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DEVELOPMENT OF ONLINE DATA MONITORING OF PERFORMANCE PARAMETERS OF SOLAR PV/T MODULE

Charles Franklin JOSEPH,
Department of Mechanical Engineering, Seshasayee Institute of Technology, Trichy 620010, India
charlesfrankiln@hotmail.com

It is complicated to monitor all the performance parameters of solar PV and PVT system manually .Especially with proposed experimental set up , about 72 parameters like panel temperatures, air inlet and outlet temperature, voltage and current output of both PV and PVT panels are to be monitored within 4 minutes interval(for about every half an hour) starting from 10.00 AM to 02.00 PM ie.2 hours before and after solar noon. As the no. of measurements are high, an indigenously system with ATMEL MEGA 2560and ATMEL328 microcontrollers from which data can be monitored by online developed. The performance of PV data acquistion system was tested using the experimental setup at Tiruchirappalli, Tamilnadu, India (11° N Latitude, 79° E Longitude) and the working of the PV and PVT monitoring system was tested for a period of 3 months from February 2017 to April 2017. Datataker DT 80 has been used for comparison of data given by developed DAQ system and the output shows reliable performance of self developed PV data monitoring system.

Key words: PV, PVT, data monitoring, microcontroller, WiFi module

1. INTRODUCTION

It is really cumbersome and tortuous job to monitor all the parameters that helps in analyzing performance of PV/PVT system manually as it involves lot of parameters like PV panel temperatures, air inlet and air outlet temperatures,volatage and current output of both PV and PVT systems. Hence the requirement of Data Acquisition System and automatic retrieval of data become necessary.

Earlier lot of researchers developed different PV data monitoring system to collect all functional parameters of PV panel to assess their performance[1].By using LABVIEW software an automated monitoring system had been developed by Othman et al. [2] to assess the performance of solar PV plant.Using this system, it is possible to collect data for long periods and at any time data can be retrieved.

Rezk et al. [3] have come out with low cost data acquisition system using LABVIEW to collect PV data and to analyze its performance. Using this system, it is possible to collect all electrical output parameters of stand-alone pv module and to plot current-voltage(I-V) characteristics on the spot. A cheaper wireless PV data login system was the result of Touati at al. [4] for data monitoring of remote and unattended PV installations. Using this system, it is possible to predict power output and to give an alarm about PV panel cleaning due to which drop in efficiency occurs below a threshold value because of dust settlement.

Le at al. [5] observed performance of PV system with MATLAB/Simulink in the dashboard used as input for theoretical simulation of PV performance. Using arduino mega 2560 microcontroller along with AT mega 2560 chip, Mahzan et al. [6] developed a PV monitoring system that convert the acquired raw data to digital input for data acquisition and stored the data on to a SD card. A real time clock(RTC) is used with the data logger to stamp data while logging process going on. The results converted where compared with data taken by a commercial data logger Data Taker DT80 for data reliability. Caruso et al. [7] proposed a real time monitoring system with AT mega 328P-PU microcontroller which was simple,cheap and high reliability when compared with a commercial monitoring system.

A brief comparison amongst above review illustrates that no research work were so far carried out using data acquisition system for PVT air configuration and acquiring the data in a real time scenario. Hence this paper is intended to illustrate the development of DAQ and retrieving the datas in real time scenario with DAQ comprising of ATMEL MEGA 2560 and ATMEL 328 microcontrollers. To obtain I-V characteristics for which load on PV and PVT system are to be varied automatically has been made possible by fabricated screw rod and nut arrangements that are kept over the sliders of the rheostats.

2. Experimental Set Up

The experimental test rig consisted of 2 sets of flat solar PV panels of which one was used as reference panel while the other was used as the test panel (i.e, PVT air system). Each set of panel comprised of 10 Nos. of 5 Wp panels totaling to 50 Wp connected in parallel. The testing section is bottomed by a duct measuring 2000 x 180 x180 mm. A suction draught DC fan () powered by separate solar panel (50W) is used to blow air in the duct underneath the testing section and this suction draught Fan has been fixed at upper end of the duct. 6 temperature sensors (LM 35) were fixed on the rear side of both sets of solar PV panel at a distance of 270, 645, 1000, 1320, 1560 and 1740 mm from lower end to monitor the temperature distribution along the PV panels. Dual pressure sensors that can measure both temperature and pressure were fixed at lower and upper end of the duct to measure the temperature and pressure of inlet and outlet air respectively. Current was measured with ACS712-05B (Hall Effect sensor; 5 A range) while for measuring the voltage, a simple 25 V voltage divider sensor network was used. The output from each set of panel was connected to an individual variable rheostat (0 -28 Ω) to vary the load and monitor the current voltage (IV) characteristics of the PV and PVT air systems. The rheostat sliders were connected to a screw and nut arrangement which were rotated by a DC motor (12 V) controlled automatically by a motor driver controller. The experimental set up is shown in fig. 1.

