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Optimization of Unit Commitment Using Ant Colony Algorithm

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ABSTRACT

Ant Colony System (ACS) model for solving Unit Commitment Problem (UCP) has been proposed in this paper. The planning problem of Electrical power distribution Networks is a mixed nonlinear integer optimization problem which is solved using Ant Colony System (ACS). The Ant System (AS) algorithm utilises the technique used by ants to construct their food recollection routes (shortest path) from their nest. Here a set of artificial ants co-operate to find the best solution through interchange of information contained in the pheromone deposited on different trajectories. Ant Colony algorithms holds good for solving combinatorial optimization problems. Even though Dynamic Programming method of solving UCP still holds good, the approach which is proposed here performs well and produce better results which have been reasoned later in this paper.

INTRODUCTION

Electricity generating companies and power systems has the problem of deciding how the best to meet the varying demand for electricity, which is dynamic in nature. The short-term optimization problem is how to schedule generation to minimize the total fuel cost or to maximize the total profit over a study period subject to a large number of constraints that must be satisfied Allen (1984). There are two related short-term optimization problems, 'Unit Commitment' and 'Economic Dispatch'. The economic operation of any power system depends on the proper planning and utilization of the resources available within the system. One of the important decisions to be taken in supplying the load demand in a power system is regarding the number of units and the amount of generation that must be available in operating condition at any instant Tong(1991). This problem of deciding the status of all generating units at any instant of time is called as Unit Commitment. Thus, Unit Commitment is the process which decides start-up and shut down of generating units at each power station.

Classification and Characteristics of Loads:

Power system planning starts with a forecast of the anticipated future load requirements. Estimates of the demand and energy requirements are crucial to effective power system planning. Load demand forecasts are used to determine the capacities of the Generating, Transmission and Distribution systems during the time of planning a power system. They are also used to establish the procurement policies for construction capital, where for sound operation; a balance must be maintained in the use of debt and equity capital. The term forecast refers to projected load requirements determined using a systematic process of defining future loads in sufficient quantitative detail.

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Classification:

Loads may be classified broadly as commercial, residential, industrial and others. Residential customers use energy for domestic purposes, whereas commercial and industrial customers use energy for commercial and industrial purpose such as running machinery, etc. In some cases, residential customers may be subdivided into rural, urban and other subdivisions. Other customers are municipalities or division of state and federal governments using energy for street and highway lighting. In addition, sales to public authorities and to road and railways also come under other classification.

Characteristics:

Commercial loads are also characterized by seasonal fluctuations, and again the fluctuations are primarily due to the extensive use of air conditioning and space heating.

Industrial loads are considered base loads that contain little weather dependent variation. However, depending on the type of industry, these loads may have unique characteristics depending on shift operations, etc. Industries involved in mining or any other high-demand, low-energy operations are usually unique enough to warrant special consideration. Other loads as described earlier may have seasonal fluctuations depending on specific consideration.

Unit Commitment:

Definition:

The task of Unit commitment problem involves scheduling of ON/OFF status of the generating units (mostly thermal units) meeting the forecasted load under certain operating constraints Gerald(1994). In general UC means allocation of generators in the generating stations to meet the load demand so as to minimize the operating cost. This operating cost may include

- Generation operating cost
- Start Up costs
- Shut Down costs
- No Load costs

Importance of Unit Commitment:

For an optimal system operation of a power system, following are the major considerations:

1. Economy of operation/Economic Dispatch Problem.
2. System Security.
3. Emission of certain Fossil Fuel Plants.
4. Optimal releases of water at Hydro generation.

Mathematical Formulation of Unit Commitment:

Mathematically the UC is formulated as

The objective function is

$$\sum_{t=1}^{T}\sum_{i=1}^{N}[F_i(P_it)+S_{ti}(t_i,t)]\cdot U_it - F(P_{it},U_{it})$$

Where:

$F_i(P_it)$ = Total Production cost in Rs/Hr

$St_i(t_i,t)$ = Start Up Cost in Rs/Hr

$F(P_it,U_it)$ = Total Cost in Rs/Hr

Operating Constraints In Unit Commitment:

1. Loading Constraints
2. Spinning Reserve
3. Minimum Up Time
4. Minimum Down Time
5. Crew Constraints
6. Fuel Constraints
7. Must Run Constraints

Methods To Solve Uc Problem:

1. Conventional Methods:

- Priority List Method
- Integer Programming Method
- Dynamic Programming approach

- Lagrangian Relaxation Method.

