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IMPROVING EFFICIENCY OF SOLAR PANELS WITH INTRODUCTION UNDERNEATH

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INTRODUCTION

In this paper the solar panel temperature has been reduced by allowing air to flow through underneath array of solar panels through the duct that results in hot air at the outlet of solar panel and production of more power. The air blown though underneath played major role in reducing the panel temperature and resulting hot air can be utilized for some other purposes.

Solar energy is considered to be one of the green energies that plays an important role in reducing green house gases thereby reducing carbon footprint as it's main output is electrical energy from incidence of sun's light energy. To make it more greener thermal energy from Solar energy are being tapped. To make cost effective, combined production of electrical and thermal energy is possible by circulating air or water, as heat removing fluid around the panel. By doing so, the performance and lifetime of PV Panels can be undoubtedly increased. More and more theoretical,numerical,and experimental studies are undertaken in this area. This energy conservation measure led to the evolution of photovoltaic thermal (PVT) hybrid system [1]. The unwanted heat from PV panel is usually recovered from their rear side by maintaining air flow or water flow, and could be used for heating air or water respectively. Based on the heat extraction medium like air and water, PVT technology can be broadly grouped as PVT air (PVTa) technology and PVT water (PVTw) technology. Recent PVT systems [2, 3] incorporate novel heat extraction techniques with high thermal conductivity nanofluids, latent heat of fusion with the use of phase change materials (PCM), latent heat of evaporation in heat pipes and semiconductor based thermo-electric modules. Of the various PVT system designs, PVTa system is much simpler due to lesser constructional complexity, operational and maintenance overheads.But, it is found that the major hurdle with PVTa system is the low values of mass density and specific heat of the heat extraction medium (i.e., air) which affects the heat extraction rate from the heated PV rear surface [4]. Therefore to circumvent these problems, several modified PVTa system designs [5] with multiple passes of air, glazed back surface, use of extended surfaces (fins), staggered plates, corrugated groves, hexagonal honeycomb structures have been explored to augment heat transfer from the heated surface of PV to the extracting medium i.e., air. The literature on these modified PVTa system designs to augment the exit temperature of air will be briefly reviewed in this introduction section. Solar air heating (SAH) system is a single kind of technology that uses solar energy for air heating only and hence the literature review on the topicof SAH is excluded in this article.

Tripanagnostopoulos [6] have tested low cost design alterations involving ribbed channel, corrugated sheet and tubes inside the channel for the generation of flow turbulence to intensify heat transfer rate to the air passing inside air channel. They recommended that these low cost alterations were suitable for thermal applications involving warm air. A double-pass PVTa system integrated with fin was considered for its performance evaluation by Othman et al. [7].In this design, the air was first heated during the first pass consisted of upper air passage betweenthe top glass cover and PV front surface by the direct sun rays. Then, the heat transfer rate to the air was increased in the second pass constituted by the lower air passage between the PV back surface with fins and a duct. For air mass flow rates of 0.05 kg/s and 0.1 kg/s, the maximum temperature rise was about 8°C and 2°C respectively. Modifications of air channel with the presence of thin sheet of metal (TMS) and protruding metal sheets (fins) from PV rear surface into the air channel were implemented by Tonui and Tripanagnostopoulos [8]. These modifications reduced the temperature of PV surfaces by 4°C to 10°C when compared to those obtained with the absence of such modifications.

The influence of PV solar cell encapsulation between glass & tedlar, and glass & glass structures in PVTa systems was analyzed by Dubey et al. [9]. Their results revealed that the glass& glass encapsulation produced better air exit temperature and electrical efficiency. The effect of

series and parallel combination of PV panels for building integrated PVT systems has been evaluated by Agrawal and Tiwari [10]. It was observed that the series combination of PV panels with constant air flow rate would be more suitable for the building integrated PVT systems.

