International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 5 Issue 5, May-2016

Experimental Study of Generation Scheduling and Short Term Unit Commitment in Electrical Power System

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ABSTRACT

The unit commitment phase determines the optimum pattern for starting up and shutting down the generating units over the designated scheduling period, while the economic dispatch phase is concerned with allocation of the load demand among the on-line generators. In a hydrothermal system the optimal scheduling of generation involves the allocation of generation among the hydro electric and thermal plants so as to minimise total operation costs of thermal plants while satisfying the various constraints on the hydraulic and power system network. This thesis reports on the development of genetic algorithm computation techniques for the solution of the short term generation scheduling problem for power systems having both thermal and hydro units. A comprehensive genetic algorithm modelling framework for thermal and hydrothermal scheduling problems using two genetic algorithm models, a canonical genetic algorithm and a deterministic crowding genetic algorithm, is presented. The thermal scheduling modelling framework incorporates unit minimum up and down times, demand and reserve constraints, cooling time dependent start up costs, unit ramp rates, and multiple unit operating states, while constraints such as multiple cascade hydraulic networks, river transport delays and variable head hydro plants, are accounted for in the hydraulic system modelling. These basic genetic algorithm models have been enhanced, using quasi problem decomposition, and hybridisation techniques, resulting in efficient generation scheduling algorithms.

Keywords: Unit commitment phase; Economic dispatch, load, Optimum.

I. INTRODUCTION

Unit commitment (UC) is the process of determining the most cost-effective combination of generating units and their generation levels within a power system to meet forecasted load and reserve requirements, while adhering to generator and transmission constraints. This is a non-linear, mixed-integer combinatorial optimization problem. Low-cost solutions to this problem will directly translate into low production costs for power utilities. As the size of the problem increases, it becomes a very complex, hard to solve problem. Multiple optimization approaches have been applied over the past years, such as the priority ordering methods, dynamic programming Lagrangian relaxation the branch-and-bound method, and the integer and mixed integer programming. Other, more recent methods are from the field of artificial intelligence, such as the expert systems neural networks fuzzy logic genetic algorithms and simulated annealing. Many of these approaches are either purely heuristic (e.g. priority ordering) or semi-heuristic (e.g. simulated annealing), thus are often very sensitive to choice of architecture, manual parameter tuning, and different cost functions. On the other hand, analytical methods can also introduce critical shortcomings.

The branch-and-bound algorithm, for instance, suffers from an exponential growth in execution time with the size of the UC problem,. In addition, using approximations for making it tractable for large scale systems causes solutions to be highly sub-optimal. Therefore in our work, we take an analytical approach to the problem, while assuring it will not become intractable nor highly suboptimal in large scale systems. We use a Markov Decision Process (MDP) framework. MDPs are used to describe numerous phenomena in many fields of science. Such a model is aimed to describe a decision making process, where outcomes of the process are partly random and partly under the control of the decision maker. In this work we assume that generation cost functions of the different generators are known to the decision maker.

Generation Scheduling The generation scheduling function is one of the core components of a modem power system energy management system (EMS). The EMS helps in the determination of the generation level of each unit by minimising utility wide production costs while meeting system and unit constraints. The generation scheduling function has to satisfy the main objective of economics, which involves an optimization of cost over a future period of time. The economic dispatch sub function which optimizes operation cost over a much shorter time interval is embedded in the generation scheduling function. Figure 1. shows how the generation scheduling functions fit in the overall EMS structure of a modern power system control.