3. Description of PV monitoring system and data retrieval system

The PV monitoring system consisted of 6 main blocks like (i) power block (ii) microcontroller block (iii) sensor (iv) real time clock (RTC) block and (v) motor block (vi) data retrieval block . The function and operation of these blocks are presented in this section. The block diagram is shown in fig. 2.

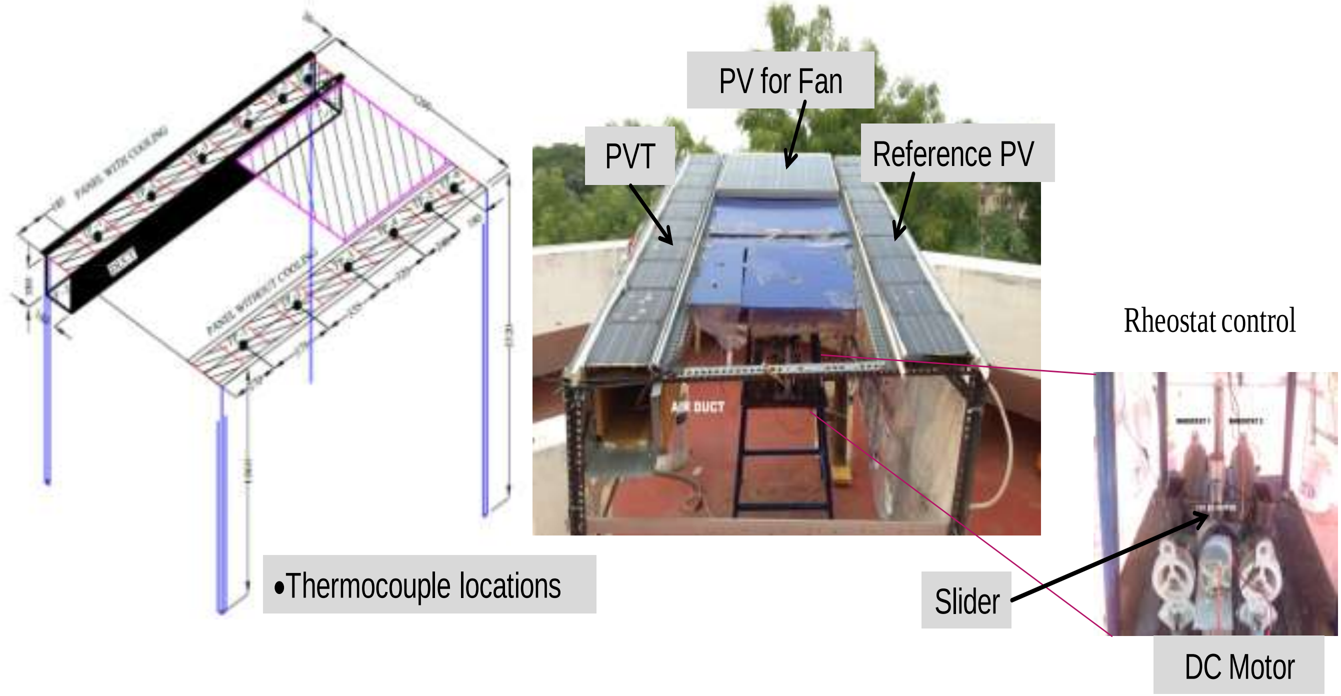


Figure 1 Experimental test facility

3.1 Power block

The power block supply 5V DC power required for the operation of the Microcontroller block, sensors and RTC Block. It also provides 12V DC power to motor block to operate the DC motor using. Since only 5 V is required to power sensors & RTC block, the voltage from 12V DC source is reduced to 5V using fixed voltage regulator (AMS1117 5.0) in the supply board (MB102). The supply board has a USB port which can be used to power the microcontroller block.

3.2 Microcontroller block

Microcontroller (ATMEL MEGA 2560) used in this work had 16 Analog input ports. Out of these16 ports, 12 ports (6 ports for the reference and 6 ports for the testing panel) were connected to 12 temperature sensors (LM 35). Ports A0 to A5 were used by the test panel and ports A8 to A13 were used by the reference panel. The remaining 4 ports were connected to digital I/O pins 50-53 of microcontroller. The analog ports were supplied with 0-5V input voltage. This microcontroller supports I^2C communication protocol. SD Card (4GB) communicates with microcontroller using SPI Interface. SPI Interface consisted of MOSI, MISO, SCK, CS, VCC and GND. V_{CC} & GND were connected to inbuilt microcontroller power supply. LCD display is operated in a 4-bit, WRITE mode and the data lines are connected to the 4 digital I/O ports. The backlit LED light is supplied with 5V DC for the visibility of the characters and the contrast for the LCD display is set by using the PWM output.

