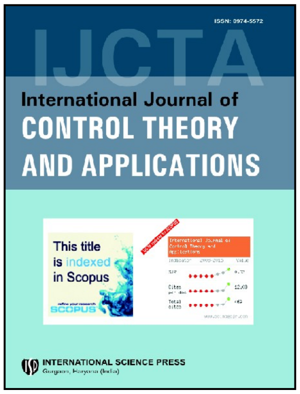

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Impact of Temperature on Performance of Photovoltaic System at NIT Agartala Campus-A Case Study

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Abstract: Now-a-days, renewable energy is used due to limited sources of fossil fuels. The performance of the photovoltaic (PV) system is mainly decreased due to shading and temperature variation. The objective of this work is to study the characteristics of the power-voltage curve (P-V curve), open circuit voltage (V_{OC}) and maximum power profile (P_{max}) with the variation of the temperature of a small PV system at National Institute of Technology Agartala campus (NITA), India. Simulation is done by using PSCAD/EMTDC. The experimental setup is installed on the rooftop of G plus 6 block of National Institute of Technology Agartala campus to validate the results of the simulation. The results reveal that the performance of the system deteriorates with increase in temperature.

Keywords: Power improvement, Solar irradiation, Solar photovoltaic, Temperature effect, Voltage improvement Electricity

I. INTRODUCTION

Now-a-day, many countries widely promoted renewable energy for generation of power due to rising demand for electricity along with rising fossil fuel prices. Solar energy is the most important clean energy in the world among all renewable sources. Solar irradiance can be converted into electricity without using any external link by using the photovoltaic effect. We can utilise the solar power with minimum cost due to less generation cost. Photovoltaic (PV) cell is the most basic component of solar panel in a PV system. The performance characteristic curve of PV system directly varies with global irradiance, ambient temperature and other environmental conditions. The most important issue is the temperature increment, which causes the significant reduction in the panel output power, voltage and efficiency, etc. Electricity produced by PV panels in photovoltaic system is inversely affected by their operating temperature. It is the product of the level of sunlight and ambient air temperature, which was described by the author in [1-3]. An article on solar panel cooling techniques was reviewed in [4] and observed that evacuated tube collectors are the best option for solar cooling. In ref. [5] different types of solar cell's characteristics are analysed and observed that both the maximum power point position and current flows through the system are increased due to the radiation intensity growth of solar.

The performance of amorphous Si photovoltaic modules was discussed in [6] and shown that energy out from Si modules generally depends on spectrum distribution, whereas energy out from mc-Si module depends on module temperature, not spectrum distribution. In [7], authors studied the effect of temperature on the performance of dense array concentrator PV system and it was observed that solar cells those are located in the middle region of the array experiences more heat as compared to lower portion cells. Most important factors (e.g. temperature, cable thickness, PV panel shading, charge controller and photovoltaic cell's I-V characteristics, inverter efficiency and battery efficiency) were discussed for photovoltaic system performance [8]. Temperature effect on different grid-connected PV technologies was analysed in [9] and observed that the coefficients range performance losses initially with temperatures above the maximum power point (MPP). In ref. [10], studied the temperature coefficient of dissimilar types of solar modules. Now-a-days, the demand for energy increases gradually in all over the world. But, our conventional energy sources are limited. Due to this reason, we are focusing on renewable energy among which solar energy plays an important role. The performance of solar systems decreases with increase in temperature above standard temperature condition (STC) of the panel. For this drawback, the temperature refrigeration technique is required. A review paper of hybrid adsorption refrigeration schemes in order to control the temperature was given in [11] which was shown to better the performance of the system.

Estimation of PV panel temperature by artificial neural networks (ANN) was studied in [12]. The new temperature refrigeration system was proposed for improving the efficiency of solar cells between 12% and 14% [13]. The Author of ref. [14] studied the effect of variation of temperature on power efficiency consumed by electrodes. Behaviour of photovoltaic system with temperature variation was analysed in [15] and it was observed that the yearly energy output from the PV system increased with improvement in the temperature coefficient. Solar thermal refrigeration and cooling methods were reviewed in [16]. Power generation from solar system totally depends on panel's cell temperature. While the short circuit current (I_{SC}) rises marginally with increasing temperature. The open circuit voltage (V_{OC}) reduces considerably if temperature increases, leading to a reduction of maximum output power.

