IJIRST –International Journal for Innovative Research in Science & Technology| Volume 5 | Issue 6 | November 2018
ISSN (online): 2349-6010

Solution of Unit Commitment Problem by using Artificial Intelligence Method

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Abstract

An important criterion in power system is to meet the power demand at minimum fuel cost using an optimal mix of different power plants. Moreover, in order to supply electric power to customers in a secured and economic manner, unit commitment is considered to be one of the best available options. It is thus recognize that the optimal unit commitment results in a great saving for electric utilities. Unit Commitment is the problem of determining the schedule of generating units subject to device and operating constraints. The unit commitment has been identified for the thesis work. The formulation of unit commitment has been discussed and the solution is obtained by classic Dynamic Programming method, Ant Colony Optimization technique and or by Particle Swarm Optimization method. MATLAB codes have been generated for all the three methods to solve the unit commitment problem. The effectiveness of these methods has been tested on two systems comprising three units and six units and total operating cost is obtained. The results of unit commitment problem by all the three methods are compared for total operating cost and for computation time.

Keywords: Unit Commitment Problem, Artificial Intelligence Techniques, Comparison with Conventional Techniques

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I. INTRODUCTION

The unit commitment problem is a hard combinatorial mixed integer optimization problem to determine the optimum schedule of generating units while satisfying a set of system and unit constraints [I]. Unit Commitment involves the selection of units that will supply the anticipated load of the system at minimum cost over a period of time. It is an operation scheduling function. To ‘commit’ a generating unit is to ‘turn it on’ that is to bring the unit up to speed, synchronize it to the system, and connect it so it can deliver power to the network. Solving the UC problem for large power systems is computationally expensive. The complexity of the UC problems grows exponentially to the number of generating units. A great deal of money can be saved by

II. CONSIDERATION USED IN UNIT COMMITMENT PROGRAMMING METHOD

A. *Economic Consideration of Unit Commitment*

A fundamental principle in developing a preliminary commitment is that the most economic operation tends to result when the fewest number of units are online. Having illustrated that commitment with a minimum number of units tends to be most economical, we must now decide which units are the best ones to commit for each hour. As a preliminary step, a commitment priority list is developed that ranks the units’ full- load hourly fuel cost per megawatt. For a given hour the priority list is reviewed, in order from lowest to highest $/MWh, committing enough units to serve the load. Refinement to this preliminary commitment will make it more economical.

B. *Reliability Considerations of Unit Commitment*

1) Several hours in advance:- the several hour projection is useful for trimming an established unit commitment schedule
2) 1-2 days in advance: 1 or 2 day projection aids in establishing unit start up and shut down cost schedule.
3) 1 week Advance - the load projection one week in advance is useful in scheduling any hydro unit on the syste turning units off (decommiting them) when they are not needed.

C. *Constraints in Unit Commitment*

1) Production Cost:- $P_{ci} = a_i + b_i pi + c_i p_i^2$
2) Start Up Cost :- $S_{ci} = \sigma + \delta_i \{1 - e^{(Toff/Ti)}\}$
3) Total Operating Cost :- $Oct = \sum_{T=1,i=1}^{T,N} \mathrm{Pci,t\,Ui,t} + \mathrm{Sci,t}\,(1 - \mathrm{Ui,t} - 1)\mathrm{U}$
4) Power Balance Constraints:- $\Sigma\, p_{i,t}\, U_{i,t} = P_{di}$
5) Power Generation Limits:- $P_{min} \leq P_{i,t} \leq P_{imin}$
6) Minimum Up time:- $T_{i,t(ON)} \geq MUT_i$

7) Minimum Down time :- $T_{i,t(Off)} \geq MDT_i$
8) Spinning Reserve Contstaints :- $\Sigma P^{max}_{i,t} U_{i,j} \geq P_{di} + R_t$

