Turkish Journal of Electromechanics and Energy
ISSN: 2547-975X
Vol:8, No:3, Page 109-117 (2023)
https://www.scienceliterature.com

Power management strategy for photovoltaic water pumping system in agriculture

D. Rekioua[1, *], F. Zaouche[1], Z. Mokrani[1], T. Rekioua[1], P. O. Logerais[2]

[1]*University of Bejaia, Faculty of Technology, LTII Laboratory, Bejaia, Algérie*

[2] *University Paris-Est, Department Genie Industrial at Maintenance (GIM), Lieusaint, France*

ARTICLE INFO

***Article Type*:**
Research Paper

Article History:
Received: 26 November 2023
Revised: 9 December 2023
Accepted: 19 December 2023
Published: 30 December 2023

Editor of the Article:
M. E. Şahin

Keywords:
Photovoltaic, Power management strategy, Batteries, Water pumping

ABSTRACT

The subject of this study is an isolated photovoltaic system with batteries, and the focus lies on optimization and control. For power optimization, three different algorithms have been used perturb and observe (P&O), incremental conductance (IC), and fuzzy logic control (FLC) algorithms. A comparison has been made and the outcomes of an implementation in Dspace 1104 device were compared to those in the simulation under MATLAB/Simulink. Using a power management control (PMC), which comes with explicit decision criteria built into this technique, makes it easier to control the investigated system. With PMC, the batteries were protected from deep discharges and overloads while the load was supplied. It is considered the situation of the water pumping for agricultural operations in Bejaia (Algeria), to show how this methodology could be applied in practice. The good performances of the suggested power management algorithm across two different profiles are demonstrated by the simulation results. This suggests that the proposed approach effectively balances the power generation, battery protection, and load supply requirements in the studied isolated PV system.

Cite this article: D. Rekioua, F. Zaouche, Z. Mokrani, T. Rekioua, P. O. Logerais, "Power management control for photovoltaic water pumping system in Agriculture," *Turkish Journal of Electromechanics & Energy*, 8(3), pp. 109-117, 2023.

1. INTRODUCTION

Hybrid renewable energy systems are increasingly in high demand in isolated areas [1-3], and the storage in these systems is a necessity [4, 5]. Many methodologies have been used for power maximization [6–10]. The nonlinear features of solar photovoltaic (PV) panels are more frequently addressed by intelligent maximum power point tracking (MPPT) approaches [11-13, 14-17]. The perturb and observe (P&O) technique is a simple and straightforward MPPT algorithm. The conductance incremental method mentioned in [10] requires a challenging control circuit. Additionally, sophisticated techniques based on MPPT control have been introduced. Although fuzzy logic control (FLC) is reliable in responding to changes in speed and power [15]. Numerous studies address the problem of managing the energy and the power of solar systems [18–22]. The main emphasis is on the ability of the various sources to control each other while delivering the load and protecting the storage system. Power management was used to optimize and manage a PV system with batteries.

For power optimization, three different algorithms have been used P&O, incremental conductance (IC), and FLC algorithms. The outcomes of an implementation in Dspace 1104 device were compared to those in the simulation. There are significant differences between this study and previous studies in the literature. The major goal is to optimize a hybrid renewable energy system within the context of Bejaia, Algeria. The priority is to address the region's power generation, battery protection, and energy demands, notably for agricultural water pumping. This geographical specialization differs from more general inquiries. The study involves implementing these optimization approaches in Dspace 1104 and then comparing the results to simulation findings. This method improves the study's practical application by testing the algorithms in a real-world situation, increasing the reliability of the results.

This study is notable for its unique application: water pumping for agriculture in Bejaia. By matching the study with local demands, it not only answers the region's practical needs but also demonstrates a tangible implementation of the optimized hybrid renewable energy system. Furthermore, the study lays a particular emphasis on battery protection and assuring load demand delivery. This dual focus distinguishes it from research that focuses exclusively on power generation without taking into account battery health and load control. To do this, the study employs and investigates three separate optimization techniques for power optimization in a PV system with batteries: P&O, IC, and FLC.

**Corresponding author's e-mail:* djamila.ziani@univ-bejaia.dz

The comparative study adds a vital element to the research by revealing the effectiveness of each method in specific environmental conditions. Recognizing the nonlinear properties of solar PV panels, the research incorporates intelligent MPPT techniques, such as FLC. At the same time, it addresses the oscillation issue associated with simpler strategies such as P&O.

The regional specificity, comparative examination of optimization methods, implementation and simulation comparison, emphasis on a practical application in agriculture, and contextualized integration of intelligent MPPT approaches are the distinguishing features. These characteristics add to the study's originality and usefulness in the larger landscape of research on hybrid renewable energy systems.

2. PROPOSED SYSTEM

The system in Figure 1 is composed of PV panels, and batteries coupled with a bidirectional converter that allows current to flow in both ways, allowing the batteries to be charged and discharged by the meteorological conditions.

