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UNIT COMMITMENT & ECONOMIC DISPATCH BY PARTICLE SWARM OPTIMIZATION TECHNIQUE

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Abstract. One of the important power system operational strategy is to operate the system with least operational cost while meeting the technical requirements like power balance in the system and generator limits. This can be achieved using Unit commitment (UC) or Economic Dispatch (ED). UC solves the problem of finding out which generators have to be switched 'ON' so as to meet the demand with least operating cost while maintaining the generator limits. Whereas, the ED gives the schedule of the generating units so as to minimize the total operating cost of the power system while maintaining the power balance and generator limits. Conventional optimization techniques like priority list method, dynamic programming, etc, are used to solve the UC problem where as Lambda iterative method, Newton's method, etc., are used for ED problem. The present work tries to solve the UC and ED problems combined, using Particle Swarm Optimization (PSO) Technique. PSO is a versatile Optimization technique which is gaining publicity in solving various Optimization problems. PSO proved to be capable of solving multi objective, non linear, non convex optimization problems of Electrical power system. Algorithms are developed for priority list method to solve UC problem, Lambda iterative method to solve ED problem and PSO to solve UC and ED simultaneously. Programs are built for the algorithms in GNU Octave, an open source alternative to MATLAB®. The programs are used to solve the UC and ED problems of six unit and three unit system. UC problem is solved for the test systems using priority list method and the solution of UC problem is taken as an input to solve the ED problem using Lambda iterative method for the committed units. The solution obtained by the above said method is compared with the solution obtained using PSO method. The solutions show the power of PSO in solving the UC&ED problem for the considered test systems in terms of solution quality.

I. INTRODUCTION

Both Unit Commitment and Economic Dispatch problems have the same objective i.e., to minimize the operating cost of the thermal generating units. Unit Commitment solves the optimization problem by deciding which thermal unit has to be switched 'ON' depending on the load, whereas the Economic Dispatch minimizes the operating cost by scheduling the thermal units while meeting the system demand. An obvious thought is to solve the problems simultaneously to arrive at a more cost effective solution [8]. The present work also aims to solve both the optimization problems simultaneously using Particle Swarm Optimization Techniques which is gaining attention these days [11][13][14].

Conventionally Unit Commitment is solved using Priority list method [1], Dynamic Programming [7] etc. [9]. Economic Dispatch can be solved by Lambda iterative method, Newton's method, Efficient Method etc. [2]. These problems can also be solved by using latest optimization techniques like Genetic Algorithm based techniques, Particle Swarm Optimization Techniques [10-12]. These techniques are population based techniques which have good convergence properties and are capable of solving nonlinear, non convex, multi objective optimization problems and are capable of convergence to global or near global optimal solution [16]. But, these techniques have

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more computational burden, lack convergence criterion, tuning the parameters of the method affect the solution quality considerably [13][15]. In spite of these drawbacks, these heuristic optimization problems are gaining huge popularity.

The present work solves the UC and ED problem for three and five unit systems. The UC problem is solved using Priority list method and the solution of this method is used to solve the ED problem for the committed units using Lambda iterative method. The problems are also solved simultaneously using PSO Technique.

II. MATHEMATICAL MODELLING

Objective function: The unit commitment problem is to switch 'ON' the generating units which are more efficient to meet the system demand while satisfying the generator limits so as to minimize the total operating cost of generation. The Objective of ED is to minimize the total operating cost of the generating units by scheduling the generating units to meet the demand while maintaining the generator limits.

The operating cost of generation is usually modeled as a quadratic in real power generation of the thermal units. Though in the recent works the generating cost is modeled as the sum of a quadratic and a sinusoidal function of real power [17] the present work uses the simplified cost function which is a quadratic in real power [1].

$$F(P_i) = \sum_{i=1}^{NG} (a_i P_i^2 + b_i P_i + c_i)$$

Where a_i ,b_i ,c_i are fuel cost coefficients for the thermal unit considered. '$a_i P_i^2$'term accounts for the interest and profit for the investment towards generation, '$b_i P_i$' signifies the expenses towards fuel and maintenance cost of the thermal unit 'i', 'c_i' accounts for the salaries of the permanent employees and fixed costs of generating unit respectively, 'NG' is the number of generators in the system.

