INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2017) 1–8

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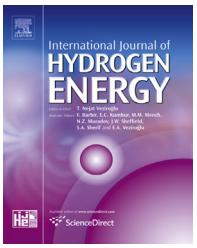

Providing energy management of a fuel cell–battery–wind turbine–solar panel hybrid off grid smart home system

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ARTICLE INFO

Article history:
Received 31 July 2016
Received in revised form
3 February 2017
Accepted 28 February 2017
Available online xxx

Keywords:
Fuel cell hybrid power source
Energy management
Smart home
Load demand management

ABSTRACT

It is important that smart home can use produced energy more effective and obtain optimum economy as well as provide ease of use. With use of fuel cell (FC) as main energy source in an off grid smart home that supplied by alternative energy sources (AES), more quality, economic and eco-friendly energy can be achieved. This off grid smart home system can use auxiliary energy sources with FC to supply instantaneous power and sustainable energy. Therefore, it is needed to develop energy management algorithms (EMA) for AES in smart home systems. These algorithms can be able to respond user's preferences and needs and also enable to benefit optimally from AES. In line with these requirements in this study, an EMA for a smart home, which is equipped with FC, battery, solar panel and wind turbine is presented. A fuzzy logic controller is designed for EMA. The proposed system is tested in MATLAB/Simulink and obtained results of the simulation are analyzed and discussed.

Introduction

AES and their applications are popular research areas according to depletion of fossil fuels and environmental concerns [1–3]. One of the most promising AES is FC that uses hydrogen as fuel [4,5]. Compared to the other energy conversion systems, FCs are preferred in many applications due to quitter working and their sensitivity to the environment [6,7]. However, structural deformations such as excessive humidification and membrane drying may occur on a FC in case of instantaneous changes in load demand; using it as a main energy source alone for residential systems is not sufficient [8–10]. Therefore, to increase the efficiency and lifetime of the FC, additional energy storage units that cooperating with FC should be integrated into the system and also the optimum energy management should be provided [11–14].

FCs can be used with auxiliary energy sources and also smart homes are one of the most promising of energy management systems [12,15,16]. This is because loads that used in smart home are controllable and appropriate for the other energy sources' capacities. Energy sources are used more efficiently and peaks in the load demand can be reduced due to load shifting [17].

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http://dx.doi.org/10.1016/j.ijhydene.2017.02.204

Please cite this article in press as: Keskin Arabul F, et al., Providing energy management of a fuel cell–battery–wind turbine–solar panel hybrid off grid smart home system, International Journal of Hydrogen Energy (2017), http://dx.doi.org/10.1016/j.ijhydene.2017.02.204

Smart homes can be either on or off grid, also in each condition it can be fed with the renewable energy sources (RESs) [10,18]. Withal, more economic and sustainable energy can be provided with energy storage units [4,16,19]. With the ability of smart home energy management, RESs work more effective. In general, an EMA is preferred to increase the consumption and stored energy when there is an increase in the energy produced by the sources depending on geographical conditions such as wind and solar [20–22]. On the other hand, if there is a decrease in production of the sources, EMA shifts the loads. However, when FC is added into such systems, a new EMA should be developed according to FC characteristics. With a proper EMA, the power flow between sources and loads can be controlled by shifting the switching patterns [23]. Thus, EMA in a hybrid system can improve the FC efficiency and life time by load shifting to an improved efficiency system condition by an amount sufficient to offset the losses of the energy storage and discharge processes [24].

Smart home model used in the simulation is shown in Fig. 1. The main reasons for choosing smart home as a load demand are that there is quite a number of recent studies on smart grids and the usage area of smart homes are likely to be increased in the near future [7,9,13,15,16]. Also the smart home used in the simulation is preferred as an off grid load and the whole energy is supplied by the RESs and FC.

In this study, a simulation was carried out for providing energy management of an off grid smart home that consists of regular residential load and an electric vehicle (EV) charging station is supplied with hydrogen, solar and wind energy. Optimum load sharing is performed even in instantaneous energy variations due to the RESs or load changes. Thus, it is aimed to increase the efficiency and the lifetime of the FC by reducing the instantaneous load rates on it and prevent the FC from structural deformation problems. As a control algorithm, a fuzzy logic controller is used due to possibility of excessive number of stochastic load and source power variations. In addition, another reason for choosing fuzzy logic control is that different kind of sources are exist in the system. Overall, the control objectives of the EMA is to provide economic load sharing between sources, to operate FC efficiently and safely, to reduce fuel consumption with a minimum effect on user comfort level, to provide sustainable energy. According to the results obtained, optimum load sharing in smart home and more efficient operation of FC in linear region is acquired with EMA. By this way the lifetime of FC is increased. It is concluded that the proposed EMA has an applicable and simple strategy for complex systems and the solution improves the lifetime and efficiency of energy sources.

This paper is organized as follows. In section "System topology", fundamental system topology of proposed EMA is presented. The designed fuzzy logic controller in Matlab/Simulink (Fuzzy toolbox) and its main structure is defined in section "Fuzzy logic controller". In section "Results and discussion" results of the simulation study is given and overall study is discussed and finally conclusions are presented in section "Conclusion".

System topology

System topology is given in Fig. 2. In the designed study, whole energy demand is supplied by AES as hydrogen – wind – solar. Typically in such hybrid systems, common method in energy management operate the RES at the maximum power point. As a result of this, if the total RES power is higher than the load demand, the exceeding power is used to charge batteries. On the contrary, if the total RES power is less than load demand, the required power is provided by the batteries. Additionally, if the batteries are completely discharged, the required power is supplied by the FC. However, in some conditions such as, if the batteries are fully charged and load demand is less than the RES power, RES cannot be operated at maximum power point. Operation cases are shown in Table 1.

The purpose of this topology is using FC as a main source for an off grid smart house. Additionally, other RES such as wind and solar are used for reducing the load on the FC at peak

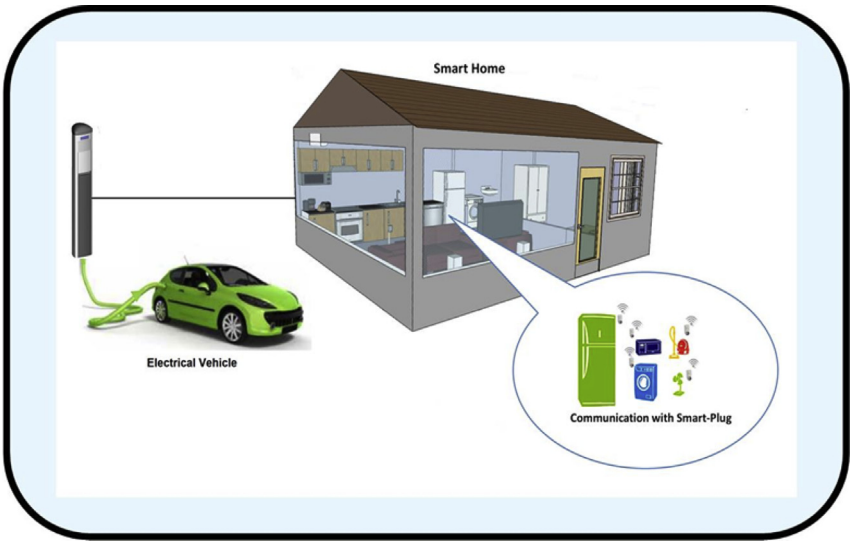

Fig. 1 – Smart home model.

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