Hierarchical microgrid energy management in an office building

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HIGHLIGHTS

- A hierarchical microgrid energy management method in an office building is proposed.
- An office building is modelled as a virtual energy storage system (VESS).
- A V2B control strategy is developed to dispatch the EVs as a flexible resource.
- The VESS and the EVs are coordinated and dispatched in two different time scales.

ARTICLE INFO

Keywords:
Microgrid
Virtual energy storage system
Vehicle-to-Building
Electric vehicle
Energy management

ABSTRACT

A two-stage hierarchical Microgrid energy management method in an office building is proposed, which considers uncertainties from renewable generation, electric load demand, outdoor temperature and solar radiation. In stage 1, a day-ahead optimal economic dispatch method is proposed to minimize the daily Microgrid operating cost, with the virtual energy storage system being dispatched as a flexible resource. In stage 2, a two-layer intra-hour adjustment methodology is proposed to smooth the power exchanges at the point of common coupling by coordinating the virtual energy storage system and the electric vehicles at two different time scales. A Vehicle-to-Building control strategy was developed to dispatch the electric vehicles as a flexible resource. Numerical studies demonstrated that the proposed method is able to reduce the daily operating cost at the day-ahead dispatch stage and smooth the fluctuations of the electric power exchanges at the intra-hour adjustment stage.

1. Introduction

Increasing attention is being paid to technologies in renewable energy and energy efficiency improvement due to the rapid growth of global energy use and environmental deterioration \cite{1,2}. According to the International Energy Agency, energy consumption of buildings occupies about 32% of the global energy use and they are responsible for about 30% of the total end-use and energy-related CO\textsubscript{2} emissions \cite{3}. As a result, a number of regions and countries have taken specific initiatives to facilitate a high penetration of renewable generation and the low energy consumption technologies in their building sectors, including the European Union \cite{4}, the United States \cite{5} and China \cite{6–9}. In China, the building sector currently accounts for 27.6% of the total energy use and it is estimated to reach 35% by 2020 \cite{6,7}. The Chinese government has paid attention to the retrofits and renovations of the existing buildings, and provided financial support for the energy management in large public buildings \cite{8,9}. Therefore, as the major power consumers at demand side, buildings represent a great potential contributor for reducing the energy consumption and relieving power imbalance of the electric grid.

Aiming to facilitate a high penetration of renewable generation and the low energy consumption technologies at the demand side, there is significant development of low-carbon buildings integrated with renewable generation \cite{10}. However, renewable generation is usually intermittent, uncertain and uncontrollable, which induces power mismatches between power demand and supply for low-carbon buildings \cite{10}. Microgrids provide an opportunity and a desirable infrastructure for facilitating integration of intermittent renewable generation in low-carbon buildings \cite{11}. Microgrids can increase the penetration of intermittent renewable generation and provide an economical energy supply for the low-carbon buildings by utilizing advanced energy management technologies and intelligent communication technologies \cite{12}. The fluctuations of the electric power exchanges at the point of

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http://dx.doi.org/10.1016/j.apenergy.2017.10.002
Received 31 July 2017; Received in revised form 19 September 2017; Accepted 1 October 2017
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Please cite this article as: Jin, X., Applied Energy (2017), http://dx.doi.org/10.1016/j.apenergy.2017.10.002
common coupling (PCC) of a Microgrid can also be smoothed by coordinating and optimizing the operation of various energy sources and energy loads of the Microgrid [13,14]. Therefore, Microgrid energy management in buildings is attracting more and more attentions in recent years.

Studies have been carried out to investigate the Microgrid energy management methods in a commercial building. The operational performance of a Microgrid in a building in Hong Kong was studied considering operating cost and environmental constraints [10]. A multi-objective dispatch model was proposed in [15] to minimize the daily operating cost and the pollutants emission. An electric chiller (EC) was used as the cooling system of a building in [16] and the electric power consumption of the EC was dispatched using a nonlinear programming method for cost saving. In [17], the electric power consumption of an EC was dispatched in the dynamic economic dispatch process with the discrete EC operating constraints. As a flexible resource, the integration of electric vehicles (EVs) to the building is creating new opportunities for the Microgrid energy management [18,19]. EVs have a certain flexibility to shift their electricity consumption in time and facilitate the integration of intermittent renewable generation [20,21]. A Microgrid energy management method in an office building was proposed in [22] to reduce the impact of EV charging on the external grid with different charging strategies being considered. In [23], a Vehicle-to-Building (V2B) operational model was proposed for the EVs to reduce the total energy cost of a Microgrid in a building.

The existing research work has made good contributions to the Microgrid energy management in a building. However, the flexibility of the building with heat inertia hasn’t been fully explored in the Microgrid energy management. As the major power consumer of the Microgrid, a building can perform as a distributed thermal storage to provide thermal energy to the building and adjust the building’s indoor temperature set-points. Therefore, Microgrid energy management in a building with heat inertia has been fully explored in the Microgrid energy management.
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