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RESEARCH ARTICLE

PERFORMANCE ASSESSMENT FOR AUTONOMOUS PHOTOVOLTAIC SYSTEMS ADAPTED BY THE MAXIMUM POWER POINT TRACKING CONTROL

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ABSTRACT

Despite the enormous solar potential of African countries, the main concern of autonomous PV systems is still in its poor efficiency. This paper proposes an approach to improve the performance of these autonomous photovoltaic systems subject to "disturbances and observation". An autonomous PV system model adapted by the MPPT control (Maximum Power Point Tracking) is designed and studied. The system PV generator is the MSX60 module which produces a peak power of 60W, an optimal current of 3.5A and an optimum voltage of 17.1V under standard test conditions (STC). The mathematical equations developed for PV generator performance modeling are based on the current - voltage characteristic of the modules. The complete simulation of this model under Matlab / Simulink software has enabled to find the maximum performance point of the photovoltaic systems according to the different inducers of loss of availability. The simulation results have been validated by experimental data from the National Agency of Biofuels of Mali.

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INTRODUCTION

Actually, the energy consumption has increased not only in industrials but also insimple consumers. This is explained by the multiplicity and diversity of energy needs: heavy industry, domestic households, etc. Indeed, energy needs which were covered by fossil fuels, have become a veritable problem for countries, particularly under developed countries, because of the volatile price of these fossil fuels. In addition, fossil fuels are decreasing over time and are considered environmentally harmful (greenhouse gas emissions, global environmental and air pollution) (Miller, (2001)). Thus, many countries are currently focusing on alternative or additive energies (solar energy, wind energy ...) to offset the energy crisis (Thiaux, Y. (2010)). Moreover, developing countries such as Mali which have a great solarpotential, must exploit solar energy to reduce their energy expenditure in fossil fuel and increase their energy coverage even in environments far from urban centers (rural areas). (Labbé, 2006). Renewable energies offer the possibility of producing clean electricity and, above all, less dependence on fuel resources, on condition to accept their natural and sometimes random fluctuations (Mrabti *et al.* (2008). Photovoltaic systems seem to be well established as a means of converting solar energy into electrical energy but has to face the low efficiency problem. This reason motivates our particular interest for photovoltaic systems study and regulation. The objective of this work is to contribute to a better understanding of DC-DC converter performance adapted by digital control when it is coupled to a photovoltaic generator and to improve its output voltage in order to obtain a well electricity generator. The rest of this paper is organized as follows: section II concerns the review of photovoltaic systems, Section III discusses the methodology of our approach, section IV gives the results obtained and their discussions. Finally, Section V gives the conclusion and the perspectives to this work.

Photovoltaic systems review: An autonomous or isolated photovoltaic (PV) installation is a system that is not connected to an electrical distribution network. The photovoltaic effect was observed for the first time in 1839 by the French physicist Edmond Becquerel. It is materialized by the direct conversion of the energy of the solar radiation into electrical energy by means of cells generally based on silicon. It can supply electrical power to areas where there is no network. It is particularly suitable for domestic and semi-industrial applications such as water pumping in the garden, lighting in secluded area, telephone terminal feeding along the highway, etc.

The diagram of assembly of an autonomous PV system is the following:

