations of these constraints, a heuristic search algorithm is applied.

Stage 2: PSO Module for Economic Dispatch

A PSO given by Kennedy et al. (1995) is a population-based meta-heuristic search algorithm which is inspired by the movement of a flock of birds searching for food. In PSO, swarm of particles are represented as potential solutions, and each particle i is associated with two vectors, i.e. velocity vector $V_i=(v_{i1},v_{i2},.....v_{ix})$ and the position vector $P_i=(p_{i1},p_{i2},.....p_{ix})$, where, x stand for dimension of the search space. The velocity and the position of each particle are initialized by random vectors within the corresponding ranges. During the evolutionary process, the velocity and position of i^{th} particle on dimension x are updated as:

$$v_{ix}^{k+1} = w \times v_{ix}^{k} + c_1 \times rand_1 \times (PB_{ix} - p_{ix}^{k}) + c_2 \times rand_2 \times (GB_{gx} - p_{ix}^{k}) \quad (13)$$

$$p_{ix}^{k+1} = p_{ix}^{k} + v_{ix}^{k+1} \quad (14)$$

where, c_1, c_2 are acceleration coefficients (cognitive and social),w is the inertia weight parameter, which controls the global and local exploration capabilities of the particle. In (13), PB_{ix} is the position with the best fitness found so far for i^{th} particle, and GB_{gx} is the best position in the neighborhood. Inertia weight (w) is varied according to the following equation

$$w = (w_{\max} - w_{\min}) \times \frac{iter_{\max} - iter}{iter_{\max}} + w_{\min}$$

where, $iter$ is current iteration number and $iter_{max}$ is maximum iteration number.

One of the main drawbacks of the PSO is its premature convergence, especially while handling problems with more local optima and large/complex constraints. To overcome this problem, crazy particle swarm optimization (CPSO) was introduced. The idea was to randomize the velocities of some of the particles, referred to as ‘‘crazy particles’’, selected by applying a certain probability. The probability of craziness ζ is defined as a function of inertia weight by Aruldoss et al., 2005; Chaturvedi et al., 2009.

$$\zeta = w_{\min} - \exp\left(-\frac{w}{w_{\max}}\right)$$

The, velocities of particles are randomized as per the following logic

$$v_{ix} = rand(0, v_{\max}) \ ; if \quad \zeta > rand(0,1)$$

$$= v_{ix}; \ \text{Otherwise} \quad (17)$$

Stage 3: Improved Solution Modification Process (ISMP)

The solution obtained from previous two stages may not be optimal, so this stage introduces a modification process that yields a more precise solution by acting on the produced solution. The proposed ISMP decrease the cost by saving the total shape of solution while satisfying time constraints (6) and (7). The steps for ISMP are as follows:

1. Determine all the units in each hour which are allowed to be turned OFF as the decommitment group (DG).
2. In the same hour, determine the commitment group (CG) with units that are allowed to be ON, instead of the units belongs to DG.
3. In this step, it is needed to replace the units belonging to the DG with units belonging to the CG. After doing ELD on the new arrangement, if the total operating cost of this hour has been decreased, it will be preferred to be the final arrangement.

The priority of the units for committing and decommitting action in the two groups, CG and DG respectively, are decided using (11). The units with larger value of per unit cost (11) are decommitted first in the DG and the units with smaller value of per unit cost (11) are committed first in the CG. Figure 1 describes the ISMP in more detail. Three modifications have been done on primary configuration of ten units system. In 22nd hour, 3rd unit and 4th unit are decommitted from DG. Similarly in 23rd hour, 5th unit from DG is decommitted and 6th unit from CG is committed as shown in Figure 2. Rectangular and oval boxes present the units of DG and CG, respectively.