D. Flow Chart

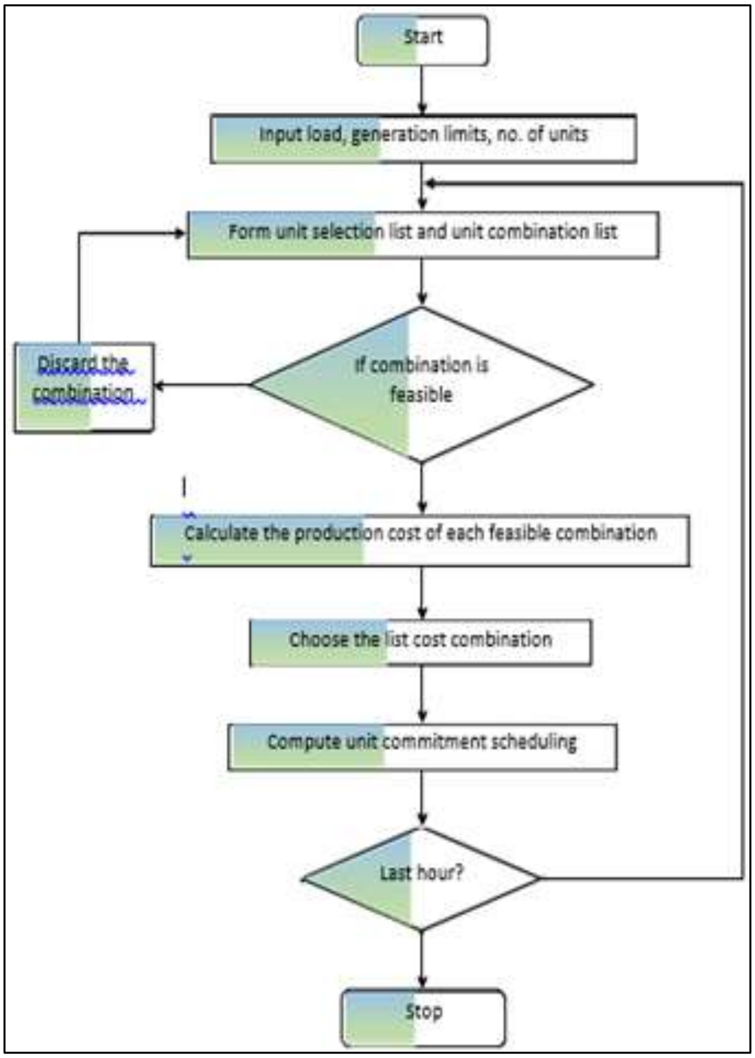


Fig. 1: Flow Chart

E. Dynamic Programming Method

Dynamic programming [I] can be used to compute the UC table, if the load is assumed to increase in small but finite steps. The total number of units available, their individual cost characteristics and the load cycle on the station are assumed to be known priori. Also it shall be assumed that the load on each unit or combination of unit changes in suitably small but uniform steps of size ΔMW (e.g., 1MW).
$F_N(x)$ = the minimum cost in Rs/hr of generating MW by N units
$F_N(y)$ = the minimum cost in Rs/hr of generating MW by N units
$F_{N-1}(x-y)$ = the minimum cost in Rs/hr of generating (x-y) MW by N units
$F_N(x) = \min F_N(y) + F_{N-1}(x-y)\}$

F. Ant Colony Method (ACO)

Ant colony optimization (ACO) [II] is based on the cooperative behaviour of real ant colonies, which are able to find the shortest path from their nest to a food source. The method was developed by Dorigo and his associates in the early 1990's.
Pheromone trail evaporation:
When an ant k moves to the next node, the pheromone evaporates from all the arcs $I\ j$according to the relation,

$$\tau_{ij} = (1-p) * \tau_{ij} \ ; \forall (i, j) \in A$$

Where p ∈ (0, 1] is a parameter and A denotes the segments or arcs travelled by ant k in its path from home to destination.
After all the ants return to the home node (nest), the pheromone information is updated according to the relation,

$$\tau_{ij} = (1-\rho) * \tau_{ij} + \sum_{k=1}^{N} \Delta\tau_{ij}^{(k)}$$

Where ρ∈ (0, 1] is the evaporation rate (or the pheromone decay factor) and $\Delta\tau_{ij}^{(k)}$is the amount of pheromone deposited on arc *ij*by the best ant k.

- $\Delta\tau_{ij}^{(k)}$Can be computed as,

$$\Delta\tau_{ij}^{(k)} = \begin{cases} \frac{\varsigma f_{best}}{f_{worst}}; & \text{if (i, j) } \in \text{ global best tour} \\ o; & \text{otherwise} \end{cases}$$

