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OPTIMIZATION OF THE OPERATION OF A PUMP SYSTEM AND PHOTOVOLTAIC MEMBRANE ULTRAFILTRATION BY USE OF A FUZZY CONTROLLER

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ABSTRACT

This article presents a smart approach optimization performance of a photovoltaic pumping system (PVPS) coupled to a module of ultrafiltration membrane to water by the use of a fuzzy controller for power for obtaining a better drinking water flow. The complete system, operating over the Sun is and simulated on Matlab/Simulink is a system PV-boost/MPPT-fuzzy/MLI-inverter/MLI-motor-pump/ Membrane ultrafiltration module. The boost converter (IGBT) switch is controlled by a fuzzy controller that adjusts the duty cycle regularly depending on the climatic conditions and ensures the operation of the complete system at the point of maximum power, allowing the Group motor-pump-module to ultrafiltration to deliver a flow and a pressure of drinking water superior to the system using the MPPT-P&O controller.

Keywords: *Photovoltaic pumping, Controller MPPT, Boost converter, Fuzzy logic, Ultrafiltration membrane.*

I. INTRODUCTION

The use of photovoltaic conversion of solar energy to operate the pumps to water today is a developing technology, characterized by gradually declining costs and in-creasing association with technology. Since the first installation of the late 1970s, solar pumping systems of water to cover domestic needs of livestock or irrigation water in isolated areas, have won a lot of acceptance in performance and reliability and nowadays they belong to the most significant applications of photovoltaic energy.

Running over the Sun photovoltaic pumping systems are generally composed of a photovoltaic generator (GPV), converters of energy, a motor and a pump. As a result of this system, we integrate an ultrafiltration mem-brane module to make the virtually safe drinking water and reduce waterborne diseases affecting the population of developing countries at the same time. The main barrier to the use of photovoltaic pumping systems continues to be their high initial cost and low performance in water. Investigations for the optimization of the operation of the virtually recent years can be grouped into two categories. The first concerns those who seek to optimize the functioning of the GPV through research of the point of maxi-mum power (MPPT) via different algorithms [1], [2], [3], [4]. In the second category, we bring together those who seek to optimized the command.

In this work, we use an intelligent algorithm based on fuzzy logic built into the MPPT controller that generates the impulses of the boost chopper control. The results of the functioning of the system of pumping and filtration photovoltaic (SPF -PV) using this technique show a clear improvement compared with using the algorithm P&O [8].

This article in its joints, first introduces the title material and methods which illustrates in detail the model Simulink of GPV, the floor of adaptation (converter and inverter) integrating the technique of locking of the cyclical report through the MPPT-fuzzy command and then the Simulink model of the single phase motor induction coupled centrifugal pump and membrane ultrafiltration module. Then a presentation discussed the results obtained by simulation of the complete system and finally the conclusion

II. METHOD & MATERIAL

Material

As part of this work, we had used a computer brand acer processor Intel(C) dual core, 2.3 GHz, the Matlab R2013b software, a photovoltaic module brand Helios H750 to fuel the Group motor-pump to a water-mark ultrafiltration equipment Multi-Inox 34 ES that uses module tangential ultrafiltration SM1C35-A004 and an experimental database identified 11 January 2016 (from 9: 00 to 16: 00) at the University of Ngaoundéré.

Methods

Photovoltaic generator

In this article, we use the basic structure of a photovoltaic cell to a diode. The equivalent circuit of the GPV and the various equations leading to equation (1) are provided in [9].

$$I_{pv} = I_{cc} - I_c\left[\exp\left(\frac{V_{pv} + R_s I_{pv}}{V_t \times N_{cs}}\right) - 1\right] \quad (1)$$

The scheme bloc of figure 1 shows model Simulink model of the PV (a) et du GPV (b) module, based on equation (1) whose parameters interact are resolved by Newton-Raphson's methods in Matfile.

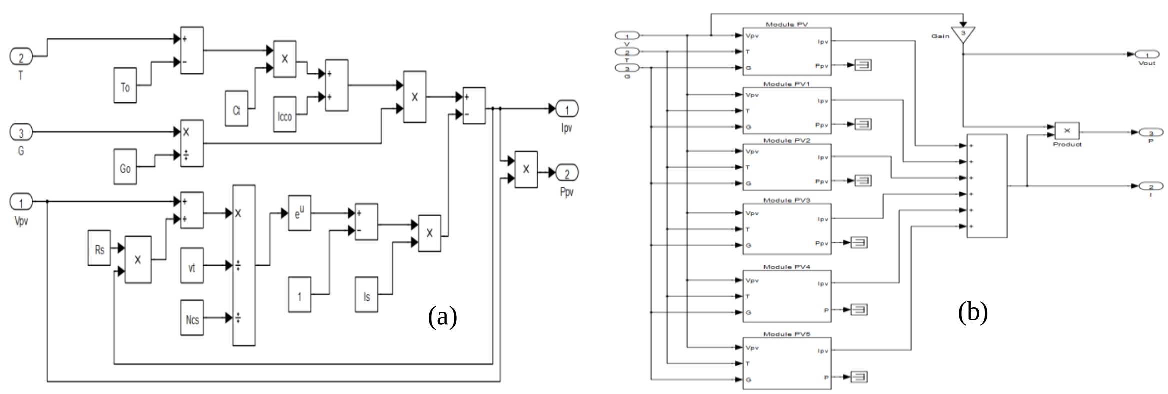

Fig.1. Simulink model of the module and PV generator

For the simulation of the GPV, we combine in series 3 rows of 6 PV modules in parallel (NP = 6, NS = 3) as submitted to the figure1.b for a 1559.09 W under 24.06 A and 64.8 V available power and allowing the pump to provide 1.3 l/s under 6 bar.

