Constraint-Based Scheduling for Reducing Peak Electricity Use

Helmut Simonis and Tarik Hadzic*

Cork Constraint Computation Centre
Department of Computer Science, University College Cork, Ireland
{h.simonis,t.hadzic}@4c.ucc.ie

Time variable electricity tariffs have been introduced in many countries to properly price the cost of electricity generation over changing demand at different times of the day. In Ireland, the All Island Electricity Market (`http://allislandmarket.com`) generates a whole-sale market price in half hour time slots, with prices sometimes varying by a factor of three between peak and non-peak periods. The high cost at peak utilization is linked to the use of inefficient, expensive stand-by generation plant with an increased carbon footprint. Shifting large-scale customer demand away from peak utilization increases stability of the national grid, and can possibly delay or avoid heavy investment in new generator capacity.

In Ireland, wind power plays an increasing role as a renewable energy source. Unfortunately, its integration in the national grid is problematic, due to the relative isolation of the Irish electricity grid, and wind energy's time variable, and only partially known, supply level. Matching electricity use to changes in wind energy supply is quite difficult for domestic usage, but can be possible for industrial users, given the right pricing incentive. Widespread adaption of electric cars might be another way of fully utilizing the wind energy potential, but this is still years in the future.

The current adaption of time variable tariffs for large scale electricity users is still quite limited. This is partially due to the cost of the required smart metering tools and the necessary detailed understanding of electrical usage over short time periods, but also due to a lack of decision support tools which allow the exploitation of time variable tariffs to reduce costs. We are trying to fill this gap using constraint programming.

Our current work is therefore focused on the problem of solving industrial scheduling problems considering time variable energy cost, and using available renewable energy in the most efficient way. This requires agile scheduling tools, which can react quickly to changes in prices, while still considering other optimization criteria like product quality, factory throughput and just-in-time production.

Constraint Programming has been a very successful tool in solving large scale industrial scheduling problems [1,5,6], creating flexible scheduling tools for industries in many domains. Its main advantage over competing technologies is

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the ease of adapting a system to a changing environment, and the potential to incorporate user-defined strategies and heuristics besides powerful mathematical reasoning techniques.

So far our work [3,4] has centered on finding lower bounds on the energy cost for a schedule. We have defined and compared multiple models and algorithms which can predict the energy cost of a partially defined schedule. The best results use an adaptation of the Linear Programming model for the cumulative constraint from [2]. Experimental results indicate that very good estimates (better than 98% of the optimal value) can be achieved. Obtaining the lower bounds is a required first step in defining constraint filtering rules which remove infeasible values from consideration during search. We are currently working on these methods for a family of global constraints which combine energy cost considerations with other scheduling concepts for single or multiple machines, or overall, cumulative resource consumption in a factory. At the same time, we are considering scheduling strategies which can help to find good schedules quickly, without exploring a very large search space completely. The resulting tools will then be evaluated on a number of test cases from industry.

Our current methods are focused on industrial scheduling problems for large scale electricity consumers in manufacturing and other industries. But the underlying technology is also applicable in other areas of significant electricity usage like HVAC (heating/ventilation/air-conditioning) for buildings, or cooling systems in the food industry or for data centres. These are domains where there also is significant overlap with other projects in our centre, and existing collaboration within UCC and with industrial partners.

References

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