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Unit Commitment Using Soft Computing Techniques

Pujitha Chowdhary Kolli*

PG student, Department of Electrical and Electronics Engineering,
P.V.P. Siddhartha Institute of Technology
Kanuru, Krishna Dist. Vijayawada, Andhra Pradesh- 520 007, India

N. Vijaya Anand

Associate Professor, Department of Electrical and Electronics Engineering,
P.V.P. Siddhartha Institute of Technology
Kanuru, Krishna Dist. Vijayawada, Andhra Pradesh-520 007, India

Dr. CH. Padmanabha Raju

Professor, Department of Electrical and Electronics Engineering,
P.V.P. Siddhartha Institute of Technology
Kanuru, Krishna Dist. Vijayawada, Andhra Pradesh-520 007, India

ABSTRACT

In order to provide sufficient power to the consumers in a cost-effective and secured way the commitment of thermal units is the best option available. It is thus recognized that the optimal unit commitment of thermal systems results in a great saving for electric utilities. Unit Commitment (UC) is a non linear, mixed-integer combinatorial constrained optimization problem in which the main objective is to schedule generation to minimize the total operating cost, subjected to constraints. This paper introduces a new solution technique to the unit commitment problem called Time Varying Acceleration Coefficients Particle Swarm Optimization (TVAC-PSO). The proposed approach has been validated for a three generator system with 24 hour load cycle and an IEEE 30-bus system. The obtained results are compared with the approaches available in the literature.

Keywords: Unit commitment, Time varying acceleration coefficients particle swarm optimization.

1. INTRODUCTION:

In present era of integrated power systems, the power obligation is predominantly met by thermal power generation. Several operating strategies are available to meet the required power demand, which varies from hour to hour over the day. It is preferable to use an optimum or suboptimum operating strategy based on economic criteria. In other words, an important criterion in power system operation is to meet the power demand at minimum operating cost at the same time meeting the equality and inequality limits. In order to supply high-quality electric power to customers in secured and economic manner thermal unit commitment (UC) is considered to be one of the best available options. It is thus recognized that the optimal UC of thermal systems, which is the problem of determining the schedule of generating units within a power system, subject to device and operating constraints results in a great saving for electric utilities [1], [3]. The high dimensionality and combinatorial nature of the unit commitment problem curtails the attempts to develop any exact mathematical optimization method capable of solving the whole problem for any real-size system. To provide eminence solutions to the UC problem various methods are proposed. These include deterministic and stochastic search approaches [2], [4]. Deterministic methods include the state enumeration, priority list, pmax, dynamic programming, lagrangian relaxation and the branch and bound methods. In state enumeration method the UC problem is solved by detailing all probable combinations of the generating units and then the combination that gives the minimum operating cost is selected as best possible solution [4]. While considering the priority list method the units are committed based on the priority list formed using the full load average production cost (FLAPC). The units with least FLAPC are committed first followed by the remaining units in their increasing order of FLAPC. This method can be applied to the real time power systems. But the priority list method has disadvantages such as occurrence of suboptimal solutions as it won’t consider each and every one of the possible combinations of generating units [1], [4], [5]. Whereas in the dynamic programming method the entire problem is divided into sub problems and by solving each sub problem the required solution is achieved. The major shortcomings in making use of dynamic programming method are high computational time, it is often nontrivial to write code that evaluates the sub problems in most efficient order, it is computationally expensive and it cannot be used for large scale systems as it suffers from exponential increase in dimensionality [4], [6]. The stochastic search algorithms such as particle swarm optimization, genetic algorithms, evolutionary programming, ant colony optimization, tabu search are able to achieve success over the limitations of conventional optimization methods [7-14] . Exceptional solutions are obtained using these methods which can handle complex nonlinear constraints. The new optimization technique explicitly the time varying acceleration coefficients particle swarm optimization provides a way out to the unit commitment problem in order to acquire minimum operating cost. This paper provides a detailed analysis of the unit commitment problem solution using PSO and TVAC-PSO and compared for finding a solution to unit commitment problem. In section2 formulation of unit commitment is discussed. In section 3 nature inspired Particle Swarm Optimization. In section 4

TVAC-PSO is discussed. In section 5 unit commitment formulation using TVAC-PSO is discussed. In section 6 experimental results, are compared with other methods available in literature.

