Study of Performance of Solar Photovoltaic Thermal Collector at Different Temperatures

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Abstract- Photovoltaic is the method of producing electricity by using the solar cells. The main problem associated with the solar cell is its lower efficiency. Photovoltaic cell converts only about 15% of the solar energy falling into the useful electricity. The increase in the temperature increases the resistance of these cell and in turns decreases the cell efficiency. So, cooling these panels is the effective way of increasing the cell efficiency. This work here primarily concentrate on two objectives. First one, to show that the performance of the solar panel increases by reducing the temperature. This cooling is done by air cooling or water cooling on the self designed modified panel. The second objective is to show that the heat removed can be used for other useful purpose like room heating, supplying to power plants, etc. In this present work the solar panel is cooled by passing air with the help of blower and cooling the panel by water based system by making the copper channels on the rare side of the panel.

Index Terms- Photovoltaic, Cell efficiency, panel

I. Introduction

Solar energy is the best alternative source for the replacement of the conventional sources of energy which are constantly depleting. Most of the energy demand of the present world is being satisfied by the fossil fuels. The harmful gases emitted by burning these fossil fuels have reached the alarming level in the present global scenario. So, the global community is shifting and looking forward for the reliable source for the energy consumption and the minimizing climate changing effect. Global innovation for the alternate sources of energy has contributed to the development and research in the sector of the renewable energy. Primarily photovoltaic solar energy can be the promising renewable energy source. The photovoltaic cell generates the electricity when exposed to the sun in the external environment. As these are exposed to the environment, the external factors and environment influences the performance and working of these panels. Temperature and irradiation intensity are two environmental factors that affects the performance and efficiency of these panels. So, thermal factor is the main factor that determines the maximum power output of the solar panel.

The present work here deals with the designing of the channel type PV/t system for the passing of the air and water that takes away the heat energy from the panel. Here the electric efficiency, power output and thermal efficiency of the panel are studies under different temperature for the normal solar panel, water based system and air based system.

