Performance Study of LabVIEW Modelled PV Panel and its Hardware Implementation

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Abstract Decarbonizing the vitality area and diminishing carbon discharges to confine environmental change are the primary worries of 21st century. Renewable energy and efficiency interventions, supported by rapid electrification, will provide more than 90% of the reducing CO_2 emissions planned by 2050. The transition of energy will also raise gross domestic product by 2.5% and overall jobs by 0.2% worldwide by 2050. Conventional Poly crystalline roof top solar PV has an efficiency of 22.7%. Tropic of cancer passes through eight states of India, The temperature in summers varies from 40°C to 50°C which results in decrease in efficiency of solar panel. So we require efficient MPPT controllers to overcome this gap. In Ghaziabad, the experimental test is performed with latitude of 28, 6692 (N) and longitude 77, 4538 (E). Solar PV simulator is designed using LabVIEW software. Effect of variations of temperature, irradiations, series resistance and shunt resistance on solar panel has been studied. Simulated results are tested using experimental setup with help of arduino interfaced LabVIEW.

Keywords Solar Simulator · MPPT · LabVIEW · Arduino

1 Introduction

Non renewable electricity supply is not adequate to meet current and future power requirements. The Global Off-Grid Lighting Association (GOGLA) has

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identified 7.6 million off-grid solar products that were sold in 2018 with a capacity of 59 MW. Growing concerns on air pollution and global warming, the clean renewable source of electricity has been expected to play important role ore big function within the global strength of future. If we have to gain the motive 24x7 electricity to every citizen within the country, the pleasant answer for the medium term seems to be solar power. Geographically, India has ideal characteristics for solar energy. Solar radiation provides most promising and everlasting gist of sources which we have tapping its better output using artificial intelligence may have best possible output from it. With the increase in adoption of LEDs, low voltage electronics and efficient DC motor technology, houses energy need to be fulfilled by using DC directly from solar panels. This can reduce energy consumption by over 50%. Solar energy is the obvious alternative renewable energy source for the future growth and development. MPPT technique has been used to get maximum power output from PV system by matching the load resistance and achieves maximum electricity [1,2]. Cotton wicks based heat spreaders reduces the temperature up to 12% [3]. In the given article, the solar energy is used to feed the DC motor which is operated using Fuzzy PID logic (FPID) controller instead of conventional controller to have better speed accuracy [4]. Specific temperature control methods are used to increase solar panel performance [5,6]. Article explores the comparison of different G2GPVT and G2T efficiencies and it is reported that the G2GPVT performance is higher than the G2T performance [7–9]. Cost reduction of Glass and back sheet of solar panel is discussed [10,11]. Glazed and unglazed PV thermoelectric panels are also studied [12]. This addresses the data acquisition approach using LabVIEW for solar cell model [13].Realtime monitoring of solar PV using Dashboard studied [14]. Portable data acquisition system is designed for solar power plant. Yearly data gathered from plant is compared with commercial equipments [15,16]. MATLAB and Simulink based solar cell model is explained . 150 W solar panel with PWM technique is simulated using LabVIEW [17]. Various problems are discussed while interconnection of solar PV and grid [18]. Data acquision system for solar cell using LabVIEW has been discussed [19]. Solar cell behaviour has been studied using MATLAB/Simulink [20,21]. Pulse width modulator has been designed for 150W solar PV module [22,23]. Problems associated with integration of power grid with solar power plant has been studied [24]. Degradation of solar PV under different environment conditions has been studied [25,26]. Feasibility of rooftop installed solar PV has been studied [27]. Solar PV characteristics measuring and monitoring based on LabVIEW environment [28].

The goal of this paper is to analyse solar PV panel output using LabVIEW by mathematical modelling in graphical environment. An experimental model is developed to validate the simulated model using arduino and LabVIEW. Paper is divided into following parts:

1. Modelling of a Photo voltaic Cell
2. MPPT Control algorithm (Perturb and Observe)
3. Simulation Results

4. Hardware Implementation

2 Modelling of a Photo Voltaic Cell

For better outcomes performance of the solar panel should be optimized. I-V and P-V characteristics of PV cell should be investigated for the single diode identical circuit is delineated in Fig.1.

