21th International Conference on Renewable Energies and Power Quality (ICREPQ'23)
Madrid (Spain), 24th to 26th May 2023
Renewable Energy and Power Quality Journal (RE&PQJ)
ISSN 2172-038 X, Volume No.21, July 2023

Power Management Control of photovoltaic/Batteries/Fuel cells System

D. Rekioua[1], F. Zaouche[1], Z. Mokrani, T.Rekioua[1]

[1] Laboratoire LTII, Faculté de Technologie, Université de Bejaia, 06000 Bejaia (Algerie)
Phone/Fax number:+0021334 81 68 19, e-mail: **djamila.ziani@univ-bejaia.dz**

Abstract. A study of a stand-alone photovoltaic./batteries/fuel cell power system has been presented in this paper to produce energy continuously. A management control circuit (PMC) has been designed to obtain the different control signals that allow supervising power flow of the hybrid system. The application has been made to a stand-alone system for four days at Bejaia region. Fuzzy logic Control (FLC) is used to optimize power The structures PV/Battery/Fuel cells system have been investigated. A modelisation of each component has been made. A supervisor control circuit has been designed to obtain the various control signals needed to control the overall system. A simulation study has been done in Matlab. The different results are presented to show the effectiveness of the proposed strategy

Key words. Photovoltaic, Batteries, Fuel cells, Power Management Control.

1. Introduction

Renewable There are many photovoltaic systems that have been developed and supported as sustainable solutions. Also, to optimize power, maximization algorithms are used [1-4].It can be classical and advanced methods. To supervise the power flow of hybrid systems, several management strategies have been developed and proposed in the literature [5-17]. The authors of [5] describe a strategy for a hybrid system consisting of a solar panel, a wind turbine and a fuel cell powered by bioethanol converted to hydrogen. Three different power techniques are compared for an isolated application in [6]. Authors in [7] addressed and studied this issue, but this time they used a hybrid storage device consisting of a battery and a super capacitor to support abrupt changes.

In this paper, a stand-alone PV/battery/fuel cells power system to generate uninterrupted electricity is studied using a sizing, simulation, and optimization technique. This multi-source power generation system can be more resilient and flexible than a single source system. For example, on a sunny day, the PV panels will generate a lot of power and can be used to meet the load demand, while also charging the batteries. On a cloudy day, the PV panels may not generate enough power, but the batteries can be used to supplement the power supply. In case of an emergency, the fuel cells can be used as a back-up power source. The electrolyzer can also be used to produce hydrogen as a source of energy storage, hydrogen can be used in fuel cells to generate electricity or used as a transportation fuel.

An application for the power supply of a residential residence on four different days. Fuzzy logic control was used to optimize the power (FLC). PV/battery systems, PV/FCs, and PV/battery/FCs were three topologies that were suggested. A supervisor control circuit has been designed to obtain the various control signals needed to control the overall system.

2. Studied PV/FCs/Batteries system

In this structure, multiple sources of power generation are used to supply a customer load. (Fig.1).

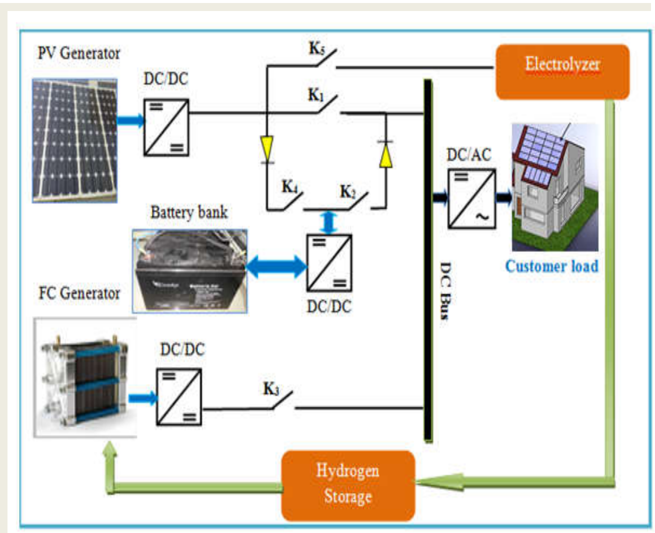


Fig. 1. Studied system.

