INTERNATIONAL JOURNAL OF HYDROGEN ENERGY 39 (2014) 9973–9984

Available online at www.sciencedirect.com

ScienceDirect

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

Comparative study of artificial intelligence techniques for sizing of a hydrogen-based stand-alone photovoltaic/wind hybrid system

*Akbar Maleki, Alireza Askarzadeh**

Department of Energy Management and Optimization, Institute of Science and High Technology and Environmental Sciences, Graduate University of Advanced Technology, Kerman, Iran

ARTICLE INFO

Article history:
Received 30 November 2013
Received in revised form
19 April 2014
Accepted 21 April 2014
Available online 20 May 2014

Keywords:
Hybrid systems
PV/wind/fuel cell
Optimal sizing
Artificial intelligence

ABSTRACT

As non-polluting reliable energy sources, stand-alone photovoltaic/wind/fuel cell (PV/wind/FC) hybrid systems are being studied from various aspects in recent years. In such systems, optimum sizing is the main issue for having a cost-effective system. This paper evaluates the performance of different artificial intelligence (AI) techniques for optimum sizing of a PV/wind/FC hybrid system to continuously satisfy the load demand with the minimal total annual cost. For this aim, the sizing problem is formulated and four well-known heuristic algorithms, namely, particle swarm optimization (PSO), tabu search (TS), simulated annealing (SA), and harmony search (HS), are applied to the system and the results are compared in terms of the total annual cost. It can be seen that not only average results produced by PSO are more promising than those of the other algorithms but also PSO has the most robustness. As another investigation, the sizing is also performed for a PV/wind/battery hybrid system and the results are compared with those of the PV/wind/FC system.

Introduction

Photovoltaic (PV) systems and wind turbines (WTs) are being used worldwide to contribute in meeting the electrical power demand. The most important challenge of the single-renewable energy systems is their dependency to the environmental conditions (solar radiation and wind speed). As a solution, renewable energy sources are combined with each other (hybrid system) to provide more continuous electrical power. Therefore, hybrid systems have more reliability than single-renewable energy systems.

For a PV/wind hybrid system, it is necessary to provide an energy storage device. The storage system meets the remaining demand when the renewable sources have low energy. The storage device can be a battery bank, super capacitor bank, superconducting magnetic energy storage (SMES), or an FC/electrolyzer system. Conventionally, deep-cycle lead acid batteries are used for energy storage. Nevertheless, the associated environmental concerns limit the application of PV/wind/battery-based systems. Recent researches have focused on using FC/electrolyzer as the storage device [1–17]. Using PV/wind/FC system leads to having a non-polluting reliable energy source. In such system,

* *Corresponding author*. Tel./fax: +98 342 6233176.
E-mail addresses: akbar.maleki20@yahoo.com (A. Maleki), a.askarzadeh@kgut.ac.ir, askarzadeh_a@yahoo.com (A. Askarzadeh).
http://dx.doi.org/10.1016/j.ijhydene.2014.04.147

electrolyzer produces hydrogen by the excess electrical energy of the PV and wind sources. The hydrogen can then be used to supply an FC which is considered as a secondary power source when the demand is high.

For the better understanding of the different aspects of hydrogen-based hybrid systems, thereby to efficiently utilize PV/wind/FC systems, various investigations have been developed. In hybrid systems, appropriate sizing is one of the most important issues that results in having a cost-effective energy system. Literature study indicates that there are many attempts based on probabilistic, analytical and heuristic methods for optimal sizing of hybrid systems. Diaf et al. [18] have optimized hybrid system size based on loss of power supply probability (LPSP) and the levelized cost of energy (LCE). Borowy and Salameh [19] have introduced loss of load probability (LLP) concept for finding the optimal size of the PV/wind hybrid system. Shrestha and Goel [20] have presented a methodology for optimal sizing based on energy generation simulation. Maghraby et al. [21] have used the desired system performance level (SPL) requirement to select the number of PVs and batteries. Energy balance has been used for design of hybrid PV/wind systems [22]. Prasad and Natarajan [23] have presented a methodology for optimization of PV/wind system based on deficiency of power supply probability (DPSP), relative excess power generated (REPG), unutilized energy probability (UEP), life cycle cost (LCC), levelized energy cost (LEC) and life cycle unit cost (LUC) of power generation with battery bank. Nonlinear programming [24] and HOMER [25] are other algorithms used for optimal design of hybrid systems. Heuristic algorithms such as genetic algorithm (GA) [26,27],

