Comparison and Analysis of Instruments Measuring Plane-of-Array Irradiance for One-Axis Tracking PV Systems

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Introduction

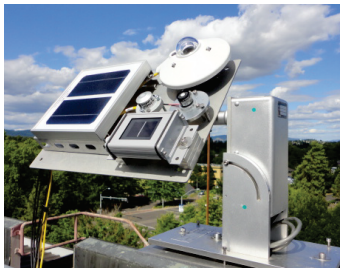

Fig. 1: One-Axis Tracker in Eugene, OR, with Kipp & Zonen CMP22, SP Lite2, Li-Cor 200A pyranometers and a RCO and an IMT reference solar cells.

- Accurate measurement of irradiance in the plane of array is necessary to estimate and monitor the performance of photovoltaic (PV) modules.
- Thermopile-based and photodiode-based pyranometers as well as reference cells are compared and contrasted on a horizontal and one-axis tracking surface.
- Data are collected in Golden, Colorado and Eugene, Oregon.
- Preliminary first-year results are presented.

Objectives

- The objective is to characterize and understand the performance of photodiode-based pyranometers and reference solar cells on a one-axis tracker.
- Evaluate the effect of atmospheric constituents on the results.

Methods and Results

Calibration of the instruments is performed to determine the cosine and spectral response of the instruments and their deviations from the reference measurements (Fig. 2).

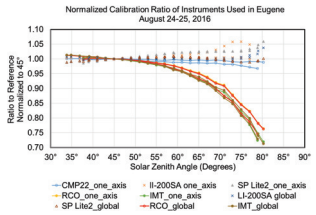

Figure 2. Ratio of calibration values of photodiode and reference cell pyranometers to the CMP22.

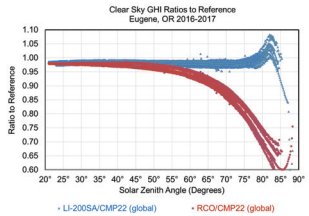

Figure 3. Comparison of a LI-200SA pyranometer and a RCO reference cell against reference measurements of a CMP22 pyranometer on a horizontal surface for 12 selected clear-sky periods during one year.

The calibrations are normalized to 45˚ to illustrate the systematic effects as a function of solar zenith angle. At angles greater than 65˚ the reference cells start to deviate by more than 5% from the calibration references.

Fig. 3: Comparison of a LI-COR 200SA and a RCO reference cell against reference measurements of a CMP22 pyranometer on a horizontal surface for 12 selected clear sky periods over one year.

- Results are a reflection of the deviation from the calibration reference as shown in Fig. 2.

Figs 4 and 5: Similar comparison for instruments mounted on a one-axis tracker from data taken at the same time as that in Fig. 3.

- Instruments are affected by ground-reflected light as the one-axis tracker rotates during the day.
- Instruments point more directly at the sun as a result of the one-axis tracker.
- Instruments are more affected by the change in the direct normal spectral distribution during the day as they are pointed more directly toward the sun.

Method and Results

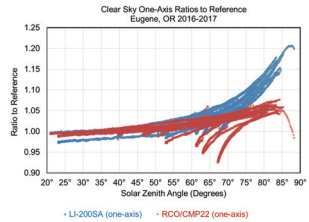

Figure 4: Comparison of output to reference CMP 22 pyranometer on a one-axis tracker plotted against solar zenith angle.

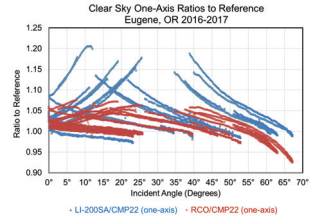

Figure 5: Comparison of output to reference CMP 22 pyranometer on a one-tracker plotted against incident angle.

One-Axis Tracker results:

- The low values of the ratio of the RCO to the reference at the bottom of Fig. 4 are from December, 2016 data. The ratios increase as the sun gets higher in the sky.
- The ratio of the LI-200SA pyranometer increases significantly for larger solar zenith angles.

Fig. 5: Plot against incident angle.

- The incident angle equal zero when the sun is normal to the instrument.
- For LI-200SA pyranometers sensitivity to the direct normal irradiance spectral distribution is increased because the instrument is oriented more directly at the sun. It is also affected by the spectral distribution of the ground-reflected irradiance.
- For reference cells, a combination of deviation from true cosine response and spectral response tend to cancel each other. More validation of this assumption is needed.

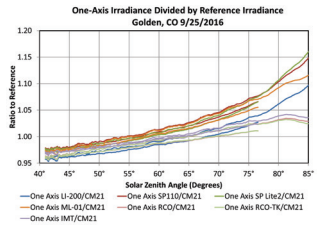

Figure 6: Plot of clear-sky data from Colorado in September 2016 is similar to data shown in Fig. 4.

Fig. 6: Plot of data from Colorado in September, 2016 is similar to data shown in Fig. 4.

- The photodiode-based pyranometers all show an increase as the solar zenith angle increases.
- Reference cells reach a maximum difference and then level off as the solar zenith angle increases.

Conclusion

- Reference cell and photodiode-based pyranometers are based on similar technologies, but they behave differently in the field.
- Both use the short-circuit current to measure the performance: photodiode-based pyranometers usually use some circuitry to minimize the temperature effects on output, and reference cells monitor cell temperature and adjust the readings.
- Pyranometers have diffusers to help reduce the deviation from true cosine response, and reference cells use a glazing similar to the PV modules that result in losses at larger solar zenith angles.
- For one-axis tracking systems, the incident angles usually are not large, so the angle of incident effects are less.
- Changes in incident radiance spectral distribution during the day affects the measurements.

Acknowledgements

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