2. Non Conventional Methods:

- Artificial Neural Networks
- Simulated Annealing
- Genetic Algorithm
- Ant Colony Optimization.

Solution Methodology:

1. A state consists of an array of units with specified units operating and the rest off-line.
2. The start-up cost of a unit is independent of the time it has been off-line.
3. There are no costs for shutting down a unit.
4. There is a strict priority order, and in each interval a specified minimum amount of capacity must be operating.

Solution Procedure for Proposed Approach:

In the forward DPA, the algorithm is set to run forward in time from the initial hour to the final hour. This forward approach has distinct advantages in solving generator unit commitment. If the start up cost of a unit is a function of time, it has been off-line, and then a forward DPA is more suitable since the previous history of the unit can be computed at each stage. The initial conditions are easily specified and the computations go forward in time as long as required Padhy(1994).

Note, however that the unit must operate within its limits. Starts up costs for all the cases used are cold-start costs (for sample system). The recursive algorithm to compute the minimum cost in hour K with combination I is

Fcost (K,I) = min [Pcost (K,I) + Scost (K-1,L : K,I) + Fcost (K-1,L)]

Where

Fcost (K,I) = least cost to arrive at state (K,I)

Pcost (K,I) = production cost to arrive at state (K,I)

Scost (K-1,L : K,I) = Transition cost from state (K-1,L) to state (K,I)

State (K,I) is the I th combination in hour K

L = Feasible state in interval (K-1)

K = Hours or Interval

I = Combination of states

Algorithm for DPA:

1. Get the input data i.e. Unit Characteristics, Initial conditions, Load pattern.
2. Create a priority list order as per the value of Incremental cost or as per the value of full load average production cost (FLAPC)
3. Calculate the total no. of unit combinations as per the formula, **T= (2^N-1) ^K**, where N = No. of units, K = No. of Hours.
4. Form the feasible states for each hour load from the total no. of states available.
5. For the hour considered, calculate the total cost for each feasible state with the help of objective function.
6. While calculating the cost, see to that for each unit, the minimum and maximum capacity constraint is satisfied.
7. Finally minimum cost for each hour is summarized and its unit combination is found.

Ant Colony System:

Ants communicate with other ants by secreting the chemical substance known as pheromones. This pheromone liberated by one ant is used as the guide for other ants of the colony. This pheromone is also very useful for the return path of the ants Botee(2012).

The pheromones have the property of evaporating after some period of time. The pheromone laid by ants is used as the main guide function for the ants.

The above sketch shows how real ants find a shortest path. (A) Ants arrive at a decision point. (B) Some ants choose the upper path and some the other path. The choice is random. (C) Since ants move at approximately constant speed, the ants which choose the lower shorter path reach the opposite decision point faster than which chose the upper, longer path. (D) Pheromone accumulates at higher rate on shorter path.

This behavior of the ants to find the shortest path for their food recollection is used in Ant System (AS) to find the optimal path or optimal solution in any problem.

The probability of selecting the path for any ant is given as

$$P_{ij}^{k}(t) = \frac{[\tau_{ij}(t)]^{\alpha} * [\eta_{ij}]^{\beta}}{\sum_{k \in allowed} [\tau_{ik}(t)]^{\alpha} * [\eta_{ik}]^{\beta}} \quad \text{if } j \in \text{allowed } k$$
$$= 0 \quad \text{otherwise}$$

Where:

τ (i,j)- amount of pheromone in the path between i and j
ή(i,j) – the factor indicates the relation of the objective function
Cij - Cost function

To minimize objective function, ή should be inversely proportional to the objective function. ή(i,j) α 1/Cij

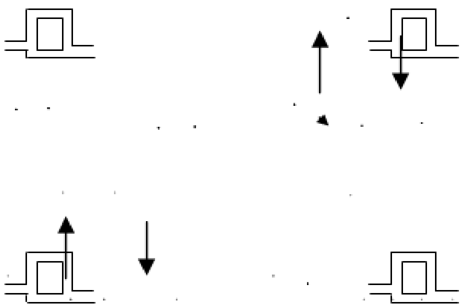

Fig. 1:

Main Characteristics:

Positive feedback – Accounts for rapid discovery of good solutions.
Distributed Computation– Avoids premature convergence.
Greedy Heuristic – Helps to find acceptable solutions in the early stages of the search process.

