INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 39 (2014) 15307–15319

Available online at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/he

The impact of using Particle Swarm Optimisation on the operational characteristics of a stand-alone hydrogen system with on-site water production

Daniel P. Clarke[*], *Yasir M. Al-Abdeli*, *Ganesh Kothapalli*

School of Engineering, Edith Cowan University, Joondalup, WA 6027, Australia

ARTICLE INFO

Article history:
Received 26 April 2014
Received in revised form
8 July 2014
Accepted 22 July 2014
Available online 22 August 2014

Keywords:
Hydrogen energy
Particle Swarm Optimisation
Power Management Strategy
Electrolysis
Water

ABSTRACT

In a previous paper, we analysed the impact of renewable energy intermittency on the operational characteristics of hydrogen energy systems with pre-set Power Management Strategies not subject to optimisation. The research presented in this follow-up paper extends that earlier work and demonstrates the validity of applying Particle Swarm Optimisation (PSO) to size and optimise hydrogen systems. Specifically, PSO is used to iteratively converge on the (short-term) battery capacity (Ah) and hydrogen storage (L) in addition to defining the switching parameters which a Power Management Strategy (PMS) uses. The PSO algorithm is guided by three operational objective functions and conducted using MATLAB/Simulink. Simulations also incorporate laboratory resolved device characteristics.

Results are benchmarked against earlier deployed methods and show improvements with a PSO optimised PMS depend on system scale, with greater relative benefits arising at smaller scales. The choice of PSO acceleration parameters also affects the time to reach an optimal solution.

Introduction

Due to dispersed population within Australia, remote communities are heavily reliant on stand-alone diesel-based power generation with access to the utility grid sometimes being uneconomical. Where such communities are also located at coastal locations, combining energy provision with potable water production becomes an attractive option. Society is becoming more environmentally aware of carbon emissions and the need for sustainable power generation practises to replace fossil fuels. The utilisation of renewable sources [1] has been identified as the best candidate for achieving stand-alone power generation with reduced emissions. Renewable energies such as wind and solar are perpetual, clean and can be used in stand-alone energy systems. However, the inevitable intermittency and unpredictability of energy sources [2] results in periods where load demand cannot be fully met via available renewables or when surpluses may exist during periods of low load (demand). This highlights the need to incorporate energy storage media such as batteries and hydrogen [3,4] coupled with better renewable resource predictions.

* *Corresponding author*. School of Engineering, Edith Cowan University, 270 Joondalup Drive, WA 6027, Australia. Tel.: +61 433489214.
E-mail address: Daniel.clarke@ecu.edu.au (D.P. Clarke).