G. *Particle Swarm Optimization*

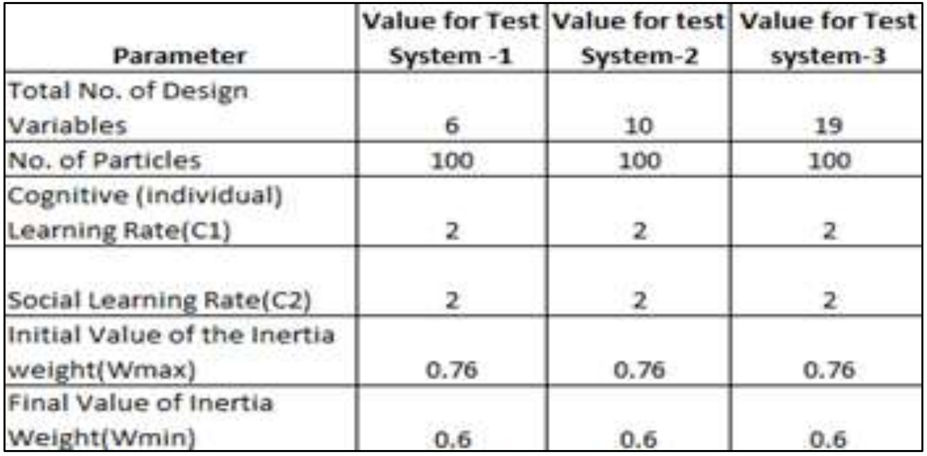
A swarm consists of a set of particles, where each particle represents a potential solution. Particles are then flown through the space, where the position of every particle is changed according to its own experience and that of its neighbours.

The position of pi is then changed by adding a velocity VI (t) to the current position the velocity vector drives the optimization process and reflects the socially exchanged information. Three different phases are differing in the extent of the social information exchange, which are detailed below. Form the basis of initial PSO algorithm. The phases are individual best, global best, local best.

III. RESULTS & COMPARISON

A. *System Parameters for PSO*

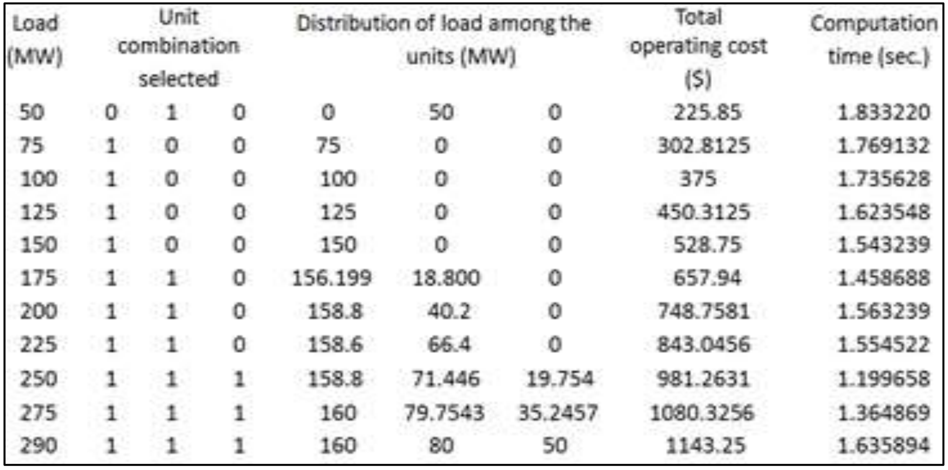
Table – 1
System Parameters for PSO



Parameter	Value for Test System -1	Value for test System-2	Value for Test system-3
Total No. of Design Variables	6	10	19
No. of Particles	100	100	100
Cognitive (individual) Learning Rate(C1)	2	2	2
Social Learning Rate(C2)	2	2	2
Initial Value of the Inertia weight(Wmax)	0.76	0.76	0.76
Final Value of Inertia Weight(Wmin)	0.6	0.6	0.6

B. *Result by PSO Table for Test System - 1*

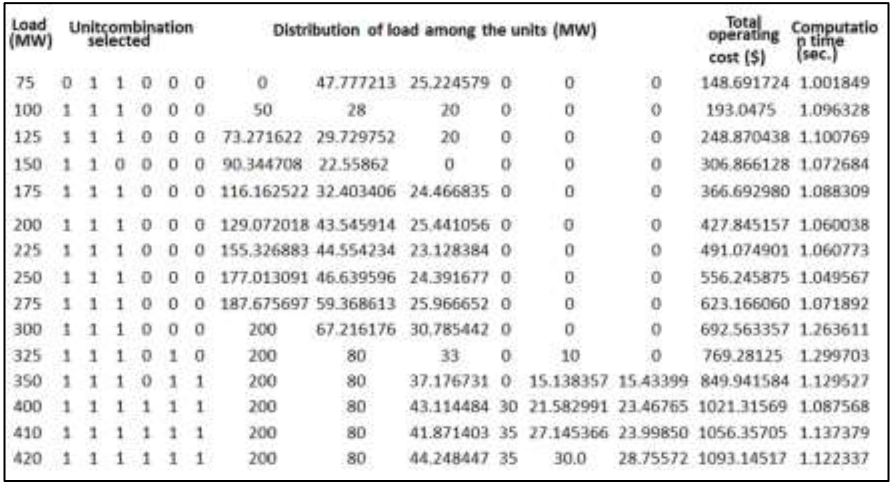
Table – 2
Result by PSO Table for Test System - 1