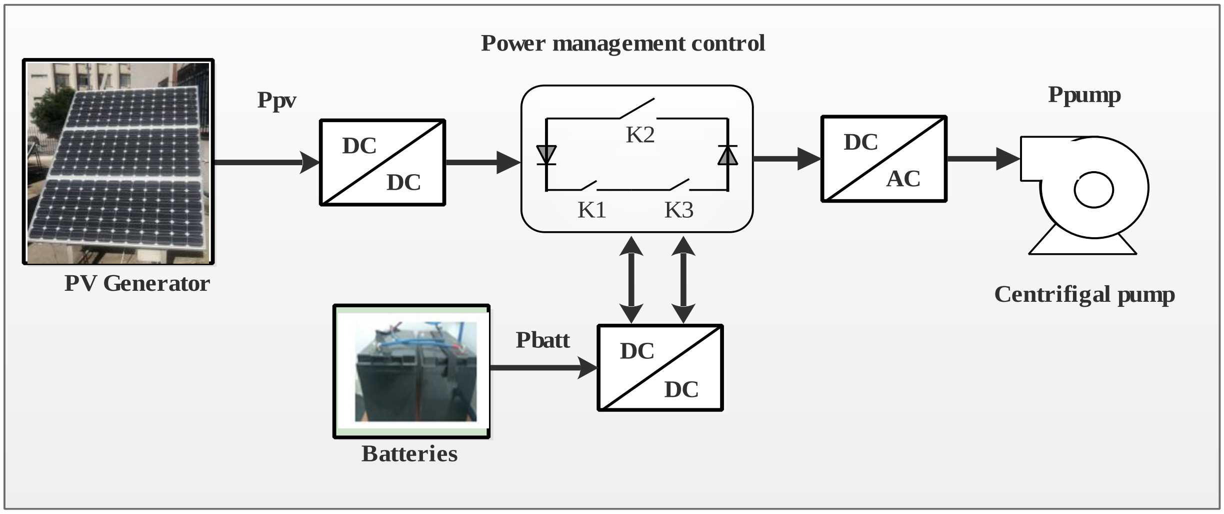


Fig. 1. Proposed system with power management control.

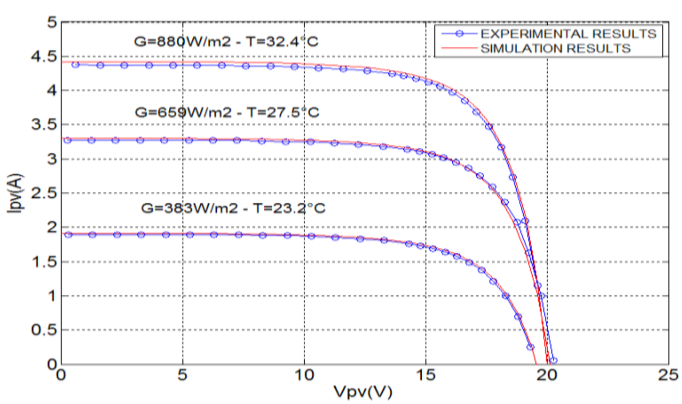
2.1. Photovoltaic Panel Modelling

The electrical curves in Figure 2(a) are obtained using the one-diode model [10, 15] (Fig. 2):

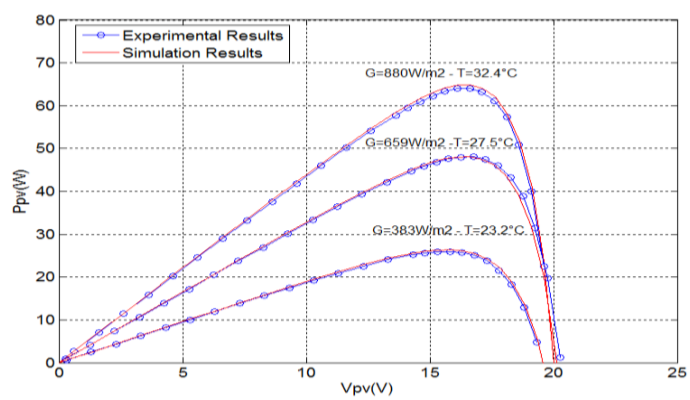
$$I_{pv} = I_{ph} - I_d - I_{Rsh} \tag{1}$$

where I_{ph} is the photo-current, I_{Rsh} the shunt resistance R_{sh} and I_d the diode-current.

The electrical characteristics in Figure 2(b) are obtained using the PV panel parameters of 80 W_p as in Table 1.



(a)



(b)

Fig. 2. Current and power PV characteristics, (a) $I_{pv}=f(V_{pv})$, (b) $P_{pv}=f(V_{pv})$

Table 1. Parameters of the PV panel.

Parameters	*Values*
Photovoltaic power	80 Wp
MPP current	4.65 A
MPP voltage	17.5V
Short-circuit current	4.95A
Open-circuit voltage	21.9V
Short-circuit current temperature coefficient	3 mA/°C
Open-circuit voltage temperature coefficient	-150mV/°C

2.2. Battery Modeling

In this research, the following model was applied to calculate the voltage and state of charge [21, 22]:

$$\begin{cases} V_{batt} = E_b - R_{batt}.I_{batt} - K_{batt}\int\left(\dfrac{I_{batt}}{Q}\right)dt \\ SOC = 1 - \dfrac{I_{batt}.t}{C_{batt}} \end{cases} \tag{2}$$

2.3. Optimization Methods

P&O method:

The basic operation is depicted in Figure 3 [10].

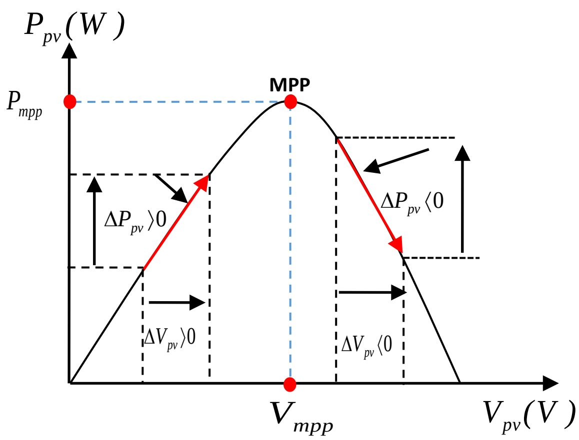


Fig. 3. P&O algorithm principle.

