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Thermal Unit Commitment

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Abstract: **In power industries, fuel expenses constitute a significant part of the overall generation costs. In general, there exist different types of thermal power units based on fuel used, with different production costs, generating capacities and characteristics in a system. The system usually operates under continuous variation of consumer load demand. Determining an optimal economical dispatch schedule of a set of generating units to meet a load demand while satisfying a set of operational constraints is called the Unit Commitment Problem. This paper describes the application of genetic algorithm and fuzzy logic for determining short-term commitment of thermal units in electrical power generation. Feasibility of these methods is examined and preliminary results to determine near optimal commitment order of thermal units in studied power system over short term are reported. The results obtained from genetic algorithm and fuzzy logic based approach are compared with the priority list method solution to unit commitment problem. The comparison proves that genetic algorithm and fuzzy logic based approach are powerful tools for solving such highly non-linear, multi constrained optimization problems in electrical power systems.**

Keywords: **Unit Commitment, Genetic Algorithm, Fuzzy Logic, Priority List.**

1. INTRODUCTION

The Unit Commitment Problem (UCP) is to determine a minimal cost turn-on and turn-off schedule of a set of electrical power generating units to meet a load demand while satisfying a set of operational constraints. The production cost includes fuel, startup, shutdown, and no-load costs. Some of the operational constraints that must be taken into account includes,

i) The total power generated must meet the load demand plus system losses.

ii) There must be enough spinning reserve to cover any shortfalls in generation.

ii) The loading of each unit must be within its minimum and maximum allowable rating.

iv) The minimum up and down times of each unit must be observed [5].

There have been several mathematical programming techniques proposed so far to solve unit commitment problems. They include Priority List, Dynamic Programming, Branch and Bound, Lagrangian Relaxation, Simulated Annealing, Expert Systems, Artificial Neural Networks [3].

The more commonly used method being simple and fast by electricity utilities is the priority list method. This method is used to rank generating units in a heuristic with increasing operation cost.

Genetic Algorithm (GA) provides a solution to UCP by working with a population of individuals each representing a possible solution. Together with a set of the main genetic operators of crossover and mutation this method provides a powerful global search mechanism, whose computation code is simple.

Fuzzy logic (FL) is useful in reducing the need for complex mathematical models in problem solving. Fuzziness is used to describe uncertainty, which is applicable to the UCP. Loading of generators, start up cost, incremental cost and production cost are considered to be fuzzy variables with the UCP.

2. THERMAL UCP FORMULATION

A. Fuel Cost (FC):

For a given set of N committed units (i = 1, …., N) at hour H (j = 1, …..H), the total fuel cost at that particular hour, is minimized by economically dispatching the units subject to the following constraints:

i) The total generated power must be equal to the demand.

ii) The power produced by each unit must be within certain limits.

This problem can be stated as follows.

$$\text{Min } FC = \sum_{h=1}^{H} \sum_{i=1}^{N} U_{ih}\,(FC_i)\,P_{ih}.$$

where, U_{ih} : Status of the unit i at hour h: 1 (ON) or 0 (OFF)

P_{ih}: Power output of unit i at hour h in MW

B. Start-up Cost (ST):

As, the temperature and pressure of thermal unit must be changed slowly, a certain amount of energy will be expended to bring the unit online. This energy, does not result into any MW generation from the unit, is called start up cost [13].

Two functions are commonly used to model start-up costs as a function of the temperature:

C. Two-step function:

$$ST_i = \begin{cases} STc & \text{if } x(t) \geq T_{cold\ start}. \\ ST_h & \text{otherwise.} \end{cases}$$

T_{cold} start is the number of hours it takes for the boiler to cool down. The STc and ST_h costs are the start-up costs incurred for a cold and hot start. Respectively and x (t) is consecutive time that unit been up (+) or down (-) at time t.

D. Exponential function:

$$ST_i = b_1\,[l - \exp(-b_3 * X_i)] + b_2.$$

b_l, b_2 and b_3 are start-up cost parameters and X_i the number of consecutive hours for which the unit i has been down [4].