Load (MW)	Unit combination selected			Distribution of load among the units (MW)			Total operating cost ($)	Computation time (sec.)
50	0	1	0	0	50	0	225.85	1.833220
75	1	0	0	75	0	0	302.8125	1.769132
100	1	0	0	100	0	0	375	1.735628
125	1	0	0	125	0	0	450.3125	1.623548
150	1	0	0	150	0	0	528.75	1.543239
175	1	1	0	156.199	18.800	0	657.94	1.458688
200	1	1	0	158.8	40.2	0	748.7581	1.563239
225	1	1	0	158.6	66.4	0	843.0456	1.554522
250	1	1	1	158.8	71.446	19.754	981.2631	1.199658
275	1	1	1	160	79.7543	35.2457	1080.3256	1.364869
290	1	1	1	160	80	50	1143.25	1.635894

C. Solution of Unit Commitment for Test System - 2

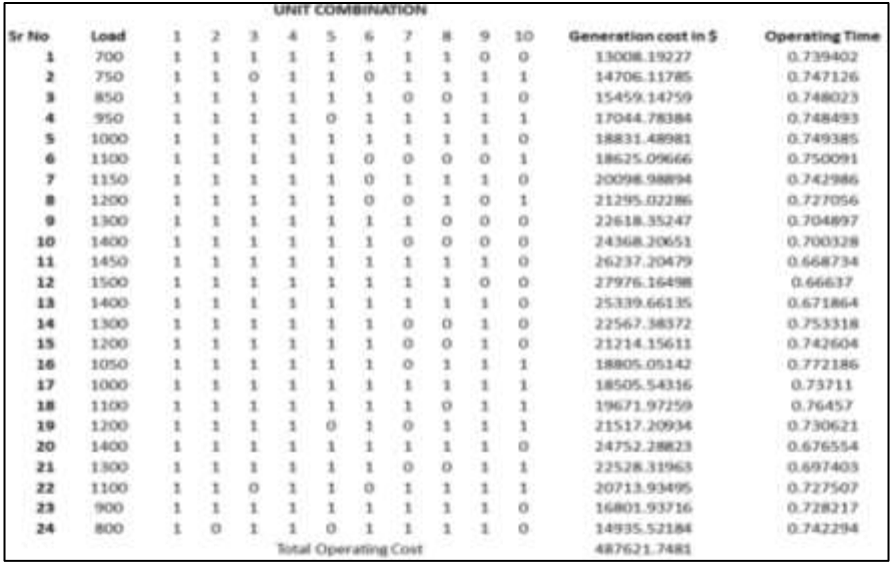
Table – 3
Result by PSO Table for Test System - 2



Load (MW)	Unitcombination selected						Distribution of load among the units (MW)						Total operating cost ($)	Computation time (sec.)
75	0	1	1	0	0	0	0	47.777213	25.224579	0	0	0	148.691724	1.001849
100	1	1	1	0	0	0	50	28	20	0	0	0	193.0475	1.096328
125	1	1	1	0	0	0	73.271622	29.729752	20	0	0	0	248.870438	1.100769
150	1	1	0	0	0	0	90.344708	22.55862	0	0	0	0	306.866128	1.072684
175	1	1	1	0	0	0	116.162522	32.403406	24.466835	0	0	0	366.692980	1.088309
200	1	1	1	0	0	0	129.072018	43.545914	25.441056	0	0	0	427.845157	1.060038
225	1	1	1	0	0	0	155.326883	44.554234	23.128384	0	0	0	491.074901	1.060773
250	1	1	1	0	0	0	177.013091	46.639596	24.391677	0	0	0	556.245875	1.049567
275	1	1	1	0	0	0	187.675697	59.368613	25.966652	0	0	0	623.166060	1.071892
300	1	1	1	0	0	0	200	67.216176	30.785442	0	0	0	692.563357	1.263611
325	1	1	1	0	1	0	200	80	33	0	10	0	769.28125	1.299703
350	1	1	1	0	1	1	200	80	37.176731	0	15.138357	15.43399	849.941584	1.129527
400	1	1	1	1	1	1	200	80	43.114484	30	21.582991	23.46765	1021.31569	1.087568
410	1	1	1	1	1	1	200	80	41.871403	35	27.145366	23.99850	1056.35705	1.137379
420	1	1	1	1	1	1	200	80	44.248447	35	30.0	28.75572	1093.14517	1.122337