II. AIM OF THIS PAPER

Electricity produced by photovoltaic panels is affected by fault due to operating temperature variation, which are primarily a product of the ambient air temperature and the level of sunlight. Increase in temperature is one of the main challenges for photovoltaic systems which cause significant reduction in maximum output power ($P_{\max}$), open circuit voltage profile (V_{OC}) and power-voltage characteristics. This paper discusses on the effect of fault on temperature variation on photovoltaic system performances at NIT Agartala campus.

III. TEST SYSTEM DETAILS

For the analysis of the impact of panel's temperature improvement on photovoltaic system, simulation model and experimental setup of the system is considered. The effect of panel's temperature improvement fault on open circuit voltage (V_{OC}) profile, maximum power profile of the photovoltaic system is analysed in simulation as well as outdoor experiment considering the constant irradiance (G) = 270 W/m2 and different temperature. The obtained data at temperature 25^0C is assumed as a reference for the sake of better explanation.

3.1. Simulation details

In a simulation study, two 60 watt PV panels are connected in series. Simulation part of the proposed test system is done in EMTDC/PSCAD which is shown in fig. 1.

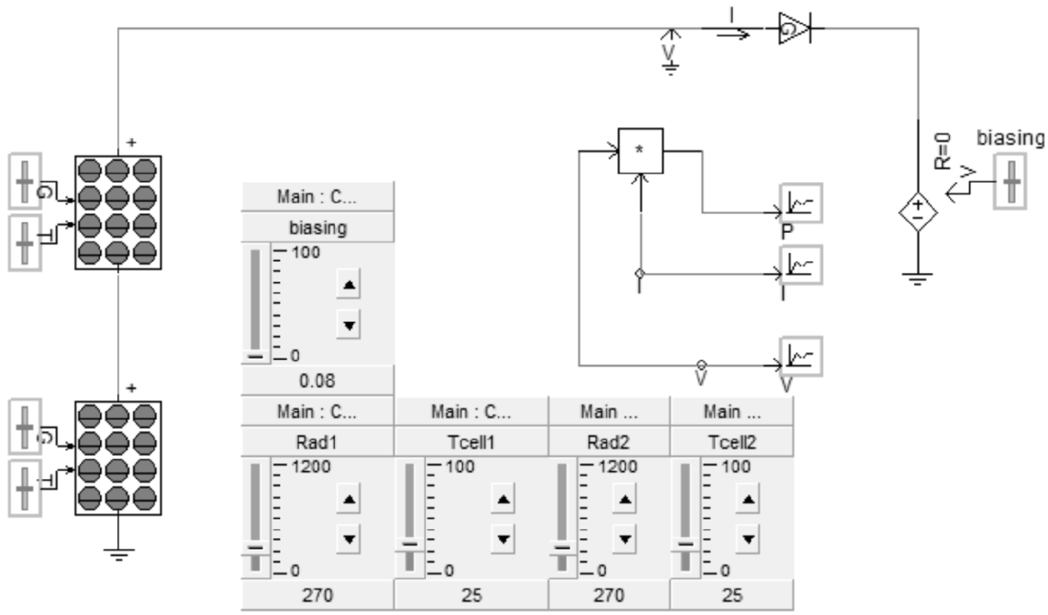

Figure 1: Simulation model of two single PV panels connected in series at G=270 W/m2, T= 25^{0}C

3.2. Experimental details

Two 60 W single photovoltaic panels (Akshaya solar power) and an ammeter are connected in series. A voltmeter is also connected in parallel to the panel. A rheostat is connected in series to measure the output voltage and current at different values of resistance. The short circuit current is measured at zero resistance and the open circuit voltage is measured directly across the output terminals of PV System. The different voltage and current are collected at different conditions of the rheostat. A Lux meter and a Pyranometer are also used to measure the light intensity and radiance, respectively. The experimental setup is shown in fig. 2.

Figure 2: Experimental model of two single PV panels connected in series

IV. RESULTS AND DISCUSSIONS

The results obtained after simulating the proposed model in PSCAD are shown in subsection 4.1. The change in PV system performance with change in panel temperature is also discussed. Experimental results are shown in subsection 4.2. The experimental results validate the results of simulation.