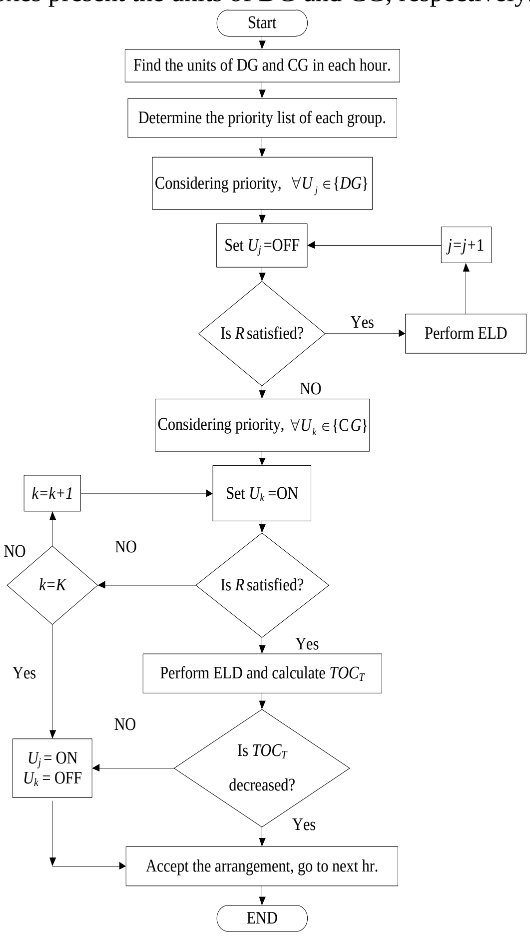

Figure 1. Flowchart of the ISMP for ATHS.

Hour\ Units	1	2	3	4	5	6	7	8	9	10
1	455	245	0	0	0	0	0	0	0	0
2	455	295	0	0	0	0	0	0	0	0
3	455	370	0	0	25	0	0	0	0	0
4	455	455	0	0	40	0	0	0	0	0
5	455	390	0	130	25	0	0	0	0	0
6	455	360	130	130	25	0	0	0	0	0
7	455	410	130	130	25	0	0	0	0	0
8	455	455	130	130	30	0	0	0	0	0
9	455	455	130	130	85	20	25	0	0	0
10	455	455	130	130	162	33	25	10	0	0
11	455	455	130	130	162	73	25	10	10	0
12	455	455	130	130	162	80	25	43	10	10
13	455	455	130	130	162	33	25	10	0	0
14	455	455	130	130	85	20	25	0	0	0
15	455	455	130	130	30	0	0	0	0	0
16	455	310	130	130	25	0	0	0	0	0
17	455	260	130	130	25	0	0	0	0	0
18	455	360	130	130	25	0	0	0	0	0
19	455	455	130	130	30	0	0	0	0	0
20	455	455	130	130	162	33	25	10	0	0
21	455	455	130	130	85	20	25	0	0	0
22	455	455	**0**	**0**	145	20	25	0	0	0
23	455	425	0	0	**0**	**20**	0	0	0	0
24	455	345	0	0	0	0	0	0	0	0

Figure 2. Improved Solution Modification Process (ISMP) on a 10 unit system with 10% spinning reserve

TESTING RESULTS

To test the efficiency of the proposed approach, it is simulated on four units system, ten units system and twenty units system. Results of the proposed method have two parts: Simulation results before ISMP (BISMP) and after ISMP (AISMP). Four different studies are conducted, which are as follows:

Study-1: This system contains four thermal units. Load demand data, unit characteristics and cost coefficients are taken from Khanmohammdi et al. (2010). Here, system is tested for 10% of spinning reserve. Results after ISMP are compared with other existing methods as shown in Table 1. The convergence characteristic of the study-1 is shown in Figure 3. It can be observed from Table 1 that proposed ATHS provides better results than the existing methods.

Table 1. Cost comparison for study-1

Method	Total Cost ($)	Time (Sec)
LR	75,232	-
PSO-LR	74,808	-
THS	74,812	-
ATHS	74,525	1.72

Figure 3. Convergence characteristics of study-1.

6.2 Study-2: This system contains ten thermal generating units. The data of the ten units system and its load are taken from Khanmohammdi et al. (2010). The system is simulated with 5% of spinning reserve. Results after ISMP are compared with other existing methods as shown in Table 2 and the corresponding convergence characteristic is shown in Figure 4. It can be observed from Table 2 that proposed ATHS provides better results than the existing methods. No modification has been done to reach to an optimum solution as compared to THS method where five modifications are needed to reach to an optimal solution, i.e. results are same before ISMP (BISMP) and after ISMP (AISMP). Unit status from proposed ATHS and THS (Khanmohammdi et al., (2010)) is shown in Table 3. The units which are not highlighted are common for both the methods. Light grey underline unit status is only for proposed ATHS and dark grey is for only THS method.

