Unit Commitment Optimization using Improved Genetic Algorithm

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***Abstract* _ This paper shows an investigation for solving the Thermal Unit Commitment (UC) problem by utilizing of Genetic Algorithm advantages. A Parallel Structure was developed to handle the infeasibility problem in a structured and improved Genetic Algorithm (GA) which provides an effective search and therefore greater economy. In addition, this proposed method could help us to obtain better performance by using both computational methods and classification of unit characteristics. Typical constraints such as; unit maximum/minimum MW limit, system power balance, minimum up and down times, start up and shut-down ramps, have been considered. A number of important UC control parameters have been identified accordingly. This method was developed and tested by using C# program. Tests have been performed on 10 and 20 units systems over a scheduling period of 24 hours. The final results were compared with those obtained genetic schemes in other same research.**

***Index Terms* _ Genetic Algorithm, Parallel Structure, Power Systems, Unit Commitment.**

I. INTRODUCTION

THE Unit Commitment problems are well known in the power industry and have the potential to save millions of dollars per year in fuel and related costs. It is an area of production scheduling that relates to the determination of the ON/OFF status of the generating units during each interval of the scheduling period, to meet system load and reserve requirements and minimum cost, which are subjected to the variety of equipment, system and environmental constraints. The Unit Commitment problem is a complex decision-making process and it is difficult to develop any rigorous mathematical optimization methods capable of solving the entire for any real-size system.

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Also, multiple constraints should be imposed which must not be violated while finding the optimal or near-optimal commitment schedule.

A true solution for UC problem can only be obtained by exhaustive enumeration, which is very time consuming. So attempts are being continuously made to solve this problem by reliable iterative and heuristic methods. A number of such methods has been developed so far [1]-[8]. Several investigations have also been carried out to solve UC problem with Genetic Algorithm (GA) [10]-[22].

In this study, an improved and optimized GA based on Parallel Structure was identified which make the search space smaller and hence the search quicker. In fact, Parallel Structure tries to quantify the amount of infeasibility by classification of unit characteristics (measuring the fitness). Other than by using both standard and convenient new genetic operators in solving this problem, a much improved results and thus a greater economy were achieved. The proposed approach applied on 10 and 20 units systems. The results were compared with those of the three previously developed genetic schemes in the same conditions [l4],[19],[20].

II. PROBLEM FORMULATION

The objective of the Unit Commitment problem is the minimization of the total production costs over the scheduling period. The total costs consist of:

i. Fuel costs,
ii. Start-Up costs,
iii. Shut-Down costs.

A) Unit Commitment Constraints

Also, there are some constraints which must be satisfied during the optimization process are:

1) *System Power Balance*: The generated power from all committed units must be satisfied the load demand;

$$P_D = \sum_{i=1}^{N} P_i \quad (1)$$

where P_D is the demand power (MW).

2) *Unit Maximum/Minimum MW Limit*: The units must operate in the specified minimum and maximum limits of capacity;

$$P_{i,min} \leq P_i \leq P_{i,max} \quad (2)$$

where $P_{i,min}$ and $P_{i,max}$ are the minimum and maximum power outputs of unit i (MW).

3) *Unit Start Up and Shut Down Ramp Limits*: Owing to the physical restrictions on thermal generating units, the rate of generation changes is limited by using certain start-up and shut-down ranges;

$$P_{i,j} \leq STR_i \quad if \quad U_{i,j} = 1 \;\; and \;\; U_{i,j-1} = 0 \quad (3)$$

$$P_{i,j} \leq SDR_i \quad if \quad U_{i,j} = 1 \;\; and \;\; U_{i,j+1} = 0 \quad (4)$$

where STR_i is start up ramp rate of unit i (MW/h) and SDR_i is shut down ramp rate of unit i (MW/h).

4) *Unit Minimum Up and Down Times*: Once the unit is started up, it should not be shut-down before a minimum up-time period and also, once the unit is shut-down, there is a minimum down-time before it can be started up again. These constraints are considered in the follows;

$$U_{i,j} = 1 \quad if \quad \sum_{j=j_u}^{j-1} U_{i,j} \leq MUT_i \quad (5)$$

$$U_{i,j} = 0 \quad if \quad \sum_{j=j_d}^{j-1} (1 - U_{i,j}) \leq MDT_i \quad (6)$$

where j_u is the hour at which unit i is started up and MUT_i is the minimum up-time of unit i (h). Also, j_d is the hour at which unit i is shut down and MDT_i is the minimum down-time of unit i (h).

