Genetic Algorithm Based Generator Scheduling-A Review

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Abstract: Generator Scheduling (GS) problem is a non-linear, mixed integer, combinatorial and constrained optimization problem. The main objective of generator scheduling is to prepare the most economic startup and shutdown schedule for generators to meet the forecasted load demand and spinning reserve for a scheduled time horizon while satisfying various constraints. GS problem can be realized as two interlinked optimization problems, the on/off scheduling problem of generators and real power allocation problem. A feasible generators schedule must satisfy various system and plant constraints. Various optimization approaches have been developed for generator scheduling problem. Natural evolution based techniques are widely used to obtain global optimal solution. Genetic algorithm is one of the evolutionary technique. This paper presents a comprehensive review on genetic algorithm based generator scheduling problem solution. A survey of all of research papers up to 2013 on this topic is given.

Key words: Unit commitment (UC) • Optimization methods • Genetic Algorithm (GA) • Generation scheduling • Constraint satisfaction

INTRODUCTION

Generator scheduling problem (GSP) in the power system determines hourly on/off schedules for the generators with their power output over a specified time horizon. The objective of generator scheduling is minimize the total operating cost of system while satisfying different system, environment and unit constraints. Mathematically it is a complex non-linear combinatorial optimization problem. The exponential increase in search space with number of generating units and various system, environmental and unit constraint make the GS problem a complex optimization problem.

The exact optimal solution for GSP can be obtained by complete enumeration but this is not applicable to large systems because it requires exhaustive computational time. So different techniques have been developed to solve this problem [1, 2]. These techniques can broadly classified as deterministic, meta-heuristic and hybridized approaches.

Deterministic approaches such as Integer programming, dynamic programming (DP), branch and bound method have a problem of dimensionality [3-5]. These method requires high computational time and computer memory. So different heuristic approaches such as priority list [6], modified DP and Lagrangian relaxation (LR) [7, 8] have been developed to reduce the computational time and search space. But these techniques find solution that is far away from global optimal solution.

To obtain a global optimal solution in reasonable computational time meta-heuristic techniques have been developed and most widely used for generator scheduling. Simulated annealing is a stochastic approach and finds global optimum solution but in more computing time. Artificial neural network, Particle Swarm optimization, Ant colony, evolutionary programming, tabu search and Genetic algorithm are some random search technique and give more feasible and near-optimal solutions [9-13].

Hybrid techniques are the combination of deterministic and meta-heuristic approaches and are extensively used to solve UCP [12, 14-16].

Objective Function: The objective of the generator scheduling is to minimize the total production cost and mathematically given as follow.
Here $T$ defines the scheduling period, $N$ defines no. of generating units, $u_i(t)$ is the status of unit at specified period, $SC(t_{i}^{off})$ represents the transition cost and $F(P)$ is the operating cost of a unit for a specified time interval and it is given as follow.

$$Min TC = \sum_{i=1}^{T} \sum_{t=1}^{N} u_i(t) F(p_i(t) + u_i(t)(1-u_i(t-1))C(t_{i}^{off})$$

(1)

Genetic Algorithm: Genetic algorithm is a stochastic search technique established on natural evolution principle. Genetic algorithm is a particular class of evolutionary algorithms that use techniques inspired by evolutionary biology such as inheritance, mutation, selection and recombination. A typical genetic algorithm requires two things to be defined:

- A genetic representation of the solution domain.
- A fitness function to evaluate the solution domain.

Initial population is randomly generated and Genetic operators such as cross over, mutation are used to produce the off springs. A crossover operator exchanges information between two different chromosome and mutation randomly changes the value of one or more strings and is used to search the unexplored search space. Several other operators have been developed to enhance the performance of GA. Although the work on genetic algorithm based optimization started in 80’s but Research papers regarding genetic algorithm for solving unit commitment problem has been found from year 1993.