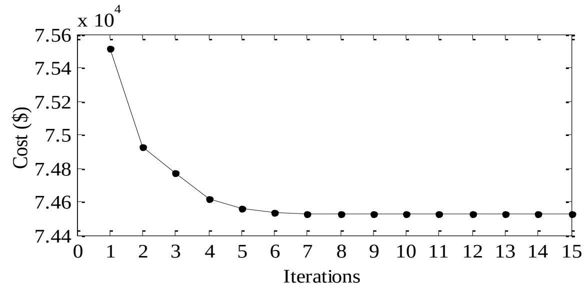

Table 2. Cost comparison for study-2

Method	Total Cost ($)	Time (Sec)
LR	75,232	-
PSO-LR	74,808	-
THS	74,812	-
ATHS	74,525	1.72

Units	**Hours (1-24)**																							
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
3	0	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0
4	0	0	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
5	0	0	0	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0
6	0	0	0	0	0	0	0	0	1	1	1	1	1	1	0	0	0	0	0	1	1	1	1	0
7	0	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	1	1	1	0	0
8	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	1	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Study-3: Same units mentioned in study-2 are performed with 10% of spinning reserve. Cost comparison with other existing methods is shown in Table 4 with execution time in second. It can be observed from Table 4 that proposed ATHS provides better results than the existing methods. Convergence characteristic is shown in Figure 5.

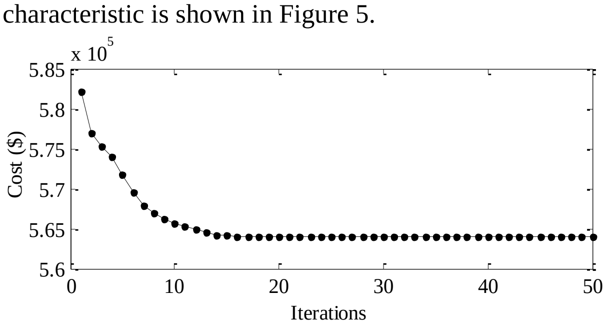

Figure 5. Convergence characteristics of study-3.

Table 4. Cost comparison for study-3

Methods	Total Cost ($)	Time (sec)
EP	564,551	100
GA	565,825	221
GA-UC	563,977	85
BF	565,872	80
ICGA	566,404	7
ALR	565,508	3.2
ELR	563,977	4
THS	BSMP 564,018	-
	ASMP 563,938	-
ATHS	BSMP 564,796	8.13
	ASMP 563,938	**11.82**

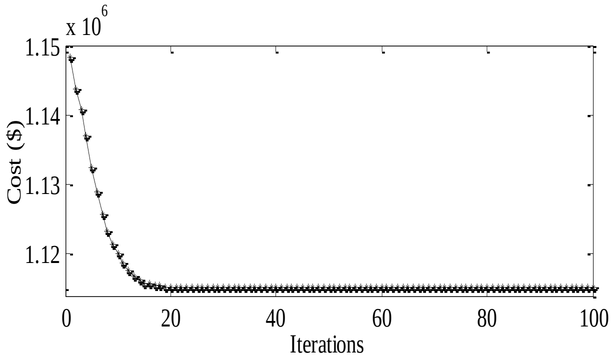

Figure 6. Convergence characteristics of study-4

The result of the generation scheduling from proposed approach for study-3 is shown in Table 6. Figure 7 shows the comparison of execution time for the two different studies. From the numerical results, it is found that proposed ATHS can find more qualified solutions with much lower execution times compared to the EP, GA, GA-UC, and BF methods. Although, ATHS requires more execution time in comparison with ICGA, ALR, and ELR, but the quality of the final results is much better than the results obtained using ICGA, ALR, and ELR. Sign (-) means that no values has been reported. Some values may have round off error.

Table 6. Operation cost and generation scheduling for 24 hour.

