Generation Scheduling

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Introduction

The purpose of generation scheduling is to optimise the generation and fuel cost in meeting the future load demands. The problem is effectively an optimization problem based on multiple constraints.

Several methods to solve the problem exist; these are based on the Lagrange multiplier, linear programming and network flow algorithm. However, these encounter problems when dealing with certain cases: the Lagrange multiplier is unable to deal with non-convexity which is inherent in the generation schedule problem; the network flow technique provides impractical solutions. Linear programming requires a large number of variables even for a short period of time, and consequently, is unsuitable. In recent years, new algorithms have been developed to overcome these difficulties and attain a more optimised solution to the problem. These rely on genetic algorithms and fuzzy set theory, and are capable of solving non-convex optimisation problems. To further increase efficiency, these are combined with the simulated annealing algorithm to develop a hybrid algorithm, combining the advantages of both the approaches.

The genetic algorithm is used to find a maxima or a minima over an interval and return the input of the function for that extremum. The input is first encoded into a chromosome or a string of 1s and 0s: one parameter can take ten of these bits and another can take five, consequently if these are the only parameters, then the length of the chromosome becomes fifteen. The algorithm works by promoting those solutions which takes it closer to an extremum and penalizing those which takes it further from an extremum.

This is similar to the biological process of evolution as described by Darwin wherein species with dominant traits are preferred over species with recessive traits. Over thousands of generations, the processes of generation, mutation and crossover take place, and species that are much more advanced than their ancestors emerge. The judging of a strong or weak solution is implemented through a cost function. Finally, after obtaining the extrema, the chromosome is decoded back into usable parameters that were needed in the first place.

Paper: Hybrid Genetic/Simulated Annealing Approach to Short-term Multiple-fuel-constrained Generation Scheduling

Link to the paper: [Hybrid genetic/simulated annealing approach to short-term multiple-fuel-constrained generation scheduling]()

The paper develops a method for short-term multiple-fuel-constrained generation scheduling which takes care of parameters such as the power balance constraint, generator operation limits, fuel availability, efficiency factors of fuels, and their supply limits. The objective is to determine, over a period of time, the most economical generation schedule of T generators and their fuel schedules for K types of fuels. An approach by combining the genetic algorithm (GA) and simulated annealing (SA) is proposed.

The procedure to solve the problem is as follows: a generator is selected randomly. Let this generator be ‘d’ or the dependent generator. The loadings and the fuel allocation factors of all other generators are determined using the hybrid algorithm or using GA. The parameters for the dependent generator r in all intervals are then calculated so that the power balance requirement is satisfied. Then the loading of the dependent generator is calculated; If it is not within the operational limits, the generation of another set of generator loadings takes place, and this process is repeated.

In adopting GA to the present problem, a chromosome represents a prospective solution which consists of the loadings and the fuel allocation factors of all the generators. The objective function is proportional to the total fuel cost function F, and consequently, the fitness function is proportional to 1/F.

In SA, in the high-temperature region, the loadings of the non-dependent generators are perturbed randomly in the range given by the operational limits, and provide a very high chance of generating feasible solutions; these may or may not be in the neighbourhood of the current solution. In the low-temperature region, the normal distribution (Gaussian function) is used to probabilistically generate new solutions in the vicinity of the current solution.

Finally, in the hybrid algorithm, The performance of GA is improved by introducing more diversity in the chromosomes in the early stages of the solution process by using the Gaussian function used in SA to replace fitter chromosomes by weaker child chromosomes. As the solution process progresses, the temperature level T in the Gaussian function is reduced as per the relation $T_k = r^{(k-1)}T_o$.

The hybrid approach ensures that the replacement probability is reduced slowly; thus, at later stages of the solution process, the chance of a fitter chromosome being replaced becomes less.

Paper: A Fuzzy-Optimization Approach for Generation Scheduling With Wind and Solar Energy Systems

Link to the paper: [A Fuzzy-Optimization Approach for Generation Scheduling With Wind and Solar Energy Systems]

This paper develops a fuzzy optimisation approach for generation scheduling for wind and solar energy systems. The fuzzy-set notation for various constrained parameters was used, which helps in representing the uncertainties inherent in practical optimisation. The optimised generation schedule is calculated with minimal total thermal unit fuel cost. The emission from the burning of fossil fuels is also considered in this approach. The effectiveness and application of the above method are tested using a simplified generation system.