Photovoltaic panels are used to convert sunlight into electricity, batteries are used to store excess energy for later use, fuel cells convert the chemical energy of hydrogen into electricity, and an electrolyzer is used to produce hydrogen from water

A. Modeling of photovoltaic panels

In this work the following model (Fig 2) is considered [3, 4], [7, 8].

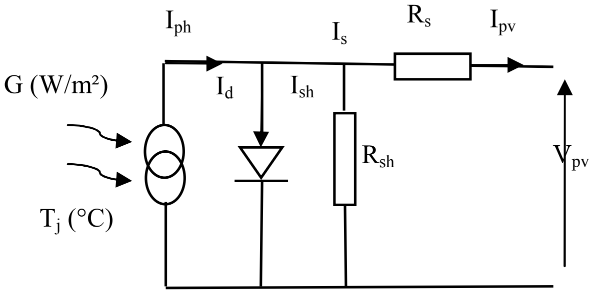


Fig. 2. Fig.2 Photovoltaic cell model

The current equation is given as [4,13]:

$$I_{pv} = I_{ph} - I_0 \times \left[exp\left(\frac{q \times (V_{pv} + R_s \times I_{pv})}{A \times N_s \times K \times T_j} \right) - 1 \right] - \frac{V_{pv} + R_s \times I_{pv}}{R_{sh}} \quad (1)$$

The photovoltaic parameters are presented in table 1

Table.1. PV Panel Parameters

Parameters	Values
Photovoltaic power	80 Wp
Maximum current at PPM	4.65 A
Maximum voltage at PPM	17.5V
Short circuit current	4.95A
Open circuit voltage	21.9V
Temperature coefficient of short-current	3 mA/°C
Voltage temperature coefficient of short-current	-150mV/°C

The following test bench (Fig.3) has been used to establish PV electrical characteristics. The electrical characteristics are shown in Fig.4.

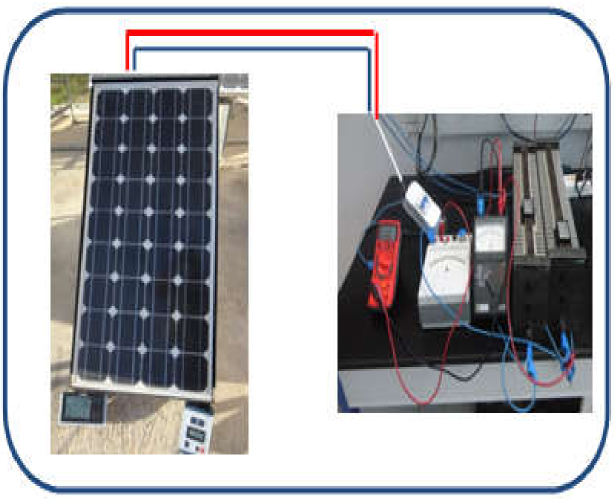
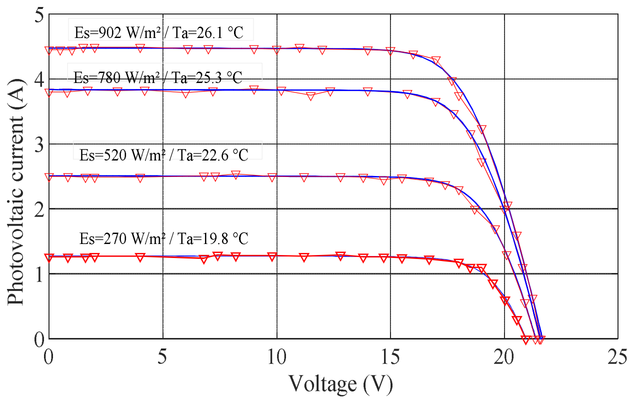
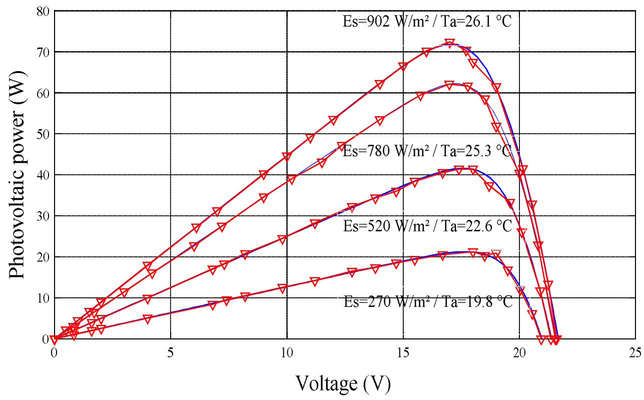


