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EFFECT OF OPERATING PARAMETERS ON THE PERFORMANCE OF THE HYBRID SOLAR PVT COLLECTOR UNDER DIFFERENT WEATHER CONDITION

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Abstract: A standalone hybrid solar air collector has been developed and tested for unload conditions at the Maulana Azad National Institute of Technology, Bhopal, India. The collector has been tested under two weather conditions namely (i) clear sky and (ii) cloudy and partially hazy. The effect of different design, operating and climatic parameters such as solar radiation intensity, relative humidity, wind velocity, ambient temperature, cell temperature and back cell temperature on the electrical performance of hybrid solar air collector has been observed and analysed with reference of two weather conditions stated above. It is observed from the experimentation that the electrical efficiency is higher when the Cell temperature and back cell temperature are low in the clear sky conditions.

Keywords: Hybrid solar air collector, cell temperature, weather conditions, electrical performance.

Introduction

Among all solar energy technologies, the hybrid photovoltaic–thermal (PV/T) systems offer an attractive option because the absorbed solar radiation is converted into thermal and electrical energy (the conversion can be done separately or simultaneously). Flat-plate collectors are the most common devices that combine thermal and electrical generation. In order to evaluate these types of collectors, a performance analysis must be undertaken in accordance with the standard test methods available. This can provide objective information, valuable for designers and manufactures in the frame of collector design and system performance optimization for a particular application. Moreover, consumers can also compare the performance and cost-effectiveness ratio of a competing product. Albeit, no dedicated guideline, as a standard test procedure, exists for the performance testing of PV/T flat-plate collectors until now. This field has not been investigated extensively in the literature; only a few references refer to PV/T models that can be applied to transient weather conditions. On the other hand, a wide number of studies associated with the PV/T collectors

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have been reported in the literature. Most of them are studies about electrical and thermal performances under steady-state conditions [1–3]. Nevertheless, steady-state outdoor testing includes several difficulties associated with the weather conditions. In many places in the world and over many periods throughout the year, the weather conditions do not fulfil the requirements for the steady-state method and long testing periods may be needed to acquire steady-state values. Dynamic or quasidynamic characterization methods can offer an effective alternative to overcome these problems. Some representative references regarding quasi-dynamic and dynamic procedures are described below.

Bernardo et al. [4] proposed an empirical model which approaches well the specific thermal power under unstable conditions. However, the specific electrical power predicted by the model showed wider divergences in comparison with the results shown in the thermal part. This system works under concentrated radiation delivered by a parabolic trough reflector. Concentrating PV/T collector using lenses are also characterized, i.e. the Fresnel concentring system presented by Chemisana et al. [5]. Jie et al. [6] developed a transient method for a hybrid PV/T collector wall (Building Integrated Photovoltaic–Thermal – BIPVT-type). The system was modelled and simulated with a special program, HYBRIDPV-1.0, written in FORTRAN. A performance analysis of a PV/T collector by means of an explicit dynamic model was proposed by Chow [7]. The model is suitable for dynamic system simulation applications. The electrical characterization was conducted by using the electric power generated under similar terms as the traditional linear expression for the thermal dependence of the PV electrical efficiency [8]. Using the lineal expression for PV efficiency dependence, Solanki et al. [9] conducted an indoor characterization and modeling of a PV/T air collector concluding that the results obtained were similar with those obtained outdoors. In addition, the nature of the characteristic curve found out was similar to the one performed by Hottel–Whiller–Bliss for flat plate collector. A deep review about PV/T collectors was presented by Kumar and Rosen [10]. Zondag et al. [11] developed a simulation procedure for the thermal and electrical yield of a PV/T collector using a 3D dynamical model and three steady state models (3D, 2D and 1D). It was observed that the time-dependent model is required for an accurate prediction of the collector yield if the collector temperature at the end of a measurement differs from its starting temperature. The model proposed requires extensive knowledge of the Runge–Kutta numerical process. The traditional linear expression for PV electrical efficiency was included in the model as well. Concerning the thermal performance, PV/T collectors have similar behaviour with the conventional thermal modules. Since no specific standards exist, the official methodologies available for referring are the same than those for thermal collectors. In this way, discussion regarding steady-state, quasi-dynamic state and dynamic procedures is based on the one stated in a previous study of the authors [12]. This research analyses and proposes a simple dynamic linear model based on the piston flow concept. The main conclusions were that the time period for measurements should be at least one order of magnitude lower than the response time of the linear model. On the other hand, the outlet temperature and the corresponding power delivered by the collector can be calculated from a linear expression involving the average temporary integral of the weather variables. The averaging time must be equal to the linear model response time. In terms of the electrical characterization, a derivation from the classical single diode model expression has been used instead of the basic and wide spread linear method to evaluate the maximum power output in operating conditions. The proposed method offers a much more detailed description of the module behavior under different working conditions, producing results for the characterization, independent of the maximum power point tracker used in the calibration. In the proposed methodology, the characteristic values of the different standards can be analytically obtained. Considering the different aspects pointed out previously, the present research defines a PV/T characterization method based on the quasi-dynamic method [13] and the derived single diode model presented in [14–16]. In addition, the quasi-dynamic procedure is complemented taking into consideration the results obtained in Ref. [13]. The paper aims at obtaining a suitable PV/T model which better reflects the thermal and electrical behaviour of the collector under stationary and transient conditions. The results are presented in two parts: (i) theoretical, (ii) experimental.