Simpower System model of the boost converter

The Simulink model of the step-up converter shown in figure 2A for main role to get the voltage from a low to a higher value by varying the duty cycle (d) in relationships (2) and (3) following.

$$V_{out} = \frac{V_{in}}{1-d} \quad (2)$$

$$I_{out} = (1-d)\,\mathrm{I}_{in} \quad (3)$$

V_{in} and I_{in} represent respectively the voltage and current at the entrance of the boost converter and V_{out}, I_{out} chopper output. Inductance L and the capacitance C of the converter values are calculated as

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$$L = d\frac{V_{in}}{f.\Delta I} \quad (4)$$

$$C = d\frac{I_{out}}{f.\Delta V} \quad (5)$$

With as frequency and the size of the ripple current and voltage respectively. Using the maximum values of current and voltage, application digital relationships (3) and (4) respectively provide 30 µH and 470 µF

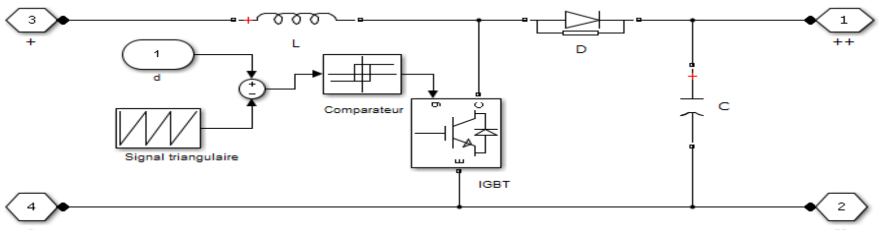

Fig. 2. Simulink model of the boost converter

At the entrance of the control signal, a comparator al-lows to analysis between a triangular signal of frequency 100 kHz and the cyclical report provided by the control algorithm MPPT-fuzzy.

The MPPT-fuzzy control algorithm

The MPPT allows the GPV to operate at the maximum despite the variation in the sunshine, temperature and power load [10], [11], [12]. Found in the literature about twenty method based on the research of the PPM of the PV modules. The order by the logic fuzzy offer the advantage of being robust, efficient and works to the PPM without swing [1], [3]. There are different ways to implement a fuzzy regulator but in general the presentation adopted splits up in three steps: the fuzzification, inference and defuzzification (figure 3).

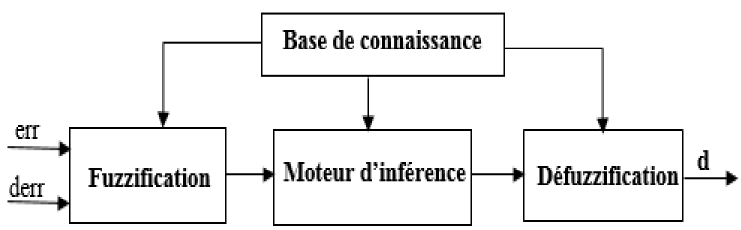

Fig. 3. Fuzzy controller block diagram of the algorithm

The step of fuzzification allows the conversion of the in-put in Fuzzy variable variables. In our case, we have two entries: error (err) and the variation of the error (derr) de-fined by the relationships (6) and (7) following.

$$err = \frac{P_{pv}(k) - P_{pv}(k-1)}{V_{pv}(k) - V_{pv}(k-1)} \quad (6)$$

$$derr(k) = err(k) - err(k-1) \quad (7)$$

When $P_{pv}(k)$ et $V_{pv}(k)$ are respectively the power and instantaneous voltage of the GPV. Attributed to these sizes of linguistic variables: NG (if not great), NP (Negative small), ZE (Zero), PP (Positive small) and PG (Positive large). Figure 4 shows the functions of membership of these five fuzzy subsets of variables of entries as well as the output variable (d).

