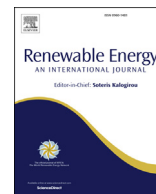




Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Optimal scheduling of demand responsive industrial production with hybrid renewable energy systems

Xiaonan Wang ^a, Nael H. El-Farra ^b, Ahmet Palazoglu ^{b,*}

^a Centre for Process Systems Engineering, Department of Chemical Engineering, Imperial College London, South Kensington, SW7 2AZ, London, UK

^b University of California Davis, Department of Chemical Engineering, One Shields Avenue, Davis, CA 95616, United States

ARTICLE INFO

Article history:

Received 9 March 2016

Received in revised form

12 May 2016

Accepted 14 May 2016

Available online xxx

Keywords:

Demand response

Renewable energy

Contract

Industrial process

Operational optimization

ABSTRACT

This paper presents a methodology for the application of real-time optimization techniques to the problem of optimally scheduling and managing the interaction between electricity providers and users so that the grid and loads can come to an agreement to achieve optimal economic performance. The energy flows in typical industrial processes (e.g., chlor-alkali production) are simulated to illustrate day-ahead scheduling and contract following behaviors, as well as real-time demand response management. A communication and incentive scheme is first proposed for the complete energy scheduling process. Energy management strategies are then developed to realize the objectives of meeting production requirements while minimizing the overall operating and environmental costs through producing, purchasing and selling electricity. The energy contract following and demand response policies are also integrated into the proposed methodology, which appear to reduce uncertainties and help maintain the reliability of the grid.

© 2016 Elsevier Ltd. All rights reserved.

1. Introduction

For industrial processes, short-term production planning or scheduling has gained significant attention over the past two decades [1,2]. It is expected that the estimation of energy consumption associated with production processes will become an important part of the operational scheduling problem, especially as the emerging emphasis on the integration of renewable and smart grid technologies brings in time-varying electricity pricing [3]. When and how much energy is generated and consumed may significantly influence the price of electricity [4]. Previous studies have already considered the impact of varying electricity prices on the production scheduling phase [5]. For example, Nolde and Morari [6] showed that the electricity load tracking in a steel plant can be realized through scheduling of all necessary production tasks, while all energy over- and under-consumption is penalized in terms of fines from the electricity providers. A major focus within the power system research community has been on the use of multi-agent techniques for the communication and scheduling of electricity generation [7]. These studies provide a motivation for

this present work which aims at developing integrated optimal energy bidding and Demand Response (DR) strategies from the perspective of the customers, especially those running energy-intensive industrial processes.

Process industries such as chemicals, paper, iron and steel consume large amounts of electricity, fuel or heat, and also contribute significantly to industrial carbon emissions [8]. A typical example of high electricity utilization with correspondingly high pollutant emissions is the chlor-alkali process, which produces chlorine, caustic soda and hydrogen through the electrolysis of sodium chloride solution whose products are used in over 50% of all industrial chemical processes [9]. Energy consumption of the chlor-alkali plant is so large that it constitutes the key determinant for profitability. Significant research work has been conducted on how to reduce the environmental impact and improve the energy efficiency of the process (e.g., see Refs. [10–12]).

The benefits of integrating renewable energy generation into existing infrastructures have been widely recognized and viewed as an essential component of the future smart grid [13]. Due to the variability and uncertainties of renewable power outputs, the traditionally recognized peak or off-peak hours should be redefined based on the net demand for the smart grid, which equals the total actual demand less the renewable energy generation, as demonstrated in Fig. 1 for a projection of the net demand in 2020 in

* Corresponding author.

E-mail address: anpalazoglu@ucdavis.edu (A. Palazoglu).

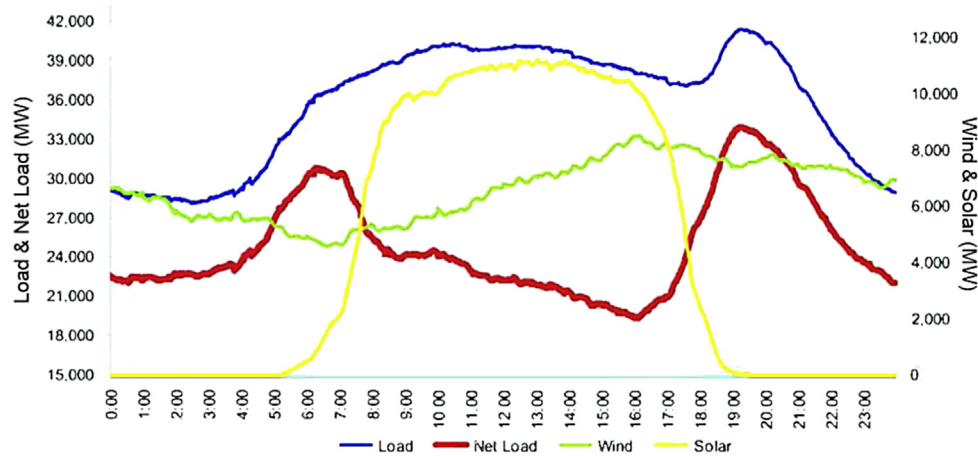


Fig. 1. Projected net demand (load and renewable) profiles in April 2020 (adapted from Ref. [14]).