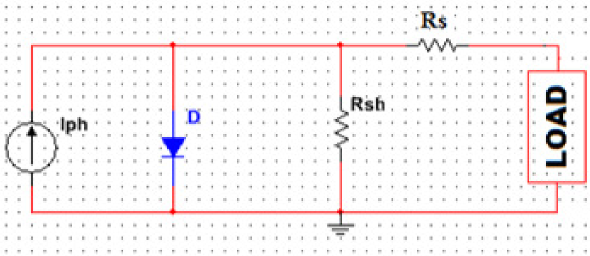

Fig. 1: Single diode identical model for photo voltaic cell.

One diode model has been illustrated for the modeling of PV panel due to its simplicity and precision in mathematical calculation[10].

PV cell current output:

$$I = N_p * [I_{ph} - I_0 - I_0 * exp[\frac{V * N_p + N_s * I * R_s}{n * V_t * N_s * N_p}]] - I_{sh} \tag{1}$$

$$V_t = \frac{K * T}{q} \tag{2}$$

$$I_{sh} = \frac{V * N_p + N_s * I * R_s}{N_s * R_{sh}} \tag{3}$$

Here: PV cells connected in parallel denoted by N_p, PV cells connected in series denoted by N_s, series resistance denoted by $R_s(\Omega)$, shunt resistance denoted by $R_{sh}(\Omega)$ and diode thermal voltage denoted by $V_t(V)$.
Fill Factor is a very critical aspect deciding the efficiency of the PV cell, and healthy PV cells typically have a value greater than or similar to 0.8.

$$FillFactor = \frac{I_m * V_m}{I_{sc} * V_{oc}} \tag{4}$$

I_m is current at maximum power point and V_m is voltage at maximum power point.
Solar PV efficency

$$\eta = \frac{I_{sc} * V_{oc} * FillFactor}{P_{in}} \quad (5)$$

P_{in} is incident irradiations.

3 MPPT Control Algorithm(PERTURB AND OBSERVE)

P&O algorithm MPPT algorithm is implemented to track the maximum power for 200 W solar panel. Flow chart of implementation of basic P&O MPPT algorithm is shown in the Fig.2. Module voltage has experiencing a perturbation intermittently and related output power of the cell has been correlated with the past cycle. Perturb and Observe continuously increment or decrements the panel voltage and compare the current output power of PV module with that of the previous[4]. Tracking of MPP using P&O algorithm is performed in closed loop manner[17]. Output voltage and current of solar panel is acquired using Arduino. Operating power of the panel has been calculated by the voltage sensor and current sensor (ACS-712) output. Arduino is used for data acquisition. LabVIEW program of P&O based algorithm is shown in Fig.3. Based on P&O algorithm variable duty cycle is generated which is feeded to boost converter. Variable duty cycle is generated using Arduino PWM pin. Using this process MPP is achieved for 200W solar Panel.

Perturb and Observe based MPPT algorithm using math script window of LabVIEW is presented in Fig.3. It provides variable duty cycle for boost converter.

Here 'D' is the initial duty cycle for Boost converter, 'dD' is the small change in duty cycle. 'DP' is small variation in power and 'DV' is small variation in small variation in voltage. Based on these a P&O algorithm is created using math script window in LabVIEW. It will provide variable duty cycle for boost converter. Here duty cycle is denoted by 'd'.

4 Simulation Results

LabVIEW programming block diagram of the PV panel is presented in Fig.4 using different mathematical equations of saturation current, photo current and reverse saturation current. Solar Panel of 200W is simulated in LabVIEW. Its Performance is studied under variation of different parameters like temperature, irradiance, series resistance and parallel resistance. Solar PV Module specifications and constant are listed in Table 1.

LabVIEW programming VI is created. A 200W solar panel is simulated using Table 1 Parameters. In this VI Temperature and Irradiance are input variable for solar Panel. Based on different values of Temperature and Irradiance, Power and current graphs are simulated.

