THE USE OF FILTERING FOR THE DYNAMIC CHARACTERIZATION OF PV/T FLAT-PLATE COLLECTORS

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Abstract

In this work, filtering was applied to experimental measurements of data under forced transient conditions in order to characterize the thermal performance of PV/T flat-plate collectors. The data were derived from outdoor dynamic-state thermal performance test. A filtering is considered alongside other efforts to optimize the results of the Multiple Linear Regression (MLR) process. After applying a filtering method, data fluctuations were smoothed to expose its features, and to provide a reasonable starting approach for parametric fitting. The results obtained show that the regression coefficient (r^2) and *t-ratio* values for the characterized parameters increased significantly after filtering process. The zero efficiency and heat loss values obtained after applying the filtering process showed a good degree of agreement in comparison with the results obtained from outdoor steady-state thermal performance tests.

Keywords: filtering method, forced transient conditions, outdoor dynamic-state test

1. Introduction

Solar PV/T collectors generate thermal energy from the amount of incoming solar energy which is received by the collector surface. However, when characterizing the thermal performance of the collector, it is often difficult to guarantee steady-state testing conditions because the weather is rarely unsuitable for conducting outdoor steady-state performance test. As a result, it is usually necessary to test over an extended period in order to cover a determined range of conditions. Dynamic-state testing conditions are required to overcome the potential difficulties associated with steady-state testing. Outdoor dynamic-state testing is important for characterizing collectors and this can also serve as an alternative way to test performance as opposed to more costly outdoor steady-state performance tests. The dynamic-state performance test under forced transient conditions is also useful for developing a new model and it is also appropriate for working with advanced design collectors. Forced transient conditions are applied to the experimental measuring process and measurements are usually taken by covering and then exposing the collector surface to the sun. Forced transient conditions are required to increase the variability of the mean fluid temperature time derivative. This can be achieved by varying the irradiation level[1] and then applying it to the forced transient conditions used in the study. In fact, the trend lines for solar radiation which were examined under forced transient condition, did not show very good agreement with the trend line for the outlet fluid temperature. We therefore proposed a data filtering process in order to smooth out the data. Some of these methods have already been proposed for use in conjunction with the filtering process and forced transient conditions. X.A.Wang, Y.F.Xu and X.Y.Meng[2] developed a filtering method based on a second order thermal model using digital recursive filters for data processing. This was applied to solar radiation data in order to obtain values for effective solar radiation. However, no more detailed information is available about concerning the regression coefficient and t-ratio of the result. E.H Amer *et al.* [3] have proposed using the dynamic testing method for solar thermal collectors and also the use of forced transient conditions, this could produce a regression coefficient of around 0.972. This filtering process is explained in more detail in the present report, where it is applied alongside and simultaneous to all the other data and incorporates solar radiation under forced transient conditions to achieve the highest r^2 and *t-ratio* values. Preliminary experimental research relating to this study has also been carried out at the Solar Energy Research Centre of the Universitat de Lleida (CREA) [4][5].

2. Data Filtering and Collectors Testing

2.1. Data Smoothing

Most of the fluctuations in the experimentally measured data obtained in this study were attributable to the forced transient conditions. These fluctuations could have confused the interpretation of the data. The smoothing process is an important tool for reducing the effects of fluctuations in time series[6]. The results of the smoothing process provide a better estimate than the original values because noise is reduced. This process smoothes out fluctuations in data through averaging a selected number of data. With respect to the collection of experimental data from the outdoor testing system used in this study, the number of selected data depended on the data period and the data sampling rate. The filtering process was applied to all input data relating to solar radiation that were measured under forced transient conditions and to the inlet fluid temperature, fluid mass flow rate, and ambient temperature.

2.2. Identification Parameters

A quasi-dynamic model for a solar thermal collector was formulated according to the energy balance concept[1],[7]. The useful heat gain rate from collectors depends on the solar radiation absorbed by the collector surface, excluding any heat losses. The model was based on the one node concept. The thermal capacity of the collector was referred to the mean inlet and outlet temperatures of the working fluid. The Multiple Linear Regression method was applied to the characterization process in order to identify any characteristic parameters. The parameters identified were : the effective transmittance-absorptance coefficient (zero loss efficiency), the overall collector heat loss coefficient and the effective heat capacity. The accuracy of the characterization was quantified with reference to the regression coefficient on (r^2) and *t-ratio* values.

