Comparision Analysis of Different Solar Photovoltaic Array Connections under Partial Shading Condition

Arnaan Ronghangpi[1], Jyoti Mahanta[2], Joram Henjum[3]

[1,2,3] Department of Electrical and Electronics Engineering, School of Technology, Assam Don Bosco University
Airport Road, Azara, Guwahati-781017, Assam, INDIA.
[1]arnaanronghangpi192621@gmail.com, [2]jyotimahanta.jm@gmail.com, [3]foxtailretusa17@gmail.com*

Abstract: ***Due to its high potential in renewable energy generation work, Solar Photovoltaic (PV) systems are getting importance throughout the globe. Again, to study the PV system it is utmost important to know the modeling of the different components viz., PV cell, PV module and PV array along with its behaviour in different irradiance condition. In line with this, a detailed model is discussed in this paper, to simulate PV cell, module and Array. To construct an array, different types of connections such as Series, parallel, TCT and Bridge link connections are considered.***

Keywords: PV Array Connections; TCT; Renewable Energy; Solar Photovoltaic (PV) Systems.

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1. Introduction

Due to the growing demand of energy, conventional energy sources are depleting day by day. Further, the use of petrol, diesel, coal etc increases the environmental pollution, which is a major cause of global warming. Global warming is the rise in temperature of the Earth's Atmosphere, which leads to melting of polar ice caps and glaciers. This leads to rise in water levels endangering the coastal areas and islands. When coal, wood, and gas are burned, they release toxic gases such as Sulphur Dioxide (SO_2), Nitrogen Oxide (NO), which reacts with the oxygen and water molecules; thus, forming Sulphuric Acid and Nitric Acid leading to Acid Rain. Acid Rain causes damages to monuments, crops, other plant life and animal life. Thus, we have to come up with alternative sources of energy, to overcome such terrifying causes. So looking into this matter, people have started coming up with various sources of energy. One such source is the solar energy.
Solar energy is found in abundance everywhere.

Human beings have also learned to harvest the light of Sun as a source of energy to produce electricity. The Sun's energy is harvested using the solar PV panels. The solar PV panels are made of semi-conducting devices like Silicon (Si) which reacts to the light rays which falls on the surface of the plates and the electrons and holes react and starts moving from the positions creating a potential difference (i.e. voltage) and depending on the size of the solar plant installed.

On the occurrence of shading condition, in which the cell gets shaded by any external materials (trees, mud), hotspot is generated. Hotspot is a condition when reverse current flows resulting in the rise of temperature in the panel, which damages it. Sun is a very important source of energy that is renewable and free [1,2]. This energy is harvested using Si based PV cells. This is because, Si reacts really well with the light and highest possible output is obtained [3]. The intensity of the energy changes as the Earth rotates, so tracking it become necessary. So, the MPP (Maximum Power Point) of the PV panels are analyzed [4]. This analysis helps in the making of a device called MPPT (Maximum Power Point Tracker). This device constantly checks the MPP of the PV panel and helps in maintaining the maximum output that can be obtained from the PV panels [5]. Various configurations of PV connections were analyzed and accordingly the resulting values depended solely on the connections that the PV panel is connected in [6]. But, a lot of environmental factors like pollution causes the performance level of the PV modules to go down [7]. Dust also causes the PV modules to give less output than it can generate [8]. The temperature in which the PV panel is kept also affects the output of the PV module [9] [10].

Here, the hotspot formation is given high focus and its effect is analyzed and a connection

that is least affected by the hotspot formation is established.

2. Modelling of Photovoltaic (PV) Array

2.1 PV Cell

A PV cell is an electrical device. It is made of semiconducting materials that react with the light that falls on it. Thus, creating a potential gradient due to flow of electrons directly results in production of electricity. In other words, it is defined as a device whose electrical characteristics like current, voltage and resistance, vary when exposed to light.

Solar cell are described as photovoltaic, irrespective of whether the source is sunlight or artificial light, they are used as photo detectors.

The PV cell works on three basic criteria:

- The absorption of photons generates electron-hole pairs.
- The separation of charge carriers.
- The separated charges are extracted to an external circuit.

A Silicon PV cell can generate a maximum open-circuit voltage of approximately 0.5-0.6 volts.