D. Solution of Unit Commitment for Test System – 3

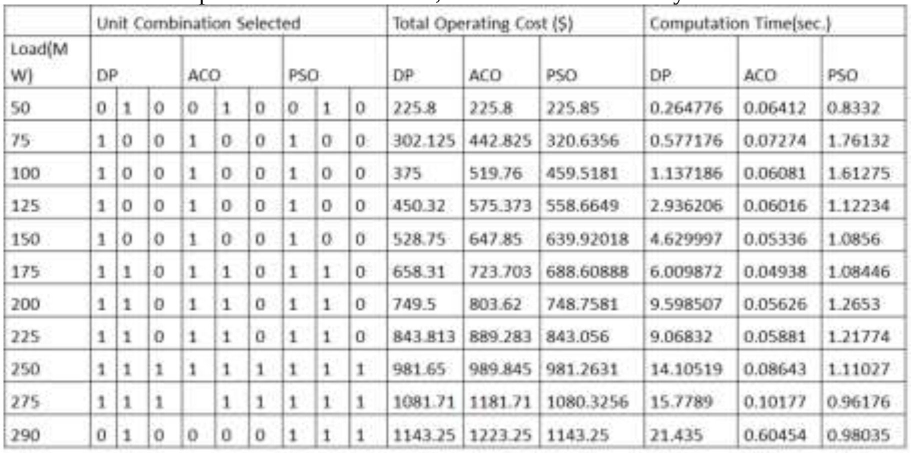
Table – 4
Result by PSO Table for Test System - 3



		UNIT COMBINATION											
Sr No	Load	1	2	3	4	5	6	7	8	9	10	Generation cost in $	Operating Time
1	700	1	1	1	1	1	1	1	1	0	0	13008.19227	0.739402
2	750	1	1	0	1	1	0	1	1	1	1	14706.11785	0.747126
3	850	1	1	1	1	1	1	0	0	1	0	15459.14759	0.748023
4	950	1	1	1	1	0	1	1	1	1	1	17044.78384	0.748493
5	1000	1	1	1	1	1	1	1	1	1	0	18831.48981	0.749385
6	1100	1	1	1	1	1	0	0	0	0	1	18625.09666	0.750091
7	1150	1	1	1	1	1	0	1	1	1	0	20098.98894	0.742986
8	1200	1	1	1	1	1	0	0	1	0	1	21295.02286	0.727056
9	1300	1	1	1	1	1	1	1	0	0	0	22618.35247	0.704897
10	1400	1	1	1	1	1	1	0	0	0	0	24368.20651	0.700328
11	1450	1	1	1	1	1	1	1	1	1	0	26237.20479	0.668734
12	1500	1	1	1	1	1	1	1	1	0	0	27976.16498	0.66637
13	1400	1	1	1	1	1	1	1	1	1	0	25339.66135	0.671864
14	1300	1	1	1	1	1	1	0	0	1	0	22567.38372	0.753318
15	1200	1	1	1	1	1	1	0	0	1	0	21214.15611	0.742604
16	1050	1	1	1	1	1	1	0	1	1	1	18805.05142	0.772186
17	1000	1	1	1	1	1	1	1	1	1	1	18505.54316	0.73711
18	1100	1	1	1	1	1	1	1	0	1	1	19671.97259	0.76457
19	1200	1	1	1	1	0	1	0	1	1	1	21517.20934	0.730621
20	1400	1	1	1	1	1	1	1	1	1	0	24752.28823	0.676554
21	1300	1	1	1	1	1	1	0	0	1	1	22528.31963	0.697403
22	1100	1	1	0	1	1	0	1	1	1	1	20713.93495	0.727507
23	900	1	1	1	1	1	1	1	1	1	0	16801.93716	0.728217
24	800	1	0	1	1	0	1	1	1	1	0	14935.52184	0.742294
						Total Operating Cost						487621.7481	