The performance of PVTa systems having bifacial solar cells was investigated by Ooshaksaraei et al. [11] with alterations in air pass configuration and direction of air flow. They observed that the double air pass configuration in parallel flow exhibited the maximum thermoelectric efficiency. The lowest thermoelectric efficiency was obtained with a single pass

PVTa system. The thermoelectric efficiency was within these limits for the case of a double pass with counter flow and returning flow PVTa system. Performance of PVTa system with segmented plates positioned in staggered fashion involving radiation heat transfer was determined by Ali et al. [12]. It was revealed that augmented heat transfer between air and staggered segmented plates could be possible with a wise choice of thickness and length of the segmented plates. The augmentation in heat transfer was due to the disruption in the development of thermal boundary layers and mixing of air. The testing on hybrid PVTa system with single and double duct, and having single and double air passes was carried out by Amori and Abd-Al Raheem [13]. It was established that PVTa collector design with double duct with single pass was suitable for PVTa application.

The heat transfer to flowing air in PVTa system was enhanced by Hussain et al. [14] with a hexagonal shaped honeycomb structured heat exchanger. The heat exchanger was placed in an adjacent parallel plane along the direction of air flow under the PV module. This arrangement resulted in a 60% enhancement in heat energy extraction. Greater contact surface of the honeycomb configuration was believed for the improved heat withdrawal rate from the panel rear side to the flowing air. Shyam and Tiwari [15] placed semitransparent solar PV module at the initial and later portions of the flow passage in PVTa system to study their effects in raising the air delivery temperature. They observed that the use of semitransparent solar PV module delivered air at outlet temperatures between 80 and 120°C. It was also recommended to use semitransparent solar PV module in the initial portions for better overall performance rather placing in the outlet portions.

In this paper, one duct is introduced to remove heat.This system is an innovative combination of producing thermal energy as well as electrical energy and cost effective data logging method. By using the duct, the heat conglomerated in different layers below the panel and inside the duct is absorbed by the plate and removed by air thereby reducing PC panel temperature and hence both thermal and electrical performance is increased. In addition to this we have incorporated a system in which measurements can be logged in at every half an hour starting from 10.00 AM to 2.00 PM with various rheostat load settings.

EXPERIMENTAL SET UP

To accomplish our task, we have two sets of flat plate solar panels one named as WITH OUT COOLING and another as WITH COOLING.Each set of panel comprises of 10 Nos.5 Watts panel totaling 50 Watts connected in parallel.The output from each set of panel is given to one rheostat (range is 0Ω -28 Ω) each.

The testing section is bottomed by duct measuring 2000 X 180 X180 mm. As a passive technique, a suction draught DC fan consuming 0.36 A powered by separate solar panel is used to blow air underneath the testing section. These suction Draught Fan has been fixed at upper end of the duct.

2 X Six temperature sensors affixed underneath the both sets of solar panel at a distance of 270,645,1000,1320,1560,1740mm from lower end.Dual Pressure sensors that can measure both temperature and pressure at any particular point have been fixed one at lower end and another at upper end of the duct.

For logging in measurements like Current, Volt at different settings of the rheostat, suitable sensors have been used for both sets of panels.

Screw Rod and Nut arrangement have been fabricated and kept over the sliders of both rheostats.Screw Rod is rotated by DC motor controlled by Motor Drive Controller.

Readings like Current, Volt and Pressure taken manually and compared with sensor results.

COMPONENTS USED

Sl.No.	Description	Specifications
1	2 X 10 Nos .Solar Panel	5 watts output
2	Duct	2000 X 80 X80 mm
3	Rheostat	0Ω -28Ω
4	Temperature Sensor LM 35	a) Input Voltage 4v-30v b) Range -55^0 C --- +150^0 C c) Output 0 – 5v
5	Dual Pressure sensor BMP 180	a) Input Voltage 5 v b) Range 300 m bar-1100 m bar c) Output I^2 C Communication Protocol
6	Current Sensor ACS 712-05B (Hall Effect Sensor)	d) Input Voltage 4-8V e) Range -5 A -- +5A f) Output 185mv/A
7	Voltage Sensor – A Simple Voltage Divider network	upto 25 v
8	Micro Controller (µC) - 1 Nos, ARDUINO MEGA 2560	1. ATMEL 2560 Microcontroller 2. 54 output pins,16 input pins 3. Max. input volt 0_5v 4. Flash Memory 256 KB-Program fed 5. Static Ram 8 kb 6. Clock speed 16 MHZ Speed
9	Real Time Clock-DS 3231 MAXIM INTEGRATED	g) I^2C Real Time Clock h) 32.768 KHZ Speed i) V_{CC} - 5 Volt j) Battery backup for continuous time keeping k) Dual output module
10	SD CARD MODULE	

LAYOUT OF THE SYSTEM

The system is divided into Power Block, Microcontroller Block, Sensor & RTC Block and Motor blockthe details of which are explained below.