Fig. 3. Test bench to determinate the electricalcaracteristics



(a) $I_{pv}=f(V_{pv})$



(b) $P_{pv}=f(V_{pv})$

Fig. 4. Electrical characteristics

B. Battery model:

Fig.3. presents the used model [4, 16].

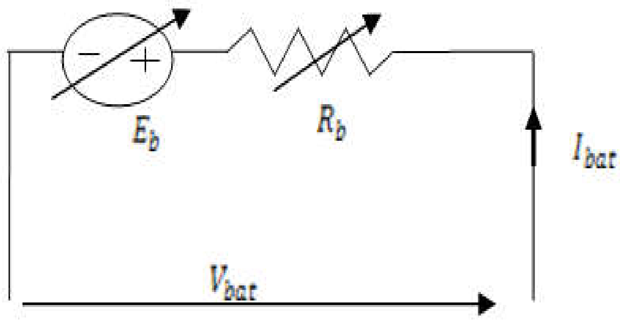


Fig. 5. Battery model

The different equations of the capacity model are [3, 4]:

$$V_{bat} = E_b \pm R_b \cdot I_{bat} \quad (2)$$

$$C_{bat} = C_{10} \times \frac{1.76 \times (1 + 0.005 \times \Delta T)}{1 + 0.67 \times \left(\frac{I_{bat}}{I_{10}} \right)} R_b \cdot I_{bat} \quad (3)$$

$$SOC\ (\%) = 100\ .(\ 1 - \frac{Q}{C_{bat}}) \quad (4)$$

$$Q = I_{bat}\ .t \quad (5)$$

C. PEM electrolyzer modelling

An electrical model (Fig.4) has been used.

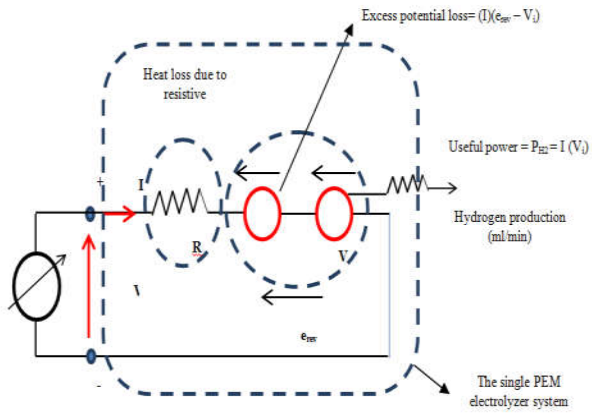


Fig. 6. Single cell equivalent PEM electrolyzer model

The electrical (I-V) characteristic can be express by:

$$I(T,p)=\begin{cases} 0 & V \le e_{rev}(T,p) \\ \dfrac{1}{R_i(T,p)}\left(V-e_{rev}(T,p)\right) & V \ge e_{rev}(T,p) \end{cases} \qquad (6)$$

$$V(T,\ p)=e_{rev}(T,p)-e_{rev}(T,p)e^{-\frac{5p}{0.02}}+R_i.I \qquad (7)$$

Where e_{rev} is the reverse voltage, R_i the initial PEM cell resistance and I is the input current.

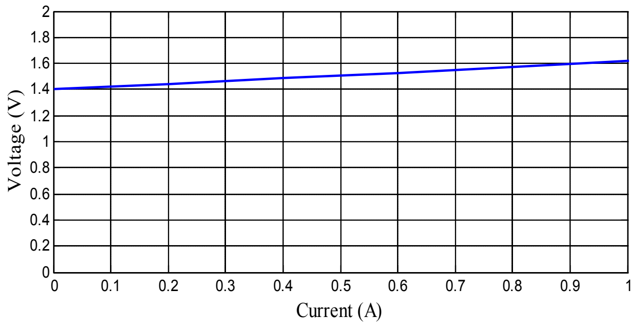


Fig. 7. I-V characteristic for single cell equivalent PEM electrolyzer.

