A branch-and-check approach to solve a wind turbine maintenance scheduling problem

Aurélien Froger[a], Michel Gendreau[c,d], Jorge E. Mendoza[b], Eric Pinson[a], Louis-Martin Rousseau[c,d]

[a]*L'UNAM Université, Université Catholique de l'Ouest, LARIS EA7315, Angers, France*
aurelien.froger@uco.fr, eric.pinson@uco.fr
[b]*Université François-Rabelais de Tours, CNRS, LI EA 6300, OC ERL CNRS 6305, Tours, France*
jorge.mendoza@univ-tours.fr
[c]*Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT), Montréal, Canada*
michel.gendreau@cirrelt.ca, louis-martin.rousseau@cirrelt.net
[d]*Department of Mathematics and Industrial Engineering, Ecole Polytechnique de Montral, Montréal, Canada*

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Driven by climate change mitigation efforts, wind energy has significantly increased in recent years. In this context, efficient wind turbine maintenance planning and scheduling becomes a critical tool to prevent unnecessary downtime and excessive operational costs. We discuss here a challenging maintenance scheduling problem rising in wind farms. We address the problem on a short-term horizon considering an individual management of the technicians through a space-time tracking. The objective is to find a maintenance plan that maximizes the production of the turbines while taking into account wind predictions, multiple task execution modes, and task-technician assignment constraints.

We solve the problem taking advantage of its intrinsic decomposition into a scheduling problem on the one hand and into a resource management problem on the other hand. The scheduling problem consists in building a maintenance planning in order to maximize the wind energy production. If we assume a fixed maintenance planning, the resource management problem checks if the technicians requests can be satisfied while meeting the location-based incompatibility constraints and coping with individual resource availability periods. Note that an optimal solution of the scheduling problem leading to a feasible resource management problem is optimal for the whole problem. To efficiently solve the problem while exploiting this decomposition, we develop a branch-and-check approach (Thorsteinsson, 2001). Since the sub-problem does not possess the integrality property, we invalidate infeasible solutions of the relaxed master problem using combinatorial Benders' cuts as introduced in (Codato and Fischetti, 2006). However, generating cuts stating that at least one variable of the master problem must change value may lead to a very slow convergence, so we use those cuts as a last resort. We solve beforehand the linear relaxation of the sub-problem to identify potential violated Benders feasibility cuts. We also build up alternative cuts by approximating the sub-problem by a b-matching problem and a maximum-weight clique problem. These approximations allow us to potentially identify multiple cuts. Since these cuts are expressed using a reduced number of variables of the master problem, they produce stronger combinatorial Benders' cuts too. To speed-up the process, we also generate cuts for non-integer nodes. Last but not least, since the master problem is likely to be difficult to solve, we first solve its linear relaxation using a classic Benders decomposition approach.

We report results on randomly generated instances built with input from wind forecasting and maintenance scheduling software companies. Within a time limit of 3 hours, the method shows an average gap of 1% with respect to the optimal solutions if known (half of the instances are solved to optimally), or to the best found upper bounds otherwise. It significantly outperforms the direct resolution of an integer linear programming model.

Codato, G. and Fischetti, M. (2006). Combinatorial Benders' Cuts for Mixed-Integer Linear Programming. *Operations Research*, 54(4):756–766.

Thorsteinsson, E. S. (2001). Branch-and-check: A hybrid framework integrating mixed integer programming and constraint logic programming. In Walsh, T., editor, *Principles and Practice of Constraint Programming CP 2001*, volume 2239 of *Lecture Notes in Computer Science*, pages 16–30. Springer Berlin Heidelberg.