POWER BLOCK

It consists of 2 Nos. of DC Supplies one to power the Microcontroller block and another to power Sensors & RTC Block.Another 12V DC supply is used to power the DC motor using motor driver.

Since 5 volt is required, to power Sensors & RTC Block, voltage from 12V DC source is reduced to 5VDC using AMS1117 5.0 fixed voltage regulator in the MB102 supply board.The MB102 supply board comes with a USB port which can be used to power the microcontroller block.

MICROCONTROLLER BLOCK

Microcontroller has 16 Analog input pins, and out of 16 pins,12 pins are connected to 12temperature sensors, 6 each from Ideal & Testing Panel.Pins A0 to A5 are used by TestingMode and pins A8 to A13 are used by Ideal Mode. SPI Interface consists of MOSI,MISO,SCK,CS,VCC,GND.V_{CC} & GND connected to inbuilt microcontroller powersupply pins and the otherremaining four ports are connected to digital I/O pins 50-53 ofmicrocontroller.

The analog pins is supplied with 0 volt -- 5 volt as maximum Input voltage. Thismicrocontroller supports I^2C communication protocol.SD Card communicate with microcontroller using SPI Interface,LCD display is operated in a 4-bit, WRITE mode and the data lines are connected to the 4digital I/O ports.The backlit LED light is supplied 5V DC for the visibility of the characters andthe contrast for the LCD display is set by using the PWM output.LCD display is operated in a 4-bit,SENSOR & RTC BLOCK Sensor & RTC block consists of temperature sensors, pressure sensors, current sensors,voltage sensors and RTC.

Temperature sensor is attached to the panel to measure the panel temperature(Tp) in 6 different points in each testing and ideal configuration.The output voltage produced by the temperature sensors is of 0mV+10mV/°C and the signal is fed to analog input port of the microcontroller.

Pressure sensor is used to measure the absolute pressure at both the ends of the duct (P)and it also measure the temperature of the air (Ta) at both ends. As both the pressure sensor have the same address and uses I^2Ccommunication protocol to send data to the microcontroller, serial analog multiplexer 74HC4052 is used to select the appropriate pressure sensor. RTC is also connected with the multiplexer.Using the selection line the pressure sensors and the RTC is selected and the data is sent to the microcontroller.

The main part of the whole system is the RTC module which is used to synchronize the function with the real world time.It uses 2-wire communication protocol and it is hooked up with serial analog muxfor working in conjunction with the pressure sensor.For accessing this module, DS3231 library is used in program to transmit and receive data.

Current is measured using the ACS712-05B which works based on the Hall Effect and the range is from ±5A both AC and DC. The current to be measured is connected in series with the 2 input terminals.For 0A, it produces voltage signal 2500mV and for the increase in the current the voltage signal will be produced 185mV/A.

For measuring voltage, voltage divider sensor network is used with the capacity of 25V. The voltage to be measured is connected to the input terminals and the output signal is tapped from the S terminal of the sensor.

Motor Block:

It is designed using a 5V relay and L293D motor driver for forward and reverse operation of the motor.

