Journal of Innovative Image Processing (ISSN: 2582-4252)
www.irojournals.com/iroiip/

Modelling and Simulation of a Photovoltaic Cell for Green Instrumentation Technology

T. Suganya[1]*, G. Thirugnanam[2], V. Rajendran[3], P. Mangaiyarkarasi[4]

[1]Lecturer/ICE, Faculty Development Training Centre, Government College of Technology, Coimbatore
[2]Associate Professor, Dept. of Electronic and Communication Engg., Government College of Technology, Coimbatore
[3] Principal, Government Polytechnic College for Women, Coimbatore
[4]Associate Professor, Department of Electronics and Instrumentation, Government College of Technology, Coimbatore

E-mail: [1*]suganya_t@yahoo.com, [2]thirugnanam_g@gct.ac.in, [3]dhanaraja2006@yahoo.com, [4]mangaiyarkarasip80@gmail.com

Abstract

Some photons are absorbed at the p-n junction; therefore a solar module is made up of photons of various energy. To represent the electrical behaviour of a solar cell, a single diode equivalent model has been utilised. A current source connected to a diode, a shunt resistance, and a series resistance component is used to simulate a perfect solar cell. Due to variations in light intensity and temperature, the parameters of the solar cell fluctuate. The mathematical model of the solar cell is developed using parameters in this study, and the model is then simulated with Matlab/Simulink. Solar cells may be used to generate renewable energy, which can be used in green instrumentation.

Keywords: Solar Cells, Electronic Modelling, Green Instrumentation

1. Introduction

Green instrumentation is a type of equipment that operates in a safe and dependable manner. It protects the environment by reducing environmental impact. Green instrumentation also makes use of renewable energy and technology that are environmentally friendly. Solar energy and solar-powered technologies are one such plentiful resource. When the sun shines on a solar panel, the energy from the sun is absorbed by the solar cells in the panel, resulting in an electric field and the flow of electricity. The sun generates massive quantities of energy that power seas, air currents, and the evaporation cycle, as well as driving river flow, hurricanes, and tornadoes that devastate natural landscapes.

DOI: https://doi.org/10.36548/jiip.2022.1.005
Received: 27.03.2022, received in revised form: 28.04.2022, accepted: 07.05.2022, published: 19.05.2022

The magnitude of 7.8 quake that devastated San Francisco in 1906 generated an estimated 1017 joules of energy, which the sun provides in one second. Oil reserves on Earth amount to 3 trillion barrels, each carrying 1.71022 joules of energy, which the sun provides in 1.5 days. Humans consume roughly 4.61020 joules each year, which the sun provides in an hour. The sun continually provides around 1.21025 terawatts of energy, which is far more than any other renewable or non-renewable energy source. This energy is far more than the energy required by humans, which is around 13 terawatts. By using 0.16 percent of the Earth's territory with 10% effective solar cells, 20 Terawatts of electricity would be produced, about twice as much as the world's fossil fuel use, including multiple nuclear fission reactors [3].

A photovoltaic (PV) system transforms sunlight directly into energy. A PV system's key component is the solar panel. Solar panels or arrays are made up of groups of solar panels. A solar panel is essentially a semiconductor diode that has light exposure. Solar panels are made with a variety of semiconductors and producing techniques [4]. The power generated by a solar panel is electrical in nature and may be used at any time. It is determined by the solar cell's intrinsic properties as well as the amount of incoming solar energy [5].

Photons of varying energies make up solar energy, and some of them are absorbed at the p-n junction. Photons with lower energy than those of the solar panel band gap can't be utilised since they don't create voltage or current. Photons with energies larger than the band gap create electricity, but only the energy corresponding to the band gap is used. The rest of the energy is squandered as heat in the body of the solar cell. [6, 7]. To comprehend the electronic properties of a solar cell, an electrically analogous model must be developed.

A current source in connected in series with a diode can simulate an ideal solar cell; however, no solar panel is perfect, thus resistance to shunt and series components are incorporated into the model. A single diode PV cell prototype is employed in this research. For deriving the I-V features of PV cells, the study use the comparable circuit of the solar cell, which takes into account irradiance and temperature variation [1].

2. Comparable circuit of a solar cell

A current system is linked in parallel connection with a diode in the sole diode equivalent circuit of the PV solar cell depicted in Fig.1, as well as a serial Rs and a parallel (shunt) R_{sh} resistance. As illustrated in Fig.2, the shunt resistance R_{sh} is expected to be considerable and may be ignored. Figure 3 depicts the schematic symbol for a solar cell.

