International Conference on Green Energy & Environmental Engineering (GEEE-2018)
Proceedings of Engineering and Technology – PET
Vol.38 pp.69-74

Control of the DC Voltage Output Photovoltaic System

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Abstract— In this paper explains the simulation and control of DC/DC converter based solar energy conversion system. Controls strategies are investigates for the operation in the maximum power and constant output voltage under various temperature and irradiation levels . Photovoltaic array is charged at the Maximum Power Point(MPPT) near operating point and had done with MPP Tracking Algorithm. In order to extract the maximum amount of power from the PV generator, 'Perturb and Observe' control method for the MPPT of a PV system under variable temperature and insulation conditions, is considered.

The study system is simulated with MatLab/Simulink under different temperature and irradiance levels. Different cases are simulated, and the results have verified the validity of models and control schemes. The simulation results shows the controllers ensures to operate photovoltaic panel at its maximum power point and provide the DC output voltage at its reference whatever are the atmospheric conditions.

Keywords- *Renewable energy, PV system, voltage control, MPPT, climatic conditions.*

1. Introduction

Several forms of renewable energies have emerged in recent years and photovoltaic systems have being undergoing a dramatic development and have become more popular now[1, 2]. It is used today in many applications. Indeed solar energy can be used with photovoltaic solar conversion systems to convert solar radiation into electrical energy. These sources of energy take a very important place in energy conversion systems but the performances are influenced by the climatic conditions. Indeed, the voltage current and power values change according to temperature, solar radiation and the variation of the load. The PV generators exhibit non-linear current-voltage characteristics. On the other hand, the optimum operating point changes with the solar irradiation, and cell temperature. Therefore, online tracking of the maximum power point of a PV array is an essential part of any successful PV system. A variety of maximum power point tracking (MPPT) methods is developed in literature.

In this paper explains the simulation and control of DC/DC converter based solar energy conversion system. Controls strategies are investigates for the operation in the maximum power and constant output voltage under various temperature and irradiation levels . The photovoltaic system studied is constitute by PV panel , MPPT buck converter where the Perturb and Observerve (P&O) algorithm and a three-level inverter feeding a three-phase load is investigate. To convert DC to AC, inverters are used. The boost converters are used to transfers maximum power from the solar array to the DC bus, in a coordinated way and at a voltage always greater than the input magnitude.

ISSN 2356-5608

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The study system is simulated with MatLab/Simulink under different temperature and irradiance levels. Different cases are simulated, and the results have verified the validity of models and control schemes. The simulation results shows the controllers ensures to operate photovoltaic panel at its maximum power point and provide the DC output voltage at its reference whatever are the atmospheric conditions.

2. *Model of solar systems*

The photovoltaic energy production can be directly converts the under exposed solar radiation into DC electric power [8-9].

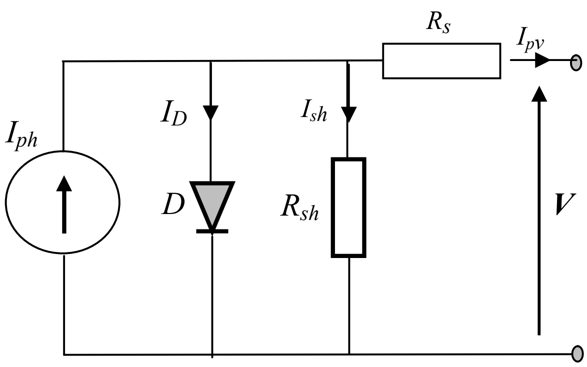

Fig.1 Electrical equivalent circuit of a photovoltaic cell

The output current and the voltage of the photovoltaic cell are given by the following equations:

$$I_{pv} = I_{ph} - I_D - I_{sh} \tag{1}$$

Where; I_{ph} presents the generated photo-current which is strongly related to the solar operating and standard radiation (G_o and G_s) and solar cell operating and standard temperature (T_o and T_s) according to the following relation [10]:

$$I_{ph} = \frac{G_o}{G_s}\left[I_{sc} + K(T_o - T_s)\right] \tag{2}$$

With I_{sc} is the cell's short-circuit current at standard temperature T_s=25°C.

I_D is the current across the diode (D) and affected by the diode saturation current I_{Ds} [11]:

$$I_D = I_{Ds}\left(\exp\frac{V_{pv} - R_s}{V_T} - 1\right) \tag{3}$$

Where; V_T presents the thermal voltage expressed by:

ISSN 2356-5608

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$$V_T = \frac{n.K.T_o}{q} \tag{4}$$

With n is the diode ideality factor, K is the Boltzmann constant (K = 1.38 10^{-23} J/K) and q is the electron charge (q = 1.6 10^{-19} C).