Updating Of Pheromone:

As the pheromones liberated by the ants has a tendency to evaporate after some constant period of time the pheromone deposited will be reduced. At the same time the pheromone will also be added to that path when more ants move through that path. So to evaluate these two effects on the concentration of pheromone in the path pheromone updating is done.

Ant System uses a updating method known as Global Pheromone Revision Rule. According to this rule the pheromone intensity is updated after completion of entire path for particular ant. The Global Revision rule is given by

$$\tau_{ij}(t+n) = (1-\rho)\tau_{ij}(t) + \Delta\tau$$

Where

ρ = Evaporation Coefficient.

The first term in the formula is the effect of evaporation on the intensity. (1-ρ) represents the factor after evaporation.

The second term represents the effect of addition of pheromone by different ants given by:

$$\Delta\tau_{ij} = \Delta\tau_{ij} + \Delta\tau_{ij}k$$

Where: $\Delta\tau_{ij}k$= additional change in pheromone due to ant k

Local Pheromone Revision rule is applied to update the pheromone intensity in each branch . This local pheromone revision rule is the process which is done after every transition of ants from one node to the other node.

The local pheromone revision rule is given by the formula

$$\tau(r,s) = (1-\rho)\tau(r,s) + \rho\tau_{o}$$

Where

τ_{o}=minimum pheromone level

The Ant Colony System (ACS) which uses this local pheromone revision rule converges quickly. This is because the pheromone intensity is updated after every transition of the ants from one point to the other. As a result of this the ant was able to find the shortest path as it starts the search for next point itself. The optimal path will get a rapid increase in the pheromone intensity. The optimal solution was found out quickly

Algorithm:
Step 1:
Initialization:
Set time ,t=0; Cycles NC=0;

Pheromones intensity in each unit is set initially to a constant value and also change in pheromones intensity is set to zero

τ_{ij} =c ; $\Delta\tau_{ij}$ =0.

Step 2:

Get the number of units. Place m ants on n units.Store the starting unit of each ant in the Tabu list (i.e) Tabu (1,m) for all m ants.

Step 3:

Calculate the production cost of the unit using the formula.

Fcost(K,I) = min [Pcost (K,I) + Scost (K-1,L : K,I) + Fcost (K-1,L)

Step 4:

Do for K=1 to m

Calculate the probability for ants to move to the next unit for all possible paths. The probability of transition of ants from states i to j is given by the formula

$$P_{ij}^{k}(t) = \frac{[\tau_{ij}(t)]^{\alpha} * [\eta_{ij}]^{\beta}}{\sum_{k \in allowed} [\tau_{ik}(t)]^{\alpha} * [\eta_{ik}]^{\beta}} \quad \text{if } j \in \text{allowed } k$$
$$= 0 \quad \text{otherwise}$$

Enter the state j which is the transition of the ant from state i in the second row of Tabu list . (i.e) in Tabu (2,k)

Similarly, transition is made for all states.

Step 5:

Pheromones intensity in each unit is updated using global pheromone revision rule.

$$\tau_{ij}(t+n) = (1-\rho)\tau_{ij}(t) + \Delta\tau$$
$$\Delta\tau_{ij} = \Delta\tau_{ij} + \Delta\tau_{ij}{}^{k}$$

Step 6:

If the number of cycle is less than the maximum number of cycles (NC< NC max) clear Tabu list, go to step 2 else go to Step7.

