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Short Note

Estimating insolation based on PV-module currents in a cluster of stand-alone solar systems: Introduction of a new method

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Abstract

In order to evaluate the performance of solar home systems (SHS), data on local insolation is a prerequisite. We present the outline of a new method to estimate insolation if direct measurements are unavailable. This method comprises estimation of daily irradiation by correlating photovoltaic (PV)-module currents from a number of solar home systems, located a few kilometres apart. The objective is to obtain reliable daily and monthly insolation figures that are representative for an area of a few square kilometres.

Keywords: Solar irradiation; Insolation; Monitoring

For determining the performance of solar systems over a number of years, information on insolation is required. Local measurements with a reference cell or pyranometer would be the most straightforward and reliable approach. When in situ measurements of insolation are not available, and there is also no nearby meteorological station, time series of satellite-based insolation might be an alternative. However, these are not yet readily available. NASA provides a tool where monthly average insolation can be obtained for every location in the world, based on 10 years of satellite monitoring (NASA, 2003). This is useful for sizing purposes, but is insufficient for PV-system performance evaluation.

A method was developed to calculate insolation based on PV-module currents of a number of nearby systems. The procedure to construct a time series of daily irradiation figures uses time series of only two measured parameters: battery voltage and PV-module current. Half-hourly averages of PV-module

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currents are measured when the battery is being charged. Module currents and voltages are entered in a one-diode model to determine the photocurrent, which is directly related to irradiance in the module plane. Deviations between calculated photocurrents and insolation occur when the battery is full and the charge regulator cuts-off charging, or when there is shading. To reduce these two effects, data of a number of different solar systems are combined. It is unlikely that full batteries or shading occurs with all the systems at the same time.

Four steps are required to calculate insolation from PV-module currents:

(1) Calculation of photocurrents based on measured PV-module currents, and battery voltages, using a one-diode model of the PV-module. Results are time series of photocurrents for a each of the solar systems.
(2) Scaling of photocurrents to obtain in-plane irradiance by equating maximum photocurrent in a year to maximum clear sky irradiance. In this step the uncertainties caused by the unknown PV-module power are substantially reduced.
(3) Conversion of in-plane irradiance to global horizontal irradiance using a modification of a procedure described in Duffie and Beckman (1991) to calculate in-plane irradiance when horizontal irradiance is known.
(4) The resulting time series of global horizontal irradiance data of different solar systems can be combined to calculate daily global horizontal irradiation that is representative for a larger area. In this process step only those systems are selected that are not affected by shading, or have reduced module currents due to a full battery.

1. Preliminary results

This method has been applied successfully in calculating insolation based on measured module currents of nine solar PV-systems in an area of about 10 by 10 km in a remote area in Indonesia. It was possible to calculate a two and a half year time series of insolation. A two-month time series of calculated insolation figures is compared with daily average insolation measured with a reference cell in Fig. 1.

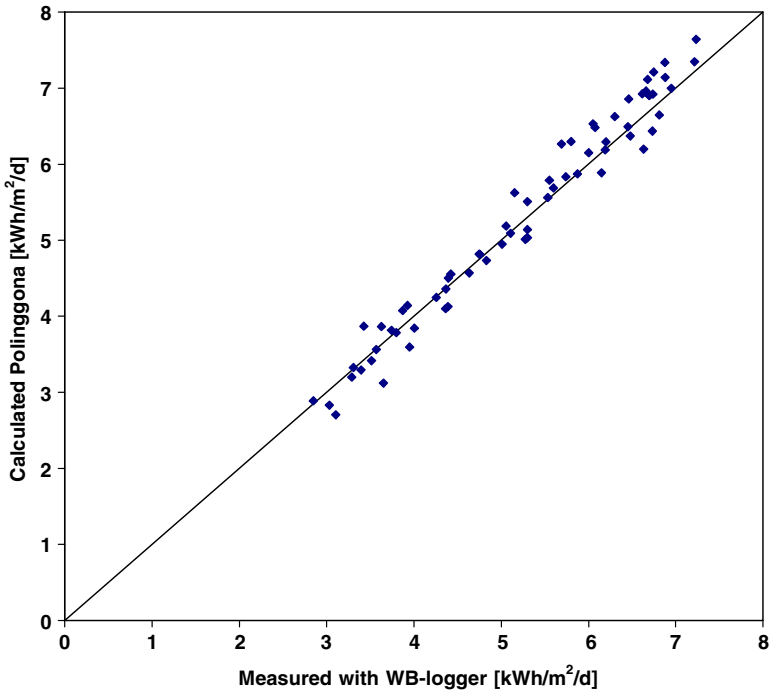

Fig. 1. Comparison of calculated daily irradiation figures based on four data loggers in Polinggona with World Bank data logger measurements in Polinggona over the period of September 17th–November 22 2001.

There is an excellent agreement between measured and calculated daily averages. An a priori estimate of the systematic error amounted to 10%. With a two-month time series of reference cell measurements, the calculated daily average insolation was on average only 0.07 kWh/m^2/day higher than the measurements (1.3%), while the RMSE amounted to 0.26 kWh/m^2/day (5%).

These preliminary results show that the proposed method can result in reliable daily insolation values in case direct measurements are missing. The authors intend to publish more results and a more detailed description of the method in a later stage. For additional information one can contact the corresponding author.

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