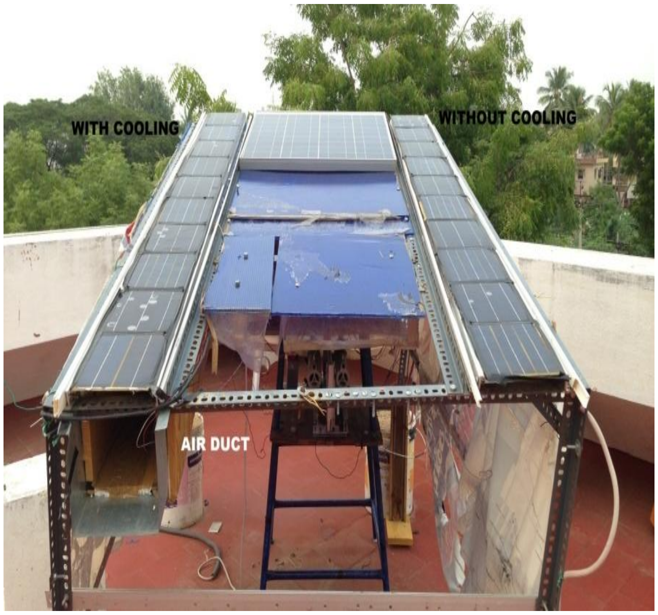
It consists of 2 input terminals and 2output terminals connected to the microcontroller and DC motor respectively.The motor driver bypasses the 12V DC supply to the DC motor and controls using the logic from the microcontroller.

MEASUREMENTS

The following parameters were measured during experimentation.

1. Panel Temperature from six different points of both sets of panels

2. Inlet and outlet Temperature of air
3. Inlet and outlet velocity of air
4. Voltage and current from set of panels corresponds to without cooling
5. Voltage and current from set of panels corresponds to with cooling



PV Panels of mono crystalline type silicon solar panels are kept in line over a frame at 23° facing south and are connected in parallel to get more current output, referred as Without Cooling panel. A similar setup, referred as With Cooling panel kept and bottomed by duct.

A variable speed DC fan fitted at the top end of duct used to vary mass flow rate. In between both sets of panels another 50Wp solar panel referred as Power Supply Panel that caters power requirement of variable speed DC fan. Air is made to pass below the panels through the duct takes away the heat from the solar panels created by insolation, thereby reducing panel temperature. The whole setup is open to sky without any obstruction to avoid any shading effect which will reduce solar insolation as shown in fig.1

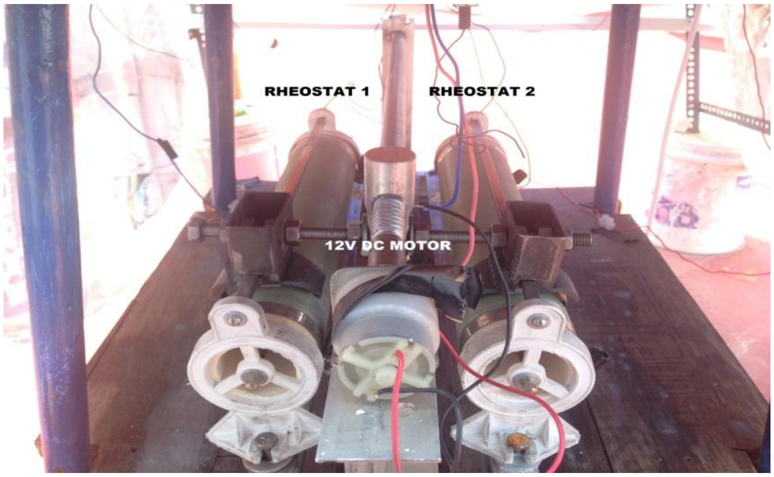


Figure 1. Experimental Set up

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EXPERIMENTAL PROCEDURE

To assess the thermal and electrical characteristics, both PV and PVT system tested concurrently at real time environment conditions. The readings are recorded automatically by performance monitoring system at every half an hour interval for different load settings starting from two hours before and ending two hours after solar noon. The Screw Rod connected to the sliders of both the Rheostats that acts as load for both sets of panels provides different load settings namely 10%,35%,60%,85% of full load. At various load settings sufficient time is given to obtain stable readings for error free measurements. The panel temperatures of both sets of panels, air inlet and outlet temperatures current and volt are recorded automatically while mass flow rates is measured by anemometer.