3.3 Sensor block

Sensor block consisted of various sensors for the measurement of temperature, pressure, current and voltage. Temperature sensors (LM35) are attached to the rear side of the PV panel to measure the panel temperature (T_p) at 6 different points of the test and reference panel as discussed in the previous section. The output voltage produced by the temperature sensors were in the range of 0- 10mV/°C and the signals were fed to analog input ports of the microcontroller. Pressure sensors (BMP180) measure the absolute pressure (*p*) at the both the ends of the duct and they also measure the temperature of the air (T_a) at the inlet and outlet of the duct. As both the pressure sensors have the same address and uses I^2C communication protocol to send data to the microcontroller, a serial analog multiplexer 74HC4052 was used to select the appropriate pressure sensor. The current was measured with 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 with the increase in the current the voltage output signal is 185 mV/A. For measuring voltage, voltage divider sensor network was 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.

3.4 RTC block

The heart of the PV monitoring 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 multiplexer for working in conjunction with the pressure sensor. For accessing this module DS3231 library is used in program to transmit and receive data. 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.

3.5 Motor block

The motor block was designed with a 5V relay and L293D motor driver for forward and reverse operation of the motor. It consisted of 2 input 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.

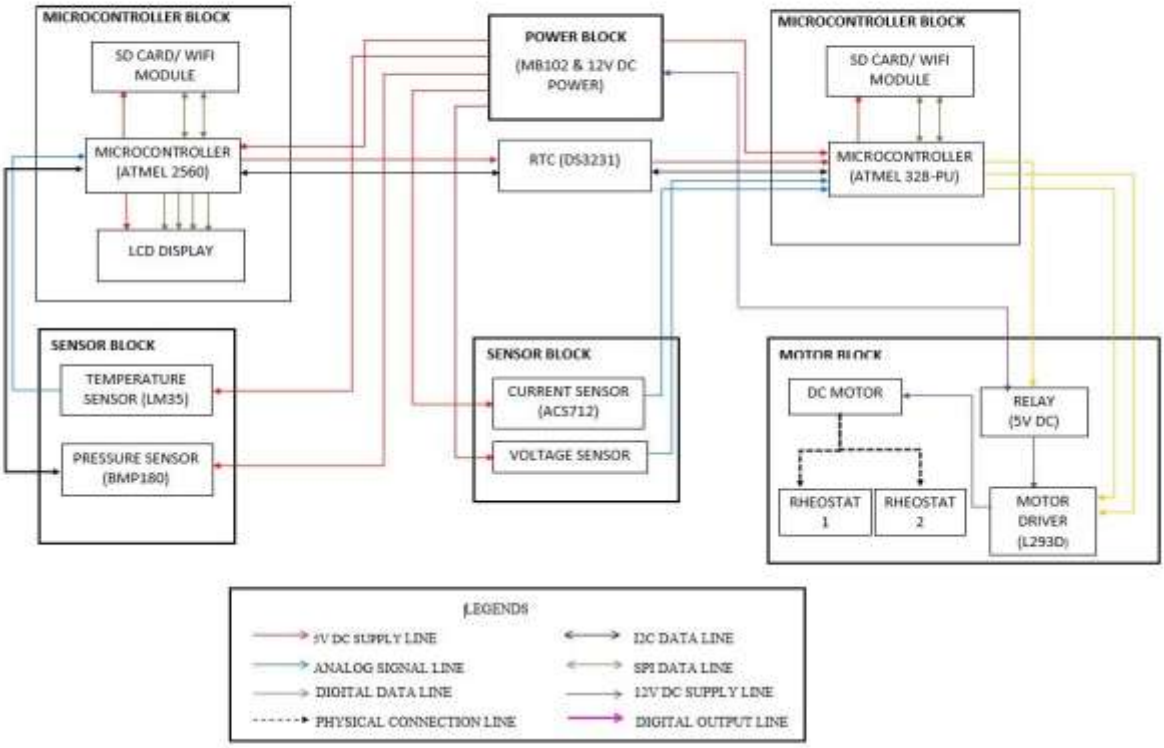
3.6 Data Retrieval block

The data can be monitored in real time using the dashboard (Web App). The hardwares that are used are Raspberry Pi Model 4 2GB,WiFi modules (ESP-01) for microcontrollers, Working Internet connection at home. Both microcontroller blocks are modified to connect to the internet using the WiFi module (ESP-01). The microcontroller is then connected to the MQTT broker using the WiFi connection. The microcontroller publishes the processed data to the topic. The Raspberry Pi(RPi) hosts the MQTT broker and also acts as a gateway to the end user to access the dashboard. Whenever a value is published from the microcontroller the data is stored in a Database (SQL DB preferred). When an end user is using the dashboard for real time monitoring, the old data stored in the DB is retrieved and plotted and then followed by new data also being plotted on the dashboard. Real time data monitoring is based on the Web Sockets.