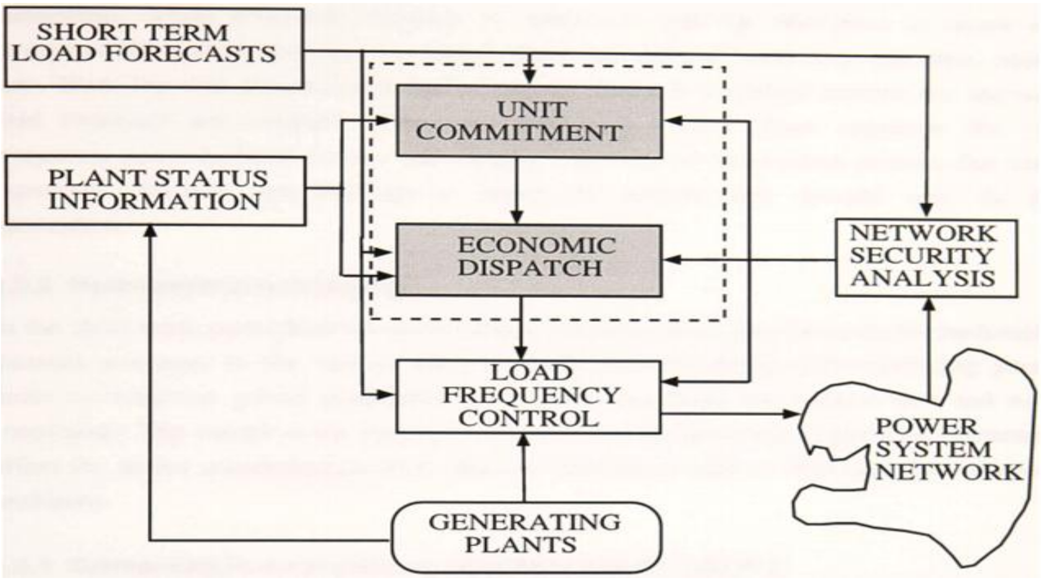

Figure 1. Generation scheduling and control functions in a modern EMS

The advances in computer hardware and communications technologies makes real time plant and network data available for the generation scheduling and control functions. Most generating units are now equipped with on line performance monitoring equipment that can provide very accurate up to date information about the equipment performance. This means that unit performance characteristics used in generation scheduling can be more accurately determined. The ideal generation scheduling system for the present day EMS system should:

- incorporate real time plant information in modelling plant characteristics,
- take into consideration real and reactive power system constraints,
- satisfy environmental considerations,

These requirements call for reliable and robust optimisation algorithms.

We note that this is often not the case with European system operators, since in a European competitive electricity market, cost information is not available. However, in many other cases this information is indeed available, such as in some north American TSOs, and generation companies with multiple generation units (such a company would not know the characteristics of the power system, nevertheless it is not problematic since they do not play a role in our formulation). In addition, the UC problem can easily be extended to generate production schedules in a competitive market environment. Another paper shows the framework in which a traditional cost-based unit commitment tool can be used to assist bidding strategy decisions to a day-ahead electricity pool market. In general, European TSOs can approximate generation costs based on historical data (that include past and present bids they receive from generators) and market simulation. Also, in future work, the uncertainty in these approximations can be naturally expressed in our MDP model.

A Problem that must be solved on a daily basis by a power utility is to determine a schedule of what units will be used to meet the demand anticipated over a future 24-hour period. This is commonly referred to as the unit Commitment problem, and its solution has been the subject of intensive efforts over the last 20 years. References give an extensive account of these efforts and an appraisal of the state of the art. Generally, the available approaches can be categorized into two groups. The first group consists of rigorous optimization approaches that are impractical for application to problems of realistic size. The second group consists of heuristic approaches that are actually used in practice, but give no assurance that the schedules produced are optimal or even close to optimal. The purpose of this paper is to describe an optimization methodology which is, for the first time, capable of solving realistic unit commitment problems. The approach is based on a duality transformation of the original problem and optimal solution of the associated (no differentiable) dual

Generation scheduling and Unit commitment (UC) plays a major role in the daily operation planning of power systems. System operators need to perform many UC studies, in order to economically assess the spinning reserve capacity required to operate the system as securely as possible. The objective of the UC problem is the minimization of the total operating cost of the generating units during the scheduling horizon, subject to many system and unit constraints. The solution of the above problem is a very complicated procedure, since it implies the simultaneous solution of two sub problems: the mixed-integer nonlinear programming problem of determining the on/off state of the generating units for every hour of the dispatch period and the quadratic programming problem of dispatching the forecasted load among them.

When load forecasts and generators available for power are given, then there is a need to decide when each generator would be started up and shut down as fixed costs are involved in starting and stopping generators. So, the main objective is to minimize the operating cost while having enough capacity to track the load during changes and cover for random generator failures. The objective of the dispatch is to schedule the committed generators to meet the load, maintain voltages and frequency within prescribed tolerances an minimize operating cost without unduly stressing the equipments.

II. ECONOMIC DISPATCH WITH GENETIC ALGORITHMS

Economic dispatch of generating units in a power system is concerned with the allocation of the load demand among the on-line (synchronised) generating units in order to minimise fuel costs, while satisfying the various unit and power system network constraints. Economic dispatch is a sub-problem of both the unit commitment and hydrothermal coordination problems, and assumes that the decision to commit any unit to generation has been made prior to performing economic dispatch. The economic dispatch problem has been the subject of intensive research for a number of years, and a summary of the solution methods is presented in [Wood and Wollenberg], [Sterling, 1978], [Happ, 1977]. In the thermal scheduling problem, an appropriate technique for solving the economic dispatch subproblem must be used. In this chapter, the possibility of using the genetic algorithm method for solving the dispatch sub-problem is investigated by comparing its performance with other conventional methods.

