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An effective heuristic for combined heat-and-power production planning with power ramp constraints

Aiying Rong *, Risto Lahdelma

University of Turku, Department of Information Technology, Joukahaisenkatu 3, FIN-20520 Turku, Finland

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Abstract

Combined heat-and-power (CHP) production is an increasingly important technology for its efficient utilization of primary-energy resources and for reducing CO_2 emissions. In the CHP plant, the generation of heat-and-power follows a joint characteristic, which makes the determination of both the marginal power production cost (MPPC) and the feasible operating region for the plant more complicated than for the power-only generation plant. Due to the interdependence between heat and power production, the power-ramp constraints, which limit how much the power production of a CHP plant may increase or decrease between two successive periods, may also imply constraints on the heat production. In this paper, we investigate the impact of power-ramp constraints on CHP production planning and develop a robust heuristic for dealing with the power-ramp constraints based on the solution to the problem with relaxed ramp-constraints (RRC). Numerical results based on realistic production models show that the heuristic can generate high-quality solutions efficiently.

Keywords: Combined heat-and-power production; Energy optimization; Ramp constraints; Deregulated power market

* Corresponding author. Tel.: +358 0 2 3338684; fax: +358 0 2 3338600.
E-mail address: aiyron@utu.fi (A. Rong).

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1. Introduction

Combined heat-and-power (CHP) production means the simultaneous production of useful heat and electric power. When steam or hot water is produced for an industrial plant or a residential area, power can be produced as a by-product. Vice versa, surplus heat from an electric power-plant can be used for industrial purposes, or for heating space and water. The implementation of power-generating capacities on the basis of CHP technologies is one of the most important trends of modern power-engineering development. CHP is considered an environmentally-beneficial technology because of its high energy-efficiency when compared to conventional condensing power-plants. The energy efficiency of a gas turbine is typically between 36% and 40% when used for power production only, but over 90% if also the heat is utilized. This leads to significant savings in fuel and emissions, typically between 10% and 40% depending on the technique used and the system replaced [1].

The world-wide trend towards a deregulated power industry is also resulting in greater interest in efficient utilization of generation resources. CHP is an excellent technology for promoting a fair competition in the deregulated electric power-market, environmental and climate protection, and security of energy supply. The deregulated power-market, where the wholesale price of the power to be freely determined by market demand and supply, has some impacts on power production. Earlier, in the regulated power market, the CHP production planning problem was symmetrically driven by heat-and-power demand. The liberalization of the power market has created an asymmetrical planning problem, where heat is produced to meet the variable demand and the power is produced to respond to the volatile price on the power market [2]. Accordingly, the role of the power-ramp capability of the plants has changed. Earlier, the power-ramp capability was used to provide the spinning and operating reserves of the system and the ramp limits of the plants constrained the contributions of some plants to spinning and operating reserves. Therefore, some plants were started based on the traditional unit commitment (UC) schedule only when the increase in the system load exceeded the capability of on-line plants [3]. Under the deregulated power-market, where payment is based only on energy supplied, the energy producers, who want to maximize their revenue while maintaining the operating limits, prefer to have their plants on-line and loaded near the high economic dispatch limits [4]. That is, ramping is an economic issue for producers rather than a reliability issue for system operations given adequate system reserves: a producer who disregards the ramp-rate issue will be more vulnerable to real-time prices (and possibly penalties) for deviating from their schedule than one who includes it in the scheduling process [5].

Introduction of the competitive market implies that different actors, such as producers, traders, distributors and end customers are exposed to substantial risks caused by volatile market situations. A simple and effective method for risk analysis is based on analyzing multiple randomly-generated scenarios of power-price and heat demand profiles [6–9]. In each scenario, a deterministic long-term planning model is solved. When solving a large number of randomly-generated scenario models, the robustness and speed of algorithms for solving deterministic problems are imperative.

In this paper we address the deterministic CHP production planning problem with power ramp constraints in a general manner for multi-period production planning under the deregulated power market without UC involvement. This problem specification is useful in risk analysis in conjunction with long-term strategic decision-making. Because power-ramp constraints for the plants couple the power production within the time steps