Equality Constraint: The total power generated by all the units should be equal to the power demand plus power loss at every instant of time. This is a stiff constraint as the stability of the power system and the system frequency are dependent on the power balance in the system. This can be mathematically represented as follows:

$$\sum_{i=1}^{NG} P_i = P_D + P_L$$

Where P_D is the total real power demand on the power system, P_L is the total real power loss of the system.

P_L can be calculated by using Kron's Loss formula [2]

$$P_L = P'BP + B_0'P + B_{00}$$

'P' is the real power generation matrix. B, B_0, B_{00} are loss coefficient matrices [2].

Inequality constraints: The power produced by a generating unit can't be beyond its rating. Also the real power produced by the units can't be below a certain limit due to economic reasons. This constraint is significant in the ED problem as it involves the scheduling of the thermal units. This constraint is obviously less significant in the UC problem as the problem deals with switching ON or OFF the thermal units. This can be written in mathematical form as: $P_i^{min} \le P_i \le P_i^{max}$

III. PRIORITY LIST METHOD FOR UNIT COMMITMENT [1]

This is the simplest of methods used for unit commitment problem. In this method calculate the incremental fuel costs of the generating units at the maximum capacity of the generating unit. The units are switched ON from smallest incremental fuel cost until the demand is met. In other words the sum of max powers of the units in ON is greater than the demand. The flowchart of the method is given below.

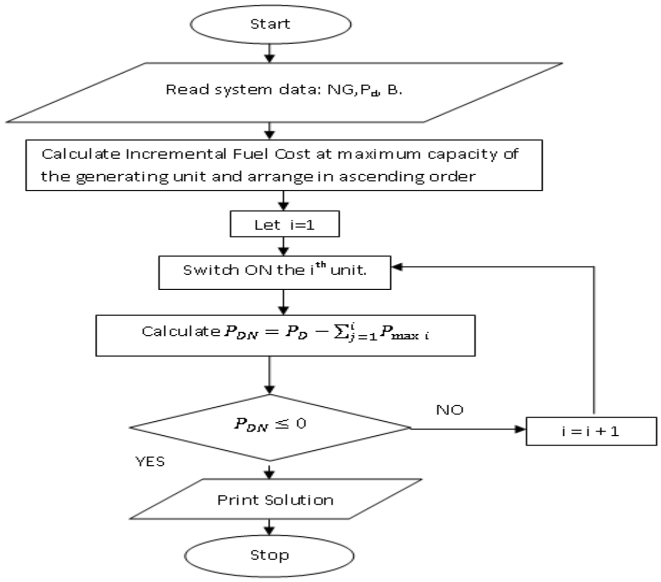

FIGURE1. Flowchart for UC using Priority List Method

IV. LAMBDA ITERATIVE METHOD FOR ECONOMIC DISPATCH [2]

It is one of the most frequently used classical methods for Economic Dispatch. The method is simple and requires the cost function to be modeled as quadratic for better convergence. The method is an iterative method based on Lagrangian relaxation Technique. The flowchart for Lambda Iterative Method for ED including losses is given in Fig. 2. In the flow chart 'dp' is the error in the equality constraint. Acceleration factor of 0.05 is taken, which dictates the speed of convergence.

