Study and simulation of a photovoltaic solar panel connected to the electrical network

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Abstract. *This work presents a photovoltaic generation system, and deals with the connection of a photovoltaic system to the three-phase electricity grid. This system injects solar energy into the grid as active power.*
This injection is carried out through a single-stage conversion system, consisting of a DC-DC converter (Boost) and an AC DC inverter.
MPPT controller is applied for point tracking of maximum power of PV system under normal lighting and temperature conditions.

Keywords: Photovoltaic system, DC-DC converter, DC-AC converter, MPPT, electrical network.

1. Introduction

Solar energy is a source of energy accessible to all (manufacturers, communities and individuals) .Thanks to it, it is possible to produce three types of energy: heat energy with solar thermal installations (heaters) solar water or solar air conditioning), electrical energy with photovoltaic solar installations and solar thermal concentration [1].
Photovoltaic electricity was first developed for stand-alone applications without connection to an electrical network, for example for telecommunications satellites or for isolated dwellings. It is now found in various power applications such as calculators, watches and other everyday objects. Indeed, this electricity produced by individual photovoltaic cells can supply various continuous loads without difficulty. More recently, with the emergence of photovoltaic installations connected to the distribution network, photovoltaics have undergone significant development as a means of producing electricity. This constant evolution has been made possible thanks to fundamental research carried out in the field of photovoltaic materials, but also by the progressive improvement of the devices for managing this energy carried out in parallel. Indeed, photovoltaic electricity is an intermittent energy source, non-linear in nature and dependent on many parameters such as irradiance and temperature. It was therefore necessary to adapt this source of energy to our mode of consumption, either by storing solar production in batteries or in any other means of storage under development, or by returning it to the public electricity grid [2].

2. Modeling of a photovoltaic cell

2.1 Real model with one diode

Regarding the behavior of an actual solar cell, two parasitic resistances are considered for a more accurate description. [3]

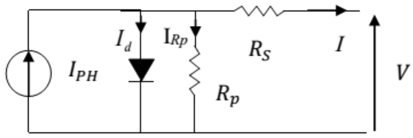

Fig 1. Diagram of the equivalent electrical circuit of a solar cell

$$I_{module} = I_{ph} - I_s\left[\exp\left(\frac{V_{module} + N_s.R_s.I}{N_s.n.V_T}\right) - 1\right] - \frac{V_{module} + N_s.R_s.I}{N_p.R_p}$$

2.2 Description of the BP 3160 module

The BP 3160 is a particularly successful 160W photovoltaic module. Multi-crystalline cells with anti-reflective coating ensure better absorption. A 3% tighter power tolerance guarantees a higher average power output. The BP 3160 has been specially designed for grid-connected applications, such as the roofs of large commercial buildings, small residential and power photovoltaic power plants. This module offers a first-rate quality-price ratio thanks to its 72 high-efficiency cells and its white Tedlar sheet.

2.1.1 Typical electrical characteristics of the BP 3160 module

Table II.1 summarizes the electrical characteristics of the PV module supplied by the manufacturer.

Parameters	Value
Maximum power	160[W]
Garanteed minimum power	155[W]
Voltage at maximum power	34,5[V]
Current at maximum power	4,55[A]
Short circuit current	4,8[A]
Open circuit voltage	44,2[V]

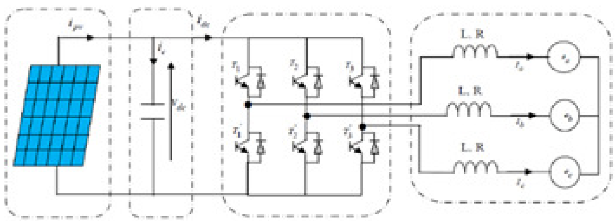

Fig 2. Overall simulation diagram of a photovoltaic module [4]

