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Research Paper

Performance study of MATLAB modelled PV panel and conventional PV panel interfaced with LabVIEW

Jaiganesh K[1*], Karuppiah N[2], Ravivarman S[3], Md Asif[4]

[1,2,3,4]Department of Electrical and Electronics Engineering, Vardhaman College of Engineering, Kacharam, Shamshabad, Hyderabad,
**Corresponding author E-mail: jaiganesh@vardhaman.org*

Abstract

The maximum electrical energy conversion efficiency of the Solar PV panel is up to 22% in normal conventional roof- top system under the temperature of 25˚C on Standard Test Condition (STC). In Indian climatic conditions, the atmospheric temperature is mostly above 35˚C to 45˚C, it incites 35˚C to 80˚C temperature on the PV panel. The black body of the PV panel absorbs more heat. This temperature affects the electrical efficiency of the panel significantly. This paper proposes the mathematical modelling of the solar PV panel for different solar irradiation and the temperature. The experimental evaluation is conducted in the latitude of 11.36 (N) and longitude 77.82 (E). The testing and monitoring was done with LabVIEW based National Instruments hardware such as NI cDAQ-9178, NI DAQ - 9227 and NI DAQ 9225. The comparative study between the simulated result and real time hardware results are discussed in this paper. The test result shows that the output of the proposed model mismatches with the experimental output of the solar PV panel due to the negative correlation between the efficiency and temperature for variable irradiation condition. It shows a power difference of 9.41W between the output of the proposed model and the experimental setup.

Keywords: *Solar Photovoltaic Panel, Irradiation and Temperature effect, Electrical Efficiency, Lab VIEW, NI Hardware.*

1. Introduction

The power generation with non-renewable energy sources are not sufficient to satisfy the power requirement. Moreover these non-renewable energy sources are responsible for the increase in global warming. The obvious alternative clean energy source which is plentiful and could provide security for the forthcoming growth and development is the solar energy. Solar power generation plays a significant role in renewable energy based power generation. In fact, the demand for solar energy has improved by 20% to 25% over the past 20 years. Due to the benefit and different applications of PV systems all the ongoing research are being carried out towards the improvement in the efficiency, cost and reliability of the system.

Mathematical modeling of PV system is very much appropriate for analyzing the continuous input variation. It empowers the researchers to have an excellent understanding of its working and output variations [1-3]. The real time monitoring of the solar PV output can be done accurately using LabVIEW software and NI hardware [4]. It gives more than 1000 real time output data per second. The panel with sun arc anti reflective coating improves the performance from 3% to 6% [5]. The temperature is reduced to 12% with the help of heat spreaders in association with cotton wicks [6]. The PV/T cooling methods are used for improving the efficiency [7-9]. The G2GPVT and G2T efficiencies are compared and it is found that G2GPVT efficiency is 1.12 % higher than G2T efficiency [10-12]. The cost reduction of Glass/Back sheet modules over G/G is 3.3% [13-14]. Performance of glazed/unglazed photovoltaic–thermoelectric panels is also studied [15-16].

Sahbel Anwar, et al discussed about the application of DAQ system for controlling the gate-source voltage of MOSFET. The characteristic of PV modules were analyzed with higher tracing frequency with low cost [17]. Chouder Aissa, et al has discussed the dynamic behavior of PV systems. The software reduces the number of instruments into single system [18]. Huang, Wei-Tzer, et al. introduced the LabVIEW model of Photovoltaic cell. This model measures all the important parameters of PV cell. This technique is also being used for monitoring purpose [19]. Ramaprabha and Badrilal Mathur studied about the solar photovoltaic array under different types of partial shaded atmospheric conditions using MATLAB model [20].