2 Mechanics and Material

2.1 Experimental setup

The photograph of the hybrid solar PV/T collector is shown in Fig. 1. The orientation of hybrid solar PV/T collector was kept in the east-west during the experimentation to harness the maximum incident solar radiation. **The PV/T collector is inclined with 25^{o}.**

Fig 1: Photograph of the Experimental set up

2.2 Instrumentation

The solar radiation measured on the inclined surface of the PV/T collector with the help of TM 207 model solar power meter manufactured by Tenmars, Taiwan having experimenting accuracy ±10 W/m^2 and measuring range of 0–2,000 W/m^2. Calibrated digital hygrometer ofAM-3003 model manufactured by Lutron, Taiwan probe type is used to measure the temperature and relative humidity at inside, outlet of greenhouse and ambient conditions. The measuring accuracy and range for measurement of relative humidity are ±3 and 10–95 %; ±0.8 and 0–50 ^{0}C are the measuring. Ground temperature was recorded with the help of MT Raytek infrared thermometer non-contact gun type having accuracy and precision ±2 % and 0.2 ^{0}C respectively. Air speed is measured with the help of hot-wire 490 Testo anemometer probe having resolution and range are 0.1 and 0.2–60 m/s respectively.

2.3 Experimentation

The experiments were conducted in no-load condition on 14-15 June 2014 on the site of Maulana Azad National Institute of Technology (Bhopal, India) located at 23.15 ^{0}N latitude, 77.25 ^{0}E longitude and 500 m altitude. Experiments were conducted only during the day time hours from 10 a.m. to 5 p.m.

Result and Discussion

After construction of the hybrid solar air collector, it was tested. The analysis was carried out such as solar radiation intensity, relative humidity, wind velocity, ambient temperature and cell temperature. First day (Day 1) of experimentation was found to be the clear sky conditions and on second day (Day 2), the weather was hazy and partly cloudy condition. The variation of these five parameters were observed hourly basis during experimentation and it is presented in Fig 2-8 Fig. 2.1 depicts the variation of solar radiation with respect to time. It shows that the maximum solar intensity was 915 W/m^2 and 640 W/m^2 for day 1 and day 2 of experimentation respectively.