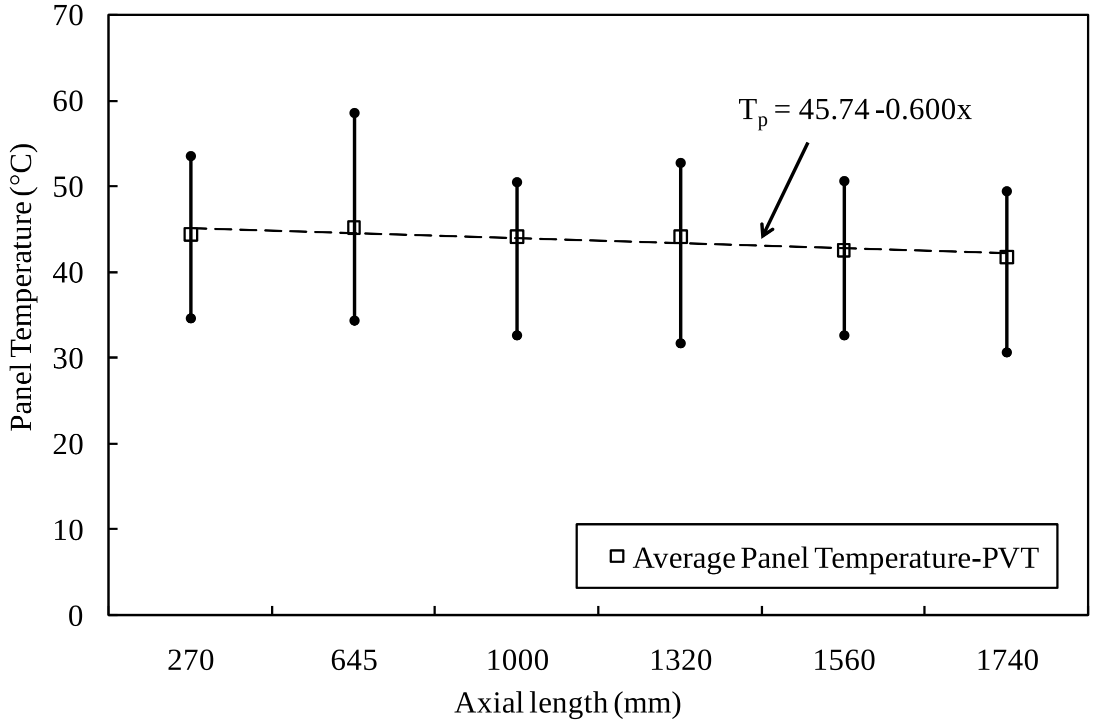
Figure 2 Layout of PV monitoring system

4. Results and discussion

4.1 Thermal Characteristics



The temperature of photovoltaic panels of the PV and PVT air systems measured with the monitoring system along the axial length are shown in fig. 3. The maximum, minimum and the average panel temperature are also shown in the fig. 3. It is observed that that the maximum panel temperature of PV and PVT air system are 100°C and 60°C respectively. The average temperature of the photovoltaic panels is about 53°C and 45°C for PV and PVT air system respectively. Also, it was observed that the axial temperature distribution has a positive and negative coefficient of axial distance (T_p = 52.77 + 0.282x and T_p = 45.74 - 0.600x) for PV and PVT air system respectively which reveal the PVT air system used in the present work is capable of maintaining lower panel temperatures by providing sufficient cooling on the rear side of the photovoltaic panel due to forced heat transfer convection.



