

Data Processing Of Measuring Sets Of Solar Collectors

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Abstract. One of the main problems of the utilizing of the systems that use renewable resources is the long payback time. An important factor is the efficiency of the collectors, that is the function of the specific solar irradiation and the temperature difference between the collector and the ambient air. During the analysis of the collectors generally we can calculate the efficiency by average values of a time-period. The calculation of the momentary efficiency is conditioned, for example, it needs cloudless sky and – of course – correct temperature and volume flow rate values. From the transient effects we need to save this values by five seconds. To process the large amount of data we need to automate the correction of the errors in the database and, also the selection of the values that suitable to calculate momentary efficiencies.

Keywords: solar collector, efficiency, solar energy, pyranometer

1. Introduction

The efficiency of the collectors is most affected by the difference between the temperature of the collector and the external air and the intensity of the solar irradiation. It means that this measuring is not reproducible. According to this fact it needs to make numerous measuring. During the processing of the database we have to average the results that have similar external parameters.

With our unit we can operate the collectors in parallel or serial connection. The equipment transfers the heat output of the collectors to the external air by a fancoil. The cooling fan can be adjusted continuously and the cooling capacity can be decreased further with a bypass pipe, so we can adjust the temperature of the entering fluid of the collectors.

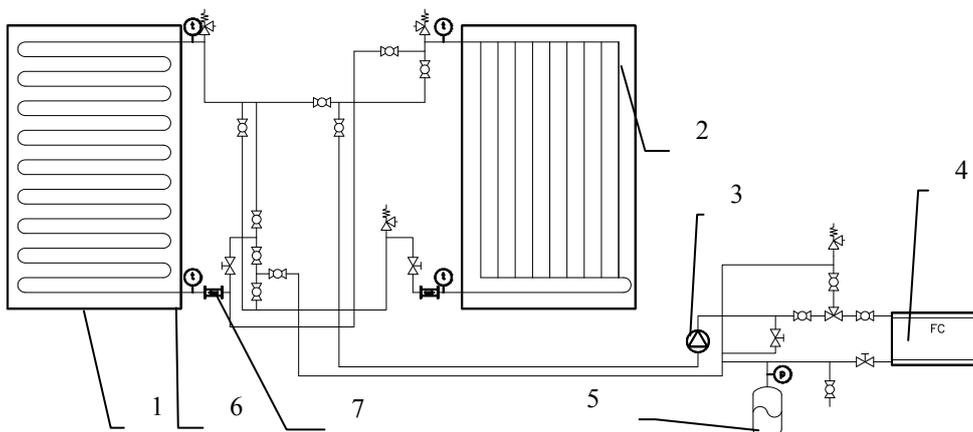


Fig. 1: Experimental equipment for measuring the efficiency of solar collectors.

1 – collector with single pipe, 2 – collector with parallel pipes, 3 – circulation pump, 4 – fancoil,
5 – expansion tank, 6 – thermometers, 7 – volume flow rate measuring

Besides the measuring of the volume flow rates and the temperatures we measured the temperature and humidity of the external air and the solar irradiation. The irradiation was measured by a Lambrecht 16131 pyranometer mounted between the collectors in the same plane.

With the device we can analyse the transient processes of the collectors in the event of changing weather.

2. Measuring error caused by the cloudy periods

For the measuring of the solar irradiation we use a calibrated Lambrecht pyranometer that senses the changes within 18 seconds. Thermopile pyranometers consist of an absorbing detector covered by two glass filter domes. Solar radiation in the wavelength region from 285 nanometers (nm) to 2800 nm, often called ‘‘short-wave radiation’’, passes through the glass domes and hits a black, heat-absorbing sensor [1].

The response time our pyranometer is less than 18s, the accuracy is $\pm 5\%$, the non-linearity is less than $\pm 1\%$. The pyranometer conforms to ISO 9060 ‘‘First class’’ standard [2].