III. GENETIC ALGORITHM

The GA is a stochastic search or optimization procedure based on the mechanics of natural selection and natural genetics. By GA utilizing, many non-linear, large-scale combinatorial optimization problems in power systems have been re-solved.

The construction of a Genetic Algorithm for this problem was separated into four distinct and yet related tasks: [18]

i. Choice of the representation of the string;
ii. Selection of the genetic operators;
iii. Determination of the fitness function;
iv. Determination of the probabilities controlling the genetic operators.

A) Important Imposed Operators of Genetic Algorithm

The standard Operators of Genetic Algorithm and also some new and effective genetic operators (which are highlighted with Italic fonts) that improve the new populations and applied in proposed method are listed below:

1) Selection: The purpose of parent selection in genetic algorithms is to give more reproductive chances to those population members which have the most fitness. In fact, this parameter is used to choose parents for the next generation. Stochastic uniform selection was used.

2) Cross-over: Crossover is a random process of recombination of strings. Based on the probability of crossover, partial exchange of characters between two strings is performed. The crossover process is included; select two mating parents, select a crossover point and exchange the chromosomes between two strings. With the crossover operation, genetic algorithms are able to acquire more information with the generated individuals. The genetic search space is thus extended and more complete.

3) Mutation: Mutation is the occasional random alteration of the bits in the string. With the binary representation, this simply means flipping the state of a bit from 1 to 0 or vice versa.

4) *Elitism*: This operator preserves the best solutions found by maintaining a group of them in the next generation. This operator is necessary to prove the convergence to the optimum through a Markov chain analysis. In fact, elitism as a powerful genetic parameter is considered to avoid losing the best individual in each generation.

5) *Small Units Determination*: small units can be committed/decommitted at short intervals. Unit price of these units are very expensive, so on-times must

be minimized. In this work, to minimize on-times of small units, those supply shortage power with electric power. Commitment orders of these units were determined based on cost characteristic. Then, based on fuel cost of each unit the lowest fuel cost is committed first. Next lower cost units are committed after first one respectively. Finally, the most expensive unit is committed last.

6) *Fitness Scaling*: This operator is used to adjust the diversity among the fitness values in the current generation. This operator is required for the proper functioning of the reproduction operator.

IV. PARALLEL STRUCTURE OF GENETIC ALGORITHM

To solve an optimization UC problem by using Genetic Algorithm, it is required to determine how to encode a solution and how to measure its fitness. The problem now amounts to measuring the fitness of some genotypes which correspond to 'infeasible' solutions. Parallel Structure has been proposed in this study to consider the infeasibility problem by using improved and structured Genetic Algorithm model which tries to quantify and classify the amount of infeasibility and therefore provides better performance of system.

A) The Properties of Parallel Structure

The importance of this Parallel Structure is that introduces a solution, which corresponds to an optimum UC schedule of the original system. In fact, multiple situations can be accessed in parallel. The properties of the Parallel Structure are described below:

- All the units of the original system have same cost functions and same limitations in the new system. These are termed as original units.
- The new system is provided with an additional unit which is free from all the constraints.
- Some constraints such as; cold & hot start-up costs, shut-down costs are supposed as major cost factors in the new system.
- Some other constraints such as; minimum up-time and minimum down-time are assumed as conditional factors in the new system.
- When the additional unit is incorporated, an additional load value is connected to the system intentionally.
- All other properties of the original system and the new system are same.

B) Objective Function

In this study, the Economic Status is Objective Function, which is defined as the determination of suitable allocation of generation among the operating units in order to minimize the production cost of supplying energy for the already committed units. Furthermore, Based on Economic Status function, the programming and achieving the results are done in this paper.

