SIMULATION OF SOLAR PV ARRAY USING MATLAB/SIMULINK

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Abstract-Solar radiant energy accounts for most of the usable renewable energy on this earth. Photovoltaic (PV) is a method of generating electrical power by converting solar radiation into direct current electricity using semiconductor that exhibits the photovoltaic effect. This paper presents a method of modeling and simulation of photovoltaic array in MATLAB/SIMULINK using solar cell block from SimElectronics® library. The method is used to implement and determine the characteristics of a particular photovoltaic cell panel and it can be used to build a solar PV system with any photovoltaic array. All modules which form the photovoltaic system model are individually modeled and validated in MATLAB/SIMULINK.

Keywords: Simulation, Photovoltaic, MATLAB/SIMULINK

I. INTRODUCTION

Photovoltaic (PV) and Renewable Energy Sources (RES) have experimented a great development in recent years [1], mainly because of the growing concern about climate change and the oil price increase, which has lead many countries to adopt new regulations to promote this kind of energy. Photovoltaic systems are very low exploitation costs (free fuel), limited maintenance requirements, reliable, silent and easy to install. In addition, in some stand alone applications photovoltaic systems are certainly convenient in comparison with other energy sources, especially in those places that are not accessible, which is unprofitable to install traditional power lines[2].

II. MODEL OF SOLAR CELL

Any photovoltaic cell model is based on diode behavior, which gives to photovoltaic cell its exponential characteristic. The solar cell can be modeled with three modeling systems[3].The first possibility of modeling can be done with instruments which can implement any differential equation or algebraic relationship of a highly complex mathematical model. Another possibility is given by Simscape®, which allows direct modeling using physical components of the electric field(resistors, capacitors and diodes) to implement exactly the same mathematical equation. A modeling system more complex than those described above is performed using SimElectronics® advanced component library, which contains a block called Solar Cell. The solar cell from MATLAB/SIMULINK is a solar current source, which includes solar induced current and temperature dependence[4].

III. SOLAR INDUCED CURRENT

Solar cell block is formed from a single solar cell as a resistance R_s connected in series with a parallel combination of a current source, two exponential diodes and a parallel resistance R_p as shown in Figure.1[4][5].
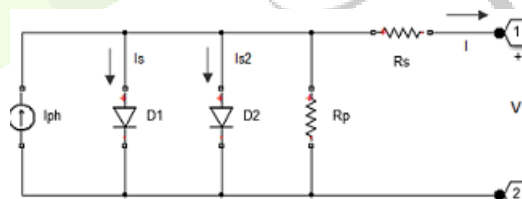

Figure 1: Two diode model of Solar cell

The output current is given by the equation $I = I_{ph} - I_s\left(e^{(V+IR_s)/(NV_t)} - 1\right) - I_{s2}\left(e^{(V+IR_s)/(N_2V_t)} - 1\right) - (V + IR_s)/R_p$ where I_{ph} is solar induced current. $I_{ph} = I_{pho}.I_r/I_{ro}$, where I_r is irradiance in W/m^2 which fall on cell surface; I_{pho} is measured solar generated current for the irradiance I_{ro}; I_s is the saturation current of the first diode; I_{s2} is the saturation current of the second diode; $V = kT/q$ is the thermal voltage, depend on temperature of the device T, k is the Boltzmann constant and q is elementary charge of the electron; N is the quality factor (the emission coefficient for the diode) of the first diode; N_2 is the quality factor (the emission coefficient for the diode) of the second diode; V is the voltage at the terminals of solar cell[8].

This block allows choosing one of two models: a model with 8 parameters in which the previous equation describes the output current, and a model with 5 parameters implied for this equation with the following simplified assumptions: the impedance of the parallel resistor is infinite and the saturation current of the second diode is zero. The model with 5 parameters allows optimization of this block according to the equivalent circuit model parameters or by short circuit current and open circuit voltage[3].

