

MATLAB based Mathematical Modeling of Solar PV Panel and Real Time Monitoring by LabVIEW and NI Hardware

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Abstract: *In this paper the mathematical modeling of the solar PV panel using MATLAB and a real time monitoring has been done using LabVIEW has been proposed. Mathematical modeling results are drawn for constant solar irradiation with variable temperature and vice versa. The analyzed result shows that the efficiency of the solar PV panel has diminished due to the higher operating temperature of the solar PV panel and deviation is to be analyzed through the mathematical model using MATLAB. The LabVIEW based monitoring involves NI hardware such as cDAQ-9178; DAQ-9225 and DAQ-9227. The output is drawn at high range of accuracy. The NI hardware is interfaced with the laptop using graphical programming through which the range of signal is configured. The solar PV panel output is connected to a DC fan as load associated with the monitoring NI hardware and a laptop. The real time output is to be monitored in the laptop in the form of graph. The expected experimental output may results in the decrease of output current and voltage due to the increase in the temperature of the solar PV panel. On comparing the modeling and experimental results, real time efficiency may lower than the simulation efficiency.*

Keywords — Solar Irradiation, Temperature, LabVIEW, NI hardware, Graphical Programming, Mathematical modeling, MATLAB.

1. INTRODUCTION

Solar energy is one of the promising sustainable energy in this scenario. The power generations using non-renewable energy sources will become extinct after 2040. Apart from the fundamental limitations of fossil fuel, ecological considerations linked with the production of the greenhouse gases and global warming are other driving forces in promoting renewable energy sources. The obvious choice is a clean energy source, which is abundant and could provide security for the future development and growth is the sun's energy. Solar power generation plays an important role in renewable energy based power generation. In fact, the demand for solar energy has increased by 20% to 25% over the past 20 years [1]. To get benefit from the application of PV systems, research activities are being conducted to gain further

improvement in their cost, efficiency and reliability. The electrical performance is primarily influenced by the type of PV used. A typical PV module converts 6-20% of the incident solar radiation into electricity, depending upon the type of solar cells and climatic conditions. The rest of the incident solar radiation is converted into heat, which significantly increases the temperature of the PV module and reduces the PV efficiency of the module [7].

Mathematical modeling of PV module holds good for being continuously updated to enable researcher to have a better understanding of its working and output variations [1]-[3]. Modeling provides the ways to understand the current, voltage, and power relationships of PV modules [6]. The output of the solar PV panel is monitored using LabVIEW associated with NI hardware. This provides high range of accuracy such that it can display one data per Nano seconds.

In this paper, the performance of the solar PV panel is analyzed by mathematical model of a solar photovoltaic cell using MATLAB. The model can be used to extract the physical parameters for a given solar PV cell with respect to the temperature and solar irradiation. The output is to be monitored with high accuracy using LabVIEW software with NI hardware such as cDAQ-9178, DAQ-9225, DAQ-9227.

2. MATHEMATICAL MODELING OF SOLAR PV PANEL

Mathematical model of the solar PV panel can be used to analyze the performance and the characteristics of the solar PV panel. It is done for the better understanding of the performance of the solar cell. It is basically a p-n junction fabricated in a thin wafer of semiconductor. The electromagnetic radiation of solar energy can be directly converted to electricity through photovoltaic effect [4].

2.1. Equivalent Circuit

The mathematical model can be built using the equations derived from the equivalent circuit shown in figure 1. Equivalent electrical circuit model is one of the key models under study since the last few decades. It is configured with either single or double diode for

investigation of current voltage relationships. In this paper, single diode equivalent circuit is used for deriving the output current and voltage equations.

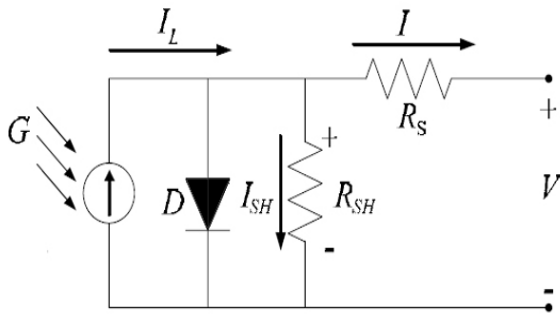


Figure 1 Equivalent Circuit of a Solar Cell

The photovoltaic panel can be modeled mathematically as given in equations [2]. The output current of PV module is

$$I_{pv} = N_p * I_{lg} - N_p * I \left[\exp \left\{ \frac{q * (V_{pv} + I_{pv} R_s)}{N_s A k T} \right\} - 1 \right] \quad (1)$$

Where $V_{pv} = V_{oc}$, $N_p = 1$ and $N_s = 36$

The output voltage equation is given by,

$$V_{pv} = \frac{kT}{q} \ln \left[\frac{I_{lg}}{I_{rs}} + 1 \right] \quad (2)$$

The output power P is given by,

$$P = I_{pv} * V_{pv} \quad (3)$$

In this equation, I_{lg} is the photocurrent, I_{rs} is the reverse saturation current of the diode, q is the electron charge, V_{pv} is the voltage across the diode, K is the Boltzmann's constant, T is the operating temperature, N is the ideality factor of the diode, and R_s, R_{sh} are the series and shunt resistors of the cell, respectively. As a result, the complete physical behaviour of the PV cell is in relation with I_{lg}, I_o, R_s and R_{sh} from one hand and with two environmental parameters as the temperature and the solar radiation from the other hand.