Hours	Power generation of units (MW)										Available Reserve (%)	Generation cost ($)	Start-up Cost ($)	Modification Rate ($)
	1	2	3	4	5	6	7	8	9	10				
1	455	245	0	0	0	0	0	0	0	0	30.00	13683.13	0	0.00
2	455	295	0	0	0	0	0	0	0	0	21.33	14554.50	0	0.00
3	455	370	0	0	25	0	0	0	0	0	26.12	16809.45	900	0.00
4	455	455	0	0	40	0	0	0	0	0	12.84	18597.67	0	0.00
5	455	390	0	130	25	0	0	0	0	0	20.20	20020.02	560	0.00
6	455	360	130	130	25	0	0	0	0	0	21.09	22387.04	1100	0.00
7	455	410	130	130	25	0	0	0	0	0	15.83	23261.98	0	0.00
8	455	455	130	130	30	0	0	0	0	0	11.00	24150.34	0	0.00
9	455	455	130	130	85	20	25	0	0	0	15.15	27251.06	860	0.00
10	455	455	130	130	162	33	25	10	0	0	10.86	30057.55	60	0.00
11	455	455	130	130	162	73	25	10	10	0	10.83	31916.06	60	0.00
12	455	455	130	130	162	80	25	43	10	10	10.80	33890.16	60	0.00
13	455	455	130	130	162	33	25	10	0	0	10.86	30057.55	0	0.00
14	455	455	130	130	85	20	25	0	0	0	15.15	27251.06	0	0.00
15	455	455	130	130	30	0	0	0	0	0	11.00	24150.34	0	0.00
16	455	310	130	130	25	0	0	0	0	0	26.86	21513.66	0	0.00
17	455	260	130	130	25	0	0	0	0	0	33.20	20641.82	0	0.00
18	455	360	130	130	25	0	0	0	0	0	21.09	22387.04	0	0.00
19	455	455	130	130	30	0	0	0	0	0	11.00	24150.34	0	0.00
20	455	455	130	130	162	33	25	10	0	0	10.86	30057.55	490	0.00
21	455	455	130	130	85	20	25	0	0	0	15.15	27251.06	0	0.00
22	455	455	0	0	145	20	25	0	0	0	12.45	22735.52	0	857.45
23	455	425	0	0	0	20	0	0	0	0	10.00	17645.36	0	39.33
24	455	345	0	0	0	0	0	0	0	0	13.75	15427.42	0	0.00
											Total	**559847.69**	**4090**	**896.77**

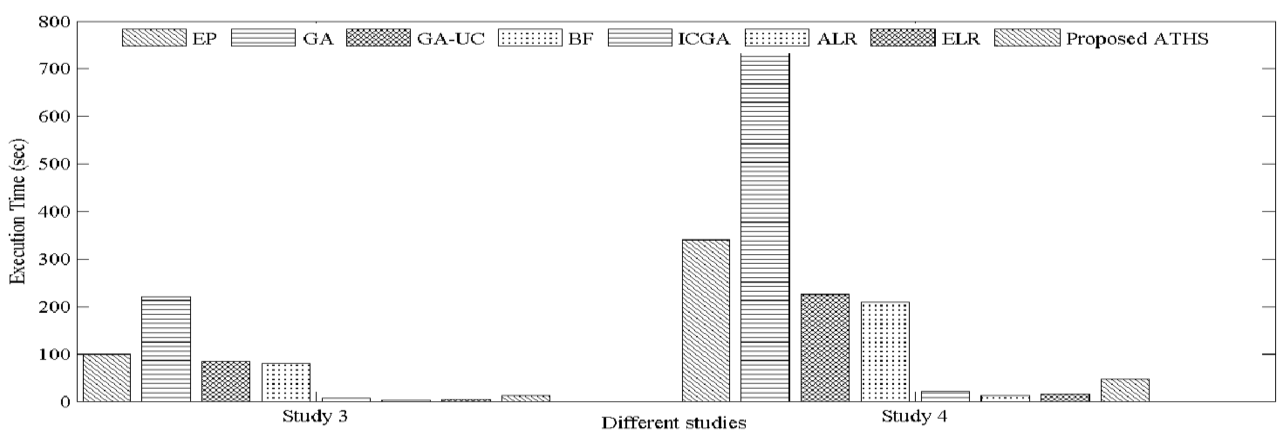

Figure 7. Execution time comparison for different studies

CONCLUSION

In this paper, advanced three-stage approach for solving unit commitment problem is proposed using crazy particle swarm optimization technique with pseudo-algorithm to handle equality constraint as compared to other existing methods. The proposed method gains from some logical and simple stages combined with meta-heuristics approach. The results obtained by the proposed ATHS are compared with the results of some earlier methods and it is found that proposed method provides better results than other existing methods within a reasonable time. For future studies, the author will try to explore the potential of proposed method in optimizing the problem considering large-scale power systems.

