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RESEARCH ARTICLE

SOLUTION TO PROFIT BASED UNIT COMMITMENT PROBLEM USING GENETIC ALGORITHM

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ABSTRACT

In this paper a genetic algorithm approach is used to solve profit based unit commitment problem under deregulated environment. The profit based unit commitment under deregulation involves determining the time intervals for commitment of generating units for an individual power producer to maximize his profit considering the effect of spot market prices. To validate the proposed algorithm a system with 10 unit data has been considered with usual unit constraints.

INTRODUCTION

Electric power consumption varies with time reflecting the cyclical nature of human activities. to meet the electricity demand electric power generation companies have to plan the operation of generating units in such a way to minimize their production cost and at the same time to maximize their profits .In deregulated frame work any power producer who is having available generating units can participate in power contribution in power market. The system under deregulation works based on selling and buying of power with intermediate operator of ISO (independent system operator). In this scenario suppose if a power producer is having M number of generating units and if he wants to maximize his profit then he has to commit the generating units in such a way to maximize his profit satisfying all the constraints. The most important constraints includes satisfying the load demand and meeting up and down time constraints and meeting ramp up and ramp down constraints and other start up and shut down constraints etc. The unit commitment problem under deregulation involves commitment of generating units of an individual power producer for maximization of his profit; this problem is of highly complex in nature as so many constraints are involved for maximization of profit as main objective function. In this paper the problem is attacked using advanced binary genetic algorithm. The proposed algorithm seems to be efficient as compared to normal conventional technique like dynamic programming in terms of constraints satisfaction and convergence time. The Genetic algorithm approach is found to be simpler in constraints handling and meeting up the critical constraints like ramping up and ramping down and power generation limits.

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Profit based unit commitment problem

Under deregulated environment the profit based unit commitment problem can be analyzed by maximizing the profit of an individual power producer considering the spot market price and demand fluctuations set be independent system operator. under this situation

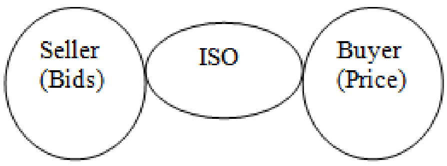

Fig. 1. Structure of deregulated frame work

Problem Formulation

The main objective function of the problem is

$$\text{Profit} = \text{Revenue} - \text{Total cost} \quad (1)$$

The revenue is obtained by supplying a certain amount of power at spot market price and the total cost is the cost of production as well as starts up and shut down costs included if any. The startup cost can be considered by taking in to account of the number of hours the unit has been off line and unit cooling time as well. This can be interpreted in the following equation

$$SU_i^t = \alpha_i + \beta_i (1 - \exp(-X_{off,i}^t / \tau_i)) \quad (2)$$

Where SU_i^t the startup cost of unit i at the interval of time t.

α_i : Combined crew start-up costs and equipment maintenance costs [$];

β_i : Cold start-up cost [$];

$X_{off,i}^t$: Number of hours the unit has been offline [h];

τ_i : Unit-cooling time constant [h].

In addition to startup cost the generating unit must satisfy all the constraints (minimum up time, minimum down time, ramp up and ramp down, minimum power and maximum power generation) as given below.

Loading constraint

$$P_{load}^t - \sum_{i=1}^{N} P_i^t * U_i^t = 0 \;\; \forall t = 1 \ldots\ldots T \quad (3)$$

Where P_i^t is the power generation of i[th] unit at hour t and U_i^t is the state of i[th] unit at hour t

Unit limits

$$U_i^t * P_i^{min} \le P_i^t \le U_i^t * P_i^{min}$$
$$\forall i = 1 \ldots . N \; and \; t = 1 \ldots\ldots T \quad (4)$$

Unit minimum up and down time constraints

$$\left.\begin{array}{l}(u_i(t) - u_i(t-1)(T_{on,t-1} - MUT)) \le 0 \\ (u_i(t) - u_i(t-1)(T_{off,t-1} - MDT)) \ge 0\end{array}\right\} \quad (5)$$

MUT = Minimum up time, MDT=Minimum down time, Ton = Generator on time, Toff = Generator off time

