ANT COLONY OPTIMIZATION FOR UNIT COMMITMENT

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Abstract-**The unit commitment (UC) problem is defined as the scheduling of a set of generating units to be on or off to meet the demand. For a power system operated by a vertically integrated monopoly, committing units is performed centrally by the utility, and the objective is to minimize the costs while supplying all demand. In this paper, ant colony optimization (ACO) is proposed to solve unit commitment (UC) problem in power system. The ACO is a cooperative agents approach which inspired by behavior of real ant of finding the shortest path from food sources without using visual clues. These cooperating agents will cooperate to find good solutions for unit commitment. In order to fulfill the demand the related constraints is consider. The proposed approach is expected to yield minimized operational cost while supplying the load from the operated generation units. The test system has been done on 6 generation units over 4 stages of 24 hours period.**

Keywords; Unit commitment, Ant Colony Optimization.

I. INTRODUCTION

Unit commitment problem is one pertinent of analyses required in scheduling and dispatching of power. It is the process of deciding in advance whether to turn on or off each generating unit at a given hour, daily up to weekly. The process of turning on and turning off the units intend to give a high cost in order to satisfy the load demand. UC problem has being critically during weekdays rather than weekend days. The UC problem arises mainly due to the variations in demand. This variation causes a problem in operating the power system economically. The UC solution is used to economically schedule generating units over period of the planning horizon subject to forecast demand and other system operating constraint. The UC decision involves the determination of the generating units to be running in each hour, spinning reserve, shut down and starts up cost of units' constraint [1].

Several optimization methods have been used to solve the UC problem. The methods perhaps will save million dollars in fuel cost. Many techniques have been developed to overcome the UC problems such as priority list (PL) method, Langrangian Relaxation (LR) method, dynamic programming (DP) method and sequential method. More recently, meta-heuristic method has been tested and used such as genetic algorithm (GA), tabu search (TS) and simulated annealing have been widely used to overcome UC problem. However, the meta-heuristic methods can accommodate complicated constraints and are claimed to produce solutions of improved quality.

ACO is probabilistic technique for solving computational problems which can be reduced to finding good and shortest path. ACO is inspired by real ant behavior which wander randomly, and upon finding food return to their colony while lying down pheromone trails. The technique has been successfully solve the combinatorial optimization problems.

In this paper, ACO is developed to solve UC problem. The developed ACO program is successful solve UC problem for 6 generation units. Along with this, total cost, total power and iterations numbers are the criteria monitored in this study. For the purpose of project, the objectives are to study, analyze and identify the UC problem incurred. The state transition, initialization, local updating, global updating and fitness evaluation are also introduced to ensure the optimality of the solution in ACO.

II. METHODOLOGY

A. Unit Commitment Problem Formulation

The objective of UC is to determine the turn on and turn off of generating units that yield minimum total cost while satisfying a set of operational constraints. The UC problem formulation can be described as follows;

$$F_T = \sum_{i=1}^{N} [F_i P_i^t] \qquad (1)$$

Where;

F_T	total cost of generating units
$F_i(P)$	cost of producing by unit i

P_i^t power generation for unit I (Megawatts)

The generation cost function described as follow:

$$F_i P_i^t = a_i + b_i P_i + c_i P_i^2 \quad (2)$$

Where a_i, b_i and c_i represent unit cost coefficient

Cost function in UC is form in

$$TC = F_T + TrC \quad (3)$$

Where;

TC	total cost
F_T	total cost of generation
Tr	total transition cost

Subject to the constraints:

i. Power balance constraint;

