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Photovoltaic system calibration with dynamic temperature model as a function of atmospheric conditions

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Incoming solar radiation is an important driver of our climate and weather. Several studies (see for instance Frank et al. 2018) have revealed discrepancies between ground-based irradiance measurements and the predictions of regional weather models. In the realm of electricity generation, accurate forecasts of solar photovoltaic (PV) energy yield are becoming indispensable for cost-effective grid operation: in Germany there are 1.6 million PV systems installed, with a nominal power of 46 GW (Bundesverband Solarwirtschaft 2019). The proliferation of PV systems provides a unique opportunity to characterise global irradiance with unprecedented spatiotemporal resolution, which in turn will allow for highly resolved PV power forecasts.

In order to use a PV plant as a sensor for atmospheric conditions, the first step is to model the generated power as a function of system-specific parameters, such as the array elevation and azimuth angles, conversion efficiency and temperature dependence (Buchmann 2018). Once the PV system is “calibrated” under clear sky conditions one can use measured PV power to infer irradiance under all sky conditions and thus also atmospheric parameters such as aerosol or cloud optical depth. In this work the forward model is described in more detail, in particular the dependence of PV power on module temperature.

As part of the BMWi-funded project MetPVNet, PV power data from twenty systems in the Allgäu region were recorded over four weeks in autumn 2018, together with the corresponding horizontal and plane-of-array irradiance, temperature and wind speed. System calibration was performed using twelve clear sky days; the corresponding irradiance was simulated using libRadtran (Emde et al. 2016). The module temperature was modelled dynamically as a function of irradiance, ambient temperature and wind speed, in order to take into account (i) the heat capacity of the PV system and (ii) the time shift between irradiance and ambient temperature during the day. A static treatment of temperature ultimately leads to errors in the retrieved irradiance and corresponding atmospheric parameters. The model was tested and validated on one free-standing and one roof-mounted system, respectively. The upcoming measurement campaign in summer 2019 will provide further opportunities to test the model: in this case convective weather systems are expected to play a role and the response of module temperature to rapid fluctuations in irradiance can be more closely examined.

References

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