E. Comparison of Results of DP, ACO & PSO for Test System-1

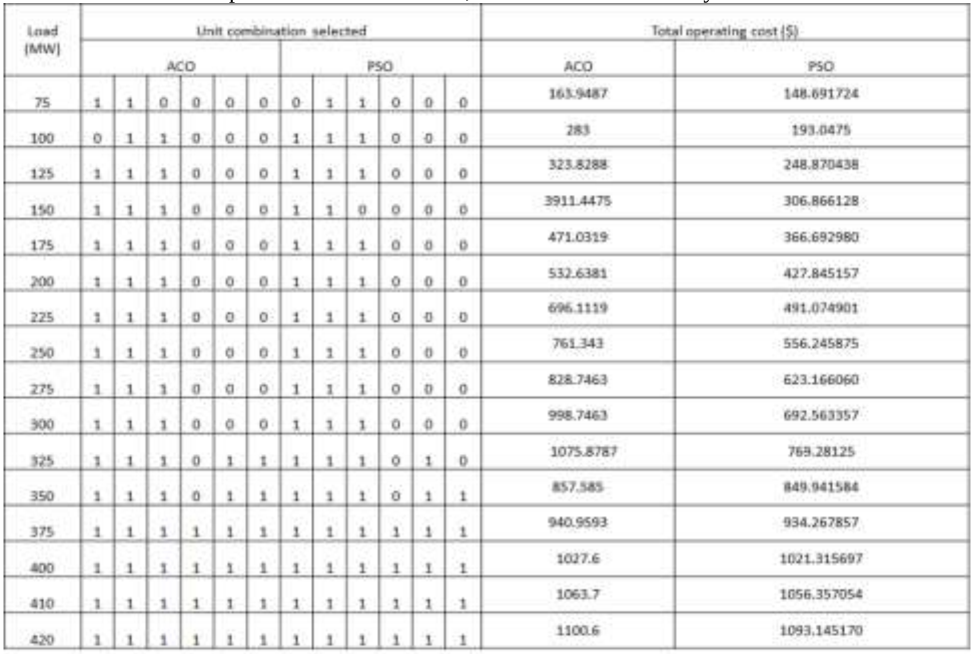
Table – 5
Comparison of Results of DP, ACO & PSO for Test System - 1



	Unit Combination Selected									Total Operating Cost ($)			Computation Time(sec.)		
Load(MW)	DP			ACO			PSO			DP	ACO	PSO	DP	ACO	PSO
50	0	1	0	0	1	0	0	1	0	225.8	225.8	225.85	0.264776	0.06412	0.8332
75	1	0	0	1	0	0	1	0	0	302.125	442.825	320.6356	0.577176	0.07274	1.76132
100	1	0	0	1	0	0	1	0	0	375	519.76	459.5181	1.137186	0.06081	1.61275
125	1	0	0	1	0	0	1	0	0	450.32	575.373	558.6649	2.936206	0.06016	1.12234
150	1	0	0	1	0	0	1	0	0	528.75	647.85	639.92018	4.629997	0.05336	1.0856
175	1	1	0	1	1	0	1	1	0	658.31	723.703	688.60888	6.009872	0.04938	1.08446
200	1	1	0	1	1	0	1	1	0	749.5	803.62	748.7581	9.598507	0.05626	1.2653
225	1	1	0	1	1	0	1	1	0	843.813	889.283	843.056	9.06832	0.05881	1.21774
250	1	1	1	1	1	1	1	1	1	981.65	989.845	981.2631	14.10519	0.08643	1.11027
275	1	1	1		1	1	1	1	1	1081.71	1181.71	1080.3256	15.7789	0.10177	0.96176
290	0	1	0	0	0	0	1	1	1	1143.25	1223.25	1143.25	21.435	0.60454	0.98035

F. Comparison of results of DP, ACO & PSO for Test System - 2

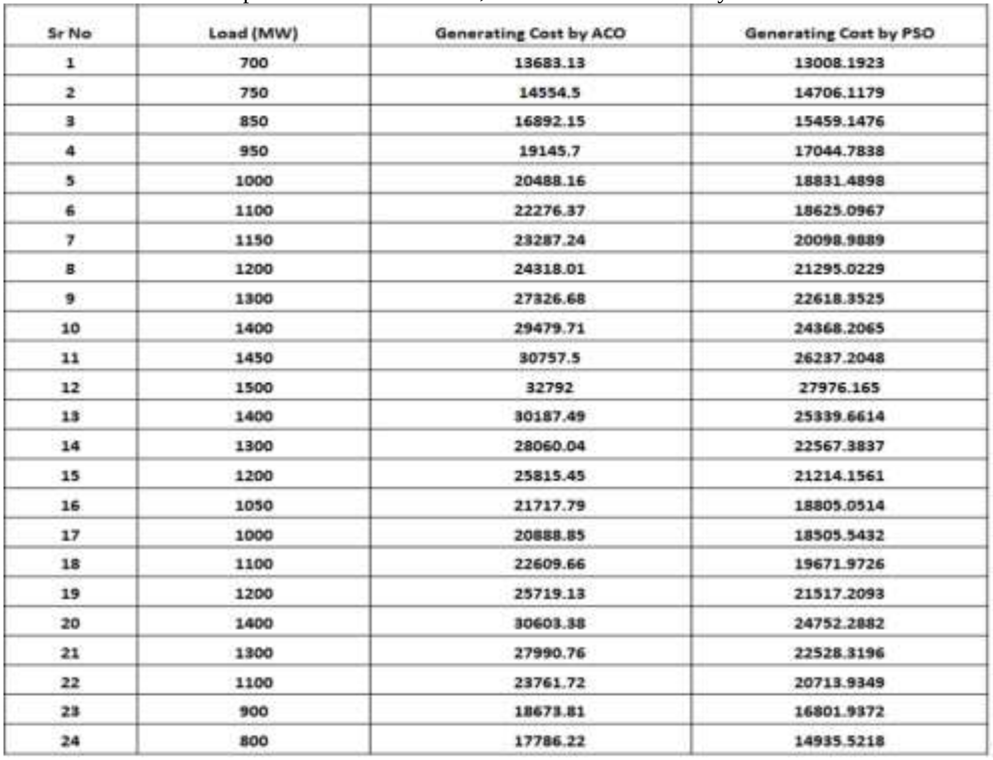
Table – 6
Comparison of Results of DP, ACO & PSO for Test System - 2