The mass – and so the thermal inertia – of the collectors is much higher than the pyranometer’s, and the reaction much slower. So during a period of a decreased irradiation that caused by a cloud rack the heat output of the collectors still high – caused by the higher irradiation of the previous minutes. If we calculate the momentary efficiency in this time, it will add wrong result, as we can see in the Fig. 2.

The cloudy periods are indicated by the significant deviation of the curve of the solar irradiation from 15:00. During the same periods the calculated values of the momentary efficiency shows bigger fluctuation and assume meaningless values above 100 %. It is an obvious measuring error. These periods must be filtered out.

The momentary efficiency could be calculated only in sunny periods. In cloudy condition we can calculate average values for a term. In the diagram we can see the cloudy periods well, but because of the big amount of data we need to define a function to filter out the clody periods automatically. For making this method we have chosen a diurnal measuring that contains cloudy and cloudless periods, too.

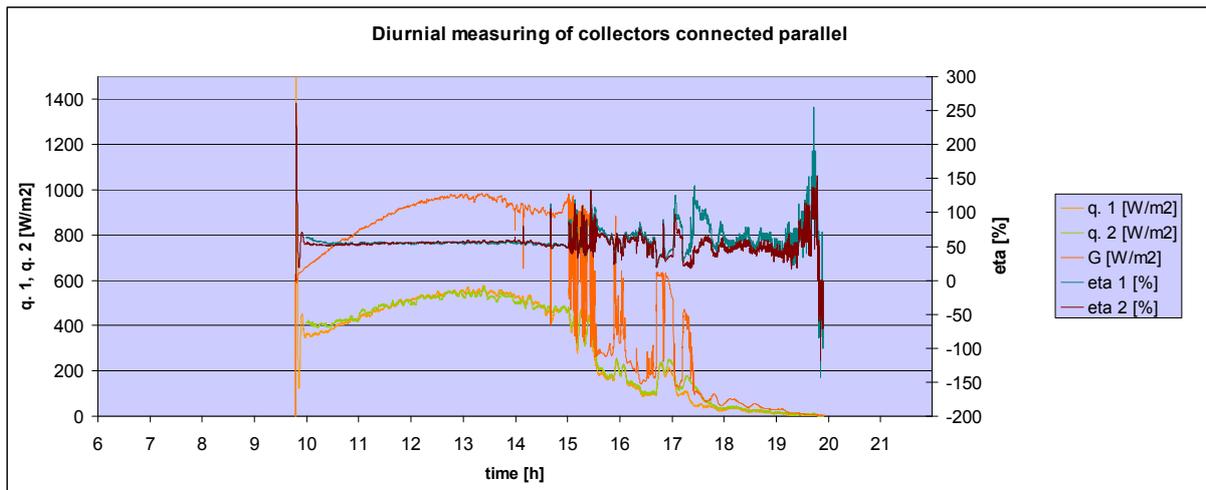


Fig. 2: Solar irradiation and momentary efficiency – the cloudy periods give incorrect results

Through a signal amplifier the pyranometer is connected to a datalogger. It saves the 0÷20 mA signal by 5 seconds.

Computations have been performed to select the optimum time interval ($\Delta\tau$) for calculations and also for data sampling. The results show that estimation of the parameters within $\pm 4\%$ of the steady state values could be obtained using $\Delta\tau$ of 5 s [3].

20 mA corresponds to 1400 W/m^2 irradiation intensity, so from the saved values of current the intensity of irradiation could be calculated by the next formula:

$$G_i = I_i \cdot \frac{1400}{20} \quad (1)$$

Legend:

G_i – the i-th calculated value of the solar irradiation intensity [W / m²]

I_i – the i-th saved value of the current signal by the datalogger [mA]

Theoretically there could be wrong data records with zero values, caused by an outage or something else. We did not experience this kind of errors, but with applying a logical function we have assured the filtering of the zero values.