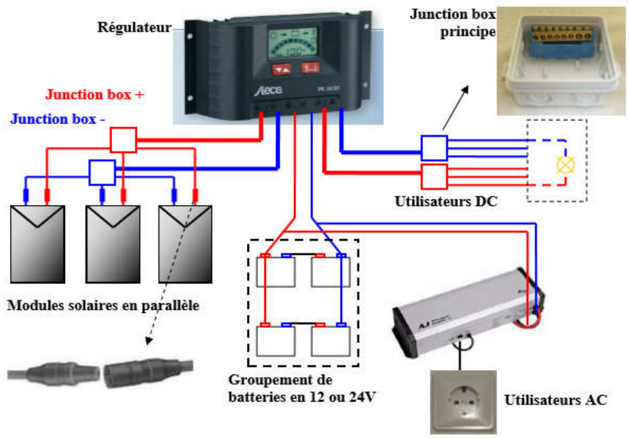

Fig. 1. Diagram of assembly of a PV system

- The energy regulator stabilizes output from the solar module so that the latter can be stored in batteries and used for direct current applications (DC = Direct Current)
- Batteries are the storage medium for storing the energy produced by the modules
- The inverter transforms the available DC energy in the batteries into 230V alternative energy. (AC = Current Alternative)
- DC and AC consumers: depending on the application, DC (12 /24V) or AC (230V) applications can be connected to the autonomous system.

Solar modules charge a group of batteries. Batteries release energy at the moment it is requested. The regulator regulates the process of charging the batteries electronically. This group of batteries is intended to give a better autonomy to the system. Much works have been done on the photovoltaic system, particularly on their design and modeling. Thus, we can mention the work of (Kassmi *et al*., 2017), they designed and realized a PV system of average power (100 W) operating in continuous mode under the optimal conditions regardless of the meteorological conditions and the variation of the charge.
The works of (Semaoui *et al*., 2006) focused on the study and modeling to size an autonomous photovoltaic system for the electrification of a village. For this, they used a tool for sizing PV systems and also a suitable load profile. Their method used for the estimation of the generator / battery pair is based on the consumption profile and the energy supply of the place. But their works were limited to optimal inclination only. Some works have highlighted the autonomous photovoltaic systems, this is the case of the works of (Boitier and Alonso, 2005) which showed the advantages but also the constraints related to the use of electrical energy photovoltaic in isolated site. In particular, the issues of consumption, storage and autonomy have been analyzed. In their work, they favored a solution only photovoltaic, although other solutions are possible (possible connection to the EDF network, power supply with a generator, gas refrigerator, wind ...). However, it would be interesting to study them to find the best solution in terms of cost and service. The works of (Rahmani , N., and Hamidi , M., 2017) aim at studying the storage of electrical energy produced by photovoltaic panels. Other works use the simulation to predict the performance of a photovoltaic system (PV) operating in the meteorological conditions of the installation site. Those of (Yahya, AO M and al., 2008) are intended to simulate the performance of a single component of the PV system, namely the PV generator. They have established a simple and reliable model, with an acceptable accuracy to predict the performance of a PV generator in the climatic conditions of their countries. This model is validated by data obtained from a PV generator installed on the site of the Faculty of Science and Technology of the University of Nouakchott. The performances obtained from the data and the model are compared. The works of (Merwan, 2017) focused on the optimization of photovoltaic energy used in agricultural areas. The works of (METIAZ, N., 2017) focused on the study and simulation of an autonomous system based on photovoltaic generator. The works of (Sadaoui,, 2017) focused on the dimensioning of the photovoltaic system applied to a wastewater treatment plant. The results they have obtained show the important role of the PV field in the stand-alone power supply of the wastewater treatment plant. Indeed, most of these cited works studied the PV model or the energy storage problem without worrying more or less the impact of load variation parameters, weather performance. In this paper, we design and model the 36-cellPV systems in series in a Matlab environment regulated by the MPPT command based on the "disturbance and observation" method.

MATERIALS AND METHODS

The equivalent diagram of a photovoltaic cell under illumination is represented by fig 2. It corresponds to a current generator I_{ph} connected in parallel with a diode. R_{ser} and R_{sh} are parasitic resistances that influence the current-voltage characteristic.

