SIMSCAPE MODEL OF PHOTOVOLTAIC CELL

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ABSTRACT: The study of photovoltaic systems in an efficient manner requires a precise knowledge of the IV and PV characteristic curves of photovoltaic modules. A Simulation model for simulation of a single solar cell and two solar cells in series has been developed using Sim electronics (Mat lab /Simulink) environment and is presented here in this paper. A solar cell block is available in simelectronics, which was used with many other blocks to plot I-V and P-V characteristics under variations of parameters considering one parameter variation at a time. Effect of two environmental parameters of temperature and irradiance variations could also be observed from simulated characteristics.

Key words: Photovoltaic Cells, PV-IV Curves, Modeling, Simulation,Matlab/Simulink.

I. INTRODUCTION

   Solar system energy is the most important renewable and sustainable energy system. Solar-electric-energy system has grown consistently and become a popular resource of energy. The main reasons for this huge attention are; 1) increase in efficiency of solar cells; 2) recent technological improvements; 3) green and environmental friendship. Typical applications of solar energy are supply the residential loads and far off electrical installations. It also has a major role in distributed generation network. Right now solar cell efficiency is relatively low around 12 to 20 %, it means that PV panel can harvest a little amount of sunlight energy (a prototype solar panel with 33.9% efficiency is announced recently by Siemens and North Carolina's Semprius Inc). Therefore, to preserve this little harvested energy, the whole system such as energy conversion stage has to be designed carefully and efficiently. It enforces system integrator to design very high efficient DC/DC and DC/AC converters. In the present paper, Simulation model for the solar cell is developed using Simelectronics (Matlab/Simulink) environment . The paper deals with the simulation study of one solar cell and two solar cells connected in series. Modeling and simulation of physical system in computer become more attractive than ever due to advanced software like Matlab/Simulink. An electric circuit model of a solar cell can represent thoroughly the Mathematical relations (Lumped circuit). The simplest model has only one diode and one photocurrent source as function of sun irradiation (Iph). The simpleone has one extra series resistance Rs [4-6]. The four-element model has shunt resistance (Rp) and finally two-diode model has five-element with one extra diode. Another PVclassification is based on the number of parameters that are used in the model. Therefore, there is three-, four-, five- and seven-parameter models. There are plenty of PV models represented by researchers, and each model has its own advantages. However, to the researcher's knowledge no study has yet been dealing with the comparison of these models. In some studies, the effect of temperature has intentionally been neglected, but this model may be suitable for very stable climates. Some others simply neglect the shunt resistance to decrease complexity and lessen computations and some even ignore series resistance (lossless model). It is obvious that only in the equator that the ambient temperature is relatively stable. On the other hand, in some areas like Sahara desert or areas with four seasons, high ambient temperature will decrease total energy harvesting significantly. This paper tries to evaluate how this kind of assumptions will affect the solar energy system efficiency. This study also compares the most common PV models and simulation results. To validate findings, simulation results are compared by industrial PV panel datasheet. The results show each model's accuracy. All models are implemented in Matlab/Simulink family software.

II. SIMELECTRONICS

SimElectronics® software works with Simscape™ software and extends the physical modeling capabilities of the Simulink® product family with tools for modeling and simulating electromechanical and electronic systems. It contains blocks that let one model electromechanical and electronic systems at a speed and level of fidelity that is appropriate for system-level analysis. The blocks let one perform tradeoff analyses to optimize system design, for example, by testing various algorithms with different circuit implementations. SimElectronics is part of the Simulink Physical Modeling family. Models using SimElectronics are essentially Simscape block diagrams. To build a system-level model with electrical blocks, a combination of SimElectronics blocks and other Simscape and Simulinkblocks can be used.