3.Proposed Power Management Control (PMC)

When there is an excess of photovoltaic power, the power management control works to charge the batteries or the electrolyzer, and when there isn't any photovoltaic power available, it uses the PEMFC. There are three scenarios in this structure depending on the amount of electricity that is available. If it is positive, a discharge load will dissipate any excess power while the batteries are charging. If it is negative, the PV panels will provide the load. Consequently, the fifth switch K5 was required. The load is only fed by batteries in the second example, while PV panels are used to supply the load in the last scenario (Fig.8).
Various modes are managed by the five switches K_1, K_2, K_3, K_4, and K_5 (Table 2.).

Table 2. Different modes

K_1	K_2	K_3	K_4	K_5	P_{pv}	P_{FC}	P_{batt}	P_{elect}	P_{load}
On	Off	Off	Off	Off	On	Off	Off	Off	P_{pv}
On	Off	Off	On	On	On	Off	Off	On	P_{pv}
On	Off	Off	Off	On	On	Off	Off	Off	P_{pv}
On	Off	Off	On	Off	On	Off	Off	On	P_{pv}
On	On	On	Off	Off	On	On	On	Off	$P_{pv}+P_{batt}$ $+P_{FC}$
Off	On	On	Off	Off	Off	On	On	Off	$P_{batt}+P_{FC}$

When there is enough energy to preserve their lifespan, the batteries and the electrolyser are recharged. They are only used when absolutely essential, taking into account the batteries' state of charge between SOC_{max} and SOC_{min} as well as the tank's hydrogen pressure. It is accomplished by concise power management algorithm (Fig.8). According to the open and closed states of the switches K_1, K_2, K_3, K4, and K_5, which are depicted in Fig. 7, the various operational modes are classified into six modes.