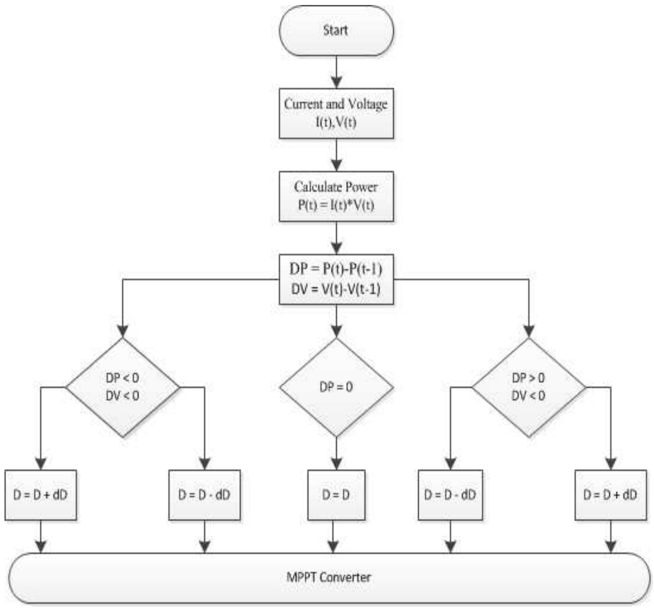

Fig. 2: P&O algorithm flow diagram.

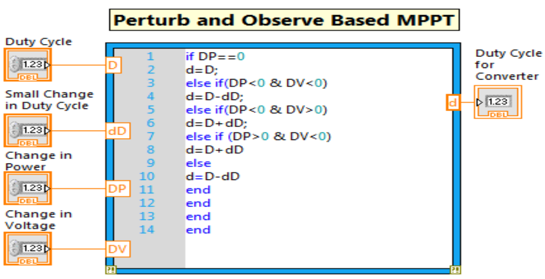

Fig. 3: P&O algorithm based MPPT program.

4.1 Effect of Temperature Variations

To find the effect of temperature variation, Irradiance level is set to a constant valve $1000W/m^2$.
Results shows that for a fixed irradiance level of 1000 W/m^2 there is a large variation in power as temperature varies from 25°C to 45°C. With increase in temperature voltage decreases rapidly while there is a very small variation in current, in turn there is a decrease in power of solar cell [21]. With decrease in temperature voltage increases rapidly while there is a very small variation

Table 1: Solar PV input and output parameters

Parameter	Symbol	Value
Open Circuit Voltage	V_{oc}	32.9V
Short circuit current	I_{sc}	8.21A
Optimum Operation voltage	V_m	26.4V
Open Operation current	I_m	7.58A
Band Gap energy	E_{go}	1.1eV
Boltzmann Constant	K	$1.38 * 10^{-23} J/K$
Coulomb Constant	q	$1.6 * 10^{-19} C$
Reference Temperature	T_r	298 K
Ideal Factor	n	1.3
Module cell in series	N_s	54
Module cell in Parallel	N_p	1
Temperature Coefficient	K_i	0.0032
Series Resistance	R_s	0.221Ω
Series Resistance	R_{sh}	415.405 Ω
Rated Power	P_m	200W

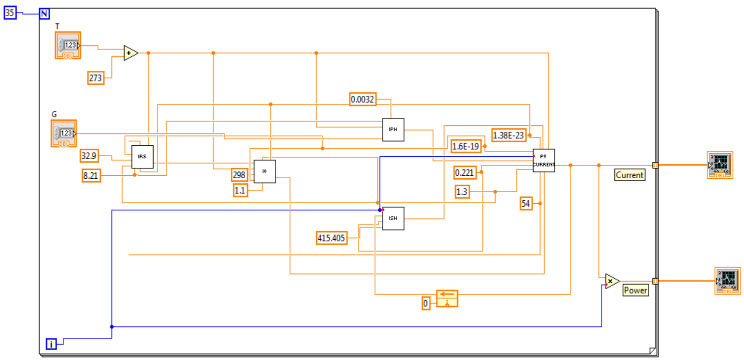

Fig. 4: Designed LabVIEW Block Diagram of Solar PV module.