Inc method:

It is based on knowledge of the photovoltaic generator's conductance variation as shown in [10].

$$\begin{cases} C = \dfrac{I_{pv}}{V_{pv}} \\ dC = \dfrac{dI_{pv}}{dV_{pv}} \end{cases} \tag{3}$$

FLC method:

The three main processes of the fuzzy logic mechanism are fuzzification, fuzzy inference, and defuzzification using Table 2 [12]. The fuzzification process introduces fuzzy sets concerning the desired values at a degree of membership. According to Figure 4(a), (b) and (c), the defined classes are noted as NG: Negative Large, NP: Negative Small, ZE: Zero Approximate, PP: Positive Small and PG: Positive Large [8], [18].

Table 2. Fuzzy logic controller rules.

Error (e)	Change of error (Ce)						
	NB	NM	NS	ZE	PS	PM	PM
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

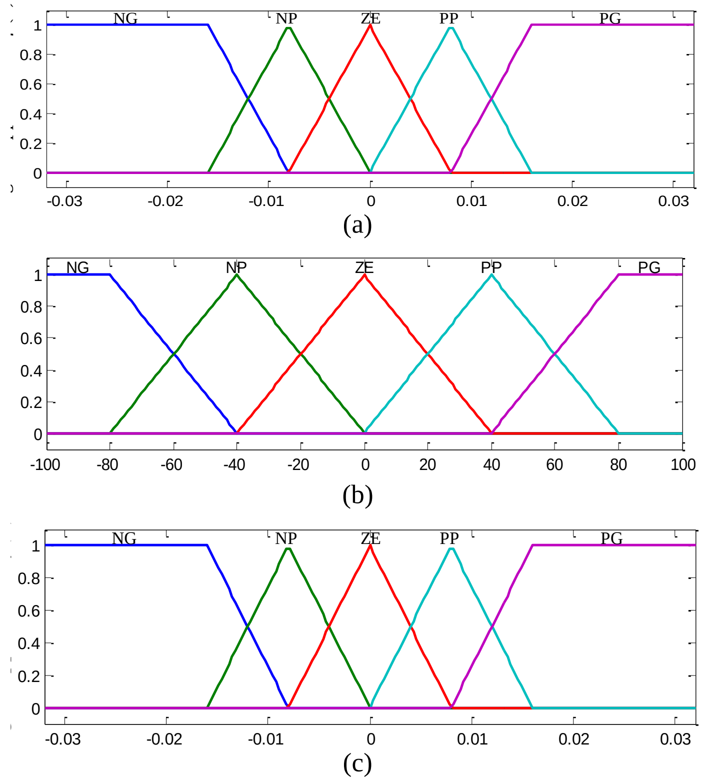


Fig.4. Membership functions; (a) Input variable (*E*), (b) Input variable (*DE*), (c) Output variable (*D*).

Fuzzy interfaces or fuzzyification are used to establish an adequate representation of the knowledge. Defuzzification utilizing the centre of gravity technique was used to calculate the FLC algorithm output [10, 15].

$$\begin{cases} \Delta V_{pv} = V_{pv}(k) - V_{pv}(k-1) \\ \Delta P_{pv} = P_{pv}(k) - P_{pv}(k-1) \end{cases} \tag{4}$$

Comparison results:

The following step profile of solar irradiance in Figure 5 was considered for the comparison of the three methods.

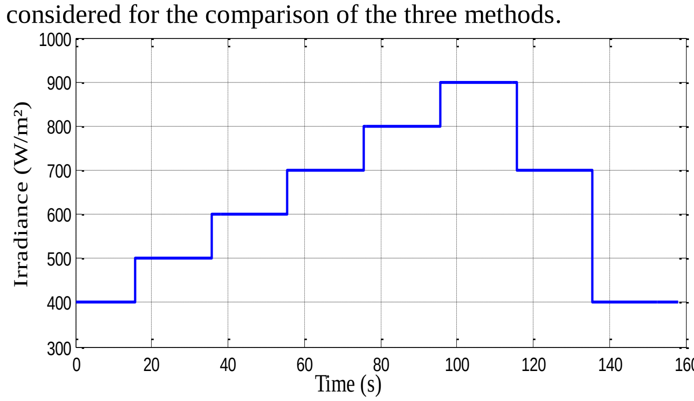


Fig. 5. Step profile of solar irradiance.

A comparison was made between the three approaches. Figure 6 demonstrates how, in contrast to the P&O and IC methods, the FLC enables to acquisition of a quick and accurate response.

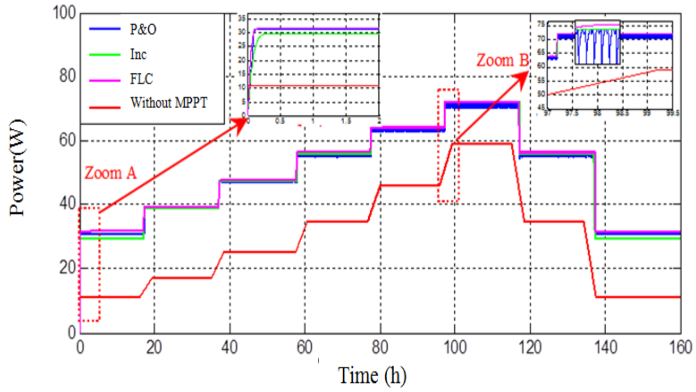


Fig. 6. Obtained photovoltaic power of the different MPPT algorithms under MATLAB.

For real-time implementation, the dSPACE 1104 was utilized. It is noticed in Figure 7 that the IC and P&O control produces oscillations at steady-state. The FLC control operates more powerfully and with fewer oscillations. Thereafter, the FLC will be applied to the water pumping system.