V. PARTICLE SWARM OPTIMIZATION FOR UNIT COMMITMENT

Particle Swarm optimization is a swarm based optimization technique. Lately, PSO is gaining reputation for its better convergence characteristics than the Genetic Algorithm based techniques [13]. Researchers have successfully used PSO Technique to solve Unit commitment problem [10][11]. A new objective function is formulated which combines the UC and ED problem. This can be solved using PSO technique [11].

$$OC_T = \sum_{t=1}^{T} \sum_{i=1}^{N} F(P_{i,t}) * U_{i,t}$$

OC_T is the operating cost of the generation for the time 'T'. $U_{i,t}$ is a binary bit indicating the unit 'i' is ON or OFF at the instant time 't'. $F(P_{i,t})$ is the fuel cost of the generator unit 'i' at time 't'. Obviously the power balance constraints are also modified as

$$\sum_{i=1}^{N} P_{i,t} U_{i,t} = P_D$$

The generator limit constraints are as it is, and are also handled in the same way as that of the lambda iterative method.

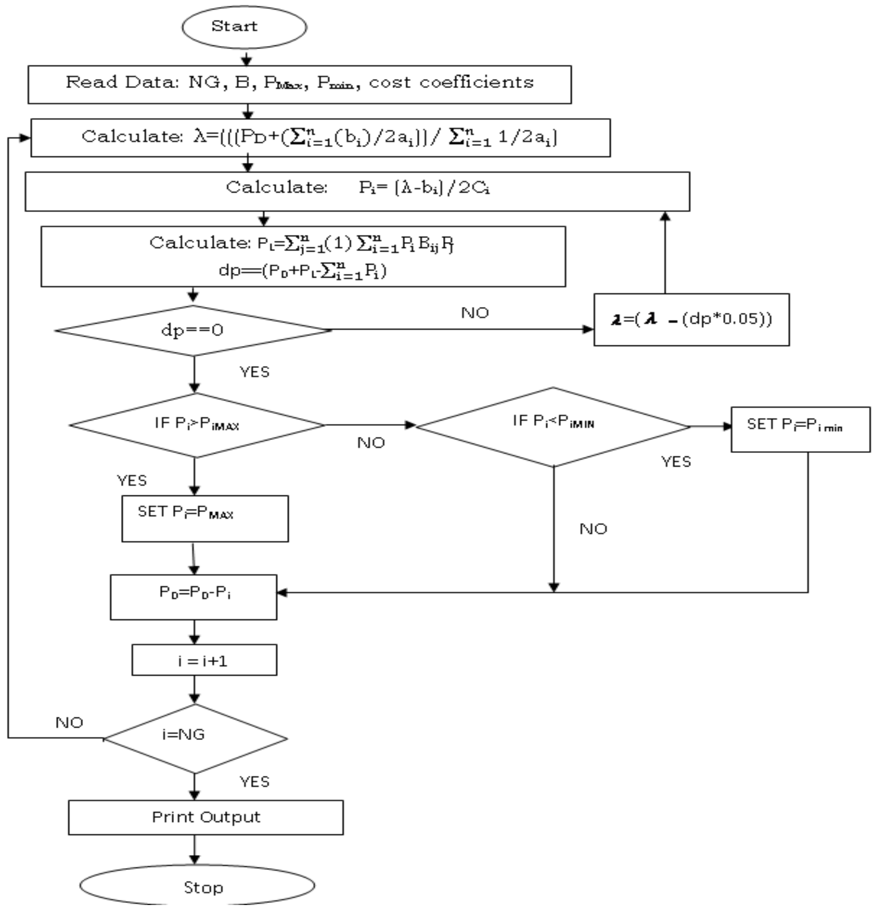

FIGURE 2. Flowchart for ED using Lambda iterative method

The Particle Swarm Optimization Technique is based upon the schooling of fishes and swarming of birds [18]. Each individual in the flock of birds or school of fish modifies its course, depending upon its personal experience and the swarm's leader. This searching technique in the nature can be simulated on a computer with a group of points. Population of points in the solution space can also be made to behave like a swarm to find the optimal solution in the solution space. The flowchart for PSO to solve Unit Commitment problem is given in Fig. 3.