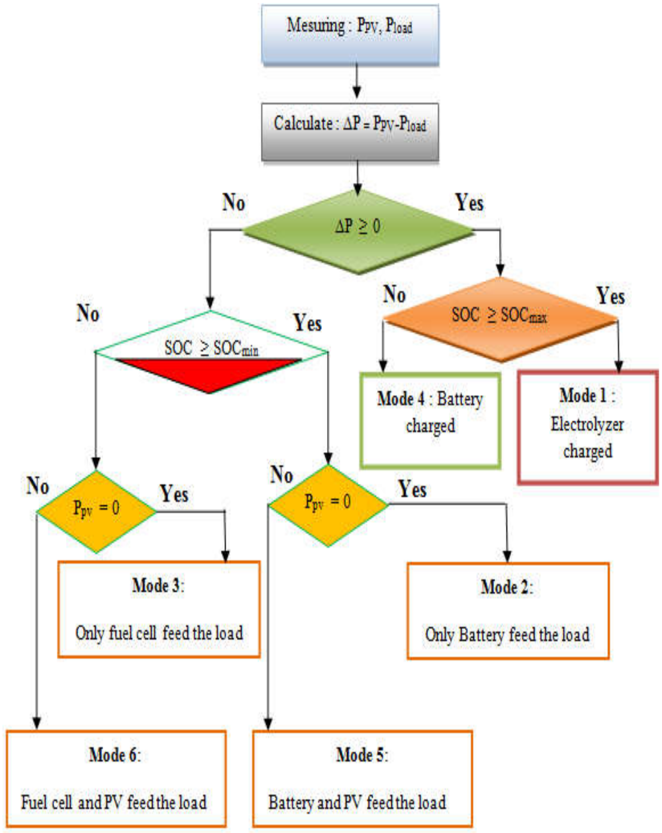


Fig. 8. PMC Flowchart

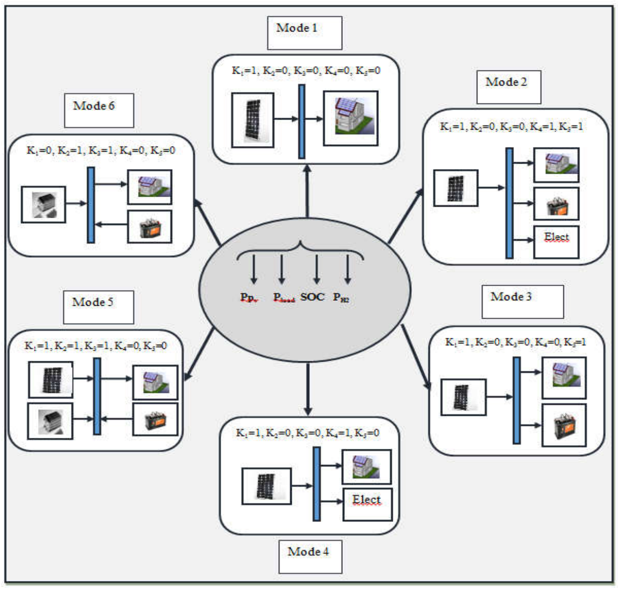
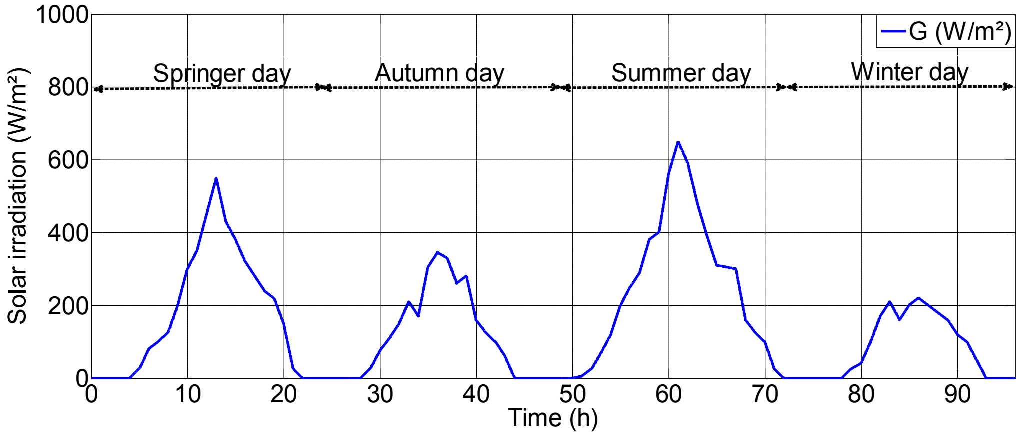


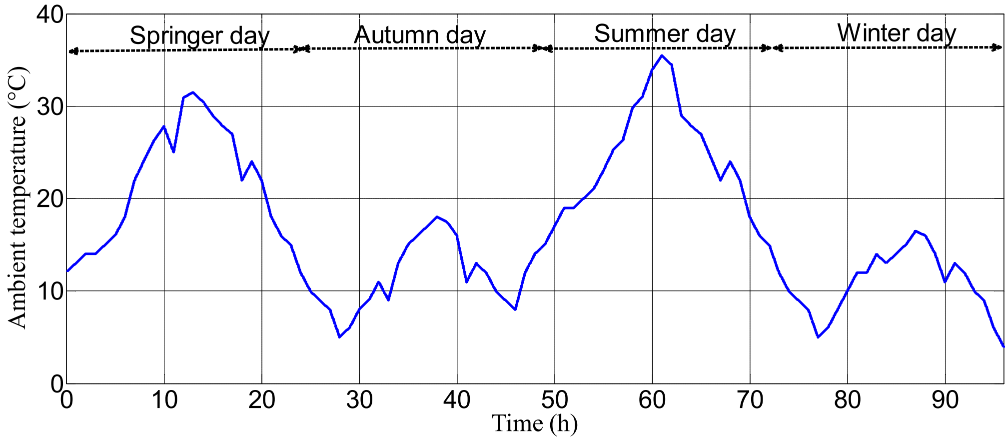
Fig. 9. Different modes of operation of the hybrid system studied

4.Application

To make credible and convincing the proposed system, an application is made. The simulation was run over four days (Fig.8), the obtained results for the configurations are as follow (Figs.9-10). Results from simulations conducted over four separate days demonstrate the effectiveness of the suggested solution. Additionally, there is always a surplus of energy that can be used to power a dump load.



