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Evaluation of Maximum Power Point Tracking of Photovoltaic Generator

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EVALUATIONOFMAXIMUMPOWERPOINTTRACKINGOFPHOTOVOLTAICGENERATOR

Strictly as per the compliance and regulations of:

Evaluation of Maximum Power Point Tracking of Photovoltaic Generator

Amal Zouhr [α] & Ismail Boumhidi [σ]

Abstract- This paper presents the Maximum Power Point Tracking (MPPT) Modelling and control of Photovoltaic Generator (PVG). The model contains a detailed representation of the main components of the system that are the solar array, boost converter, and the grid side inverter. The system adopted by a digital MPPT control "disturbance and observation". This system includes a photovoltaic generator (PVG), boost converter, MPPT "disturbance, and observation" command as well as a load. For optimum system operation, the maximum power operation of the PV array must be ensured regardless of the climatic conditions, especially the solar irradiation and the temperature of the PV module. Power control, as well as modeling and simulation, were perform.

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I. Introduction

Currently the consumption of energy is increasing because of the trend of rapid industrialization and demographic evolution, which leads to the consumption of energy sources stock come from fossil fuels (oil, natural gas etc ... .), leading to the research and development of new sources of renewable energy. Solar energy is the most important source because photovoltaic converters directly convert the energy of solar radiation into electrical energy. In the last decade the energy solar, photovoltaic became a remains strategic source of energy. For example in Morocco, national energy consummation increase with increase the population. In the south of Morocco stands Noor 3, the largest solar energy tower in the world that propels Morocco into the future of renewable energy. In the middle of the lunar landscape of Ouarzazate, the Noor 3 tower looks down from its 243 meters to the thousands of mirrors dancing around it to the rhythm of the Moroccan sun, once a year, these thousands of mirrors are tested by focusing sunlight on two points in the sky, creating the "two moons" effect that surrounds Noor 3. This optical effect is the product of a test on the mirrors that supply the tower with light. Once a year, and only for a few hours, the rotating mechanism of the mirrors is tested by directing all the Sun's rays that they reflect to two focal points in the sky, creating the two moons of Noor 3. In operation since October 2018, this Concentrated Solar Power (CSP) tower is currently the most powerful in the world, with a power output of 150 megawatts (MW) - this corresponds to the energy consumption of about 65. Thanks to a heat storage system, the station can produce electricity even at night, hours after sunset. The tower not only produces a lot of clean energy, but also recycles the water vapor it generates in order to reduce the use of blue gold as much as possible. Thus, the steam is recovered after having been used to produce electricity and it is condensed again thanks to fans that cool it to return to the state of water, then reused to make steam a true closed circuit where the fans use the energy produced on site. With its large capacity to produce clean energy and low water consumption, Noor 3 is propelling Morocco into the future of renewable energy. A photovoltaic system will therefore consist of the previously described generator [2-3], usually associated with one or more of the following elements:

- An orientation or tracking system (rarely encountered in our latitudes),
- Electronic management (storage, current shaping, energy transfer),
- Storage to compensate for the random nature of the solar
- source,
- DC/AC converter
- A low-voltage direct current or standard alternating current load. The most commonly used PV systems are of three types:
- PV systems with electrical storage (electrochemical storage battery). These supply power to operating devices :
  * Either directly by direct current
  * Either in alternating current via a DC-AC converter; or (inverter)
- Direct coupled systems without batteries (also known as "sunlight operation").

The devices are connected either directly to the solar generator or, possibly via a DC-DC converter (adapter) [4] or a DC-DC converter (adapter impedance) [5-9]. For battery less systems, there is the possibility of using a form of storage that does not require a battery, or not of an electrochemical nature. -Systems connected to the local grid via a frequency-controlled inverter of the network, with the network serving as storage. The study of photovoltaic systems