Unit ramp rate limits

$$\left.\begin{array}{l}\max(P_i^{min}, (P_{i,t-1} - DR_i)) \le P_{i,t} \\ \min(P_i^{max}, (P_{i,t-1} + UR_i)) \ge P_{i,t}\end{array}\right\} \quad (6)$$

DR = Ramp down limit
UR =Ramp up limit

In addition to all the above constraints there are some other constraints like spinning reserve constraints and crew constraints and must run constraints that must be satisfied. From the above equations there are two decision variables P_i^t and U_i^t where P_i^t denotes the amount of power to be generated by unit i at time t and U_i^t is the control variable whose value is chosen to be "1" if the generating unit i is committed at hour t and "0" otherwise (of course if U_i^t =0, then P_i^t =0).

Genetic Algorithms

Genetic algorithm approach is used for solving the profit based unit commitment problem and it has several advantages as compared to other methods. The genetic algorithm approach is based on selection of best population among the search space and the selection of best solution is based on the fitness value associated with the string. The steps involved in applying the genetic algorithm to the profit based unit commitment problem are as follows.

Solution to Profit Based Unit Commitment Using Genetic Algorithms

Step-1: The unit data is considered for 10 generating units which includes minimum power limit, maximum power limit, minimum up time, minimum down time ,initial status, cost coefficient parameters, $\alpha_i \; \beta_i \; \tau_i$, ramp up and ramp down limits, the spot market price profile for the given scheduling time period etc. the genetic algorithm parameters are considered such as population size, chromosome length, cross over probability, mutation probability, number of iterations etc.

Step-2: Considering the first unit, randomly generate the status of generating unit (on or off) for the scheduling time period i.e. if the time period considered is let us say 10 hours then randomly generate a string length of 10 bits of 0s and 1s in binary format with the population size as chosen in step-1

Step-3: From step-2 within the population of strings generated randomly consider only those strings which satisfy the minimum up and down time and ramp up and ramp down limits by considering the up and down time limits of the generator and initial status of the generator.

Step-4: now we have all the strings which are called feasible strings, now for all these feasible strings identify the start up cost as well as shut down costs associated when the status is changing from off to on status or from on to off status. Considering the start up and shut down costs find the total production cost using F=a + b (p) + c (p^2). This cost is the fitness value corresponding to each binary string. The power p for each

Interval when the unit is on is calculated using $p_i^t = \min(pmax_i^t, rlup_i^t, rldown_i^t)$ where

Where P_i^t is the power generated by i[th] unit at time t and $Pmax_i^t$ is the maximum power limit of unit i at time t and $rlup_i^t$ is the ramp up limit of unit i at time t and $rldown_i^t$ is the ramp down limit of unit i at time t.

Step-5: Once we get all the values of power generation levels and total cost associated with each power level then calculate the total profit associated with the power level using
Total profit = (power x spot market price)-total cost

Table 1. Unit data (IEEE REFERENCE DATA)

UNIT 1	UNIT 2	UNIT 3	UNIT 4	UNIT 5	UNIT 6
pmin=15.20	pmin=15.20	pmin=15.20	pmin=25.00	pmin=25.00	pmin=25.00
pmax=76.00	pmax=76.00	pmax=76.00	pmax=100.00	pmax=100.00	pmax=100.00
nl1=76.473	nl1=76.558	nl1=76.602	nl1=210.108	nl1=210.685	nl1=211.300
tup=3	tup=3	tup=3	tup=4	tup=4	tup=4
tdown=2	tdown=2	tdown=2	tdown=2	tdown=	tdown=2
x0=-3	x0=-3	x0=-3	x0=-3	x0=-3	x0=-3
alpha=50	alpha=50	alpha=50	alpha=70	alpha=70	alpha=70
beta=50	beta=50	beta=50	beta=70	beta=70	beta=70
tao=3	tao=3	tao=3	tao=4	tao=4	tao=4
rup=15	rup=15	rup=20	rup=25	rup=30	rup=30
rdown=15	rdown=20	rdown=20	rdown=25	rdown=30	rdown=30
y0=0	y0=0	y0=0	y0=0	y0=0	y0=0
a=0.00895	a=0.00910	a=0.00932	a=0.00623	a=0.00612	a=0.00598
b=13.3538	b=13.3805	b=13.4073	b=18.0000	b=18.1000	b=18.2000
c=81.2980	c=81.4641	c=81.6259	c=217.8952	c=218.3350	c=218.7752

