II SIMPOSIO NACIONAL DE INGENIERÍA HORTÍCOLA
AUTOMATIZACIÓN Y TICS EN AGRICULTURA
Almería, 10-12 de febrero de 2016
Sociedad Española de Ciencias Hortícolas

Fuzzy energy management of Photovoltaic installations for Tomato drip irrigation

Imene Yahyaoui [1], Fernando Tadeo[2], & Marcelo Vieira Segatto[1]

[1] Electric Engineering Department, Federal University of Espiritu Santo, Vitoria, Brazil
e-mail: imene.yahyaoui@ufes.br
[2] System Engineering and Automatic Department, University of Valladolid, Spain

Resumen

Este articulo presenta la gestion de energia fotovoltaia para el regadeo de tomates. Ademas a los paneles fotovoltaicos, el sistema esta compuesto de baterias y relais, que permitte el suministro de la carga con energia electrica. Patra ello, la logica borrosa esta usada para el control de los relais, y esta probada usando datos experimentales del volume de agua necesario para el regadeo de las plantas de tomate.
Palabras clave: energia fotovoltaica, regadeo, gestion, tomates, logica borrosa

Abstract

This paper focuses on the energy management of a photovoltaic-based installation used for tomato drip irrigation. The system is composed of photovoltaic panels and a battery bank, linked via controllable relays and used to supply a water pump. A fuzzy-based energy management algorithm for relay switching is proposed and tested experimentally. The installation's components control is performed using experimental data of the tomato water volume during the crop's vegetative cycle, climatic parameters and site characteristics (Northern Tunisia). The relays' switching signals are tested experimentally in a small-scale laboratory installation.

Keywords: drip irrigation, photovoltaic energy, energy management, Fuzzy logic, validation

Introduction

Photovoltaic Powered Electric Water Pumping Systems (PPEWPS) are promising solutions, especially for small-scale installations in regions characterized by good amounts of solar energy over the year. These systems, used for water pumping, can be easily installed near the place of consumption, and the surface that the panels occupy can be optimized (Yahyaoui et al, 2014). Among these PPEWPS, several works focused on directly coupled systems which pump water only when the photovoltaic modules capture the solar radiation (Ben Ghanem et al, 2014), or systems that also include batteries that supply the pumps when the panels' power generation is not sufficient (An et al, 2015). Moreover, other researchers concentrated on Maximum Power Point Techniques that increase the pumped water volume (Arthishri et al, 2014).

This paper presents the continuation of a previous published work (Yahyaoui et al, 2015), in which an energy management algorithm (EMA) of a photovoltaic installation is studied (Figure 1). In fact, the installation is composed of photovoltaic panels and a battery bank that supply a water pump, used to irrigate land planted with tomatoes situated in Northern

Tunisia (semi-arid climate). Thus, a Fuzzy EMA is established to decide the switching of the relays linking the system's components. The system control aims to fulfill the crop's water volume needed during the tomatoes' vegetative cycle (from March to July) and to ensure the safe operation of the system components. Here, using a small-scale laboratory installation, an experimental validation for the EMA is presented.

Energy management algorithm principle

The proposed EMA aims to maximize the use of the photovoltaic power generated, minimize the battery use and guarantee the water volume needed for irrigation, by controlling the switching of the relays R_b, R_l and R_{lb} that link the installation components (Figure 1). The decision on this switching (instants and duration when the pump is connected to the power sources) is carried out by Fuzzy logic, based on the estimations of the photovoltaic power generated $\tilde{P}_{pv}$, the power demanded by the pump $\tilde{P}_{pump}$, the battery bank depth of discharge *dod* and the water volume in the reservoir *L* (Yahyaoui et al, 2015). $\tilde{P}_{pv}$ is estimated using the measured values of the solar radiation *G* and the ambient temperature T_a. $\tilde{P}_{pump}$ and *dod* are estimated using the measured currents I_{pump} and I_{bat} respectively. The level *L* is measured directly using a pressure sensor.

The management criteria are then defined as follows:

a) Maintain a high water level in the reservoir to guarantee the water volume needed for the crop irrigation (Figure 2).
b) When the reservoir contains enough water, store the excess photovoltaic energy in the battery bank to minimize the use of the battery bank.
c) Ensure a depth of discharge *dod* less than $dod_{\max}$, to protect the batteries against deep discharge, and higher than $dod_{\min}$, to protect them from excessive charge.
d) Ensure a margin of 10 % of the photovoltaic power: the pump can be connected to the panel only if the measured photovoltaic power P_{pv} is 10 % higher than the power required by the pump P_{pump}, to guarantee a continuous power supply for the pump.

Case study

The EMA is performed following four steps: the knowledge base generation, fuzzification, inference diagram and defuzziyfication (Yahyaoui et al, 2015). The Fuzzy EMA is first tested by simulation, which shows that EMA allows the water volume needed by the crops during their vegetative cycle to be pumped (Figure 2).