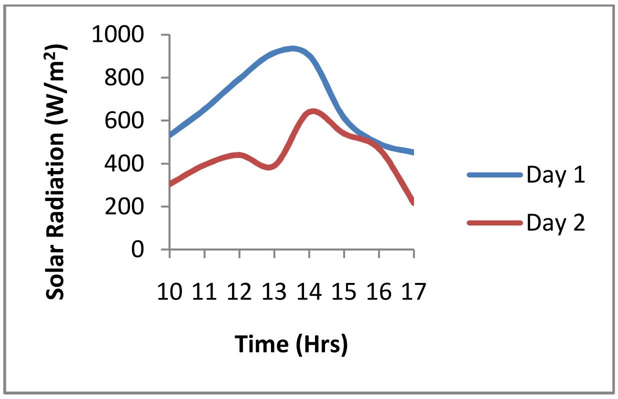

Fig 2.1: Variation of Solar radiation

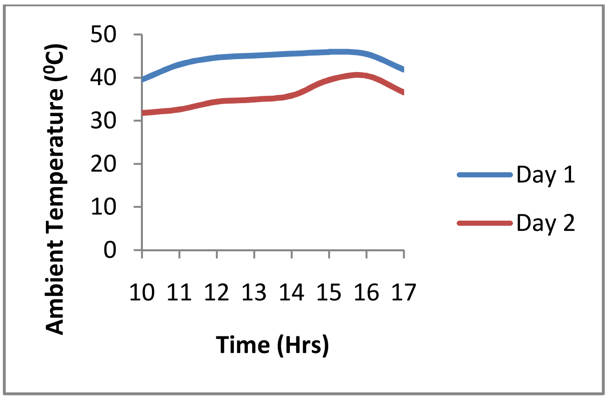

Fig 2.2: Variation of Ambient Temperature

Fig 2.2 shows the variation of ambient temperature on the both day of experimentation. On the day of clear sky, which is day 1 is found to be always greater temperature than cloudy and hazy weather conditions. The average ambient temperature on day 1 is 43.85 ^{0}C and 35.72 ^{0}C for day 2 respectively.

Fig 3.1 shows the variation of ambient relative humidity of day 1 and day 2 respectively. The average ambient relative humidity is 20.95 % for day 1 and 35.58 % for day 2 respectively. It is found that day 2 have higher ambient relative humidity as compared to day 1 of the experimentation.

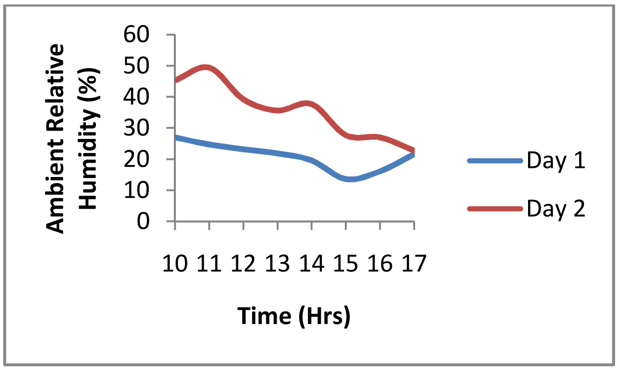

Fig. 3.1 Variation of ambient relative humidity

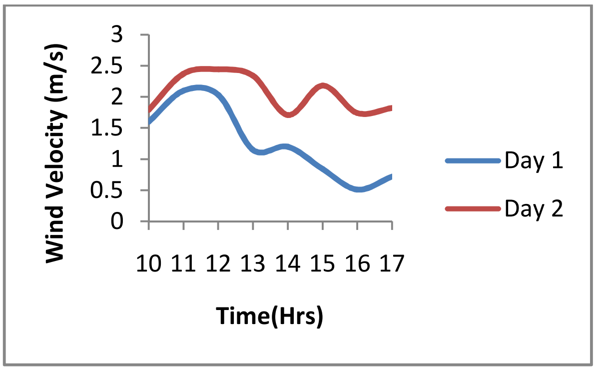

Fig 3.2 Variation of ambient wind velocity

Fig 3.2 demonstrates the variation of ambient wind velocity. It is observed that day 2 of experimentation having higher wind velocity as compared to day 1. The range of wind velocity on day 1 is 0.51-2.1 m/s for day 1 and 1.71-2.44 m/s for day 2 respectively.

Fig 4.1 shows the variation of the cell temperature of the hybrid solar air collector. Due to clear sky conditions on day 1, cell temperature is always found to be the higher than the day 2. The higher cell temperature decreases the efficiency of the solar panel. The variation of cell temperature on day 1 is 45.3-61.4 ^{0}C for day 1 and 35.4-53.8 ^{0}C for day 2 respectively.