And the shunt resistor current I_{sh} is denoted by the given expression:

$$I_{sh} = \frac{V_{pv} + R_s\, I_{pv}}{R_{sh}} \tag{5}$$

To form a photovoltaic panel, the cells must be assembled in series and parallel where, connecting cells in series increases the output voltage, however the parallel connection increases the output current. The mathematical model presenting the produced power of the photovoltaic panel becomes a simple algebraic model defined by the current-voltage relation [12]:

$$I_{pv} = N_p\, I_{ph} - N_p\, I_{Ds} \left\{ \exp\left[\frac{\frac{V_{pv}}{N_s} + \frac{I_{pv}\, R_s}{N_p}}{V_T} \right] - 1 \right\} - \frac{N_p}{R_{sh}} \left(\frac{V_{pv}}{N_s} + \frac{I_{pv}\, R_s}{N_p} \right) \tag{6}$$

Where; N_s and N_p present the connected series and parallel cells number, respectively.

3. Voltage control

The voltage and current supplied by the photovoltaic network are affected by unstable climatic conditions [6]. In order to ensure the proper functioning of the PV module at its maximum power point, we use the algorithm "disturb and observe (P & O)" [7]. P & O is simple and uses a few measured parameters. This method consists of two input signals: the PV voltage and the current, and an output signal which is the optimal voltage to be applied to the controller. Its connection is indicated by the below (Fig. 2).

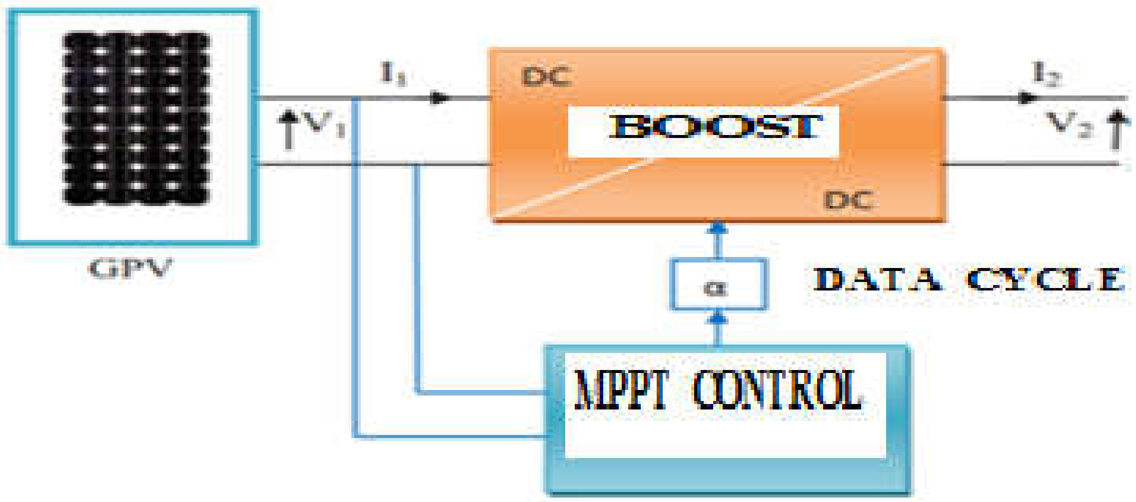

Figure 2 : Photovoltaic conversion chain

ISSN 2356-5608

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The steps of the P & O algorithm are described as shown in the following figure (Fig. 3) [8].

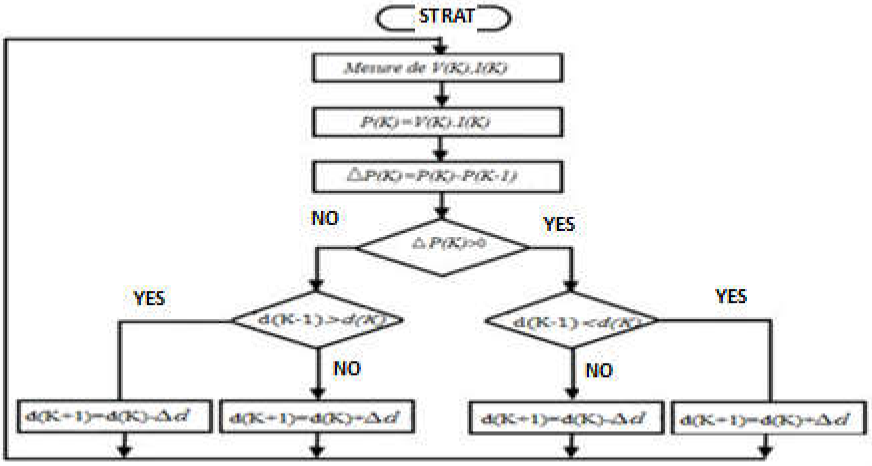

Figure 3: Algorithme P&O

The booster chopper is characterized by its duty ratio d (0 <<1) with which the average values of the output quantities can be expressed with those of the input. The electric diagram of the booster chopper is given in the figure (Fig. 4).