IV. TEMPERATURE DEPENDENCE

Several solar cell parameters (the solar-induced current I_{ph}, the saturation current of the first diode I_s, the saturation current of the second diode I_{s2}, the series resistance R_s and the parallel resistance R_p) depend on temperature. Photovoltaic cell temperature is specified by value of the fixed circuit temperature parameter, TFIXED[4]. Between the solar induced current I_{ph} and temperature of solar cell T[4-8] appears in the equation

$$I_{ph}(t) = I_{ph}(1 + TIPH1(T - T_{meas}))$$ where $TIPH1$ is the first temperature coefficient for I_{ph}; T_{meas} is the parameter extraction temperature.

V. MODEL OF PHOTOVOLTAIC ARRAY

In the model Figure 2 represents a PV cell array connected to a variable resistor. This resistor has an input ramp which just varies resistance linearly in closed circuit until it reaches the 30th steps. Inside the array subsystem are 8 rows of photovoltaic solar cells connected in series, formed by 8 solar cells of SimElectronics® library as shown in Figure 3. This structure can be built in any configurations by connecting multiple strings of solar cells in series or in parallel.
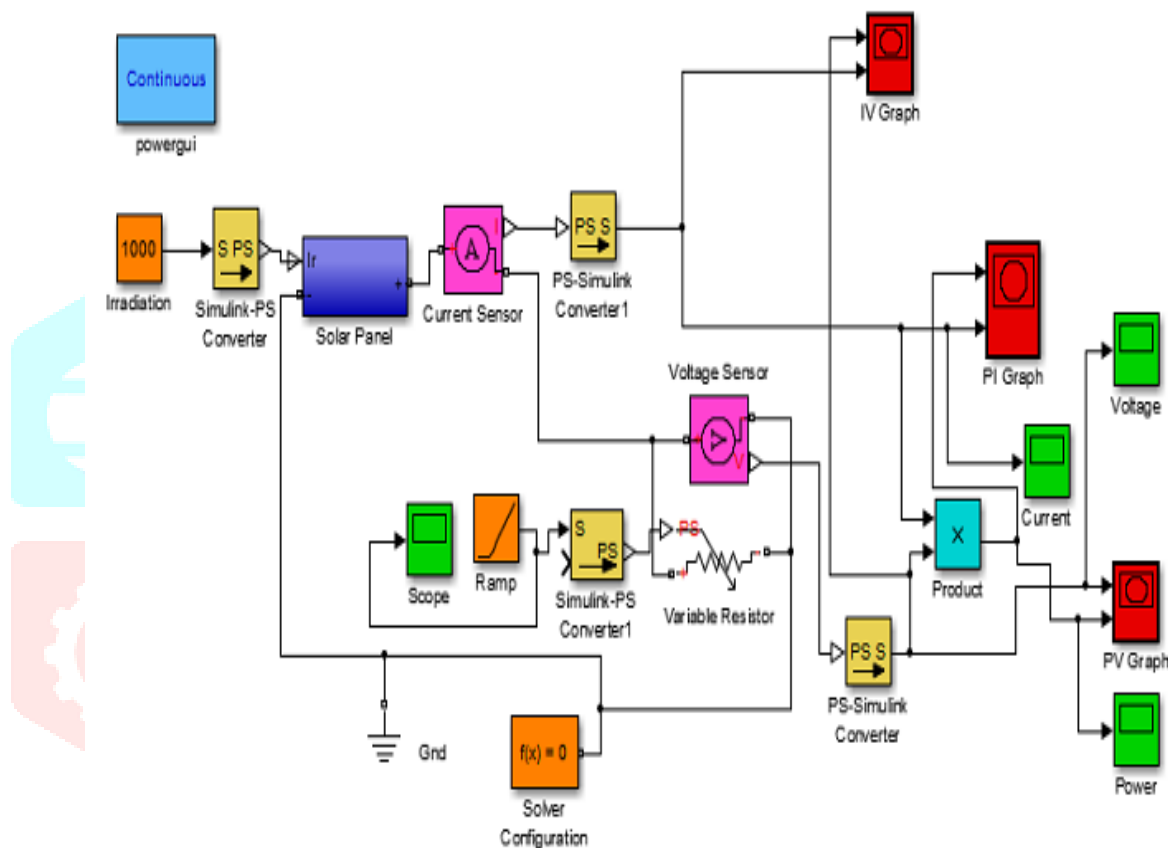

