

Influence of Solution Coding on Solving the Unit Commitment Problem with Metaheuristics

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1 Introduction

In Power Systems Engineering, as well as in many other areas of Electrical Engineering, optimising the usage of resources, subject to several constraints, is extremely important and usually difficult, due to specific technical, economical, or other particular aspects of the problem.

The unit commitment problem is an important scheduling problem in planning the operation of power generators, and it is a good example of the interest devoted by the Power Engineering sector, to this area of research. It is the on/off decision problem of selecting the power generating units to be in service within a given planning horizon (from 1 day to 2 weeks, generally split in periods of 1 hour) and for how long. The committed units must satisfy the forecasted system load and reserve requirements, at minimum operating cost, subject to a large set of other system, technological and environmental constraints. Due to important start-up and shut-down costs, the problem is in general very hard to solve, as it is not possible to perform a separate optimization for each time interval. Furthermore, given that the operating costs depend on the load assigned to each generator, the problem of committing units over the planning horizon is directly connected to the additional problem of (roughly) assigning the load demand to the on-line units ("pre-dispatch" problem). The final, actual assignment is done later, for a much shorter period (usually from 15 to 60 minutes).

Due to its combinatorial nature, obtaining an optimal solution for this problem is challenging, computationally difficult and sometimes impossible. Therefore, heuristic approaches have for long been used to find a satisfactory solution (not necessarily optimal) within the time available for decision making.

In this paper, a Simulated Annealing approach to the Unit Commitment problem is presented. Two different coding schemes are studied and compared, and some neighbourhood structures and several searching strategies, based on specific problem characteristics, are discussed. Preliminary computational experience, performed on several instances, shows that this approach is flexible, effective and able to handle several variations on the problem structure.

2 Problem characteristics and solving techniques

The description of the Unit Commitment problem, presented above, clearly shows that two types of decisions need to be made: decide the state of each unit for each period of time, modeled as binary variables; and decide the units output power, modeled as continuous variables. While the second set of decisions leads to a nonlinear optimization problem and can be easily solved through standard nonlinear techniques, the first set of decisions (Unit Commitment) leads to a combinatorial optimization problem. The problem is hard to solve and, for real size problems, there are no efficient optimization techniques available. Therefore, heuristic approaches are used to find satisfactory (not necessarily optimal) solutions within the time available for decision making.

During the last decades, several approaches have been developed to solve the Unit Commitment problem. Traditional approaches are, for example, priority-list based methods, Dynamic Programming and Lagrangian relaxation [7].

In this context, priority-list based methods are considered to be the simplest methods [9]. In such methods, which are often the support for heuristic algorithms and expert systems software, the units are committed/decommitted according to a merit list, based on a merit function (e.g. full load average production costs). Unfortunately, they do frequently lead to unsatisfactory results and more sophisticated methods must be considered. On the other hand, Dynamic Programming [3], though leading to optimal results, has the major problem of suffering from the "curse of dimensionality". Therefore, it is not applicable for real large scale problems. In what concerns Lagrangian relaxation [1], it has already proved to have a great potential, when large scale systems are studied. It aims at generating feasible solutions, while minimizing the duality gap. However, there is a big difficulty in obtaining feasible solutions, due to the dual nature of the algorithm.

Trying to overcome the major drawbacks that the previous methods present, some attention has been given to metaheuristics [6] in the last few years. Due to their efficiency and their interesting design and implementation features, metaheuristics have been used for a long time, with success, in dealing with other single objective combinatorial problems. In what concerns the Unit Commitment problem, the results obtained by these approaches ([2], [11]), along with some interesting algorithmic features (such as flexibility and easy configuration), are particularly encouraging for further research in this area. In fact, due to their flexibility, metaheuristics are capable of easily incorporating new information in the problem, without a big effort in updating software that has already been developed. Therefore, studying different scenarios of the same problem turns out to be reasonably simple.

3 A metaheuristics approach to the Unit Commitment problem

In this section two coding schemes for problem solutions, are presented. While the first coding scheme is a binary matrix, and is often used to represent Unit Commitment problems' solutions, the second is an integer representation of the solution that is particularly interesting because it can efficiently check if minimum up/down constraints, that force units to remain in a given state for a certain amount of time, are verified. Some new neighbourhood structures are also presented and searching strategies, based on particular characteristics of the problem, are discussed.

3.1 Coding schemes

In metaheuristics reported in the literature, for solving the Unit Commitment problem, a solution is represented by a binary matrix, where each column represents the operation schedule of one unit over the planning horizon ([5], [10]) and each element of a column represents the state of that unit, at a

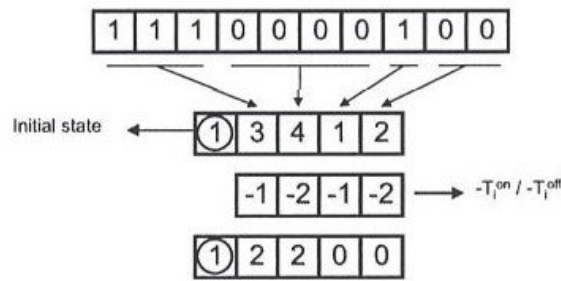


Figure 1: Solution Coding

given period of time. This scheme is particularly interesting because it is a direct natural representation of the problem solution. However, when simple neighbourhood operations are applied to the solution, they often lead to non-feasible solutions and a large effort must be done in order to recover feasibility.