III SOLAR CELL MODEL

The most important component that affects the accuracy of the simulation is the PV cell model. Modeling of PV cell involves the estimation of the I-V and P-V characteristics curves to emulate the real cell under various environmental conditions. The most popular approach is to utilize the electrical equivalent circuit, which is primarily based on diode. The Solar Cell block in SimElectronics, represents a single solar cell as a parallel current source, Iph, an exponential diode, D and a shunt resistance, Rsh that are connected in series with a resistance Rs. Fig.1(a) shows the symbol of solar cell in SimElectronics, Fig.1(b) shows the equivalent circuit.
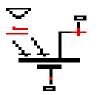

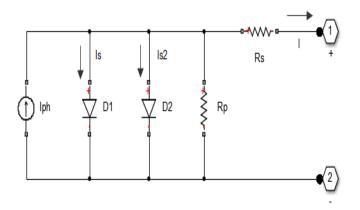
Fig. 1(a) Symbol of a Solar cell

Fig.1(b) Equivalent Circuit of the Solar cell

Solar cell block is formed from a single solar cell as a resistance*s R* connected in series with a parallel combination of a current source, two exponential diodes and a parallel resistor *R* [3],[4].The output current *I* is given by equation (1).

The output current I is given by equation (1):

$$I = I_{ph} - I_s \cdot \left(e^{\frac{V + I \cdot R_s}{N \cdot V_t}} - 1 \right) - I_{s2} \cdot \left(e^{\frac{V + I \cdot R_s}{N_2 \cdot V_t}} - 1 \right) - \frac{V + I \cdot R_s}{R_P} \quad (1)$$

where

Ir is the irradiance (light intensity) in W/m2 falling on the cell.
Iph0 is the measured photo-generated current for the standard irradiance Ir0.
Isis the diode reverse saturation current.
k is the Boltzmann constant.
T is the measurement temperature parameter value.
q is the elementary charge of an electron.
V is the voltage across the solar cell electrical ports.
I is the output current of PV cell.
N is the diode ideality factor. The Ideality factor varies for amorphous cells, and is typically 1-2 for polycrystalline cells.
This block can be parameterized in terms of the preceding equivalent circuit model parameters or in terms of the short-circuit current and open-circuit voltage the block uses to derive these parameters. This block allows hosing one of two models: a model with 8 parameters in which the previous equation describes the output current, and a model with 5parameters if for this equation is applied the following simplifying 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(a) SIMSCAPE MODEL OF SHELL SQ 175 SOLAR CELL MODULE HAVING 72 INDIVIDUAL CELLS
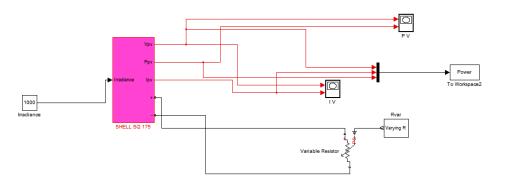

Fig. 2. SimElectronics Simulation Model for a single Cell

This Model was developed using blocks of SimElectronics and Simulink. Solar cell was connected with blocks such as current sensor and voltage sensor to measure the current and voltage across solar cell. Blocks for varying Irradiance level and Temperature, were also connected in the above model. Rest of the blocks were the interface between major blocks and used for plotting I-V characteristics. The solar cell was parameterized by equivalent circuit parameters. Diode reverse saturation current, Is, was taken as 0.1nA, measurement temperature was kept as 25oC. Solar-generated current, Iph0, and Irradiance used for measurements, Ir0, were kept at their default values of 7.34A and 1000 W/m2 respectively. 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.
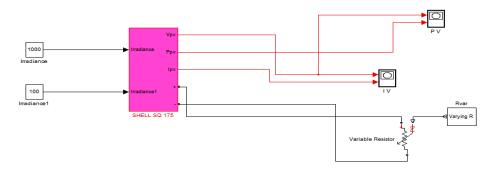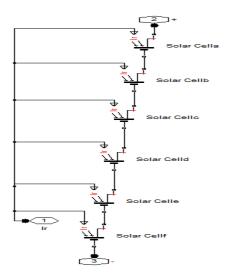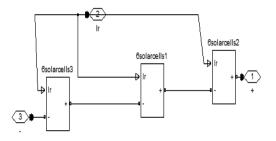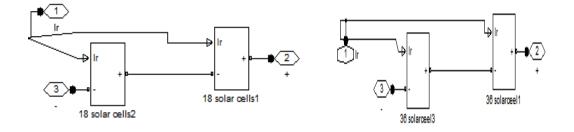