4.1. Simulation results

Impact of fault on the PV system power-voltage curve, open circuit voltage and maximum power output characteristics are analyzed in simulation as well as outdoor experiment due to temperature variation. It is noticed that power - voltage profile graph of the PV system is inversely proportional with increase in temperature of the panel in a PV system. fig. 3, fig. 4, fig. 5, fig. 6 and fig. 7 show the variation of power-voltage curve of photovoltaic system at temperature 25^0C, 29^0C, 36^0C, 43^0C and 48^0C, respectively.

From the fig. 3, fig. 4, fig. 5, fig. 6 and fig. 7, it is obtained that the open circuit voltage and maximum output power decreases with increase in temperature of photovoltaic panel in a PV system. It reveals that the theoretical concept is validated by the results of simulation. The variation of voltage and power with change in temperature in simulation is tabulated in Table 1.

It is observed from Table 1 that both open circuit voltage and maximum power are reduced remarkably with an increase in panel temperature in a PV system. It is also observed that 0.0789 volts average voltage profile and 0.0594 watts average power profile of the PV system depreciates with increase in /p C solar panel temperature.

Table 1
Variations of voltage and power of PV system with temperature in simulation

Parameter	*Temp 25 °C*	*Temp 29 °C*	*Temp 36 °C*	*Temp 43 °C*	*Temp 48 °C*
V_{oc} (volt)	37.66	37.38	36.90	36.42	36.08
P_{max} (watt)	30.72	30.52	30.15	29.75	29.51
Average decrement of voltage /°C increment of temperature	0.0789 volts				
Average decrement of power /°C increment of temperature	0.0594 watts				