In this paper we propose a different coding scheme. To build this scheme (Figure 1), one starts by representing a solution in its traditional form, with a vector associated to each production unit (1 's mean that the unit is *on*; 0 's mean that the unit is *off*). Then, a new (integer) coding is built with the first element representing the initial state of each unit and the following elements representing the number of consecutive periods that a unit remains in a given state. Finally, for each element in each column (except for the first one) the minimum up/down time value (T_i^{on}/T_i^{off}), that forces the unit to remain in a given state for a certain period of time, is subtracted. This final structure is particularly suitable for checking the minimum up/down time constraints. In fact, a sufficient condition for these constraints to be verified, is that each value in the array is greater or equal to zero.

3.2 Neighbourhood structures

In metaheuristic approaches for solving the Unit Commitment problem that can be found in the literature, the neighbourhood operations tend to be focused on the bit level (e.g. randomly choose a unit i and a period t and change the state of i in period t ([4], [5])). In this paper, neighbourhood operations that deal with blocks of data are considered. By doing so, we take advantage of specific features of the problem and aim at obtaining more efficient algorithms.

Neighbourhood structure 1

Neighbourhood structure 1 is defined in the following way: for a randomly chosen unit i , all periods t associated with transitions of state, are detected. Then, a value of t is randomly selected in the set of transition points and: 1) the state of unit i in period t is changed; or 2) the state of unit i is changed for all periods between t and the next transition point t_1 , if the number of periods between t and t_1 is smaller than a given value n , previously defined (Figure 2).

Neighbourhood structure 2

Neighbourhood structure 2 aims at suppressing states of "short duration". A parameter d , defined at the beginning of the search, must therefore be considered and, if one unit remains in the same state for less than d consecutive periods, that state is said to be a "short duration state". During the search, a unit i is randomly selected and "short duration states", for that unit, are detected. Finally, based on a probability function, which depends on the load forecasted for that period, a "short duration state" is chosen and suppressed (Figure 3).

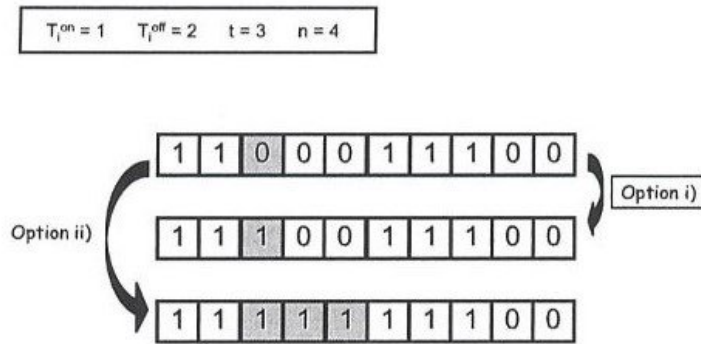


Figure 2: *Neighbourhood Structure 1* (represented in the basic coding scheme)

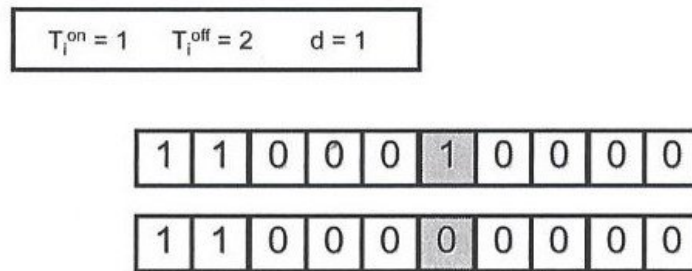


Figure 3: *Neighbourhood Structure 2* (represented in the basic coding scheme)

4 Preliminary results and future developments

In this paper, the Unit Commitment problem has been presented and a resolution approach based on Simulated Annealing has been proposed. With the aim of improving the efficiency of the algorithm, particular attention was given to the solution coding and neighbourhood structure. Two alternative solution coding schemes (a binary and an integer one) were defined and neighbourhood structures, that consider specific problem characteristics, have been developed, evaluated and compared. As a first step to perform this evaluation, a simple SA algorithm, that was parameterized through straightforward experimentation, has been deployed. Preliminary computational results, when compared with those described in the literature, show that the approach is flexible, effective and able to handle several variations in the problem structure.

In the near future, new searching strategies will be developed in order to improve the efficiency of the current implementation. Other metaheuristics (Tabu Search, GRASP and hybrid heuristics) will also be implemented and, following the line of some of the authors' previous research [8], particular attention will be given to multiobjective versions of the problem.

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