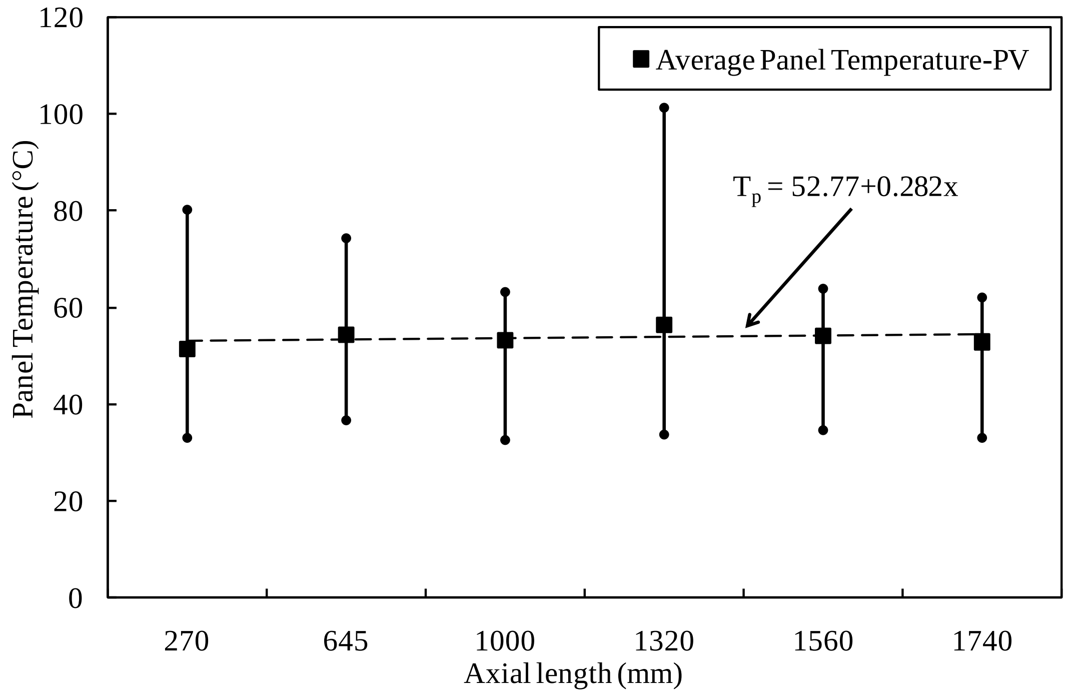


Figure 3 Temperature of photovoltaic panels of the PV and PVT air systems measured with the monitoring system along the axial length

The heat absorbed by the air in PVT air system was calculated first principles using $Q = mc_p(T_{out} - T_{in})$, where $m = \rho AV$ is the mass flow rate of rate, c_p is the specific heat capacity of air at constant pressure, T_{out} is the outlet temperature of air and T_{in} is the inlet temperature of air. The inlet and outlet temperature of air during the experiments is shown in fig. 4. It is revealed that outlet air temperature is increased by 2- 4°C compared to the inlet air temperature.