II. Literature Review

M.S.Sodha et al[1].developed a thermal model of an integrated photovoltaic and thermal solar (IPVTS) water/air heating system. They gave an analytical expression for the temperature of solar cell and water and an overall thermal efficiency of IPVTS system have been derived as a function of climatic and design parameters. In this paper numerical computations have been carried out for composite climate of New Delhi for parametric studied. Comparison of the IPVTS system with water and air heater has also been carried out. It is found that the characteristic daily efficiency of IPVTS system with water is higher than with air. An analytical expression for the water temperature of an integrated photovoltaic thermal solar water heater under constant flow rate hot water withdrawal has been obtained and investigated by Arvind Tiwari et al.[2].In this work, the analysis based upon basic energy balance for hybrid flat plate collector and storage tank, respectively, in the terms of design and climatic parameters. And also the further analysis has been extended for hot water withdrawal at constant collection temperature. In this paper numerical computations have been carried out for the design and climatic parameters of the system used by Huang et al. It is observed that the daily overall thermal efficiency of the present system increases with increase constant flow rate and decrease with increase of constant collection temperature. The exergy analysis of IPVTS system has also been carried out. It is further to be noted that the overall exergy and thermal efficiency of an integrated photovoltaic thermal solar system (IPVTS) is maximum at the hot water withdrawal flow rate of 0.006 kg/s. Wei He et al.[3] found out using experiments that the electricity conversion-efficiency of a solar cell for commercial application is about 6–15% and 85% of the incoming solar energy is either reflected or absorbed as heat energy. Thus the working temperature of the solar cells increases considerably after prolonged operations and the cells efficiency drops significantly. They concluded that for improving the efficiency of solar cell, hybrid photovoltaic and thermal (PVT) collector technology using water as the coolant has been seen as a solution for improving the energy performance. Through good thermal-contact between the thermal absorber and the PV module, both the electrical efficiency and the thermal efficiency can be raised. Fin performance of the heat exchanger is one crucial factor in achieving a high overall energy yield. In this paper, the design developments of the PVT collectors are briefly reviewed. Their observation is that very few studies have been done on the PVT system adopting a flat-box absorber design. Accordingly, an aluminum-alloy flat-box type hybrid solar collector functioned as a thermosyphon system was constructed. While the system efficiencies did vary with the operating conditions, the test results indicated that the daily thermal efficiency could reach around 40% when the initial water-temperature in the system is the same as the daily mean ambient temperature. Anand.S.Joshi [4] has been made an attempt in this paper to evaluate exergy analysis of a hybrid photovoltaic–thermal (PV/T) parallel plate air collector for cold climatic condition of India (Srinagar). The climatic data of Srinagar for the period of four years (1998–2001) has been obtained from Indian Metrological Department (IMD), Pune, India. Based on the data four climatic conditions have been defined. The performance of a hybrid PV/T parallel plate air collector has been studied for four climatic conditions and then exergy efficiencies have been carried out. It is observed that an instantaneous energy and exergy efficiency of PV/T air heater varies between 55–65 and12–15%, respectively. These results are very close to the results predicted by Bosanac et al.This paper presents a review of the available literature on PV/T collectors by P.G.Charalambous[5] The review is presented in order to enable an easier comparison of the findings obtained by various researchers, especially on parameters affecting PV/T performance (electrical and thermal). The review covers the description of flat plate and concentrating, water and air PV/T collector types, analytical and numerical models, simulation and experimental work and qualitative evaluation of thermal/electrical output. The parameters affecting PV/T performance, such as covered versus uncovered PV/T collectors, optimum mass flow rate, absorber plate parameters (i.e. tube spacing, tube diameter, fin thickness), and absorber to fluid thermal conductance and configuration design types are extensively discussed. Based on an exergy analysis, it was reported that the coverless PV/T collector produces the largest available total (electrical + thermal) exergy. From the literature review, it is clear that PV/T collectors are very promising devices and further work should be carried out aiming at improving their efficiency and reducing their cost, making them more competitive and thus aid towards global expansion and utilization of this environmentally friendly renewable energy device. Experimental and numerical simulations were implemented by Tiwari *et al.*[6] to evaluate the overall performance of PV/T air collector. In this study, different kind of configurations of PV/T air collector (like unglazed, glazed, with and without tedlar were used to investigate the electrical and thermal performance. It was shown that the glazed PV/T air collector without tedlar provides the best performance. Saurabh Mehrotra et al [7].also studied and done experimental analysis related to solar cell immersed in water. They also studied the performance of solar cell with temperature. With the increase in surface temperature of solar cells or panels their efficiency decreases quite dramatically. To overcome the heating of solar cell surface, water immersion cooling technique can be used i.e. it can be submerged in water so as to maintain its surface temperature and provide better efficiency at extreme temperatures. In this study, electrical parameters of solar cell were calculated which showed that the cooling factor plays an important role in the electrical efficiency enhancement. Solar cell immersed in water was monitored under real climatic conditions; cell surface temperature can be controlled from 31-39 .C. Electrical performance of cell increases up to great extent. Results are discussed; panel efficiency has increased about 17.8% at water depth 1cm. The study can give support to the concentrated photovoltaic's System by submerging the solar cells in different mediums.

III. Experimental Investigation

Separate models for the air based and water based PV/T system were self designed by using the locally available materials and the performance was studied. Temperature sensors were used for temperature measurement.

*1.1 **Experimental Setup***

Three different 20 W panels were used for the purpose of experimentation. One of the panels was studied without any modification on it and other two were modified to fit our suitable system for the study and experimentation purpose. The solar panel was manufactured by the Didas International. The solar panel had the dimensions of 20*550*350 mm^3. Figure below shows the complete setup.

Fig: Complete setup to study performance.

In the figure the normal solar panel and the modified solar panel are placed side by side. The rear side of the panel is modified so as to prevent the heat loss and utilize the heat absorbed by the flowing fluid for useful purpose.

Experimental Setup for Water Based System

For the experimental setup of the water based system, the channel made of the copper tubes is prepared and fabricated on the rear side of the panel. The tubes have the black coating on the outer surface and it has exit and inlet hose for the water to flow. The tubes were taken from the refrigerator radiator. Different temperature sensors were placed at different position on the rare side of the panel to monitor the temperature. Water is passed through these channels and they decrease the temperature of the panel. The electric performance is measured at this temperature.

Experimental Setup for Air Based System

The fabrication of the air based system was easier than the water based system. Here the blower was used to continuously pump the air at the rear end of the panel. The entire rear surface was covered with the insulation material (thermacol) and exit and entry for the air was provided. The temperature sensors were placed to monitor the temperature**.**

1.2 Experimental Procedure

The flow rate for the water is measured and the water is passed through the water channels fitted at the rare side of the panel. The temperature of the panel is noted from the temperature sensor and it is maintained to specific temperature and the voltage and current of the panel is measured by the help of the digital multi-meter.