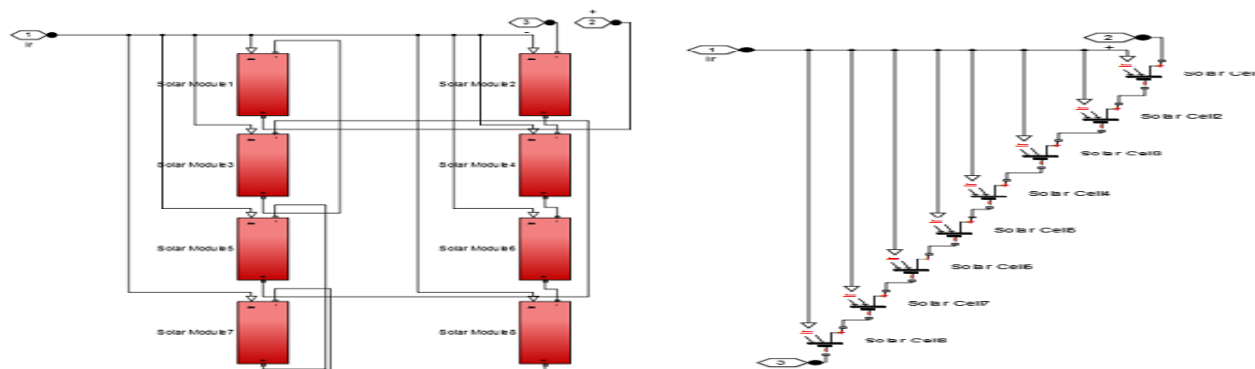Figure 2: The Simulink model of photovoltaic array

Figure 3: Connection of Solar cells in PV panel subsystem

The advantage of using of this high level of implementation is to create a simple equivalent circuit, which have much more complex parameters, including the effect of temperature in the device which is very important for behavior of this type of system. The photovoltaic panel model is validated by simulating at a value of irradiance of 1000 W/m^2 and a temperature of 25ºC.

Parameter	Value
Short-circuit current [A]	$Isc = 7.34$
Open-circuit current [V]	$Voc = 0.6$
Quality factor	N = 1.5
Series resistance [Ω]	$Rs = 0$
First order temperature coefficient for Iph [1/K]	TIPH1 = 0
Temperature exponent for Is	TXIS1 = 3
Temperature exponent for Rs	TRS1 = 0
Parameter extraction temperature [°C]	$Tmeas = 25$
Fixed circuit temperature [°C]	TFIXED=25

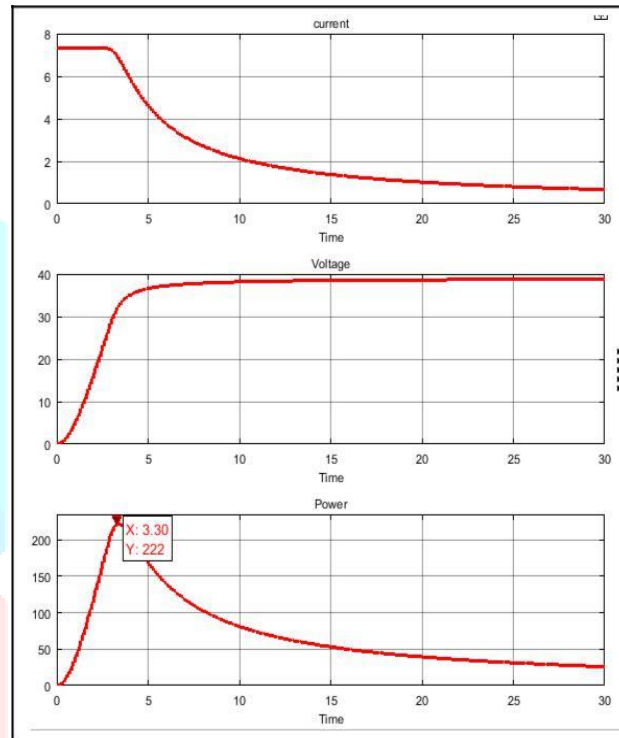Table 1: The parameters of single solar cell