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comes down to the study of load adaptation. The aim is to optimize the system to have the best system adaptation efficiency (ratio of the electrical energy supplied to the use to the electrical energy that could have been supplied by the generator still operating at its maximum power point). Among the solutions available, electrochemical storage by battery pack offers a good reversibility between discharge and recharge, Lead acid batteries, currently offering one of the best compromises between service rendered and operating costs. In summary, the operating point of the solar module is determined by the battery voltage and the sunlight. The terminal voltage of the solar module is slightly higher than that of the battery (during charging). Under these conditions, the solar module can be considered as a current generator whose value is proportional to the amount of sunshine. Moreover, the property of the PV panels are very sensitive to climatic variations such as illumination and temperature. The observation and disturbance are very replied for the controlling and command the system photovoltaic connected to the grid. This method is very slow when there is a fast modified in illumination [10]. This paper is organized as follows: In section 2, the modeling a photovoltaic generator are presented. The simulation are displayed in section 3 to overcome the simulation results validating our approach. A conclusion ends the paper in section 4. Our work objective is the study of the impact of some parameters on a photovoltaic generator from the modeling of the latter under Matlab simulation.

II. Modeling a Photovoltaic Generator

a) Modeling a cell

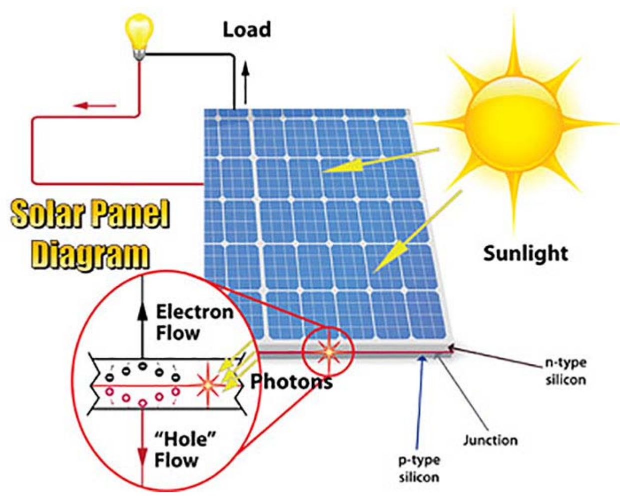

Fig. 1: Photovoltaic panel

The physics of the PV cell is very similar to the classical p-n junction diode as it presented in the figures 1 and 2.

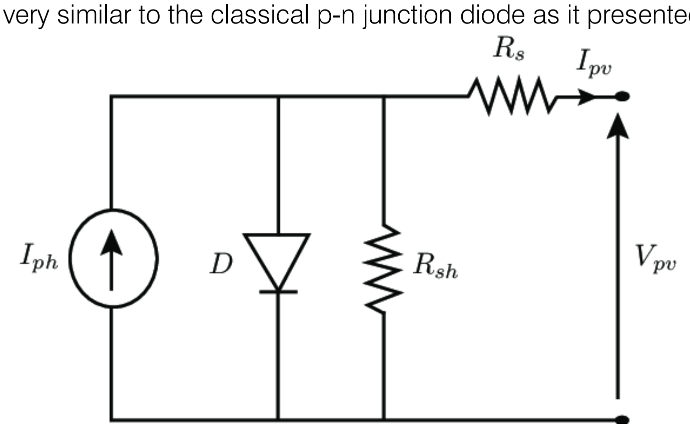

Fig. 2: Model of a photovoltaic cell

Fig. 2 represents the equivalent diagram of a photovoltaic cell:

$$I = (Iph - Id-)\ Ish \quad (1)$$

A block diagram Fig.3 comprising four parameters can present the equivalent electrical diagram of the photovoltaic generator (PVG). Two input variables, which are the isolation in the plane of the panels E, the junction temperature of the cells Tj and two output variables: current supplied by the PVG Is, voltage at the terminals of the PVG Vs.

Fig. 3: Photovoltaic generator block diagram

To generalize our calculation for various illuminations and temperatures, we use the following model:

$$I_{CC}(T) = I_{cc}(T_{ref}).\left[1+\alpha(T-T_{ref})\right]$$

$$I_{ph} = I_{cc}\left(\frac{G}{1000}\right) \tag{2}$$

$$I_{sat}(T) = I_{sat}\left(T_{ref}\right).\left(\frac{T_{ref}}{T}\right)^{\frac{3}{n}}\left[\exp\left(\frac{q.E_{\theta}}{nk}\right).\left(\frac{1}{T}-\frac{1}{T_{ref}}\right)\right]$$

With:

n reprents the quality factor of the diode, normally between 1 and 2, α represents the coefficient of variation of the current.