RESULTS AND DISCUSSION

The temperature at different points on the panel along the axial length collected for both panels and assessed as given below in the figure 2.It is observed that with fan rotating at high speed sucking air through duct during some days of May and June 2016, it is possible to obtain axial temperature distribution $y = 39.55 - 0.068x$ for PVT system and $y = 41.72 + 0.028x$ for PV System

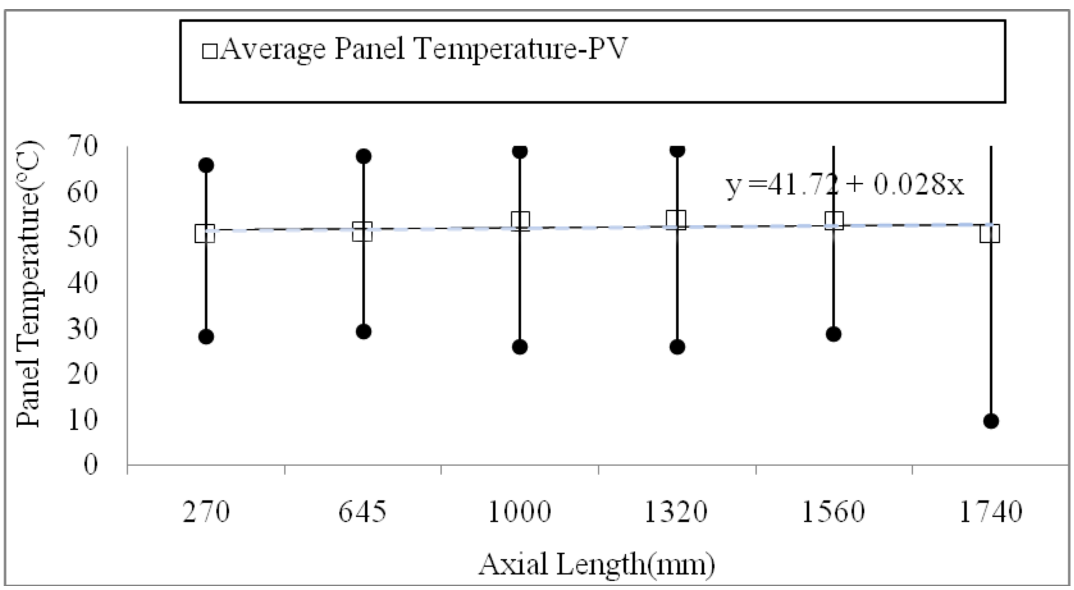

Figure 2. Measurement of Temperature of photovoltaic panels of PV and PVT air systems along the axial length

The heat absorbed by air in PVT air system is calculated using $Q = m\, c_p(T_{out} - T_{in})$, where $m=\rho AV$ denotes mass flow rate, $c_p$is the specific heat capacity of air at constant pressure, T_{out} is the outlet air temperature and T_{in} is the inlet air temperature.