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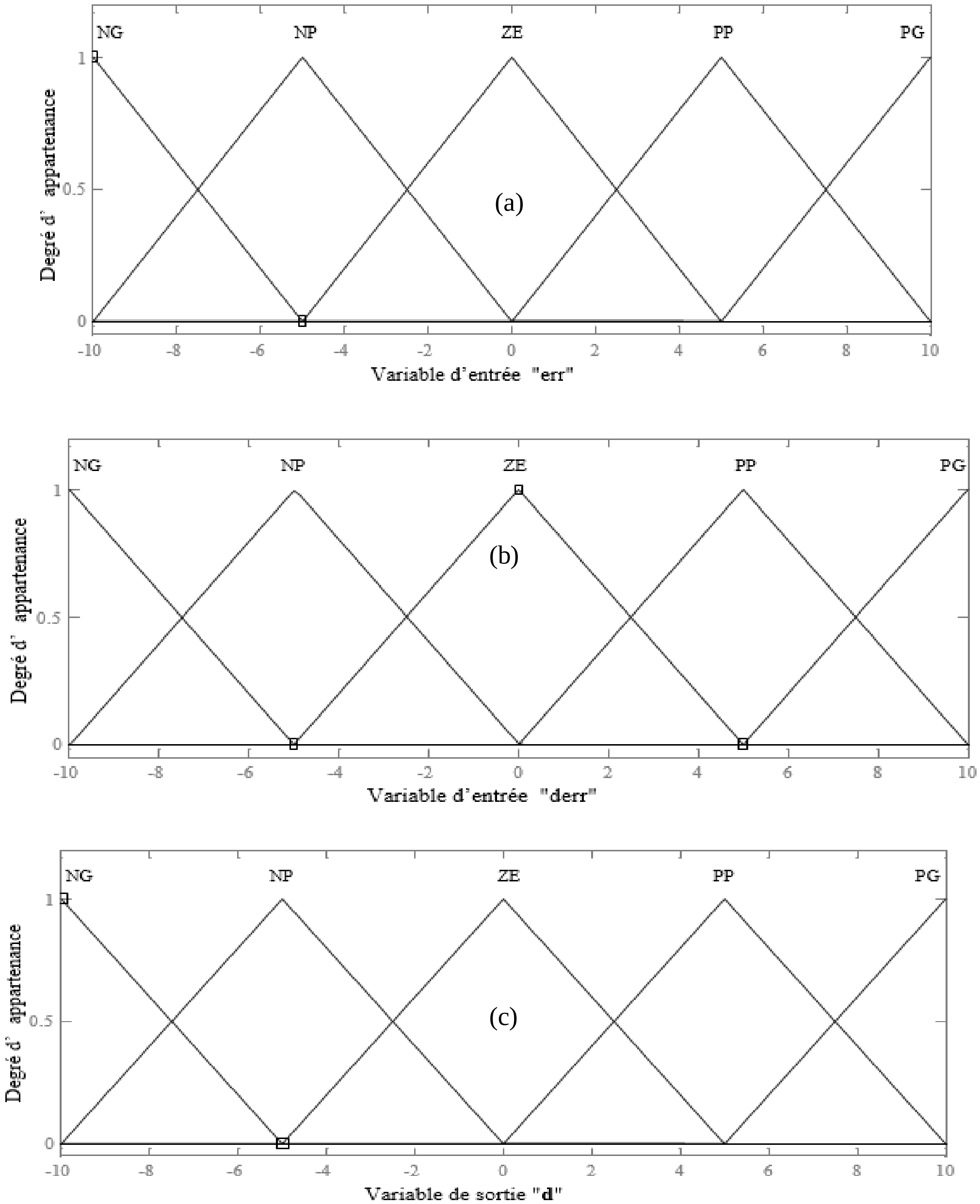

Fig. 4. Membership functions of: (a) input err; (b) input derr and (c) the exit d

In the step of inference, we make decisions. Indeed, it establishes logical relationships between the inputs and the output setting membership rules. Subsequently, it paints the picture of inference ruler (table 1).

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Table 1. Fuzzy controller ruler base

derr ↓ / err →	NG	NP	ZE	PP	PG
NG	**ZE**	**ZE**	**PG**	**PG**	**PG**
NP	**ZE**	**ZE**	**PP**	**PP**	**PP**
ZE	**PP**	**ZE**	**ZE**	**ZE**	**NP**
PP	**NP**	**NP**	**NP**	**ZE**	**ZE**
PG	**NG**	**NG**	**NG**	**ZE**	**ZE**

We take the example of table 1 control rules: "If err is PG and derr is ZE then d is NG". This means that: «If the operating point is far from the point of maximum power (PMP) to the left side and the change in the slope of the curve $P_{pv}(k) = f(V_{pv})$ is approximately zero, then reduce the duty cycle (d) widely". Finally defuzzification, converts the fuzzy subsets of output into a digital value by the method of gravity center and multiplied by the scale factor for the standardized control signal. We present the following figure the implementation of our fuzzy regulator.