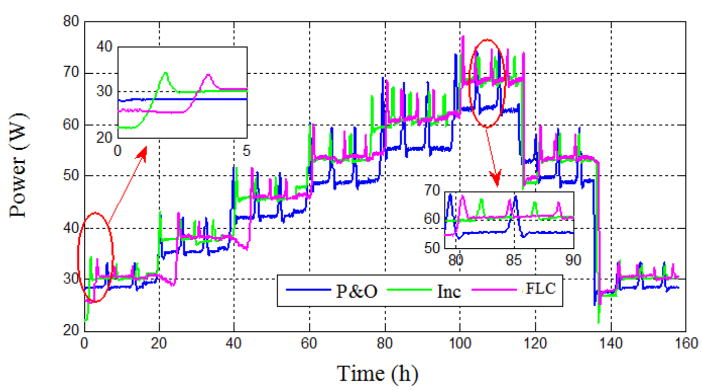


Fig. 7. Obtained PV power of the different MPPT algorithms.

3. PMC OF PV PUMPING WATER SYSTEMS (PVPWS)

3.1. Sizing of PVPWS

The hydraulic, mechanical, electrical and inverter input powers are respectively given as [15]:

$$\begin{cases} P_{Hyd} = \rho.g.H.Q_v \\ P_{mec} = \dfrac{P_{Hyd}}{\eta_{pump}} \\ P_{ele} = \dfrac{P_{mec}}{\eta_{IM}} \\ P_{dc} = \dfrac{P_{ele}}{\eta_{inv}} \end{cases} \tag{5}$$

The electrical energy load is:

$$E_{load} = \tau_{pump}.P_{dc} \tag{6}$$

with:

$$\tau_{pump} = \frac{V}{Q_v} \tag{7}$$

Then the photovoltaic power is:

$$P_{pv} = \frac{E_{Load}}{\tau_{pump}\left(1-\sum losses\right)} \tag{8}$$

Thus, the number of panels are [22]:

$$\begin{cases} N_{pv} = \dfrac{P_{pv}}{P_{pv-unit}} \\ N_{pv\text{-}serial} = \dfrac{V_{dc}}{V_{mpp}} \\ N_{pv\text{-}para} = \dfrac{N_{pv}}{N_{pv-serial}} \end{cases} \tag{9}$$

Finally, the capacity of the battery is [21, 22]:

$$C_{batt,tot} = \frac{E_{load}.D_{aut}}{V_{batt}.PDD.K_T} \tag{10}$$

In our case, the different components of the examined system were sized to supply a water tank of 77 m^3 (H=11.5 m and Q_v=22 m^3/h), as in Table 3.

Table 3. Sizing results.

Symbols	*Results*
Hydraulic power	689.43 W
Mechanical power	1253.50 W
IM electric power	1474.71 W
Inverter input power	1552.32 W
Pumping time	3.5 hours
Daily electrical energy load	5433.13Wh/day
Photovoltaic power	1940.40 W_p
panels number	24 panels
Serial panels	6 panels
Parallel panels	4 panels
Capacity of the batteries	10 batteries

3.2. Water Pumping System Modeling

Induction motor modelling:

The voltage equations are as follows [7]:

$$\begin{cases} V_{sd} = R_s I_{sd} + d\phi_{sd}/dt \\ V_{sq} = R_s I_{sq} + d\phi_{sq}/dt \\ 0 = V_{rd} = R_r I_{rd} + d\phi_{rd}/dt + \omega\,\phi_{rq} \\ 0 = V_{rq} = R_r I_{rq} + d\phi_{rq}/dt - \omega\phi_{rd} \end{cases} \tag{11}$$

and:

$$T_{em} = P\left(\phi_{sd} I_{sq} - \phi_{sq} I_{sd}\right) \tag{12}$$

where: the subtracts *sd* and *sq* correspond to the (d, q) stator components, R_s is the stator resistance, and the indices R_d and R_q relate to the rotor's (d, q) components, and R_r is the rotor resistance.

Pump model:

The load torque is given as [15]:

$$T_r = k_{pump}.\omega^2 \tag{13}$$

The total head is:

$$H = H_g + \psi\, Q_v^{\,2} \qquad (14)$$

k_{pump} and Q_v stand for, the constant, and the flow rate, respectively.

Control Strategy:

The Field-Oriented Control (FOC) method was used to control an induction generator (IG) about 1.5 kW; the different parameters are summarized in Table 4.

Table 4. Induction motor parameters.

Symbols	*Results*
Rated Power (P_N)	1.5 kW
Rated current (I_N)	5.2/3 A
Rated voltage (V_N)	220/380 V
Number of pair poles (P)	2
Rated speed (N_N)	1460 rpm

The various equations are as follows:

$$\begin{cases} T_e = p \,.\, \dfrac{M}{L_r} \,.\, \Phi_r \,.\, I_{sq} \\ \Phi_r = \dfrac{M \,.\, I_{sd}}{1 + T_r \,.\, s} \\ \omega_r = \dfrac{M \,.\, I_{sq}}{T_r \,.\, \Phi_r} \\ \omega_s = \dfrac{M \,.\, I_{sq}}{T_r \,.\, \Phi_r} + p \,.\, \Omega \end{cases} \qquad (15)$$

The mechanical power is:

$$P_{mec} = K.\omega^3 \qquad (16)$$

The angular velocity and the mechanical torque are [15]:

$$\begin{cases} \omega = \sqrt[3]{\dfrac{P_{pv}}{K_{pump}}} \\ T_{em} = \sqrt[3]{K_{pump}.P_{pv}^2} \end{cases} \qquad (17)$$

4. PHOTOVOLTAIC WATER PUMPING SYSTEM

The field-oriented control (FOC) and the fuzzy logic control (FLC), optimization were used in Figure 8. The simulation was performed considering two days as in Figure 9 to show the feasibility of the PV pumping system. The batteries that make up the power deficiency to continuously supply the motor pump and the greatest amount of photovoltaic power available were used to generate the reference power. Three switches K_1, K_2 and K_3 are used respectively for the PV control signal, Battery control signal and compensation batteries with PV.

The various switches are given in Figure 10, Figures 11 and 12 show the battery's state of charge (SOC) as well as the various modes.