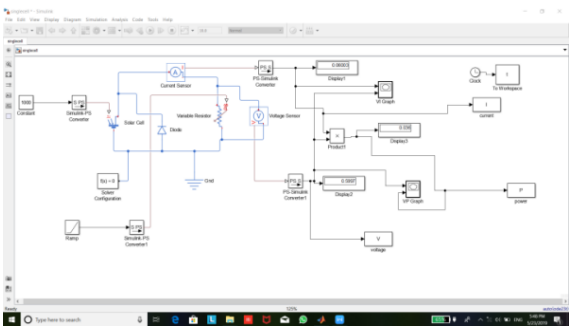

Figure 1: Equivalent circuit diagram of PV cell

In Fig. 1, the following formula is derived:

$$I_l = I_p - I_d - I_{sh} \quad \text{.....(1)}$$

Here, I_l = Output current
I_p = Photo current
I_d = Diode current
I_{sh} = Shunt current

$$I_l = I_p - I_o\left[1 - e \wedge \left(\frac{V + IR_s}{\eta V_t}\right)\right] - \frac{V + IR_s}{R_{sh}} \quad \text{.....(2)}$$

$$I_d = I_0\left[1 - e \wedge \left(\frac{V + IR_s}{\eta V_t}\right)\right] \quad \text{..... (3)}$$

I_0 = Reverse Saturated Current
V_t = Thermal junction Voltage
η = Diode coefficient

$$I_{sh} = \frac{V + IR_s}{R_{sh}}$$

R_{sh} = Shunt Resistance

2.2 PV Module

It is a package, connected assembly of solar cells. In other words, it is a group of cell connected together.

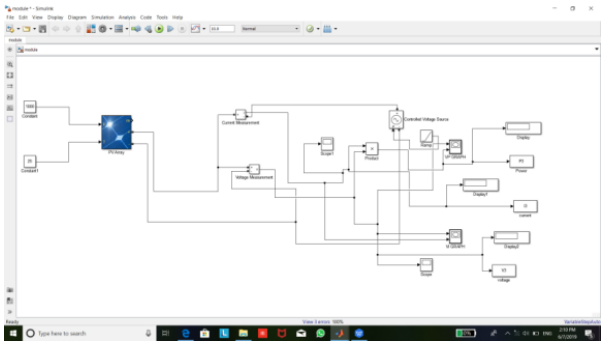

Figure 2: A PV Module

There are three types of PV module:

(i) Silicon Solar Panel
(ii) Thin Film Solar Panel
(iii) Crystalline Solar Panel
- Monocrystalline
- Polycrystalline

2.3 PV Array

The combination of two or more PV Module or collection of linked solar modules is termed as PV array. There are different types of connection in a PV array. They are as follows:

- **Series-Parallel connection**

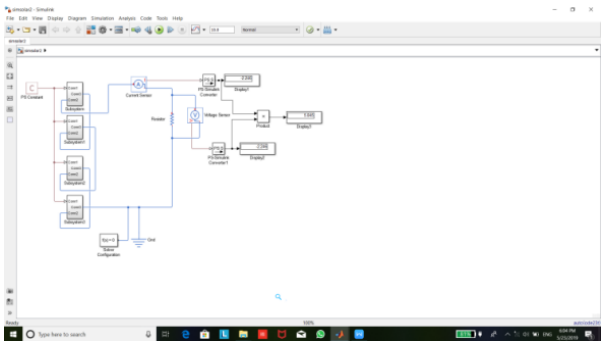

Figure 3: Circuit Diagram of Series-parallel connection

- **Parallel connection**

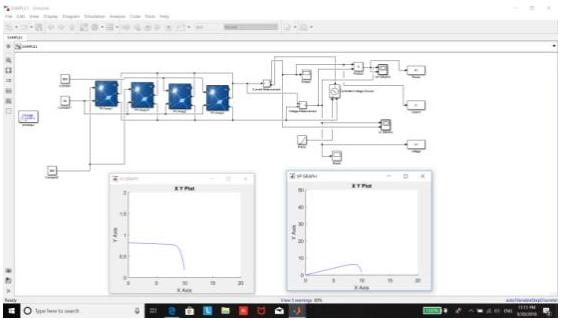

Figure 4: Circuit diagram of parallel Connection

- **Total Cross Tied (TCT) connection**

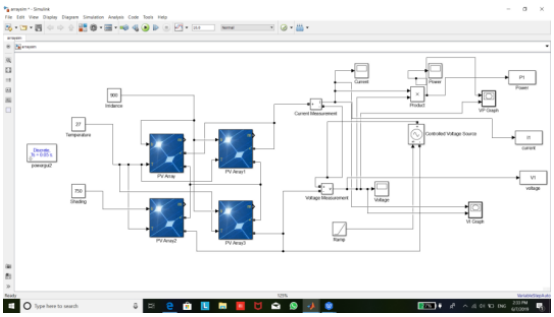

Figure 5: Circuit Diagram of TCT Connection

- **Bridge linked connection**

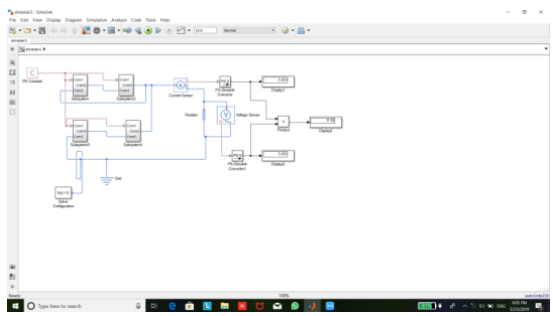

Figure 6: Circuit Diagram of Bridge Linked Connection

3. Results and Discussion

In this paper, we studied the characteristic of a single solar cell and found the equivalent circuit. Through the MATLAB SIMULINK simulation, we formulated the formulae for the total output current, which varies according to the input photo current.

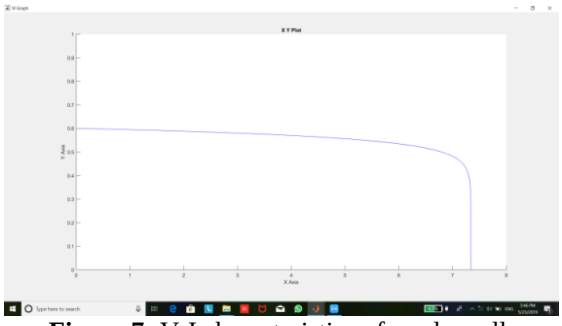

Figure 7: V-I characteristics of a solar cell

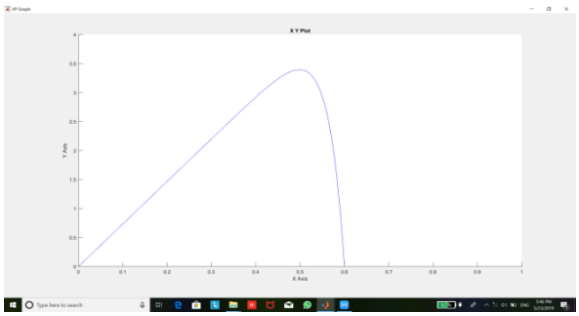

Figure 8: V-P characteristics of a solar cell

From the simulation through MATLAB, the study made so far for the different connection of PV array give the following characteristics:

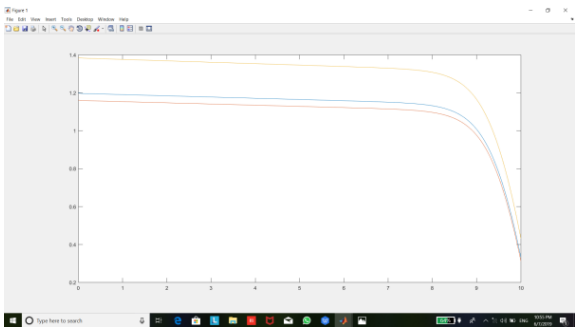

Figure 9: V-I comparison between the different values obtained during different conditions of Series Parallel connection

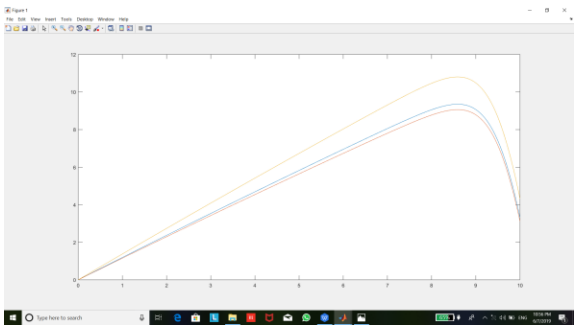

Figure 10: V-P comparison between the different values obtained during different conditions of Series Parallel connection

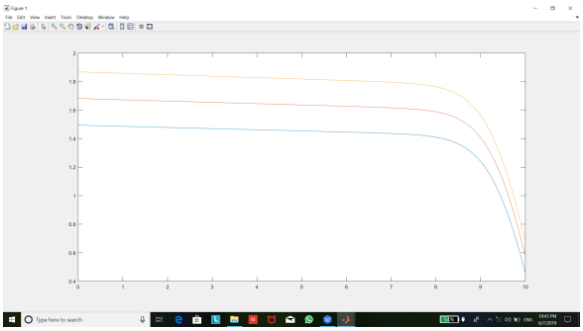

Figure 11: V-I comparison between the different values obtained during different conditions of TCT connection