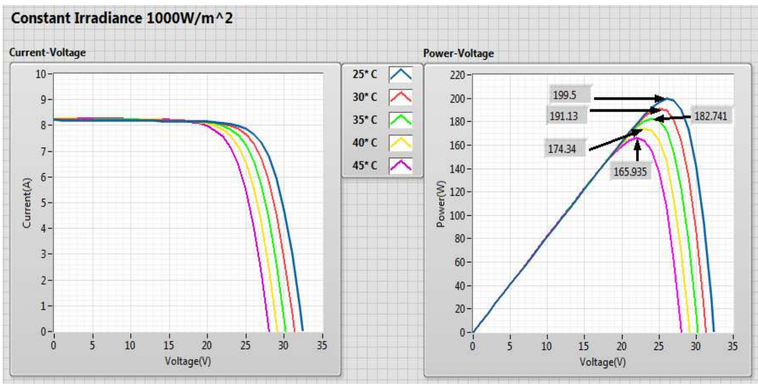

Fig. 5: I-V and P-V curve under varying temperature.

in current, in turn there is increase in power of solar cell. From Fig.5 it is clear that when temperature is 25°C maximum power point is 199.5W, at 30°C maximum power point is 158.995W, at 35°C maximum power point is 118.116W, at 45°C maximum power point is 76.9244W and 36.4265W is maximum power point at 45°C temperature. Maximum power point decreased from 199.5W to 36.4265W as temperature increased from 25°C to 45°C.

4.2 Effect of Irradiance Variations

Average solar radiation coming on earth atmosphere is 1368 W/m^2. Due to ecosystem intensity of Sun's rays are decreased and intensity of radiations at surface is about 1000 W/m^2 on a clean day. To find the effect of Irradiance variation, Temperature level is set to a constant valve = 25°C.

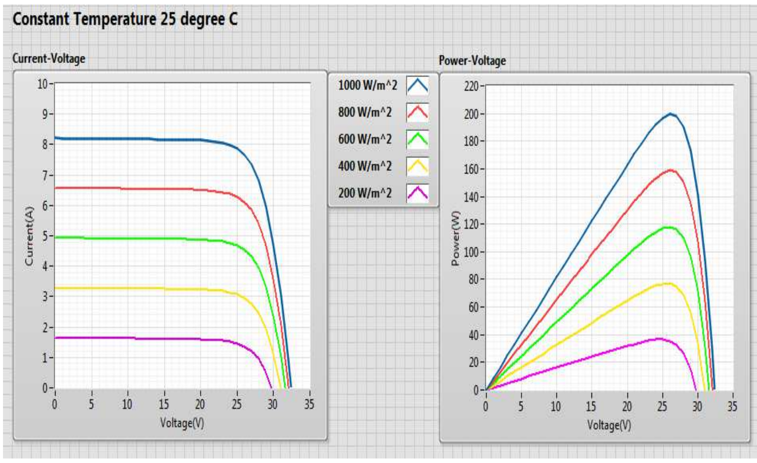

Fig. 6: I-V and P-V curve under varying irradiances.

Solar irradiance is lowering due to presence of cloud, motion of the earth and due to shadow effect. Results shows that: At constant temperature 25°C current decreases rapidly while there is a very small variation in voltage, in turn there is a decrease in power of solar cell with decrease in solar irradiance. From Fig.6 it is clear that when irradiance level is 1000 W/m^2 maximum power point is 199.5W, at irradiance level 800 W/m^2 maximum power point is 191.13W, at irradiance level 600 W/m^2 maximum power point is 182.741W, at irradiance level 400 W/m^2 maximum power point is 174.34W and 165.935W is maximum power point at irradiance level of 200 W/m^2. Maximum power point decreased from 199.5W to 165.935W as irradiance level decreased from 1000 W/m^2 to 200 W/m^2.

Fig.7 contains the data of solar panel output current under variations of both temperature and irradiance.

Temperature → / Irradiance ↓	Current (A)				
	25*C	30*C	35*C	40*C	45*C
1000W/m2	8.2159	6.57416	4.93242	3.2907	1.64899
800W/m2	8.23011	6.5852	4.94029	3.29888	1.65054
600W/m2	8.24977	6.60159	4.95343	3.29841	1.65714
400W/m2	8.26041	6.60914	4.95788	3.30664	1.65542
200W/m2	8.274	6.62004	4.96561	3.31461	1.65683

Fig. 7: Solar panel current data with variation of temperature and irradiance.