The Table 1 represents a electrical characteristics of FVG.

Table 1: Electrical characteristics of PVG

Standard illumination, G	1000 W/m2
Standard temperature, T	25°c
Maximum power Pmax	60W
Voltage at Pmax or optimal voltage	17.1 V
Current at Pmax or Optimal current	5.5 A
Short-circuit current Isc	3.8 A
Open circuit voltage Vco	21.1 V
Number of cells in series	36
Forbidden band energy	1.12 ev
Temperature coefficient Isc	65 mA/°c
Temperature coefficient Vco	-80 mV/°c
Power temperature coefficient	(0.5+-0.05)%/°C
Saturation current Isat	20 nA

b) Modeling a module

An elementary cell does not generate enough voltage: between 0.5 and 1.5 according to technology [11]. It usually takes several cells in series to generate a usable voltage.

The module voltage is therefore

$$V_m = N_s.V$$

V_m: the voltage of the module.

N_s: number of cells in series per module

The Module photocurrent depends on solar irradiation and temperature according to (1). Kirchhoff's law gives the current generated by the module

$$I_{cell} = I_{ph} - I_d - I_{sh} \tag{3}$$

Iph current is directly dependent on the solar illumination Es and the temperature Tj of the cell according to

$$I_{ph} = P_1.E_s\left[1+P_2(E_s-E_{ref})+P_3(T_j-T_{jref})\right] \tag{4}$$

The cell temperature can be calculated from the ambient temperature and the radiation as follows

$$T_j = T_a + E_s\left(\frac{N_{oct}-20}{800}\right) \tag{5}$$

The current in the diode is given by the formula

$$I_D = I_{sat}\left(e^{\frac{q(V_{cell}+R_sI_{cell})}{AKT_j}} - 1\right) \tag{6}$$

With Isat is the saturation current strongly dependent on temperature. It is given by equation

$$I_{sat} = P_4.T_j^3.e^{-\frac{E_g}{K.T_j}} \tag{7}$$

The current of the shunt resistor is given by

$$I_{sh} = \frac{V_{cell} + R_s I_{cell}}{R_{sh}} \quad (8)$$

The current generated by the cell is given by:

$$I_{cell} = I_p(E_s, T_j) - I_d(V_{cell}, I_{cll}, T_j) - I_{sh}.V_{cell} \quad (9)$$

c) *Model of a photovoltaic*

For modules mounted in series and in parallel one can write as [12]

$$I_{chaine} = I.N_p \,,\; V_{chaine} = V_m.N_{s-module} \quad (10)$$

With: I_{chaine} the current delivered by a module chain Photovoltaic.

N_p represent number of modules in parallel.

N_{s_module} represent number of modules in series.

V_{chaine} represent the voltage at the terminal of the chain (V).

III. Simulation Results

The photovoltaic generator scheme in the Matlab-Simulink environment is represented by [13-18]

