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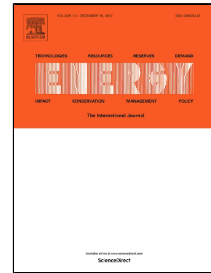
Energy, exergy and economic analysis of a hybrid renewable energy with hydrogen storage system

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PII: S0360-5442(18)30234-2  
DOI: 10.1016/j.energy.2018.02.008  
Reference: EGY 12308  
To appear in: *Energy*  
Received Date: 10 November 2017  
Revised Date: 02 January 2018  
Accepted Date: 04 February 2018

Please cite this article as: A. Khosravi, R.N.N. Koury, L. Machado, J.J.G. Pabon, Energy, exergy and economic analysis of a hybrid renewable energy with hydrogen storage system, *Energy* (2018), doi: 10.1016/j.energy.2018.02.008

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**Energy, exergy and economic analysis of a hybrid renewable energy with hydrogen storage system**A. Khosravi<sup>1\*</sup>, R. N. N. Koury<sup>1</sup>, L. Machado<sup>1</sup>, J. J. G. Pabon<sup>1</sup><sup>1</sup>Post-graduate Program in Mechanical Engineering, Federal University of Minas Gerais (UFMG), Belo Horizonte, Brazil<sup>1\*</sup> Corresponding author: Alikhosravii@yahoo.com**Abstract**

The goal of this study is to define and assess an off-grid hybrid renewable energy with hydrogen storage system. The system combines solar and wind energy, hydrogen production unit and fuel cell. This photovoltaic/wind hydrogen energy system focuses on a large scale system with constant electrical load and especially suitable for remote area applications. Energy, exergy and economic analysis are conducted for this system. The pattern of the produced power for the photovoltaic (PV) system and wind turbine with a dynamic model of solar and wind energy are determined. Also, components sizing of the proposed system is determined. Energy and exergy analysis of the PV system was reported the average of 12% and 16% for energy and exergy efficiencies, respectively. The average energy and exergy efficiencies of the wind turbine were obtained approximately 32% and 25%, respectively. The maximum exergy destruction for the PV system was obtained around 65%. Also, based on economic analysis, energy storage system was included 50% of the total investment.

**Keywords:** Wind energy; Photovoltaic; Fuel cell; Hydrogen storage system; Energy and exergy analysis; Economic investigation

**1. Introduction**

The fossil fuel energy resource is gradually being replaced by renewable energy in the world. The sources of fossil fuel energy are limited and use of these resources cause the environmental pollution and depletion of ozone layer [1]. Although Iran is rich in oil and natural gas, analysis of renewable energy resources stated that this country is a suitable place for using renewable energy systems like solar and wind energies. Between the renewable energy sources, wind energy is more accessible and fairly cheaper [2]. Wind energy is a clean resource and doesn't pollute the air like fossil fuel power stations. Solar energy is a kind of the renewable energies that is obtained from the sun [3]. The energy of the sun is converted to the thermal or electrical form the energy [4]. Solar energy is distributed over a wide geographical region and the cost of this energy is stable for the long-term in the future with low maintenance costs [5]. The studies have shown that Iran is potentially one of the best regions to use PV systems with 300 clear sunny days and average of 2200 kWh/m<sup>2</sup>/year solar radiation [6].

The main problem to utilize the solar and wind energies is the great variation in available power which occurs from season to season, day to day, hour to hour. This would not be a problem if the load was well correlated to the energy availability, but unfortunately, this is not often the case. Efficient storage is essential for large-scale exploitation of intermittent renewable sources. Today most renewable electricity systems use battery as storage system [7]. This type of storage is expensive and large per unit of stored energy but has the advantage of high efficiency. Batteries can be used for short-term storage, but in order to keep the solar/wind power system dependable, a relatively large number of batteries will generally be needed [8]. This can result in high costs. Until now, one of the key factors constraining the advantage of renewable power sources has been the inability of batteries to store enough electricity to provide user needs during extended periods of calm or cloudy days. The

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