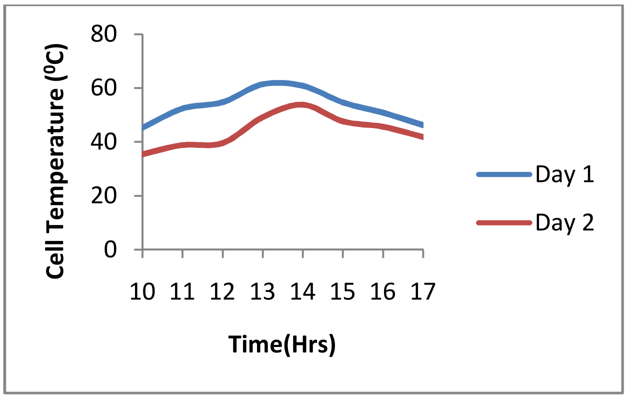

Fig 4.1 Variation of cell temperature

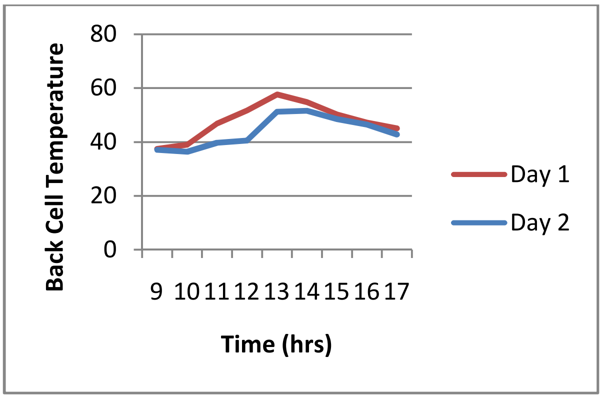

Fig 4.2 Variation of Back cell temperature

Fig 4.2 shows the variation of the back cell temperature of the hybrid solar air collector. Due to clear sky conditions on day 1, back cell temperature is found to be higher than the day 2. The higher back cell temperature decreases the efficiency of the solar panel. The variation of back cell temperature on day 1 is 37-57.6 ^{0}C and 37.4-51.6 ^{0}C for day 2 respectively.

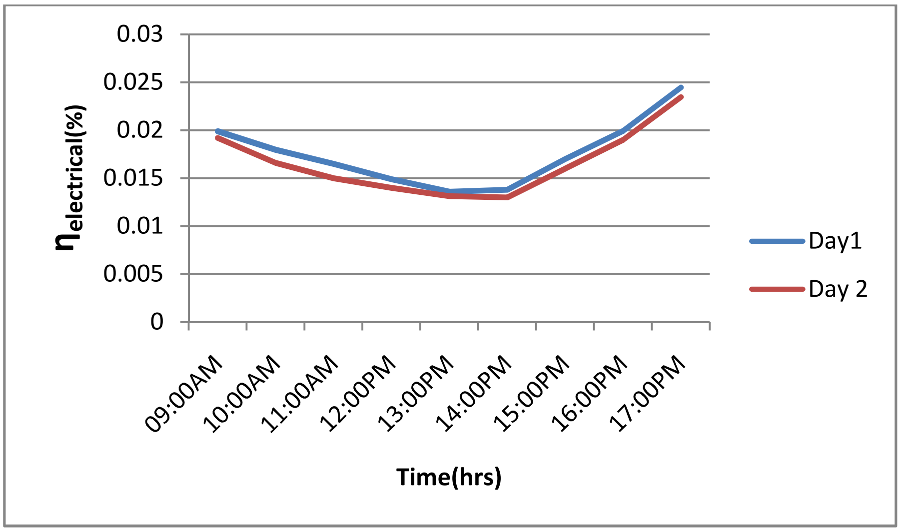

Fig 5. Variation of Electrical efficiency (%)

Fig 5 shows the variation of the Electrical efficiency(%) of the hybrid solar air collector. Due to clear sky conditions on day 1, electrical efficiency found to be higher than the day 2. The higher back cell temperature decreases the efficiency of the solar panel. The variation of Electrical efficiency on day 1 is 0.0136%- 0.0244% and 0.0129%-0.0234% for day 2 respectively.

Conclusion

The study can be used to provide the design and testing data for this type of hybrid solar air collector in other locations of the country. It is observed that the electrical performance of the system is higher when the design parameters such as cell temperature and back cell temperature are lower and there is a significant increase is found in the electrical efficiency in the clear sky conditions as compared to cloudy and partially hazy weather conditions. Climatic parameter like global radiation and wind velocity also affects the performance of the system. In order to increase the efficiency of the collector, suitable modification can be applied in the collector to provide proper cooling.

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