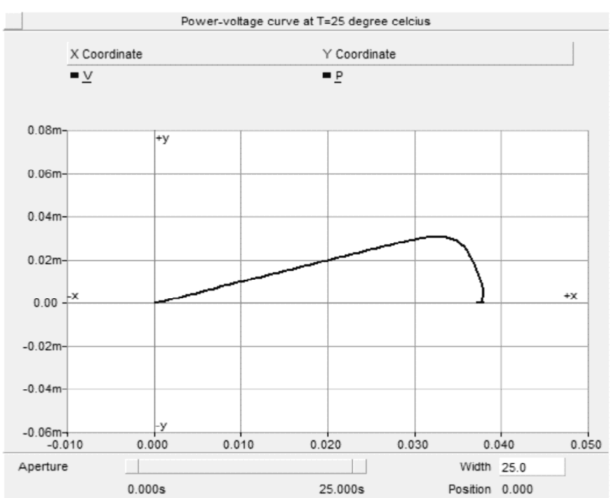

Figure 3: Power-voltage graph in simulation at T = 25^0C

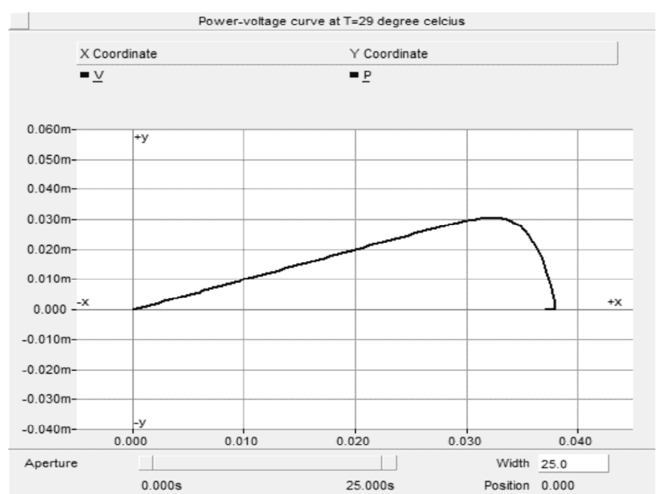

Figure 4: Power-voltage graph in simulation at T = 29^0C

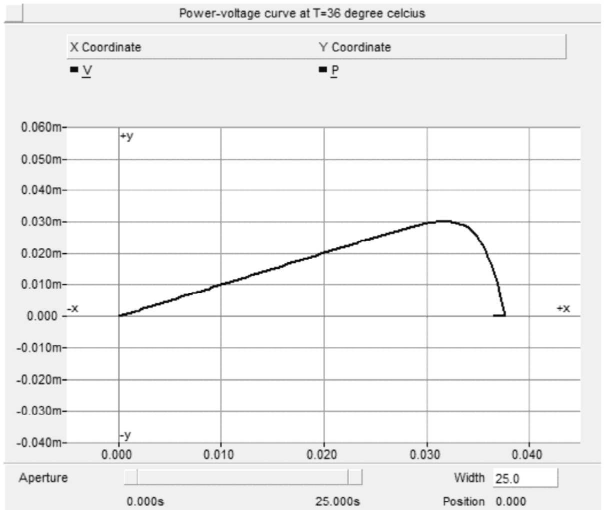

Figure 5: Power-voltage graph in simulation at T = 36⁰C

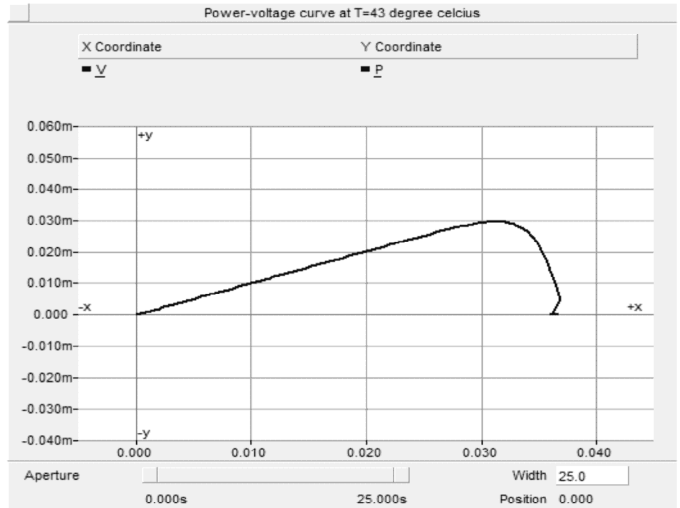

Figure 6: Power-voltage graph in simulation at T = 43⁰C

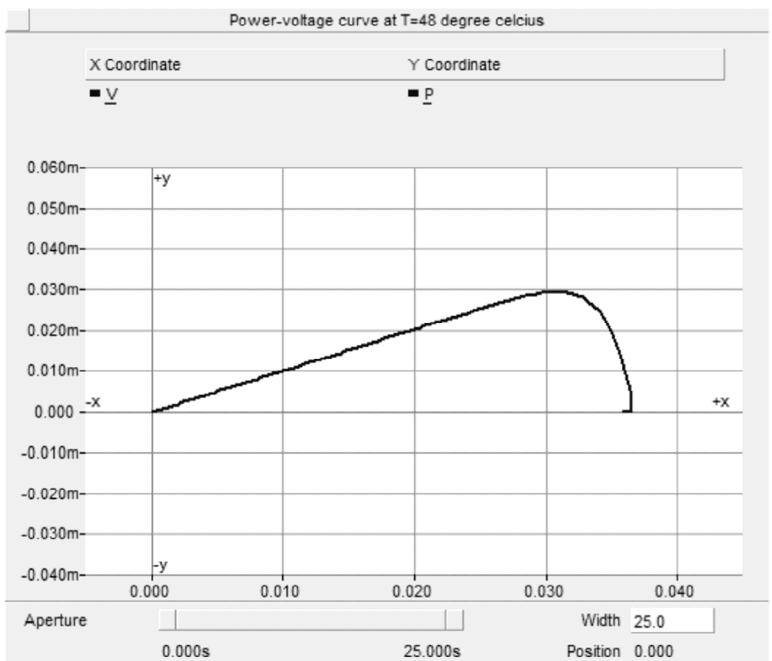

Figure 7: Power-voltage graph in simulation at T = 48⁰C

4.2. Experimental results

Two 60 W single photovoltaic panels (Akshaya solar power) are connected in series to analyse the result of temperature variation in solar panels in outdoor. It is obtained that power-voltage graph profile of PV system deteriorates with the increase in PV panel temperature in photovoltaic systems. Figure 8 shows the variation of power and voltage flow through photovoltaic system at T=25⁰C in NIT Agartala campus, India. Similarly, fig. 9, fig. 10, fig. 11 and fig. 12 show the variation of power-voltage curve of photovoltaic system at temperature 29⁰C, 36⁰C, 43⁰C and 48⁰C, respectively. The combined power-voltage curve of the PV system is shown in fig. 13.