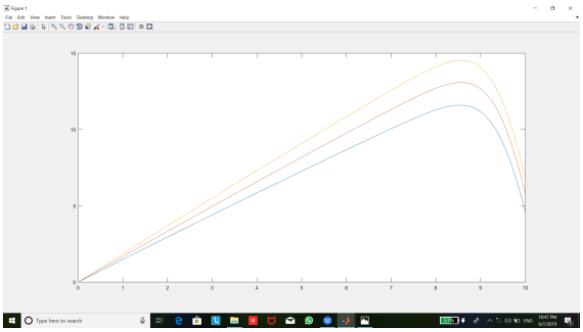

Figure 12: V-P comparison between the different values obtained during different conditions of TCT connection

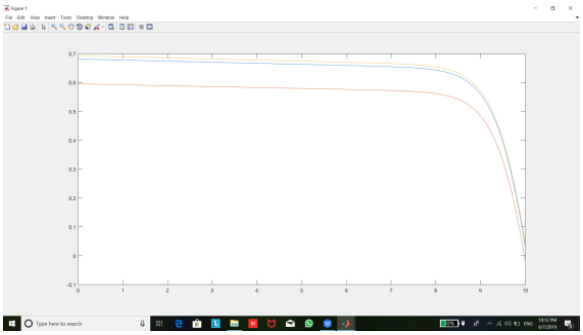

Figure 13: V-I comparison between the different values obtained during different conditions of Honeycomb connection

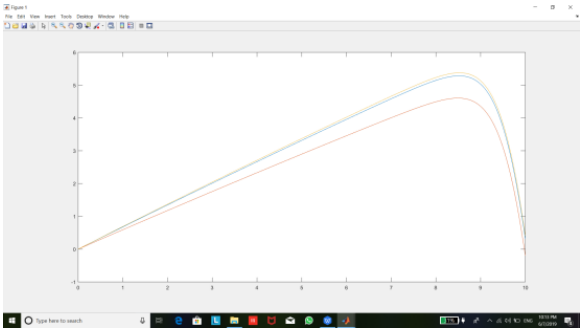

Figure 14: V-P comparison between the different values obtained during different conditions of Honeycomb connection

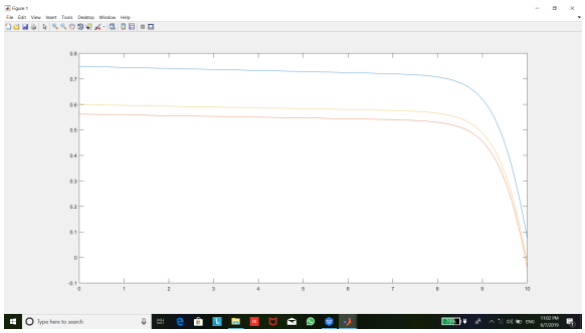

Figure 15: V-I comparison between the different values obtained during different conditions of Bridge linked connection

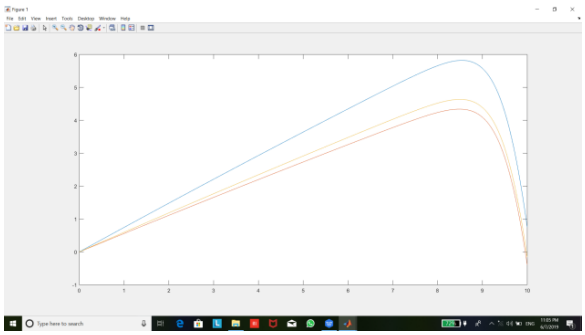

Figure 16: V-P comparison between the different values obtained during different conditions of Bridge linked connection

4. Conclusion

According to the research on Analysis of the problems occurring due to Partial Shading of Solar Photovoltaic Array and its probable solutions, we concluded that problems occurring on the PV panel primarily due to shading condition and hotspot generation on a cell can be overcome by using protection diode and bypass diode. The diodes provide an alternative path for continuous flow of current without affecting the other panels.

The factors affecting the output of an array can be minimized by finding the best connection, which will have high efficiency and high output power. By analyzing the simulation of various connections and studying their V-I and V-P characteristics, it was found that the TCT is the best among the PV array connections under consideration .

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Authors' Profiles

Arnaan Ronghangpi is pursuing B.Tech. degree in Electrical and Electronics Engineering, Assam Don Bosco University (India).)

Joram Henjum is pursuing B.Tech. degree in Electrical and Electronics Engineering, Assam Don Bosco University (India).

Jyoti Mahanta is pursuing B.Tech. degree in Electrical and Electronics Engineering, Assam Don Bosco University (India).