Figure 1 indicates the no. of research papers on unit commitment using GA from 1993 to present. Genetic algorithm techniques for solving generatorscheduling/unit commitment problem can be categorized in:

- Traditional Genetic algorithm
- Hybridized genetic algorithm approaches (combination of genetic algorithm and other techniques)

Application of Genetic Algorithm for Generator Scheduling: D. Dasgupta, et al. [17] proposed simple genetic algorithm for determining the near optimal solution for the unit commitment planning. Penalty function is used in this approach for constraint violation.
An elitism scheme is proposed so that the best solution are copied in a group and passed to next step. The scheme was implemented on 10 generators over time base of 24-hours. The work of Dasgupta was extended by X. Ma, et al. [18]. The results of genetic algorithm approach to solve generator scheduling problem were improved by using two point crossover. A forced mutation operator was proposed for handling constraints. Two types of coding scheme with different string length were used. The scheme having smaller string length was found best for 10 unit system. The introduction of forced mutation operator improved the performance of the algorithm.

In [19] a new coding scheme for UC variables was developed in GA. In the proposed coding scheme MUT/MDT constraints were directly integrated in the binary string which was used to represent the on/off status of unit. Other constraints like spinning reserves, power balance etc. were handled by adding a fixed penalty term in objective function. Test results for 38-units practical system showed the efficiency of proposed approach.

The search space and results of traditional genetic algorithm were improved by T.M. Field [20]. A new domain specific operator for flipping of a bit and multi UC scheduling was proposed. Multi scheduling with different reserve help the utility while choosing economical scheduling.

S. Orero et al. [21] developed the genetic algorithm to handle unit ramps rate limits while solving UCP. Ramping was considered only in generation scheduling and not in economic dispatch sub problem. Quadratic loss factor for MUT/MDT handling and an absolute value penalty factor for the spinning reserve/load demand constraint violation are used in proposed strategy. The robustness of the algorithm depends on the selection and grading of the penalty factors. The scheduling was obtained for 26 generators.

In [22] the author used a mixed binary and decimal coding scheme in genetic algorithm to solve UCP. Total operating cost based penalty less fitness function has been used in this strategy. The combinatorial problem was solved by GA and quadratic programming was used for generation allocation. Simulation results show that the scheme produced global optimal solution in a reasonable CPU time.

For constraint optimization in genetic algorithm a dynamic fitness function method was proposed by V. Petridis [23]. To generate only feasible solution domain specific recombination and permutation operators were proposed. A new decoding scheme is designed to reduce the probability of generating infeasible solution. Penalized value depending upon the degree of violation is added in the objective function for constraint handling. Results show superiority of proposed method compared with non-varying fitness function strategies.

T. Senju, et al. [24] presented a new GA, in which he developed unit characteristics based operator and intelligent technique for producing initial population. The initial population was produced based on load curve data for the feasible initial population generation. New shift, intelligent mutation and crossover operator were introduced. Unit were classified in different groups based on MUT/MDT constraint. The scheduling is obtained up to 100-generators over a time of 24-hours.

In [25] the suitability of parallel repair GA for generation planning were discussed in detail. The approach gave a model framework that was less restrictive compared to DP and LR. A hybrid parallel model was developed to avoid local convergence and to minimize computing time. A comparison of results of LR method and proposed genetic algorithm, demonstrate the performance of proposed strategy.

A new scheme was applied in [26] for chromosome representation and encoding the variables for solving large scale commitment problem. To ensure the feasible solution genetic operators were applied after the satisfaction of power balance constraint. Remaining constraints were added in the objective function. Schedule for 10-generators was obtained over a time span of 24-hour.

I.G. Damousis, et al. [27] proposed a new solution for UCP based on the integer coded GA in which string size and computational time is reduced as compared to binary coded GA. To avert distortion in the search space created from the penalty function method used for constraint violation, MUT/MDT were directly coded in the chromosome. Unit swapping operator and Excessive-reserve elimination operator were proposed to improve the performance of ICGA.

In [28] some new search operators were introduced in genetic algorithm to obtain generator scheduling. The proposed strategy uses Production cost, Unit startup cost and load demand for defining mutation probability. Repair algorithm was used to handle system and unit constraints. The schedule was obtained for a practical
system consisting of 12-generators. The proposed algorithm produced near optimal solution but consumed more time.

In [29] a genetic algorithm for solving large scale UCP was presented. To increase computational speed and to handle the MUT/MDT constraint, units having similar characteristics were clustered in a group and then genetic algorithm was applied to obtain the generator schedule. Test results had showed an improvement in the cost compared with cost obtained traditional GA.