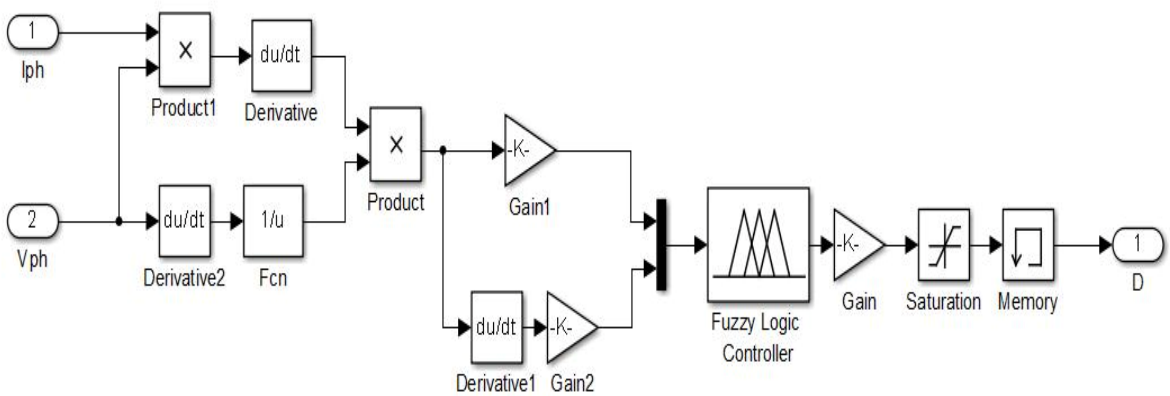

Fig. 5. Simulink model of fuzzy control

Converter DC-AC: single-phase inverter

The single-phase inverter illustrated by the Simulink model (figure 6) allows the manufacturing of the alternating voltage part of the resulting voltage of the boost converter. Pulse width modulation (PWM) technique is used in order to control the switching of the inverter bridge.

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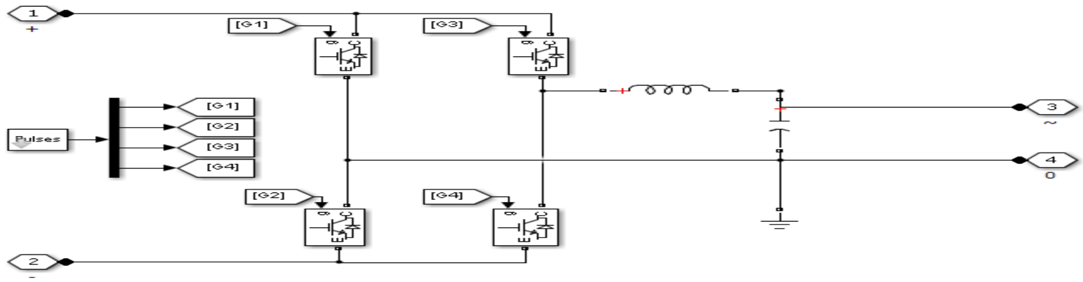

Fig. 6. Simulink model of the single-phase inverter

(G_1, G_2, G_3 and G_4) impulses of a same arm switches (IGBTS) are complementary and generated by the PWM command implemented as shown in figure 7 next.

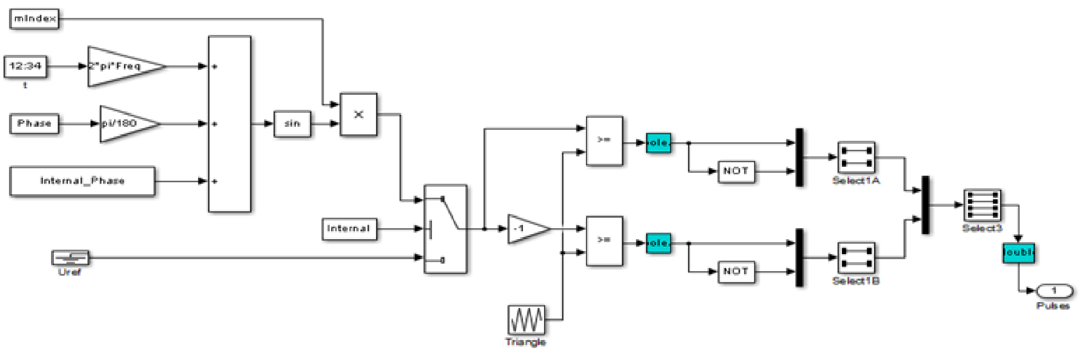

Fig.7. Implementation of the PWM

Model of the single-phase induction motor coupled to the pump centrifugal

We represent in figure 8 following single-phase motor coupled to the centrifugal pump Simulink model.

