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An innovative energy management framework for cooperative operation management of electricity and natural gas demands

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ABSTRACT

Introduction of the power to gas and combined heat and power technologies, has led to remarkable interdependency between electrical and gas systems. By taking advantage of this interdependency, cleaner and more efficient energy management systems could be implemented. This paper attempts to establish an innovative energy management framework which takes advantage of this interdependency and devices like power to gas and combined heat and power to simultaneously smoothen electricity and natural gas demand profiles for a year ahead. The method outperforms this task using the electricity profile valleys to reduce peak natural gas consumption and using natural gas profile valleys to shave electricity consumption peak. In this way, the stress on both networks for supplying demand in peak periods is released. The proposed method is able to achieve demand smoothness and cost reduction objectives considering penalty factors for demand variance. For this purpose, multiple integrated energy hubs are used to simulate the energy consumption of an area. The designed mixed integer linear model is handled by General Algebraic Modeling Software and CPLEX solver. The results demonstrate that by applying the proposed method, the system is able to save 16.92% in the energy cost and decrease electricity and natural gas demand standard deviations by 8.34% and 66.64%, respectively.

1. Introduction

The increasing interactions between electrical and gas systems has led to development of affordable and cleaner energy systems. This has been achieved by introducing the energy hub concept [1], which is an interface among different energy vectors and contains devices such as power to gas systems (P2G), combined heat and power systems (CHP), electric boilers and etc. [2]. Designing a proper energy management structure for these energy hubs can bring many benefits for consumers and environment such as cost and carbon dioxide (CO2) reduction [3]. Recently, there has been a widespread investigation about the P2G systems in literature. The process simply includes conversion of electrical energy to hydrogen (H2) or methane (CH4) via electrolysis and methanization methods, respectively [4]. The produced gas can be stored or directly used to generate electricity or heat [5].

The P2G technology has been used for various purposes in literature. For example, Maroufmashat et al. in [6] have optimized the cost of managing energy in future communities by using hydrogen as an energy vector. They have also determined the optimal size of the electrolyzer and hydrogen storage system used inside the P2G unit. Chen et al. in [7] have studied the effect of uncertainties of both electrical and gas systems on overall operating states of integrated energy systems. It has been found that P2G benefits electrical and gas grids in several ways including curtailment and congestion relief in electricity network, reinforcement of gas network and etc. Authors of [8,9] have studied the role of energy storage in P2G systems. However, Ni et al. in [8] have considered roles of different types of energy storage systems inside an energy hub containing P2G unit, while in [9], Walker et al. have compared P2G with other storage technologies in different applications using Analytical Hierarchy Process. The authors have found that considering criteria such as portability, energy density and ability for seasonal storage make P2G very useful in utility scale energy storage applications. Also, Al Rafea et al. have investigated the integration of renewable energy resources into larger scale fossil fueled combined cycle power plants by considering hydrogen as an energy vector [10]. It has been shown that using hydrogen as a fuel in combined cycle power plants would create extra cost and decrease annual revenues. In [11], Gholizadeh et al. have used P2G to decrease the amount of electrical and thermal load shedding in case of electricity and gas network contingencies. In [12], Antenucci et al. have optimized the placement of P2G stations within the electrical network to allow complete recycling of CO2 emissions of electric power system. Qu et al. in [13] have

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