To every i-th row of a new column we have calculated the specific change of solar irradiation intensity:

$$\Delta G_{\text{spec}} = \frac{G_i - G_{i-1}}{G_i} \quad (2)$$

3. Methods for selecting cloudless periods

In the past and before the widespread introduction of inexpensive electronic sensors, BS was measured by a fairly primitive instrument called a Campbell-Stokes recorder. This consists of a small glass sphere that focuses the sun's image on to a rectangle of sensitive paper. As the sun moves across the sky it marks a trace on the paper, but only when the sunshine is strong enough to create a sufficiently hot focus. [4]

By our first method if this specific change exceeds a threshold value, the time is marked as cloudy. In Fig. 3. we can see the results (blue). The function assumes 0 under cloudy and 100 under cloudless periods, according to specific change of solar irradiation. (The value of 100 is not important, it is necessary only for the easier representation in the diagram.)

As we can see in the diagram, the function filter out the cloudy periods in the morning well, but from 14:00 to 17:00 the short cloudy periods marked as sunny. We have tried to solve this problem with the increasing of the threshold value of the specific change of solar irradiation. The yellow curve of the diagram was made with 0,1 threshold value. As we can see the problem of the afternoon period was not resolved, but the new function discards the cloudiness in the morning. So this operation in itself is not enough to select the cloudy periods well.

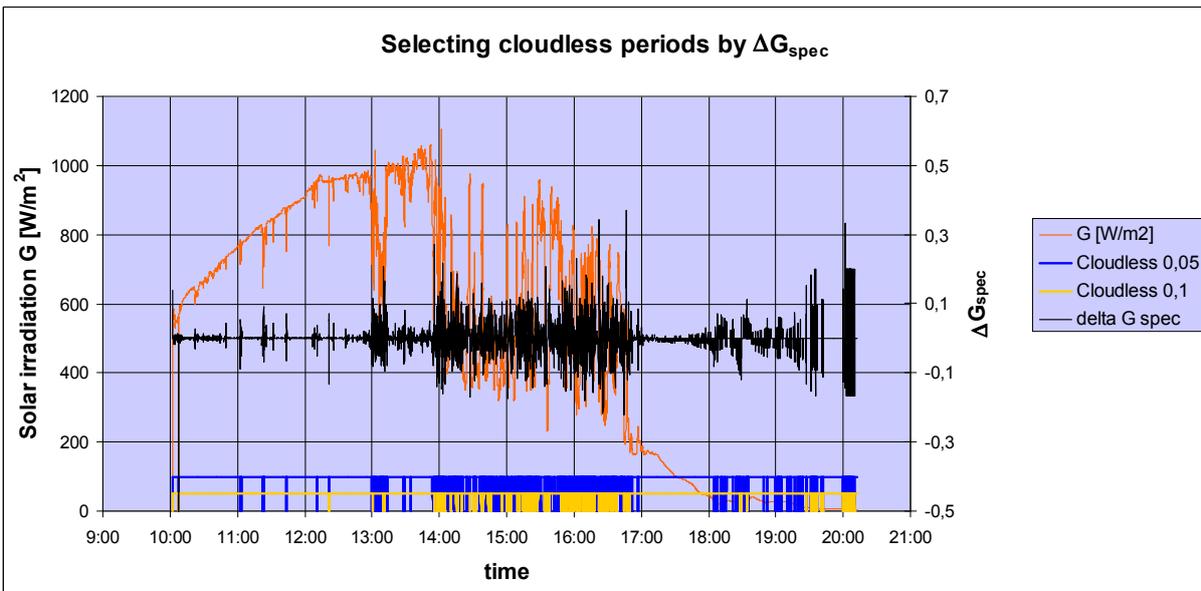


Fig. 3: Selecting cloudless periods if the specific change of solar irradiation less than 0,05 (blue curve) or less than 0,1 (yellow curve)

In our second method we have set the threshold value to 0,05 again. We have complemented the first method with a new requirement: to mark a time as sunny, the previous five minutes have to satisfy the condition about the threshold of ΔG_{spec} . We can see the result in the Fig. 4. (yellow curve).

As we can see, this method eliminates the former wrong selections between 14:00 and 17:00. The 5 minutes long periods are required for the correct efficiency calculating because of the heat inertia of the collectors. At the same time we must see the wrong “cloudless” mark between 12:45 and 13:00.