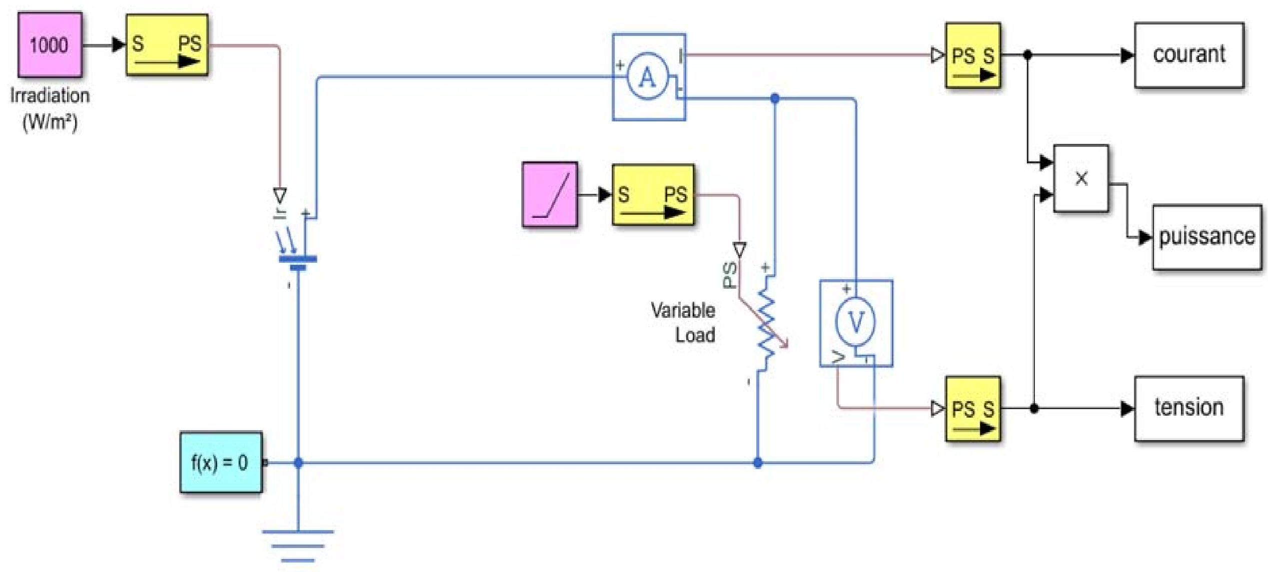

Fig. 4: PVG scheme in MATLAB-SIMULINK

The simulation results of the photovoltaic generator are represented by figures 5 to 11. These figures represent the current-voltage and power-voltage characteristics for various illuminations.Figures 5 and 6 present the impact of illumination on current/voltage and power/voltage characteristics. At a constant temperature, it is found that the current undergoes a significant variation, but against the voltage changes slightly. Because the short circuit current is a linear function of illumination while the open circuit voltage is a logarithmic function

a) *Impact of temperature*

Define Figure 7 presents the impact of temperature on the characteristic $I = f(V)$ It is essential to understand the effect of changing the temperature of a solar cell on the characteristic $I = f(V)$ in Fig.7. The current depends on the temperature since the current increases slightly as the temperature increases, but the temperature has a negative impact on the open circuit voltage. When the temperature increases the open circuit voltage decreases. Therefore, the maximum power of the generator is decreased.