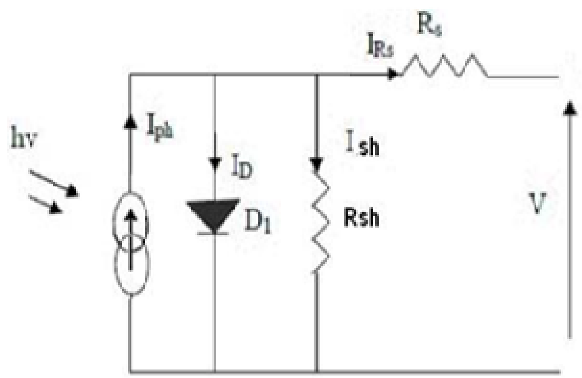

Fig. 2. Equivalent circuit of a photovoltaic cell

The mathematical model, for the current-voltage characteristic of a PV cell, is given by

$$I_{PV} = I_{ph} - I_{sat}\left[exp\left(\frac{e\left(V_{PV} + (I_{PV} * R_{ser})\right)}{nKT}\right) - 1\right] - \frac{V_{PV} + (I_{PV} * R_{ser})}{R_{shu}} \qquad (1)$$

- Isat: the saturation current,
- K: Boltzmann constant, (1,381.10-23 J/K),
- T: effective temperature of Kelvin cells (K),
- e: charge of the electron (e=1,6.10-19C),
- n: ideality factor of the diode of junction (1< n<3),

- I_{pv}: current supplied by the cell,
- V_{pv} voltage at its terminals,
- Iph: photo-generated current of the cell depending on the illumination and the temperature,
- Rshu: shunt resistor characterizing the leakage currents of the junction,
- Rser: resistance in series representing the various resistances of contacts and connections.

It is characterized by two inputs parameters that are the illumination E and the junction temperature of the cells T_j and two output parameters that are the current supplied by generator I_s and the voltage at its terminals V_s. The choice of orders is based on the method of disturbances and observations "P & O". This one is an widespread approach in the research of the MPPT because it is simple and only requires measurements of voltage and current of the photovoltaic panel. It can track the maximum power point even during variations in illumination and temperature. Figure 3 below shows the block diagram of the MPPT command.

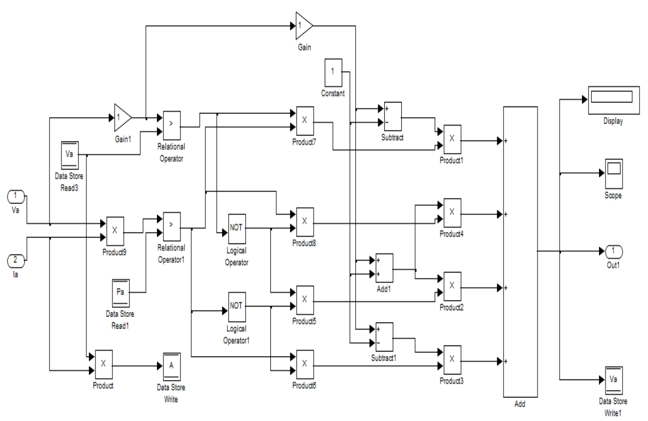

Fig.3. Block diagram of the MPPT command

In our study, we chose the boost converter, also known as the "boost" or parallel chopper. It is an electronic device that converts its input voltage (DC voltage) into a higher output voltage (also continuous).

RESULTS AND DISCUSSION

The results of simulations obtained in the SIMULINK-MATLAB environment are shown in Figures 4 to 10. Fig 4 shows the current-voltage characteristic at different temperatures and a constant illumination G = 1000W / m ^{2}: This characteristic shows that the short-circuit current varies slightly in the same sense that the variation of the temperature. Otherwise, more the temperature increases, more the short-circuit current increases. On the other hand, it reveals that for constant illumination, the open circuit voltage decreases when the temperature increases. The results obtained for this simulation are in agreement with those given by the manufacturer Isc = 3.8A; Vco = 21.1V for t = 25 ° C and E = 1000W / m^2. Figure 5 below shows the power-voltage characteristic for different temperatures and a constant illumination of G = 1000W/m^2. The power-voltage characteristic shows that for a constant illumination, the rise in temperature causes a decrease in the power delivered by the PV generator and therefore the energy efficiency. It is also noted that, for a temperature of 25 ° C and an irradiance of 1000 W / m^2, the power delivered by the PV generator is 60W;