Load (MW)	Unit combination selected												Total operating cost ($)	
	ACO						PSO						ACO	PSO
75	1	1	0	0	0	0	0	1	1	0	0	0	163.9487	148.691724
100	0	1	1	0	0	0	1	1	1	0	0	0	283	193.0475
125	1	1	1	0	0	0	1	1	1	0	0	0	323.8288	248.870438
150	1	1	1	0	0	0	1	1	0	0	0	0	3911.4475	306.866128
175	1	1	1	0	0	0	1	1	1	0	0	0	471.0319	366.692980
200	1	1	1	0	0	0	1	1	1	0	0	0	532.6381	427.845157
225	1	1	1	0	0	0	1	1	1	0	0	0	696.1119	491.074901
250	1	1	1	0	0	0	1	1	1	0	0	0	761.343	556.245875
275	1	1	1	0	0	0	1	1	1	0	0	0	828.7463	623.166060
300	1	1	1	0	0	0	1	1	1	0	0	0	998.7463	692.563357
325	1	1	1	0	1	1	1	1	1	0	1	0	1075.8787	769.28125
350	1	1	1	0	1	1	1	1	1	0	1	1	857.585	849.941584
375	1	1	1	1	1	1	1	1	1	1	1	1	940.9593	934.267857
400	1	1	1	1	1	1	1	1	1	1	1	1	1027.6	1021.315697
410	1	1	1	1	1	1	1	1	1	1	1	1	1063.7	1056.357054
420	1	1	1	1	1	1	1	1	1	1	1	1	1100.6	1093.145170

G. Comparison of ACO & PSO for Test System - 3

Table – 7
Comparison of Results of DP, ACO & PSO for Test System - 3



Sr No	Load (MW)	Generating Cost by ACO	Generating Cost by PSO
1	700	13683.13	13008.1923
2	750	14554.5	14706.1179
3	850	16892.15	15459.1476
4	950	19145.7	17044.7838
5	1000	20488.16	18831.4898
6	1100	22276.37	18625.0967
7	1150	23287.24	20098.9889
8	1200	24318.01	21295.0229
9	1300	27326.68	22618.3525
10	1400	29479.71	24368.2065
11	1450	30757.5	26237.2048
12	1500	32792	27976.165
13	1400	30187.49	25339.6614
14	1300	28060.04	22567.3837
15	1200	25815.45	21214.1561
16	1050	21717.79	18805.0514
17	1000	20888.85	18505.5432
18	1100	22609.66	19671.9726
19	1200	25719.13	21517.2093
20	1400	30603.38	24752.2882
21	1300	27990.76	22528.3196
22	1100	23761.72	20713.9349
23	900	18673.81	16801.9372
24	800	17786.22	14935.5218