2. FORMULATION OF UNIT COMMITMENT PROBLEM

The aim of the UC problem is minimizing the total operating cost in order to meet the demand. It is assumed that the production cost, PC_i for unit 'i' in a given time interval is a quadratic function of the output power of the generator, P_{Gi} [4].

$$F_i(PC_i) = a_i P_{Gi}^2 + b_i P_{Gi} + c_i \qquad (1)$$

Where a_i, b_i, c_i are the corresponding unit's cost coefficients. For the scheduling period 'T' the sum of the production cost's obtained from the corresponding committed units gives the total operating cost, OC_T.

$$OC_T = \sum_{t=1}^{T} \sum_{i=1}^{N} PC_{i,t} UC_{i,t} \qquad (2)$$

Where $UC_{i,t}$ is a binary variable to signify the on/off status of the unit 'i' at time t. The objective is to minimize OC_T subjected to the constraints. The assumption is that the total system demand is supplied by all the generators connected to same bus. The constraints included are:

a. Power Balance Constraint

The total generated power and load at corresponding hours must be equal.

$$\sum_{i=1}^{N} PG_{i,t} UC_{i,t} = P_D \qquad (3)$$

b. Power Generation Limits

The generated power of a unit should be within its minimum and maximum power limits.

$$P_{imin} \leq P_i \leq P_{imax} \qquad (4)$$

3. PARTICLE SWARM OPTIMIZATION (PSO)

Particle swarm optimization is a stochastic, population-based search and optimization algorithm for problem solving. Particle swarm optimization was first introduced by Kennedy and Eberhart in the year 1995 [7], [9], [10]. It is an exciting new methodology in evolutionary computation. PSO is inspired from the simulation of the behavior of social systems such as fish schooling and birds flocking [3]. It is a simple and powerful optimization tool which scatters random particles, i.e., solutions into the problem space. These particles, called swarms collect information from each array constructed by their respective positions. The rules for how the particles move through the space are invented from the simple flocking rules. Individuals interrelate with one another while learning from their individual knowledge and slowly the population entities shift into superior areas of the problem space. The fitness values of all the individuals are estimated by the appropriateness function which is to be optimized. The flying of the particles is directed by their velocities. In the investigation each particle memorizes its own best location found so far. This location is called the personal best and is denoted by P_{best}. In addition among the P_{best} values obtained the best fitness is given by only one particle, which is called the global best, denoted by G_{best}. In each iteration the updating of particle's position as well as the velocity must be done. The P_{best} and G_{best} locations are restructured according to the fitness values of the restructured individuals. The update equations for the velocity and position are given by

$$V_i^{t+1}=w*V_i^t+c_1*rand*(P^t_{besti}-x_i^t)+c_2*rand*(G^t_{best}-x_i^t) \quad (6)$$

$$x_i^{t+1}=x_i^t+V_i^{t+1} \quad (7)$$

Where c_1, c_2 are acceleration coefficients
r_1, r_2 are two independently engendered evenly dispersed random numbers between 0 and 1
x is the location of the particle, w is the inertia weight, V_i^t is the particle's velocity in i^{th} dimension.
For updating the velocities in PSO, a particle is persuaded by its P_{best} and G_{best} positions. The searching of the optimum solution is done by regulating the flight of the particle towards its P_{best} and G_{best} locations.

4. TVAC-PSO

The time-varying inertia weight (TVIW) can locate a good solution at a significantly faster rate but its ability to fine tune the optimum solution is weak, due to the lack of diversity at the end of the search. It has been observed by most researchers that in PSO, problem-based tuning of parameters is a key factor to find the optimum solution accurately and efficiently. In TVAC, this is achieved by changing the acceleration coefficients and with time in such a manner that the cognitive component is reduced while the social component is increased as the search proceeds. In this section, for getting the better global solution, the traditional PSO algorithm is improved by adjusting the weight parameter, cognitive and social factors [13], [14]. The velocity updating equation is rewritten as follows:

$$V_i^{t+1}=w*V_i^t+c_1 * rand*(P^t_{besti}-x_i^t)+c2*rand*(G^t_{best}-x_i^t) \quad (8)$$

Where $c_1 = c_{1max} - \frac{c_{1max} - c_{1min}}{iter_{max}} * iter$ (9)

and $c_2 = c_{2max} - \frac{c_{2max} - c_{2min}}{iter_{max}} * iter$ (10)

c_{1min} , c_{1max} are the initial and final cognitive factors and c_{2min} , c_{2max} are the initial and final social factors .

5. UNIT COMMITMENT USING TVAC-PSO

For solving the unit commitment problem the subsequent steps are used in the TVAC-PSO procedure [13], [14].