(a) Solar Irradiance



(b) Ambient temperature

Fig. 10. Climatic conditions for four days

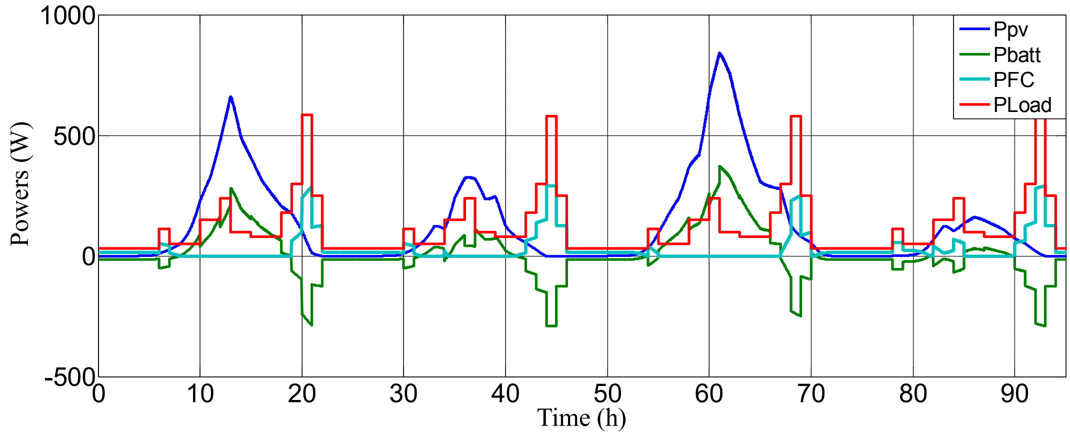


Fig. 11. Different Powers after control.

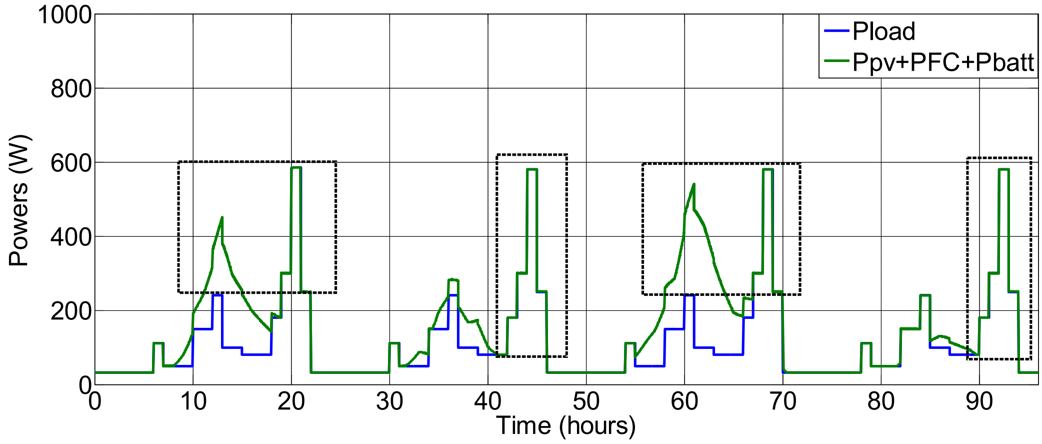


Fig. 12. Powers obtained after power control management during four days.

5.Design of a supervisor control circuit

The supervisor control circuit (SCC) is composes of two parts: a control part and a power part, separated by an isolation circuit (Fig.11).