Atia Yousry, Mohamed Zahran and Abdullah Al-Hossain discussed about the data acquisition system with LabVIEW model for solar cell [21]. Aristizabal AJ. et al designed a portable equipment for data acquisition from solar power plant. The one year data study of the plant gave a very reliable value compared with commercial equipment [22].Nema Savita RK and Gayatri Agnihotri have explained the behaviour of solar cell, module and array using matlab / Simulink [23]. Mahmoud, IM. et al described the pulse width modulator developed by LabVIEW for 150W PV modules [24]. Das Pratima has discussed about the problems in photovoltaic power plant when connected with power grids [25].Ndiaye Ababacar et al. has discussed about the degradation of photovoltaic module in different environment conditions [26]. In [27] they discussed about the feasibility of grid connected PV systems installed in rooftops [27]. LabVIEW based data acquisition using graphical user interface of solar PV cell was discussed which is used for measuring and monitoring of cell characteristics [28]. Verma Deepak et al discussed about the partial shading of PV under uniform irradiation to obtain MPPT [29].The review given by Kumar Dash, Soubhagya was to obtain MPPT under uniform and non-uniform solar irradiation effect [30].

The objective of this paper is to analyze the performance of the PV panel by mathematical model using MATLAB. This model is used to calculate the PV cell power for variable temperature and irradiation. In order to validate the developed model, an experimental setup was built and the attained results are monitored using LABVIEW. Finally the experimental output and the model outputs are analyzed. The DC output obtained from the mathematical model is compared with conventional PV panel. Due to the negative temperature coefficient, the conventional panel output is less than the mathematical model. The method proposed in this study provide low-cost results to offer fast, safe and consistent system by making the system database ready for performance analysis of PV systems.

2. Mathematical modelling

Mathematical model of the solar PV panel is used to estimate the performance and the characteristics of the solar PV panel. The performance of the solar cell under different temperature and irradiation is studied. A solar cell is basically a p-n junction made-up of thin wafer of semiconductor material. The radiation from the solar energy is directly transformed to electrical energy by means of photovoltaic effect. When the solar cell is exposed into the sunlight and when the photons have energy more than the band-gap energy of the semiconductor, it builds electron-hole pairs proportional to the actual solar irradiation. The mathematical model that is built using the equations derived from the equivalent circuit is shown in Figure 1.

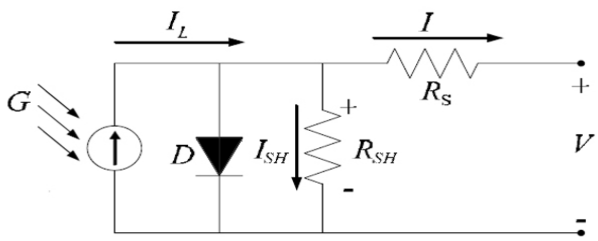

Fig. 1: Equivalent Circuit of PV Cell

From the equivalent circuit, the parameters are derived in terms of equations and thus the output current, output voltages are obtained. The solar PV panel is exhibited mathematically as per the equations given below.

Module photo-current $I_{\lg}$

$$I_{\lg} = [I_{scr} + K_i(T-298)] * \lambda / 1000 \qquad (1)$$

Modules reverse saturation current - I_{rs}

$$I_{rs} = I_{scr} / [\exp(qV_{oc} / N_s kAT) - 1] \qquad (2)$$

Module Saturation Current I_0

It varies with the cell temperature, which is given by

$$I_0 = I_{rs}[\frac{T}{T_r}]^3 \exp[\frac{q * E_{g0}}{Bk}\left\{\frac{1}{T_r} - \frac{1}{T}\right\}] \qquad (3)$$

The output current of PV module is

$$I_{pv} = N_p * I_{ph} - N_p * I[\exp\left\{\frac{q*(V_{pv} + I_{pv}R_s)}{N_s AkT}\right\} - 1] \qquad (4)$$

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

The output voltage equation is given by,

$$Vpv = \frac{KT}{q}\ln[\frac{Iph}{Irs} + 1] \qquad (5)$$

The output power P is given by,

$$P = I_{pv} * V_{pv} \qquad (6)$$

The above equations are modelled using MATLAB and then the output voltage, output current and output power are obtained. The final model obtained is shown in Figure 2. The output power of PV panel is shown in Figure 3.