1. Population of particles pi and additional variables are initialized. All particles are typically generated arbitrarily within acceptable range $P_{imin} \leq P_i \leq P_{imax}$ where P_i represents the power generated by i^{th} unit in the power system.
2. The parameters for instance figure of particles, the dimension of population, primary and ultimate inertia weight, particle's speed i.e., velocity, number of iterations etc.
3. The fitness function for the population is estimated.

$$OC_T = \sum_{t=1}^{T}\sum_{i=1}^{N} PC_{i,t} UC_{i,t} \quad (11)$$

Where $PC_i = a_i P_{Gi}^2 + b_i P_{Gi} + c_i$. Each individual's fitness value is compared with its P_{best} . The fitness value amongst the P_{best} values is denoted as G_{best}.

4. Modify the individual's velocity V_i of each individual using the equation (8)
5. Revise the individual's position x_i using equation (7)
6. If each individual's estimated value is better than the prior P_{best}, the present value is located as P_{best}. If the finest P_{best} is superior than G_{best} the value is taken G_{best}.
7. If the termination criteria i.e., the number of iterations attains the utmost value then go to step 8, else go to step 3.
8. Evaluate the total cost, power distribution between the units, number of units committed.
9. The individual that engenders the newest is the best possible power generated by each unit with the least total generation cost.

The flow diagram for TVAC-PSO applied to unit commitment is shown in Fig.1.

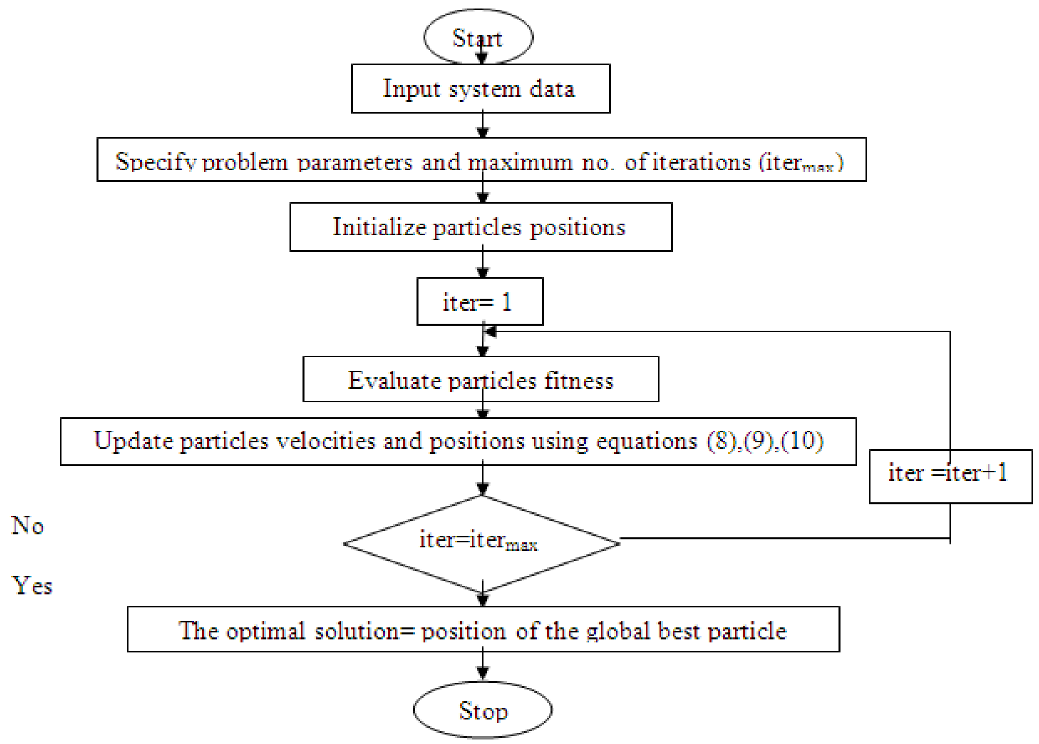

Fig.1. Flowchart of TVAC-PSO

6. EXPERIMENTAL RESULTS:

Test sytsem1

Three machine system was investigated for the validation of the proposed approach. The data of the units are given in Table 1. It relate these parameters/ variables with the table and shows the unit number (1-3), parameters of the fuel cost curve (a, b and c), minimum generation capacity (P_{min}), and maximum generation capacity (P_{max}) of each unit and Table 2 gives the 24 hours load data.

The parameters used for TVAC-PSO are shown in Table 3. The results have been tabulated in Table 4. This table gives the complete unit commitment schedule, and the results obtained by TVAC-PSO method. Table 5 gives the comparison of the different methods. From the last column of the table 5 it is shown that the total operating cost obtained using the TVAC-PSO method is minimum compared to all other methods.