Then, for the air based system the blower is connected and flow rate of the air is measured by the help of the digital anemometer. The temperature of the panel gradually reduces and the current and voltage output of the panel was taken at some specific temperature.

1.3 Mathematical Relations

The thermal efficiency of the PV system is given by the relation below

$\eta_{\text{thermal}} = \{ m\, C_p\, (T_o - T_i)\}/HA$

Here m is mass flow rate in kg/s and Cp is specific heat in J/Kg K. T_o is the outlet temperature in K, T_i is inlet temperature in K and A is area of the panel in m2and H is the solar radiation in W/m^2.

Thermal efficiency depends on the mass flow rate, temperature difference and incident solar radiation. The temperature in turn depends on the ambient temperature.

The electrical efficiency can be calculated by the formula given below

$$\eta = \frac{V_{OC} I_{SC} FF}{P_{in}}$$

The fill factor can be calculated as

$$FF = \frac{P_m}{V_{OC} \times I_{SC}} = \frac{\eta \times A_c \times E}{V_{OC} \times I_{SC}}.$$

The fill factor is defined as the ratio of the actual maximum obtainable power to the product of the open circuit voltage and short circuit current. This is a key parameter in evaluating the performance of solar cells. Here Voc is open circuit voltage of PV module in Volts and I_{sc} is short circuit current of PV module in ampere. FF is fill factor of the PV module.

IV. Result and Analysis

From the experimental analysis the data is taken, calculated and these data are plotted into the graph s that is shown below. The data is taken at different temperature; especially at temperatures 28^{0}C, 32^{0}C, 36^{0}C and 40^{0}C. At these temperatures electrical efficiency, thermal efficiency and output power is calculated and graph for these parameters is drawn.

The graph below shows the temperature at different time of the same day.

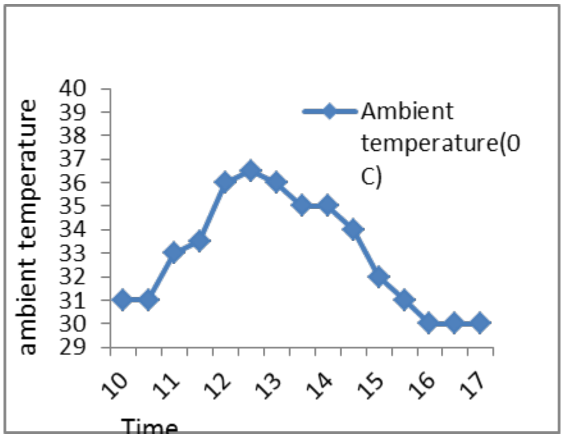

Fig: Time vs Ambient Temperature (^{0}C)

The temperature was noted on the specific day and it was found that the temperature on the next day was almost the same.

Different graphs for the thermal efficiency, electrical efficiency and the power output plotted.

