PHTOVOLTAIC ENERGY GENERATION UNDER PARTIAL SHADING CONDITIONS

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Abstract- *This paper presents analyzes the behaviour of a photovoltaic device (cell or module) under partial shading conditions. It can be used as a tool to study the effects of partial shadingconditions on PV panels to optimize its operation. However, PV performance is often affected by solar insolation and shading. Often, the PV arrays get shadowed, completely or partially by the passing clouds, neighboring buildings and towers, tress, and utility or telephone poles. Yet, the shadowed arrays will result in loss in generation. This project objective is to observe or studied how much power produced by the PV under certain partial shading condition. In order to achieve that, a few method/model has been used. From all the models mention in this paper, only one is chosen that seems to be the suitable and easy to understand how it will be implemented. However, this technique still does not showed successful. Some improvement is needed to obtain the required result. As conclusion, this project objective is not achieved within the time given. The work that left undone is to come out with new program that combined the matrix and the programmed model.*

Keywords- *photovoltaic, solar, model*

I. INTRODUCTION

Solar energy is a renewable energy that comes from natural source and harnessing the energy from the sun. Solar photovoltaic technology is the most frequent technology applied using large array of solar panels to harness the sun radiation by converting the radiation from sunlight directly to electricity. The objective of this paper is to study the characteristic of a PV array under partially shading conditions. It is very important to understand them in order to have optimum operation. The electricity usage of Unnes is expected to be increase in the future. Therefore, in order to meet the demand, solar photovoltaic technology will be implemented in Unnes area

Photovoltaic (PV) arrays generate maximum power as the radiation of sun strikes to all surfaces or areas of the arrays. However, PV performance is often affected by solar insolation and shading. Often, the PV arrays get shadowed, completely or partially by the passing clouds, neighboring buildings and towers, tress, and utility or telephone poles [1]. Yet, the shadowed arrays will result in loss in generation. Due to uncertainty of partially shading condition, maximum power to be generated is difficult to estimate if no analysis model and numerical value algorithm model is applied.

By modeling a prediction model using a MATLAB, it will estimate the generated power produced by the PV arrays. It also can be a tool to study the effect of the partially shading to overcome the loss in generation and optimize its operation. Therefore, the estimated loss in generation will lead to a new development tracking techniques to extract the maximum possible power. This project will start with some literature review related to PV energy generation. Then, model a PV using MATLAB software. The data obtained will be analyzed.

II. PHOTOVOLTAIC CELLS OPERATION

Solar photovoltaic is categorized as an active solar energy technology. It uses unique properties of semiconductors to directly convert solar radiation into electricity. The conversion from solar radiation into electricity occurs by photoelectric effect. In addition, a thin slice of semiconductor called wafer is use to make the solar cells which
 are sensitive to sunlight and produce a small direct current when exposed to light. PV system can produce alternating current (AC) compatible with any conventional appliances with the appropriate power conversion equipment. It also operates in parallel with and interconnected to the utility grid.

A solar cell is the basic building block of a PV system. The cells are connected electrically in series or parallel circuits to produce higher voltages, currents and power levels. A typical PV cell produces 0.5V to 1V of electricity. The combination of PV cells that had been sealed in environmentally protective laminate called

PV modules will produce an appreciably amount of electrical power with no moving parts, noise or emissions. One or more PV modules assembled as a pre-wired, field-installable unit will become PV panels.

One important way to convert solar radiation into electricity occurs by the photovoltaic effect [2]. The photoelectric effect relies on the principle that whenever light strikes the surface of certain metals, electrons are released. A solar cell consists of two silicon panels attached together. One layer is doped with N-type dopant while the other is doped with P-type dopant. Front and back contact is installed to the two layers to allow an electrical flow of electrons. In addition, the glass is installed on top of it to protect the layers and the electrical contacts from damage.mIn the N-doped semiconductor, there is an excess electron while in P-dopedmsemiconductor there is a positively charge electron hole. The electrons one layer will find their corresponding free hole in the other layer. Consequently, an internal electrical field is produced at this transition that does not permit electrons and holes to jump into the other layer. However, if photon hits the silicon layers, electron hole pairs will be created. If this happens in the electrical field, electrons are move to the N-doped layer while holes are move to the P-doped layer. The system will falls into the state which is imbalance because of the excess electrons on the N-doped layer.