REFERENCES

Al-Rashidi, M. R. and El-Hawary, M. E. (2009), "A Survey of Particle Swarm Optimization Applications in Electric Power Systems", IEEE Transaction Evolutionary Computation, 13, 913–918.

Aruldoss, T., Victoire, A., and Jeyakumar, A. E. (2005), "Reserve Constrained Dynamic Dispatch of Units With Valve Point Effects", IEEE Transaction on Power System, 20, 1273–1282.

Chaturvedi, K. T., Pandit, M., and Srivastava, L. (2009), "Particle Swarm Optimization With Crazy Particle for Non-Convex Economic Dispatch", Journal of Applied Soft Computing, 9, 962–969.

Damousis, I. G., Bakirtzis, A. G., and Dokopoulos, P. S. (2004), "A Solution to the Unit Commitment Problem Using Integer-Coded Genetic Algorithm," IEEE Transaction on Power System, 19, 1165–1172.

Eslamian, M., Hosseinian, S. H., and Vahidi, B. (2009), "Bacterial Foraging Based Solution to the Unit Commitment Problem," IEEE Transaction on Power System, 24, 1478–1488.

Gaing, Z.L. (2003), "Discrete Particle Swarm Optimization Algorithm for Unit Commitment", In: IEEE Power Engineering Society general meeting, 1, 13-17.

Juste, K. A., Kita, H., Tunaka, E., and Hasegawa, J. (1999), "An Evolutionary Programming Solution to the Unit Commitment Problem", IEEE Transactions on Power Systems, 14, 1452-1459.

Kennedy, K., and Eberhart, R. C. (1995), "Particle Swarm Optimization," in Proceeding of IEEE International Conference on Neural Networks, Perth, pp. 1942–1948, 1995.

Kerr, R. H., Scheidt, J. L., Fontana, A.J., and Wiley, J. K. (1966), " Unit commitment", IEEE Transactions on Power Apparatus and Systems, 85, 417-421.

Khanmohammdi, S., Amiri, M., and Haque, M. T. (2010), "A New Three-Stage Method for Solving Unit Commitment Problem," Journal of Energy, 35, 3072–3080.

Ongsakul, W., and Petcharaks, N. (2008), "Unit Commitment by Enhanced Adaptive Lagrangian Relaxation", IEEE Transactions on Power Systems, 19, 620-628.

Ouyang, Z., and Shahidehpour, S. M. (1991), "An Intelligent Dynamic Programming for Unit Commitment Application," IEEE Transactions on Power Systems, 6, 1203–1209.

Pappala, V.S., and Erlich, I. (2008), "A New Approach for Solving the Unit Commitment Problem by Adaptive Particle Swarm Optimization", Power and Energy Society general meeting-conversion and delivery of electrical energy in the 21st century, 1-6.

Passino, K.M. (2002), "Bio Mimicry of Bacterial Foraging for Distributed Optimization and Control", IEEE Control Systems Magazine 22, 52–67.

Senjyu, T., Shimabukuro, K., Uezato, K., and Funabashi, T. (2003), "A fast Technique for Unit Commitment Problem by Extended Priority List", IEEE Transactions on Power Systems, 18, 882- 888.

Senjyu, T., Yamashiro, H., Shimabukuro, K., Uezato, K., and Funabashi, T. (2003), "Fast Solution Technique for Large-Scale Unit Commitment Problem Using Genetic Algorithm," IEEE Proceeding Generation, Transmission and Distribution, 150, 753–760.

Senjyu, T., Yamashiro, H., Uezato, K. and Funabashi, T. (2002), "A Unit Commitment Problem by Using Genetic Algorithm Based on Characteristic Classification," in Proceeding IEEE/Power Engineering Society Winter Meeting, 1, 58–63.

Shahidehpour, M., Yamin, H., and Li, Z. (2002), "Market Operations in Electric Power Systems", New York: Wiley, 2002.

Sriyanyong, P., and Song, Y.H. (2005), "Unit Commitment Using Particle Swarm Optimization Combined with Lagrange Relaxation", In: Power Engineering Society general meeting, 3, 2752-2759.

Wood, A. J., and Wollenberg, B. F. (1984), "Power Generation Operation and Control", New York: Wiley.

Zhao, B., Guo, C.X., Bai, B.R., and Cao, Y.J. (2006), "Improved Particle Swarm Optimization Algorithm for Unit Commitment", International Journal of Electrical Power and Energy System, 28, 482–490.