Review Report of the PhD Thesis

"Scheduling under energy consumption limits" by Mr. István Módos,

Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Control Engineering

Reviewer: Prof. Dr. Iiro Harjunkoski, Hitachi-ABB Power Grids / Aalto University

Overview

A PhD Thesis summarizes the main results of work done over several years, showing the maturity gained through many academic and industrial interactions and trial-and-errors on trying to create new methods and solutions to complex problems.

The main goals of the considered work are in short: 1) study relevant literature, 2) formalize the scheduling problem, 3) investigate the proposed scheduling problem and design algorithms for solving it and 4) experimentally evaluate the performance of the developed algorithms.

The thesis of Mr. Módos covers all these topics and his work has been published as 4 international scientific journal papers and 4 international conference contributions. The purpose of the thesis is to present this work in an understandable manner and put it into a scientific context proving that it addresses a significant gap in the scientific literature and that the results and conclusions are relevant and make an important contribution to the state-of-the-art. In the following, I will highlight the main findings to the thesis.

Main findings

The definition of the scheduling problem used in this thesis is very much focused on the electricity consumption and ignores many challenging requirements for a realistic scheduling problem (p. 13). This allows the candidate, on the one hand, to fully focus on the dynamics provided by the electricity component but, on the other hand, reduces the applicability of the method. This fact should be systematically acknowledged and clarified.

In the literature review, there are many contributions not cited that are relevant to this thesis. Not having done a full literature review with this thesis in mind I want to highlight two of them.

- In Jain and Grossmann (2001) CP and MILP are used in a hybrid fashion very closely following the same logics and providing cuts to exclude non-optimal solutions. This work is also done on a multiple parallel machine, single-stage problem but lacks the ability to track electricity consumption.
- One of the early papers on demand-side management considering electricity consumption was published by Castro et al. (2009). Here, both continuous and discrete-time approaches were deployed along some aggregation schemes, that are related to this work as well.

The formalization of the scheduling problem is done in a very analytical and thorough manner. This extends any earlier approaches that I have seen and can be seen as a strong contribution, also opening up alternative ways of representing tackling the problem. Nevertheless, the notation of the problems is somewhat cryptic, and this reader would have appreciated reading the problem variant in text form, instead of just a complex formula.

The thesis could benefit from more illustrations and in few cases the Lemma-Proofs could be replaced – or supported – by a simple figure (e.g. 4.39).

In writing the model candidates, disjunctive models could be structured in a clearer manner allowing further simplifications on a logic level. Also, here the logic and binary variables are not at all distinguished. Using indicator constraints for implicit MILP approaches should be avoided as they are solver-specific features that are not mathematically fully sound. These constraints could have been additionally written out without the indicator features as both options can be deployed on selected solvers.

The example problems were solved using a single-thread option, which may result into a negative bias to e.g. Gurobi, quite often having an optimal thread setting of around 8. No solution times are reported, except the time-limit of 600 seconds. These could be relevant for evaluating the applicability to practical problems.

The stochastic studies of the problem focus on building a robust schedule that can satisfy the deviations of a large sample of random problem instances. Using the combination of the developed methods shows good performance to the large-scale problems compared to earlier approaches. The main concern here is that the problem is a single-machine problem with pre-defined product sequence. Thus, the main optimization decision is to map the metering intervals to the scheduling time-indices and therefore it is not clear whether the methods are fully applicable to real-life problems.

The conclusions and future work are well-motivated, however, I want to bring to the attention the contribution of Zhang et al. (2017), which partly addresses the questions listed in the 3rd point of future work.

The thesis contains some mistakes and typos, which do not compromise its scientific contribution.

Summary

The thesis is well structured and shows solid understanding of the underlying mathematics and available optimization technology. The candidate has also built several efficient heuristics, which are deployed intelligently to solve large-scale problems. He can illustrate their applicability especially to the single-machine problem with pre-defined delays.

There are definitely room for improvement, as seen in the main findings, but the suggestions are mainly related to the presentation quality and lacking overview of literature, not directly lowering the scientific quality of the work.

The candidate has clearly demonstrated his ability to conduct independent research on a novel concept and to communicate the results in an accessible way. Therefore*, I am happy to recommend the approval of his PhD Thesis*.

I do hope that the above main findings are helpful to the candidate and can support his future research career.

Iiro Harjunkoski, Research Fellow / Adjunct Professor

Hitachi-ABB Power Grids
Kallstadter Str. 1
68309 Mannheim
Germany
iiro.harjunkoski@hitachi-powergrids.com

School of Chemical Engineering
Aalto University
Kemistintie 1, 02150 Espoo
Finland

Questions

1) How applicable is the developed method to cover more complex but very relevant and frequent scheduling constraints, i.e. sequence-dependent changeover times?
2) How do the cuts in principle deviate by those developed by Jain and Grossmann (2001)?
3) How close to the current work can discrete-time RTN come and what are the main drawbacks / benefits of the proposed methods compared to it?
4) How would you embed more stochasticity into the problem, i.e. one cannot know exactly how large deviations happen and when?
5) What should be done to expand the presented work towards multi-machine problems, where the sequence of jobs should be optimized?

References

Jain, V., & Grossmann, I. E. (2001). Algorithms for hybrid MILP/CP models for a class of optimization problems. *INFORMS Journal on Computing, 13*(4), 258-276. doi:10.1287/ijoc.13.4.258.9733

Castro, P. M., Harjunkoski, I., & Grossmann, I. E. (2009). New continuous-time scheduling formulation for continuous plants under variable electricity cost. *Industrial and Engineering Chemistry Research, 48*(14), 6701-6714. doi:10.1021/ie900073k

Zhang, X., Hug, G., & Harjunkoski, I. (2017). Cost-effective scheduling of steel plants with flexible EAFs. *IEEE Transactions on Smart Grid, 8*(1), 239-249. doi:10.1109/TSG.2016.2575000