2.2. Final Model

The equations 1-3 are modeled using MATLAB and the substituted as per the equation and then the output power is obtained. The final model obtained is shown in figure 2. The solar irradiation and temperature is given as the inputs which are varying inputs. In modeling, the solar irradiation varies from 600 W/m² to 1000 W/m² and the operating temperature varies from 30°C to 70°C. These ranges are chosen according to the weather conditions

averagely. The auxiliary parameters are modeled a subsystems.

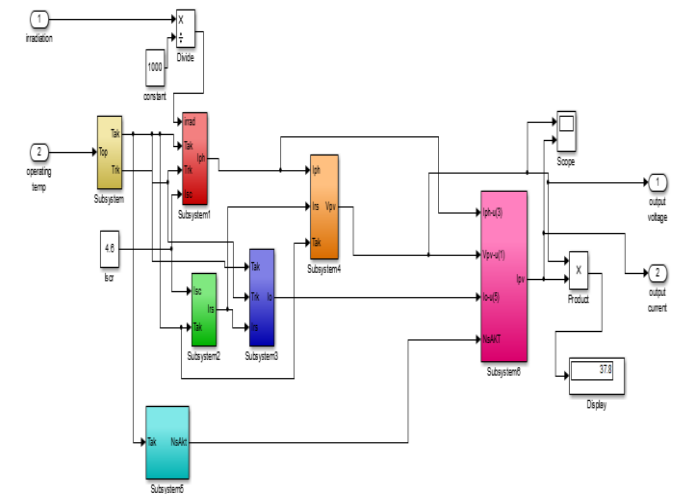


Figure 2 Final Model of a solar PV Panel

2.3 Output Power

The output of the mathematical model of solar PV panel is analyzed with variable temperature and solar irradiation.

Table 1 Output for Constant Solar Irradiation Variable Temperature
Solar Irradiation $\lambda = 1000 \text{ w/m}^2$

S.NO	Temperatur e (°C)	Current (A)	Voltage (V)	Power (W)
1	40	4.398	12.19	53.57
2	45	4.248	12.19	51.8
3	50	4.013	12.2	48.94
4	55	3.647	12.2	44.49
5	60	3.098	12.2	37.8
6	65	2.303	12.2	28.11
7	70	1.2	12.2	14.64

The table 1 shows that the output current decreases drastically and the voltage slightly decreases with respect to the increase in temperature. The output voltage and output current have maximum value when the solar irradiation has maximum and the temperature has minimum values. In this table voltage is almost same value but the current has changed according to the temperature. Up to 50°C current has minimum changes, but above 50°C the current value decrease progressively.

When the temperature is constant and the solar irradiation changes, output current and the voltage changes to a fast response is shown in the table 2. With constant temperature and varying solar irradiation, the output voltage and current are given in the table below. The output power is optimum for higher range of solar irradiation at lower temperature.

Table 2 Outputs with Constant Temperature Variable Solar Irradiation

Temperature = 36°C

S.NO	Solar Irradiation w/m^2	Current (A)	Voltage (V)	Power (W)
1	1000	4.466	12.19	54.45
2	900	4.018	12.09	48.58
3	800	3.57	11.98	42.76
4	700	3.121	11.85	36.99
5	600	2.673	11.7	31.27
6	500	2.224	11.53	25.63

An analysis is made with output values obtained which shows that when the solar irradiation is higher, the power generation also higher (i.e., high photocurrent is generated) up to a particular temperature. In cloudy days or any shading occurs the photo current generation is reduced drastically and power output also reduced.

2.4 Model Output

The simulation result is shown in the figure 3. It illustrates the variation of the output power when the solar irradiation and temperature changes. The output changes as per the input changes randomly. X and Y-axes denote the time in seconds and power respectively.



Figure 3 DC output power waveform of Solar PV Panel

3. MONITORING USING LABVIEW

LabVIEW (Laboratory Virtual Instrument Engineering Workbench), registered trademark of National Instrument Inc. (NI), is instrumentation and analysis software for PCs running. It is programming environment

including all of the tools necessary for instrument control, data acquiring, storage, analysis, presentation and integrating all of these features in one system. It uses graphical programming and a graphical language, called G. The main goal of LabVIEW is creation of the virtual instruments. The output from the solar PV panel is being monitored using LabVIEW software associated with NI hardware such as NI Compact DAQ -9178, NI DAQ-9225, NI DAQ- 9227. Using graphical programming and NI hardware, the analog output is monitored in the laptop in the form of graph.

