Applying VNS with ILP neighbourhoods on EURO/ROADEF 2010's challenge scheduling problem of nuclear power plants' outages and refuelings

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Integer Linear Programming (ILP) solvers made recent progress with heuristics based on the linear relaxation, variable fixing, or some branching strategies (see [6]). It allowed to speed up ILP resolution to optimality, improving convergence of primal bounds. An other consequence is that it allowes to use a Branch&Bound solver in a heuristic mode.

Our previous contribution in META (see [1]) developped how to use such fonctionnalities in a VNS scheme defining neigbourhoods with ILP. This allowed to have an hybrid method, combining Variable Neighbourhood Search (VNS, see [4]) and exact method intelligences, that can be used to tackle big size instances for industrial real life problems modelled in ILP. The application presented was a discret ILP model of Unit Commitment Problem developped in [2].

We develop here the VNS approach on the problem given EURO/ROADEF 2010's challenge, scheduling nuclear power plants' outages and refuelings. The problem is defined and a MILP formulation is given in [3], we consider the deterministic version on the average scenario.

1 Implementing a VNS scheme with ILP neighbourhoods

We remind first the approach we used in [1], using ILP neighbourhoods in a VNS scheme. VNS basic idea is to consider different types of neighbourhoods, and to change systematically the type of neighbourhood within a local search, to have less local extrema with better primal bounds. A local extrema for the VNS is indeed a local extrema for all considered neighbourhoods.

The method requires an initial solution. Our VNS scheme improves this solution in a steepest descent procedure, with variable neighbourhoods. The neighbourhoods are defined by fixing some variables in the original ILP to its value in the current best solution. It assures that the considered ILP is feasible, and the current solution is given to the ILP solver as warmstart. The solution provided after a defined resolution time limit (depending on the types of neighbourhood) is thus the next best current solution. A large number of neighbourhoods types can be defined. The stopping criteria could be a defined time limit, a defined number of iteration without improvement, or till there is no improvement on different types of neighbourhoods.

This heuristic method is generic for an ILP, and easy to implement. Indeed, solution costs are computed directly with the ILP solver, and the current best solution stays always feasible for all the initial constraints, which is convenient for very constrained problems where most of classical local search procedures require to penalize constraint violations to explore a connected feasibility domain. However, these local improvements are more time consuming than other heuristics', it is balanced with the large size of the neighbourhoods, and the progress on the ILP primal heuristics to have quickly good solutions in these large neighbourhoods. This approach can be naturally parallelized, considering parallely different types of neighbourhoods.

An ILP solver like Cplex is convenient for such use. Fixing variables in the original ILP leads to a small ILP after preprocessing and variable elimination, specially when variable fixing implies other fixing through some coupling constraints. Here, we just need to improve in a short resolution time the initial solution given as warmstart, which is very helpful for ILP solvers, the effort is to emphasize primal bounds improvement. This is parametrized through branching strategies (more diving in the Branch&Bound tree), higher frequency of primal heuristics, or limitting resolution time for cutting planes passes and preprocessing which are efficient only for computation to optimality. A generic resolution mode which emphasizes the primal bound can be generally defined for Cplex with parameter `mipEmphasis`.

2 A MILP formulation for the EURO/ROADEF 2010's challenge

We will present for this conference a MILP formulation for the EURO/ROADEF 2010's challenge. Our formulation has similarities with the one developped in [3], considering the deterministic case, only one stochastic scenario. In both formulations, constraints CT6 and CT12 are omitted, leading to a MILP formulation where the only binary variables are the outages weeks decisions, other kind of variables (generated power, refuelings, fuel stock) are continuous.

A first difference is in the binary variable definitions, we define $d_{i,k,w}$, for all nuclear power plant i, weekly time step w and production cycle k with $d_{i,k,w} = 1$ if and only if the outage beginning week for unit i's cycle k is before week w where variables $x_{i,k,w}$ in [3] are equal to 1 if and only if outage beginning week for cycle (i,k) is exactly w. These two variants are similar to those in [2]. With variables x, definition leads to SOS constraints, only one variable $x_{i,k,w}$ is equal to 1 for (i,k) given. With variables d, contraints $d_{i,k,w} \leq d_{i,k,w+1}$ can be used for clique cuts generation, and lead to efficient branching with classical branching rules implemented in Cplex.

Moreover, light constraints are proposed for CT6 and CT12. For CT6, it implied to add a consequent number of variables and constraints, and that led to untractable formulations for a straightforward resolution with Cplex with real size instances.

3 Implementing VNS for EURO/ROADEF 2010's challenge

The implementation used OPL modeling language to solve ILP with Cplex. We used the ROADEF challenge dataset, with a preprocessing to aggregate scenarios and daily time steps to weekly time steps. Our MILP formulations allowed to build initial solutions with some POPMUSIC decomposition strategies.

VNS neighbourhoods definition is generic here, it consists to define restricted time windows around the initial solution. Some strategies can be defined, a constant tolerance around the initial solution, a degressive tolerance smaller for the nearest stops, reoptimizing only a subset of units in the maximal time windows or a subset of cycles.

VNS approach with all the previous neighbourhoods gave outstanding results. Moreover, this allowed to have industrial application results, being able first to price the financial cost not to consider stretch constraints in the model. At last, we were able to estimate the quality of local extrema of the ORION approach developped and used operationally in EDF and so to price the importance of each type of neighbourhood.

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