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Combined heat and power production planning under liberalized market conditions

Michal Dvořák*, Petr Havel

Czech Technical University in Prague, Faculty of Electrical Engineering, Department of Control Engineering, Karlovo náměstí 13, 12135 Praha 2, Czech Republic

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ABSTRACT

This paper presents a methodology for optimization of technological operations in a CHP plant and for simultaneous planning of electricity trading with profit maximization being the objective. A general modelling framework is developed, which is aimed at rapid CHP plant models prototyping using an object-oriented modelling language. The framework consists of two main parts – first-principle models of technological components and a model of trading with standardized power products on power markets. The complexity of models is chosen considering their further implementation within a mixed-integer linear optimization problem. The choice of linear and piece-wise linear problem formulation results from the need of its applicability for practical problem instances, while non-linear descriptions usually involve unacceptable computational times. Using the proposed methodology and general-purpose solver Gurobi, optimal solution for short-term problems (24–48 h) are found within few minutes. In the case of medium- and long-term problems (weeks to months), near optimal solutions (with an error usually under 0.5% and 1.0% respectively) are found within 2 h.

1. Introduction

The main task of district heating plants with combined heat and power (CHP) production is to supply a district with heat. Additionally, these plants often supply industrial processes with hot water and/or steam and trade the cogenerated electricity on power markets. CHP plants are therefore very complex systems and planning of their technological operations represents a very complicated problem. The recent liberalization of energy markets brought additional degrees of freedom (market opportunities) which made the problem even more difficult. Before the liberalization CHP plants usually generated as much electricity as possible considering the heat demand which the plant is obliged to satisfy. However, after the liberalization, electricity is typically traded in the form of standardized power products on power markets. The delivery pattern of a power product is strictly specified and any deviation is penalized. Therefore, apart from the plan of technological operations also a combination of different power products to be traded is sought. In this paper this task is formulated as an optimization problem and an approach for its solving is presented.

The goal is to provide a methodology general enough to be usable for any district heating plant. The methodology should handle real-world instances of the problem and solve them in reasonable computational times.

1.1. Literature survey

In order to formulate the optimization problem a model that describes the system is needed. In literature two basic approaches for CHP plant modelling were used

- black-box approaches using data interpolation [1] or defining operating regions of whole CHP plants [2] or of individual components [3]
- and first-principles approaches employing balance equations [4–9].

The main advantage of the first-principles approach is its generalization capability. It can therefore be used even when historical data are not available or incomplete and it can offer solutions that were not considered before. On the other hand a black-box model can credibly propose only solutions that are included in the historical data it was identified from. If the historical data is incomplete simulations of a first-principle model may be performed to obtain the missing data needed for regression analysis as was shown in [10].

* Corresponding author. Tel.: +420 224355788.
E-mail addresses: michal.dvorak@fel.cvut.cz, dvorak.mich@gmail.com (M. Dvořák).

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