Mathematical Model Derivation of Solar Cell by Using OneDiode Equivalent Circuit via SIMULINK

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Abstract

In order to meet the need for a promising development, it must be made to increase the efficiency of photovoltaic systems and to decrease the cost of energy from the sun. Optimum system designs have to be made to pay less than for photovoltaic systems, as well as panel prices. Simulation and modeling of solar cells is very important for the photovoltaic system design. The main subject of this article is thederivation of mathematical model of Photovoltaic solar cells having a diode equivalent circuitby using Matlab Simulink programming and drawing of current-voltage and power-voltage characteristics.

1. Introduction

As is known, the energy is the most important factor improves the quality of life, that economic and social progress. However, rising energy prices, global warming and climate change, world energy demand, which is rapidly running out of dependence on fossil fuels will continue to be in the near future, developments in the field of new energy technologies, countries leads to a new search. From the reports on the future of the Earth's energy, energy needs and resources distribution between the years of 2000-2100, oil well will decrease in 2100 year,, coal will scarcely remain, continue to increase the use of solar energy is observed[1].

The development of photovoltaic solar cells in 60 years nearly, private and public funded research and development work has been based. Solar cell prices fall and due to the use of clean energy source in power generation has increased in recent years. Even though solar cells are expensive, they are some important advantages; do not have any moving parts, smoothly with minimal maintenance can be used in 25-30 years and they don't leaving waste work for the duration of a pollutant to the environment. For this reason, many studies have been done on solar cells [2].

Photovoltaic systems, solar batteries, connectors, protection elements, storage elements and by depending on the characteristics of the load supplied is structure containing some additional elements. The solar cells are the most important element of these systems; in particular the initial investment cost and used other elements the quality and the amount of have got defining the features. Therefore, the first stage of the installation of the high efficiency solar cells and in the best conditions is very important to design a system to work [3].

Solar cells are the surface of that converts sunlight directly into electricity the semiconductor substances. This working principle solar cell produces a voltage at the ends depending on the amount of light falling. The voltage generated varies direct proportion to the amount of sunlight [4].

2. The Structure of Solar Cell

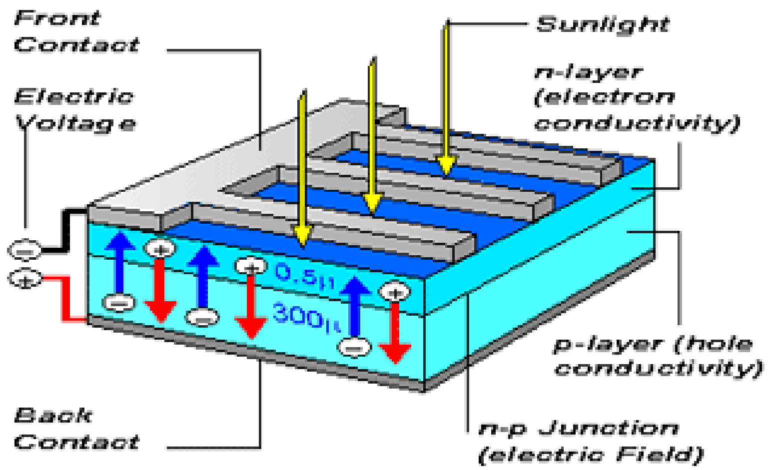

Figure 1: Structure of Solar Cell [5]

Photovoltaic cells are semiconductor substances that surface come sunlight converts into directly electricity energy. N and P-type doping of is required for semiconductor substances can be used in the photovoltaiccells. Doping isdone additives by the addition as controlled into the pure semiconductor melt. A elements of 5 group in the periodic table add as the most common photovoltaic cell material used silicon to obtain a N-type silicon in silicon melt (for example, phosphorus is added). P type silicon of the melt 3 in order to obtain a group elements (aluminum, indium, boron, etc.) is added. The crystal structure of N-type silicon structure allows more electrons. N-type silicon, "exciting" are called, P-type silicon structure are missing an electron. This deficiency is called hall and P-type silicon, "receiver" is called. The semiconductor joints form P and N-type doped materials by put together. The electron-holepair is created light by falling at joint region. Then, they are separated with the help of the electric field in the region. As shown in Figure1, electron-hol pairs of divergent make up a useful power output at the ends of the photovoltaic cell [6].