The corresponding holes can be found in the P-doped layer. It goes without saying that the free electrons and free holes is try to combine. However, the electrical field does not allow such condition. If the N-doped layer is connected to the P-doped layer using a cable, electrons are traveling to the free holes through the cable. This flowcalled an electrical current. solar cells collect the rays of the sun and convert solar radiation into direct current which is eventually converted to more useable alternating current by a piece of equipment called an inverter Another device connected to the inverter that will measure the electricity produced by the photovoltaic system. Generated electricity is sent to the grid by transformer. The transformer will step up the voltage of the generated electricity to ensure the same voltage potential with the grid.

III.   RESULT AND DISCUSSION

II.1   Modeling The Solar Cell

This model of photovoltaic cell was based on a MATLAB model from Akihiro Oi"s thesis paper [5]. A simple PV cell circuit is basically an ideal current source in parallel with an ideal diode. The current source represents the current generated by the PV cell due to the photons received by it [6]. Short-circuit current and open-circuit voltage are the parameters that often used to characterize a PV cell are. These parameters are generally provided by the manufacturer. PV cell is equivalent with the current source parallel with a diode. The output current of the PV cell can be found using the equation:

$$I = Isc - Id$$

Where:
Isc is the short-circuit current that is equal to the photon generated current
Id is the current shunted through the intrinsic diode.
The diode current is given by the Shockley"s diode equation:

$$Id = Io*(e^{\,q*Vd/(k*T)} -1)$$

Where:
"Io" is the reverse saturation current of diode (A),
"q" is the electron charge (1.602 x 10-23 C),
"Vd" is the voltage across the diode (V),
"K" is the Boltzmann"s constant (1.381 x 10-23 J/K),
"T" is the junction temperature in Kelvin (K).

Combining the diode current equation with the equation for the output current of the PV cell creates:

$$I = Isc - Io*(e^{\,q*V/(k*T)} -1)$$

Where:
"V" is the voltage across the PV cell
"I" is the output current

However, in I-V characteristic of PV cell, there are reverse biased condition. We can solve for the reverse saturation current (Io) by setting I = 0 (no output current).

$$0 = Isc - Io*(e^{\,q*V/(k*T)} -1)$$

$$Io = Isc /(e\ q*V/(k*T) -1)$$

Often, a simple PV cell model neglects to account for a few things. In order to create a more accurate model, series resistance, Rs, parallel resistance, Rp, and recombination must be factored into the equation. In an ideal cell, R s = Rp = 0, which are relatively common assumption [7]. A series resistance R s was included which represents the resistance inside each cell in the connection between cells [8]. A shunt resistance is parallel with the diode. Its effect is minimal so it will be neglected. Therefore, we can assume that Rsh = ∞. The simplified photon-generated current equation is:

$$I = Isc - Io*(e\ q*(V+I+Rs)/(k*T) -1)$$

The value of the photon generated current, Isc can be assumed to be directlymproportional to the irradiance, and the short circuit current value under standard test conditions, Go is 1000 W/m2. Therefore, the photon generated at any other irradiance, G (W/m2) equation is:

$$Isc*IG = Isc*TGo*(G/Go)$$

II.2 Simulink Diagram

A Photovoltaic cell simulink diagram is represented as shown below:
Description of Simulink Diagram of Photovoltaic Cell Based, the simulink diagram contains insolation constant block that represent the standard value of irradiance which is 1000 W/m2. We assume that the irradiance is equal to the current source and we can say it is an input, Ipv to the model. In addition, there is another input to the model which will be subtracted to the current input. It is the repeating signal of voltage, Vpv which is given by Vpv block. Within the MATLAB function block, we need to insert user define function as shown in Figure 1. The function is for P-N junction characteristic. Also the parameter of the Isc gain is set as shown in Figure 2. The product of the current, Ipv and voltage, Vpv is output power, Ppv. The output of the system which is I-V and I-V characteristics will be displayed in the X-Y PlotWindow.
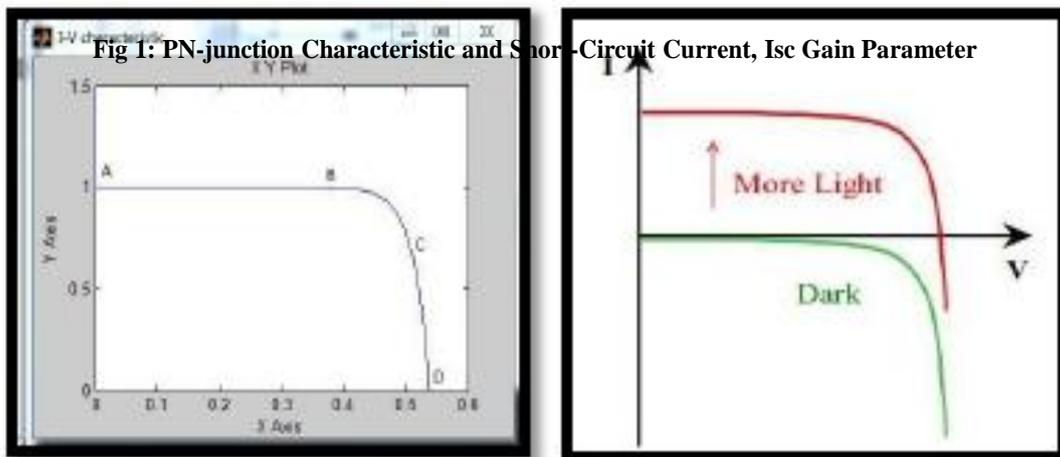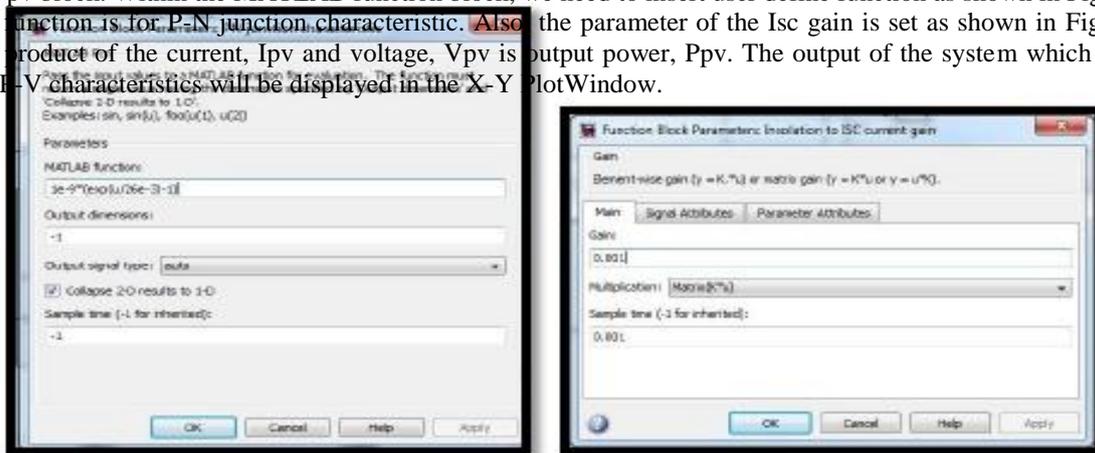

Fig 1: PN-junction Characteristic and Short-Circuit Current, Isc Gain Parameter

Fig 2: Repeating Sequence Stair and Solar Cell Parameters

The short-circuit current, Isc depends on the radiation of the moment. The higher the irradiation, the greater the current [10]. However, voltage is not much varied and maintains almost constant value even though the irradiance is increasing or decreasing. . The output current of a PV cell is depends on the external voltage applied Io A and the amount of sunlight strikes on the cell. When the cell is short- circuited, the current is at maximum (short-circuit current, Isc), and the voltage across the cell is 0 [2]. When the PV cell circuit is open, with the leads not making a circuit, the voltage is at maximum (open circuit voltage, Voc), and the current is 0 [11].