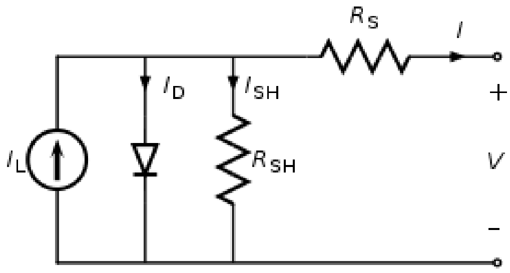

Figure 1. Comparable circuit of a solar panel.

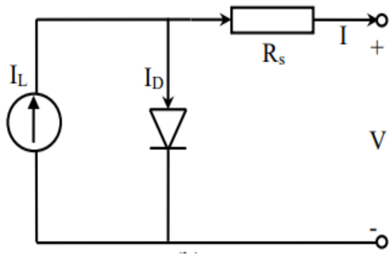

Figure 2. Comparable circuit of a solar panel with R_{sh} neglected.

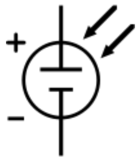

Fig. 3. Schematic symbol of solar cell.

3. Characteristic Equation

From the comparable circuit demonstrated in Fig. 1, it is evident that the current generated by the solar panel for the ideal state, R_s is very small ($R_s = 0$) and R_{sh} is very large ($R_{sh} = \infty$) [2]. Kirchhoff's current law equation is used to characterise the circuit.

$$I = I_{ph} - I_d \tag{1}$$

where,

I - Solar cell's output current,

I_d - Current of Diode,

I_{ph} – Current created by Light.

The current of diode is characterized by Shockley diode equation:

$$I_d = I_o(e^{\frac{qV}{nkT}}-1) \tag{2}$$

where,

I_o- The leakage of current density of diode in the absence of light

q - Charge of Electrons

V - Solar cell's Voltage

n - Factor of Ideality considered to be 1

k - Constant of Boltzmann

T - PV cell Temperature

The location of leakage current I_o is:

$$I_0 = I_{sc}\left(\frac{T}{T_{ref}}\right)^3 e^{\frac{qE_g\Delta T}{nk}} \tag{3}$$

$$\Delta T = \frac{1}{T_{ref}} - \frac{1}{T} \tag{4}$$

where,

I_{sc}- PV cell's short circuit current

T_{ref}- Temperature of reference (usually 25˚C)

E_g- The semiconductor's band gap energy.

$$I_{ph} = \frac{\emptyset}{\emptyset_{ref}}\left(I_{scr} + \propto_{isc}(T - T_{ref})\right) \tag{5}$$

where,

Φ - Irradiation from the Sun,

Φ_{ref} - Solar irradiation as a benchmark,

α - PV cell short circuit current temperature factor,

I_{scr} – PV cell short circuit current at benchmark temperature.

4. Implementation of the current equation model using Simulink

Figure 4 depicts the I-V characteristics of a single diode model. Figure 5 shows the photocurrent (Iph) computed by using simulink to apply equation (5). Implementing equations (3) and (4), i.e. leakage current Io and temperature change, yields the diode current (Id) given in equation (2).