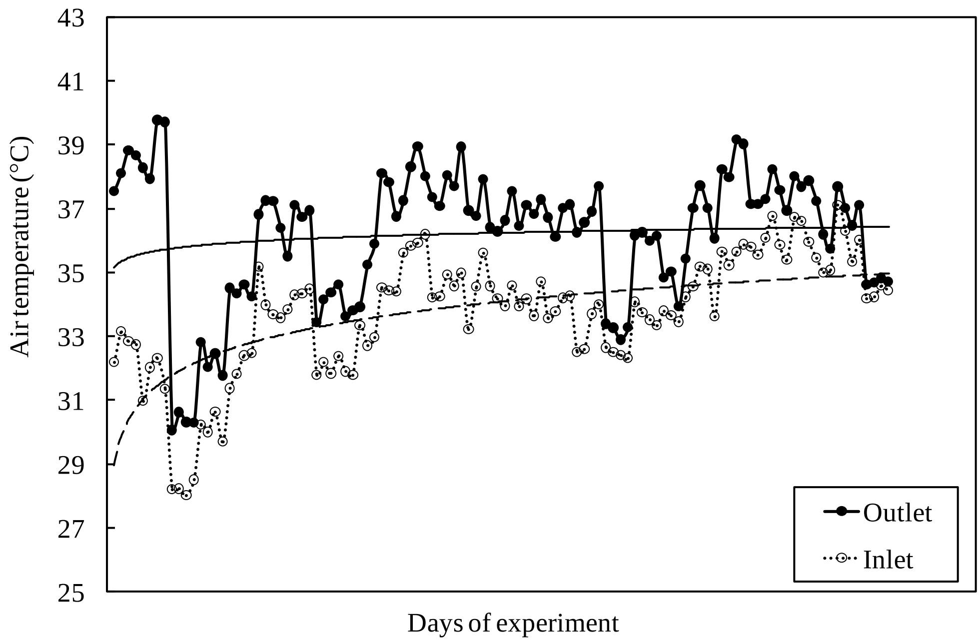


Figure 4 Inlet and outlet temperature of air in PVT system

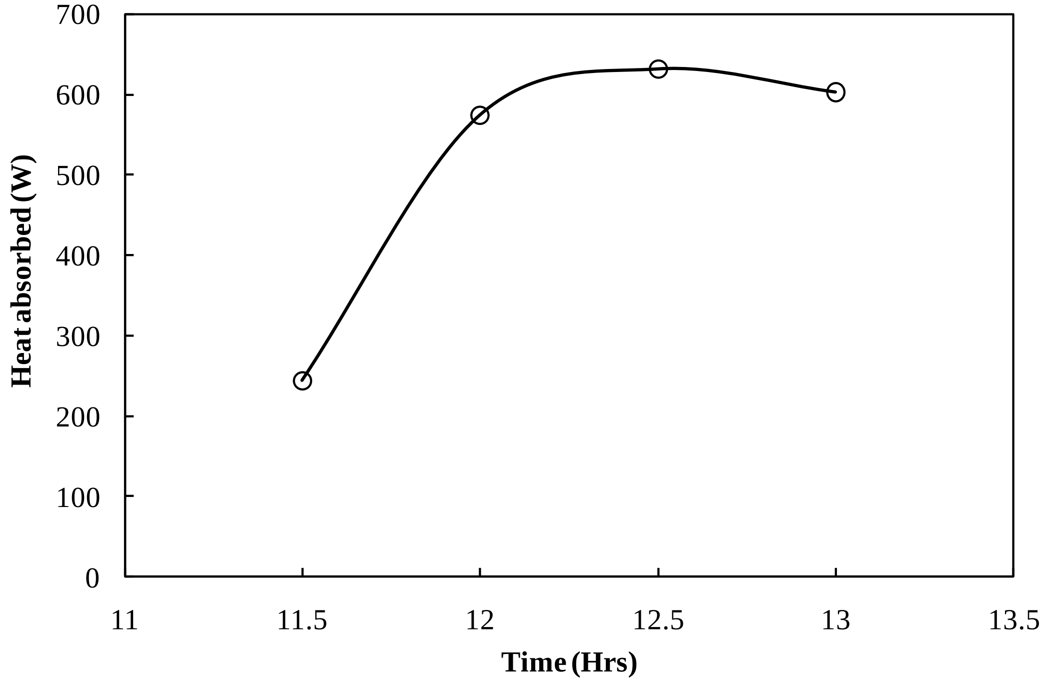


Figure 5 Heat absorbed by the air in PVT air system

The heat absorbed by air in PVT air system during a solar noon (26/5/2017) was depicted in fig. 5 which indicate about 600 W of heat could be extracted by the air from the PV panel and could be used for residential building heating purposes. Due to rapidly changing nature of solar energy, the heat absorbed by air in PVT air system may increase or decrease significantly. This is the reason for the sudden increase of heat energy absorbed by the air.

4.2 Electrical Characterieristics

The electrical power output obtained with the developed on different days of experimentation (February to April. 2017) at 11 am in a 4 minute interval with PV and PVT air system is illustrated in fig. 6 in which the hollow bars represent the power obtained with PVT air system while solid bars represent the power obtained with PVT air system. During the 4 minute interval, measurements were recorded for 4 different load settings that vary from 80% of the full load to 20% of the full load of the rheostat. The duration between the different load readings is about 80 second. It is evident that the electrical power output from PV is enhanced with PVT air system which is attributed to cooling effect caused by the air movement through the duct placed underneath of the PV surface. Fig. 7 shows the electrical power yield recorded with the monitoring system from November 2016 to May 2017. The maximum power developed was 24.33 W and 16.1 W with PVT air and PV system respectively while the average power developed was 8.45 W and 6.34 W with PVT air and PV system respectively.