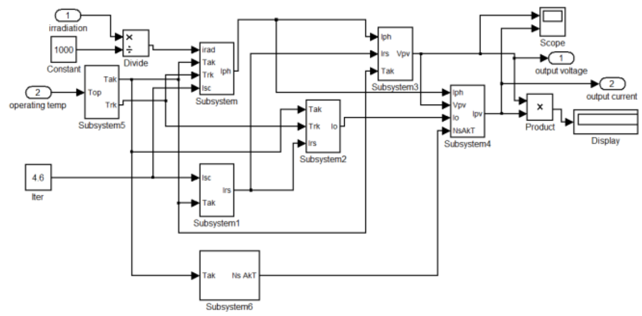

Fig. 2: MATLAB Model for PV panel

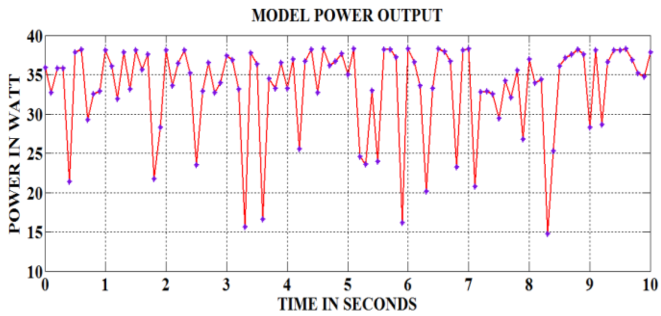

Fig. 3: Output Power of PV panel for Different Timing

Table 1. Output Power in Watts with Variable Temperature and Solar Irradiance

Irradiation in W/m^2	Temperature in ˚C					
	60	62	64	66	68	70
750	26.84	24.08	20.89	17.21	12.99	8.196
800	29.01	26.11	22.75	18.88	14.4	9.444
850	31.19	28.15	24.63	20.58	15.96	10.72
900	33.39	30.20	26.51	22.29	17.47	12.01
950	35.59	32.26	28.41	24.01	18.99	13.32
1000	37.8	34.32	30.32	25.74	20.53	14.64

The power variation occurs due to the variation of current and voltage. The current and voltage depends on the irradiation and temperature. The maximum power 37.8W was obtained when solar irradiation and temperature are at 1000 W/m^2 and 60˚Crespectively. The power produced by the PV panel is gradually decreased according to temperature and irradiation. It is clearly shown that the temperature has a negative correlation with efficiency. The power produced by the PV panel at different temperatures and irradiation are tabulated in Table1. The minimum power 8.196W is produced at a minimum irradiation of 750W/m^2 and at a maximum temperature of 70°C.

3. Experimental setup

The solar PV panel is to be tested experimentally and monitored using LabVIEW. The experimental setup is arranged with the following components such as 74W solar PV panel (Glass to Tedlar), DC Fan (2A, 16V), PC/Laptop with LABVIEW software, NI CDAQ-9178, NI DAQ-9227, NI DAQ-9225, Adaptor with USB Cable, Power cable. The 74 W solar PV panel is mounted on rooftop at 45˚ inclined. The solar irradiation falls over the PV panel till the sun set. The positive terminals of the PV panel is connected with the + ve of the current device NI DAQ-9227. Then the negative (–ve) 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 terminal 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 is connected to the LabVIEW installed in the laptop using USB cable. Using the Graphical programming device, the NI hardware devices are configured and its range, frequency, number of samples is given so that the real time output is displayed in the form of graph.

4. National Instruments Hardware

The following description gives the details of NI hardware's kit used for monitoring the PV panel current and voltage. The DAQ's are connected with CDAQ and then all the data are send to the PC and stored in it.