T. Wei, et al. [30] updated the result of genetic algorithm by using adaptive crossover rate that varies with the maximum colony adaptation and the average colony adaptation degree of each generation. Rate of variation was adjusted by evolutionary generation and colony adaptation degree. The approach was found to be more precise and good convergent than simple GA.

In [31] a real coded GA and hybrid Taguchi GA method was applied to solve the UCP. The Taguchi technique was used to enhance the offspring’s quality created from crossover and mutation operation. The proposed strategy not only enhanced search space but also produced optimal solution with improved convergence. Results indicated that the HTGA had improved efficiency as compared real genetic algorithm.

An optimal unit commitment schedule using genetic algorithm was developed by the author in [32]. A hill climbing method is applied to improve the performance of genetic algorithm. The proposed strategy combined the features of accelerated search and easy convergence. Test results revealed that the approach has better practical value for optimal generator unit commitment problem with good sharpness and high flexibility.

In [33] a three dimensional matrix based GA approach was proposed for representation of chromosome and unit commitment schedule. The strategy used Binary coded GA for UCP and real coded GA for EDP. To ensure the feasibility of solution power balance constraint was satisfied prior to genetic operation. Tests on 10-generators revealed the feasibility of proposed method.

In [34] a new integer coded GA was applied for generation planning. A hybrid crossover based on average modified bound and swapped operator and a hybrid uniform and non-uniformed mutation operator were proposed. Test results for system up to 300-generators are given and justify the efficiency of proposed approach.

A new genetic algorithm using parallel structure was proposed to handle the constraint violation and solution infeasibility [35]. The proposed approach used unit characteristics classification and computational method to attain better results. By using parallel structure the computation time was much reduced compared to traditional GA method.

In [36] the author proposed a genetic algorithm based approach to solve the UCP in which Optimal flow of power with line constraints is also included. In first step UC scheduling was obtained with prevailing constraint and in the second step line constraint violations were reduced using genetic algorithm based optimal power flow. A practical system with 12-generators, 66 buses and 93 transmission lines was used to test the effectiveness of proposed approach.

In [37] the author used deterministic genetic algorithm to solve unit commitment. A deterministic selection procedure and an annular crossover operator was proposed to avoid premature convergence. Increased possibility of genetic information exchange was achieved by proposed annular crossover operator. A repair algorithm was used for constraint handling. A better convergence was obtained by proposed strategy when compared with traditional GA approaches.

A parallel structure integrated with improved and optimized genetic algorithm was proposed in [38]. The proposed approach effectively handles the infeasibility of the solution. An intelligent mutation and a scaling function for selection in each generation was proposed. The strategy gave better economy, speedy GA performance and increased probability to find global optimal feasible solution.

In [39] author applied genetic algorithm to solve multi objective function optimization problem. Unit commitment problem along with constraint emission was discussed in the proposed strategy. To handle minimum up time and minimum down time constraints in genetic algorithm the integer base coding method was proposed for generating initial feasible solution. No penalty function was used for MUT/MDT constraints. Constrained Emission was also considered in proposed approach. Commitment schedule over 24 hours was obtained for 10-generators. Test results provide evidence for the effectiveness of the proposed approach.

An intelligent coding scheme for genetic algorithm was proposed by D. Sundararajan, et al. [40] to solve the scheduling problem. The Minimum up time and minimum
down time constraint were satisfied by proposed intelligent coding scheme. Penalty parameter constraint handling technique was used to obtain a satisfactory balance of power constraints. The scheme produced much improved results for 10 and 26-generators over 24 hours.

The startup and shut down time in genetic algorithm were represented in the binary strings of variables in [41]. Penalty function method was used to handle other constraint. A new operator known as transportation operator was proposed. Exchange of information takes place between chromosomes of two randomly chosen units. The proposed approach helped in improving the computational efficiency genetic algorithm.

An improved genetic algorithm with an approach to solve both real and integer parts of the UCP was proposed in [42]. Ramp rate constraints are also incorporated in the proposed strategy. Multi point variable crossover technique was used. Experiments were performed up to 100-units and performance of proposed strategy was found satisfactory.