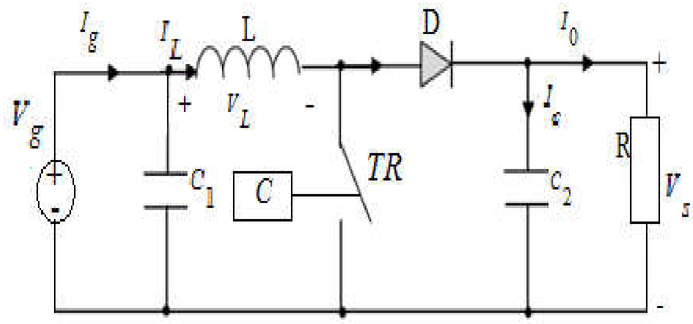

Figure 4: Convertisseur (DC/DC) survolteur de tension (type Boost)

The Boost converter is known by the name of voltage booster. At the first cycle (αT), the transistor (TR) is closed, the current through the inductance increases gradually, it stores energy during the first cycle. Then, the transistor (TR) opens and the inductance (L) opposing the current decrease (), generates a voltage which is added to the source voltage, which is applied to the load (R) through the diode (D) [9]. Kirchhoff's laws are applied to the two equivalent electric circuit cases of the chopper
For the first period α.Ts: TR closed:

$$I_{C_1} = C_1 + \frac{dV_g}{dt} = I_g - I_L \tag{7}$$

$$I_{C2} = C_2 + \frac{dV_0}{dt} = -I_0 \tag{8}$$

$$V_L = L\frac{dI_L}{dt} = V_g - R_L I_L \tag{9}$$

Kirchhoff's laws are applied to the two electric circuits of the chopper
For the first period α.Ts: TR closed::

$$I_{C_1} = C_1 + \frac{dV_g}{dt} = I_g - I_L \tag{10}$$

$$\mathrm{I}_{C2} = \mathrm{C}_2 \frac{dV_0}{dt} = I_L - I_0 \tag{11}$$

$$V_L = L\frac{dI_L}{dt} = V_g - V_0 - R_L I_L \tag{12}$$

ISSN 2356-5608

4. Result simulations

According the simulation parameters from the KC200GT solar array at nominal operating conditions 25°C, 1000W/m^2, we have analysed to obtenaid the simulation results.

The characteristics I=f(V) and P=f(V) for different temperatures such as 25°C (standard temperature), 40°C, 60°C, 80°C and 100°C with standard irradiation E=1000W/m^2 are , respectively, presented in figures 2 and 3. It is observed that as the temperature increases the open circuit voltage decreases without any considerable change in the short circuit current.
Moreover, it is very important to note that the maximum power (P_{max}) is decreasing.

The figure 5.and 6 shows the I=*f*(V) and figure 7.and 8 shows P=*f*(V) characteristics for different solar irradiance 400W/m^2, 550W/m^2, 700W/m^2, 800W/m^2 and 1000W/m^2 (standard solar irradiance), with the standard temperature *T*=25°C. In these conditions, it is observed that for low values of solar irradiations the short circuit current is reducing but the change in open circuit voltage is very less.

Under the conditions of a radiation G = 1000 and a temperature of 25 °, the figure (Fig. 7) shows the evolution of the duty cycle applied to the chopper and the figure (Fig. exit.