As temperature varies from 25°C to 45°C at constant level of irradiance ($800W/m^2$) there are small variations in output current (6.57416A to 6.6251A) of solar panel. As irradiance varies from $1000W/m^2$ to $200W/m^2$ at constant temperature (30°C) output current decreased from 8.23011A to 1.65054A. From the simulation results it is observed that effect of variation of temperature is very less as compared to variations of irradiance on solar panel current.

Fig.8 contains the data of solar panel output power under variations of both temperature and irradiance.

Temperature → / Irradiance ↓	Power (W)				
	25*C	30*C	35*C	40*C	45*C
1000W/m2	199.5	158.995	118.116	76.9244	36.4265
800W/m2	191.13	152.272	113.032	73.4758	34.7355
600W/m2	182.741	145.531	107.931	70.1608	33.0634
400W/m2	174.34	138.776	102.818	66.8304	31.4333
200W/m2	165.935	132.015	97.6992	63.4876	29.7929

Fig. 8: Solar panel Power data with variation of temperature and irradiance.

From the simulation results it is observed that varying temperature and varying irradiance both affect the power of solar panel. It is also observed that output voltage of solar panel is decreases as temperature increases from STC (standard test conditions 25°C) and voltage increases as temperature decreases below STC. Effect of varying irradiance is very less on solar panel voltage.

4.3 Effect of Variations of Series Resistance

Fig.9 shows the power vs voltage graph of solar panel under variations of series resistance (R_s). It is observed that as the series resistance increases output power of solar panel decreases. As the year goes series resistance of the panel is increased.

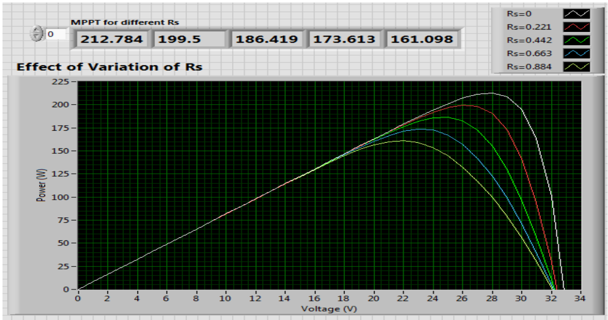

Fig. 9: Effect of variation of series resistance on solar PV power output.

When series resistance is 0.221 Ω, output power of solar panel is 199.5W. At series resistance 0.442Ω output of panel drop to 186.419W. At series resistance 0.663 Ω output of panel is 173.613W. At series resistance 0.884Ω output of panel is 161.098W. From here it is observed that around 6.5% power decreased as series resistance doubled from $(R_s) = 0.221\Omega$ to $(R_s) = 0.442\Omega$.

4.4 Effect of Variations of Shunt Resistance

Fig.10 shows the power vs voltage graph of solar panel under variations of shunt resistance (R_{sh}).

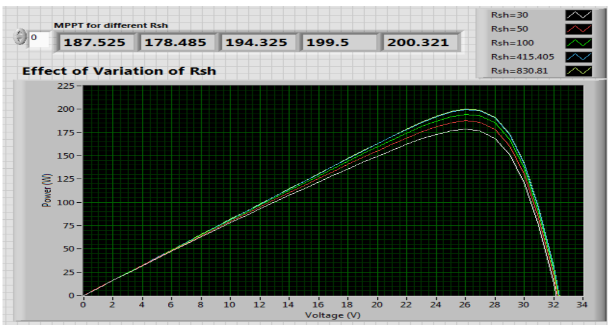

Fig. 10: Effect of variation of shunt resistance on solar PV power output.

It is observed that as the shunt resistance increases output power of solar panel increases. As the year goes shunt resistance of the panel is decreased. When shunt resistance is 415.405Ω, output power of solar panel is 199.5W. At shunt resistance 100Ω output of panel is 194.325W. At shunt resistance 50Ω output of panel drop to 178.485W. It is observed that as the shunt resistance increases output power of solar panel increases. As shunt resistance doubled $R_{sh} = 830.81\ \Omega$, output power of solar panel is 200.321W. From here it is observed that around 0.4% power increased as shunt resistance doubled.