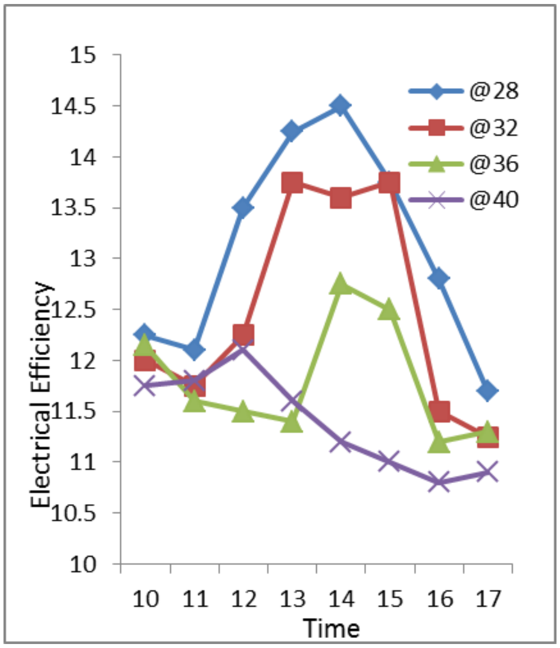

Fig: Time vs electrical efficiency for water based system

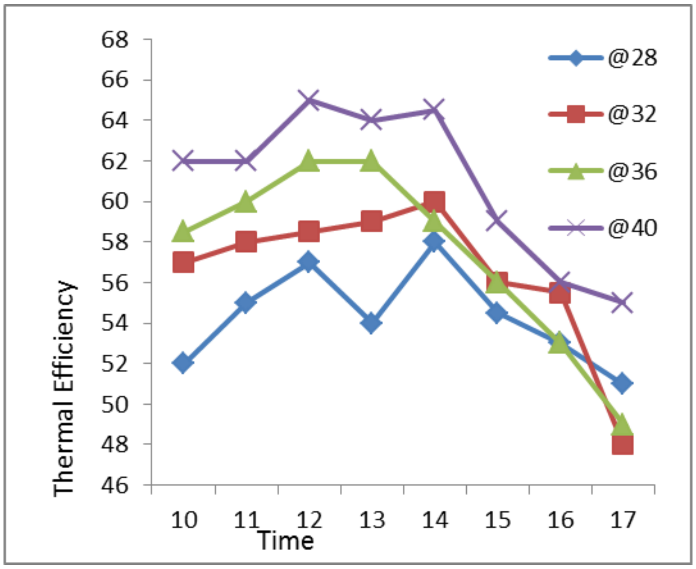

Fig: Time vs Thermal efficiency for the water based PV/T system

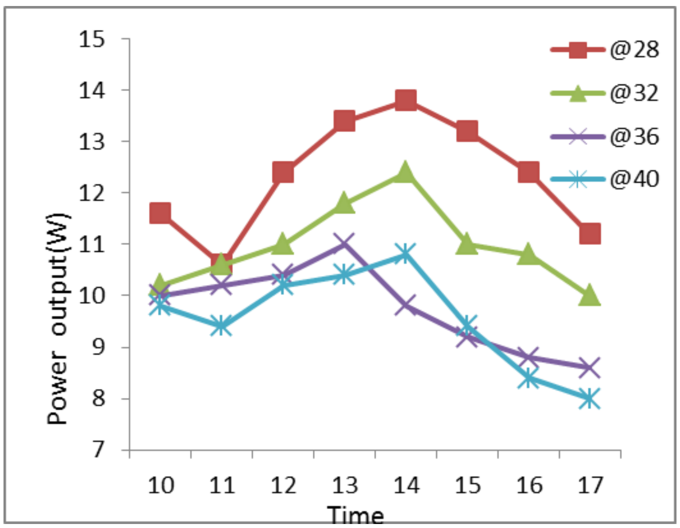

Fig: Time vs Power output for the water based PV/T system

The above graph gives the clear variation of the power output at different timings during a day. The power of the panel is calculated at different temperature and it is noted down. The power output is in Watts and it is found out that the power output is maximum at 28^0C. From the observation it is found that as the temperature decreases the maximum power of the panel start increasing. The four values of temperature were taken and the graph was drawn for showing the variation of power output at same time during the day for different temperature values.