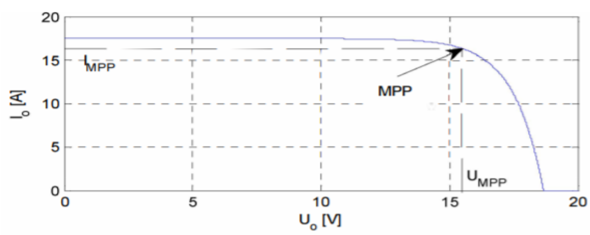

Fig. 4. I-V attributes of a single diode model for solar panel

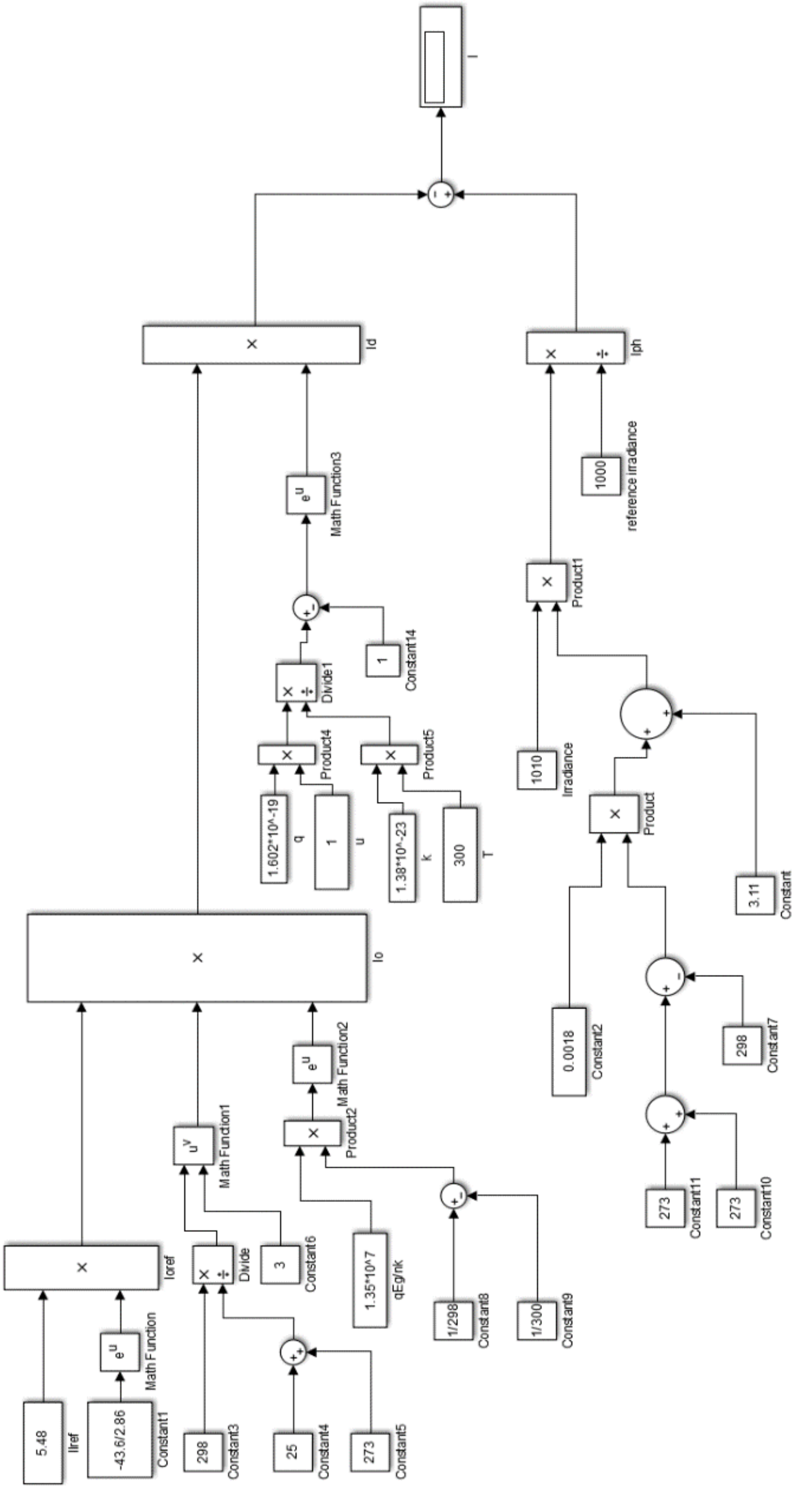

Figure 4. Simulink model for implementing the current equation of a solar cell.

5. Conclusion

Simulink is used to simulate and build a single diode solar cell in this study. Calculating parameters such as leakage current, temperature change, and diode parameters yields the I-V attributes of a single diode solar panel. However, the quantity of energy generated is dependent on a number of parameters, including solar cell type and size, sun irradiation, temperature, and climatic conditions. As a result, by considering the aforementioned criteria, the effectiveness of a solar panel may be further enhanced, and it can be utilised to build green instrumentation technology.

References

[1] Beddiaf Zaidi, Izzeddine Saouane, Chander Shekhar.: Simulation of Single-Diode Equivalent Model of Polycrystalline Silicon Solar Cells. International Journal of Materials Science and Applications. 7, 8 -10 (2018)

[2] Galad, Martin, and PavolŠpánik: Design of photovoltaic solar cell model for stand-alone renewable system. IEEE -ELEKTRO, 285-288 (2014)

[3] Balaji Padmanabhan. : Modeling of Solar Cells . Thesis (2008)

[4] SedraA S and K. C. Smith, Microelectronic Circuits. London, U.K.: Oxford Univ. Press, 2006.

[5] M.A.Eltawil, Z. Zhao.: Grid-connected photovoltaic power systems: Technical and potential problems—A review, Renewable and Sustainable Energy Reviews. 14, 112–129, (2010)

[6] Chilundo, Rosa &Mahanjane, Urânio& Neves, Diana.: Design and Performance of Photovoltaic Water Pumping Systems: Comprehensive Review towards a Renewable Strategy for Mozambique. Journal of Power and Energy Engineering. 06, 32-63, (2018)

[7] E.M.G. Rodrigues,R.Melicio1,V.M.F. Mendes and J.P.S. Catalao.: Simulation of a Solar Cell considering Single-Diode Equivalent Circuit Model. Proceedings of the International Conference on Renewable Energies and Power Quality - ICREPQ´11.1, 369-373 (2011)