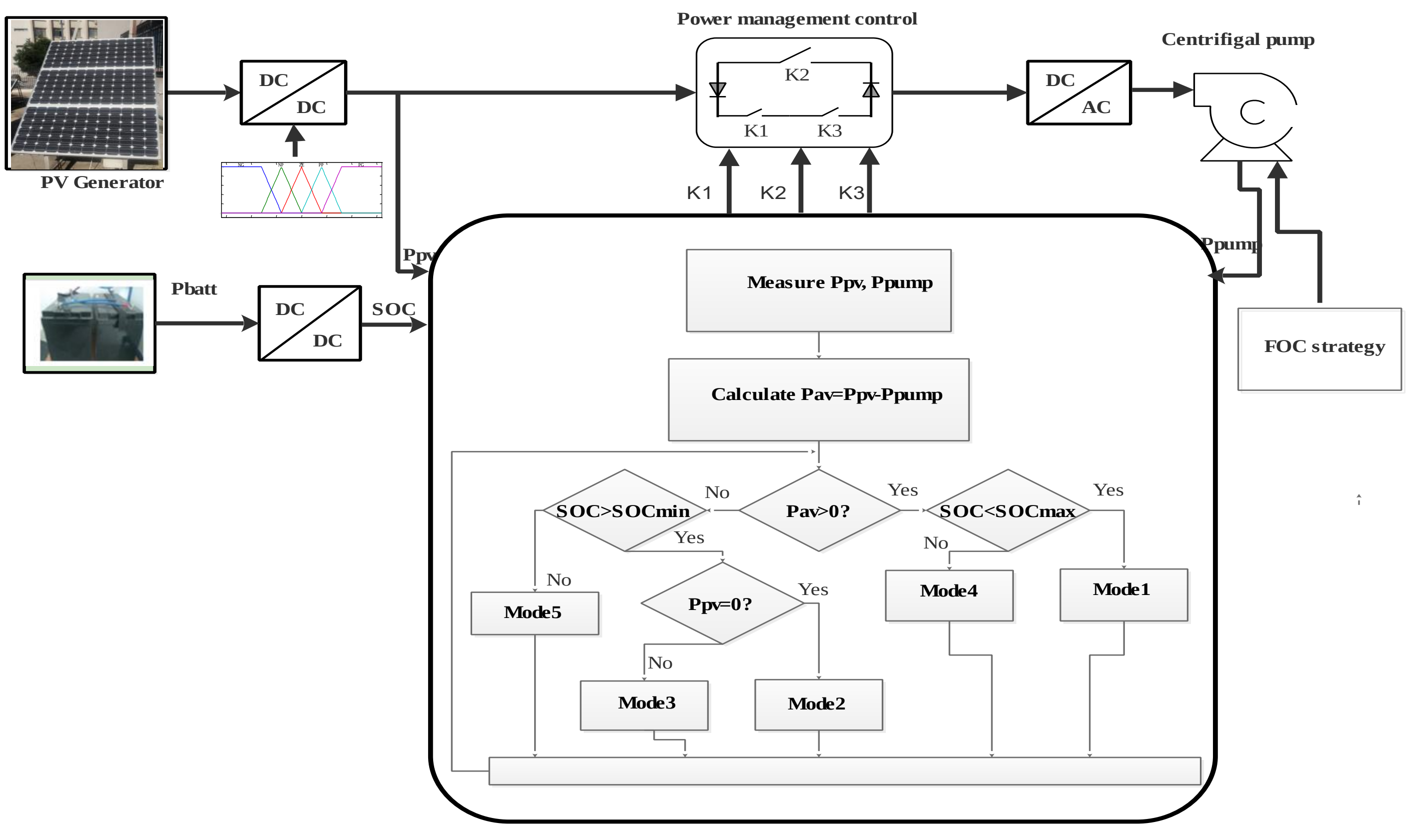
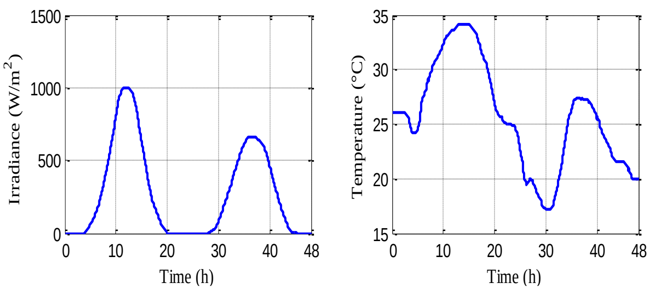


Fig.8. Proposed system structure with FLC and PMC

Figure 11 represents variations in the battery state of charge. It is noticed that the maximum value is about 82%, not exceeding the upper value authorized in the proposed PMC algorithm (SOC_{max} = 90%). Also, the minimum value is about 35% and has not reached the minimum value authorized in the algorithm (SOC_{min} = 30%), indicating the proper operation of the proposed PMC, which protects the batteries.

Figure 12 depicts the different modes obtained during consecutive days. All operating modes (Mode 1, Mode 2, Mode 3, and Mode 4) appeared in the first profile with high solar irradiance. However, during the second-day profile with less solar irradiance, only Mode 1 and 2 appear.



(a) (b)

Fig. 9. Solar irradiance and ambient temperature (a) solar irradiance, (b) ambient temperature.