UNIT 7	UNIT 8	UNIT 9	UNIT 10	Time	Spot market price
pmin=54.25	pmin=54.25	pmin=54.25	pmin=54.25	1	9.00
pmax=155.00	pmax=155.00	pmax=155.00	pmax=155.00	2	9.60
nl1=120.673	nl1=120.491	nl1=120.399	nl1=120.392	3	14.33
tup=5	tup=5	tup=5	tup=5	4	25.49
tdown=3	tdown=3	tdown=3	tdown=3	5	31.80
x0=-5	x0=-5	x0=-5	x0=-5	6	31.00
alpha=150	alpha=150	alpha=150	alpha=150	7	36.28
beta=150	beta=150	beta=150	beta=150	8	42.40
tao=6	tao=6	tao=6	tao=6	9	52.22
rup=100	rup=150	rup=150	rup=150	10	52.20
rdown=100	rdown=150	rdown=150	rdown=150		
y0=0	y0=0	y0=0	y0=0		
a=0.00463	a=0.00473	a=0.00481	a=0.00487		
b=10.6940	b=10.7154	b=10.7367	b=10.7583		
c=142.7348	c=143.0288	c=143.3179	c=143.5972		

Step-6: After calculating all the profits associated at each interval then find the cumulative sum of the profit of each string and arrange all the profits in a matrix form. Now the genetic algorithm procedure starts and the first step is the selection of the strings and the selection of the best population is based on the fitness value considering average of all the fitness values.

Step-7: Now the iteration counter is set to zero and genetic operators are considered for the selection of best population and the new population is generated by cross over operation considering the cross over probability and mutation operation considering the mutation probability

Step-8: After cross over and mutation then the best string having maximum profit of the string considering the total cumulative sum of the profits of the strings is identified and is stored for future comparison for next iteration.

Step-9: The procedure is repeated till the counter reaches the maximum number of iterations and once the solution converge to the values which further getting no change then that solution is considered to be the best solution.

Step-10: The final string that satisfy all the constraints and having maximum profit is considered as the best possible solution for that unit and this process is repeated for all the generating units till the maximum number of iterations reached.

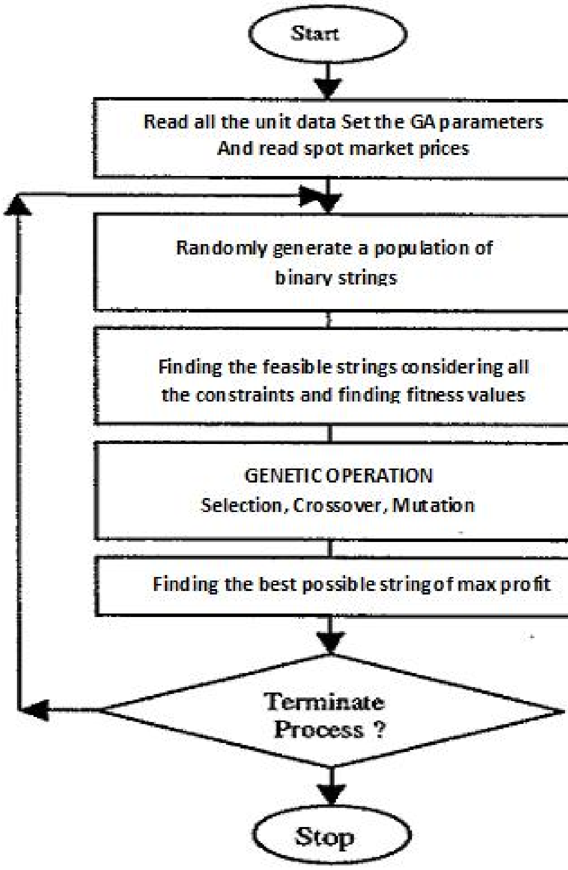

Figure 2. Flow chart

GA parameters

Population size=2000;
Chromosome length=10
Pc=0.6(cross over probability)
Pm=0.6(mutation probability)
dai =200 (maximum number of iterations)

All the parameters are defined in addition to time intervals and corresponding spot market prices are defined when reading unit data.