Fig3. SimElectronics Simulation Model for a single Cell

IV(b) SIMSCAPE MODEL OF SHELL SQ 175 SOLAR CELL MODULE HAVING 72 INDIVIDUAL CELLS- 5REPRESENTATION OF INDIVIDUAL BLOCKS

The parameters of a single solar cell

Parameter	Value
Short-circuit current [A]	$I_{sc} = 7.34$
Open-circuit voltage [V]	$V_{oc} = 0.6$
Quality factor	$N = 1.5$
Series resistance [Ω]	$R_s = 0$
First order temperature coefficient for I_{ph} [1/K]	TIPH1 = 0
Temperature exponent for I_s	TXIS1 = 3
Temperature exponent for R_s	TRS1 = 0
Parameter extraction temperature [°C]	$T_{meas} = 25$
Fixed circuit temperature [°C]	TFIXED = 25

V. RESULTS

One can say that, photocurrent depends on the irradiation of the moment, for a fixed temperature (in these cases, 25° C). The higher the irradiation, the greater the current. On the other hand, voltage is going to maintain almost Constant and it is not going to vary much, although increases or diminishes the irradiation. The characteristic V-I curve for radiation incident on the photovoltaic cells is amended as shown in Figure 4[10]. If the irradiance decreases, the photovoltaic current generated decreases proportionally to that, and variation of no-load voltage is very small [1] .**Fig. 4.** V-I characteristics for fixed values of solar radiation at temperature of 25 c.^{0} **Fig5.** V-p characteristics for fixed values of solar radiation at temperature . **Fig. 6.** The V-P characteristics of the photovoltaic array For multiple peaks.
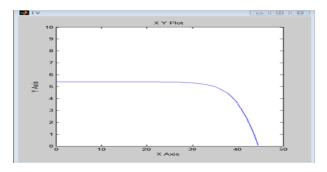

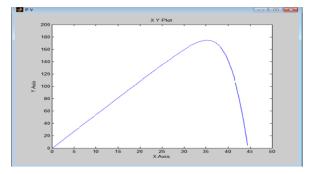**Fig. 4.** The V-I characteristics of photovoltaic array.

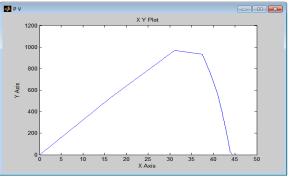**Fig. 5.** The V-P characteristics of the photovoltaic array.

Fig. 6. The V-P characteristics of the photovoltaic array For multiple peaks.

VI. CONCLUSIONS

Model for simulation of a solar cell has been developed in Simelectronics (MATLAB/Simulink) using solar cell block and other interfacing blocks. The objective of the models is to achieve similar IV and PV characteristics curves to the graphs that are in the datasheet of the manufacturer of the different solar panels. The most similar will be the best model, or the one that behaves more like the physical model. In the made models, the results are similar and they resemble the desired results, although they are simple models, and it is possible to study the behavior and performance of photovoltaic cells in the time domain. In low sun irradiation level, two-diode model is more accurate. The sun irradiation pattern usually starts in low irradiation in the morning and in the evening; therefore, two diode model will be the best choice and is very close to real situation. In fact, all practical PV modules will finally be installed outside; therefore neglecting ambient effect is not a good assumption. Simscape based models have its intrinsic advantages that researcher has verity of built in tools for further study. It means PV model is able to integrate by abundant built-in power system components available in the software library. In this survey, we have only used the most popular models represented in Matlab/Simulink.

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