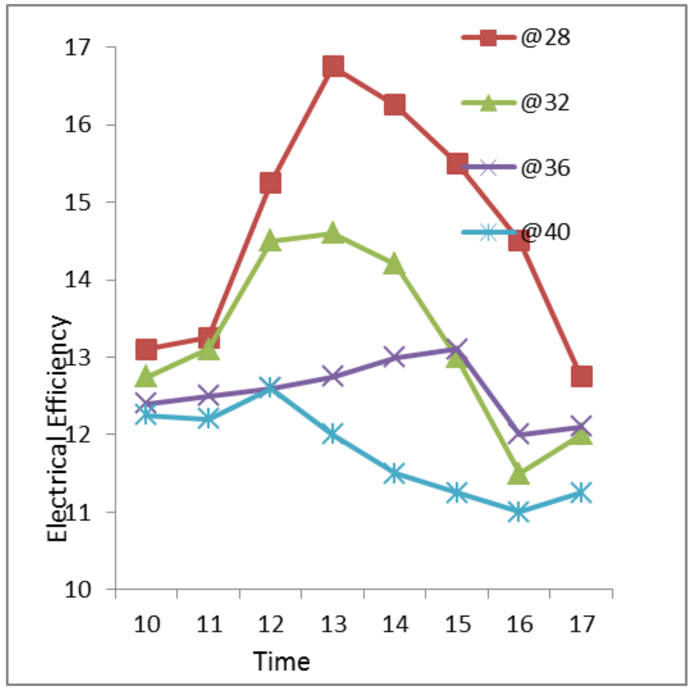

Fig: Time vs Electrical efficiency of the air based PV/T system

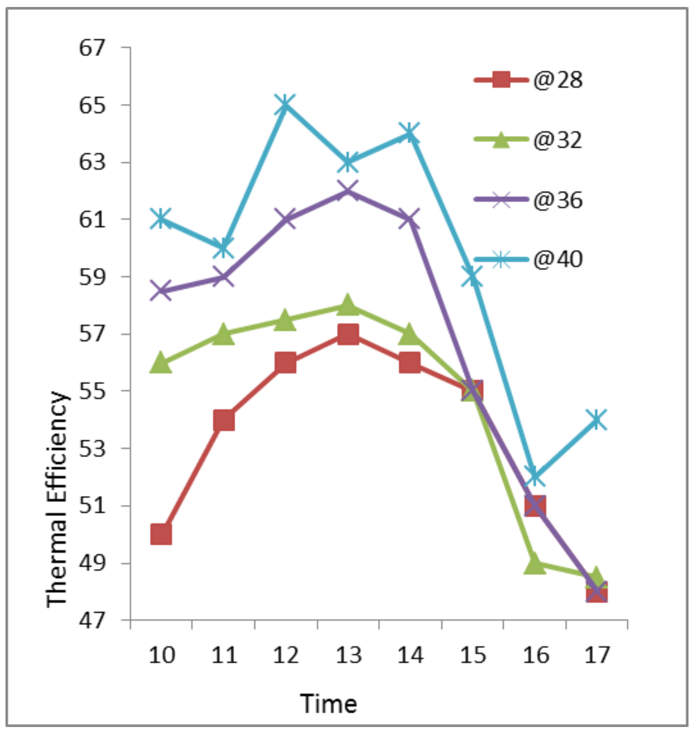

Fig: Time vs thermal Efficiency of the air based PV/T system

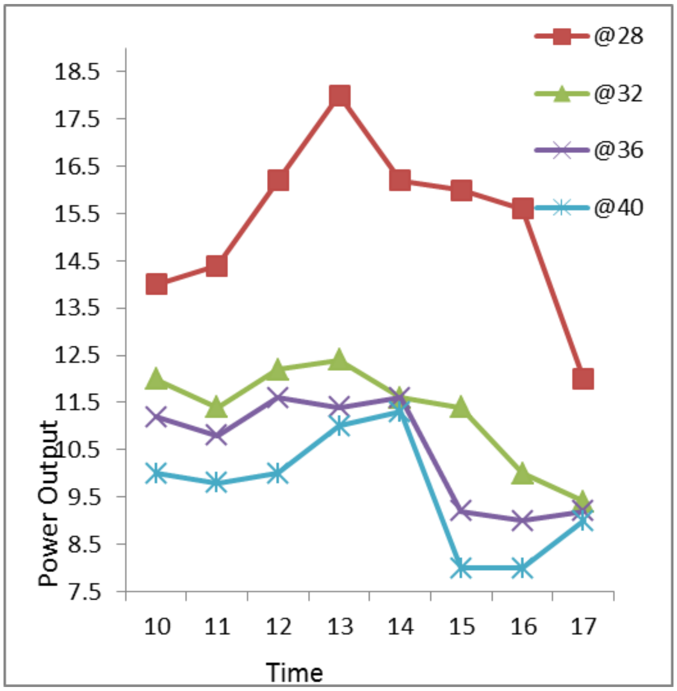

Fig: Time vs power output of the air based PV/T system

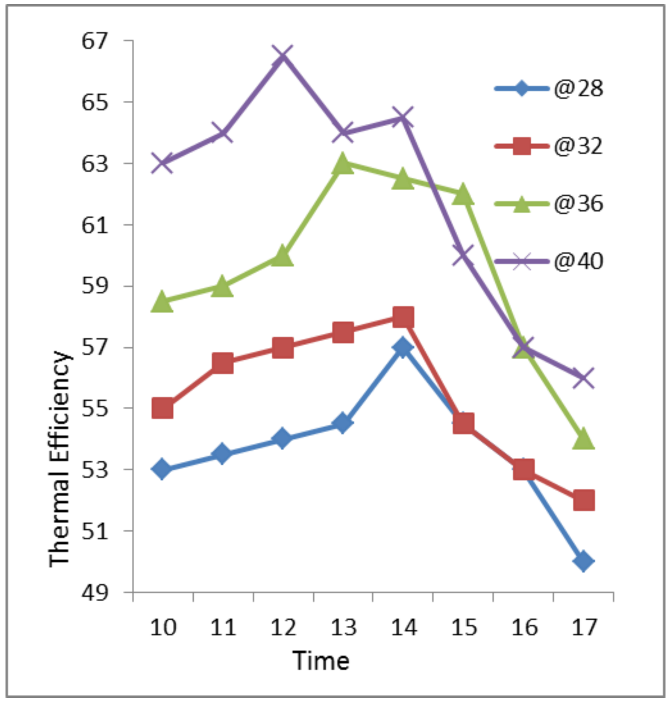

Fig: Time vs Thermal Efficiency of normal panel.