4.1. CDAQ-9178

NI Compact DAQ USB chassis provides the plug-and-play simplicity for USB to sense and measure the electrical parameters on the top of the single bench. It is more suitable for collecting the data from the work field and on the production lines by connecting more than 60 sensors. Specifically, NI C Series Input/output modules with patented NI Signal streaming technology, delivers high-speed data transfer and ease of flexibility with different measuring systems. Different types of Modules exist with sensor measurements includes thermocouples, RTDs, Pressure transducers, accelerometers, strain gauges, torque cells, microphones and flow meters.
The most important benefit of USB connecter with other PC peripheral buses is simpler to identify the device. While connecting any Windows PC with the NI-DAQ mix with NI Compact DAQ USB chassis additional configuration is not needed and it automatically detects the above. For the purpose of simple data logging applications the device is ready to operate with the LabVIEW single express software.

4.2. DAQ- 9227 & DAQ- 9225

The NI 9227 C series is used to measure the current range of 5A rms normal to 14A peak value with the isolated channels. When it is used with NI 9225, NI 9242 or NI 9244 (high voltage modules) NI 9227 current module is able to measure the energy consumption and power for the applications such as electronic device testing. The NI 9225 C series is an analog input module. The maximum measurement range of this module is 300 Vrms. Also it is used for the measurement of high-voltage applications such as power quality monitoring, power metering, motor test, battery stack testing and fuel cell test.

5. Results and Discussion

The real time output voltage and output current monitored using LabVIEW software and NI hardware. The current value decreases due to increase in temperature of the solar PV cells and the variation in the solar irradiation. The Table 2 portrays the real time output current and voltage observed for three hours from 12.30 pm to 3.30 pm.

Table 2: Real Time Output Current and Voltage for Three Hours

TIME	Current in Amp	Voltage in volt	Power in watts
12:30 to 1:00 PM	1.79	15.77	28.39
1:00 to 1:30 PM	1.74	15.69	27.36
1:30 to 2:00PM	1.78	15.76	28.13
2:00 to 2:30 PM	1.73	15.69	27.17
2:30 to 3:00 PM	1.64	15.76	25.91
3:00 to 3:30 PM	1.51	15.70	23.76

5.1. Real Time Graph using LabVIEW

The Figure 4 shows the Voltage Vs Time monitored in real time with LabVIEW. In this graph y-axis refers the voltage and x-axis refers time in minutes. The decrease in the voltage graph shows the voltage drop due to change in irradiance on the particular time. The Figure 5 shows the Current Vs Time monitored in real time with LabVIEW. In this graph y-axis refers the Current and x-axis refers time in minutes. The decrease in the current graph shows the reduction in current due to change in irradiance on the particular time.

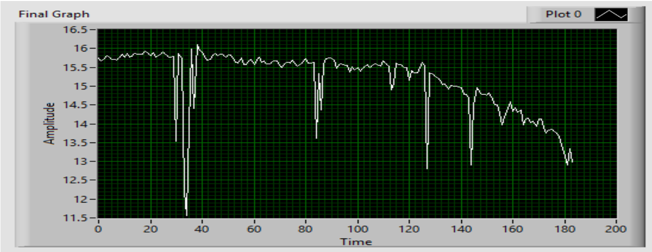

Fig. 4: Real Time Voltage Graph

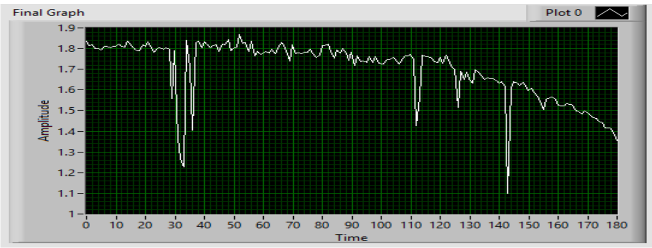

Fig. 5: Real Time Current Graph

6. Conclusion

The output current and voltage of the MATLAB model and the total output power is calculated. The effect of temperature and irradiation are found from the power output. At maximum temperature (70°C) with minimum irradiation (750W/m^2), the power generation is very less that is 8.196W only. At the minimum temperature (60°C) with maximum irradiation (1000W/m^2) the power generation is 37.8W. This result shows clearly the effect of temperature and irradiation on the PV panel. The real time data taken from LabVIEW interfaced system is 28.39W maximum is lower than the MATLAB 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

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