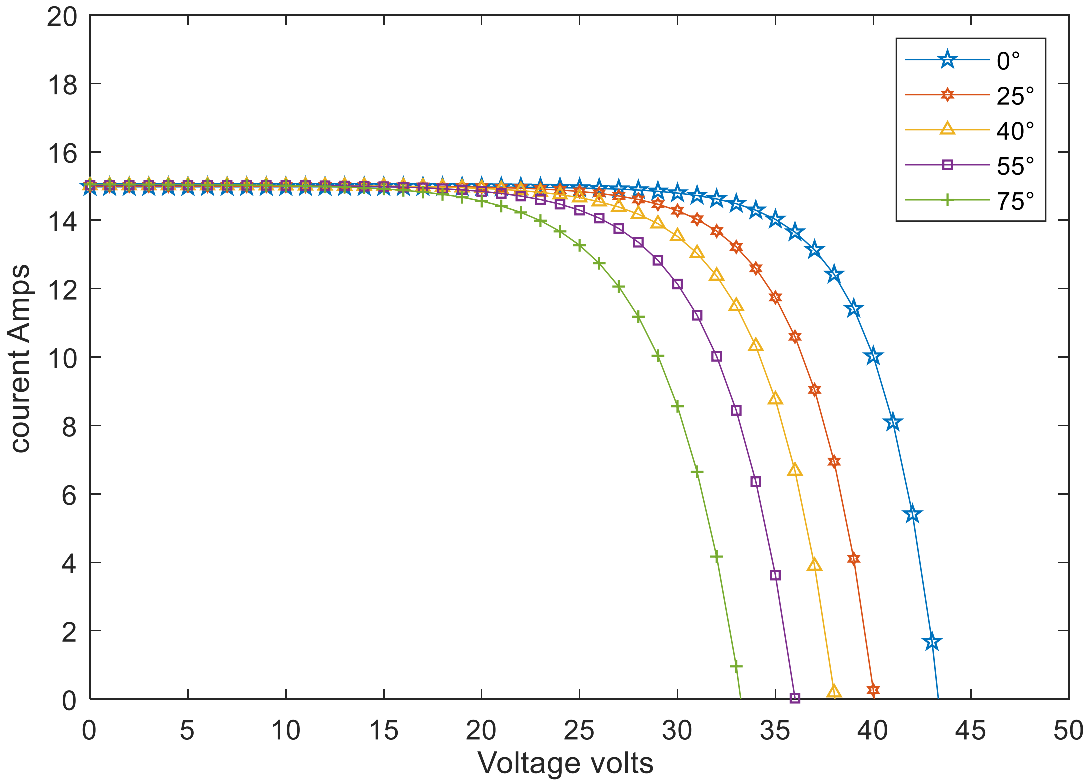

Fig. 7: Characteristic current-voltage for various values of the temperature $I = f(V)$ E=1000W/m²

Fig.8 illustrates the variation of the power delivered by the generator as a function of the voltage for various values of the temperature, which allows us to deduce the impact of the temperature on the characteristic $P = f(V)$.

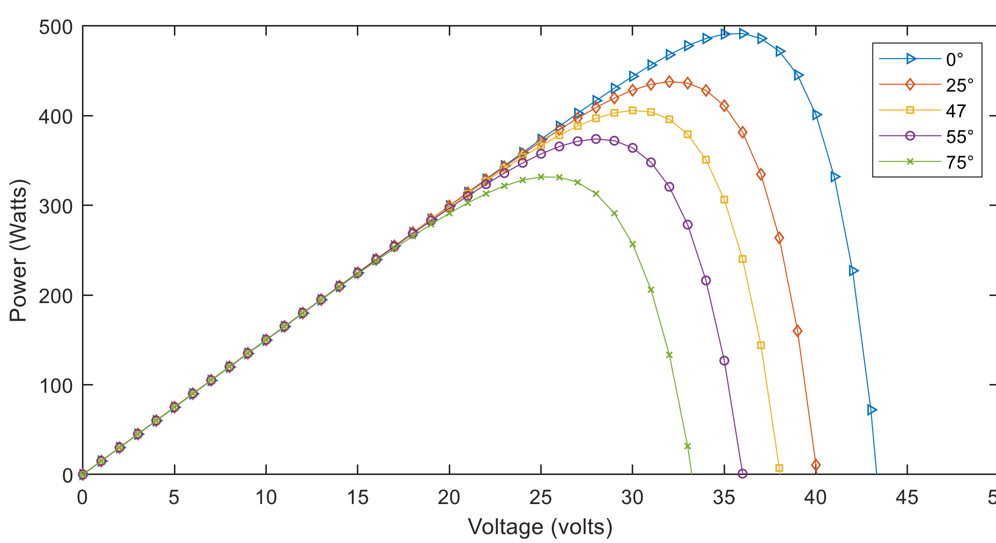

Fig. 8: Characteristic power-voltage for various values of the temperature $P = f(V)$ $E = 1000W/m^2$

Fig. 9 illustrates the variation of the power delivered by the generator as a function of the current for various values of the temperature, which allows us to deduce the impact of the temperature on the characteristic $P = f(I)$.