The FEM was experimentally tested using a scale plant installed in the laboratory in the Engineering Systems and Automatic department of the University of Valladolid, Spain. The plant is composed of a pump, a 0.05 m^3 reservoir, a 150 W Programmable Power Supply, which is used as a photovoltaic panel associated to an MPPT bloc, and a 12A.h/12V lead-acid battery. Some of the experimental results are presented in Figure 3.

In fact, during the day, when there is an energy excess, it is used to charge the battery bank by switching on the relays R_l and R_b (mode 3). Mode 4 is possible when all the photovoltaic power generated is used to charge the fully discharged batteries. Hence, the experimental results show that the algorithm allows the pump to be supplied and the battery bank's safe operation to be ensured thanks to the control switching of the relays.

Conclusions

Experimental tests for the EMA show that the algorithm ensures the pumping of the water volume needed by the tomatoes, the system's autonomy and the battery bank's safety. It must be pointed out that the proposed algorithm is general, in the sense that it can be used for the PV irrigation of systems of different sizes, providing the monthly water demand.

Acknowledgement

This work is funded by the Research Foundation of Espiritu Santo State (FAPES), Brazil, and the Spanish Ministry of Economy project MINECO DPI2014-54530-R. Miss Yahyaoui is funded by a grant from the Education Ministry of Brazil.

References

An, L., and Lu, D. D. C. 2015. Design of a single-switch DC/DC converter for a PV-battery-powered pump system with PFM+ PWM control. IEEE Transactions on Industrial Electronics, 62(2), 910-921.

Arthishri, K., Balasubramanian, R., Kathirvelu, P., Simon, S. P., and Amirtharajan, R. 2014. Maximum power point tracking of photovoltaic generation system using Artificial Neural Network with improved tracking factor. Journal of Applied Sciences, 14, 1858.

Benghanem, M., Daffallah, K. O., Alamri, S. N., and Joraid, A. A. 2014. Effect of pumping head on solar water pumping system. Energy Conversion and Management, 77, 334-339.

Yahyaoui, I., Sallem, S., Kamoun, M. B. A., and Tadeo, F. 2014. A proposal for off-grid photovoltaic systems with non-controllable loads using fuzzy logic. Energy Conversion and Management, 78, 835-842.

Yahyaoui, I., Chaabene, M., and Tadeo, F. 2015. Fuzzy Energy Management for Photovoltaic Water Pumping System. Internationnal Journal of Computer Application, 110, 29- 36.