$$P_{load}^t = \sum_{i=1}^{N} P_i^t \quad (4)$$

The output power, P_i^t must satisfy the total load demand , P_{load}^t

ii. Real power operating limits of generating unit

$$P_i^{min} \leq P_i^t \leq P_i^{max} \quad (5)$$

The output power for each unit must be within the minimum and maximum range

B. ACO for UC problem

Ant Colony Optimization studies inspired for the behavior of real ant that are used to solve function or combinatorial optimization problem. The first ACO system was introduced by Marco Dirgo, and was called 'ant system'[1]. The first algorithm was aiming to search for an optimal path in a graph; based on the behavior of ants seeking a path between their colony and a source of food. In real world, ants will lay down pheromone trail in their way to food source. If other ant find such a path, they will not travelling randomly, but to instead follow the trail, and eventually find food. The pheromone is the medium communication among the ants. However, the pheromone trail will start to evaporate, thus reducing the attractive strength. To have pheromone continuously, the other ants which pass through the trails, will laid down their pheromone to attract more ants to use the same path. The strengthening of runway makes it more attractive as the shortest route. While the long route will eventually disappear, pheromones are volatile. Thus, the shorter path will receive a greater amount of pheromone per time, per unit and in turn, a larger numbers of ant will choose the shorter path. Due to this positive feedback, all the ants will rapidly choose the shorter path. This behavior of ants can be applied to solve optimization problems. The algorithm will move from an unstable state in which no edge stronger than another, to a stable state where the route is composed of the strongest route.ACO has been developed to solve UC problem. The process involves initialization, state transition, local updating rule, fitness evaluation, and global updating rule.

Step 1: Initialization

During initialization the problems parameters such as ant, node, β, rho, mind, maxd, lpmax, and RU are set.Every parameter requires to be set for limiting the search range in order to avoid computation time.

Ant	no.of nodes
Node	no of nodes
β	parameter which determines the relatives importance of pheromone versus distance (β□0)
q_o	parameter of algorithm ($0 \leq q_o \leq 1$)
rho	heuristically defined coefficient (0□rho□1)
mind	minimum distance for every ants tour
maxd	maximum distance for every ants tour
lpmax	maximum iteration
RU	speed regulation
d_{max}	can be calculated by using this formula:

$$d_{max} = max\left[\sum_{i=1}^{n-1} d_i\right] \quad (6)$$

while,

$$d_i = r - max(u) \quad (7)$$

r =current node

u=unvisited node

Step 2: Generate first node randomly

In the first step, the colonies of ants are first generated randomly which is ranging from 1 to n

Step 3: State Transition Rule

The application of state transition rule simulates the length of the path taken by an agent to reach next state s from the current state r based on following rule:

$$s = \begin{cases} \arg max_{k(r)} [\tau(r,u)].[\eta(r,u)]^{\beta} & , if \leq q_0\ (exploitation) \\ \sigma & \end{cases} \quad (8)$$

Where;

q	a random number uniformly distributed in [0.....1]
q_o	a parameter (0≤qo≤1)
σ	a random variable selected according to the probability distribution in equation (4)

The probability ant k at node r move to next node is following equation.

$$P_k(r,s) = \begin{cases} \frac{[\tau(r,s)][\eta(r,s)^{\beta}]}{\sum_{u \epsilon J_{k(r)}} [\tau(r,s)][\eta(r,s)^{\beta}]}, if\ \sigma \epsilon J_k(r) \\ 0, otherwis \end{cases} \quad (9)$$

Where;

τ the pheromone intensity

$J_k(r)$ the set node that visited by any k from node r

β a parameter, which determines the relative importance of pheromone versus distance (β□0)

$\eta = {}^{1}/_{\delta}$, the inverse of distance $\delta(r,s)$

The parameter q_o determines the relative importance of choosing the more preferable (exploitation) versus less desirable paths. Every time an agent in a current state has to choose a next state s, it sample a random number ($0 \leq q_o \leq 1$) [7]. According to (7), if $q \leq q_o$, the best path is exploitation, otherwise desirable path is chosen based on (7) and (8)

Step 4: Apply local updating rule

During the development of the paths, an agent changes the pheromone level on local updating by applying the local updating rule. This rule has effect lowering the pheromone level so that these will become less attractive to other agent

$$\tau(r,s) \leftarrow (1-\rho)\tau(r,s) + \rho\tau_o(r,s) \quad (10)$$

Where;

τ_o initial pheromone level

ρ decay/evaporation coefficient (0<ρ<1)

Step 5: Calculate the fitness

Fitness will be calculated after all agents have completed their tours. It will obtain from the best tour with minimum distance. The fitness is computed using the following equation:

$$x = \frac{d}{d_{max}} \times x_{max} \quad (11)$$

Where;

d distance for every ant's tour

x_{max} maximum distance

Step 6: Global updating

After all agents have built their individuals solution, a global pheromone updating rule is applied only to the best tour path. This tour is allocated higher level of pheromone. Global pheromone updating is performed by applying:

$$\tau(r,s) \leftarrow (1-\alpha)\tau(r,s) + \rho\Delta\tau(r,s) \quad (12)$$

Where;

$$\Delta\tau(r,s) = \begin{cases} L_{gb,} if\ (r,s) \in global - best\ tour \\ 0 \quad otherwise \end{cases} \quad (13)$$

α Pheromone decay parameter (0<α<1)

L_{gb} length of the globally best tour from the beginning of the tour

The computational flow of ACO to solve the UC problem are illustrate as Fig.1.