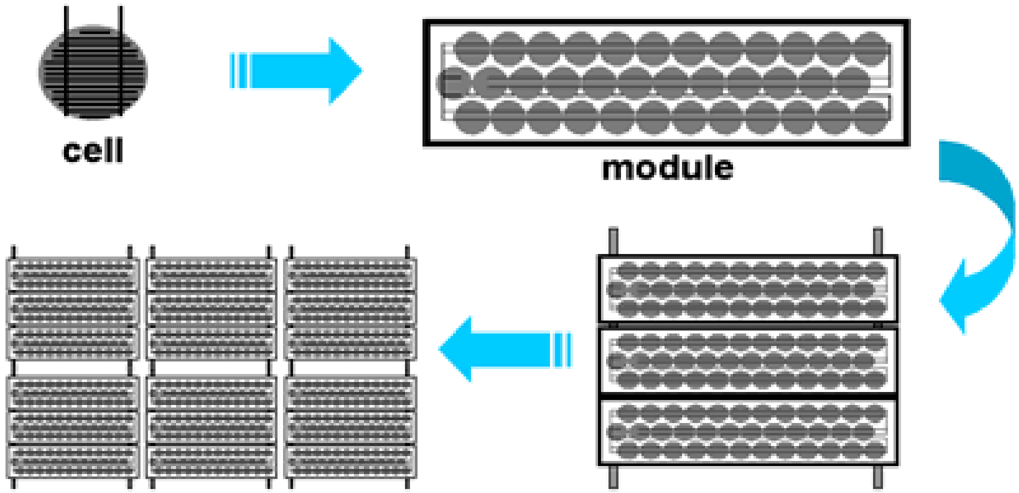

Figure 2: Structure of Solar Panel [7]

Moduls and series are formed by combination of solar cells and moduls respectively in figure 2.

3. A Diode Model

A photovoltaic cell can be modeled as a current source PN connected in parallel with a diode. Current source produces a constant current. This current is proportional to the intensity of the light falling upon the cell. Photovoltaic systems affected weather conditions and solar radiation by directly. The yield of the photovoltaic system and the price related to external working conditions and the variable conditions the operation of the system components at the best spot. Therefore, solar energy applications, while the photovoltaic system under different and varying conditions accurately assesses the performance of each element are important. This situation also affects the system design and cause electrical parameters sudden by changing the network changes set over time in the event of certain. The performance of a solar cell is needed to understand the correlation between current and voltage of the cell. The solar cell characteristics affect the operation of the inverter and design of control system [8].

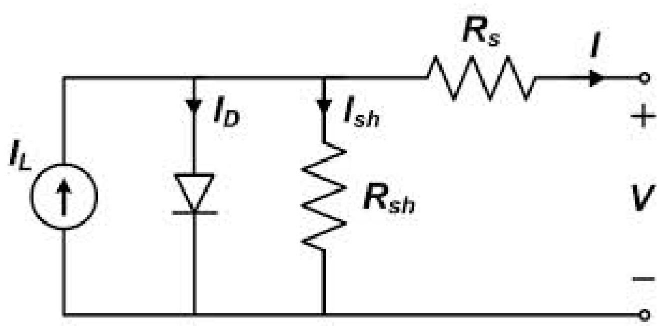

Figure3: A diode model

There is a current source (solar cell),a parallel diode and a resistance (Rsh) and a resistance are connected in series to them (Rs) at single-diode model equivalent circuit (Duffie and Beckman, 1980). This circuit is given in figure 3.

Table 1: Photovoltaic Model Parameters

R_s	*Series Resistance*	I_{pil}	*PV Battery Output Current*
R_p	*Parallel Resistance*	V_D	*Diode Voltage*
q	*Electron Load*	G_{ref}	*Nominal Amount of Solar Radiation*
m	*Ideality Factor*	G	*Amount of Solar Radiation*
k	*Boltzmann Constant*	I_{sc}	*Nominal Short-Circuit Current*
T	*Kelvin Temperature*	V_{oc}	*Nominal Open Circuit Voltage*
N_{pc}	*Number of Parallel*	I_M	*Maximum Power Point Current*
N_{sc}	*Number of Serial*	T_{ref}	*Nominal Operating Temperature*
P_M	*Maximum Power*	V_M	*Maximum Power Point Voltage*
C_0	*Temperature Coefficient*	K_v	*Voltage Temperature Coefficient*
I_D	*Diode Current*	I_e	*Electron Current*
I_{ph}	*Photovoltaic Current*	I_h	*Hole Current*
I_{sh}	*Parallel Resistor Current*	K_i	*Current Temperature Coefficient*
I_{oref}	*Reference Current*	E_g	*Diodes Bandwidth*
b	*Constant Semiconductor*	I_0	*Diode Saturation Current*