Table 1 Data pertaining to the units for test system 1

Unit	Min(MW)	Max(MW)	a($/MW^{2}H)	b($/MW^{2}H)	c($/H)
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 Load data for test system 1

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

Table 3 Parameters for TVAC-PSO

Parameter	**Value**
Population size	50
Number of iterations	500
C_{1max}	2
C_{1min}	0.4
C_{2max}	2
C_{2min}	0.4
W_{max}	0.9
W_{min}	0.4

Table 4 Unit Commitment results for 24 hours load cycle using TVAC-PSO

S. No	**Load**	**Units committed**			**Allocation of load**			**Total cost ($)**
1	1200	1	1	1	600	400	200	11873.48
2	1200	1	1	1	600	400	200	11873.48
3	1150	1	1	1	600	400	150	11294.06
4	1100	1	1	1	591.04	398.3	110.63	10754.56
5	1000	1	1	0	600	400	0	9635.72
6	900	1	1	0	510	390	0	8673.04
7	800	1	1	0	446.8	353.2	0	7736.1
8	600	1	0	0	600	0	0	5875.32
9	550	1	0	0	550	0	0	5387.7
10	500	0	1	1	0	387.2	112.8	4886.3
11	500	0	1	1	0	387.2	112.8	4886.3
12	500	0	1	1	0	387.2	112.8	4886.3
13	500	0	1	1	0	387.2	112.8	4886.3
14	500	0	1	1	0	387.2	112.8	4886.3
15	600	1	0	0	600	0	0	5875.32
16	800	1	1	0	446.8	353.2	0	7736.1
17	850	1	1	0	480	370	0	8202.57
18	900	1	1	0	510	390	0	8673.05
19	950	1	1	0	550	400	0	9148.1

20	1000	1	1	0	600	400	0	9635.72
21	1050	1	1	1	590	400	60	10216
22	1100	1	1	1	591.04	398.4	110.63	10754.56
23	1200	1	1	1	600	400	200	11873.48
24	1200	1	1	1	600	400	200	11873.48

Total Operating Cost = 201433.32

Table 5 Comparison of production cost

Method	Total cost ($)
Priority List	203067.975
P_{MAX}	202001.385
Dynamic Programming	201634.485
Particle Swarm Optimization (PSO)	201559.88
TVAC-PSO	201433.32

Test system 2

In this an IEEE standard 30-bus system with 6 generator units is considered. The data for test system is given in table 6. The results obtained for the system TVAC-PSO method for a load of 283.4MW is shown in Table 7. This table gives the method used for solving the UC problem and entire unit commitment schedule and corresponding total operating cost. From results shown in table 7 it can be observed that the total operating cost obtained using the TVAC-PSO method is minimum compared to all other methods.

Table 6 Data for test system 2

Unit	Min(MW)	Max(MW)	a($/MW^{2}H)	b($/MW^{2}H)	c($/H)
1	50	200	0.0037	2.0000	0
2	20	80	0.00175	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 7 Comparison of production cost

Method committed	Units	Allocation of load						Total Cost($)
Priority list	110100	200	55.9	0	27.5	0	0	769.16
P_{max}	111000	200	60.46	22.931	0	0	0	773.60
DP	111000	186.76	46.63	50	0	0	0	828.51
PSO	111000	207.39	54.38	21.61	0	0	0	771.70
TVAC-PSO	111100	199.47	50.30	18.53	15.08	0	0	769.39

CONCLUSION

The formulation of unit commitment was discussed and the solutions obtained using the Particle Swarm Optimization and Time Varying Acceleration Coefficients Particle Swarm Optimization methods are compared. From Table 5 and 7 the total production cost obtained from the solution of unit commitment using TVAC-PSO is minimum compared to the outcomes obtained using the methods available in literature.

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Pujitha Chowdhary Kolli was born in Vijayawada, A.P, India in the year 1991. She received bachelor's degree in Electrical & Electronics Engineering from ANU in year 2013. Presently she is PG student in P.V.P.Siddhartha Institute of Technology, Kanuru, Krishna Dist.,Vijayawada,A.P,India.

Vijaya Anand Nidumolu was born in Eluru, A.P, India in the year 1977.He received his B. E in Electrical & Electronics Engineering from Dr. B.A. Marthwada university in year 1999. He obtained his M.E in Power Systems & Automation from Andhra University in year 2002. His areas of interests are modeling of large scale systems and power system operation & control. Presently he is working as Associate Professor in P.V.P. Siddhartha Institute of Technology, Kanuru, Krishna Dist.,Vijayawada, A.P, India.

Dr.Ch.Padmanabha Raju is currently working as Professor in the Department of Electrical & Electronics Engineering, P.V.P.Siddhartha Institute of Technology, Vijayawada, Andhra Pradesh, India. He obtained Ph.D from J.N.T.University, Kakinada .His areas of interest are Power System Security, OPF techniques, Deregulation and FACTS