3. Results and discussions

3.1 Characteristics of the PV system

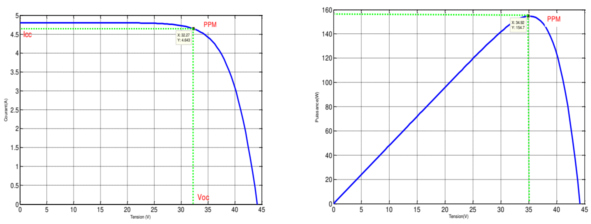

Fig 3. I(V) et P(V)

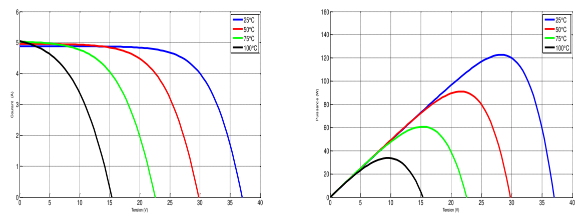

Fig 4. I (V) and P (V) under the influence of temperature

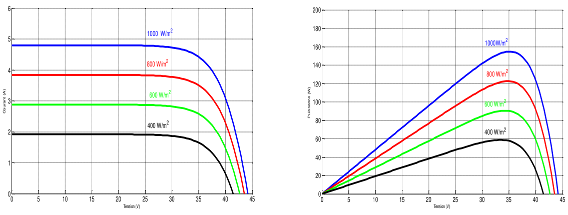

Fig 5. I (V) and P (V) under the influence of illumination

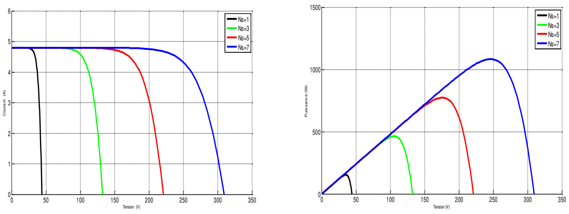

Fig 6. I (V) and P (V) of PV cells connected in series

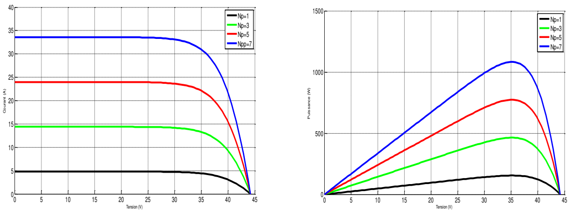

Fig 7. I (V) and P (V) of PV cells connected in parallel

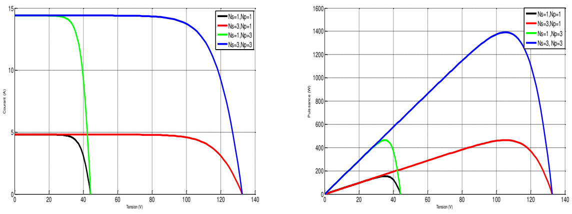

Fig 8. I (V) and P (V) of PV cells connected in mixed

3.2 Characteristics at the output of the boost chopper [5]:

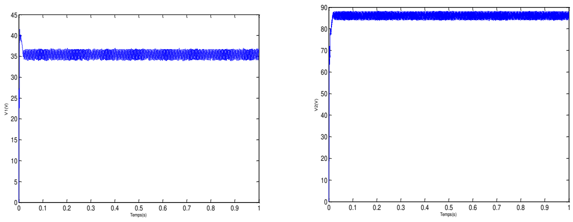

Fig.9 Voltage at the input and output of the chopper

3.3 Characteristics at the output of the inverter:

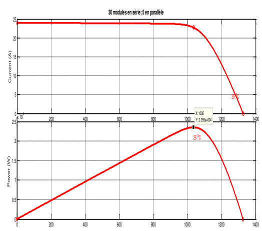

Fig 10. I(V) et P(V)

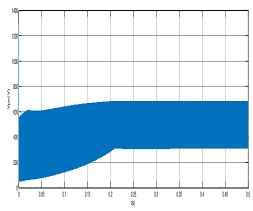

Fig 11. Vpv(t)

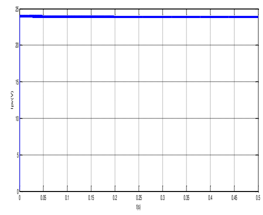

Fig 12. Ipv(t)