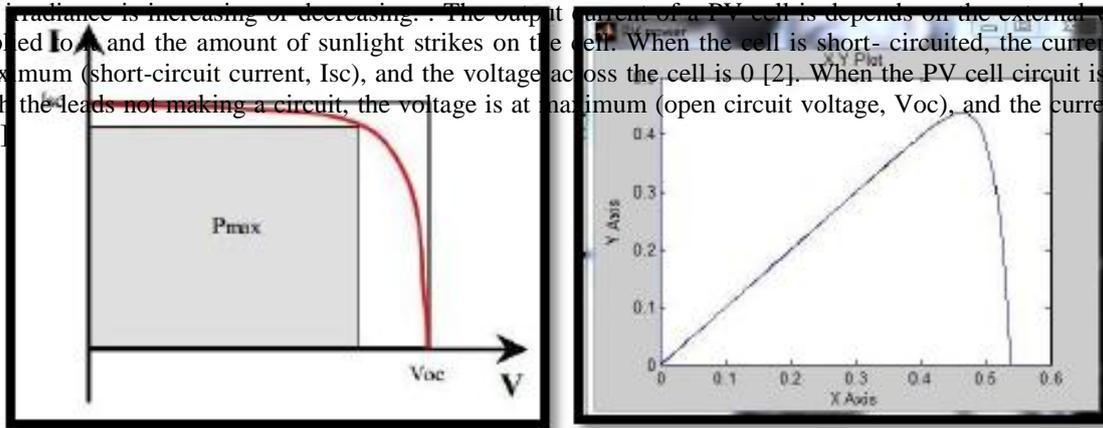**Fig 3: I-V Characteristic Curve and Progression of Solar Cell I-V Curve as the Incident Light Increases**

Figure 3 (on the left) shows the resultant of I-V characteristic curve of a solar cell at 1000 W/m2 irradiance and at a fixed cell temperature. Figure 3 (on the right) shows the I-V curve of a diode without illumination in a green colour. When forward bias potential is applied, the curve shows the turn-on and buildup the forward bias current in the diode. Without illumination, no current flows through the diode unless there is external potential applied. The IV curve shifts up when there is incident sunlight and it indicates there is also external current flow from the solar cell to a passive load.

IV. CONCLUSION

As a conclusion, the I-V and P-V characteristic curves obtained are acceptable. It is recommended to use other design method approach for shading conditions. Project is smoothly progress according to pre-planed gantt chart. It is feasible for this project to be completed in this semester.

REFERENCE

1. Hiren Patel and Vivek Agarwal, "MATLAB-Based Modeling to Study the Effects of Partial Shading on PV Array Characteristics", *IEEE Transactions on Energy Conversion,* vol.23,pp. 302, 1, 2008
2. S. Rustemli, F. Dincer, "Modeling of Photovoltaic Panel and Examinin Effects of Temperature in Matlab/Simulink", *Electronics and Electrical Engineering*, pp. 35, 3(109), 2011
3. Akihiro Oi. Doctoral thesis. Design and simulation of photovoltaic water pumping system. MathWorks Inc. *Learning Simulink Release 14* The MathWorks, 2004
4. Castaner, Luis and Santiago Silvestre *Modelling Photovoltaic Systems Using PSpice* John Wiley & Sons Ltd, 2002
5. Tyson DenHerder, "Design and Simulation of Photovoltaic Super System using Simulink," *California Polytechnic State University*, 2006.
6. J. A. Gow. C. D. Manning "Development of a photovoltaic array model for use in powerelectronics simulation studies," *IEE Proceedings on Electric Power Applications,* vol. 146, no. 2, pp. 193-200, March 1999.
7. Francisco M. González-Longatt, "Model of Photovoltaic Module in Matlab™," *2DO CONGRESO IBEROAMERICANO DE ESTUDIANTES DE INGENIERÍA ELÉCTRICA, ELECTRÓNICA Y*

COMPUTACIÓN, Ii Cibelec, 2005.

8. Ramos Hernanz, JA. , Campayo Martin, J.J., Zamora Belver, I., Larranaga Leska, J., Zulueta Guerrero, E., and Puelles Perez, E., "Modelling of Photovoltaic Module," *International Conference of Renewable Energies and Power Quality*, ICREPQ"10, March 23-25, 2010, Granda, Spain.

9. Kalogiru S. "Solar Energy Engineering: Processes and Systems." *AcademicPress*, 2009, pp. 48.

10. SolarCell Voltage – Current Characterization retrieved at April 25, 2012