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EDITORIAL

Special issue on maintenance scheduling: theory and applications

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This special issue of the *Journal of Scheduling* is devoted to maintenance scheduling. This represents a particularly challenging issue faced by many companies across many industries. The allocation, coordination and timetabling of relevant resources are key steps that must be taken so as to perform required work within prescribed time windows whilst respecting priorities and budgets. It is also critical that maintenance scheduling is well integrated into the overall resource planning process. For example, electricity companies deal with many complex demand and maintenance scheduling issues in their power generation facilities (such as thermal or nuclear power plants). As a typical instance, certain types of nuclear power plant must be regularly shutdown for refuelling and maintenance. In such cases, maintenance scheduling is a more critical issue than demand satisfaction, especially when there is uncertainty in demand. The decisions on the energy production rate, refuels and outage scheduling are subject to various types of constraints. A solution satisfies imposed non-linear production profiles, complex fuel variation equations, bounds on refuelling, bounds on stocks, minimum/maximum spacing between maintenance outages, and maintenance resource constraints (material, teams). An additional characteristic of energy production and maintenance scheduling, which makes the problem even more difficult, is that the planning horizon can be long. For example, it can take several years, which leads to a long-term large-scale optimisation problem.

The French Operations Research Society (Recherche Opérationnelle et d'Aide à la Décision ROADEF) has been organising international competitions, referred to as the ROADEF challenges since 1999. These challenges aim to bridge the gap between theory and practice and they allow industrial partners to follow recent developments in the field of Operations Research and Decision Analysis. Moreover, they enable researchers to deal with a complex real-world problem. ROADEF challenges additionally promote industrial and academic collaborations.

ROADEF and the European Operational Research Society (EURO) jointly organised the ROADEF/EURO Challenge 2010 which was dedicated to a large-scale production management problem with varied constraints in collaboration with Electricité de France (EDF). EDF is one of the leading electric utility companies in the world. The organising committee of the challenge consisted of the guest editors of this special issue and received support from the EDF research and development team consisting of Marc Porcheron, Agnès Gorge, Olivier Juan, Tomas Simovic and Guillaume Dereu.

In 2008, EDF power generation facilities represented a total of 98.8 GW of installed capacity. The varied range of EDF facilities mix all forms of energy: thermal (nuclear, coal, fuel oil and gas), hydraulic and other renewable energies. The peculiarity of France is that most of the electricity EDF generates is produced by thermal power plants: 90 %

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in 2008, among which 86 % by nuclear power plants. A mean combinatorial problem arises due to the thermal power plants that have to be repeatedly shutdown for refuelling and maintenance. This outage scheduling problem is an old problem. EDF has been working on it for more than 10 years, but recently, the problem has evolved creating the possibility of improving the reload quantity. The old solution without considering the new capability was not satisfactory for the EDF optimisation team, so they decided to propose the problem as the subject of the ROADEF/EURO Challenge 2010. The problem description, consisting of realistic constraints regarding safety, maintenance cost, logistic requirements and plant operations, was published. Furthermore, real-world industrial instances were made public from the challenge web site (challenge.roadef.org). Then the competition started. The teams were allowed to submit their algorithms to either the *junior* or the *senior* category. In 2010, a *parallel* category was introduced to promote multi-threaded implementation of algorithms and any team was allowed to submit to this category. The challenge was taken on rapidly, so that in a few months, 44 different teams from across the world had registered to compete. 25 different countries participated in the competition from five different continents (Europe, Asia, America, Africa and Australia). It was no more a ROADEF/EURO challenge but a world challenge. After 6 months, the first test on submitted algorithms involved 21 teams from 13 different countries. A new set of five much harder to solve instances was made available after 3 months of work. The qualifying finalists of the ROADEF/EURO Challenge 2010 were invited to present their algorithms in a special session at the 24th European Conference on Operational Research in Lisbon in 2010. Finally, the results were announced at this conference for 16 teams from 11 different countries and five different prizes were given for a total amount of 10,000 Euros.

We sought relevant submissions from the entire scheduling community and invited participants of the ROADEF/EURO Challenge 2010 to contribute to this special issue of the *Journal of Scheduling*. Consequently, we have eight accepted papers. Five papers, four of which competed and made it to the finals at the ROADEF/EURO Challenge 2010, describe different methodologies to solve the real-world EDF instances. The winning methodology of the senior category is presented in "An 0-1 integer linear programming approach to schedule outages of nuclear power plants" by Jost and Savourey. The second ranking approach of the junior category, a three-stage hybrid heuristic, is discussed by Godskesen, Jensen, Kjeldsen and Larsen in "Solving a real-life large-scale energy management problem". Two other competing approaches in the ROADEF/EURO Challenge 2010 are described in "Solving electricity production planning by column generation" by Rozenknop, Calvo, Alfandari, Chemla and Létocart and in "A solution approach based on Benders Decomposition for the preventive maintenance scheduling problem of a stochastic large-scale energy system" by Lusby, Muller and Petersen. A highly competitive approach is presented in "A constraint programming based approach to a large-scale energy management problem" by Brandt, Bauer, Völker and Cardeneo, even though the authors did not participate in the challenge. The rest of the studies deal with different maintenance scheduling problems, including "Mixed integer programming based maintenance scheduling for the Hunter Valley Coal Chain" by Boland, Kalinowski, Waterer and Zheng, "A multi-start tabu search method for a single machine scheduling problem with periodic maintenance and sequence-dependent setup times" by Pacheco, Ángel-Bello and Álvarez, and "Approximation schemes for scheduling on a single machine subject to cumulative deterioration and maintenance" by Kellerer, Rustogi and Strusevich.