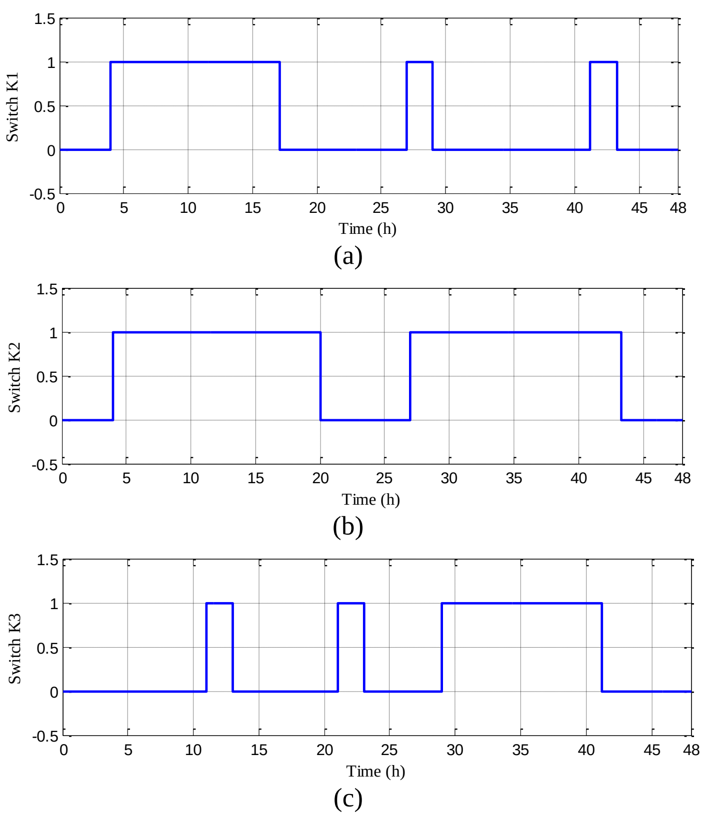


Fig 10. Control signals of the switches K_1, K_2 and K_3. (a) Switch K_1, (b) Switch K_2, (c) Switch K_3.

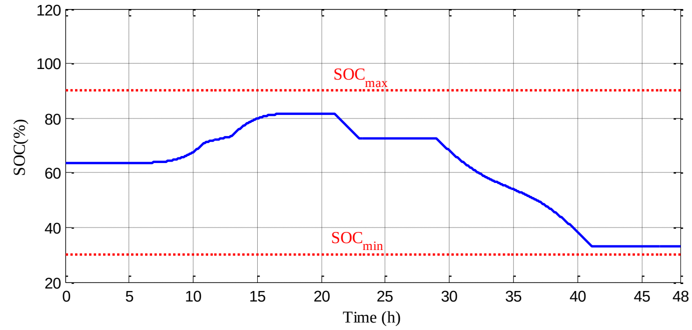


Fig. 11. Batteries state of charge.

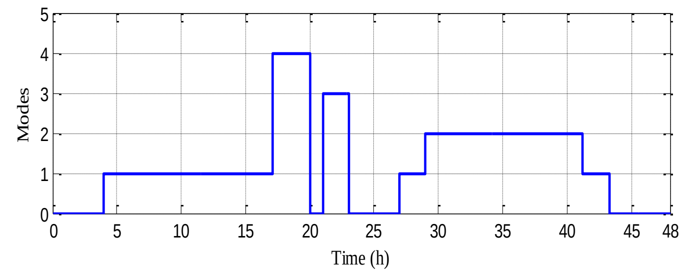


Fig. 12. Obtained various modes.

The DC bus voltage is kept constant as seen in Figure 13.

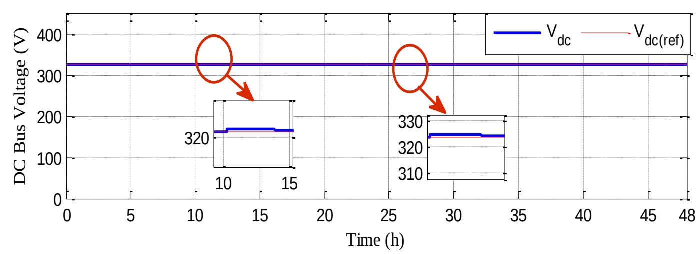


Fig. 13. DC bus voltage.

The stator current has a sinusoidal shape as in Figure 14, and it is clear that the electromagnetic torque as in Figure 15 follows the resistive torque.

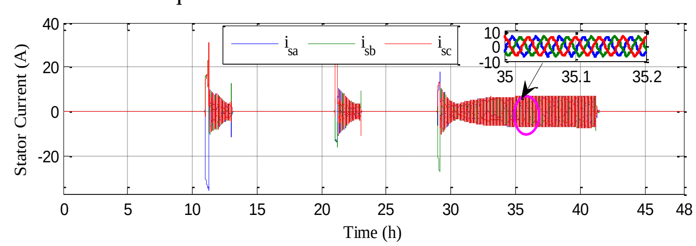


Fig. 14. Stator current variations.

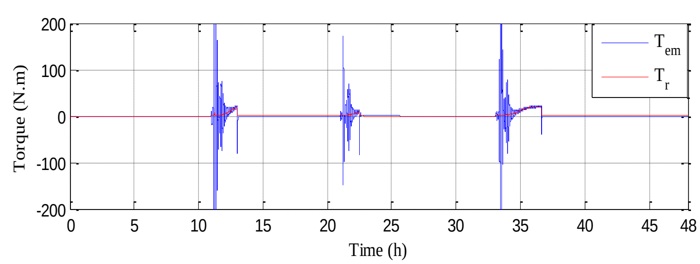


Fig. 15. Electromagnetic torque variations.

Figures 16 and 17 show the speed fluctuations of the rotor and the water flow, respectively. Figure 18 depicts the various powers.

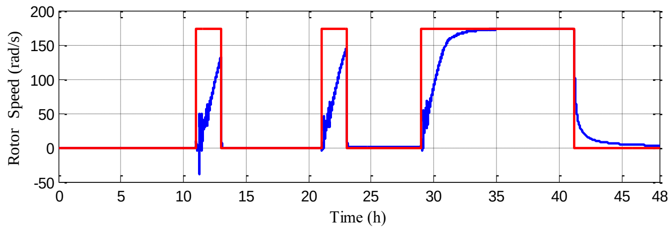


Fig. 16. Rotor speed fluctuations (blue) and its reference (red).