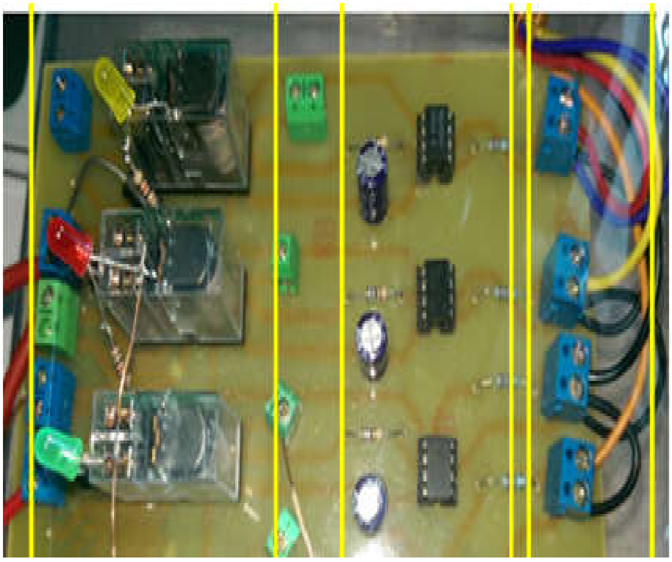


Fig. 13. Supervisor control circuit

The oscilloscope is used to compare the control signals from the three switches to those that were produced through simulation using Matlab/Simulink (Fig.12). It is noticed that the obtained practical signals are similar to those obtained by simulation. The first signal is used to the charge of the batteries while the second signal corresponds to the supply of the load only by batteries. The third signal is used to supply the load only by photovoltaic panels.

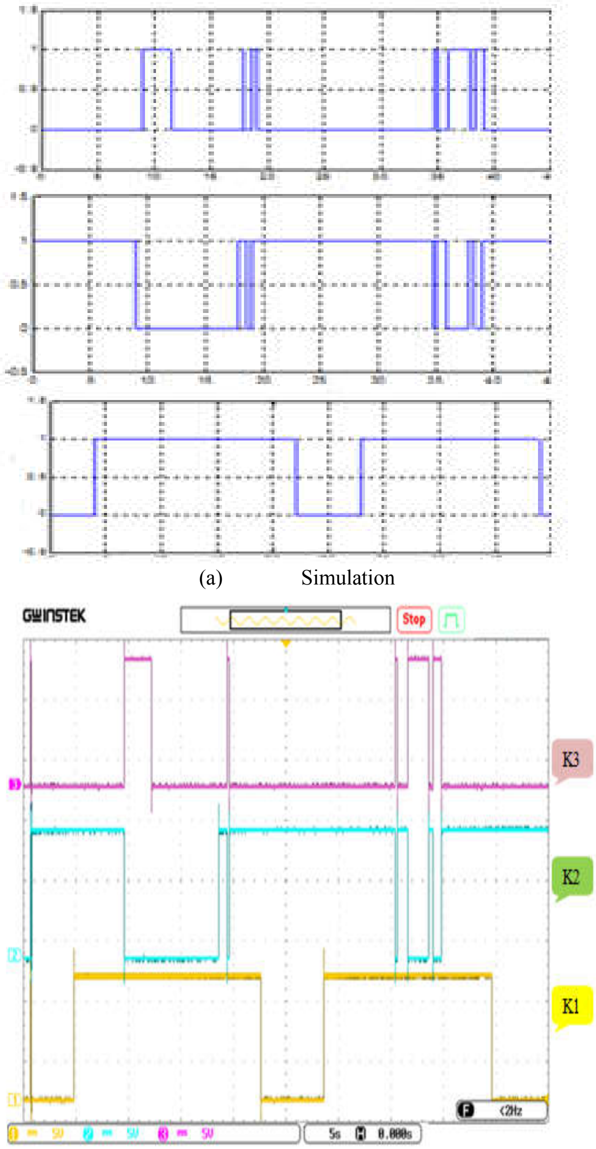


Fig. 14. Obtained Signals.

6. Conclusion

The management of the power flow from several sources providing a standalone residential house has been proposed in this study. It has been improved on the speed of tracking the maximum point of operation and on the stability of the system. Obtained simulation results made under four different days show the effectiveness of the proposed PMC. The supervisor control circuit has been designed to obtain the different control signals that allow the power management control of the global system. The implementation has been done using Dspace card. The obtained signals are similar to those obtained by simulation under Matlab/Simulink.

