Incorporating theoretical and practical approaches to assess the amount of sunlight captured by a tilted surface in a tropical climate

ABSTRACT

Global solar radiation can theoretically be approximated in terms of tilt and azimuth of the surface regarding the impossibility of simultaneous measurement of solar radiation at various surface tilt and azimuth angles. Moreover, the random and anisotropic nature of diffuse radiation in a tropical climate makes it extremely difficult to estimate global solar radiation accurately as a function of surface tilt and azimuth angles. This study aims to develop a novel experimental and theoretical approach in the form of a computational network in order to determine a precise combined model integrated with global horizontal solar radiation to evaluate global tilted solar radiation in a tropical climate. Obtained results revealed that precisely estimation of the global tilted solar radiation was possible, by combining geometric factors for the tilted beam solar radiation, a combination of Gueymard and Louche models for the tilted diffuse solar radiation, and isotropic ground reflectance model for the ground reflected radiation, along with global horizontal solar radiation. It was observed that the accuracy of the model developed was higher for the partly sunny sky compared to the cloudy and rainy sky, estimates were more accurate on south-facing surfaces, and the model's accuracy declined with the increasing tilt angle of the surface. The statistical analysis exhibited excellent agreement between the measured data and simulation results, considering the value of normalized mean absolute error (nMAE %), normalized root mean squared error (nRMSE %), and mean absolute percentage error (MAPE %), which were in the ranges 0.22–0.94, 0.27–1.11, and 0.23–1.02, respectively for estimating global tilted solar radiation in various regions of Peninsular Malaysia, and they were respectively found in the range of 10.2–27.5%, 16.1–38.9%, and 6.0–17.8%, for evaluating the monthly optimum tilt angle towards the south, that leads to a loss of solar energy from 1.3 to 5.4 kWh/m2/year in Peninsular Malaysia. This search revealed that the experimental and theoretical approach employed in this study can be extended to more climatic regions.