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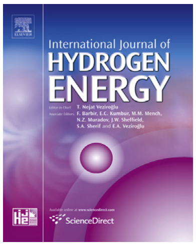

The development and optimization of customized hybrid power systems

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ABSTRACT

This paper develops a hybrid power model that can be used to optimize customized systems. We build the hybrid model in Matlab/SimPowerSystem™, which consists of a proton exchange membrane fuel cell, a Li–Fe secondary battery set, photovoltaic (PV) arrays, and a chemical hydrogen production system. Based on experimental data, we adjust the model parameters and show that the simulation model can correctly predict the experimental responses, with a root-mean-square error of 0.6% in state-of-charge. Therefore, we can apply the model to optimize the design of customized power systems. We consider three load profiles: the lab, the department office, and the household, and modify the sizes of the PV arrays and battery capacities to optimize the system cost for each load. In addition, we analyze the impacts of power management on the system cost. The findings indicate that the developed hybrid power model is effective at estimating system responses, and can significantly reduce the time and cost for developing customized power systems.

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Introduction

Hybrid power systems have drawn much attention in recent years due to increasing energy demands and decreasing fossil fuel resources. However, the development of hybrid power systems for different load requirements can be very costly and time-consuming because of the need to verify the designed systems before implementation. Therefore, many researchers have proposed simulation models for designing hybrid power systems and have integrated different renewable energy sources (RES). For example, Rekioua et al. [1] compared different topologies for the optimization of a hybrid photovoltaic-electrolyzer-fuel cell (FC) system. Zervas et al. [2] proposed a hybrid system based on model-predictive control that combined photovoltaics (PV), an electrolyzer, metal hydride tanks, and a proton exchange membrane fuel cell (PEMFC).

The component sizes and system costs of the hybrid power models can be adjusted and optimized. For instance, Nelson et al. [3] studied a hybrid wind/PV/FC generation system and optimized the component sizes. Zhou et al. [4] discussed the hardware cost of a PV–H_2 system using the developed model and designed energy management strategies to achieve high energy efficiency. Jallouli and Krichen [5] proposed a system sizing technique to minimize components for a stand-alone PV–H_2 system. Elbaset [6] applied the loss of power supply probability to match the load requirements with the optimal component sizes and system cost. Yang et al. [7] built a Hybrid Solar-Wind System Optimization Sizing (HSWSO) model to

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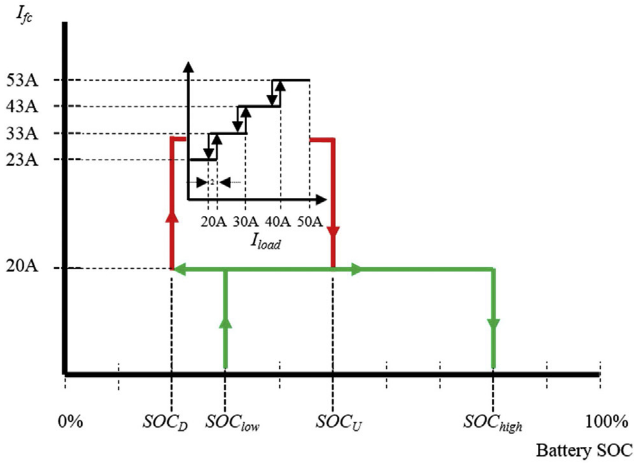
optimize the component sizes with system reliability requirements.

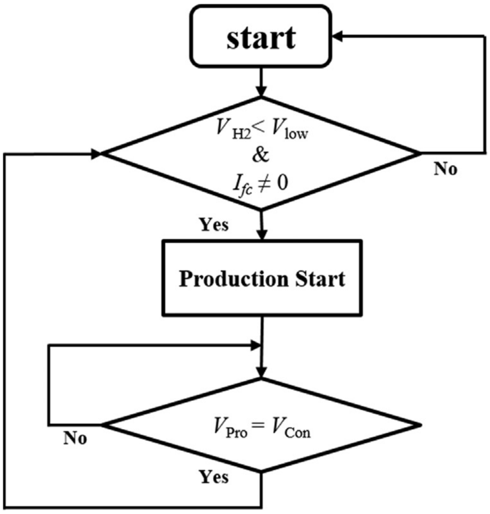
Power management strategies also have a significant influence on system optimization. For example, Wang and Nehrir [8] designed overall power management strategies to adjust power flow among energy sources and storage units for a hybrid wind/PV/FC energy system. Thounthong et al. [9] proposed intelligent fuzzy logic control for a PV/FC/supercapacitor hybrid system. Ipsakis et al. [10] used SOC levels to regulate the power between RES and storage units, and analyzed the sensitivity of SOC levels on system performance. Lund [11] discussed the energy distribution of a large-scale integration of wind, PV, and wave power system by EnergyPLAN. Riffonneau et al. [12] presented an optimal power management mechanism that used dynamic programming and rule-based management for a grid network with connected PV systems and battery storage.

This paper extends these ideas by developing a hybrid power model that can be used for system optimization. We construct a hybrid power system that can provide sustainable electricity. We then develop a hybrid power model using MATLAB/SimPowerSystem™, and modify the model parameters based on the experimental responses. As a demonstration, we apply three load profiles (lab, office, household) to the simulation model, and define the objective function and reliability index for system optimization. In addition, we discuss the effects of power management on system cost.

This paper is arranged as follows: Section The hybrid power system configuration introduces the hybrid power system that consists of PEMFC, PV arrays, a battery set, and a chemical hydrogen production system. The hybrid power system is shown to provide sustainable electricity for the lab. Section Hybrid power model develops the corresponding power model using MATLAB/SimPowerSystem™, and adjusts the model parameters based on the experimental response. Section Load profiles and objective functions introduces three load profiles, and defines the objective function and reliability index for system optimization. Section Optimization procedures and results describes the optimization procedures, and compares the optimization results based on the load profiles. We also discuss the impacts of power management on system costs. We then draw conclusions in Section Concluding remarks.



(a) PEMFC current



(b) Hydrogen production control

Fig. 2 – Power management strategies.

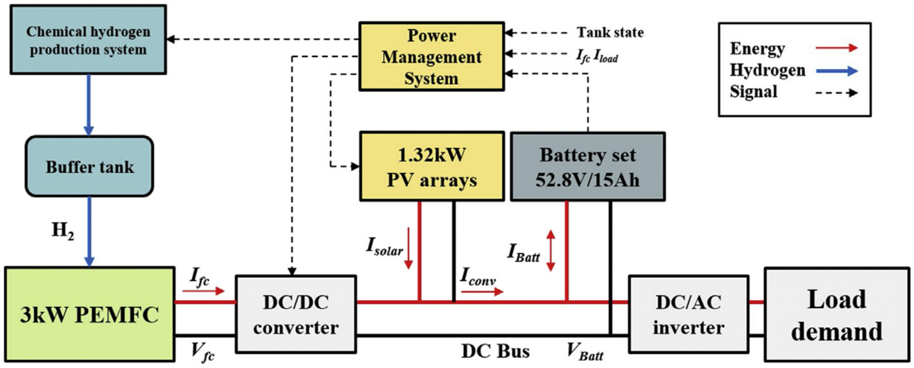


Fig. 1 – Hybrid power system configuration.

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