2.3. Collector Testing

Testing was performed in a similar way to in steady-state performance tests. Measurements were taken for inlet and outlet fluid temperatures, ambient temperature and solar radiation under forced transient conditions. The collector was exposed to the sun and the input temperature of water was kept constant throughout testing, while other values were allowed to vary. Data were sampled for 5 second periods with the data periods depending on the time response of the solar thermal flat-plate collectors. The forced transient condition process was applied by covering the collector surface and then exposing it to the sun for intervals than were longer than the response time. The response time is the time that the collector to response of the collector to any transient inputs that reached 95% of the final steady state value[3].This process was applied using a Lambertian mask which reduced the intensity of the incoming solar radiation by up to 50 %.

3. Results and Discussion

A prototype PV/T flat-plate collector was tested on the CREA building roof at the Universitat de Lleida, Spain, which is located in Lleida at latitude 41.36° N and at longitude 0.37 ° E. The Experimental measurement was performed on a low thermal performance flat-plate collector with an aperture area of 0.63 m^2. Experimental data were obtained under forced transient conditions on the 24th May 2010. Figures (1) and (2) show a data comparison between solar radiation with and without applying the filtering process. From these figures, the trend line for the solar radiation without filtering is the represented by square shape while the outlet fluid temperature is the represented by triangle shape. It is evident that the sharp fluctuations in solar radiation observed without the filtering process did not correlate well with the outlet fluid temperature curve. As a consequence, the least square fitting process for applying the Multiple Linear Regression process was barely able to achieve appropriate results with the data collected. It was therefore decided to apply filtering methods to these data in order to increase the correlation coefficient. Filtering methods constitute a realistic way of smoothing out the abrupt changes associated with the solar radiation data collected under forced transient conditions. As seen in the figures 1 and 2, filtered solar radiation data followed a similar trend to outlet water temperature.

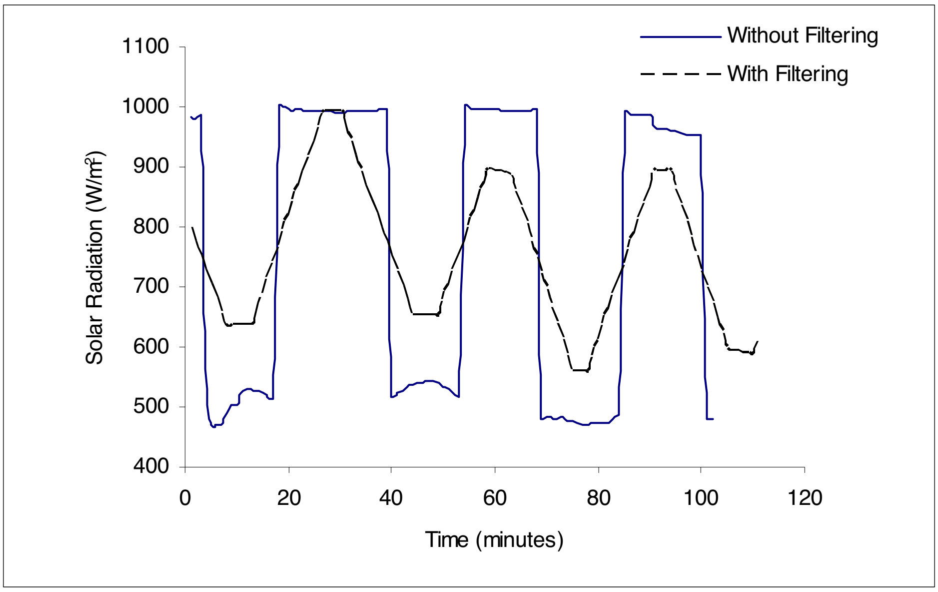

Fig. 1. Trend lines for solar radiation under forced transient conditions both with and without applying a filtering process (experimental measurements taken on 24 May 2010)

In Table 1 presents statistical results, it can be observed that increasing the r^2 and *t-ratio* values after applying the filter process produced significant differences. An important fact was the zero efficiency and heat loss value obtained after applying this process, this exhibited a good degree of agreement with the results of the outdoor steady-state thermal performance test, as shown in Tables 1 and 2 and Fig.3.