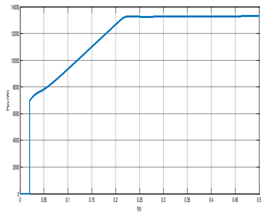

Fig 13. Ppv(t)

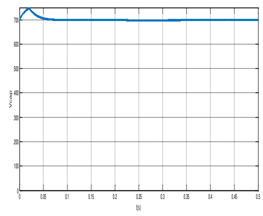

Fig 14. Vcap(t)

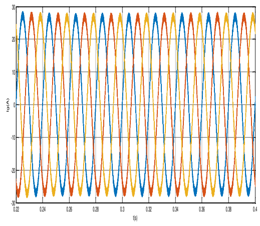

Fig 15. Ig(t)

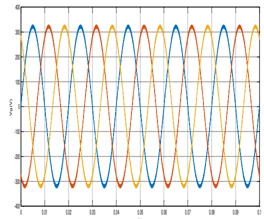

Fig 16. Vg(t)

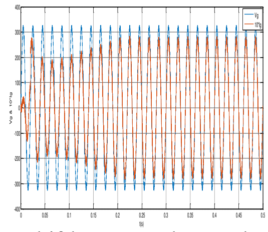

Fig 17. Phase shift between voltage and current

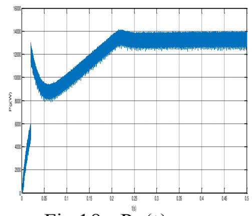

Fig 18. Pg(t)

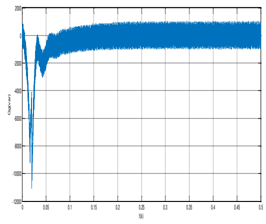

Fig 19. Pg(t)

The proposed system includes 30 modules in series and 5 modules in parallel. The simulation results obtained show that the voltage and current are amplified to reach 1035V and 23A, respectively. in which corresponds to a 5 times improvement in current over the output of a single panel and approximately 30 times in voltage as shown in “Fig. 10 ”
On the other hand, the supply voltage and current obtained from the PV modules reach respectively 600 V and 24 A, which corresponds to the maximum power supplied by the PV module, i.e. P = 1350W , as illustrated in the figures “Fig. 11, Fig.12 and Fig.13 ”. The proposed system is integrated directly into the grid, with the inverter supplying approximately 28 A to the grid (see “Fig. 15”). Note that the inverter reduces the input voltage considered as capacitor voltage (i.e. the output of the capacitor) by 700 V as shown in figure "Fig. 14 ”at approximately 320 V as shown in the figure“ Fig. 16 ”. The result obtained in “Fig.17 ”shows that the phase difference between the mains voltage and current is zero. In addition, the power injected into the grid is purely active, which means

6. Conclusion

Photovoltaic energy is gradually becoming a full-fledged energy source, increasingly required to produce electrical energy ranging from domestic to large power plants connected to the grid.
The modeling and control of a photovoltaic generator connected to the grid operating with a DC / DC converter (Chopper Boost) under the Matlab Simulink environment was presented. For the

photovoltaic system to operate at its maximum power, it must include an adaptation stage associated with an MPPT algorithm, several types of MPPT algorithms have been developed in the scientific literature. In our study, we used the "Perturb and Observe" (P&O) algorithm. The purpose of this configuration is of course to inject the active power produced by the photovoltaic generator into the grid while ensuring good quality of energy supplied to consumers.
In the last part we tried to perform a simulation under the Matlab Simulink environment of a photovoltaic plant connected to the electricity grid. We have presented the different transformations that take place in the chain from the photovoltaic generator which produces the direct current then passing the direct-alternating converter (the inverter) which is controlled by PWM and which has the function of transforming the energy of direct to alternating form to be able to supply alternating current loads.
The photovoltaic generator compensates on the one hand for losses in the inverter and on the other hand for losses in the overall circuit. If there is sufficient sunlight, the system can supply electrical energy to consumers and to the power grid.

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