Abstract

- Low-cost, multiparameter sensing and measurement devices enable cost-effective monitoring of the functional, operational reliability, efficiency, and resiliency of the electric grid.
- The National Renewable Research Laboratory (NREL) Solar Radiation Research Laboratory (SRRL), in collaboration with Arable Labs, Inc., deployed Arable Lab’s Mark multiparameter sensor system.
- The device measures the downwelling and upwelling shortwave solar resource and longwave radiation, humidity, air temperature, and ground temperature.
- The system is also equipped with six downward- and upward-facing narrowband spectrometer channels that measure spectral radiation and surface spectral reflectance.
- This study describes the shortwave calibration, characterization, and validation of measurement accuracy of this instrument by comparison with existing instruments that are part of NREL-SRRL’s Baseline Measurement System.

Method

- Calibration using the NREL SRRL outdoor calibration methodology.
- The calibration was carried out using the NREL SRRL reference direct normal irradiance (DNI) and diffuse horizontal irradiance (DHI) radiometers.
- Optimum calibration of the solar zenith angle of 37.5° was selected, and the calibration factor was derived using:

\[ R = \frac{\varphi}{\operatorname{GHI}_{\text{ref}}} \]

where \( R \) is the instrument’s responsivity, in \( \mu\text{V/(W m}^{-2}\text{)} \), and \( \varphi \) is the instrument’s sensor output voltage (\( \mu\text{V} \)).

Results

A. Shortwave Data Analysis

To correct for directional dependency, a correction was applied as a function of solar azimuth (the bias line in Fig. 2), as follows:

\[ E_{\text{cor}} = E_{\text{raw}} - \sum a_i d_i \]

where \( E_{\text{cor}} \) is the corrected irradiance for the unit under test (UUT), \( E_{\text{raw}} \) is the uncorrected (raw) irradiance, \( d_i \) is the solar azimuth, and \( a_i \) are numerical coefficients obtained by least-squares fitting.

B. Spectral Data Analysis

A long-term analysis included an all-sky comparison at 1-minute temporal resolution during a 3-month period (6/18/2017 to 11/28/2017). The results show good agreement with an R-square value of 0.99 compared with the reference CMP22 instrument.

Conclusions and Future Work

- The comparison of the Arable Mark device demonstrated good agreement with the existing photodiode pyranometers, such as the LI-200 sensor from LICOR (with an average bias of less than ±1%).
- The calibration and characterization methodologies employed by NREL result in ±2% bias compared to the reference GHI data obtained with a thermopile pyranometer during a 3-month period.
- The spectral capabilities of the Mark instrument were found satisfying compared to a reference spectroradiometer, at least under clear-sky conditions.
- Future work will characterize shortwave and spectral data from the Mark device on fixed-tilt, one-axis, and dual-axis tracking in addition to further characterize longwave, temperature, and humidity data.

References