E. Objective function:

The objective (or cost) function (OF) of the UCP is to determine the state of the units U_{ih} (0 or 1) at each period H, so that the overall operation cost is a minimum within the scheduling time span.

$$\text{Min } OF = \sum_{h=1}^{H} \sum_{i=1}^{N} U_{ih}(FC_i)P_{ih} + ST_i U_{ih}(1-U_{i,h-1}) + SD_i\, U_{i,h-1}\,(1-U_{i,h})$$

Subjected to the constraints

i. Total power generated should meet the load requirement and system losses,

$$\sum_{i=1}^{N} U_{ij}\; P_{ij} = PD_j \qquad j = 1, 2, \ldots\ldots, H$$

where PD_j is power demanded at hour j.

ii. Spinning reserve at each hour (SR_j) must be satisfied to cover any shortfall in generation,

$$PD_j + SR_j = \sum_{i=1}^{N} U_{ij}\; P_{imax,j} \qquad j = 1, 2, \ldots\ldots, H$$

iii. Each generator must operate within its minimum and maximum power output imits,

$P_{imin} \leq P_{ij} \leq P_{imax}$ $\quad$ $i = 1, 2, \ldots\ldots, N$

iv. The consecutive number of hours for which a generating unit must remain on (minimum up time, MUT) or off (minimum down time, MDT) should not get violated,

$U_{ij} = 1$ for $T_{ion} < MUT_i$ and $U_{ij} = 0$ for $T_{ioff} < MDT_i$

where, T_{ion} and T_{ioff} is the consecutive number of hours for which the unit is on and off till the end of last hour respectively [8].

3. SHORT TERM THERMAL UCP BY GENETIC ALGORITHM METHOD

Genetic algorithms are search algorithms based on the mechanics of natural selection and natural genetics. They combine Charles Darwin's survival of fittest theory with a structured and random information exchange. The resulting algorithm has innovative flair of human search [6]

A. Operators of GA:

Encoding of a Chromosome :

The chromosome should in some way contain information about solution, which it represents. The most used way of encodings is a binary string. The chromosome then could look like this:

Chromosome 1 1 1 0 1 1 0 0 1 0 0 1 1 0 1 1 0
Chromosome 2 1 1 0 1 1 1 1 0 0 0 0 1 1 1 1 0

Crossover:

Crossover selects genes from parent chromosomes and creates a new offspring. Crossover can then look like this. (| is the crossover point):

Chromosome 1 1 1 0 1 1 1| 0 0 1 0 0 1 1 0 1 1 0
Chromosome 2 1 1 0 1 1 1| 1 1 0 0 0 0 1 1 1 1 0
Offspring 1 1 1 0 1 1 1 1 1 0 0 0 0 1 1 1 1 0
Offspring 2 1 1 0 1 1 1 0 0 1 0 0 1 1 0 1 1 0

Mutation:

After a crossover is performed, mutation takes place. This is to prevent falling all solutions in population into a local optimum of solved problem.

Original offspring 1 1 1 0 **1** 1 1 1 0 0 0 0 1 1 1 1 0
Original offspring 2 1 1 0 1 1 0 **0** 1 0 0 1 1 0 1 1 0
Mutated Offspring 1 1 1 0 **0** 1 1 1 0 0 0 0 1 1 1 1 0
Mutated Offspring 2 1 1 0 1 1 0 **1** 1 0 0 1 1 0 1 1 0.

B. Algorithm:

Outline of the Basic Genetic Algorithm [6]

1. [Start] Generate random population of n chromosomes (suitable solutions for the problem).

2. [Fitness] Evaluate the fitness f(x) of each chromosome x in the population.

3. [New Population] Create a new population by repeating following steps until the new population is complete.

I) [Selection] select two parent chromosomes from a population according to their fitness (the bigger fitness, the bigger chance to be selected).

II) [Crossover] with a crossover probability, crossover the parents to form a new offspring (children). If no crossover was performed, offspring is an exact copy of parents.

III) [Mutation] with a mutation probability mutate new offspring at each locus (position in chromosomes).

IV) [Accepting] Place new offspring in a new population.

4. [Replace**]** Use new generated population for a further run.

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5. [Test] If the end condition is satisfied, Stop and Return the best solution in current population.

6. [Loop] Go to Step 2.

C. Fitness Function:

To apply a GA to a problem, which is highly constrained, one of three basic approaches can be adopted, namely:

- Generate only feasible candidate solutions by testing each proposed chromosome for feasibility, a very time consuming process. This is similar to an enumerative procedure.
- Modify the genetic operators to suit the constraints. This would only be possible for few constraints; otherwise the representation could become too complex.
- Penalize solutions, or parts of the solution space, that violate the constraints.

Fitness function = Objective function+ Penalty function (L-R,Utility factor)+Penalty function (min-up, min-down) [7].

D. Test System:

In order to prove effectiveness of GA for solving UCP, it is applied to test system of eight units (n = 8) over time period of eight hours (t = 8) [1,9].

TABLE I : LOAD DEMAND & RESERVE REQUIREMENT OF TEST SYSTEM.

