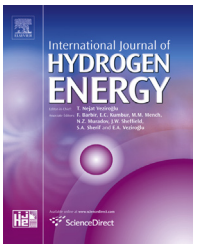
INTERNATIONAL JOURNAL OF HYDROGEN ENERGY XXX (2016) 1–13

Available online at www.sciencedirect.com

ScienceDirect

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



Review Article

# Energy management strategy based on fuzzy logic for compound RES/ESS used in stand-alone application

*Issam Abadlia* [a,*], *Tahar Bahi* [a], *Hamza Bouzeria* [b]

[a] *Department of Electrical Engineering, LASA Laboratory, Badji Mokhtar University, BP 12, Annaba 23000, Algeria*
[b] *Department of Electrical Engineering, Hadj Lakhdar University, Batna 05000, Algeria*

ARTICLE INFO

*Article history:*
Received 15 December 2015
Received in revised form
24 June 2016
Accepted 16 July 2016
Available online xxx

*Keywords:*
Power management system
Renewable energy source
Energy storage system
Photovoltaic/fuel cell/battery
Fuzzy logic power management strategy

ABSTRACT

This paper deals with the development of intelligent power management strategy (PMS) of renewable energy source (RES) associate an energy storage system (ESS) used in standalone application. The proposed system composed of renewable energy source is photovoltaic (PV) and energy storage system is a hydrogen fuel cell (FC) and battery energy storage. The system consists in principal of PV generator, an alkaline water electrolyser, a storage gas tank, a proton exchange membrane fuel cells (PEMFC) and battery is added to ensure continuous power supply and to take care of the intermittent nature supplying power distribution. Electrical power from PV generator meets the user loads and the surplus power used for water electrolysis to produce hydrogen, it is the power electrolyser ($P_e$), or stored in the battery. The system controlled using an intelligent fuzzy logic controller (FLC) to manage the power flow. The aim of this study is to optimize the proposed power generation system that guarantees the energy continuity and maximise the production of hydrogen. Prices rules of fuzzy switching regulators as conform the proposed configuration to ensure an optimal injecting of the FC power and to use the surplus power for water electrolysis. The proposed fuzzy logic energy management strategy (FLPMS) enables to convert the total PV produced power, get involved the fuel cell to the deficit power demands, maximise the production of the hydrogen and ensure the contentious charges/discharges of the battery.



## Contents



* *Corresponding author.*
E-mail address: i_abadlia@yahoo.fr (I. Abadlia).

http://dx.doi.org/10.1016/j.ijhydene.2016.07.120
0360-3199/

## Introduction

Photovoltaic system is gaining increased importance as renewable energy source due to the advantages of little maintenance, absence of moving mechanical parts, no noise and not polluted [1,2]. However, PV output power is intermittent and dependent on climatic conditions. One method to overcome this problem is to integrate PV systems with other power sources such as diesel, wind, fuel cell and using batteries for energy storage [3–7]. The diesel generator has some significant disadvantages such as noise and exhaust gases pollution. Wind energy conversion system has moving mechanical parts, consists of a variable speed wind turbine, electrical alternative machine, three-phase Diode Bridge and a dc–dc boost converter which controlled to extract maximum power point tracker [8]. This arrangement increases the cost of electricity and also, wind energy source is not regular in the time, nor continuous.

Integration of PV system with utility sources is used as cost effective solution and also eco-friendly. In the last years novel technologies of renewable energy sources applications as associate a green static energy sources namely energy storage systems such as fuel cell and battery energy storage as added to produce and storage as much energy from PV system to ensure the load demand [9]. Storage energy systems figure batteries are very important for solar power generation systems. Solar energy is stored during sunny and windy days and released later during cloudy days or at night, and to smooth power demands, electric energy is stored during off peak periods and later used during peak periods. A fuel cell combines hydrogen with oxygen (from air) in chemical reaction, producing water, electricity and heat. Fuel cell do not "burn" the fuel, the conversion takes place electrochemically without combustion. Fuelled with pure hydrogen, they produce zero emissions of pollutant and green house gases at the location of the power plant [10]. Fuel cells produce heat when generating electricity. Thus, they are combined cooling heat and power applications. FCs generation systems offer high energy conversion efficiency and hence the potential to reduce fuel costs and $CO_2$ emissions [11]. FCs offers many advantages over other generation systems: low pollution, high efficiency, diversity of fuels, reusability of exhaust heat and onsite installation [12–16].

Many such mix systems comprising of PV and FC have been discussed in literature. In Ref. [9], D. Rekioua et al. defunct depictions of different hybrid systems with fuel cell where a hybrid photovoltaic-electrolyser-fuel cell system have been simulated. The mathematical model and the simulation of a stand-alone renewable power system, referred to as ''Photovoltaic–Fuel Cell hybrid system'', was described by J.J. Hwang et al. in Ref. [17], have also received considerable attention. The comprehensive model for the PV/electrolyser/FC system with battery energy storage was depicted by S. Slouma et al. in Ref. [18]. The use of these hybrid renewable energy systems presents some advantages over larger power plants, such as environmental-friendly, high power quality, uninterruptible service, cost savings, on-site generation, and expandability.

Nowadays the compound storage and generation systems represent an extremely efficient solution for stand-alone generation systems based on renewable sources. The integration of different technologies produces good performances but in compound systems must be preliminarily defined a proper strategy to control the power flows. Therefore, in order to achieve flexible and reliable performance of hybrid RES/ESS system, different power conditions of distributed RES and storage capacity of ESS need to be globally considered. In previous works, several hybrid systems and power management based on conventional techniques are developed [19,20]. However, the classical control techniques require exact mathematical model of the system and are very sensitive to parameter variations. Intelligent control techniques are more efficient and robust than classical techniques, since they do not require an exact model of the system. In Ref. [21] a studies of a power management of the ESS based on hydrogen storage (electrolyser, hydrogen tank, fuel cell) and battery integrated in hybrid renewable energy systems was described. Which the comprehensive of power management tool that utilizes an adaptive model based on neuro-fuzzy inference control system is depicted. In Ref. [22] the predictive control and optimization of grid-tied photovoltaic storage systems also was described.

In this paper we propose an intelligent PMS based on fuzzy logic for compound RES/ESS used in stand-alone. The system is a typical stand-alone based RES with energy storage system. Photovoltaic is primary source. ESS is a backup power source used in the necessary periods as composed of fuel cell and battery as secondary. Surplus power from PV used for water electrolyses to produce hydrogen and/or stored in battery depend to state of the power system with considering the importance of production of hydrogen. Also, battery is promoted to deliveries power to the load or to produce hydrogen. Fuzzy logic controller is proposed to manage the power exchange among different sources and to provide some services to the power system. In the proposed control method, FC,

Please cite this article in press as: Abadlia I, et al., Energy management strategy based on fuzzy logic for compound RES/ESS used in stand-alone application, International Journal of Hydrogen Energy (2016), http://dx.doi.org/10.1016/j.ijhydene.2016.07.120