RESULTS

Table 2. UNIT COMMITMENT SCHEDULE FOR 10 HOURS

Unit	t=1	2	3	4	5	6	7	8	9	10
1	1	1	1	1	1	1	1	1	1	1
2	1	1	1	1	1	1	1	1	1	1
3	0	1	1	1	1	1	1	1	1	1
4	0	0	1	1	1	1	1	1	1	1
5	0	0	1	1	1	1	1	1	1	1
6	0	0	1	1	1	1	1	1	1	1
7	0	0	1	1	1	1	1	1	1	1
8	0	0	1	1	1	1	1	1	1	1
9	0	0	1	1	1	1	1	1	1	1
10	0	0	1	1	1	1	1	1	1	1

Table 3. POWER GENERATION SCHEDULE FOR 10 HOURS

Unit	T=1	2	3	4	5	6	7	8	9	10
1	15.2	30.2	45.2	60.2	75.2	76.0	76.0	76.0	76.0	76.0
2	15.2	30.2	45.2	60.2	75.2	76.0	76.0	76.0	76.0	76.0
3	0.0	20.0	40.0	60.0	76.0	76.0	76.0	76.0	76.0	76.0
4	0.0	0.0	25.0	50.0	75.0	100.0	100.0	100.0	76.0	76.0
5	0.0	0.0	30.0	60.0	90.0	100.0	100.0	100.0	100.0	100.0
6	0.0	0.0	30.0	60.0	90.0	100.0	100.0	100.0	100.0	100.0
7	0.0	0.0	100.0	155.0	155.0	155.0	155.0	155.0	155.0	155.0
8	0.0	0.0	150.0	155.0	155.0	155.0	155.0	155.0	155.0	155.0
9	0.0	0.0	150.0	155.0	155.0	155.0	155.0	155.0	155.0	155.0
10	0.0	0.0	150.0	155.0	155.0	155.0	155.0	155.0	155.0	155.0

Table 4. PROFIT SCHEDULE FOR 10 HOURS

Time	Unit-1	Unit-2	Unit-3	Unit-4	Unit-5	Unit-6	Unit-7	Unit-8	Unit-9	Unit-10
1	-231.149	-231.756	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
2	-203.532	-204.653	-249.012	0.000	0.000	0.000	0.000	0.000	0.000	0.000
3	-56.376	-58.071	-60.295	-433.484	-457.500	-460.800	-73.271	38.770	33.475	28.597
4	616.235	613.907	609.147	148.817	206.705	200.685	2039.409	2033.395	2027.883	2022.814
5	1255.104	1252.080	1262.387	782.061	964.175	955.890	3017.459	3011.445	3005.933	3000.864
6	1208.118	1205.057	1201.587	1019.805	1010.465	1001.425	2893.459	2887.445	2881.933	2876.864
7	1609.398	1606.337	1602.867	1547.805	1538.465	1529.425	3711.859	3705.845	3700.333	3695.264
8	2074.518	2071.457	2067.987	2159.805	2150.465	2141.425	4660.459	4654.445	4648.933	4643.864
9	2820.838	2817.777	2814.307	3141.805	3132.465	3123.425	6182.559	6176.545	6171.033	6165.964
10	2819.318	2816.257	2812.787	3139.805	3130.465	3121.425	6179.459	6173.445	6167.933	6162.864

Conclusions

It is recognized that the optimal unit commitment of thermal systems 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 formulation of profit based unit commitment has been discussed and the solution is obtained by genetic algorithm approach. An algorithm based on genetic algorithm, which is fitness based optimization technique, has been developed to solve the profit based unit commitment problem. The effectiveness of these algorithms has been tested on system comprising 10 units.

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