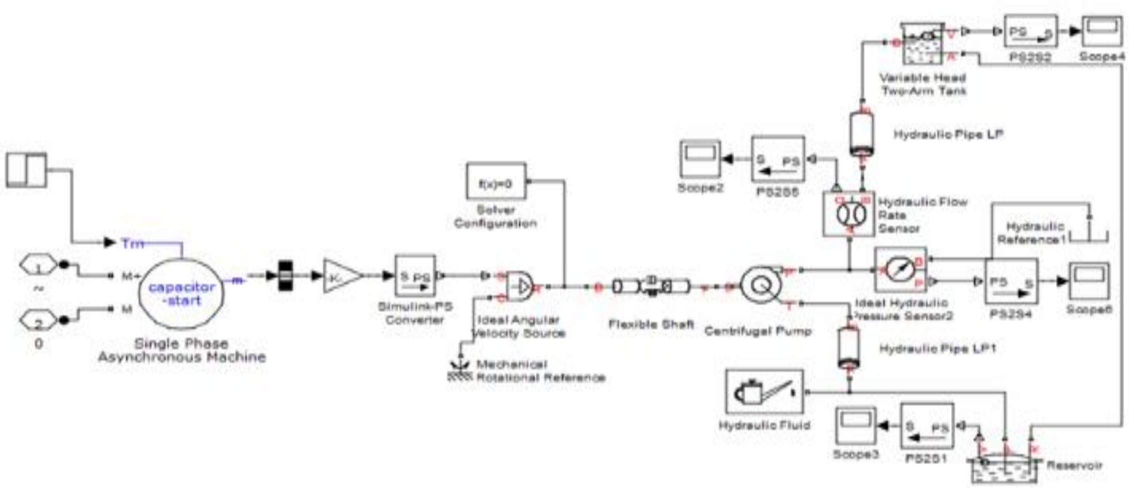

Fig.8.Motor-Centrifugal pump Simulink-Simscape model

Ultrafiltration membrane module

The module used in this work is that fiber-hollow with 1.5 m long and 20 cm in diameter, containing 10000 cylindrical fibers of size 0.01µ. Used here tangential filtration technology allows to slow down the colmatassion of the membrane and facilitates its cleaning process (decolmatassion). During the operation of the SPF-PV, the permeate (filtered water) oozes through the wall of the module then is collected at the opposite interface (figure 9.a) [13]. In the block diagram representing the Simulink model of ultrafiltration module shown in figure 9.b, we take into account the different load losses (table 2) in the membrane ultrafiltration unit dimensioned in Ernest and al 2016, factors affecting mainly the pressure of the SPF-PV [8]. An automatic switch between the motor and the pump to switch of the filtration of cleaning process.

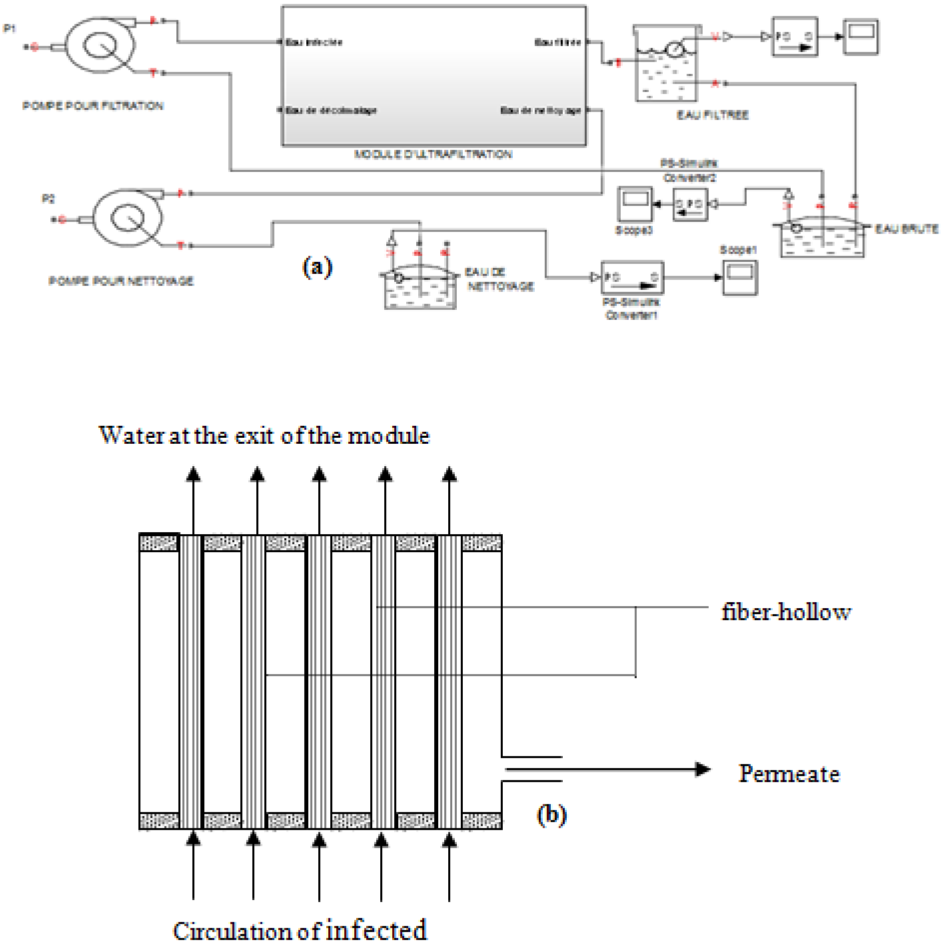

Fig.9. (a) Model Simulink of ultrafiltration unit, (b) inner workings

Tableau 2. Various losses in the unit of ultrafiltration membrane

Type of load loss	**Values (m of water)**
Frictional pressure loss	$\Delta P_1 = 0{,}517$
Pressure drop due to elbows	$\Delta P_2 = 1{,}529$
Pressure drop due to the valves	$\Delta P_3 = 0{,}24$
Pressure drop in the filtration column	$\Delta P_4 = 5{,}165$
Total pressure loss	$\Delta P = 7{,}451$ (0,073 bar)

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Simulation of the complete system

Figure 10 next shows in the scheme paired blocks, the different subsystems that make up the full SPF - PV. The simulation of this model is made by 45t of Matlab/Simulink ode Solver.