4.5 P&O Based MPPT Control Algorithm

Change in duty cycle with voltage variations of solar cell are delineated in Fig.11.

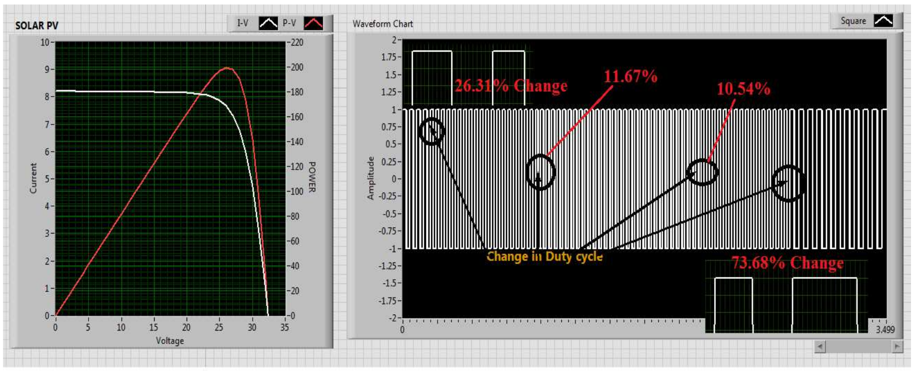

Fig. 11: PV module characteristics and Variable duty cycle based on MPPT.

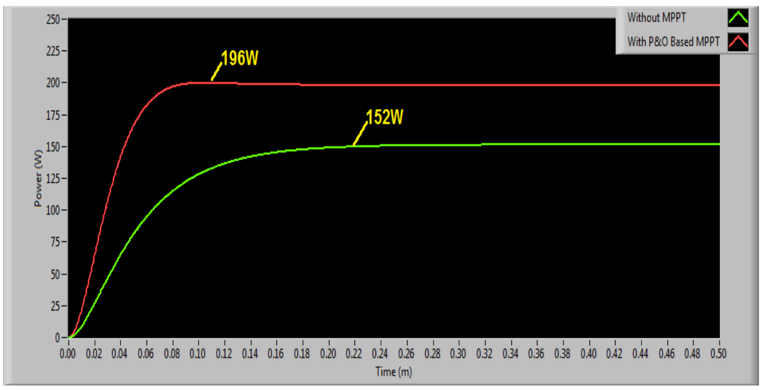

Fig. 12: Solar Panel Power output with and without MPPT.

Change in duty cycle is observed at different time span. When output power of solar panel is below MPP (Maximum Power Point) there is an increase in duty cycle. Initially there is a decrease of 26.31% in duty cycle after some time there is increase of 11.67% in duty cycle then there is decrease of 10.22% in duty cycle and at last there is 73.68% increase in duty cycle, which is based on the variations in output power of the solar panel.

Output power generated from solar panel without MPPT is output power is 152W, after implementation of P&O MPP algorithm output power of solar panel is boosted to 196W. Using MPPT algorithm, maximum point is reached early as shown in figure. There is a 28.94 % power of solar panel is boosted after using a P&O MPPT algorithm.

5 Hardware Implementation

Hardware implementation for 5W solar panel is shown in Fig.13. Here solar panel data (current and voltage) is acquired using Arduino UNO. Arduino is interfaced to LabVIEW using LINX. Sub VI is created for P&O MPPT algorithm.

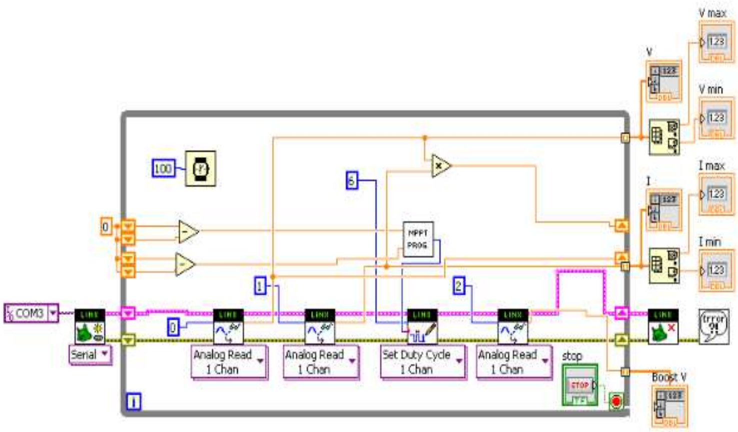

Fig. 13: Arduino based data acquision and MPPT controller.