The economic status (ES) of a feasible overall schedule at time period j (interval), is given by; [19]

$$ES = \sum_{j=1}^{m} \min(FC_j) + \sum_{j=1}^{m} \min(STC_j) + \sum_{j=1}^{m} SDC_j \qquad (7)$$

where;

FC_j = Total generation (fuel) cost related to j^{th} interval ($),

STC_j = Total start up cost related to j^{th} interval ($),

SDC_j = Total shut down cost related to j^{th} interval ($),

m = Total number of intervals.

Total generation (fuel) cost of thermal unit in j^{th} interval is expressed as second-order function of each unit output;

$$FC_j = a_i + b_i P_i + c_i P_i^2 \qquad (8)$$

where a_i , b_i , c_i are the coefficient of each generator (unit) i . Also P_i is the generated power in this unit (MW).

Also, $\min(FC_j)$ was determined through standard Lambda iteration technique, whereas $\min(STC_j)$ was determined by selecting cold start or hot start properly. Because of the better economy achievement is concerned, the inverse of this economic status was surveyed as the fitness of the corresponding solution.

V. IMPLEMENTATION OF PROPOSED GENETIC MODEL

The implementation of proposed developed Genetic Algorithm determine the optimal (or near optimal) commitment schedule for a given period. The current Genetic Algorithm chart is improved and used in representing step by step structured way which is followed to overcome some constraints in UC problem.

The implemented GA consists of input data, binary strings coding, initializing of the population, decoding the commitment schedule by using Economic Status, evaluation of fitness function and application of Selection-Crossover-Mutation of the UC schedules. The optimized Flowchart of the algorithm is given in Fig. 1.

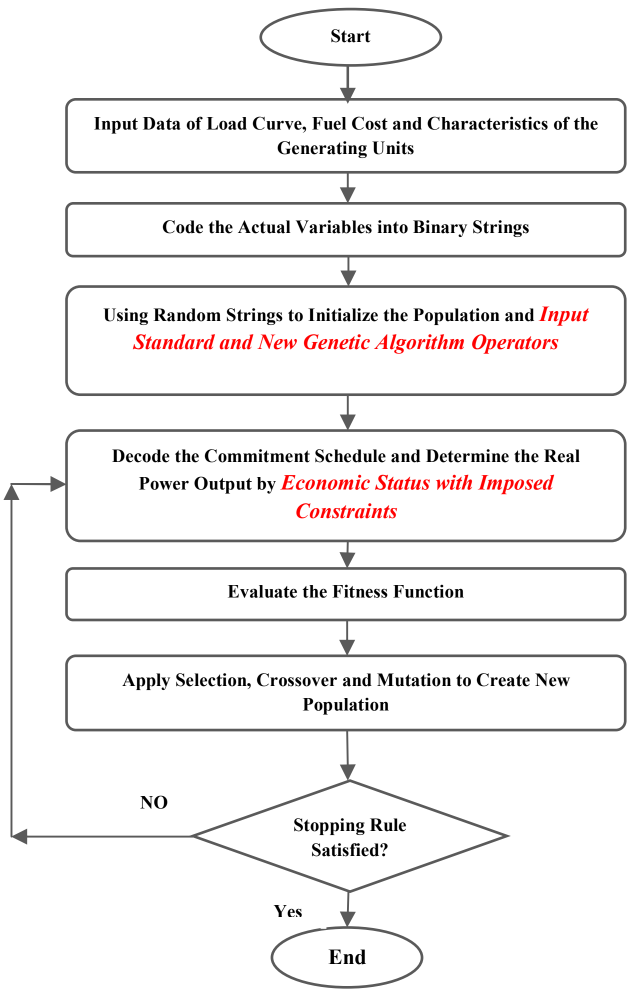

Fig. 1. Improved Flow chart of the Unit Commitment problem by Optimized Genetic Algorithm

As shown in Fig. 1, some parts of optimizations in GA structure such as; input standard and new GA parameters for system control, decoding the Commitment schedule and determination of output real power by using Economic Status with imposed constraints are implemented and executed in the new system.

VI. SIMULATIONS AND RESULTS

The proposed system is executed and evaluated on two case studies. The algorithm has been tested on 10 and 20 units systems. In each case a total scheduling period of 24 hours has been considered. The properties of the 10 units system are presented in Table I whereas the corresponding load profile is presented in Table II. [14] For the 20 units problem the initial 10 units system are duplicated and demand load data are multiplied by 2.