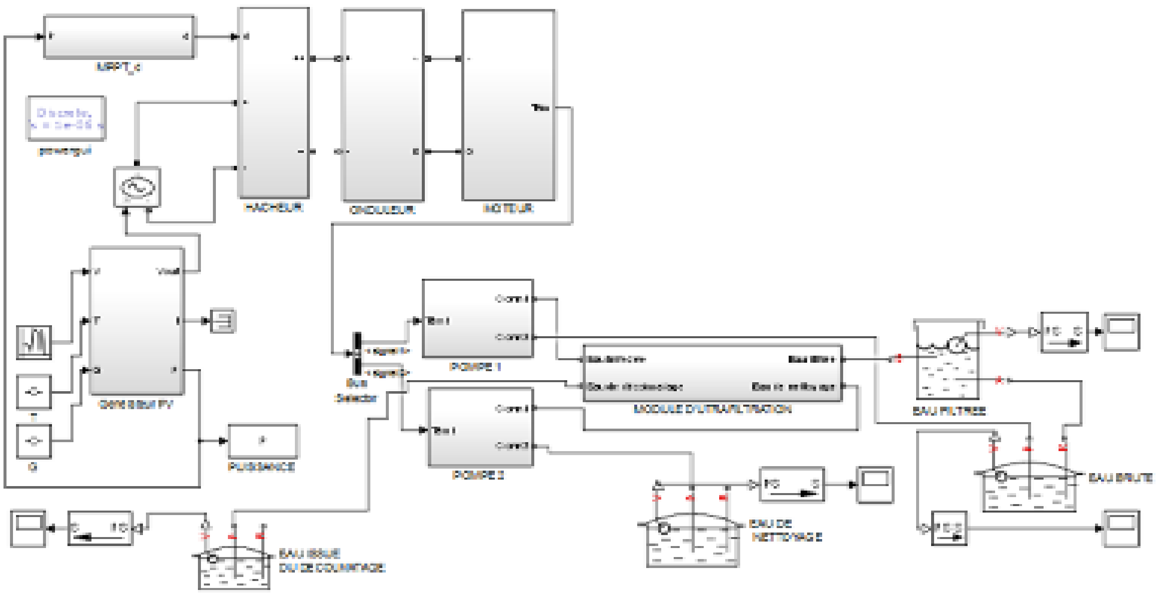

Fig.10. Complete simulation of the system

III. RESULTS & DISCUSSION

Influences of the variation of irradiance and temperature on the GPV

Figure 11 shows the behavior of irradiance and temperature during a day (9: 00-16: 00) at the University of Ngaoundéré Cameroon. We see that the irradiance reaches its maximum value to the approximately between 12: 00 and then begins to drop. These curves allow us to conclude that the weather parameters in the Adamawa fluctuate constantly.

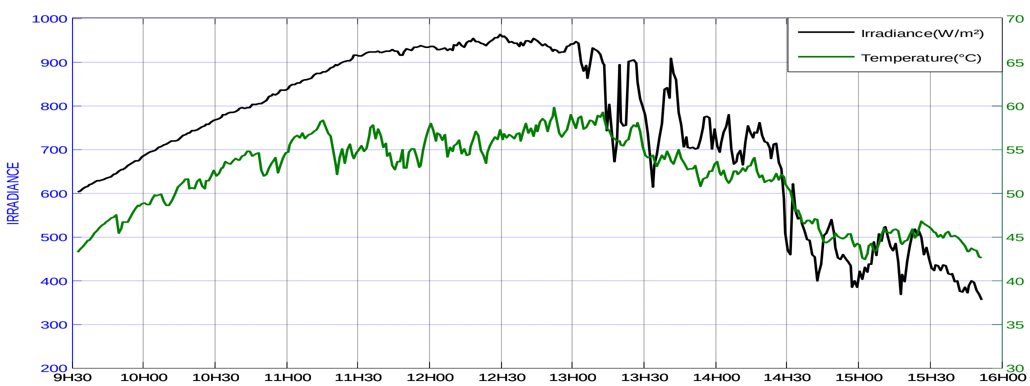

Fig.11.Curves of irradiance and temperature during a day

The generator is not connected to a load, we varied (G) irradiance at fixed temperature (T) and then the irradiance temperature fixed. The results in figures 12 and 13 allow us to conclude that the simulation of the PV module under the Simulink in Matlab software environment is functioning normally and that the variation of irradiance (temperature) influence the current PV (open circuit voltage).