http://dx.doi.org/10.1016/j.ijhydene.2014.07.116

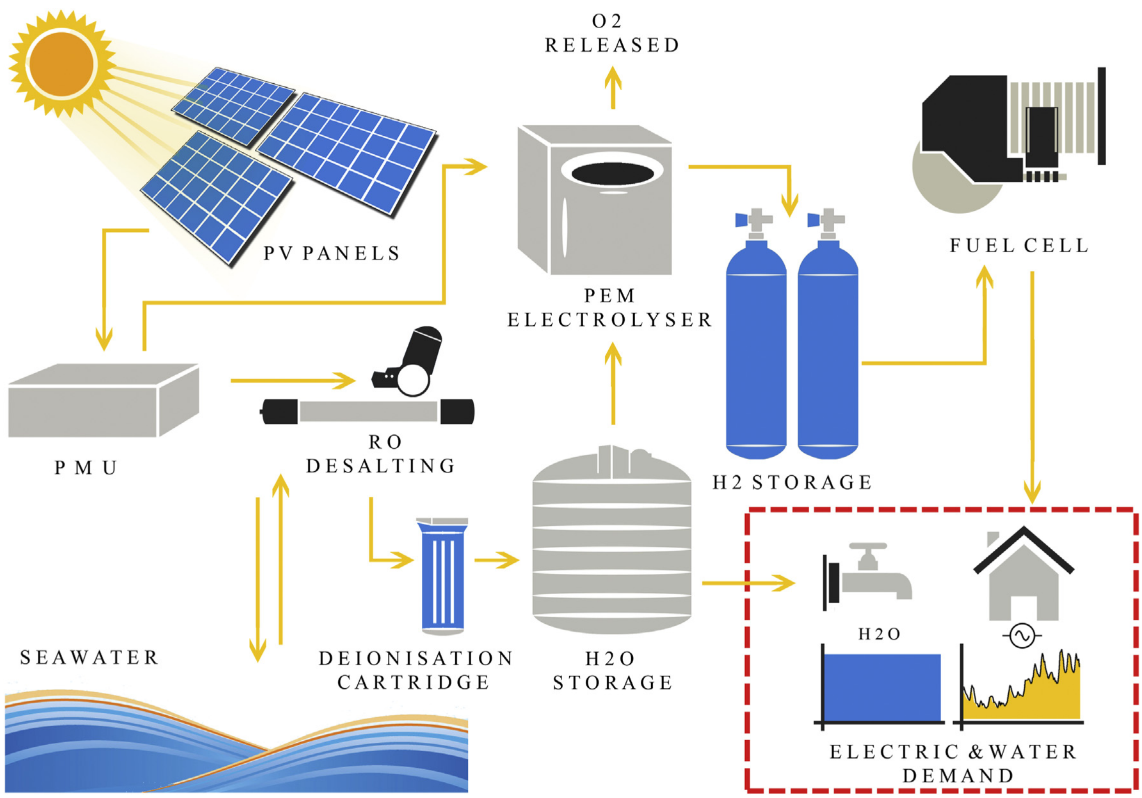

Fig. 1 – Stand-alone hydrogen energy system with on-site water production. All energy system components outside the dashed box constitute the "hydrogen generation assembly". The dashed box indicates an electric load and water demand that is interfaced with the "hydrogen generation assembly".

In such application scenarios and for a given resource and load profile, the overall penetration of renewables, reliability of meeting external loads and indeed the operational characteristics (switching, performance) of the energy system components are a function of both the Power Management Strategies (PMS) deployed and the scale of hardware. Therefore, optimisation techniques are essential to maximise system performance and reduce the likelihood of unnecessarily cycling devices into On/Off mode such as fuel cells due to degradation issues [5,6].

With the above in mind, the sizing and operational strategies of a stand-alone energy system have been achieved using various optimisation techniques including iterative, probabilistic, as well as intelligent methods which rely on Genetic Algorithms (GA), fuzzy logic and neural networks [7,8]. In this regard, Particle Swarm Optimisation (PSO) has been deployed to optimise some aspects of stand-alone energy systems and found to have fewer tuneable parameters [9] as well as obtaining better solutions compared to Genetic Algorithms [10,11]. For this reason, more work warranted to study the factors which affect the performance of PSO. However, two important challenges present themselves in this regard. Firstly, the effective use of PSO still requires tuning "acceleration parameters" to achieve accurate results and the impact of such (acceleration) parameters in relation to stand-alone hydrogen energy systems has largely not been addressed in the literature [12,13]. Secondly, the merit of using PSO to help scale hydrogen energy system components and optimise the operational characteristics of the energy system (as a whole) has not been adequately addressed to date. The current research aims to address both these deficiencies.

Outside the scope of the present paper which analyses the use of PSO to size and optimise Power Management Strategies, most other published research with PSO focusses on its impact from a techno-economic perspective. Within stand-alone hydrogen systems, the use of PSO has been shown to positively affect total system costs [14–18], with the cost of electricity improving by 18.5% [19] or to shorten the payback time from 12.3 years to 5.7 years [20]. Additionally, the use of PSO has been shown to reduce environmental impact from the running, production and installation of renewable energy systems over a 25 year lifetime by increasing total carbon emissions saved from approximately 3260 tons to 3980 tons [20]. In order to increase the probability of meeting an electric load demand, most research done to date on hydrogen systems has predominantly been based on Power Management Strategies (PMS), which are themselves not optimised [8,21–23]. Optimising the PMS by adjusting specific control set-points used in stand-alone hydrogen systems further maximises system performance whilst reducing system costs [24,13]. However, rarely has the effect of optimising a PMS onto the operational characteristics (and longevity) of energy system components been addressed in the literature. For hybrid systems, a PSO optimised PMS can minimise dependence on