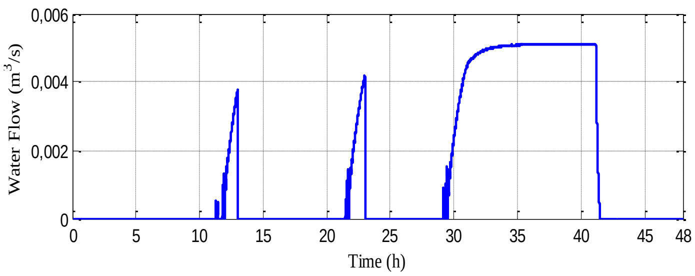


Fig.17. Water flow variations.

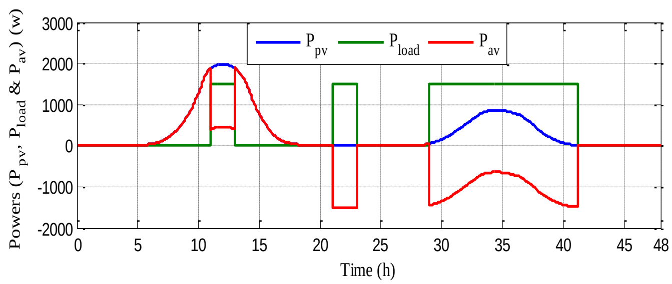


Fig. 18. Power waveforms.

As depicted in Figure 18, on the initial day of high solar irradiation, the load was adequately powered, resulting in an excess of energy that was used for charging the batteries. Conversely, in the second profile, where the solar panels are insufficient to supply the load demands, the batteries compensate by giving the necessary power in addition to the photovoltaic (PV) system.

4. CONCLUSION

In this work, a photovoltaic system with integrated battery storage was studied. The properties of the key components and the configuration of the system are given. An application was made for water pumping. The suggested system was supported by simulation results. The results obtained demonstrated that the selected control approach was successful. The system can be run as efficiently as possible while maintaining great performance The system can be run as efficiently as possible while maintaining great performance for the photovoltaic system using the specified power management regardless of the weather variations. This fact guarantees that the proposed application will be able to perform exactly as expected.

Nomenclature

C	Conductance
C_{batt}	Battery capacity
$C_{batt,\ tot}$	Total battery capacity
D_{aut}	Autonom days
dC	Incremental conductance
DOD	Depth of discharge
E_b	Battery fem
E_{load}	Electrical energy load
g	Gravity
H	Total head
I_{batt}	Current battery
I_{mpp}	Maximum power point current
I_d	Diode-current
I_{ph}	Photo-current,
I_{pv}	Photovoltaic current
I_{sd}	Direct rotor current
I_{sq}	Qaudrate stator current
I_{rd}	Direct rotor current
I_{Rsh}	Shunt current
I_{rq}	Qaudrate rotor current
K_T	Temperature coefficient
M	Inductance mutuelle
N_{pv}	Photovoltaic panel number
N_{pvser}	Serial Photovoltaic panel number
N_{pvpar}	parallel photovoltaic panel number
P	Number of pole pairs
P_{dc}	Output inverter power
P_{pv}	Photovoltaic power
P_{mpp}	Maximum power point power
R_{batt}	Internal resistance battery
R_s	Stator resistance
R_{sh}	Shunt resistance
R_r	Rotor resistance.
SOC	State-of-charge
T_e	Electromagnetic torque
V	Volume of the tank
V_{batt}	Voltage battery
V_{mpp}	Maximum power point voltage
V_{pv}	Photovoltaic voltage
V_{sd}	Direct stator voltage
V_{sq}	Qaudrate stator voltage
Q_v	Volumetric water flow
ρ	Water density
τ_{pump}	pumping time
ϕ_{sd}	Direct stator flux
ϕ_{sq}	Quadrate stator flux
ϕ_{rd}	Direct stator flux
ϕ_{rq}	Quadrate stator flux

References

[1] L. Gómez, J. C.; De León Aldaco, S. E.; A. Alquicira, J., "A Review of Hybrid Renewable Energy Systems: Architectures, Battery Systems, and Optimization Techniques," *Eng*, vol.*4*, pp.1446-1467, 2023.

[2] P. Roy, J. He, T. Zhao, Y.V. Singh, "Recent Advances of Wind-Solar Hybrid Renewable Energy Systems for Power Generation: A Review," *IEEE Open J. Ind. Electron*. Soc. vol. 3, pp.81–104, 2022.

[3] D. Rekioua, "Energy Storage Systems for Photovoltaic and Wind Systems: A Review," *Energies*, vol.*16*, 3893, 2023.

[4] R. S. Sankarkumar, R. Natarajan, "Energy management techniques and topologies suitable for hybrid energy storage system powered electric vehicles: An overview," Int. Trans. Electr. Energy Syst. vol. 31, e12819, 2021.

[5] R. Aissou, T. Rekioua, D. Rekioua, A. Tounzi, "Robust nonlinear predictive control of permanent magnet synchronous generator turbine using Dspace hardware," *International Journal of Hydrogen Energy*, 41(45), pp.21047-21056, 2016.

[6] J. M. A. Elgendy, B. Zahawi and D. J. Atkinson, "Assessment of Perturb and Observe MPPT Algorithm Implementation Techniques for PV Pumping Applications, " *IEEE Transactions on Sustainable Energy*, 3(1), pp. 21-33, 2012.

[7] D. Rekioua., T. Rekioua., "DSP-controlled direct torque control of induction machines based on modulated hysteresis control" 2009 Proceedings of the International Conference on Microelectronics, ICM, vol. 5418603, 2009, pp. 378-381.