California [14]. However, the forecasting of the net demand is challenging, as both aspects of energy supply and demand need to be accurately estimated. There currently exists day-ahead scheduling methods for the generation side that include a hybrid system utilizing fossil fuels and renewable generators, such as grid-connected wind turbines and solar panels [15]. The grid at the day-ahead stage has the knowledge and updated information of the available energy generation from all renewable generators, and thus can generate a reasonably accurate supply curve. However, on the demand side, this information is difficult to pin down and requires a meaningful communication link between consumers and utility companies.

It has already been shown that accounting for the varying energy costs over a future time horizon in the production scheduling phase in process systems is both technically feasible and economically plausible (e.g., see Refs. [6,16,17]). The long-term contract strategies have long been in existence for the wholesale electricity market for improved and regulated transmission and distribution [18,19]. To apply a contracting scheme in the short-term market, the time-varying incentive mechanism offered by the smart grid operators needs to make sure that customers are compensated sufficiently to participate in demand management programs voluntarily [20]. Therefore, the grid operators are interested in knowing the users' patterns of electricity consumption, and more importantly, how much power is expected to be sold back to the grid at a certain time when two-way electricity exchange is allowed. This raises the questions of how the user profiles are defined and tracked. Also, it should be noted that a critical trade-off exists between following the contracted electricity profiles and paying for any deviations to maximize real-time profits as the loads change during the day.

Motivated by these considerations, we develop in this work a methodology for the application of day-ahead scheduling and real-time optimization to optimally schedule and manage the interaction between electricity providers and industrial users so that the grid and loads can come to an agreement to achieve optimal economic performance. The methodology is developed and illustrated in the context of a specific case study, which involves a chlor-alkali plant integrated with photovoltaic thermal (PVT) systems, wind energy conversion systems and fuel cells, focusing on the combined problem of supply and recovery of power, heat and materials. The rest of the paper is organized as follows. A communication scheme between the grid operator and the plant operator, along with the system modeling, is first described in Section 2. The formulations of the optimization problems are then discussed in Section 3 from the

day-ahead and real-time perspectives, followed by results and discussion in Section 4 to demonstrate the benefits of the developed demand scheduling structure in reducing uncertainties, stably satisfying production requirements and minimizing overall system economic and environmental costs. Conclusions and future research directions are given in Section 5.

2. Scheduling scheme

There currently exists thorough day-ahead scheduling procedures for the generation side, including not only traditional fossil fuels powered plants, but also some renewable generators, such as grid-connected wind turbines and solar panels [21,22]. The grid at the day-ahead stage has the knowledge of the available energy generation, and thus can demonstrate an estimated supply curve. However, with more uncertainties present on the demand side, it becomes necessary to build a scheduling and communication link between consumers and utility providers. The ultimate goal is to achieve predictable and manageable energy demand curves.

From the user's perspective, the electricity consumption patterns and quantities are first estimated and then communicated to the electricity providers. Based on the historical consumption behavior and current conditions, a contract can be drawn and a price schedule is agreed upon. At the same time, a discounted pricing scheme can be offered to encourage the user to follow the contract that drives the energy demand to follow the supply curves. The day-ahead scheduling scheme with the electricity grid can be carried out at a fixed time on a daily basis, and real-time operational strategies can be updated hourly or on a 15-min basis consistent with the dynamics of the electricity market. For the residential users, it has been common to use pricing incentives to encourage load shifting to help avoid peak hours, and this strategy should also be meaningful for the industrial sector. The communication and scheduling scheme between the smart grid and industrial operators can be conducted through three steps as proposed in Fig. 2. These steps are discussed in more detail in the following sections to illustrate the complete methodology.

2.1. Demand response and scheduling

The smart scheduling and energy contracting between the grid operators and users has been an emerging trend aimed at achieving optimal economic grid performance. The Independent System Operator (ISO) or Regional Transmission Organization (RTO) in North America operates a region's electricity grid, and provides and

Download English Version:

<https://daneshyari.com/en/article/4926755>

Download Persian Version:

<https://daneshyari.com/article/4926755>

[Daneshyari.com](https://daneshyari.com)