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Design optimization for the hybrid power system of a green building

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ABSTRACT

This paper proposes an optimal design procedure for a green building equipped with renewable energy, energy storages, and proton exchange membrane fuel cells (PEMFCs). First, we introduce the hybrid power system of the green building and construct a simulation model using Matlab/SimPowerSystem™. The model parameters are tuned so that the system responses can be estimated without extensive experiments in the optimization processes. Second, we define the cost and reliability indexes to optimize the system design using three steps: component selection, component sizing, and power management (PM) adjustment. We further define the safety index to evaluate the system's sustainability under extreme conditions when no renewable energy is available. Last, we apply the proposed procedures to the green building and demonstrate the benefits of the optimal design. The proposed method can be directly applied to develop customized hybrid power systems in the future.

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Introduction

Renewable energy, such as solar and wind energy, has drawn much research attention because of increasing air pollution and decreasing fossil fuel reserves. Nevertheless, the power supply of solar and wind is unreliable because it depends on weather conditions. Therefore, hybrid power systems, which normally consist of several energy sources and energy storage, are usually applied to supply sustainable power. Commonly-used energy sources include grid power, generator, and proton exchange membrane fuel cells (PEMFCs). Among them, the PEMFC is a promising alternative energy because of its high efficient, noiseless, low pollution, and steady power supply. Thus, considerable researches focus on the hybrid power system comprising PEMFCs and renewable energy [1]. For example, Rekioua et al. [2] developed a stand-alone hybrid photovoltaic-PEMFC system. Mezzai et al. [3] proposed a hybrid photovoltaic/wind/PEMFC power model. Ezzat and Dincer [4] integrated fuel cell-photovoltaic system for vehicle application and conducted comprehensive energy and exergy analyses.

The design of hybrid power systems involves determining issues such as the most suitable components, the optimal component sizes, and power management (PM). First, previous research discussed the selection of suitable components according to the location and load demands; for example, Maleki and Askarzadeh [5] used photovoltaic (PV) arrays, a wind turbine (WT), a diesel generator, and a secondary battery to design a hybrid power system in Rafsanjan, Iran. They

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concluded that the system containing the WT, diesel generator, and secondary battery can satisfy the load demand with the least cost. Devrim and Bilir [6] analyzed the weather data in Ankara, Turkey and found that WTs can compensate for PV energy in winter. Therefore, a hybrid WT-PV-battery-electrolyzer-PEMFC system can achieve better performance than a system without a WT. Rezk and Dousoky [7] used HOMER software to optimize performance of stand-alone hybrid systems with six different configurations, which was installed at Minya Governorate, Egypt for water pumping. The PV/FC system was shown to achieve the minimum costs. Second, component sizes were found to have significant impacts on the cost and reliability of hybrid power systems. For instance, Hosseinalizadeh et al. [8] optimized the hybrid systems consisting of PV arrays, WT, and PEMFCs for four cities in Iran. The PV arrays were found to be more beneficial than the WT, thus indicating that using more PV and fewer WTs could reduce the cost. Rezzouk et al. [9] adjusted the component sizes in the Homer simulation to optimize the component life and energy costs by considering the weather and load data. Fathy [10] discussed the optimal size of a hybrid PV/WT/SOFC system in Helwan, Egypt to minimize the annual cost for the required load demands. Third, the PM was also found to affect system costs. For example, Nasri et al. [11] regulated the currents of the PV arrays, the ultra-capacitor, and the PEMFCs to maximize the energy efficiency for different loads. Ipsaki et al. [12] applied management of the PEMFCs and electrolyzer according to the state of charge (SOC) and concluded that PM with a hysteresis band can improve the component life and reduce system costs. Dash and Bajpai [13] formulate a power management strategy to integrate the power output from the PV array, PEMFC, battery, and onsite hydrogen generation by electrolysis.

This paper extends the ideas of previous studies by proposing an optimal design procedure that considers all three factors. The procedure comprises three steps: selecting suitable components, optimizing component sizes, and modifying PM strategies. We apply Matlab/SimPowerSystem™ to build a hybrid power model of a green building that is constructed by China Engineering Consultants Inc (CECI) in Miao-Li county of Taiwan. The model parameters are tuned by experimental data so that we can predict the system responses for different settings without conducting extensive experiments. The component size and PM strategies of the model are optimized iteratively until the optimal results converge. Furthermore, we propose a safety index to evaluate the duration of system sustainability under extreme conditions when no renewable energy is available.

This paper is arranged as follows: Section Hybrid power system of the green building describes the green building and its hybrid power system. Section Hybrid power model applies Matlab/SimPowerSystem™ to build a hybrid power model so that the system responses can be estimated without extensive experiments. Section Load profiles and performance indexes introduces the office load profile and defines the performance indexes for system optimization.

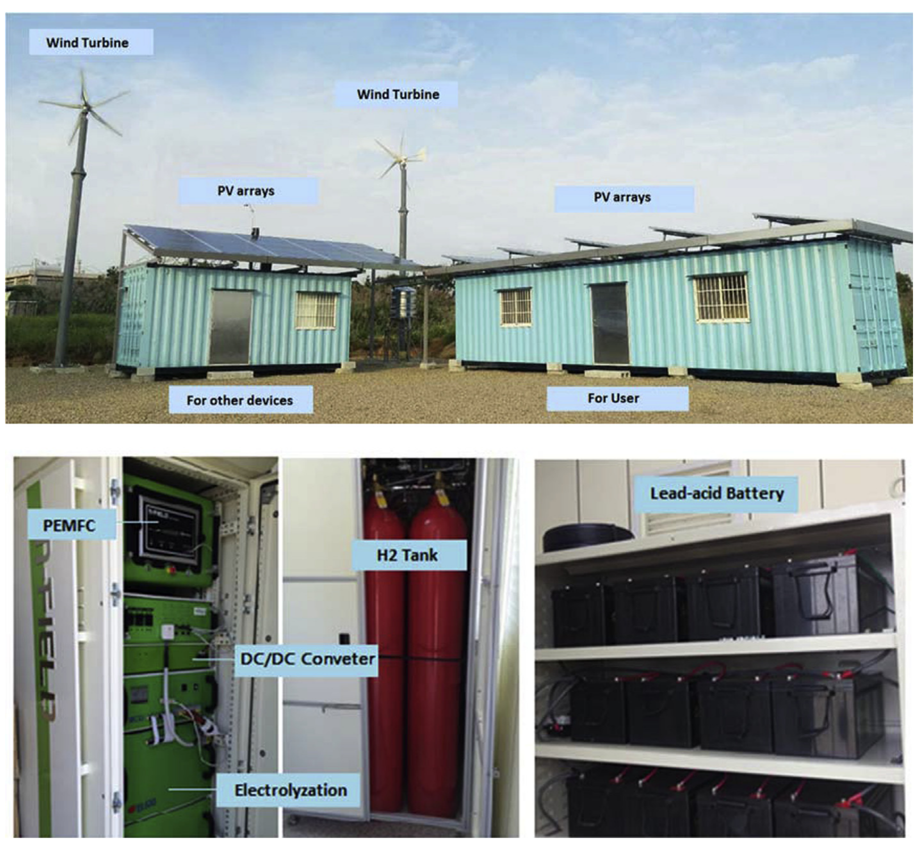

Fig. 1 – The CECI green building [14]. (For interpretation of the references to color/colour in this figure legend, the reader is referred to the Web version of this article).

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