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Photovoltaic System Modeling: A Validation Study at High Latitudes with Implementation of a Novel DNI Quality Control Method

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As the share of photovoltaics (PV) in electricity production increase, accurate modeling and forecasting of its output becomes more and more critical. PV output is affected by multiple factors, which makes accurate modeling of these systems a non-trivial task, requiring an understanding of all the underlying interactions. The aim of this study is to provide new insight on the performance of a popular parametric PV output model, utilized in the Photovoltaic Geographical Information System (PVGIS), by evaluating the performance of the selected model components at two Nordic sites, and demonstrating the usefulness of model site-optimization by providing general information on the health of a PV system while estimating shadowing, snow cover and conversion losses. The study focuses on reviewing the following crucial PV modeling components: impinging and absorbed radiation, module temperature, system efficiency, and system power output. In addition, a novel Quality Control (QC) approach is introduced for handling calculated direct normal irradiance (DNI) values.

It is shown that the proposed QC efficiently filters unrealistic calculated DNI data, and provides a straightforward method for universal implementation as long as site-specific characteristics are taken into consideration. The QC enhances the precision of the calculated DNI by reducing root-mean-square error over 80 % and mean absolute error (MAE) by 1/3, while increasing correlation from 0.80 to 0.99. It also reduces the positive bias by almost 50 %. The PV module temperature scheme has a MAE below 2 °C in snow-free conditions, while the bias is below one degree Celsius. The plane-of-array radiation model has a MAE around 10 W/m2 with a bias of approximately -6 W/m2 when evaluating full radiation datasets. The roughly estimated losses due to snow cover for the winter period 2017-2018 correspond to the PV output of August 2017 (Helsinki) and July - Mid-August 2018 (Kuopio).

Implementation of a site-specific optimization significantly enhances the model's performance at both sites especially regarding the model bias, and provide useful insight on the variable system losses regarding snow cover, inefficient inverter behavior and shadowing. A similar approach can be a potential solution for implementation with Numerical Weather Prediction model input data, as long as high quality input data is available.