**Application of Hybridized GA for Generator Scheduling:**

X-Qiang, *et al.* [43] developed a dynamic programming crossover operator to create off springs. The DP is included in place of crossover parameter without affecting the GA and DP algorithm. The proposed approach uses dynamic programming on genetic algorithm based parent population to produce new chromosome. The penalty function or repair algorithm was not used for handling constraints as DP crossover generates the feasible off springs if the initial population satisfy the constraints. The approach worked well for non-linear optimization problem.

A genetic based neural network and dynamic programming (DP) strategy was proposed by H. Shyh-Jier [44]. At initial phase a genetic based enhanced neural network was applied to generate the initial commitment schedule and then DP was used to ameliorate this schedule. Computation performance of proposed method was more compared to other approaches.

A.H. Mantawy, *et al.* [45] developed hybrid method using genetic algorithm and tabu search method. The solution was coded as combination of binary number and decimal number to save memory and to reduce the computation time for the GA. The approach uses genetic algorithm for generation of initial population and tabu search algorithm in the reproduction phase. The proposed method reduces the probability of premature convergence of genetic algorithm.

T. Takata, *et al.* [46] presented a hybrid genetic algorithm and langrangian relaxation technique for solving unit commitment problem. To overcome the limitations of Langrangian Relaxation in handling constraint genetic algorithm was employed. In Genetic algorithm constraint satisfaction can easily be obtained by simply adding penalty factor in the objective function. Moreover, the introduction of heuristics to facilitate genetic manipulation of the string, which improved the efficiency of the optimization. Simulation results had shown that this method was effective in solving practical UCP.

In [47] a hybrid fuzzy logic and genetic algorithm was developed to solve the generator scheduling problem. The fuzzy logic based model was proposed to deal with load balance and spinning reserve constraint and to calculate penalty term for other constraint handling. GA was then used for generation planning. A high quality solution was obtained from proposed approach compared to results obtained from traditional GA, LR and integer programming.

A hybrid approach containing genetic algorithm and simulated annealing was developed to obtain the unit on/off scheduling in [48]. The proposed approach increases the speed of SA and improves the performance of genetic algorithm. Scheduling was obtained for a practical system of 40-generators.

A chaos search immune algorithm embedded in the genetic algorithm was proposed by C.C. Liao in [49]. Initially immune and genetic algorithm were nested then the fuzzy logic and chaos search was implemented to solve the UC problem. Crossover and mutation probability are changed from constant value to varying value and calculated by using fuzzy logic. The proposed strategy guaranteed Global optimal convergence of solution. Test results showed the proficiency of proposed method.

A fuzzy logic to make the fuzzy based unit commitment model and genetic based approach for scheduling was proposed by A.H. Mantawy [50]. The model takes the uncertainty in the expected load demand and spinning reserve in the framework of fuzzy. A penalty term is calculated by the proposed fuzzy model to converge the solution to more optimal solution. The economic dispatch part of problem was solved by dynamic programming.

A two-layer strategy consisting of genetic algorithm and improved lambda iteration was presented by the author in [51]. Unit level and population level crossover were introduced to increase the search space. A swap
mutation operator was proposed for committing the unit on/off based on unit’s FLAPC. Lambda iteration approach was used for power allocation.

J. Zhang, et al. [52] developed a hybrid genetic algorithm and particle swarm optimization. The approach uses genetic algorithm for optimizing unit commitment problem and particle swarm optimization for economic load dispatch problem. Probability of Local optimal convergence is prevented by using PSO. Feasible UC scheduling is obtained for 10-generator over a time horizon of 24-hours.

CONCLUSION

Generation scheduling is very critical in daily operation of power system. The optimal Generator scheduling gives significant production cost savings. A comprehensive review genetic algorithm based generator scheduling is discussed in this paper. The GA approach has been found very effective to find an optimal solution. The GA based techniques not only produce better solution but also reduces the computational time and search effort. Various GA based schemes are discussed in this paper and it is found that intelligent genetic algorithm, parallel structure genetic algorithm and hybrid GA techniques appear to be best among all proposed GA strategies.

REFERENCES