Table I. Properties of 10 units system

	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
Pmax (MW)	455	455	130	130	162
Pmin (MW)	150	150	20	20	25
a ($/h)	1000	970	700	680	450
b ($/MWh)	16.19	17.26	16.60	16.50	19.70
c ($/MW^2-h)	0.00048	0.00031	0.002	0.00211	0.00398
min up (h)	8	8	5	5	6
min dn (h)	8	8	5	5	6
hot start cost ($)	4500	5000	550	560	900
cold start cost ($)	9000	10000	1100	1120	1800
cold start hrs (h)	5	5	4	4	4
initial status (h)	8	8	-5	-5	-6

	Unit 6	Unit 7	Unit 8	Unit 9	Unit 10
Pmax (MW)	80	85	55	55	55
Pmin (MW)	20	25	10	10	10
a ($/h)	370	480	660	665	670
b ($/MWh)	22.26	27.74	25.92	27.27	27.79
c ($/MW^2-h)	0.00712	0.00079	0.00413	0.00222	0.00173
min up (h)	3	3	1	1	1
min dn (h)	3	3	1	1	1
hot start cost($)	170	260	30	30	30
cold start cost($)	340	520	60	60	60
cold start hrs(h)	2	2	0	0	0
initial status (h)	-3	-3	-1	-1	-1

Table II. Load profile corresponding to tested thermal units system

Hour	Demand (MW)	Hour	Demand (MW)
1	700	13	1400
2	750	14	1300
3	850	15	1200
4	950	16	1050
5	1000	17	1000
6	1100	18	1100
7	1150	19	1200
8	1200	20	1400
9	1300	21	1300
10	1400	22	1100
11	1450	23	900
12	1500	24	800

In Table I, "initial status" indicates how long the unit has been committed/decommitted. If positive, it indicates the number of hours the unit has been committed. If negative, it indicates the number of hours the unit has been decommitted. The final generation increases with the number of units.

Based on improved Genetic Algorithm, C# program has been developed for the proposed method. For programming in first step, it is assumed that i = 1,2,3,… 10 units and j =1,2,3,… 24 hours. In second step, it is assumed that i = 1,2,3,… 20 units and j =1,2,3,… 24 hours. The program has been run on PC with INTEL DUO CORE CPU 1.8 GHz and 2 GB RAM.

Initial population and the probability values have been adjusted to settings for runs of a test method for a particular problem set. For the test method probability values have been adjusted through trial and error method, because of stochastic nature of GA, to bring out the best result that may be obtained from this method.

Table III and Table IV show the best results based on Economic Status and the Average Time Requirement of the reference methods i.e. Simple Genetic Algorithm (SGA) [14], Parallel System Genetic Algorithm (PSGA) [19] and Unit Classification Genetic Algorithm (UCGA) [20] as well as the worst results of the proposed method for the system studied here.

Table III. Comparative Results (Economic Status) of the Test Method

System	Economic Status [$]			
	SGA Method [14]	PSGA Method [19]	UCGA Method [20]	Proposed Method
10 Units	565825	591715	563977	562184
20 Units	1126243	1133786	1125516	1123227

Table IV. Comparative Results (Average Time Requirement) of the Test Method

System	Average Time Requirement [sec]			
	SGA Method [14]	PSGA Method [19]	UCGA Method [20]	Proposed Method
10 Units	221	677	85	23
20 Units	733	1095	225	74

VII. CONCLUSION

The Unit Commitment program based on proposed Genetic Algorithm (Parallel Structure) was applied on two test systems using 10 and 20 thermal units in a scheduling period of 24 hours. Different types of constraints and load profile in specific scheduling period was tested to show the performance of Parallel Structure. By utilizing improved Genetic Algorithm, C# program has been developed for the proposed method by using the Economic Status as objective function and optimized Genetic Algorithm Flowchart (by using important imposed genetic operators) as programming guideline.

It is proved the better performance of optimized GA which is improved and tested in this project. This is exactly what this study attempted to consider. In fact, the proposed method is provided much-improved results i.e. greater economy as a major conclusion and much faster operation as another result of this study. The convenient efficiency of this method is achieved and performed which can lead other research in this area for obtaining better results in future.

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