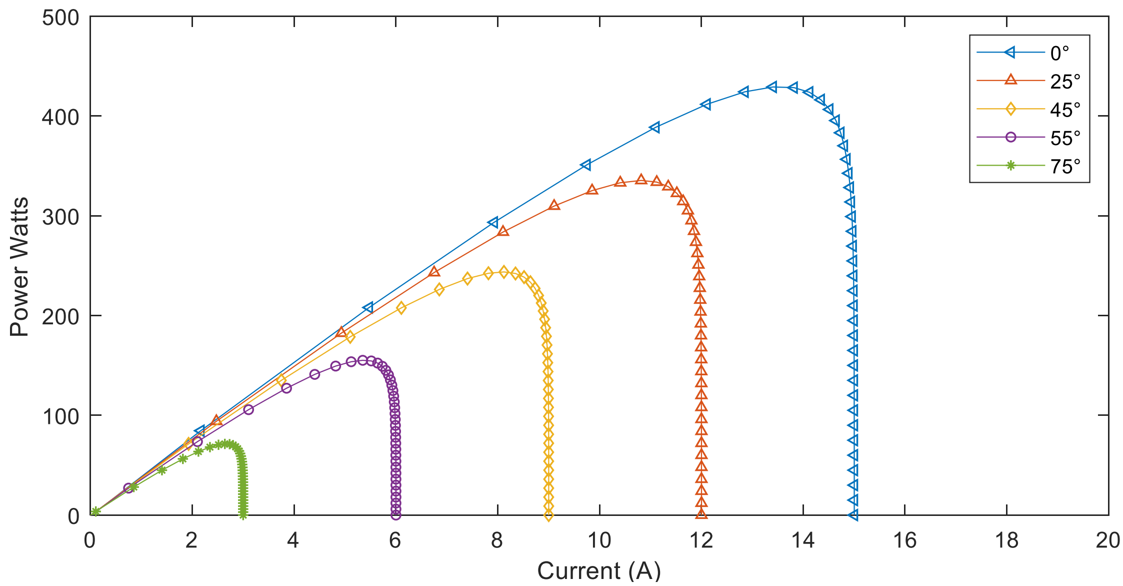

Fig. 9: Characteristic power-current for various values of the temperature $P = f(I)$; E = 1000W / m²

b) Impact of solar radiation

Fig. 10 represents the characteristic I-V of a module reflecting the impact of various radiation at a fixed temperature, the current of the module is proportional to the radiation, while the open circuit voltage changes slightly with the radiation, the optimum power is also proportional to the radiation.

