A two-stage multi-objective scheduling method for integrated community energy system

Wei Lin, Xiaolong Jin, Yunfei Mu, Hongjie Jia, Xiandong Xu, Xiaodan Yu, Bo Zhao

A HIGHLIGHTS

- A two-stage multi-objective scheduling method for an ICES is proposed.
- A multi-objective optimal power flow method is developed as the first stage.
- A multiple attributes decision making method is developed as the second stage.
- The optimal operational schedules of ICES are analyzed under different objectives.

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ABSTRACT

In order to determine the optimal day-ahead scheduling schemes of the integrated community energy system (ICES), a two-stage multi-objective scheduling method (TMSM) was proposed, which consists of a multi-objective optimal power flow (MOPF) calculation stage and a multiple attributes decision making (MADM) stage.

1. Introduction

With the growing concerns over the energy depletion and environmental challenges around the world, increasing attention is being paid to the issues in energy conservation, energy efficiency improvement and emission reduction. The European Union presented its energy targets for 2030, which will attain at least a 40% reduction in greenhouse gas emissions as compared to 1990 level, and increase the utilization of renewable energy to 27% of gross energy consumption [1]. As to the United States, the greenhouse gas emission reduction target will reach 26–28% below the 2005 level by 2025 [2]. The Chinese government has committed to reduce its greenhouse gas emissions per unit of GDP (i.e. carbon intensity) by 40–45% at 2020 [3].

In order to realize these targets, the integrated community energy system (ICES) is attracting more and more attentions in recent years, where heat, gas, and electrical energy are becoming tightly coupled at the community level [4–7]. Compared with electric system, the ICES is not only able to provide new solutions for a more secure, sustainable and economical energy utilization [8], but also beneficial for the improvement of energy efficiency and reduction of greenhouse gas emission [9]. Therefore, the concept of ICES has been applied to practice by a number of demonstration projects in many countries, e.g. the Chilo...
Islands of Chile [8], the Ubiquitous Energy Network in Zhaqing New District of China [10] and the HyLink system at Totara Valley of New Zealand [11].

A number of methods have been proposed to schedule the ICES in an optimal way. An optimal day-ahead scheduling method for the ICES considering the reconfigurable capability of the electric distribution network was developed in [12]. Apart from the target of economy benefit maximization [12], multiple operational objectives were also considered to guarantee the sustainable development of society and environment. The conflicting benefits of electricity and natural gas network were optimized by a coordinated scheduling strategy proposed in [13]. In [14], a multi-objective framework was proposed to address the coordination operation of electricity and natural gas network, where the economic, dynamic security of electricity network and natural gas network were set as the objectives. The energy cost and electrical transmission loss of electricity-gas network were optimized by an improved heuristic method in [15]. Jin et al. [12] concentrated on the optimal economic operation of ICES, but the environmental friendliness and other aspects of the scheduling scheme were not considered. Multi-objective optimization model for integrated electricity and natural gas system was developed in [13–15]. However, the integrated system considered in [13–15] is a transmission level system, in which case the electric and natural gas network were coupled by gas-fired generation units. The “community” of ICES is usually related to urban areas at the distribution level with different sizes (e.g. industrial park, university campus and residential community), which aims to supply the local community with its energy demands [8,16]. And the interactions among various energy systems of ICES are usually realized in the energy centers (ECs), where diverse types of energy conversion equipment are coupled [9].

Therefore, a two-stage multi-objective scheduling method (TMSM) for ICES was proposed, which consists of a multi-objective optimal power flow (MOPF) calculation stage and a multi-attribute decision making (MADM) stage. Five typical indices were considered in the TMSM to characterize the operation of ICES, namely the operation cost (OC) and total emission (TE) of ICES, the power loss (PL) and sum of voltage deviation (SVD) of the electric distribution network, the sum of pressure deviation (SPD) of the natural gas network. The increasing number of objectives would result in computational complexities, such as the inaccuracy of solutions, large computation expense and time consumption. In order to tackle these problems, Huang et al. [17] proposed a method that it extracted the principal target and reduced the number of objectives. By applying this method to the DTLZ5 test function (a multi-objective optimization test function with five objectives), the effectiveness was verified. Inspired by [17] and further considering that five operational indices are worthy of different attention under different operation scenarios, the principal indices are selected based on the analytic hierarchy process (AHP) [18] for a certain operation scenario and further set as the objective functions at the MOPF calculation stage. Operation constraints from the electric distribution network, the natural gas network and the ECs were considered in the MOPF calculation stage. The operational needs of the ICES in...
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