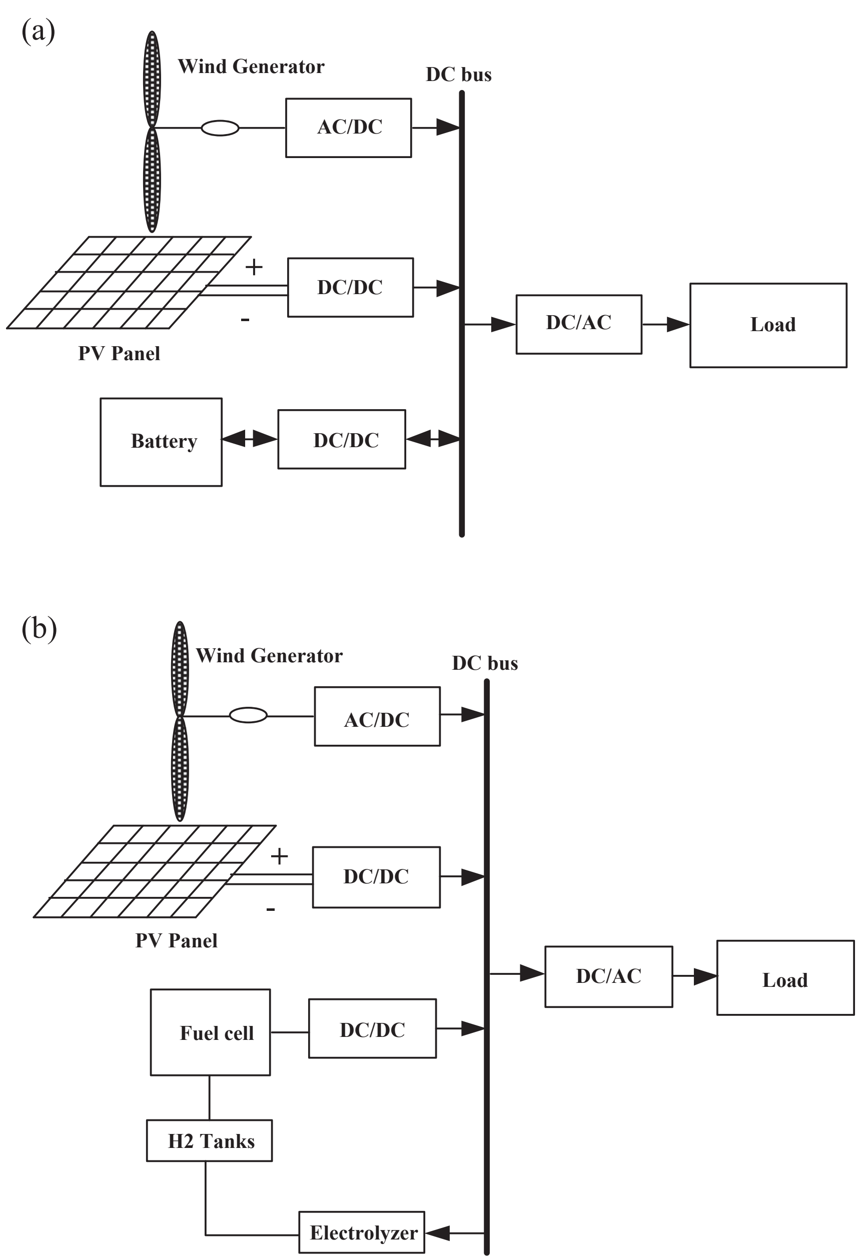

Fig. 1 – Schematic of the hybrid systems. (a) PV/wind/battery-based hybrid system and (b) PV/wind/FC-based hybrid system.