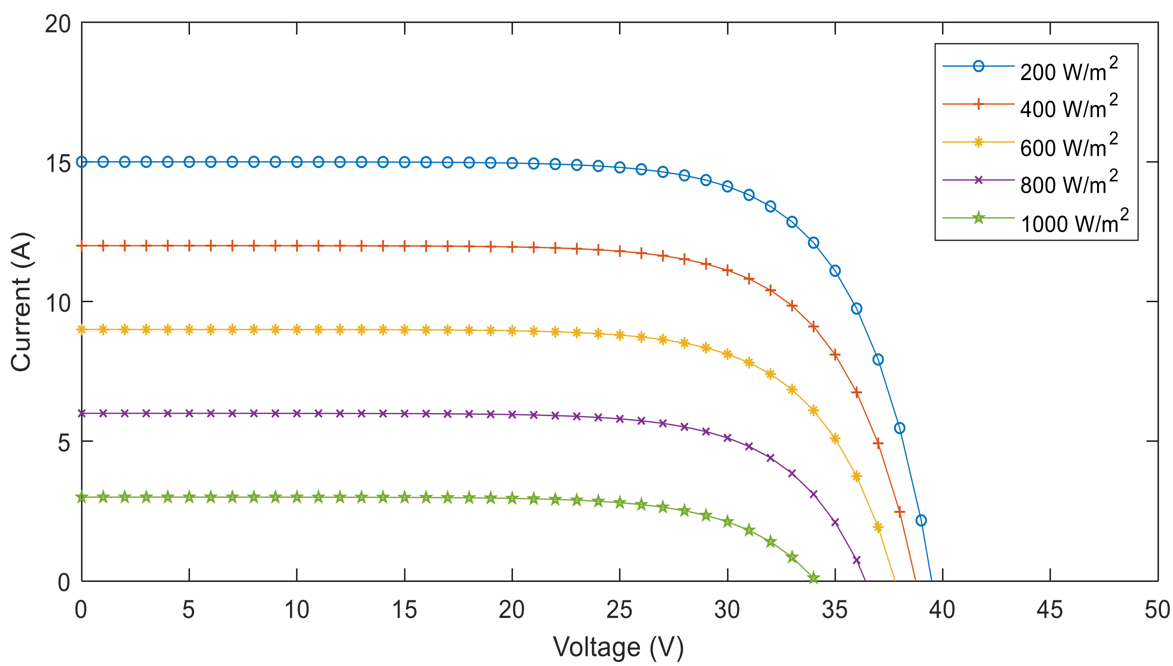

Fig. 10: Current-voltage characteristic for various radiation values $I = f(V)$; T = 25C

In Fig. 11, we represent the variation of the power transmitted by the generator as a function of the voltage for various illumination values, which allows us to deduce the impact of the illumination on the characteristic P (V).

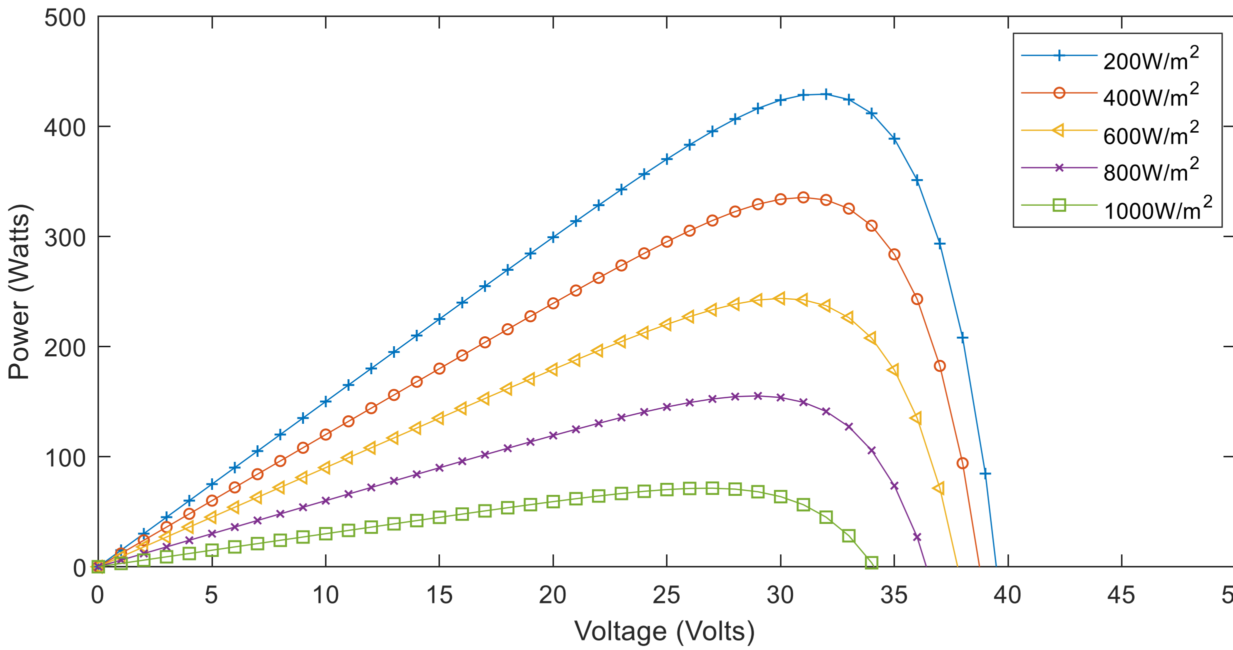

Fig. 11: Power-voltage characteristic for various radiation values $P = f(V)$; T = 25C

IV. Conclusion

The analog and mathematical modeling of a one-diode photovoltaic generator with two series and shunt resistors was the essence of the first part of our work in this paper, which allowed us to start the simulation part under Matlab / Simulink with a more objective methodology.

The simulation results show the impact of the parameters that come into play in the performance of solar energy production systems such as solar irradiation, temperature, Rs series resistance, shunt resistance Rsh, panel inclination.

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