Kirchhoff's the currents law is applied to circuit at figure 3;

$$I_{pil} = I_{ph} - I_{D1} - I_{D2} - I_{sh} \tag{1}$$

Diode current, is the total current through for the p-n junction, is the total currents generated by the electrons and holes activated by photons mathematical. States of electrons at conduction band and space current at valence band Boltzmann distribution net flows and the space electron current flows [4];

$$I_e = I_{eo}.(e^{\frac{qV_D}{kbT}} - 1) \tag{2}$$

$$I_h = I_{ho}.(e^{\frac{qV_D}{kbT}} - 1) \tag{3}$$

$$I_D = I_e + I_h = I_o.(e^{\frac{qV_D}{kbT}} - 1) \tag{4}$$

[28]

Diode current ID, varies the absolute temperature of the diode, voltage and as a function of the current drawn by the load. At equation 4, q, electron charge (1.602×10^{-19} C), the potential difference between the ends of the diode VD, m, the ideality factor, k: Boltzmann constant (1.381×10^{-23} J / K) and T is the absolute temperature in Kelvin represents [9].

$$I_D = I_o.\left(e^{\frac{qV_D}{mkT}} - 1\right) = I_o.\left(e^{\frac{q(V_{PV}+I.R_S)}{mkT}} - 1\right) \tag{5}$$

$$I_{sh} = \frac{V_D}{R_{sh}} = \frac{(V_{pv}+I.R_s)}{R_{sh}} \quad (6)$$

$$I_{pil} = I_{ph} - I_D - I_{sh}$$

$$I_{pil} = I_{ph} - I_o.\left(e^{\frac{q(V_{pv}+I.R_s)}{mkT}} - 1\right) - \frac{(V_{pv}+I.R_s)}{R_{sh}} \quad (7)$$

Equity in connection with temperature equation 7; [11]

$$I_{pil} = I_{ph.}\left(1 + C_0(T - 300)\right) - I_o.\left(e^{\frac{q(V_{pv}+I.R_s)}{mkT}} - 1\right) - \frac{(V_{pv}+I.R_s)}{R_{sh}} \quad (8)$$

V_M=N_{sc}.V_{new} (9)

I_M=N_{pc}.I_{new} (10)

[4]

$$I_0 = I_{oref}.\left(\frac{T_c}{T_{cref}}\right)^3 .\exp\left[\left(\frac{q.E_g}{n.k_b}\right)\left(\frac{1}{T_{cref}} - \frac{1}{T_c}\right)\right] \quad (11)$$

I_{oref} = Reference Current

E_g =Diodes Bandwidth

$$I_{ph} = [I_{sc} + \alpha.(T_c - 25)]\frac{G}{G_{ref}} \quad (12)$$

Eq. (8) is performed by using of Eqs. (11-12) to obtain current of solar cell [4,10].

4. Matlab Simulink App

The modeled parameters of the photovoltaic panel shows at figure 4.