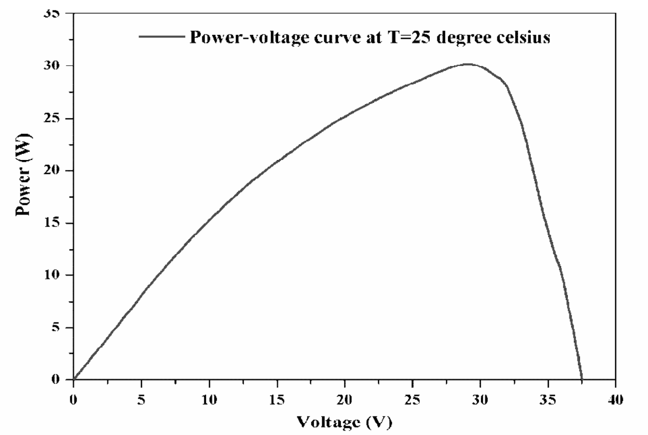

Figure 8: Power-voltage graph in real time at T = 25⁰C

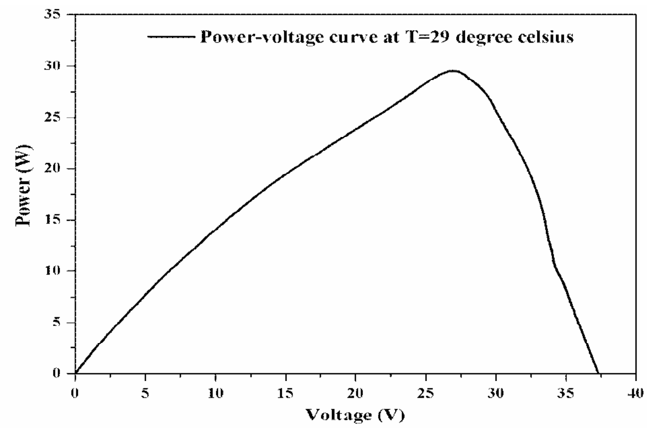

Figure 9: Power-voltage graph in real time at T = 29⁰C

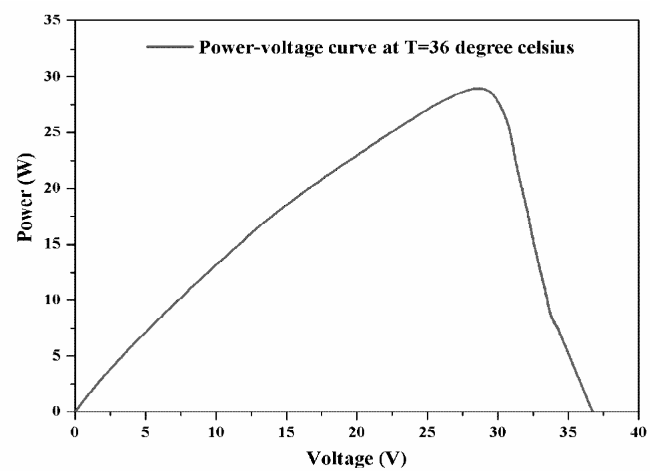

Figure 10: Power-voltage graph in real time at T = 36⁰C

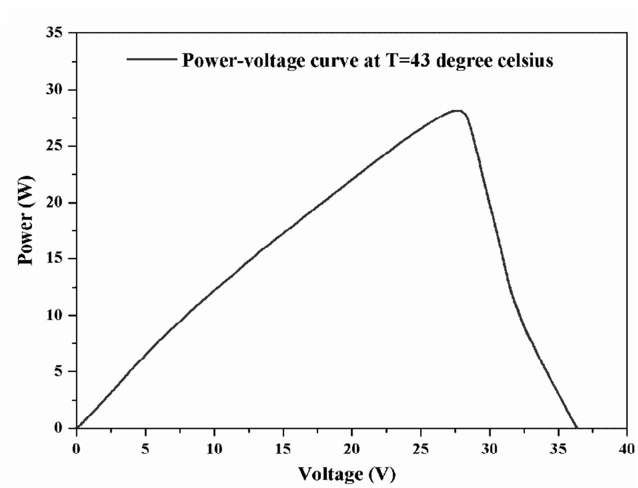

Figure 11: Power-voltage graph in real time at T = 43⁰C

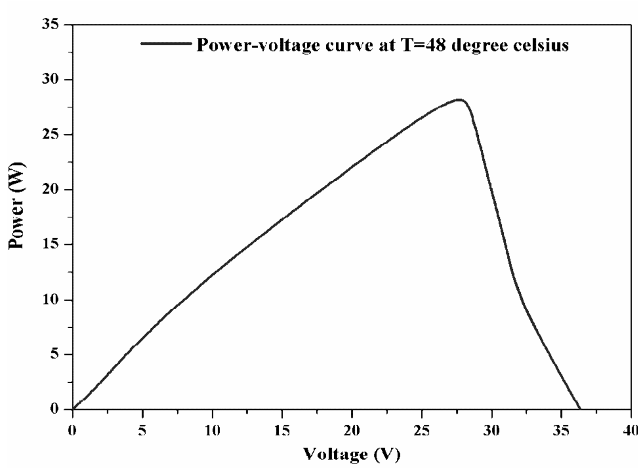

Figure 12: Power-voltage graph in real time at T = 48⁰C

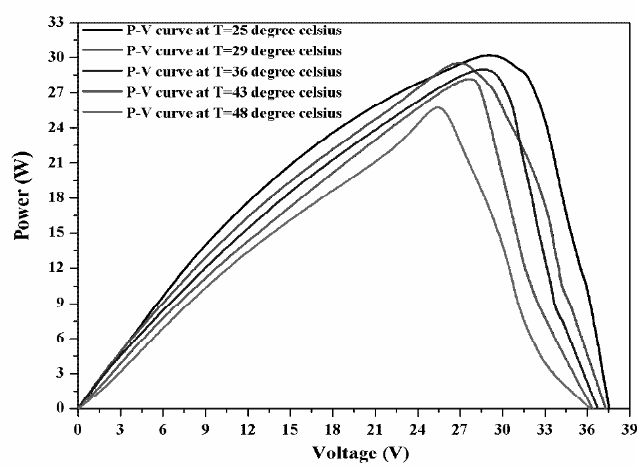

Figure 13: Power-voltage graph in real time at different temperatures

It is obtained from fig. 13 that power profile and voltage profile of proposed solar system is improved with decrease in panel temperature. The voltage and power profile of the PV system deteriorates with increase in temperature. Experimental results validate the concept of solar system performance with increase in temperature. The variations of voltage and power profile with change in temperature in real time are tabulated in Table 2.

Table 2
Variations of voltage and power of PV system with temperature in real time

Parameter	*Temp 25 °C*	*Temp 29 °C*	*Temp 36 °C*	*Temp 43 °C*	*Temp 48 °C*
V_{oc} (volt)	37.52	37.30	36.73	36.35	36.19
P_{max} (watt)	30.75	30.41	30.29	29.80	29.49
Average decrement of voltage /°C increment of temperature			0.0726 volts		
Average decrement of power /°C increment of temperature			0.0645 watts		

