Response time acceleration

Using post-processing, response times of heat flux sensors and pyranometers may be accelerated

The output of a sensor may not be able to follow the heat flux during rapidly changing heat flux conditions. If that is a problem, users may consider accelerating the response of a sensor at the datalogger or in post-processing. Using this "acceleration method", response times may be reduced a factor 2.

Figure 1 *SR30 pyranometer for PV system monitoring.*

Figure 2 *Model FHF05-85X85 heat flux sensor installed on a pipe.*

Introduction

Heat flux sensors and pyranometers generate output signals that represent the local heat flux or irradiance. The data are sampled and, usually after averaging over a certain interval, recorded. Sampling and recording intervals are often related to the sensor response time and the application.

Sampling and recording intervals

Sampling and recording intervals are typically chosen to ensure that the derived total or mean is representative of the time interval. The recording interval usually is an integer multiple of the sampling interval, and an integer number of recording intervals fits within 1 h.

The sampling rate depends on the sensor response time and on the application. Please consider:

- what is the smallest time interval of interest?
- what is the response time of the sensor?
- what are sampling or recording intervals from which data may be used?
- what statistical information is needed, average, min, max, standard deviations; can the data acquisition system calculate and store these parameters over the recording interval?
- does the sensor itself (if it is digital), internally average the data? If so, the "acceleration" method may not be applicable.

Depending on the answers to these questions, different applications may have different sampling intervals, ranging from one minute, to one second, or even faster.

Recommendations for pyranometers

The recommended method for outdoor use of pyranometers is to take samples at a < 3 s interval, integrated over the duration of at least one power line cycle (e.g., 0.02 s for 50 Hz) [5]. Whether the samples are further averaged (e.g., recorded as 60 s averages) or stored as individual measurements depends on the application. IEC 61724-1 [6] recommends for high accuracy class A measuring systems a sampling interval of at most 3 s and a maximum recording interval of 1 min. Modern data acquisition systems can calculate and store not only the average, but also minimum, maximum and standard deviation of the set of samples over a recording interval.

The accuracy of the time should be kept within ± 10 s. Internal clocks of automatic data acquisition systems tend to gain or lose time during operation (of the order 1 min/year or more). Time should not only accurately set at the beginning of the data recording, but also regularly checked.

Response time acceleration (simple approach)

The output of a sensor may not be able to follow the solar irradiance or heat flux during rapidly changing conditions. Users may consider accelerating the response of a sensor in post-processing. For example, this is possible for all Hukseflux pyranometers and heat flux sensors, for which the dynamic response can be characterised by a single time constant, with the equation:

$$H_{acc} = H_{meas} + T\ d/dt\ (H_{meas}) \qquad (1)$$

where H_{acc} is the (accelerated) heat flux, H_{meas} is the heat flux measured by the sensor and T is the sensor time constant or 63 % response time. The equation suggests that adding $T\ d/dt\ (H_{meas})$ to the measured heat flux H_{meas} , compensates for the time lag of the sensor. This response time improvement is implemented in some digital sensors (for example in pyranometers with on-board electronics) but may also be implemented in post-processing at the datalogger or during further evaluation of the data.

For the first derivative, $T\ d/dt\ (H_{meas})$, a centre difference approximation is used.

$$H_{acc}(t) = H_{meas}(t) + (T / 2s)\ (H_{meas}(t+s) - H_{meas}(t-s)) \quad (2)$$

With t the time of sampling or recording and s a sampling or recording interval.

A complete compensation of the time lag cannot be achieved with this approach; however, a significant acceleration is possible, also for sensors with multiple time constants. It is important to keep in mind that although response time acceleration can improve measurement accuracy for changing inputs, it may potentially reduce accuracy for steady-state or constant inputs. This is because statistical noise measurement errors will be magnified by the numeric differentiation. Hukseflux can provide you with a spreadsheet illustrating the possibilities for pyranometer SR30 and foil heat flux sensors of FHF05 series.

Performance testing

Users should test the performance of a response time acceleration after programming. This may be done by using a step change in solar irradiance or heat flux, typically using lamps and shutters (lamps must typically heat up before getting stable) or film heaters.

Examples

For pyranometers the 95 % response time is specified. This 95 % response time equals around 3 times the time constant T or 63 % response time. Using post-processing and equation 2, the 95 % response time of pyranometer model SR30 may be reduced from the specified 4 s to 2 s using equation 1 provided they use a sampling interval of 1/50 of the 95 % response time i.e., 0.08 s.

In general, a reduction of response times (63 % as well as 95 %) by a factor 2 can easily be achieved provided that the data is available at around 1/50 of the original 63 % response time.

Compliance to ISO TR 9901/ ISO 9060

ISO TR 9901:2021 [5] allows use of response time acceleration, referring to sources [1,2,3]
In ISO 9060:2018 [4] clause 4.3.3 states that classification is based on the final signal. It allows post-processing to be used as part of the instrument specifications if done either in the instrument or in the external datalogger or control unit. In this case the datalogger or control unit is considered an inseparable part of the measurement. User then essentially considers the sensor and control unit as a new pyranometer.

References

[1] SUEHRCKE, H., LING, C. P. and MCCORMICK, P.G. *The dynamic response of instruments measuring instantaneous solar radiation*, Solar Energy, Vol. 44, No. 3, pp. 145–148, 1990.

[2] DRIESSE. A., *Radiometer response time and irradiance measurement accuracy,* 35th European Photovoltaic Solar Energy Conference, 24-28 September 2018, Brussels, Belgium.

[3] ZEMEL, A., *Correction schemes for solar sensors with multiple time constants,* Solar Energy, Vol. 51, No. 5, pp. 377-382, 1993.

[4] ISO 9060:2018, *Specification and classification of instrument for measuring hemispherical solar and direct solar radiation*.

[5] ISO/TR 9901:2021, *Solar energy — Field pyranometers — Recommended practice for use*

[6] IEC 61724-1:2021 *Photovoltaic system performance monitoring – Guidelines for measurement, data exchange and analysis*

About Hukseflux

Hukseflux is the leading expert in measurement of energy transfer. We design and manufacture sensors and measuring systems that support the energy transition. We are market leaders in solar radiation- and heat flux measurement.
Customers are served through the main office in the Netherlands, and locally owned representations in the USA, Brazil, India, China, Southeast Asia and Japan.

Would you like more information?
E-mail us at: info@hukseflux.com