From the above graphs we can analyze that at the same time during the day there is the difference in nature of variance of the electrical efficiency and thermal efficiency as a effect of temperature of the panel. As, the temperature of panel rises the electrical efficiency decreases whereas the thermal efficiency increases. For the air based PV/T also we can conclude that as the temperature decreases the maximum power increases.

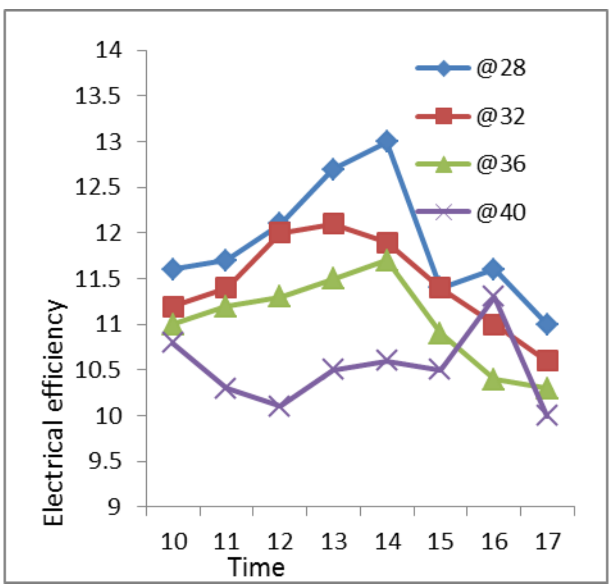

Fig: Time vs Electrical Efficiency of normal panel

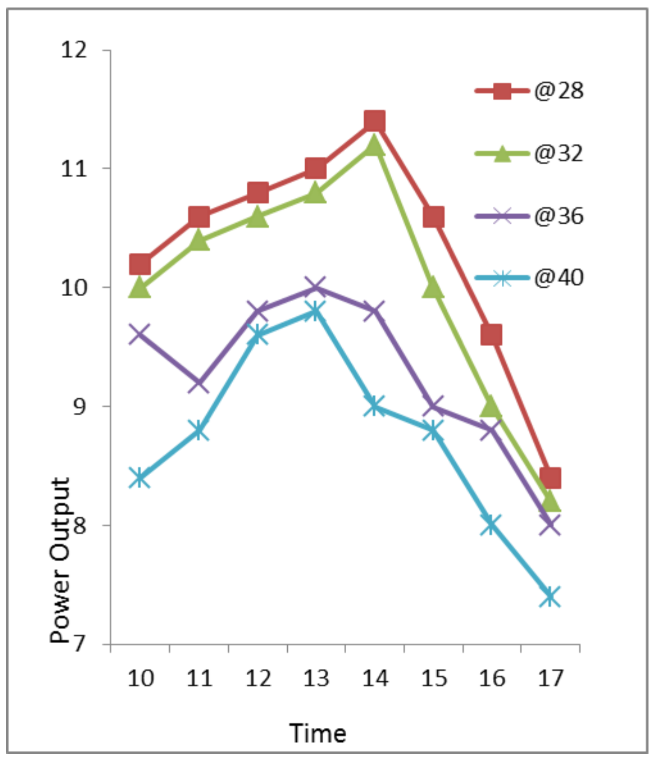

Fig: Time vs power output of Normal panel

V. CONCLUSION

From the detailed study and analysis of the graph for the power output, electrical efficiency and thermal efficiency it can be concluded that the power output and the electrical efficiency of the panel increases on cooling the panel. From the detailed study the two methods used- water based cooling and the air based system, it can be concluded that both can be used for cooling of the panel. When there is the lowering of the temperature there is the increase of the performance factor of the panel. We can also have the advantage of such type of cooling. The heated fluid can be used for other various purposes. So this installation can avoid the use of separate air heater and water heater. So, from this technique we can get both the advantage increase of performance factors and getting heated air or water.

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