ARTICLE IN PRESS

INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2016) 1–12

Available online at www.sciencedirect.com

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Validation of hybridization methodologies of fuel cell backup power systems in real-world telecom applications

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ARTICLE INFO

Article history:
Received 23 November 2015
Received in revised form
18 August 2016
Accepted 22 August 2016
Available online xxx

Keywords:
Fuel cell
Telecom
Power management
Backup power
UPS
Reliability

ABSTRACT

Two commercial fuel cell backup power units have been tested under real life operating conditions at two base stations of a leading telecom operator in Turkey. Each unit has a distinct system architecture and employs different power management methodology. Systems have been tested for a total of 646 on/off cycles providing more than 300 h of backup power during electricity grid shutdowns. In 98% of the tests, systems have delivered the power demanded by the equipment in the base station successfully. For the remaining times, failures are frequently recorded with the auxiliary components in the hydrogen generation equipment. Excluding these peripheral issues, reliability of the fuel cell technology is found to be more than 99%. It is recognized that power management methodology has a significant impact on the system response during system operation. power management algorithms determine how the base station load demand is shared between the fuel cell and the batteries. However, no significant benefit has been recorded for either of the hybridization methodology over the other. Both topologies have been shown to be very reliable over the test period.

Introduction

Fuel cells have been considered as promising candidates for power generation applications owing to their high energy densities and environmental friendly operations. Fuel cells stand out as viable alternatives for automotive applications considering long range and fast refueling requirements that are well satisfied by the incumbent technologies. On the other hand, commercialization of the fuel cell technology is sluggish because the materials used in the fuel cell stacks and particular balance of plant components increase the total costs of the fuel cell systems. However, mass production of fuel cell systems presumably will shift the supply and demand curve towards a more favorable equilibrium for the hydrogen economy.

Nonetheless, even with the current state of the technology, there are some *early markets* that the fuel cell systems are commercially feasible and have higher market penetration potentials. Fuel cells have been commercially used in material handling vehicles, stationary power applications and uninterruptable power supply (UPS) systems. In spite of their high capital costs, fuel cells can make business cases for early market applications thanks to the reduced operating and

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http://dx.doi.org/10.1016/j.ijhydene.2016.08.130

maintenance costs when compared to alternative battery and fossil fuel technologies.

Conventional backup power technologies mainly consist of battery banks and diesel generators. Batteries have zero emissions throughout their operation, therefore can be used indoors but they suffer from short cycle times. Diesel generators provide extended backup durations and have long lifetimes but their noisy operations and emissions make them unfavorable for use in urban locations. On the other hand, fuel cells as environmental friendly alternatives provide quiet and robust operations under a wide range of weather conditions. Their extended backup durations, reduced maintenance requirements and longer lifetimes are the advantages of fuel cells over batteries.

Several studies have addressed the economic benefits of fuel cell backup power systems over the existing technologies [1,2]. In the recent analysis of National Renewable Energy Laboratory of the US Department of Energy, total cost of ownership (TCO) of fuel cell systems are compared with the incumbent technologies [3]. Diesel generators are shown to be lower cost alternatives for the expense of noise, emissions and low efficiencies. On the other hand, fuel cell backup power systems have lower annual operating costs than batteries for extended backup times [4].

It is also suggested that the fuel cell backup power systems can make strong business cases in markets with unreliable electricity grids; explaining the soaring interest of the telecom operators in fuel cell systems in developing countries [5]. It has been reported that various fuel cell companies have installed numerous fuel cell backup power units for telecom operators in India [6,7], S. Africa, China [8,9], Indonesia, Malaysia, Philippines, Singapore and S. Africa [10].

Fuel cell backup power systems for telecom applications are typically realized as hybrid solutions of fuel cells and a supplementary power source [11,12]. It is reported that the total cost of ownership and efficiency of the hybrid system are affected by the individual durability of each power source in the system [13]. Power management of hybrid fuel cell systems, having a critical impact on the lifetime and efficiency, has been studied by various researchers. Boscaino et al. [14] reviews the recent studies and developments related to the power management of hybrid fuel cell power systems.