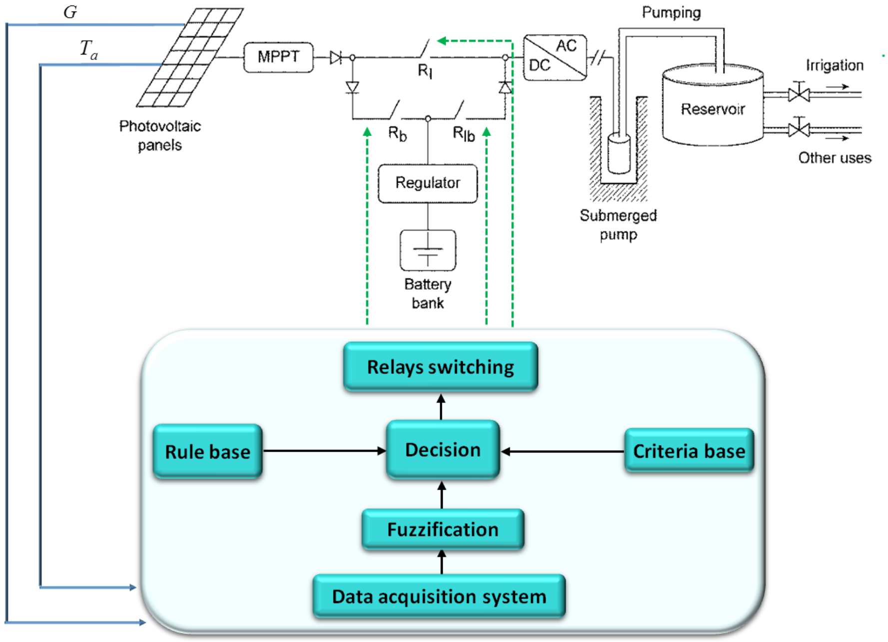

Figure 1. Fuzzy energy management principle

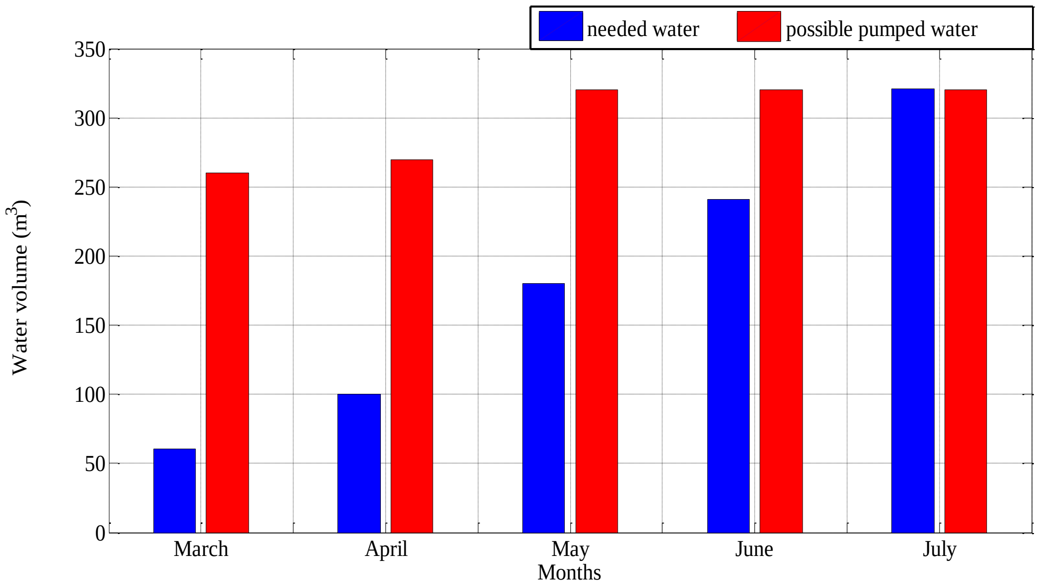

Figure 2. Needed and possible pumped water volume averages during tomatoes' vegetative cycle

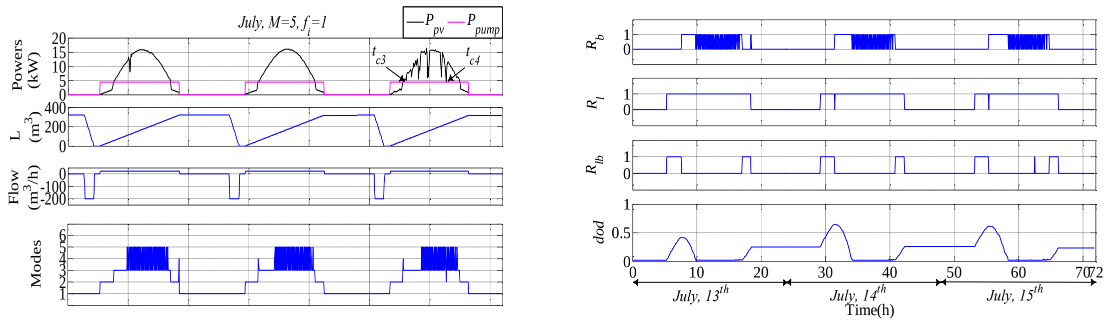

Figure 3. Fuzzy EMA in July

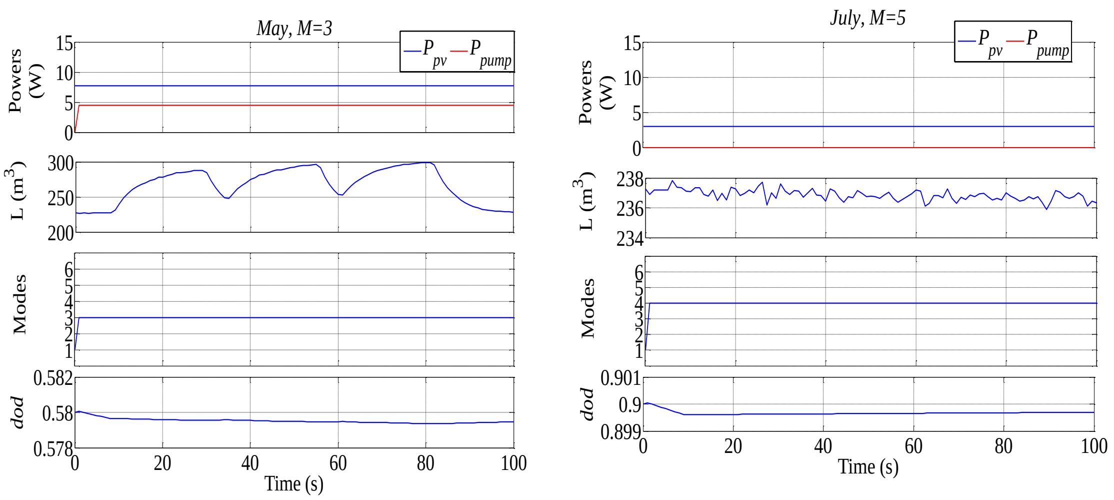

Figure 4. Fuzzy energy management results for a typical day in March