The velocity equation in the flow chart is critical in the PSO technique. It has three parts. The first one is the inertia weight component which pulls the particle towards its previous velocity direction. The inertia weight is made to decreases linearly each iteration. This is done to improve the convergence characteristics of PSO.

$$W_{it} = W_{max} - \left(\frac{W_{max} - W_{min}}{Itermax}\right) * it$$

W_{max} and W_{min} is ten percent of X_{max} and X_{min} respectively. 'Itermax' is the maximum number of iterations allowed and 'it' is the current iteration number.

The second component of the velocity equation pulls the particle randomly towards its previous personal best position. The third component of the velocity equation pulls the particle towards the leader of the swarm or global best particle of the swarm [18]. Therefore the particles of the swarm will simulate the natural swarming behavior of the animals to reach the optimal solution. The position of the particle is updated using $X_i^{it+1} = k * V_i^{it} + X_i^{it}$.'k' is a constant (=1), having units of time so that the above equation is dimensionally correct.

The strings of binary numbers which define the generating units switching ON or OFF are converted to its equivalent real number while calculating its velocity and are again converted to binary strings while calculating the objective function (CT).

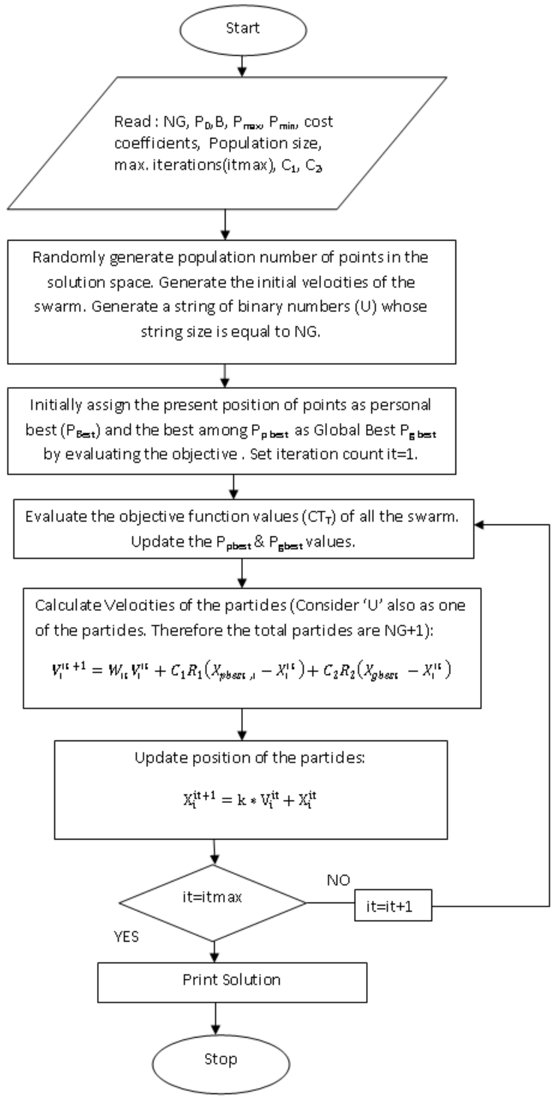

FIGURE 3. Flowchart for UC& ED using Particle Swarm Optimization Method

TABLE 3, UC & ED Solution for the six unit system with load of 700MW

	PRIORITY LIST METHOD	Priority List For UC + Lambda Iterative Method For ED	PSO METHOD
P_1(MW)	0	0	0
P_2(MW)	0	0	0
P_3(MW)	60	161.7767	159.239
P_4(MW)	0	0	0
P_5(MW)	325	287.019	287.924
P_6(MW)	315	273.910	275.607
P_L(MW)	24.1625	22.70688	21.4264
COST ($/h)	36918	35332	35332
EXECUTION TIME(S)	0.0019	2.7390	190

