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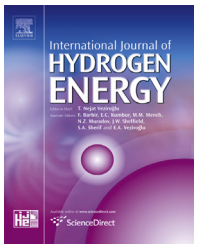

Techno-economical optimization based on swarm intelligence algorithm for a stand-alone wind-photovoltaic-hydrogen power system at south-east region of Mexico

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ARTICLE INFO

Article history:
Available online 8 July 2014

Keywords:
Renewable energy
Optimization
Particle swarm optimizer (PSO)
Differential evolution (DE)

ABSTRACT

Renewable generating systems are alternative to produce electric energy in a clean manner. However, the high costs of the constituents limit their broad use. Thus, sizing is an important issue in the renewable generating systems design, in order to reach an efficient relationship between cost and benefit. Likewise, the random nature of the sources makes the sizing a complex task with regard to a conventional system. This paper is focused on calculate the optimal size of a wind-photovoltaic-fuel cell system to meet the power demand of an isolated residential load located in the south-east region of Mexico (Chetumal city 18°31′21.4″N 88°16′11.3″W), with a solar radiation range from 0 to 0.75 kW/m^2 and wind speed range from 5 to 7.8 m/s. Swarm intelligence techniques have been successfully applied in solving many combinatorial optimization problems in which the objective space possesses many local optimal solutions. This work employs the Particle Swarm Optimizer (PSO) algorithm to search the optimal sizing for the power plant minimizing the total costs of the system; as a metaheuristic procedure, the PSO was able to find the best configuration regardless the lack of a deep knowledge of the problem. Compared against the Differential Evolution (DE) technique, the PSO performance is faster and able to provide a configuration that saves around 10% of the total cost of the hybrid system.

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http://dx.doi.org/10.1016/j.ijhydene.2014.06.034

Introduction

Due to the constant increase in demand, nowadays fossil fuels are the main source of electric power. The consequence has been the environmental pollution and which has conducted to a process of worldwide climate change. Renewable energy systems have become in a suitable technical option to produce clean electric power. However, economically their costs are not competitive with respect to conventional generating systems due to the intermittence of the renewable resources and low commercial availability. Additionally, is essential to use energy storage devices to overcome the intermittencies of the renewable sources, these elements comprising an important percentage of the cost of the integral energy solution. Therefore, from the economic aspect, the right-sizing of a renewable energy system is highly necessary for the incorporation of these technologies in remote stationary applications. S. M. Shaahid et al. [1–6] had studied the techno-economic potential of hybrid power systems based on photovoltaic, wind, diesel and batteries and their possible combinations for residential and commercial applications in Saudi Arabia. Similarly, in the south-east region of Mexico there are many isolated villages of the grid. The availability of electrical energy on these places can help to develop local economy as well as to improve living conditions of their habitants. The optimal sizing of the renewable energy system is a complex task due to the intermittent availability of the renewable resources, the current dependency to common storage energy devices such as batteries and the undetermined electric demand. In this way, this work is aimed in to provide an optimal sizing tool for a renewable hybrid power system considering the local weather conditions at the lowest possible cost. This sizing tool is based on a swarm intelligence algorithm. Algorithms based on the principles of swarm intelligence have been applied successfully to a set of numerical optimization problems. With a good degree of parallelism and stochastic characteristics, they are adequate for solving intricate optimization problems. Related publications present an extensive list of research concerning the application of swarm intelligence techniques to power systems issues [7–11].

Likewise, this research proposes an energy storage system based on hydrogen technology (electrolyzer and fuel cell). Usually, batteries have been used as energy storage mean, however, they still present some inconveniences such as low lifetime, low power density (W/kg) and complicated disposal and confinement measures. During the last two decades, fuel cells and electrolyzers have been studied as an alternative solution to the energy storage systems based on batteries due to their technical and ecological merits. Therefore, the development of hydrogen technology as a mean of energy storage represents an ecological and viable option for its integration into the energy generating systems.

At the present time, the costs of photovoltaic modules, wind turbines, electrolyzers and fuel cells are even high. Thus a critical aspect in the design of a renewable generating system is the optimization of their elements rating.

The optimal sizing of a renewable energy system based on hydrogen like a mean of energy storage has been tried lately. M. Santarelli et al. [12], used the downhill simplex method to size and estimate the cost of a renewable generating system (photovoltaic-micro-hydro power) integrated with electrolyzers and fuel cells. Nelson et al. [13]. programmed a Loss of Power Supply Probability (LPSP) technique to make an

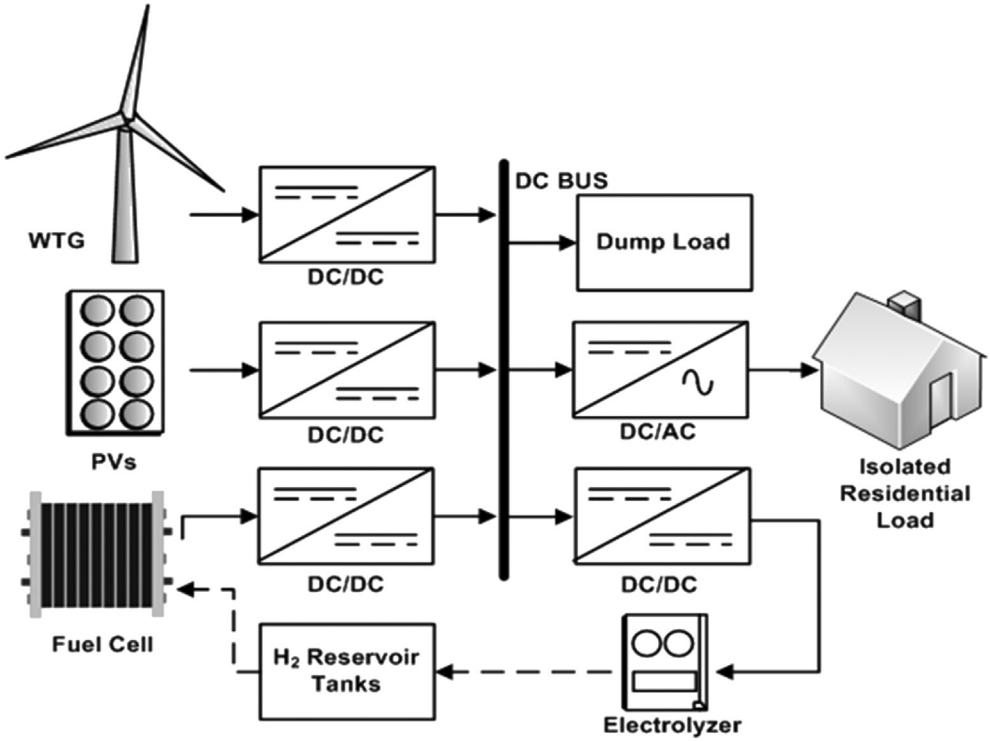

Fig. 1 – Renewable generating system configuration.