Period	Demand (MW)	Reserve + Demand
01	400	450
02	470	530
03	520	600
04	510	540
05	360	400
06	240	280
07	240	290
08	450	500

TABLE II : GENERATING UNIT CHARACTERISTICS OF TEST SYSTEM

i	P_{imax}	MUT	MDT	IC	SUC			AFLC
					b1	b2	b3	
1	80	3	2	-1	350	158	0.4	20.88
2	250	2	1	-2	400	162.62	0.9	18
3	300	4	2	1	1100	421.18	0.48	17.46
4	60	2	3	-4	0.02	0.02	.0188	23.80

where IC: Initial condition of unit (- sign indicates that unit is down for hours otherwise +).

E. Simulation result of test system with GA:

TABLE III. RESULT FOR TEST SYSTEM WITH GA BASED APPROACH

Hour j	S_{ij}				P_j MW	OC_j
	1	2	3	4		
01	0	1	1	0	550	09966
02	0	1	1	0	550	09738
03	0	1	1	1	610	11166
04	0	1	1	1	610	11166
05	1	0	1	1	440	08797
06	1	1	0	0	330	06570
07	1	1	0	0	330	06170
08	0	1	1	0	550	10838
Cumulative cost in Indian Rupees (INR), OC						74411

4. SHORT TERM THERMAL UC P BY FUZZY LOGIC METHOD

A. Fuzzy Variable:

Fuzzy logic is a mathematical theory which encompasses the idea of vagueness when defining a concept or a meaning. i.e. there is uncertainty or “Fuzziness “ in expression like large" or "small" since these expressions are imprecise and relative. Variables considered thus are termed “fuzzy” as opposed to “crisp”. Fuzziness is simply one means of describing uncertainty. Such ideas are readily applicable to the unit commitment problem.

B. Fuzzy sets:

After identify in the fuzzy variables associated with unit commitment, the fuzzy sets defining these variables are selected and normalized between 0 and 1. This normalized value can be multiplied by a selected scale factor to accommodate any desired variable. The sets defining the load capacity of the generator are as follows [2],

LCG (MW) = {Low, below average, Above Average, High}

The incremental cost (IC) is stated as,

IC = {Zero, Small, Large}

The sets representing the start up cost (SUP) is,

SUP = {Low, Medium, High}

The production cost (PRC) is given by,

PRC = {Low, Below Average, Average, Above Average, High}

In a fuzzy-logic-based approach, decisions are made by forming a series of rules that relate the input variables to the output variable using if-then statements. Then if (condition) of each rule is an antecedent to the then (consequence) of each rule. Load capacity of generator, incremental cost, and startup cost are considered as input variables and production cost is treated as the output variable. This relation between the input variables and the output variables is given as:

Production Cost = Load Capacity of Generator} and {Incremental Cost} and {Start-up Cost}

In Fuzzy set notation this is written as:

$PRC = LCG \cap IC \cap SUP$

Hence, the membership function of the production cost, μPRC is computed as follows:

$\mu PRC = \mu\ LCG \cap \mu IC \cap \mu SUP$

C. Defuzzification process:

One of the most commonly used methods of defuzzification is the centroid or centre of gravity method. Using this method, the production cost is obtained as follows [2],

$$PRC = \left[\sum_{i=1}^{n} \mu(PRC)_i * (PRC)_i \right] / \left[\sum_{i=1}^{n} \mu\ (PRC)_I \right]$$

where,μ(PRCi):the membership value of the clipped output

PRCi :the quantitative value of the clipped output

n: the number of the points corresponding to quantitative value of the output [9].

D. Simulation result of test system with FL:

TABLE IV: RESULT FOR TEST SYSTEM WITH FL BASED APPROACH

H	P_j	P_{1j}	P_{2j}	P_{3j}	P_{4j}	OC_j
01	450	300	150	0	0	09426.7
02	530	300	230	0	0	10927.0

03	600	300	250	50	0	13121.0
04	540	300	240	0	0	10927.0
05	400	300	100	0	0	08488.6
06	280	280	0	0	0	05417.3
07	290	290	0	0	0	05800.0
08	500	300	200	0	0	10576.0
Cumulative cost in Indian Rupees (INR), OC						74683.6

5. SHORT TERM THERMAL UCP BY PRIORITY LIST METHOD

A. Priority List Method:

From a modeling point of view, Priority listing is the simplest method. The calculation time for this method is small, even for large systems. This makes the methods eligible for our purposes. An important disadvantages of this method is that it is not consider accurate. Also state transition costs are not taken into account.

B. Implementation detail:

The simplest unit commitment solution method consists of creating a priority list of units, a simple shut –down rule or priority –list scheme could be obtained after an exhaustive enumeration of all unit combinations at each load level. The priority list could be obtained in a much simpler manner by noting the average full load production cost (AFLC) which is simply the net heat rate at full load multiplied by the fuel cost.