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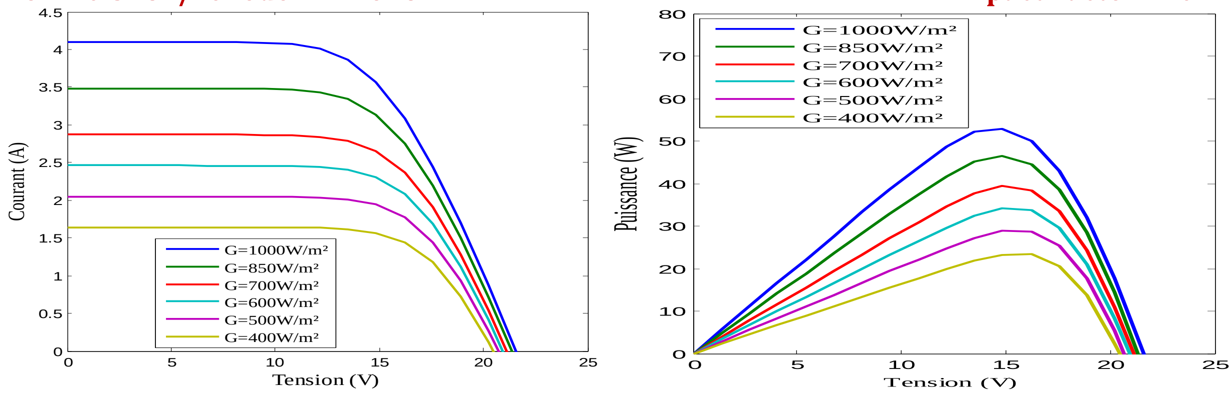


Fig. 12.Influence of variation of sunlight on the characteristics of the GPV

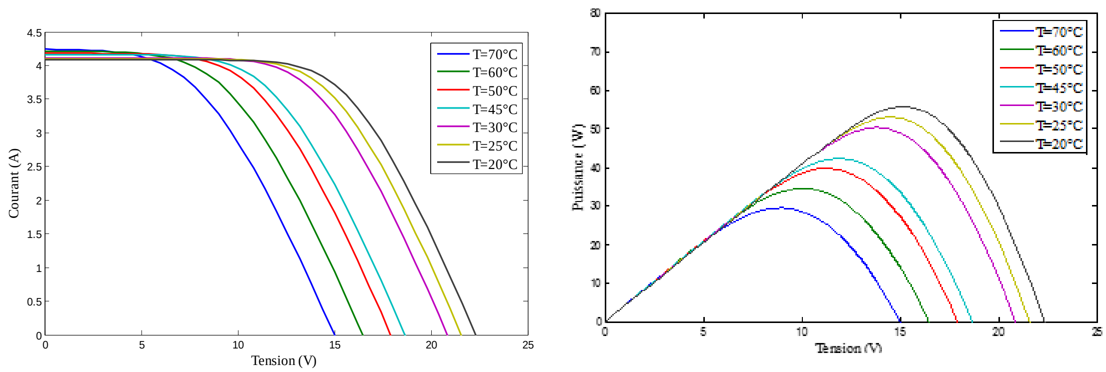
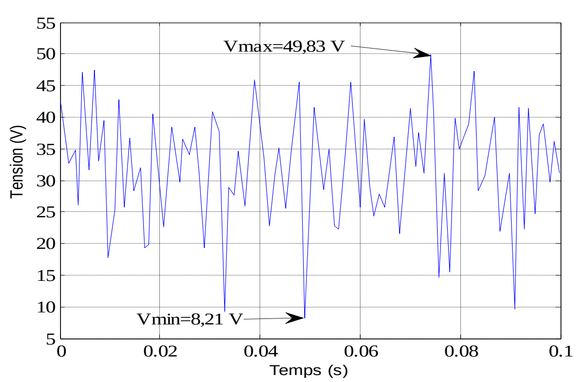


Fig.13.Influence of the change of temperature on the characteristics of the GPV

Impact of the controller MPPT-Fuzzy on the resulting voltage of the GPV

Having the certainty that the GPV is working normally, we can supply the complete system. The voltage at the terminals of the GPV fluctuation between 8,21 V and 49,83 V as shown in figure 14 enables us to conclude initially that supply a pump motor over the Sun and expect a steady flow was almost impossible. But thanks to the command MPPT-fuzzy perform at the entrance of the boost converter, the tension has been boosted and made stable to the average value of 246,57 V (figure 15).



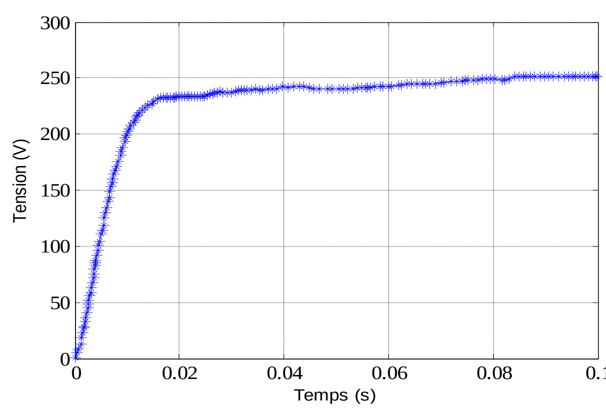


Fig.14.Voltage at the output of the GPVFig15.Voltage at the output of the converter

The resulting voltage of the chopper is converted into alternating voltage sine, of amplitude 237 V with an index of modulation of 0.98 and 0.02 s (figure 16) period and thanks to the single-phase inverter having a filter low pass at its