Economic Dispatch Problem

The economic dispatch problem considered in this work is looked at from the perspective of a sub-problem of unit commitment. It is the dispatch necessary to facilitate generation scheduling and is thus considered to take place at hourly intervals. To solve the standard economic dispatch problem, consider the operation of a power system with N synchronised units, where the ith unit is loaded to Pi MW, to satisfy a total load demand PD including total transmission losses PL. Let the fuel input-power output cost function of each unit be represented by a function Ft The main objective of optimal economic dispatch is to minimise the total fuel cost:

$$Min \sum_{i=1}^{N} F_i\left(P_i\right) \quad \textbf{(1)}$$

Subject to the power balance and unit loading limits:

$$\sum_{i=1}^{N} P_i - \left(P_D + P_L\right) = 0$$
$$P_i^{min} \le P_i \le P_i^{max} \quad i = 1,2,..,N \quad \textbf{(2)}$$

were 1 IS t e unIt m ex, P $_i^{min(max)}$ are the unIt nunlmum (maximum) generation limits. Other constraints usually considered in the dispatch problem include: 1. rate of change of generator output limitations (unit ramping rates), 2. collective import/export limitations from groups of generators, 3. restrictions on contributions to reserve capacity and assignments for frequency regulation, 4. the dependence of power system losses on load flow pattern. Most of these additional constraints are considered in the detailed on-line dispatch process and are handled by an optimal power flow program [Dommel] which also considers reactive power control in the network and is beyond the scope of this work.

Conventional Economic Dispatch Methods

Economic dispatch belongs to the class of non linear optimisation problems composed of a non linear objective function and a number of equality and inequality constraints. It is not, in general, straight forward to compute, by classical calculus, the location of the optimum loading points for all the system units, that would minimise the system operating costs, when problem constraints, such unit minimum and maximum loading limits are considered. A number of linear and non linear programming techniques have been proposed for the solution of the dispatch problem. Happ, [Happ, 1977] provides a comprehensive literature survey on economic dispatch solution techniques.

III MODELING THE THERMAL SCHEDULING PROBLEM

A number of estimates have shown that a 1 % reduction in power production costs can result in annual savings of up to one million dollars for each 1000 MW of installed capacity. This economic incentive has led to a concerted effort in the search for algorithms that can provide any improvements in system operation costs. The scheduling of thermal generators in a power system is the act of determining the optimum combination of the available units to supply a given load profile at minimum cost. Scheduling power system operation involves two basic economic decisions: 1. a unit commitment decision that determines which units should be brought on-line to meet the expected load demand and reserve requirements, and 2. an embedded economic dispatch decision that determines the most economic generation level for each of the committed (synchronised) units. In the unit commitment phase, the start up and shut down times of the units over the whole scheduling period must be specified. Once units are commited, an economic dispatch phase allocates the load among the on-line units to satisfy the load demand at a given time interval.

The thermal scheduling problem involves the determination of the start up and shut down times as well as the power output levels of all the system generating units at each time step, over a specified scheduling period T, so that the total start up, shutdown and running costs are minimised subject to a number of system and unit constraints. Obtaining an optimal schedule of generation involves the solution of a mixed integer non linear optimisation problem with a large number of constraints.

Problem objective function the main objective of scheduling in thermal systems is to minimise system operation costs. The total production cost, F_T for the scheduling period is the sum of the running cost, start up cost and shut down cost for all the units and is given by,

$$F_T = \sum_{t=1}^{T} \sum_{i=1}^{N} FC_{i,t} + SC_{i,t} + +SD_{i,t}$$

where FC_i, SC_i and SD_i are running costs, start up costs and shut down costs respectively.

RESULTS AND DISCUSSION

In this section, the results of economic load dispatch are discussed after the implementation of PSO. The programs are implemented in MATLAB R2010a. The developed algorithms for economic load dispatch problem based on particle swarm optimization technique have been discussed.

The main objective is to minimize the total fuel cost of generation of plants using PSO methods. The performance is evaluated without considering losses using two generator test systems, i.e. five generator test system and six generator test system.

Single Objective Economic Load Dispatch

Single objective Economic Load Dispatch Problem of Thermal Electric Power System Consisting of five Generating Units using Particle Swarm Optimization (PSO) Technique and Single objective Economic Load Dispatch Problem of Thermal Electric Power System Consisting of six Generating Units using Particle Swarm Optimization (PSO) Technique.