References

[1]. S. Ould Amrouche, D. Rekioua, T.Rekioua, S.Bacha, “Overview of energy storage in renewable energy systems, "International Journal of Hydrogen Energy (2016), Vo.41, no. 45, pp. 20914-20927.

[2]. N.A Kamarzaman, C.W. Tan, “A comprehensive review of maximum power point tracking algorithms for photovoltaic systems, Renewable and Sustainable Energy Reviews, vol.37, pp.585–598, 2014.

[3]. A. Mohapatra, B. Nayak, P. Das, K.B. Mohanty, “A review on MPPT techniques of PV system under partial shading condition, ” Renewable and Sustainable Energy Reviews, vol.80, pp.854–867, 2017.

[4]. D. Rekioua, T. Rekioua, Y.Soufi, “Control of a grid connected photovoltaic system, ” In: 2015 International Conference on Renewable Energy Research and Applications, ICRERA 2015, art. no. 7418634, pp.1382-1387, 2016.

[5]. D. Rekioua, E. Matagne, “Optimization of Photovoltaic Power Systems, Modelization, Simulation and Control, ” Edition Springer, 2012.

[6]. D. Feroldi, P. Rullo, D. Zumoffen, “Energy management strategy based on receding horizon for a power hybrid system, ” Renewable Energy, vol.75(0), pp.550 – 559, 2015.

[7]. E. Dursun and O. Kilic, “Comparative evaluation of different power management strategies of a stand-alone PV/Wind/PEMFC hybrid power system, ” Electrical Power and Energy Systems, vol.34,pp.81–89, 2012.

[8]. A. Achour, D. Rekioua, A. Mohammedi, Z.Mokrani, T. Rekioua, S. Bacha, “Application of direct torque control to a photovoltaic pumping system with sliding-mode control optimization, ” Electric Power Components and Systems, vol.44(2), pp.172-184, 2016.

[9]. D. Rekioua, S. Bensmail, N. Bettar, “Development of Hybrid Photovoltaic-Fuel Cell System Stand-Alone Application, ” International Journal of Hydrogen Energy, vol.9(3), pp.1604-1615, 2014.

[10]. M.Z. Abid, M.Yousif, S.Ullah, M. Hassan, “Design, sizing and economic feasibility of a hybrid PV/diesel/battery based water pumping system for farmland, ” International Journal of Green Energy, vol.19(6), pp.614-637, 2022.

[11]. T. Khatib, A. I. Ibrahim, A. Mohamed, “A review on sizing methodologies of photovoltaic array and storage battery in a standalone photovoltaic system, ” Energy Conversion and Management, vol.120, pp.430–438, 2016.

[12]. A.A. Khan, A.F. Minai, R.K. Pachauri, H. Malik, “Optimal Sizing, Control, and Management Strategies for Hybrid Renewable Energy Systems: A Comprehensive Review, ” Energies vol.15(17), pp.6249, 2022.

[13]. W. Obaid, A.K. Hamid, C. Ghenai, “Hybrid water pumping system design: A case study in Dubai, United Arab Emirates, ” Case Studies in Thermal Engineering, vol.26, art. no. 101121, 2021.

[14]. D. Rekioua, “Power Electronics in Hybrid Renewable Energies Systems, ” Green Energy and Technology, pp.39-77, Edition Springer, 2020.

[15]. M. Albarghot, M. Sasi, L. Rolland, “Matlab/Simulink modeling experimental results of a PEM electrolyzer powered by solar panel, ” Journal of Energy and Power Engineering, vol.10, pp.779-785, 2016.

[16]. A. Fathy, “A reliable methodology based on mine blast optimization algorithm for optimal sizing of hybrid PV-wind-FC system for remote area in Egypt, ” Renewable Energy, vol.95, pp.367-80, 2016.

[17]. D. Rekioua, “Energy Management for PV Installations (Book Chapter), ” Advances in Renewable Energies and Power Technologies. Elsevier, 2018.

[18]. A. Elmouatamid, R. Ouladsine, M. Bakhouya, N. El Kamoun, M. Khaidar, K.Zine-Dine, “Review of Control and Energy Management Approaches in Micro-Grid Systems, ” Energies, vol.14, 168, 2021.