As it can be seen in Fig. 1, hybrid fuel cell system architectures can be categorized into two: passive and active. In a passive hybrid architecture power sources are connected in parallel, typically without any converters. On the other hand, in an active hybrid architecture DC/DC converters are utilized between the fuel cell and the batteries. The systems with active hybrid configuration benefit from the flexibility of the design for optimization of the operation. However, passive configurations can still be preferred because of their lower complexities and easier implementation.

Wu et al. [15] presented a passive hybrid system in which the fuel cell is directly connected to a pack of supercapacitors in parallel. It is highlighted that passive hybridization results in a relaxation of the fuel cell load demand while up to 5% efficiency gains can be achieved. Lee et al. [16] have analyzed different topologies for fuel cell/battery passive hybrid systems. It is reported in their study that in case the fuel cell and battery have the same potential, desired power sharing is achieved by controlling process parameters like relative humidity, reactant pressures or battery state of charge. Likewise, Bernard et al. [17] adjusts the operating pressure to control the fuel cell power in a passive hybrid system with equipotential batteries.

Wang et al. [18] studied the impacts of two different active hybrid power management strategies. They concluded that serial connection of the fuel cell with the battery resulted in a more efficient operation than the parallel power train. However, in another study of Wang et al. [19], parallel power train strategy is implemented in an active hybrid UPS system consisting of two fuel cell stacks and one lithium battery pack. The proposed controller and power management strategy for the system, considered for use in telecom base stations, is proven to be effective. In the study of Sanli et al. [20] a power management unit has been developed for an active hybrid system in which direct borohydride fuel cell charges and discharges a NiMH battery in a controlled fashion. A similar architecture is used in the study of Hwang et al. [21], in which output of the PEMFC is regulated by a DC/DC converter before connected parallel to the lithium ion battery.

As can be seen from these studies both active and passive hybrid systems are widely used in fuel cell applications. Each method has its advantages, however superiority of one to the other, if any, is yet to be proven in a particular application.

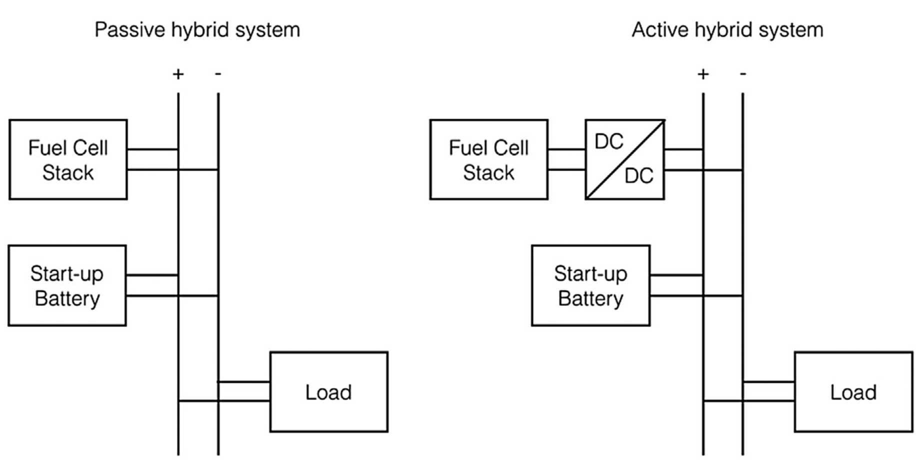

Fig. 1 – Hybridization topologies of the fuel cell backup power units tested.

Please cite this article in press as: Serincan MF, Validation of hybridization methodologies of fuel cell backup power systems in real-world telecom applications, International Journal of Hydrogen Energy (2016), http://dx.doi.org/10.1016/j.ijhydene.2016.08.130