II. Graphical Comparison

1) Test System-1

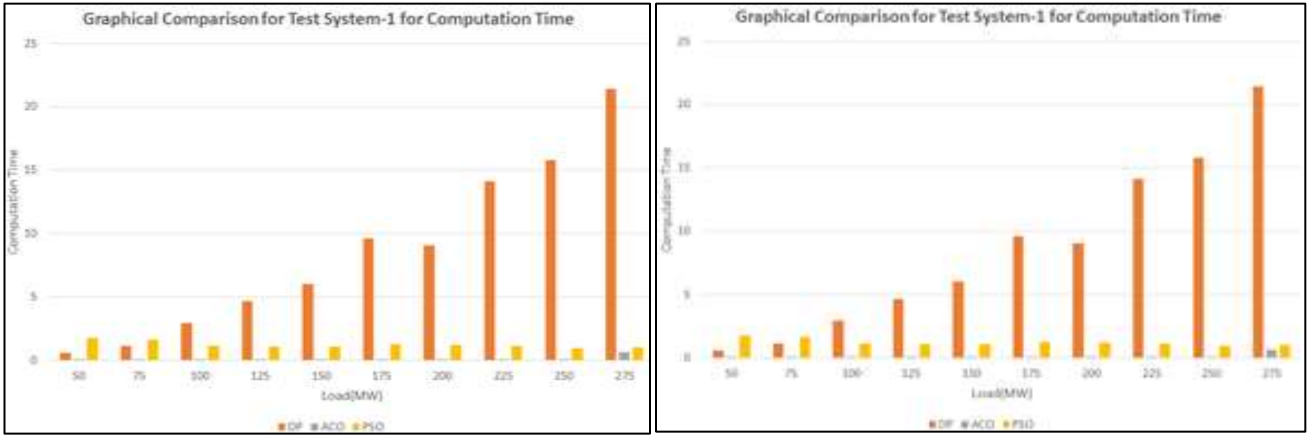


Fig. 2: Test System - 1

2) Test System-2

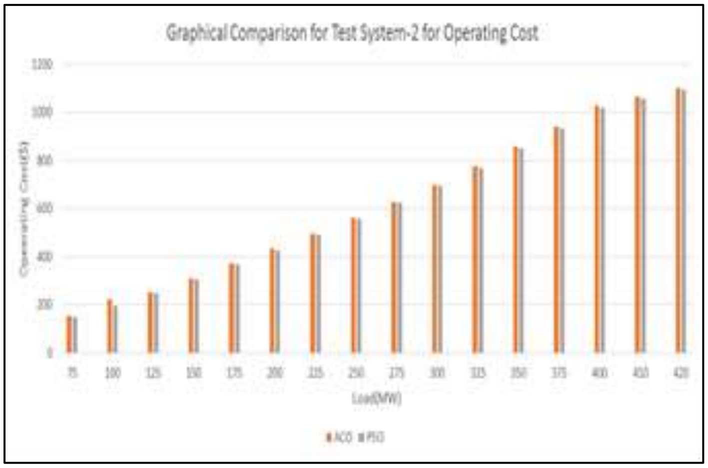


Fig. 3: Test System - 2

3) Test System-3

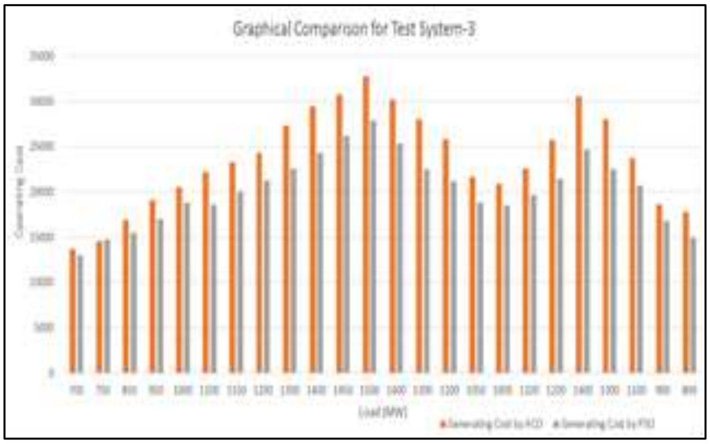


Fig. 4: Test System - 3

IV. CONCLUSION

It is recognized that the optimal unit commitment of thermal systems results in a great saving for electric utilities. It is aimed that the optimal solution of the Unit commitment problem can be solved by many of the methods like Dynamic Programming method, Priority list Method, LR method and the methods of artificial intelligence. From all of these methods by performing Dynamic Programming method, Ant Colony Optimization and Particle Swarm Optimization Method we are getting the results of optimal solution in terms of operating cost , computation time we can get the optimal solution by using Particle Swarm Optimization Technique. Dynamic Programming method gives the optimal solution for only lower number of units (Test System-1) but in case of large number of units it consumes more time compare to ACO & PSO Techniques. By comparing Ant Colony Technique and Particle Swarm Optimization there is a vast difference in the operating cost for selected unit combination. PSO is more economical than ACO for particular Test system-3.Solution of the Unit Commitment problem by using PSO & ACO is carried out and come to know that for lighter load in both the cases there will be a lower operating time but in case of heavier load the operating time will be decreasing.

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