The procedure to solve the problem is as follows: A wind and solar energy system is considered under an uncertain environment, i.e., under an uncertain load demand. Before performing the conventional generation scheduling methods, various parameters like available water, solar radiations, and wind speed, are forecasted to prevent errors. However, there is some error in the predicted values; consequently, they are represented as fuzzy set notations. A genetic algorithm is then employed to attain the desired generation schedule, and the total fuel cost is calculated with an optimal generation schedule value. For minimising the total cost, the experiment duration is divided into T time intervals.

The membership functions for the total fuel cost, load demand, available water, wind speed, and solar radiation are established to solve generation scheduling using this method. The modelling of the total fuel membership function is done so that high cost is given to low membership value. After the completion of the modelling of the membership function, the optimisation method is implemented, and the genetic algorithm is deployed for the optimisation update process.

The chromosome for applying GA uses the wind speed and solar radiation for wind power plants and solar power plants, respectively. The control variables for chromosomes in GA are designed, and a fitness function is developed for assigning the quality value to each iterative solution. Since there exists an error in the forecasted costs of the parameters, the membership value for each was obtained from its membership function. The parent population is obtained using the two strategies based on the existing chromosome's performance in offspring. The mutation and crossover are performed using simple roulette-wheel selection and defined probabilities.

On testing the above-stated method, the results reveal that it is effective in optimal generation scheduling with good performance, and the total fuel cost is optimised.

Paper: Genetic Aided Scheduling of Hydraulically-coupled Plants in Hydrothermal Coordination

Link to the paper: [Genetic aided scheduling of hydraulically coupled plants in hydro-thermal coordination]()

Hydroelectric scheduling assumes a significant part within the operation planning of a power system. The problem is predominantly focused on both hydro units scheduling and thermal units dispatching. However, when multiple hydro plants are situated on a similar waterway, the water outflow from one plant may be a very significant portion of the inflow to other plants which are located downstream. Scheduling for these coupled hydro plants has been a difficult task. The electric and hydraulic couplings create a multidimensional, nonlinear programming problem.

To solve this problem, the dynamic programming with successive approximation (DPSA) is conventionally used. For the successive approximation (SA) procedure, it is necessary to specify a starting feasible schedule for every reservoir first. Then, one reservoir is scheduled while keeping the others schedules fixed, changing from one reservoir to the other until the stopping rule is fulfilled. The stopping rule might be the cost difference between the last two iterations within a specified tolerance limit or once a specified iteration number is exceeded. In this paper a global optimization technique known as genetic algorithm (GA) has been used due to its flexibility and efficiency and final results are compared with DPSA in a case study. Genetic Algorithm is a stochastic searching algorithm. The complex water balance constraints due to hydraulic coupling are embedded in the encoding chromosome string and are fulfilled throughout the proposed decoding algorithm. To make the outcomes more viable, the impacts of net head and water travel time delay are additionally considered.

Most methods for solving the hydro-thermal coordination problem are based on decomposition approaches that involve a hydro and a thermal sub-problem. These two sub-problems are typically planned by Lagrange multipliers and then the optimal generation Schedules of both hydro and thermal units are acquired by means of repetitive hydro-thermal iterations. A very much perceived difficulty is that the solutions to these two sub-problems may oscillate between maximum and Minimum generations with small changes of the multipliers. In the proposed GA approach, the thermal sub-problem can be tackled entirely independently. No multiplier coordination is required in the solution procedure, and subsequently the oscillation problem can be totally blocked. In the thermal sub-problem, the unit commitment is performed for the remaining thermal load profile (load profile minus HCP's generations), and the subsequent thermal expense is returned as the fitness of this HCP's schedule. The optimal solutions of both units are simultaneously obtained within the evolutionary cycle of "fitness."

The scheduling of HCPs deals with the problem of getting the optimal generations for both the hydro and thermal units. It focuses on minimizing the production costs of thermal units while satisfying various constraints. With discretization of the absolute total scheduling time into sets of shorter time intervals (say, one hour as one time interval), the scheduling of HCPs can be mathematically formulated as a constrained nonlinear optimization problem.This gives us objective function for GA. The fitness function adopted here consists of thermal production cost plus the penalty cost. In order to use the best chromosomes and speed up the convergences, fitness is normalized between 0 and 1. When the fitness of each chromosome is calculated and it is sorted in descending order, the roulette wheel parent selection technique is used to select the best parents for the crossover and the mutation stages according to their calculated fitness. Mathematical outcomes show the appealing properties of the GA approach in useful application, in particular, a highly optimal solution cost and more robust convergence behavior.