VI. SIMULATION RESULTS

Figure 4: Current, Voltage and Power curves for PV array

In Figure 4, are shown the current, voltage and power which are obtained at output of PV array. These are the curves of current, voltage and power versus time. When the resistance varies, the current and voltage vary depending on the voltage-time relationship, which gives the power curve.

The characteristics of V-I and P-V of the photovoltaic array is given in Figure 5 and Figure 6. The V-I curve represent the standard behavior of the photovoltaic cell and photovoltaic array respectively. In the middle of this characteristic is the maximum power point. This point is very critical for this kind of system for maximum power extraction from the photovoltaic array. Result that the main objective is to try operating around of this maximum point in order to make the photovoltaic cells to work at maximum efficiency.
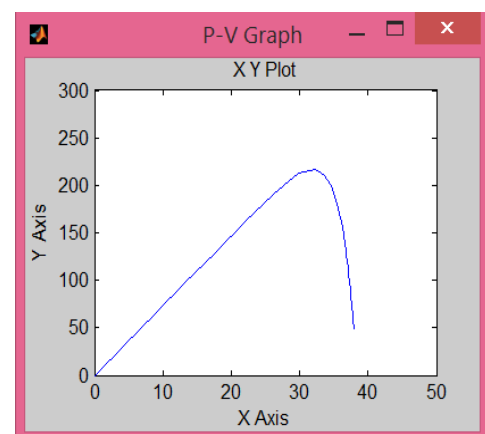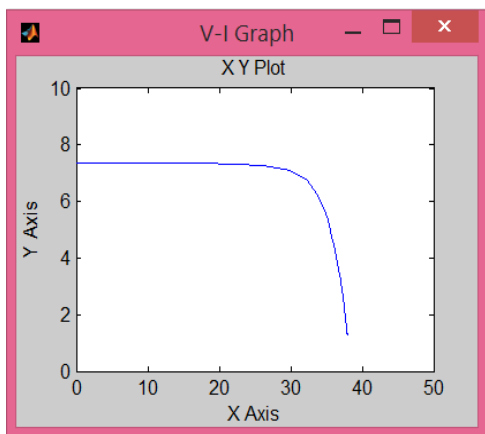
Figure 5: V-I Characteristic of PV array   Figure 6: P-V Characteristic of PV array

The V-I characteristic for radiation incident on the photovoltaic cells is amended in Figure 7. If the irradiance decreases, the photovoltaic current generated decreases proportionally to that and variation of no-load voltage is very small.

PV Array V-I Characteristics-Data

Irradiance effect on PV array performance at T=25°C   Temperature effect on PV array performance at irradiance of 1000 W/m^2
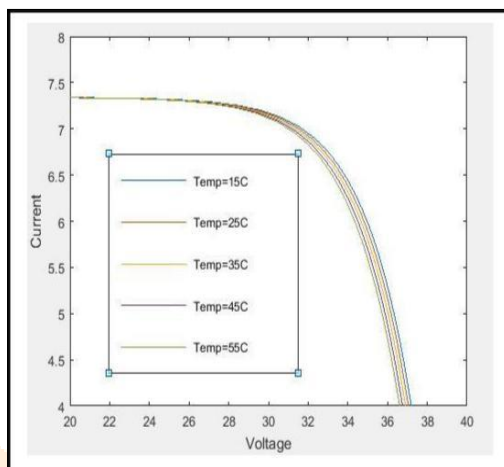