3.1 Block Diagram

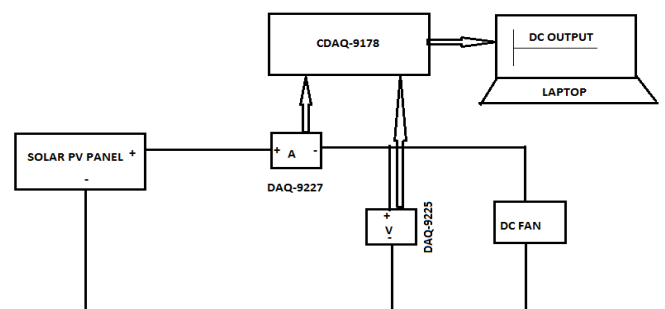


Figure 4 Block Diagram for Hardware Setup

The solar PV panel of 74 W is mounted at 45° inclined from the terrace in the North-South direction so that the solar irradiation incidents on the PV panel till the sun set. The positive terminal of the panel is connected to the positive of the current device NI DAQ-9227. Then the negative terminal is connected to the positive terminal of the DC fan (2A, 16V) and the negative terminal of the DC fan is connected to the negative of the solar PV panel. Then the voltage device NI DAQ-9225 is connected across the DC fan. Now the NI DAQ 9227 and NI DAQ -9225 is fixed in the cDAQ-9178. Power supply is given to the cDAQ-9178 and connected to the labVIEW installed laptop using USB cable as shown in figure 4. Using the Graphical programming, the NI hardware devices are configured and range, frequency and number of samples are given so that the real time output is displayed in the form of graph. Finally the output is exported to the MS-Excel for analysis. Thus the experimental setup has shown in figure.

3.2 Real Time Graph Using LabVIEW

There is a reduction in the current and voltage value because of the increase in temperature of the solar PV cells. For voltage y axis is voltage in volt and x axis is time in minutes is shown in figure 5. For current y axis is current in ampere and x axis is time in minutes is shown in figure 6.

The Graphical programming is designed to obtain the output voltage and output current. The output data is saved according to one data per minute. The monitoring

has done for three hours and data in the above table is the averaged data for every 30 minutes.

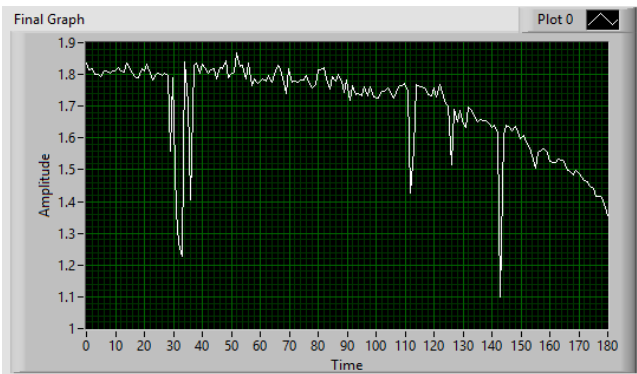


Figure 5 Real Time Current Graph

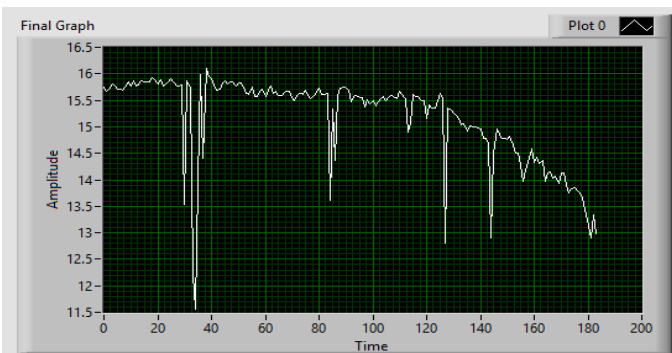


Figure 6 Real Time Voltage Graph

Using labVIEW program, the data can be logged in the sample of 1000 data per second but for convenience; the data are averaged for each 30 minutes.

4. Conclusion

Comparing the output voltage and current of the model and the experimental setup, the real time data is lower than the model value because of the increase in the temperature of the solar PV cells and variation in the climatic factors such as solar irradiation. It is necessary to reduce the operating temperature of the solar PV cells to improve the performance of the solar PV panel. In this paper, an analysis has done with the performance of the real time and model output of the conventional solar PV panel and the parameter which is responsible for the lower efficiency of the PV panel is determined and analyzed.

5. REFERENCES

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