It is observed from Table 2 that power and voltage profile of the proposed system decreases with the increase in PV panel temperature. The power-voltage graph is inversely proportional with photovoltaic panel temperature. It is also observed that the average decrement of voltage and power of the system is 0.0726 volts and 0.0645 watts respectively, with increase in /p C solar panel temperature in the PV system. The experimental results validate the results of simulation.

V. CONCLUSION

The performance of photovoltaic (PV) system depends on temperature variation. The power-voltage characteristics, open circuit voltage (V_{oc}) and maximum power (P_{max}) profile changes due to temperature variation. The experimental study is done on the rooftop of G plus 6 block of National Institute of Technology Agartala (NITA), India and simulation is done by using PSCAD/EMTDC software. The voltage and power of the proposed system deteriorates with the increase in solar panel temperature is observed from simulation and experimental result. In simulation, average voltage and power of solar system decreases correspondence to /p C improvement of temperature are 0.0789 volts and 0.0594 watts respectively, and from the experimental study, it is observed that decrements in average voltage and power profile correspondence to /p C improvement of temperature is 0.0726 volts and 0.0645 watts respectively in NIT Agartala campus

APPENDIX-A

Solar panel Type = Akshaya solar power panel

Wattage of each panel = 60W

Number of solar panel = 2

Sampling frequency (f_s) rate in simulation is 4 kHz

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