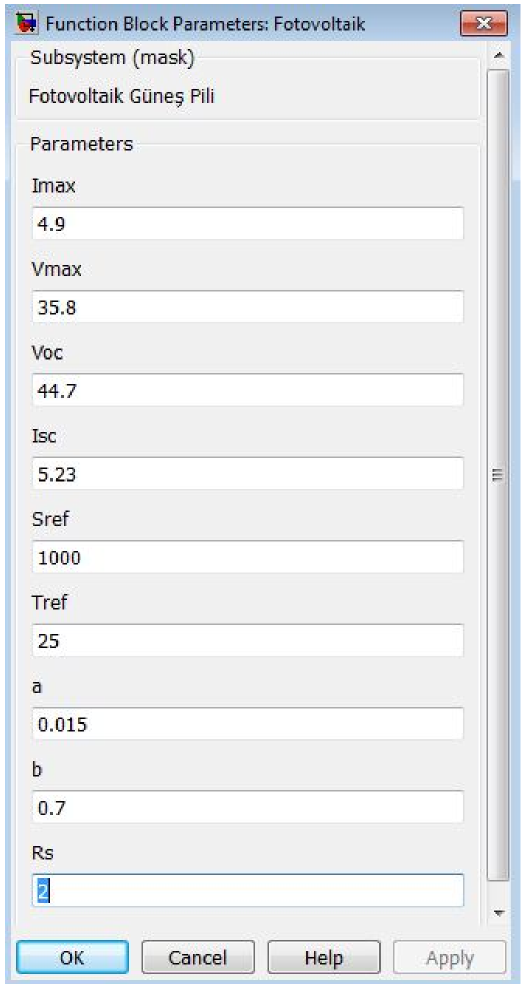

Figure4: Photovoltaic BlockParameters

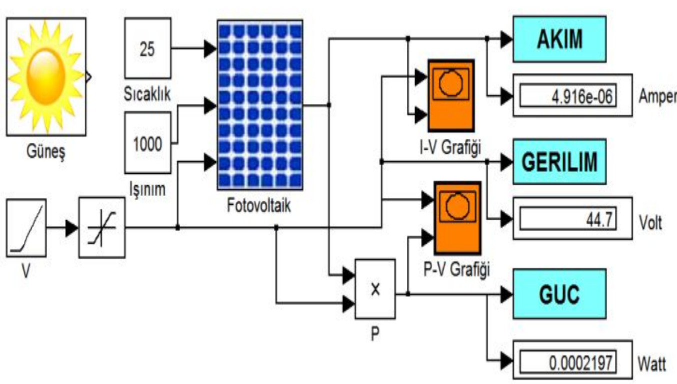

Figure 5: Matlab Simulink Apps

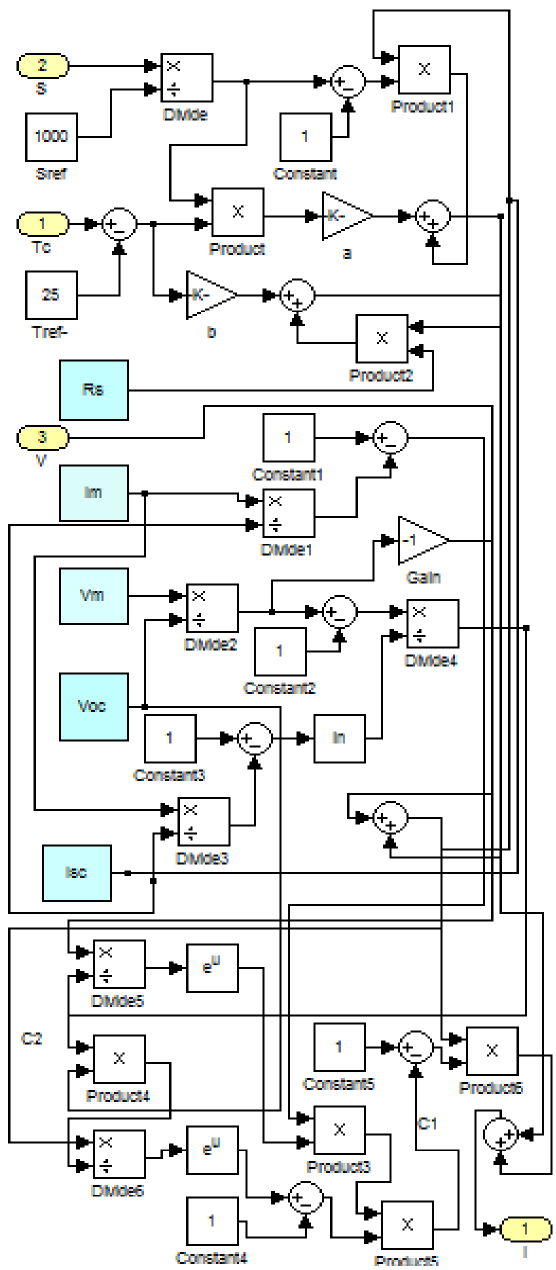

Figure 6: Model of a diode performed with Matlab Simulink

5. Modeled Solar Cell

Suntech Brand tag values of STP175S-24 model solarcells are power = 175.0 W, V_{mp} = 35.8 V, I_{mp} = 4.9 A, V_{oc} = 44.7 V, I_{sc} = 5.23 A, W = 15.5 kg, 1580x808x35 (mm), mono-Si.The current-voltage and power-voltage characteristics of different strength values given for are observed in the catalog of Suntech Brand STP175S-24 model solar cells in Figure 7. The effect solar cell of temperature shows in figure 8.

Figure 7: The Characteristics of Modeled Solar [12]

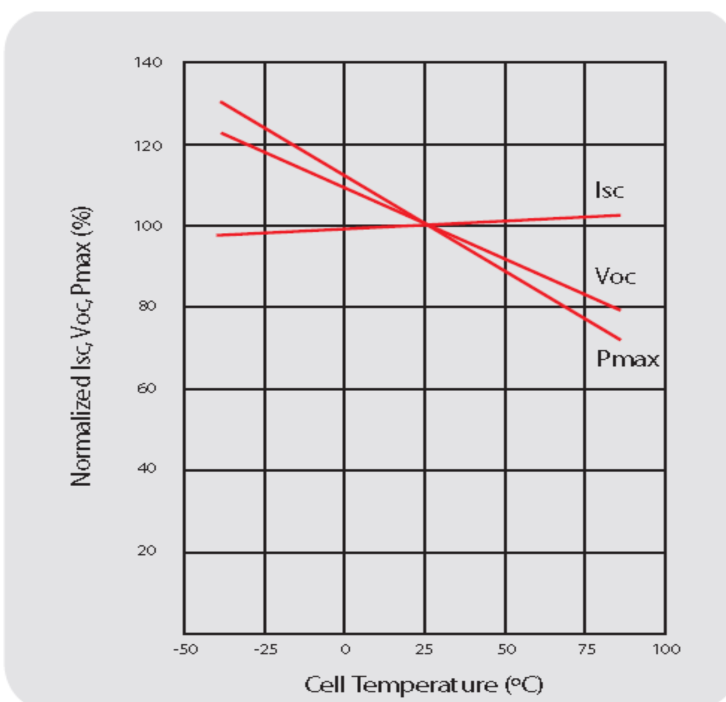

Figure 8: Temperature Response of Solar Battery [12]

6. Result

Accomplishedly, a diode mathematical model of the photovoltaic solar cell with Matlab Simulink is simulated of Suntech brand STP175S-24 model solar cell.

The research work shown that could be used with success with a diode equivalent circuit for the modeling of solar cells at simulation studies of photovoltaic system design.

Affecting the production of solar cells, ambient temperature and solar radiation were investigated with the help of the model. Also modeled parameters of the photovoltaic panel Vmp, Imp, Voc, Isc of how the changes affect production were investigated. If the media and the parametric values of photovoltaic solar cells known, the values of production can calculate.

The characteristics current-voltage, power-voltage of photovoltaic solar cell was drawn with the generated model. Photovoltaic panels provide a substantial compliance with the characteristics of the catalog have been determined.

Photovoltaic panels are created with the help of Matlab Simulink of mathematical model constant 1000 W/m^2 daylight and ambient temperature of 25 ° C shows the current-voltage characteristic in Figure 9.