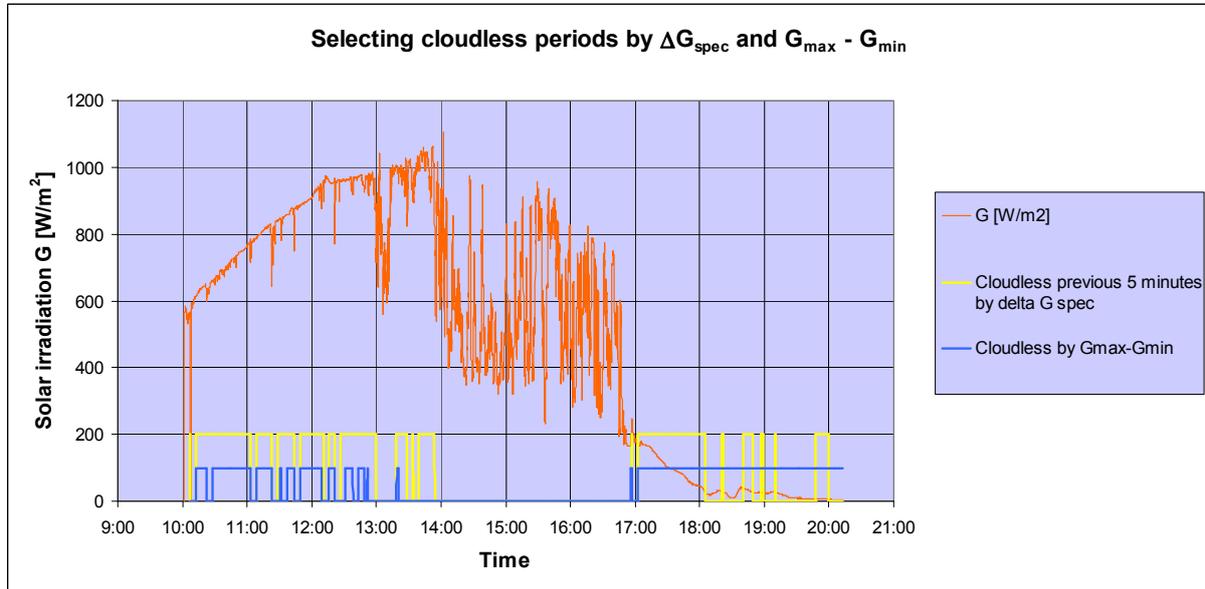


Fig. 4: Selecting cloudless periods considering the previous 5 minutes

The blue function in the diagram analyse the previous 5 minutes as the yellow one, but according to absolute changes of solar irradiance, not specific. It marks the moments that satisfy that during the previous 5 minutes the difference between the minimum and the maximum of the solar irradiation is not greater than 50 W/m^2 . Accordant to more experiment this value is suitable, but we can see in the diagram that after 18:00 the yellow curve is correct, not the blue one.

We can mark the cloudless periods correctly by the combination of these two functions. The most correct method is to mark cloudless the moments that satisfy the two requirement: the maximal absolute and relative deviations during the previous 5 minutes as written above.

In addition we have specified a third requirement related to a minimal irradiation, because the very low solar irradiance makes the measurement incorrect, as we can see in the Fig. 2. The filtering out of the low solar irradiation could be found in other publications, too: “the one that most effectively diminished the outliers while retaining valid data was the removal of data where the global instrument’s reading was less than 200 W ” [5]. So we have filtered out the period after 18:00, but the function handles the same kind of irradiation curve at higher intensity during another measurements.