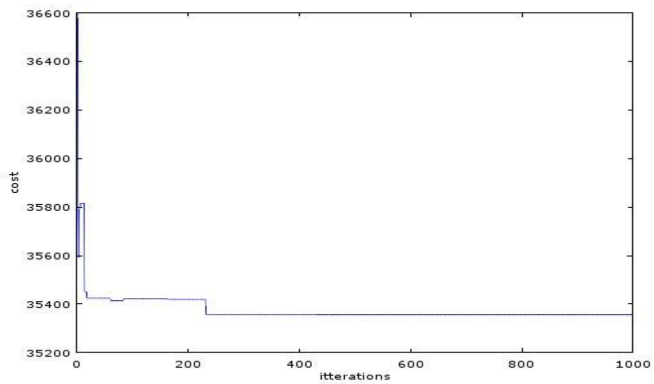

FIGURE 4, Convergence characteristics of PSO program for the six unit system.

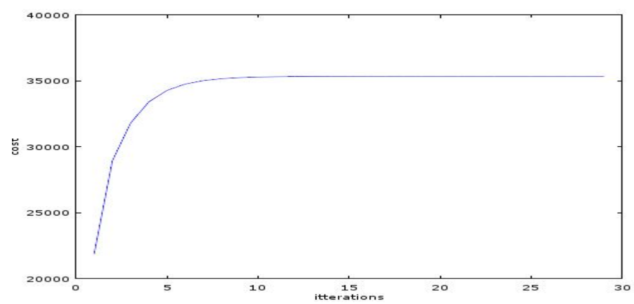

FIGURE 5. Convergence characteristics of Priority list method and λ iterative method program for the six unit system.

TABLE 4, UC & ED Solution for the six unit system with load of 400MW

	PRIORITY LIST METHOD	Priority list for UC + lambda iterative method for ED	PSO METHOD
P_1(MW)	0	0	0
P_2(MW)	0	0	0
P_3(MW)	0	0	0
P_4(MW)	0	0	0
P_5(MW)	85	215.790	215.79
P_6(MW)	315	193.2670	193.28
P_L(MW)	10.6462	9.057067	9.07
COST($/h)	23579	19905.7219	19905.52
EXECUTION TIME(S)	0.002	4.180	130

TABLE 5, Three unit system Cost Coefficients & Generator Limits

Units	P Max (MW)	P Min (MW)	Fuel cost component		
			a_i ($/ MW^2h)	b_i ($/MWh)	c_i ($/h)
1	210	35	0.03456	38.30553	1243.5311
2	325	130	0.2111	36.32782	1658.5696
3	315	125	0.01799	38.27074	1356.6592

TABLE 6, Three unit system loss coefficients

B	1	2	3
1	0.000071	0.000030	0.000025
2	0.000030	0.000069	0.000032
3	0.000025	0.000032	0.000080

TABLE 7, UC & ED Solution for the three unit system with load of 400MW

	PRIORITY LIST METHOD	Priority list for UC + lambda iterative method for ED	PSO METHOD
P_1(MW)	0	0	0
P_2(MW)	85	144.1877	214.7407
P_3(MW)	315	265.3271	194.123
P_L(MW)	10.150	9.5148	8.865
COST ($/h)	21339	20268.660	19896.944
EXECUTION TIME(S)	0.0001	0.197	265.33

VI. CONCLUSIONS

The solutions obtained for six unit system for 700MW and 400MW loading clearly show that both the classical methods and PSO Technique gave the same optimal solution which is much better than the Priority list method used alone. This indicates that both the approached give global optimal solution. However for the three unit system the solution obtained by PSO is better for 400MW loading, which indicate the consistency and robustness of PSO Technique in obtaining the global optimal solution.

In this paper, flowcharts are developed for UC & ED by PSO & Classical Techniques. Solution obtained for six units and three units system for various loadings using afore mentioned methods are presented. The solutions clearly show the robustness of the PSO technique in solving the UC & ED problem for the considered test systems for various loadings. The complexity of the PSO Technique can also be observed from the execution time. The study clearly shows the dominance of the PSO technique in obtaining the global optimal solution at the expense of computational burden.

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