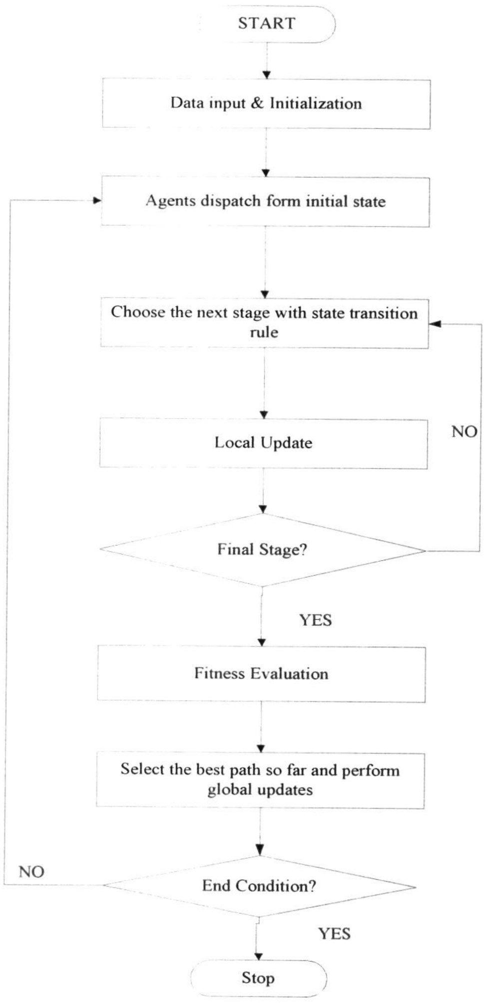

FIGURE I: FLOWCHART OF ACO UNIT COMMITMENT PROBLEM

III. RESULT AND DICUSSION

In this study, the proposed ACO was tested on 6-generation units system. The operating data for each generation are given in Table1 [2]

TABLE I: OPERATING DATA OF GENERATION UNIT

Unit	Pmax (MW)	Pmin (MW)
1	500	100
2	200	50
3	300	80
4	150	50
5	200	50
6	120	50

Table 2 shows the cost fuel parameter for 6 generating units [2].

TABLE II: FUEL COST PARAMETER OF GENERATING UNIT

	a ($)	b ($/MWh)	c ($/MWh^2)
Unit1	240	7.0	0.0070
Unit2	200	10.0	0.0095
Unit3	220	8.5	0.0090
Unit4	200	11.0	0.0090
Unit5	220	10.5	0.0080
Unit26	190	12.0	0.0075

For the purposed of this study, the startup cost is considered $1000, and the shutdown cost is neglible.

The results obtained for UC problem using ACO method are given in Table 3.

TABLE III: RESULT FOR UC USING ACO

Stage	1	2	3	4
P1(MW)	320.369	497.867	416.683	374.48
P2(MW)	0	155.950	113.453	67.783
P3(MW)	103.802	0	117.400	109.74
P4(MW)	78.704	58.297	0	0
P5(MW)	51.892	169.993	53.899	95.852
P26(MW)	58.434	65.129	67.506	0
COST($)	7445.05	12,802.04	10,234.34	7735.61
TOTAL POWER(MW)	613.201	947.236	768.941	647.855
DEMAND	610	945	765	645
OVERALL COST ($)	38,217.04			

As shown in Table 3, each of the four stages has different demand. Stage 2 has the highest demand and hence gives the highest cost as compared to other stages.

Stage 1 has the lowest demand and the cost obtained shows that it is the lowest cost as compared to other stages.

Results shown in Table 3 also shows that the output power for each 'ON' generation unit satisfy the generation limit as stated in Table 1.

Total power obtained for the solution also satisfies the demand as shown in Table 3.

IV. CONCLUSION

This paper has presented an ACO technique to solve UC problem of 6-generation units system over 4 stages of 24 hours period. The satisfactory schedule of generations can be determined by this method. The generating cost has been obtained using ACO. The total power has been fulfilled the demand needed. This indicates ACO provide better total demand calculation. The effectiveness of ACO for solving larger UC problem can be as the recommendation for future research. Besides that, total power losses also can be determined in next findings to get the exact total demand.

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