- At each hour when the load is dropping, determine whether dropping the next unit on the priority list will leave sufficient generation to supply the load plus spinning reserve requirements. If not, continue operating as is; if yes, go to the next step.

- Determine the number of hours, H, before the unit will be needed again. That is assuming that the load is dropping and will then go back up some hours later.

- If H is less than the minimum shut –down time for the next step; if not, go to next step.

- Calculate two costs. The first is the sum of the hourly production costs for the next H hour s with the unit up. Then recalculate the same sum for the unit down and add in the smart-up cost for either cooling the unit or banking it, whichever is less expensive. If there is sufficient savings from shutting down the unit, it should be shut down, otherwise keep it on.

- Repeat this entire procedure for the next unit on the priority list. If it is also dropped, go to the next and so forth [1].

C. Simulation Result of test system with priority list:

TABLE V: RESULT FOR TEST SYSTEM WITH PRIORITY LIST

Hour j	**S_{ij}**				**P_j MW**	**OC_j**
	1	**2**	**3**	**4**		
01	0	1	1	0	550	09966
02	0	1	1	0	550	09738
03	0	1	1	1	610	11166
04	0	1	1	1	610	11166
05	0	1	1	0	550	09738
06	0	0	1	0	300	05238
07	0	0	1	0	300	05238
08	0	1	1	0	550	09966
Cumulative cost in Indian Rupees (INR), OC						72216

6. COST COMPARISON

TABLE VI: COST COMPARISON OF GA AND PRIORITY LIST BASED APPROACH FOR UCP

GA	Priority List
74411 INR	72216 INR

GA and priority list based method uses power output limits at their maximum value for selected generating units. Fuzzy logic based approach to UCP operates each generating unit within its minimum and maximum power operating limits and resulted the operating cost in INR as 74683.6.

7. CONCLUSION

Feasibility of applying Genetic algorithm, Fuzzy Logic and Priority List Method in solving short-term thermal unit commitment is proved. These methods guarantees the production of solution that do not violet system or unit constraints; so long as there are generators available in the selection pool to meet the require load demand. Though the global optimality is desirable, but in most practical cases near optimal solutions is generally sufficient. This paper attempts to find the best schedule from a set of good feasible commitment decisions. The result shows that it is possible to achieve improvements using these methods.

Fuzzy logic method allows a qualitative description of the behavior of a system, the system's characteristics and response without the need for exact mathematical formulations. Genetic algorithm and priority list method usually suffer from large computational times and excessive memory requirements as the problem size increases. The result shows that fuzzy logic method is a powerful tool that can be used to solve short-term thermal unit commitment problem. An advantage of fuzzy logic lies in its ability to handle any type of unit characteristics data.

REFERENCES

[1] A. J. Wood and B. F. Wollenberg (2006), "Power generation operation and control", John Wiley and sons (Asia), second edition, 2006.

[2] A. Perlin and P. Sandrin (May 1983), "A new method for unit commitment at Electricite De France", IEEE Transaction on Power apparatus and system, Vol. PAS-102, No. 5, pp 1218-1225.

[3] B. Gerald, Sheble and George N. Fahd (Feb 1993), "Unit Commitment Literature Synopsis", IEEE Transactions on Power System, Vol.9, No.1, pp 128-133.

[4] Chuan-Ping Cheng, Chih-Wen Liu & Chun-Chang Liu (May 2000), "Unit commitment by Lagrangian relaxation & Genetic Algorithms", IEEE Transaction on Power system, Vol.15, No.2, pp 707-714.

[5] D. Dasgupta, and D.R. McGregor (1994), "Thermal Unit Commitment Using Genetic Algorithms", IEEE proceedings on Generation, transmission and distribution, vol 141, No. 5, pp 459-465.

[6] David E. Goldberg (2001), "Genetic algorithms in search, optimization and machine learning", Pearson Education Asia.

[7] Dipankar Dasgupta (June 1993), "Unit Commitment in Thermal Power Generation Using Genetic Algorithm", In proceeding of the Sixth International Conference on Industrial and Engineering application of Artificial Intelligence and expert system, Edinburgh, UK, pp 374-383.

[8] S. Baskar, Dr. P. Subbaraj & (Ms) P. Chidambaram (Mar 2001), "Application of Genetic Algorithm to unit commitment problem", Journal of Institute of Engineering (India), Vol 81, pp 195-199.

[9] S. Saneifard, N. R. Prasad, H. A. Smolleck, 'A Fuzzy Logic Approach to Unit Commitment', IEEE Transactions on Power System, Vol.12, No.2, May 1997, pp 988-995.

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