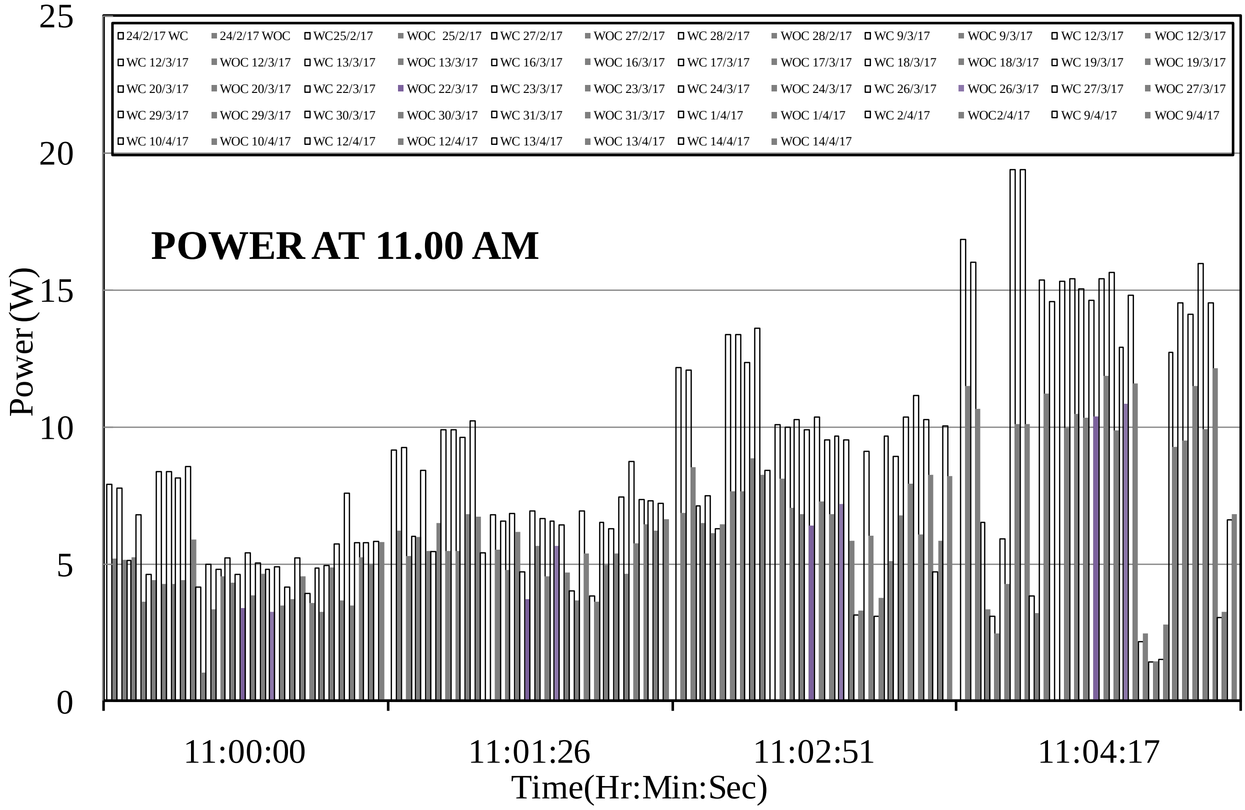


Figure 6 Electrical power output obtained with PV and PVT air system

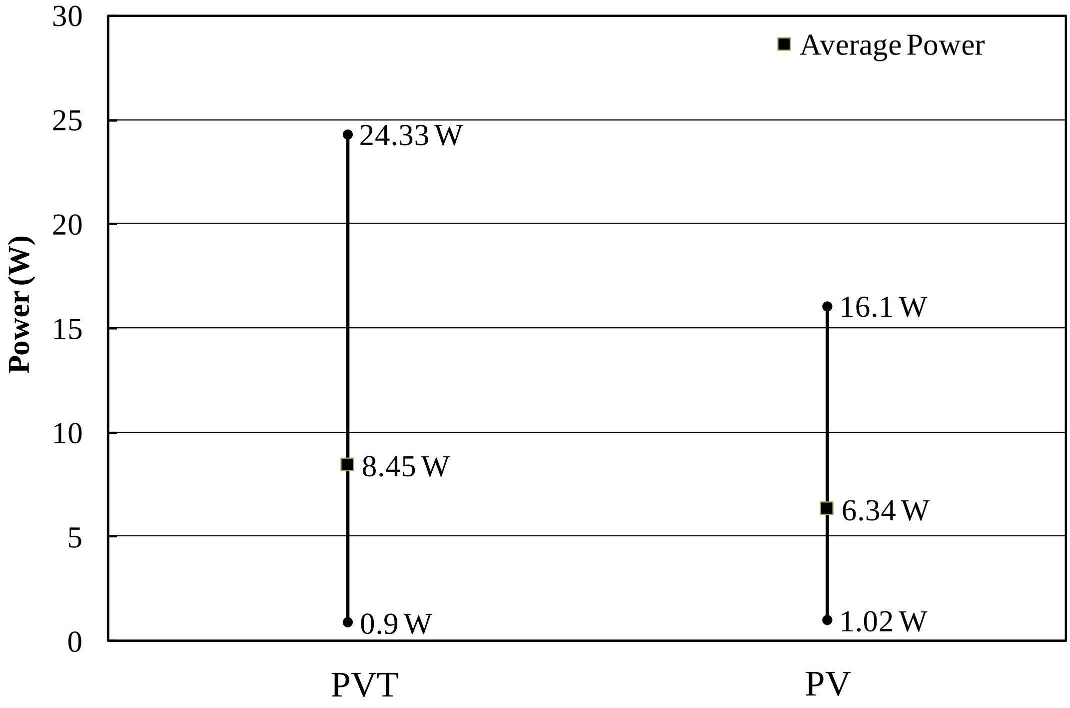


Figure 7 Comparison of electrical power yield

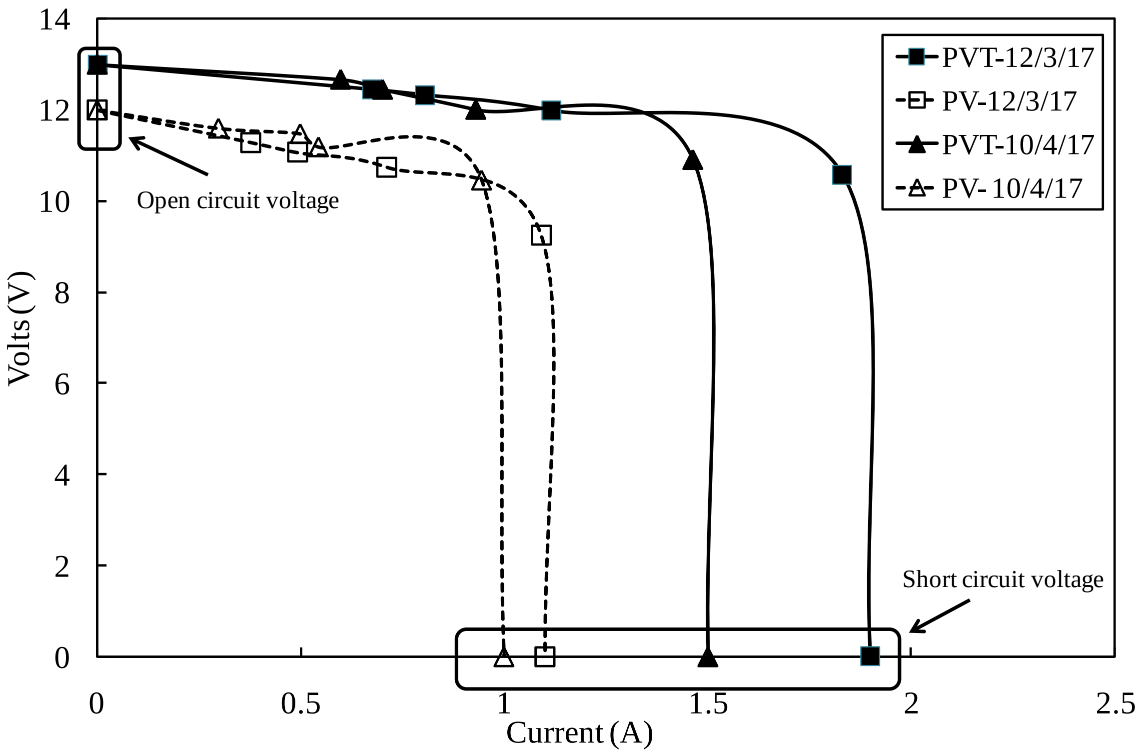


Figure 8 I-V characteristics

I-V characteristics were also monitored and a sample I-V traced on 12/3/2017 and 10/4/2017 is given in fig. 8. The increase in power output with PVT air system is due to increases in both the short circuit current and open circuit voltage. It is revealed that the in PVT system, the open circuit voltage is increased to 13.5 V while the short circuit current is increased to 1.9 A in contrast to respective values of 12 V and 1 A with PV system due to the cooling PV modules in PVT.

5.3 Validation of PV monitoring system

In order to validate the proper functioning of the PV monitoring system, various parameters measured by it were compared with those obtained with a commercial data logger. The correlation coefficient (*r*) was evaluated by the following expressions to highlight the strength of a linear relationship between the values obtained with the developed monitoring system and commercial data logger (Datataker-DT80, Australia).

$$r = \frac{n\left(\sum xy\right) - (\sum x)(\sum y)}{\sqrt{n\sum x^2 - (\sum x)^2}\sqrt{n(\sum y^2) - (\sum y)^2}} \tag{1}$$

where x represents the values measured with the proposed monitoring system, y represents the values measured with the commercial data logger and n represent the number of pairs of data. The values of correlation coefficient (*r*) for various parameters are listed in tab. 1. which indicated that the measurements given by the monitoring system were in good agreement with the values obtained with commercial data logger as the values of *r* is greater than or equal to 0.94 for the monitored values.

Table 1 Values of regression coefficient (*r*)

Sl.No.	Parameter	Correlation coefficient (*r*)
1	Current	0.98
2	Voltage	0.98
3	Temperature	0.96
4	Pressure	0.94

Acknowledgement

The author are thankful to TEQIP phase II for the creation of data logger facility (Datataker-DT80, Australia) at the department of Mechanical Engineering of Anna University BIT campus Tiruchirappalli with which the measured PV parameters by the developed monitoring system are validated.

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