The three requirement that have to be satisfied for selecting cloudless periods during the previous 5 minutes to mark a moment as cloudless:

$$\Delta G_{\text{spec}} \leq 0,05 \quad (3)$$

$$\Delta G_{\text{max}} - \Delta G_{\text{min}} \leq 50 \quad (4)$$

$$G_{\text{min}} = 100 \frac{\text{W}}{\text{m}^2} \quad (5)$$

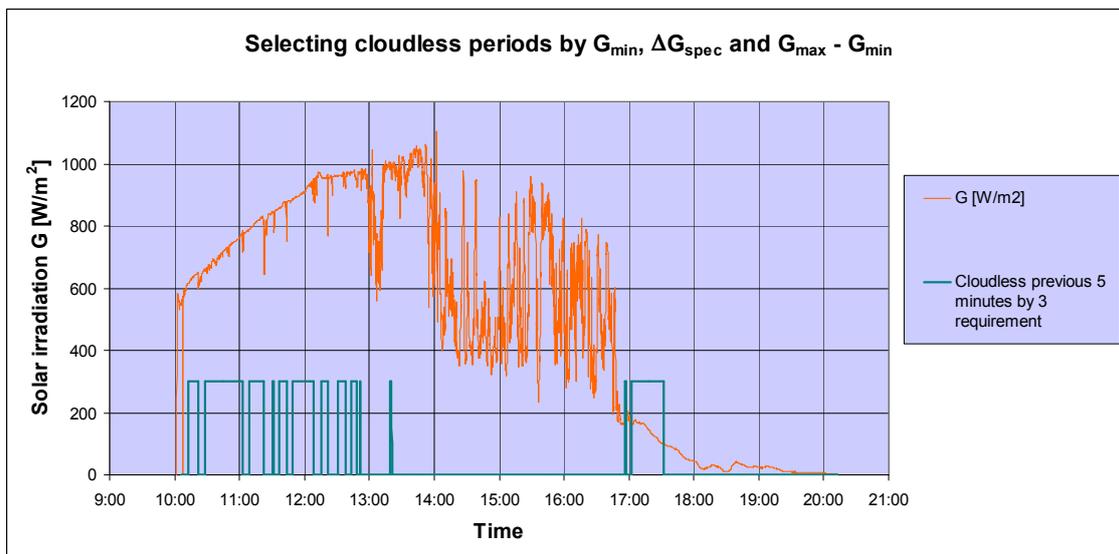


Fig. 5: Selecting cloudless periods by absolute and relative change and minimal value of solar irradiation

4. Conclusions

At the University of Szeged Faculty of Engineering we have developed a new equipment, that is suitable for measuring the efficiency of our self-designed experimental collectors or other ones. Actually we have processed the data of 135 days. We have saved the temperature and solar irradiation values by 5 seconds. During the process of the large amount of data we have got numerous experiences. To the correct results it needs the correction of the filtering out of the cloudy periods. Because of the large amount of data we have to automate this operations. In this article we represent our methods.

We measure the solar irradiation by a pyranometer that senses the changes very quickly, so in the database the decreasing of the irradiation appears in 18 seconds. The mass of the collectors is much greater than the pyranometer and the reaction of a collector is much slower. The heat from the collector results from the previous, sunny period before the appearing of the cloud. It causes an error if we relate this higher heat output to the decreased intensity of solar irradiation. For this cause it needs to filter out the cloudy periods from a diurnal measuring. The momentary efficiency can be calculated only in sunny periods. In this article we represent our method.

5. Acknowledgements

The Project named „TÁMOP-4.2.1/B-09/1/KONV-2010-0005 – Creating the Center of Excellence at the University of Szeged” is supported by the European Union and co-financed by the European Regional Development Fund.



6. References

- [1] M. Haeffelin, S. Kato, A. M. Smith, Rutledge, C.K., T.P. Charlock, J.R. Mahan, 2001. Determination of the thermal offset of the Eppley precision spectral pyranometer. *Applied Optics* 40 (4), 472–484.
- [2] Lambrecht pyranometer specifications, www.lambrecht.net
- [3] E.H. Amer 1, J.K. Nayak, G.K. Sharma, 1999. A new dynamic method for testing solar flat-plate collectors under variable weather. *Energy Conversion & Management* 40 (1999) 803-823
- [4] www.elyweather.co.uk
- [5] A. Lester, D.R. Myers, 2006. A method for improving global pyranometer measurements by modeling responsivity functions. *Solar Energy* 80 (2006) 322–331