After acquiring data from solar panel, P&O algorithm is applied using P&O MPPT. Boost converter hardware circuit is shown on zero PCB. To acquire the current ACS 712 current sensor is used its current rating is up to 5A. To acquire the voltage from solar panel, voltage divider circuit is used. Current is acquired using analog pin (A0) of Arduino UNO. Voltage is acquired using analog pin (A1) of Arduino UNO. Output for boost converter is generated using Arduino digital PWM (DIO-6).

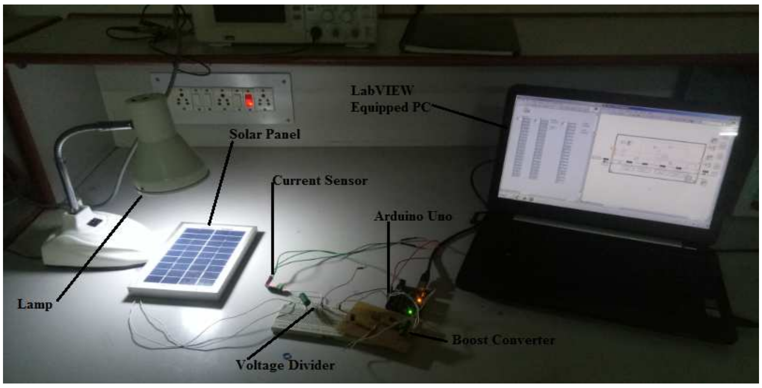

Fig. 14: Hardware implementation of P&O MPPT controller.

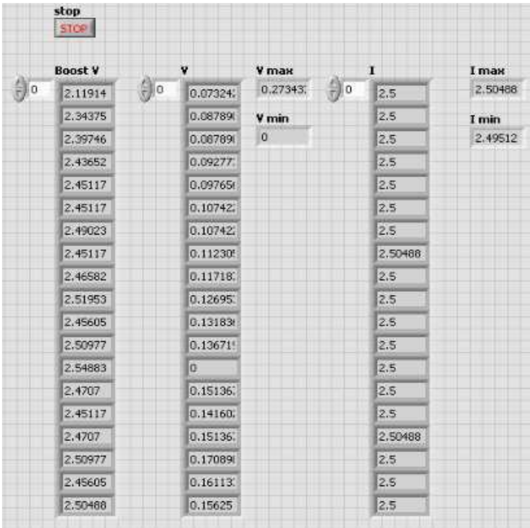

Fig. 15: Output of solar Panel after MPPT controller.

Fig.14 shows the hardware implementation of 5W solar panel. Arduino UNO is used for data acquisition and to generate variable duty cycle for boost converter. Using Boost converter voltage of solar panel is boosted. Fig.15 shows the data of voltage without (MPPT and Boosted Voltage) with MPPT controller.

6 Conclusion

From the simulation results it is concluded that effect of variation of temperature is very less as compared to variations of irradiance on solar panel current. Output voltage of solar panel is decreases as temperature increases from STC

(Standard Test Conditions) and voltage increases as temperature decreases below STC. Effect of varying irradiance is very less on solar panel voltage. When temperature is 45°C and irradiance level is $200W/m^2$ power generated by solar panel is 29.7929W. From the simulation results it is concluded that varying temperature and varying irradiance both affect the overall power of solar panel. After installation of solar panel, as time goes its series resistance increase and shunt resistance decreases which results in decrease in output power of solar panel. Using P&O MPPT control algorithm output power of solar panel is boosted around 28.94%. To increase the power output of solar panel live monitoring is required. Output of panel can be improved by use of multi level inverters and hybrid MPPT techniques.

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Conflict of interest

The authors declare that they have no conflict of interest.

Availability of data and material

Not applicable

Code availability

Custom Code

Authors' contributions

Original Article

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