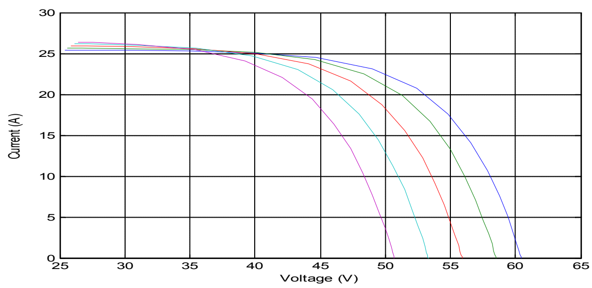

Fig.5 I=f(V) of PV with T=25°C and G variation

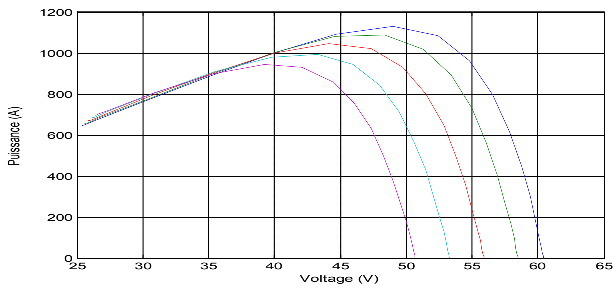

Fig.6 P=f(V) of PV with T=25°C and G variation

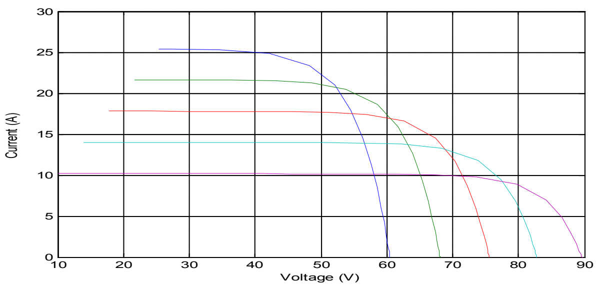

Fig.7 I= f(V) of PV with G=1000W/m^2 and T variation

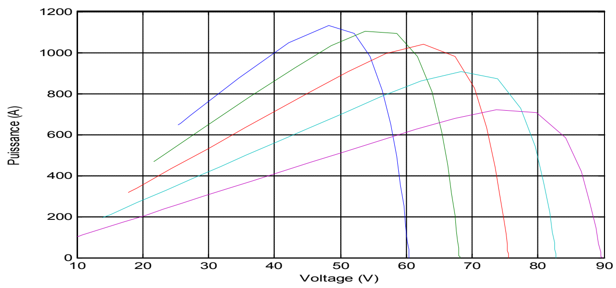

Fig.8 P= f(V) of PV with G=1000W/m^2 and T variation

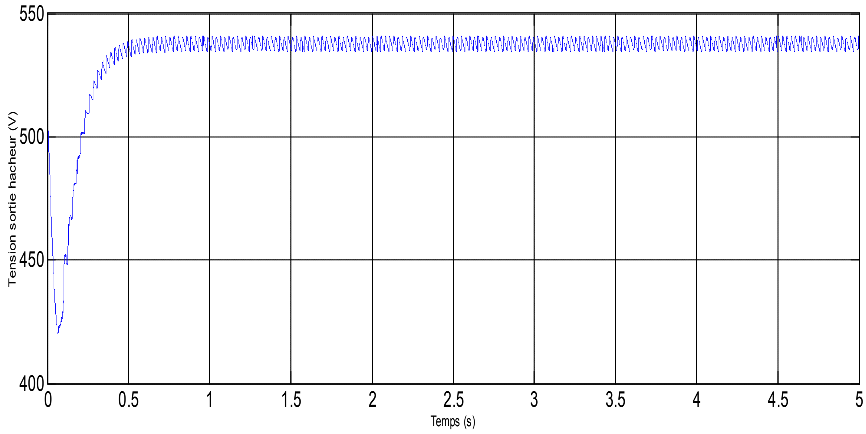

Fig9 Output voltage

ISSN 2356-5608

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5. Concusion

At the end of this work, we conclude that the models of the constituent parts of the training chain are validated by simulation. The maximum power generated from a solar module strongly depends on the intensity of solar radiation as well as the temperature.It can be seen that the open circuit voltage is dominated by temperature, and irradiation has strong influence on short circuit current . This structure is clearly recommended for photovoltaic installations installed in isolated areas.

Annexe : Electrical characteristics of the photovoltaic module MSX60

Eclairement standard, G	1000W/m2
Température standard, T	25°C
Puissance maximale P_{max}	60W
Tension à P_{max} ou tension optimale V_{opt}	17.1 V
Courant à P_{max} ou courant optimal I_{opt}	3.5 A
Courant de court-circuit I_{sc}	3.8A
Tension à circuit ouvert V_{co}	21.1V
Nombre des cellules en séries	36
Energie de la bande interdite	1.12ev
Coefficient de température de I_{sc}	65 mA/ °C
Coefficient de température de V_{co}	-800mV/ °C
Coefficient de température de puissance	(0.5±0.05)%/°C
Courant de saturation I_{sat}	20 nA

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ISSN 2356-5608