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Standalone solar-hydrogen systems powering Fire Contingency Networks

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ABSTRACT

This paper presents a case study of a standalone fire-emergency telecommunications site in southeastern Australia to compare the relative merits of a solar-hydrogen power supply system and a conventional PV-battery system with and without diesel generator back-up. Although the power units for such applications are usually small (i.e. less than 5 kW) with relatively small capital costs, their operating and maintenance (O&M) costs can contribute considerably towards the total lifecycle cost of the system, particularly for isolated sites with limited accessibility, where frequent maintenance visits are required. Solar-hydrogen systems were found to be a more economical option on a lifecycle cost basis than traditionally-used PV-batteries (both with and without diesel generator back-up) mainly due to the inherent low O&M costs of the system. This research also found that adding a small battery bank to the solar-hydrogen system offers opportunities to improve the reliability and efficiency of the system while maintaining the economics of the system almost at the same level as that for solar-hydrogen systems.

Introduction

Recent advances in hydrogen-based technologies (e.g. fuel cell, electrolyser, and hydrogen storage) suggest hydrogen may be a suitable energy storage option for a wide range of telecommunication and data transfer and control applications [1], where a longer-term (i.e. season to season), reliable and economic storage solution with minimum environmental impact is required. Hydrogen-based systems can obviate the need for bulky and expensive battery energy storage systems [2–6]. One such application, the standalone power supplies required by wireless stations in a Fire Contingency Network (FCN), is investigated in the present paper, where an added requirement is the ability to withstand natural disasters such as bush fires.

Fig. 1 is a schematic diagram of the solar-hydrogen system discussed in this paper [3–5,7,8]. A photovoltaic array supplies the load directly when primary solar energy is available, thus removing the dependence on transported fuel. Surplus electric power over the load is routed to a solid-state PEM electrolyser to generate hydrogen for storage and reuse at times when insufficient primary energy is available, such as at night, and under cloud, or smoke cover. The stored hydrogen is transformed to electricity in a PEM fuel cell when needed to maintain a continuous power supply, such as during night-time, rainy, cloudy, or smoky conditions. This combination

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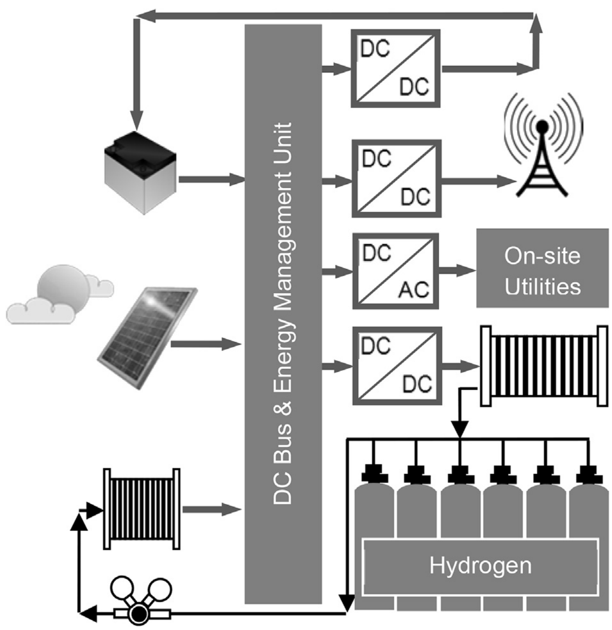

Fig. 1 – Schematic of an off-grid electricity supply based on photovoltaic primary energy with using hydrogen as long-term energy storage and battery to meet the short term energy storage requirements and also acting as a buffer.

(electrolyser, hydrogen storage and fuel cell) act as alternative electrical energy storage such as that with batteries. This storage is mainly used where long term (e.g. seasonal) energy storage is required. However, a battery bank may still be used in such system to meet short-term (e.g. diurnal) energy storage requirements of the system.

An initial review of the literature suggests a solar-hydrogen system of this kind may be preferred over conventional energy storage and power supply arrangements such as solar-battery systems with or without diesel generator back up for the following reasons:

- *Reliability*
  - Battery health status is always difficult to predict, particularly in harsh environments (too cold or too hot) [9].
  - Diesel generators may be employed to back up batteries [10]. There are some degrees of unreliability associated with these generators, particularly in harsh climate condition or fire events) [9,11–16].
- *Operation and Maintenance (O&M) costs*
  - Fewer moving parts and no need to supply fuel and less maintenance visits [1,12–14,16–18].
  - These positive effects in the overall lifecycle costing of the system is in particular more pronounced in relatively small systems (i.e. <10–15 kW) over long duration of operation (i.e. > 8 h per day) [9].
- *Lifetime*
  - Power supply systems are usually preferred to operate for close to ten years. With recent fuel cells reported lifetimes of up to 40,000 h [19–21] for stationary applications and considering about 3000–4000 h of operation per year (i.e. in the presence of renewable energy supply systems such as PVs and a small bank), fuel cell systems can get close to this 10 year preferred lifetime. This is while battery strings may need total replacement every three to five years [1,9].
- *Simplicity and scalability*
  - Comparing fuel cell with diesel generators, including the balance of the plant (e.g. air and fuel delivery and thermal management systems) [22].
  - Fuel cells are easily scalable [17].
- *Environmental impacts and risks*
  - Both batteries and diesel generators are not regarded as environmentally-friendly components due to issues with end-of-life waste management for batteries and of course exhaust emissions of diesel generators such as unburned hydrocarbons (HCs), CO and CO_2, SO_2, etc. [9,16].
  - Noise is another environmental impact for consideration; hence, the noiselessness of fuel cell systems can be regarded as another environmental advantage of this technology over diesel generators [1,16].
  - High operating temperature of diesel generators and also the explosion risk of batteries when overheated (e.g. during hot summer days) are other risk dimensions to be considered, specifically in fire-prone areas where Environmental and financial consequences of even a single fire incident are enormous [9,16].

Limited studies are published in the literature on using solar-hydrogen systems for telecommunication applications. One of the earliest studies done on the system has been reported by Varkaraki et al. in 2003 [12] on a 5-kWh emergency back-up system hydrogen-based energy storage with no batteries. The system studied in this case was designed for maximum 5 h of power supply interruption with a cumulative yearly operation of a few days. Due to limited yearly hours of operation the electrolyser and the hydrogen storage components did not need to be of high capacity (low amount of hydrogen was required); however, the peak of the demand (5 kW) led to a relatively large fuel cell and made this component to be the key contributor to the overall cost of the system. Hence, the optimisation was mainly focused on the components costs and sizing rather than the operational costs. However, a recently published paper by Jiménez-Fernández et al. [18] has looked at the optimisation of a standalone solar-hydrogen-battery system in an isolated telecommunication facility by considering both the capital and the operational and maintenance costs of the system. The paper has discussed this critical point that a system with the lowest capital cost may not be necessarily an economically optimum option since the maintenance costs and particularly the number of visits (e.g. in isolated telecommunication sites) play a very important role in determining the economic performance of the system. The research showed that although oversizing the system adds to its capital cost, it may help reduce the maintenance cost of the system through prolonging the period that the system can work reliably while being unattended. This point will be specifically discussed in the case study reviewed in this paper.