Table 1:

Hour	Load (MW)	Optimal Combination	P Cost (Rs/Hr)	
			Dynamic Program	Ant Colony
1	1713	0 1 1 0	8475.100	11232.090
2	1727	0 1 1 0	38609.100	52770.690
3	1703	1 1 1 0	68685.500	94257.450
4	1724	0 1 1 0	98812.300	135789.570
5	1726	0 1 1 0	128943.900	177326.010
6	1850	0 0 1 0	215383.100	255423.690
7	1939	0 0 1 0	255665.900	304281.810
8	2088	0 1 1 0	353143.900	406741.770
9	2086	0 1 1 0	399757.100	463117.410
10	2004	0 1 1 0	40438.800	48998.520
11	1997	1 1 1 0	80860.800	97981.920
12	1999	0 1 1 0	121287.600	146969.640
13	1951	0 1 1 0	161599.200	195853.680
14	1904	0 0 1 0	201798.000	244636.200
15	1951	0 0 1 0	242109.600	293520.240
16	2010	0 1 1 0	282562.800	342531.720
17	2060	0 1 1 0	784713.900	912368.610
18	1995	0 1 1 0	40417.200	48979.080
19	2125	1 1 1 0	1404215.500	1025007.570
20	2199	0 1 1 0	1475099.900	1241079.210
21	2010	0 1 1 0	1545746.700	56405.880
22	1991	0 0 1 0	40407.600	48970.440
23	1925	0 0 1 0	80656.800	97798.320
24	1845	0 1 1 0	120714.000	146453.400
Minimum Total Cost of Operation			8190104.30	6848494.92

Step 7:

The optimal units are chosen by the ants depending on the probabilities for the states.

Step 8:

Calculate the total production cost for the obtained unit and store the result corresponding to optimal units obtained.

Results:

Here the ant parameters for the four unit system are taken as α =0.03, β =0.05, $\tau 0$ = 0.001 (initial trial),ρ =0.65 ,m=50,Q = 100, N=100 and has been solved for 24 hours. So the transitional cost at each stage is obtained using DP and ACS is tabulated in Table 1. The result of the four unit numerical example shows that the new ACS method performs better than DP.

Conclusion:

A new Unit Commitment schedule by ant algorithm approach has been presented here. Ant algorithms are highly efficient in finding near global optimum solution for combinatorial optimization problem. This technique is applied here to solve Unit Commitment problem. The results obtained are quite encouraging which gives yet another way of solving UC problem using ACS.

REFERENCE

Allen, J., Wood and Bruce F. Wollenberg, 1984. “Power Generation Operation and Control”, John Wiley and Sons, New York.

Tong, S.K., S.M. Shahidehpour, Z. Ouyang, 1991. “A Heuristic short term unit commitment”, IEEE Trans Power Systems, 6(3): 1210-1216.

Gerald, B., Sheble and George N. Fahd, 1994. “Unit Commitment Literature Synopsis”, IEEE Trans. Power Systems, 9-1.

Padhy, N.P., 1994-2000. “Unit Commitment using hybrid models: A comparative study for dynamic programming, expert system, fuzzy system and genetic algorithm, “Electric power and energy systems, 23: 827-836.

Botee, H.M., E. Bonabeau, 1998. Evolving ant colony optimization, Adv. Complex Syst., 1: 149–159.

APPENDIX:

Unit (No.)	Max. (MW)	Min. (MW)	Minimum	
			Up Time (Hr)	Down Time (Hr)
1	80	25	4	2
2	250	60	5	3
3	300	75	5	4
4	60	20	1	1

Start UP Costs		Cold Start (Hrs)	Shutdown Costs ($)	Initial Unit status
Hot ($)	Cold ($)			
150	350	4	50	-5
170	400	5	100	8
500	1100	5	125	8
0	0.02	0	25	-6

Unit Characteristics (Four unit system)
Initial unit status: Hours off (-) line or on (+) line

Fuel cost equations:

C1= 25 + 1.5000 P1 + 0.00396 P1^2
C2= 72 + 1.3500 P2 + 0.00261 P2^2
C3= 49 + 1.2643 P3 + 0.00289 P3^2
C4= 15 + 1.4000 P4 + 0.00510 P4^2