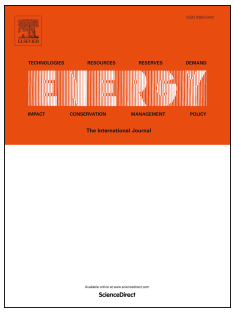
Accepted Manuscript



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PII: S0360-5442(18)30236-6

DOI: 10.1016/j.energy.2018.02.013

Reference: EGY 12313

To appear in: *Energy*

Received Date: 4 September 2017

Revised Date: 2 February 2018

Accepted Date: 4 February 2018

Please cite this article as: Alipour M, Zare K, Seyedi H, A multi follower Bi-level stochastic programming approach for energy management of combined heat and power micro-grids, *Energy* (2018), doi: 10.1016/j.energy.2018.02.013.

A Multi follower Bi-level Stochastic Programming Approach for Energy Management of Combined Heat and Power Micro-grids

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Abstract

This paper presents a multi-follower bi-level programming approach to solve the 24-hour decision-making problem faced by a combined heat and power (CHP) based micro-grid (MG). The framework contains the interests of two different agents: the MG operator/ owner (MGO), who procures the maximization of total profit incurred in attending the forecasted demand of consumers via demand response program (DRP) as well as day-ahead (DA) and real-time (RT) markets participation, and the various CHP owners (CHPOs) who procure the maximization of the profits obtained from the thermal and electrical energy sales. The interaction between the entities is determined in a bilateral contract. Further, to deal with various uncertainties, each level is formulated as a stochastic two-stage problem, where the volatility nature of consumers' loads, RT market price and wind speed uncertainties are modeled using autoregressive moving average (ARMA) technique. In this paper, in order to consider realistic model of the problem, on the contrary to the most CHP-based MG scheduling literature, the network operation constraints such as voltage magnitude of buses and line flow limits are taken into account.

Keywords: Micro- grid owner, Multi-follower bi-level programming, Combined heat and power systems

1. Introduction

Demand response program (DRP) according to the U.S. Department of Energy (DOE) is described as residential, industrial and commercial customers' proficiency to change energy-consumption schemes as a reaction to changes in the electricity price over time, or to incentive fees in order to fulfill reasonable prices and system reliability [1]. DRP also has great influence in reducing peak load, which aids to put off the requirement of generation capacity expansion as well as decreasing carbon footprint by operating a smaller number of generators to supply the peak load [2]. DRP research has recently attracted a great deal of interest from the research community. A review of the demand side management (DSM) policies in UK is presented in [3]. References [4] and [5] introduce different market clearing models regarding the DRP incorporation. A real-time (RT) DRP in response to time-varying market price has been proposed in [6] implementing robust optimization procedures. In [7], an optimization outline is addressed to maximize the DR aggregator profit in the day-ahead (DA) market.

Utilization of micro-grids (MGs) can assist effectual DSM and incorporation of renewable energy sources (RESs) at distribution level [8]. MG can be characterized as a cluster of distributed energy resources (DERs) and associated load that can maintain the operation while being connected or disconnected from the main grid in different circumstances, considering certain constraints [2]. Research on MG concerns has received lots of attention in recent years. In [9, 10], various models have been proposed to optimize the operation of MGs. On the other hand, increasing penetration of volatile RESs in MGs as well as volatile demand and real-time market prices pose several challenges to MGs in order to retain the energy (electricity/heat) production and consumption balance [11]. Hence, a proper wind speed, price and load forecast has a decisive influence on decision making strategies of the MG master.

Recently, using combined heat and power (CHP) systems in MGs has attracted more attention [12]. CHP system is a well-established technology that affords advantages with regard to environmental