Table 1: Generating unit characteristics-6 unit model

UNITS	P_{max}	P_{min}	A	B	C	MU_i	MD_i	H_{cost}	C_{cost}	C_{hour}	IniState
Unit1	200	50	0.00375	2	0	1	1	70	176	2	1
Unit2	80	20	0.0175	1.7	0	2	2	74	187	1	-3
Unit3	50	15	0.0625	1	0	1	1	50	113	1	-2
Unit4	35	10	0.00834	3.25	0	1	2	110	267	1	-3
Unit5	30	10	0.025	3	0	2	1	72	180	1	-2

Unit6	40	12	0.025	3	0	1	1	40	113	1	-2

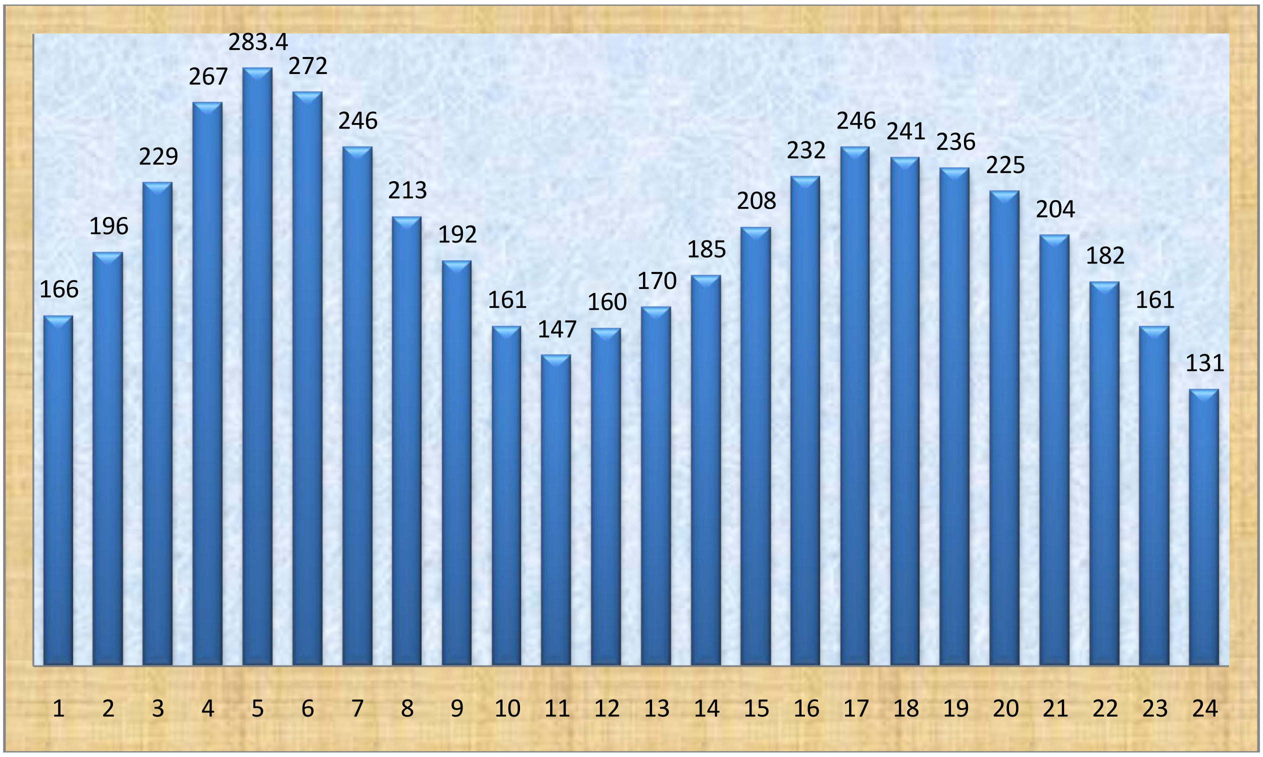

Figure 2: load demand curve

CONCLUSION

The GA, must however be carefully designed in order to be able to solve any given problem. This design involves the appropriate choice of the GA model, control parameters, fitness function and problem representation. The GA is best applied in an innovative way to any specific problem, by using as much of the problem knowledge as possible. The proper selection of the GA control parameters such as population size, crossover and mutation rates can result in improved solutions. Recent empirical evidence has shown that, if these variables are allowed to self adapt, as the GA run progresses, much better solutions could be obtained, thus avoiding the need to set the parameters a priori. At present, the GA control parameter settings are based on a mixture of experimental trials on the problem domain and theoretical insights on GA performance. It is the lack of a solid theoretical basis for a universal setting of GA control parameter settings across a wide range of problem domains that is one of the main drawbacks of the GA method.

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