Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 142 (2017) 1985–1990

Energy Procedia

www.elsevier.com/locate/procedia

9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK

Combined domestic demand response and energy hub optimisation with renewable generation uncertainty

Da Huo*[a], Chenghong Gu[a], Gang Yang[b], and Simon Le Blond[a]

[a]*University of Bath, Claverton Down, Bath, BA2 7AY, UK*
[b]*DaLian JiaoTong University, No. 794 Huanghe Road, Dalian Shahekou, 116028, China*

Abstract

The optimisation of energy hub modelling at domestic level exploits the redundancy of multiple energy carriers against customers' stochastic demand profiles, and thus increases system flexibility. On the other hand, demand response enables the shifting of deferrable appliances in response to energy carrier price to minimize the system cost and maintain customers' comfortability. Combining demand response schemes with energy hub approach yields further energy cost saving. However, the optimal operation of energy hub system may be affected by stochastic elements. In this paper, the uncertainty of solar radiation is modelled by 2 point estimated method and applied to an energy hub with demand response optimisation. The results demonstrate that incorporating demand response to energy hub optimisation brings 4% of additional energy cost saving for a single energy hub system, and that greater savings can be foreseen for large scale system.

Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.

Keywords: Demand Response; Energy Hub Optimisation; Mixed Integer Linear Programming; 2 Point Estimated Method

1. Introduction

Domestic buildings consume approximately 40% of total society's energy [1, 2]. However, energy efficiency is reduced due to losses during transmission and distribution. The energy hub approach is a viable solution to increase energy efficiency and minimize system cost at domestic level. The energy hub concept coordinates the utilization of multiple energy carriers to optimize the system for minimal energy cost or carbon emissions [3]. From a customer's

* Corresponding author. Tel.: +447450124371.
E-mail address: dh466@bath.ac.uk

1876-6102
Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.
10.1016/j.egypro.2017.12.399

perspective, the utilization of co-generation or tri-generation increases system flexibility by means of exploiting every available energy carrier, whose monetary or environmental cost may be time-dependent. For example, the utilization of different energy carriers could be accordingly adjusted to satisfy the energy demand against time-variant energy tariffs. The energy hub approach at residential level has been the focus of much research. In [4] and [5], a single family house and a group of three houses are modelled as an energy hub system, and a model predictive control (MPC) scheme is applied to optimally determine the system operations. Reference [6] formulates a novel mathematical model for appliances, storage, and renewable generators in a residential hub, and mixed integer linear programming (MILP) method is applied to optimize the energy hub with the consideration of end-user preferences.

On the other hand, demand response schemes are widely employed by domestic customers to shift flexible loads in response to the variation of electricity tariffs to reduce electricity cost or maximize user comfort levels [7]. The energy hub approach provides an enhanced solution for demand response since the electricity demand may be satisfied by exploiting other energy carriers with low costs. Therefore, combining energy hub optimisation and demand response scheme is likely to yield further energy cost saving.

The uncertainty of solar radiation is also considered in this paper. The solar PV generation at each time step is modelled by a random number to reflect the stochastic nature of solar radiation. Much research has been undertaken to model uncertainty elements. Monte Carlo methods have been widely applied to solve the optimal energy management problem with uncertainty [8, 9]. However, the utilization of Monte Carlo methods suffers from high computational burden. To effectively solve the optimisation problems with uncertainties, other modelling methods are proposed. References [10, 11] apply robust optimisation to model the uncertainty, where forecasting techniques are used to build confidence intervals of uncertainty data based on historical data. Additionally, the stochastic data can be modelled by various scenarios to an acceptable level (e.g. 10 scenarios), and each scenario corresponds with a specific probability. Two-stage stochastic programming may be applied to solve the optimisation problem under each scenario [12, 13]. The 2 point estimated method (2PEM) [14] is applied in this paper to simulate the uncertainty of solar radiation into scenarios, and deterministic optimisation can be implemented for each scenario.

This paper is organized in six sections. Following the introduction, the modelling of the domestic energy hub and the solar radiation uncertainty is introduced in section 2. Section 3 describes the demand response scheme. The optimisation problem is formulated in section 4, and the related results are discussed in section 5. Section 6 concludes the paper and suggests future work.

2. Energy hub modelling

A typical residential house is modelled as an energy hub system as shown in Fig. 1. Heating converters including a gas boiler and a micro-CHP are equipped within the hub. Solar photovoltaics (solar PV) are also installed in the energy hub system, and the modelling of solar generation uncertainty is discussed in this section.

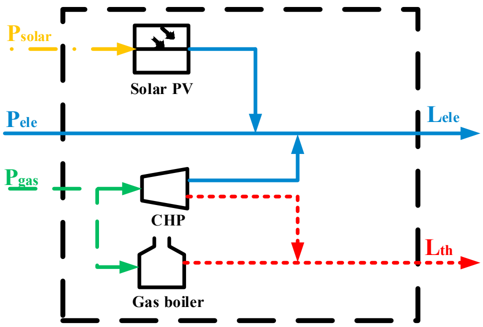

Fig. 1. Single energy hub system

As indicated in Fig. 1, the energy hub consumes solar energy, electricity, and gas through solar PV, micro-CHP, and a gas boiler to satisfy the electricity load L_{ele} and heat load L_{th}. The relation between hub output and input is formulated with a coupling matrix as indicated in equation (1).

The first matrix on the right hand side is the coupling matrix, each element in the matrix represents the relation between hub output and related energy carrier input. The parameter t within the brackets indicates the variables are time dependent. L_{ele} and L_{th} represent the electricity demand and heat demand of the residential hub, P_{so}, P_{ele}, and P_{gas}