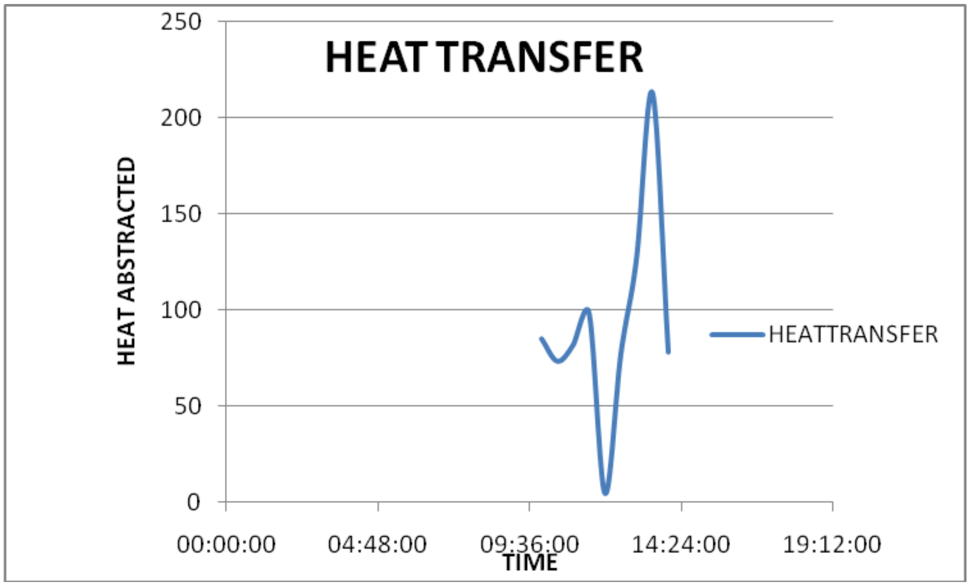

Figure 3 . Heat Absorbed through Duct

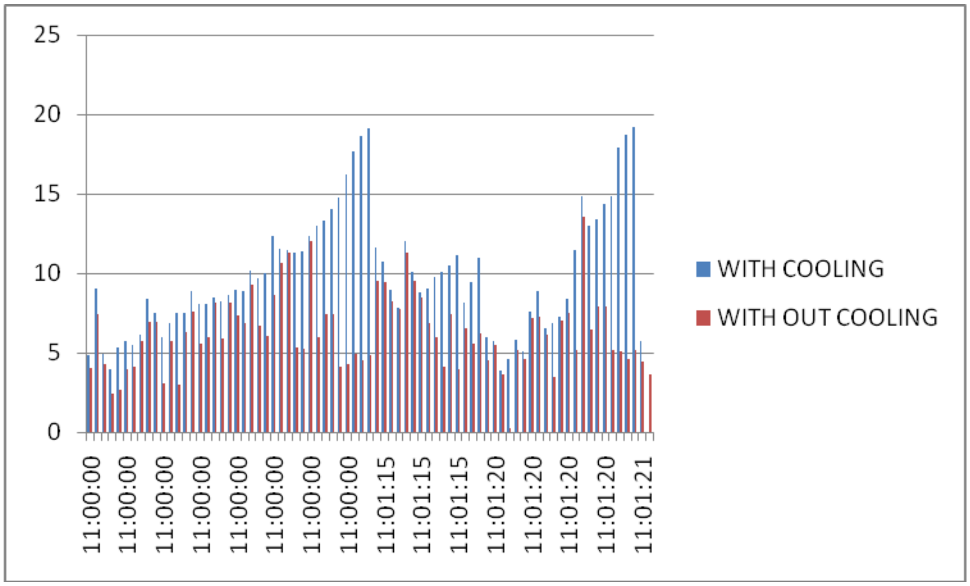

Figure 4 Electrical power output obtained with PV and PVT air system

The experiments have been conducted and readings were taken on different days starting from May 2016 to June 2016 under various climatic conditions and under different mass flow rates. The electrical power developed at 11.00 am in a 4 minute interval at different dates and at various mass flow rates are shown in figure. Measurements that have been shown were for four different load settings, say 10%,35%,60%,85% of full load. 85 seconds are the duration maintained between load settings.

The Electrical power output PV Panel fitted with duct is almost more than 50 % when compared to PV Panel with out duct as shown in fig 4. Hence it is proved than using duct underneath the panel we can produce more electrical power.