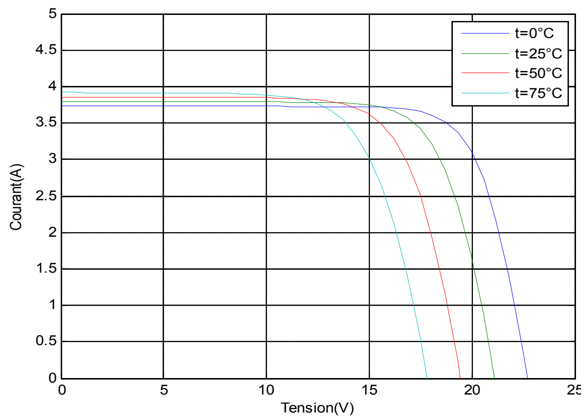

Fig. 4. Current-Voltage characteristic, for different temperatures and illumination G=1000W/m^2

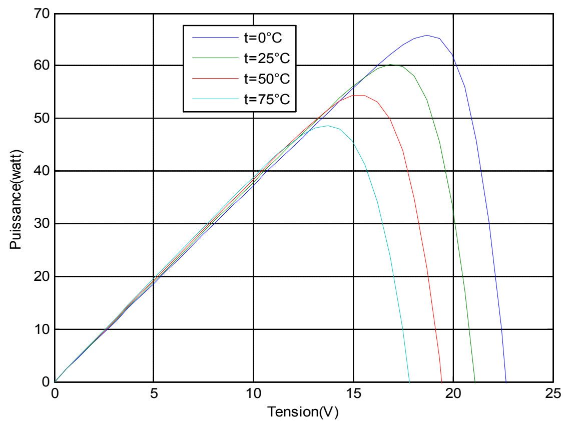

Fig. 5. Power-Voltage Characteristic, for different temperatures and illumination G=1000W/m^2

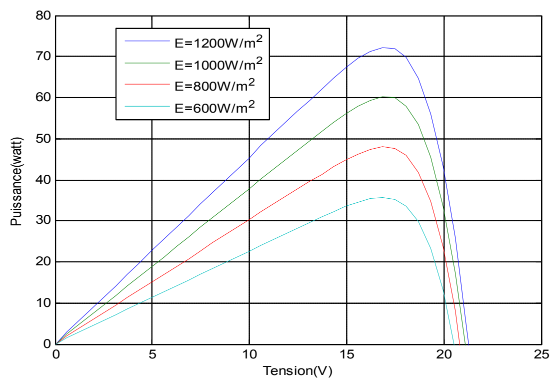

Fig.6. power-voltage characteristics for various illuminations and a temperature T = 25 ° C