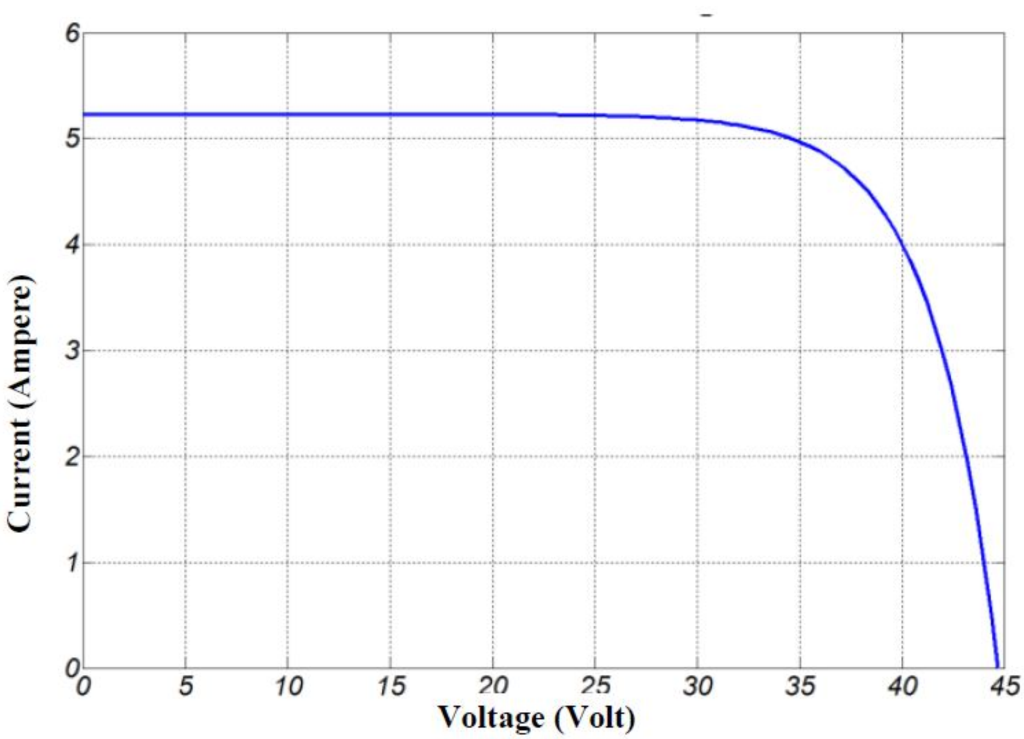

Figure 9: Current-voltage graph

At characteristicV_{oc}=44,7 V, I_{sc}=5.23 A, V_{mp} = 35.8 V, I_{mp} = 4.9 A is observed. Values of catalog with the values of the model were identified the same.

Photovoltaic panels are created with the help of Matlab Simulink of mathematical model constant 1000 W/m^2 daylight and ambient temperature of 25 ° C shows the current-voltage characteristic in Figure 10.

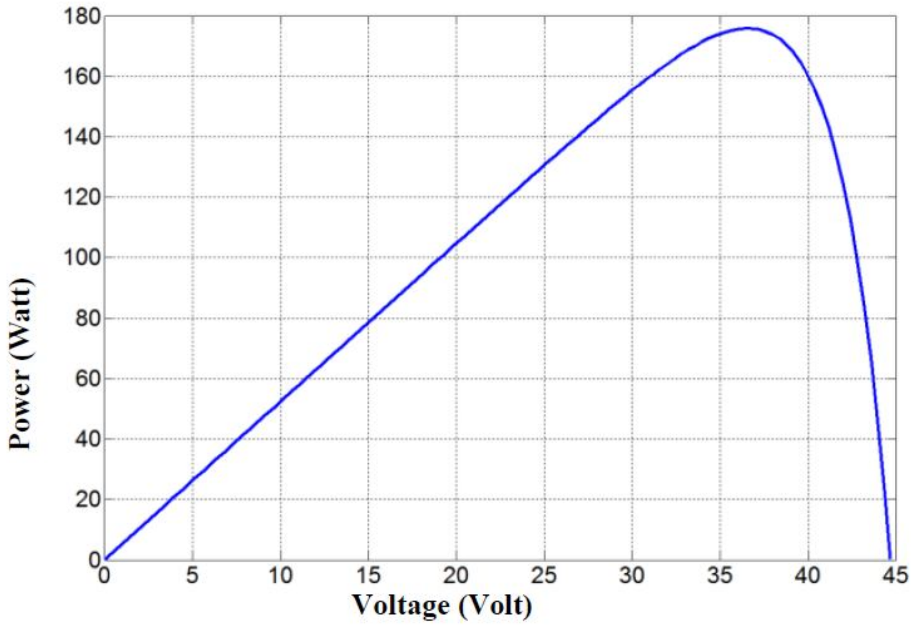

Figure 10: Power-voltage graph

At characteristic Voc = 44.7 V, Vmp = 35.8 V, Power= 175.0 W is observed. Values of catalog with the values of the model were identified the same.

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