Figure7:V-I characteristics for different values of solar radiation
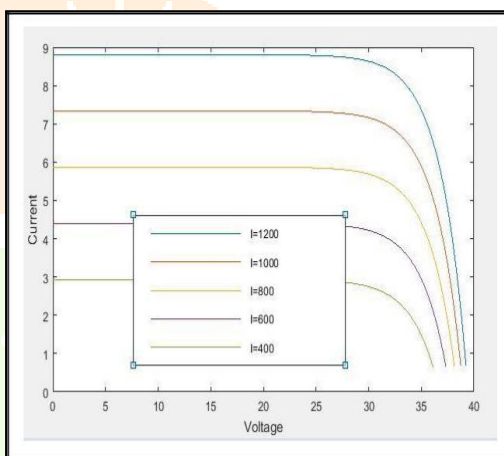at temperature of 25°C

Figure 8: V-I characteristics for different temperatures

 shown in Fig.7, when the temperature of module increases the voltage decreases and the produced current remains practically constant. In terms of produced electric power is a reduction in the performance of the PV array[2].

In Figure 9 are represented the P-V characteristics of the photovoltaic array for a level of irradiation of 1000 W/m^2 and for different temperatures and respectively in Figure 10 are given the P-V characteristics for different levels of solar radiation at the temperature of 25°.

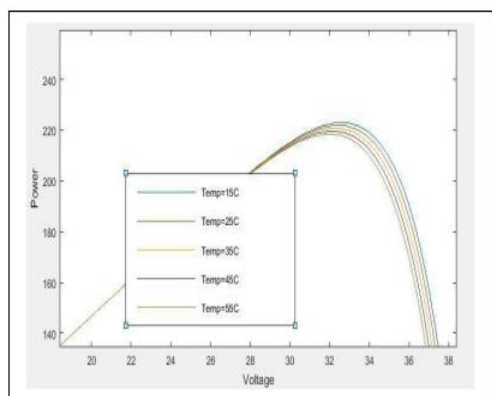Temperature effect on PV array performance at irradiance of 1000 W/m^2

Figure 9: P-V characteristics for different temperatures   Figure 10: P-V characteristics for different values of solar radiation
 Irradiance effect on PV array performance at T=25°C   at temperature of 25°C
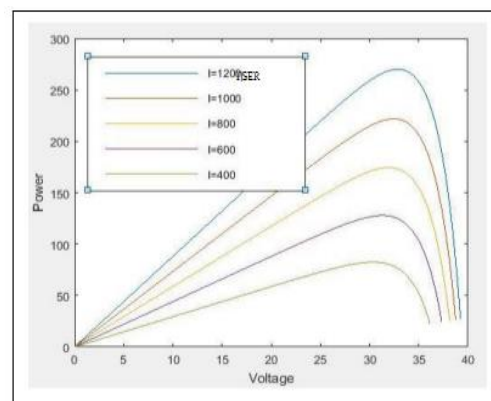
From Figure 9, it is observed that for an irradiance of 800 W/m^2, which corresponds to yellow curve is obtained a maximum power of 170 W and for an irradiation of 1000 W/m^2 which corresponds to dark blue curve, the PV array provide a maximum power of 222 W. That gives an idea of measure in the power produced by a photovoltaic array is affected by changing irradiance.

VII. CONCLUSION

This work describes a new implementation of solar cell by using MATLAB®/Simulink® of photovoltaic array and modeling using experimental data. Photovoltaic array is build by using the solar cell block and the power produced by a photovoltaic array is affected by changing of irradiance. The implemented model is validated through simulation. The simulation results show that the proposed method is efficient in terms of modeling of the functioning of the photovoltaic system.

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