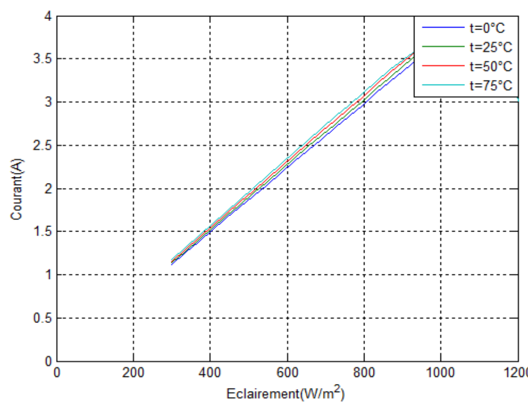

Fig.7. Current-illuminance characteristics at different temperatures

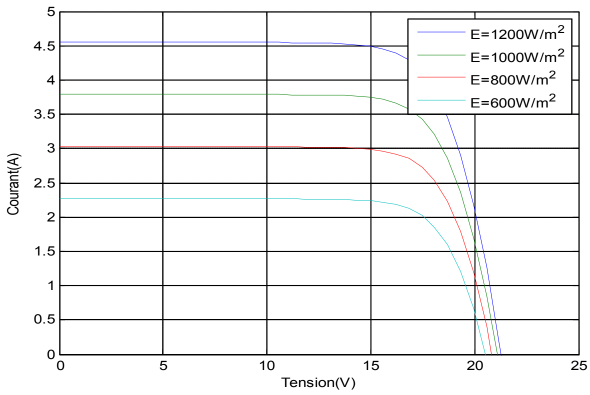

Fig. 8. Current-voltage characteristic, for different illumination

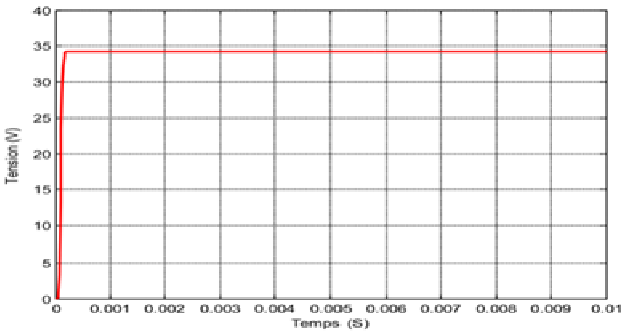

Fig. 9. Output voltage of the PV system for an illumination 1000W / m^2 and a temperature of 25 ° C

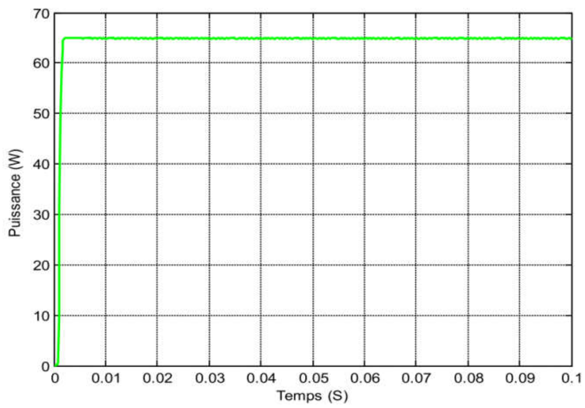

Fig.10. System output power for E = 1000W / m2 and T = 25 ° C

which is in accordance with the manufacturer data. Figure 6 shows that at a constant temperature, the change of the power according to the illumination is greater than the opened circuit voltage. Note also that the illumination and the power vary in the same direction. Figure 7 illustrates the current-illumination characteristic for different temperatures. It reveals that the current is very sensitive to illumination and varies very little with temperature. Fig8 below shows the current-voltage characteristic for various illuminations and a temperature of 25 ° C. It shows that for a constant temperature the short-circuit current varies widely in the same direction as the illumination. It reveals however that the short-circuit voltage also varies in the same direction but very weakly. Figure 9 below illustrates the output voltage of the system for an illumination of 1000W / m 2 and a temperature of 25 ° C. It shows that the voltage at the output of the system stabilizes very quickly on the one hand, and on the other hand this voltage is higher than that delivered by the PV generator. This is due to the good choice and performance of the boost converter used.

CONCLUSION AND PERSPECTIVES

From the results of the simulation obtained, we can safely say that

- The performance of the generator degrades with the increase of the temperature, the decrease of the intensity of the illumination and the variations of the load. The performance of the PV generator is evaluated from the standard conditions (CST): illumination 1000W / m2
- The DC-DC converter and the MPPT command perform their roles correctly. The converter provides under optimal conditions anoutput voltage superior than that provided by the PV generator. The MPPT control adapts the PV generator to the load: transfer of the maximum power supplied by the PV generator.
- These interesting results, show that the use of the MPPT control can significantly improve the performance of photovoltaic installations.
- It will be interesting to applicate this method "disturbance and observation" on quite high powers and, to see how to use of the artificial intelligence techniques such as fuzzy logic, neural networks and neuro-fuzzy networks in order to control the converter.

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