[8] M. E. Sahin and H. İ. Okumus, "Fuzzy logic controlled buck-boost DC-DC converter for solar energy-battery system," 2011 International Symposium on Innovations in Intelligent Systems and Applications, İstanbul, Türkiye, 2011, pp. 394-397.

[9] D. Rekioua, T. Rekioua, K. Idjdarene, A. Tounzi, "An approach for the modelling of an autonomous induction generator taking into account the saturation effect, "*International Journal of Emerging Electric Power Systems*, 4(1), pp.1-10, 2005.

[10] D. Rekioua, E.Matagne, "Modeling of Solar Irradiance and Cells. In: Optimization of Photovoltaic Power Systems," Green Energy and Technology. Springer, London, 2012.

[11] P. N. Krishna, S. R. Gupta, P. V. Shankaranarayanan, S. Sidharth and M. Sirphi, "Fuzzy Logic Based Smart Home Energy Management System," *9th International Conference on Computing, Communication and Networking Technologies*, Bengaluru, India, 2018, pp. 1-5

[12] M. B. Smida, A. Sakly, "Fuzzy logic control of a hybrid renewable energy system: A comparative study," *Wind Engineering*, 45(4), pp.793-806, 2021.

[13] S. Lalouni, D. Rekioua, K. Idjdarene, A. M. Tounzi, "An improved MPPT algorithm for wind energy conversion system," *Journal of Electrical Systems*, 10 (4), pp. 484-494, 2014.

[14] Z. Feng, Z. Jingjing; X. Ji; C. Yingying; F. Ling; L. Zhe; D. Jie; Z. Jiaming, "Energy Management Strategy of Microgrid Based on Fuzzy Control, *2018 2nd IEEE Advanced Information Management, Communicates," Electronic and Automation Control Conference*, Xi'an, China, 2018, pp. 1-1670R.

[15] D. Rekioua, S. Bensmail, T. Rekioua, "Application of adaptive fuzzy logic controller to improve photovoltaic pumping system performances," *Turkish Journal of Electromechanics & Energy*, 7(3), pp.92-99, 2022.

[16] 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.

[17] Idjdarene K., Rekioua D., Rekioua T., Tounzi A, 'Wind energy conversion system associated to a flywheel energy storage system,' *Analog Integrated Circuits and Signal Processing*, vol. 69, pp. 67-73, 2011.

[18] O. Ö. Mengi, and İ. H. Altaş, "Fuzzy logic control for a wind/battery renewable energy production system," *Turkish Journal of Electrical Engineering and Computer Sciences*: 20(2), pp.187-206, 2012.

[19] A. Hajizadeh, and M. A. Golkar, "Intelligent power management strategy of hybrid distributed generation system," *Electrical Power and Energy Systems*, vol. 29, pp. 783-795, 2007.

[20] N. Mebarki, T. Rekioua, Z Mokrani, D. Rekioua, "Supervisor control for stand-alone photovoltaic/hydrogen/battery bank system to supply energy to an electric vehicle," *International Journal of Hydrogen Energy*, 40(39), pp.13777-13788, 2015.

[21] A. Mohammedi, D. Rekioua, T. Rekioua, S. Bacha, "Valve Regulated Lead Acid battery behaviour in a renewable energy system under an ideal Mediterranean climate," *International Journal of Hydrogen Energy*, 41(45), pp.20928-20938, 2016.

[22] H. Hassani, F. Zaouche, D. Rekioua, S. Belaid, T. Rekioua, S. Bacha, "Feasibility of a standalone photovoltaic/battery system with hydrogen production," *Journal of Energy Storage*, Vol 31, pp. 101644, 2020.

Biographies

Djamila Rekioua is a full professor at the University of Bejaia. She obtained her Ph.D. in Electrical Engineering in 2002. She specialises in the control of electrical machines and renewable energies and has defended several Master's and PhD theses. She has received several awards for her research work. Her main work focuses on wind, photovoltaic, fuel cell, storage and multi-source systems. She is the author of several international publications

E-mail: djamila.ziani@univ-bejaia.dz

Faika Zaouche received her master's degree in electrical engineering from the University of Bejaia, Algeria, in 2012. She obtained a PhD degree in the same department in 2018. Her current research interests are photovoltaic systems, storage, Fuel cells and power management control. She is an assistant professor at the High School of Informatics in Amizour City (Bejaia) and a member of Laboratory TAMAYOUZ LTII at the University of Bejaia (Algeria).

E-mail: faika.aouchei@univ-bejaia.dz

Zahra Mokrani received her master's degree in electrical engineering from the University of Bejaia, Algeria, in 2012. She obtained a PhD degree in the same department in 2016. Her current research interests are photovoltaic systems, electric vehicles, storage, fuel cells and power management control. She is the author of several international publications and Internationals conferences. She is an assistant professor at the electrical engineering department and a member of Laboratory TAMAYOUZ LTII at the University of Bejaia (Algeria).

E-mail: zahra.mokrani@univ-bejaia.dz

Toufik Rekioua received his engineer from the National Polytechnic Institute of Algiers and earned a Doctoral degree from I.N.P.L of Nancy (France) in 1991. He has been a full Professor at the Electrical Engineering Department-University of Bejaia (Algeria) since 1992. His research activities have been devoted to several topics: control of electrical drives, modelling, wind turbines, photovoltaic and control in AC machines.
E-mail: toufik.rekioua@univ-bejaia.dz

Pierre Olivier Logerais has been a Professor at the Paris-Est Créteil University (UPEC) in France since 2009. His topics of research are photovoltaics, wind systems, thermal systems, optimization, supercapcities and energy storage. He is the author of several publications and has defended several master's and Ph.D. theses in France and Algeria. His teaching activities are at the IUT of Sénart - LIEUSAINT (France).
E-mail: pierre-olivier.logerais@iutsf.org