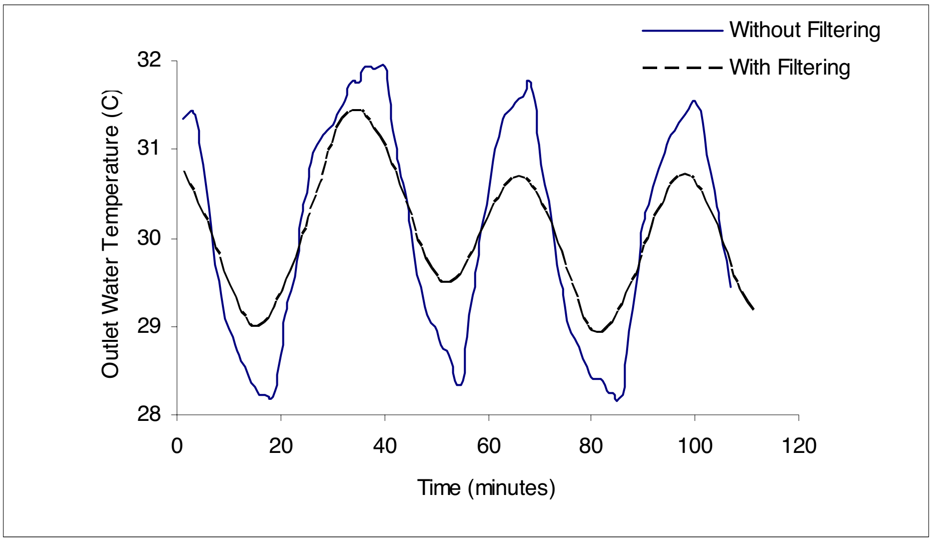

Fig. 2. Trend lines for the outlet fluid temperature both with and without applying a filtering process (experimental measurements taken on 24 May 2010)

The complete quasi-dynamic and steady characterization of the results obtained by the Multiple Linear Regression methods are presented in Tables 1 and 2 respectively.

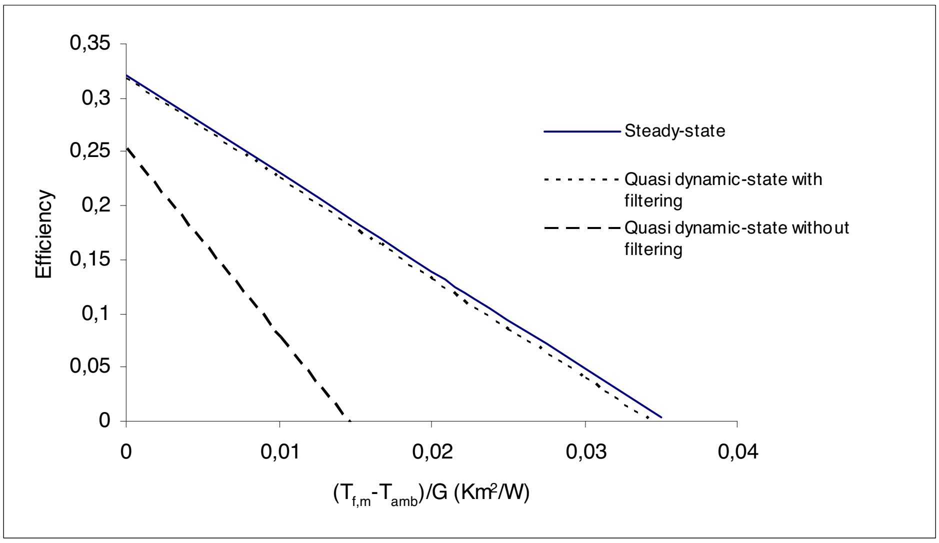

Fig. 3. Thermal efficiency curves (experimental measurements taken on 24 May 2010)

Table 1. Dynamic-state characterization results of the MLR process.

The Process	Identification Parameters			
	Zero Loss Efficiency (-) *[t-ratio]	Heat losses (W/m^2K) *[t-ratio]	Heat capacity (J/m^2K) *[t-ratio]	r^2
Without Filtering	0.253 [7.9]	17.495 [4.2]	38662.593 [5.5]	0.9842
With Filtering	0.318 [47.7]	9.299 [10.6]	28362.688 [35.3]	0.9998

* the t-ratio is the parameter value divided by its standard deviation, which is provided in brackets

Table 2. Steady-state characterization results of the linear process.

Identification Parameters			
Zero Loss Efficiency (-)	Heat losses (W/m^2K)	Heat capacity (J/m^2K)	r^2
0.320	9.029	-	0.9994

4. Conclusions

In this paper, it has developed and carried out a test to characterize the thermal behaviour of a solar PV-Thermal flat-plate collector. The filtering process, which proved well-adapted to the experimental data measurement system under forced transient conditions, and the characterizing process were examined by using the Multiple Linear Regression method. The results obtained showed different characterization values when filtering process was and was not applied, as indicated by the increases in their respective r^2 and *t-ratio* values. The zero efficiency and heat loss values obtained after applying this process exhibited a good degree of agreement with the results obtained from the outdoor steady-state thermal performance test. Applying experimental measurement processes under forced transient conditions could also help to reduce the overall testing time to only 1 day. The process would then be easier and less time consuming to apply. Similarly, it was also not necessary to have a wider range of inlet fluid temperatures.

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