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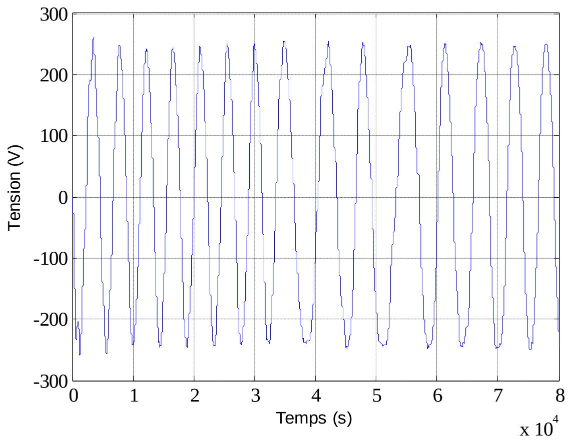
output. The allure of the speed of rotation of the motor which drives the centrifugal pump is represented in figure 17. We notice that when weather conditions are favorable, the engine get quickly his speed permanent (2820 rpm). This result is consistent with those found in [8] and [14] with the only difference that the controller P&O replaced by fuzzy controller of Mandani improves the response time of the engine.



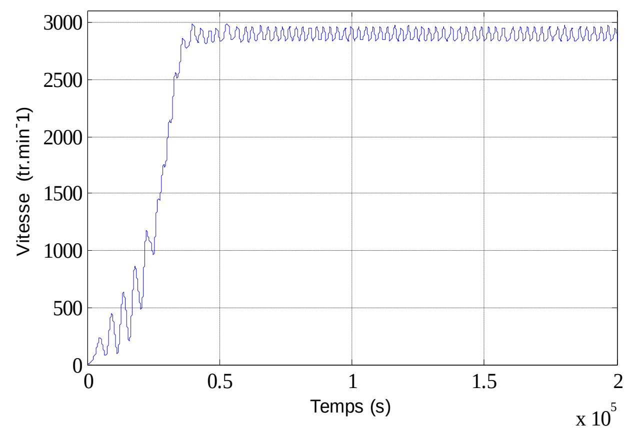
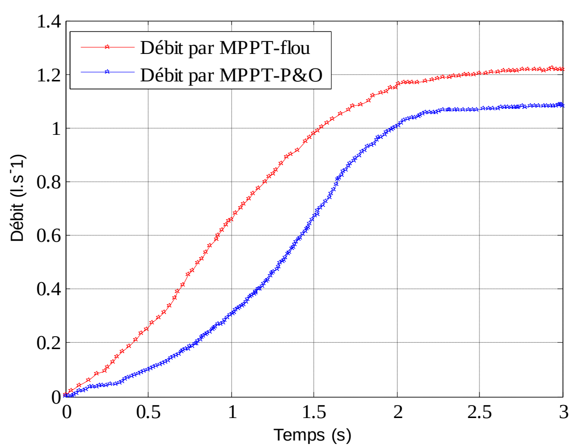


Fig. 16.Voltage at the output of the inverterFig.17. Speed of rotation of the motor

Behavior of flow and pressure under the influence of the P&O controllers and fuzzy

The shape of the curve of the flow and pressure observed in figures 18 and 19 allows us to conclude that the improvement of response time of the speed of the motor of the pump by use of fuzzy controller also significantly increases the flow and pressure of water from the SPF-PV.



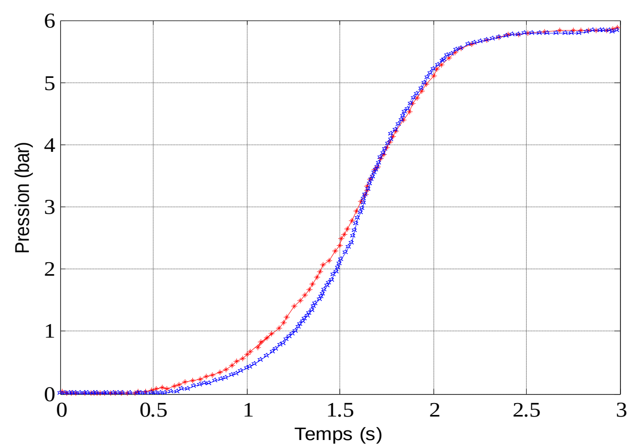


Fig. 18.The SPF - PV water flowsFig. 19.The SPF-PV water pressures

The curves of performance set by the manufacturer are of 1.3 l/s for the flow and 6 bars. Using the MPPT- P&O, the SPF - PV reached a maximum flow of 1,08 l/s pressure from 5.72 bars while using the controller MPPT-fuzzy offers a rate of 1.22 l/s under the same pressure. These results allow us to say that the use of the fuzzy controller of Mandani permits to optimize the functioning of the SPF-PV.

IV. CONCLUSION

This article presents an intelligent approach to optimize the operation of the pumping system and photovoltaic filtration using the control impulses of the boost converter, the fuzzy controller of Mandani. We have modeled and simulated in Matlab/Simulink: the GPV, the floor of adaptation (converter-inverter) integrating the MPPT-fuzzy command, the single-phase induction motor coupled to the centrifugal pump and module of ultrafiltration for drinking water. The simulation results allow us to conclude that the fuzzy algorithm gives superior results to the P&O algorithm, different flow rates of 0.41 l/s pressure is almost identical. To improve this work, it will be interesting to do a comparative optimization study of SPF-PV by using the genetic algorithm if possible consider an experimental validation of this study.

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