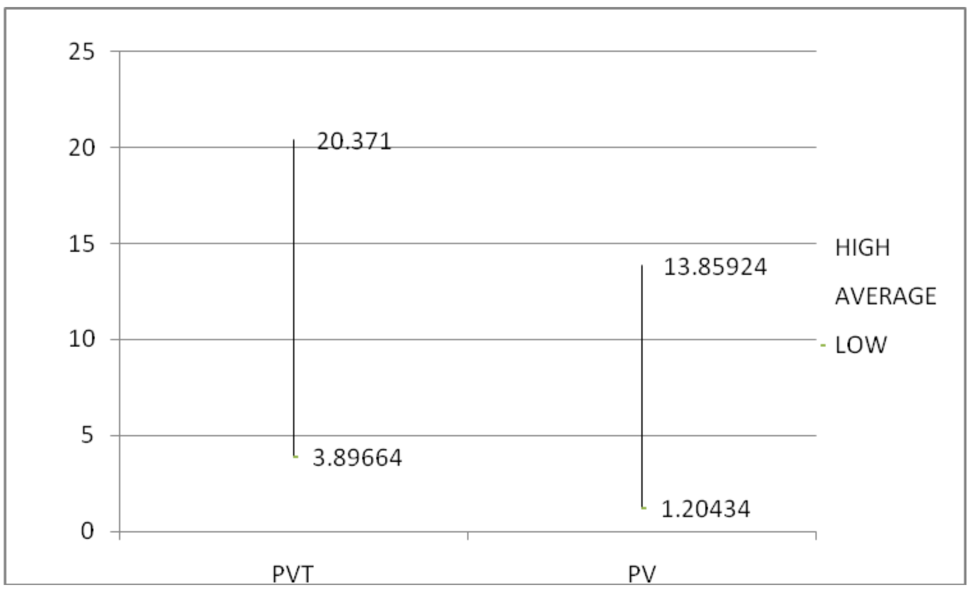

Figure 5 . Power obtained with duct

In terms of power output, Panel fitted with duct provides remarkable increase in compared to PV Panel as shown in figure 5

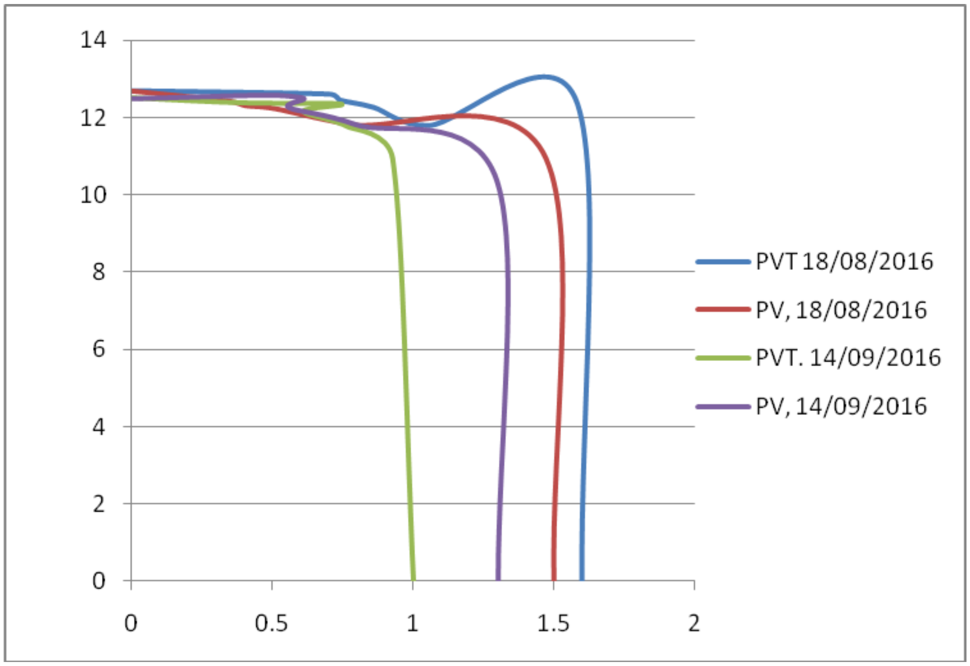

Figure 6 I-V Characteristics

Conclusions

This article reported the experimental performance of solar PVTa systems with duct fitted underneath the solar panels for the year of 2018 in the locality of Tiruchirappalli of Tamilnadu in India. The results indicated that PVT system(with cooling) with duct performed better than PV system(without cooling) The reason for enhanced energy and exergy performance of the air channel was attributed due to the phenomenon of mixing and the associated turbulence. The outcomes of the present work were summarized below.

1. The experimental findings indicated that PVTa device with duct had better thermal performance than the PV device in terms of air outlet temperature.
2. The experimental panel temperatures were in the order of 40□ C and 42□ C, while the difference in power developed was between 3 to 5 W for PVT system and PV system.
3. Heat Absorbed through the duct is around 200 W by inserting duct underneath the solar panels.
4. Power developed by the panels fitted with duct is 7 w excess of Power developed by the panels with out duct.
5. I-V Characteristics are also observed better.

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