22. 2. 2017

DR. PASCALE BENDOTTI
Expert Research Engineer
pascale.bendotti@edf.fr

Electricité de France R&D
Département OSIRIS
7 Bld Gaspard Monge
91120 Palaiseau France

February 16, 2017

REFEREE REPORT ON THE DOCTORAL THESIS

Long-term combined heat and power production and trade planning

by Michal Dvořàk

Summary
This doctoral thesis deals with different aspects of the production and trade planning problem for a combined heat and power (CHP) plant. The thesis is subdivided into six chapters. Chapter 1 provides an introduction to the CHP plant operations planning and defines the goal of this thesis, while chapter 2 presents the state-of-the-art. The next two chapters are the core of this thesis : chapter 3 gives the framework for modelling CHP plant operations and chapter 4 the proposed algorithm for solving the production and trade planning problem for a CHP plant. Chapter 5 shows numerical comparative results using the proposed algorithm and an efficient commercial solver for Mixed Integer Linear Programming (MILP). The results are relative to several sets of instances derived from real-word data of three different CHP plants. Finally chapter 6 draws some conclusions.

Evaluation
The topic of this thesis is interesting and this work gives a valuable contribution to the area. There are some aspects that I suggest to revise in order to improve the quality of the thesis. Detailed comments are reported in the next section.

I appreciated very much this PhD thesis because it deals with a relevant optimization problem arising in real-world applications – this means taking care of all the details on the way. This contrasts in a positive way with what happens quite frequently, in case a PhD thesis presents good results on selected aspects partially unrelated.

I believe the candidate's work shows a good understanding of Mathematical Programming techniques, as well as some good knowledge of what needed from the problems at hand. Though the principle of the proposed algorithm is not completely novel, I believe this thesis makes use of different techniques in an extremely sophisticated manner, thus leading to a very convincing combination.

Detailed comments
From the introduction in **chapter 1** it is clearly stated that the aim is to provide a user with a comprehensive plan defining how to operate the different components involved in a CHP plant and which standard electrical power products to buy or sell. The objective of the planning is to maximize the profit of the plant. The problem is presented as long-term. The considered time period is one hour and the horizon varies from one week to one quarter, thus suggesting rather a mid-term or even a short-term problem. The terminology may differ depending on the context. Referring to the so called Unit Commitment Problem (UCP), a long-term problem is more appropriate to decide from the values of assets the opportunity to build new plants or decommission old plants. I found it rather confusing on the one hand to think of the problem as long-term, on the other hand to consider modelling details, as given in chapter 3, that would more naturally fall into the short or mid-term paradigm. A more standard practice

22.2.2017

Dr. Pascale Bendotti
Expert Research Engineer
pascale.bendotti@edf.fr

Electricité de France R&D
Département OSIRIS
7 Bld Gaspard Monge
91120 Palaiseau France

February 16, 2017

Referee report on the Doctoral Thesis

Long-term combined heat and power production and trade planning

by Michal Dvořàk

Summary

This doctoral thesis deals with different aspects of the production and trade planning problem for a combined heat and power (CHP) plant. The thesis is subdivided into six chapters. Chapter 1 provides an introduction to the CHP plant operations planning and defines the goal of this thesis, while chapter 2 presents the state-of-the-art. The next two chapters are the core of this thesis : chapter 3 gives the framework for modelling CHP plant operations and chapter 4 the proposed algorithm for solving the production and trade planning problem for a CHP plant. Chapter 5 shows numerical comparative results using the proposed algorithm and an efficient commercial solver for Mixed Integer Linear Programming (MILP). The results are relative to several sets of instances derived from real-word data of three different CHP plants. Finally chapter 6 draws some conclusions.

Evaluation

The topic of this thesis is interesting and this work gives a valuable contribution to the area. There are some aspects that I suggest to revise in order to improve the quality of the thesis. Detailed comments are reported in the next section.

I appreciated very much this PhD thesis because it deals with a relevant optimization problem arising in real-world applications – this means taking care of all the details on the way. This contrasts in a positive way with what happens quite frequently, in case a PhD thesis presents good results on selected aspects partially unrelated.

I believe the candidate's work shows a good understanding of Mathematical Programming techniques, as well as some good knowledge of what needed from the problems at hand. Though the principle of the proposed algorithm is not completely novel, I believe this thesis makes use of different techniques in an extremely sophisticated manner, thus leading to a very convincing combination.

Detailed comments

From the introduction in **chapter 1** it is clearly stated that the aim is to provide a user with a comprehensive plan defining how to operate the different components involved in a CHP plant and which standard electrical power products to buy or sell. The objective of the planning is to maximize the profit of the plant. The problem is presented as long-term. The considered time period is one hour and the horizon varies from one week to one quarter, thus suggesting rather a mid-term or even a short-term problem. The terminology may differ depending on the context. Referring to the so called Unit Commitment Problem (UCP), a long-term problem is more appropriate to decide from the values of assets the opportunity to build new plants or decommission old plants. I found it rather confusing on the one hand to think of the problem as long-term, on the other hand to consider modelling details, as given in chapter 3, that would more naturally fall into the short or mid-term paradigm. A more standard practice

tightening bounds, defining windows to relax binary variables in segments following the currently solved segment, using enhanced bounds derived from the second cooperating part. Second the Customized B&B (CBB) algorithm is based on a B&B enumeration tree with improved bounds coming from Lagrangian multipliers. Such multipliers are obtained through iterations to solve a Lagrangian relaxation. To reduce the impact on performance, a limited number of iterations are performed to update the multipliers used in the CBB.
- In (3.14), two sets of variables are defined, while equality (3.15a) could be used to eliminate one.
- One question is why using two sets of variables instead of one. It could be equivalent, but not necessarily. In particular when it comes to dropping variables, the equality should be transformed into two inequalities, which could lead to different bounds. Some explanations would be needed.

The branching paragraph is interesting but not enough details are provided to understand what is done and the benefit from an experimental point of view.
- I suggest to make the connection between the clique inequalities (4.18) and the concerned constraints of the model.
- The comment relative to the number of branching variables to be considered depending on the number of processors available is not clear. More details should be provided along with what has been used for the numerical results.

In **chapter 5** numerical results are presented to evaluate the performance of the proposed algorithm. To assess its efficiency, a comparison is performed using a commercial MILP solver. For instances with weekly and monthly planning, the commercial solver tends to outperform the proposed algorithm. It is worth noting that the difference in terms of running time is not significant (no more than six minutes). The proposed algorithm is expected to demonstrate better performance for larger instances. The results with respect to the instances with quarterly planning tend to confirm the expected trend. Table 5.5 shows that the proposed algorithm outperforms the commercial solver, especially in terms of running time. However the set of four instances is too small and even compared to the other three sets with ten instances considered for shorter planning (weekly and monthly).
- Tables presenting results relative to a larger number of instances with quarterly planning would be needed in particular to assess the efficiency of the proposed algorithm with this type of instances.

The author of the thesis proved to have an ability to perform reasearch and to achieve scientific results. I do recommend this thesis for presentation with aim of receiving the Degree of Ph.D.

Dr. Pascale Bendotti