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Forecasting cloud motion and substation solar power using Taylor-approximated vector fields

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The intermittent nature of clouds poses a challenge to solar power forecasting and the stable and economical operation of electric grids, which must compensate the variability of renewables. The dichotomy of clear-sky and overcast conditions gives the photovoltaic (PV) power generated at any given location, and its associated forecast error, an almost binary quality. While forecasts on the national scale benefit from spatial averaging through the cancellation of such errors, distinguishing conditions at the substation or individual solar farm level requires a spatial and, given advection, temporal accuracy not provided by numerical weather simulations. Fortunately, satellite measurements provide the high spatial resolution ($\sim$2km) necessary for estimating local photovoltaic power generation. For short-term forecasting, these real-time measurements are extended using optical flow techniques to predict future cloud positions and PV power by tracking cloud motion between successive satellite images (at fifteen-minute intervals).

At Fraunhofer IEE, we have constructed an optical flow algorithm based on Image Correlation Velocimetry (Tokumaru & Dimotakis, 1995) that creates a Taylor-approximated vector field of the cloud motion. The advantage of this technique is that it creates a continuous velocity field (guaranteeing a smooth forecast) via optimized gradients to describe the motion of deforming structures over an entire image. This is in contrast to more typical cross-correlation techniques that break an image into small, negligibly deforming sub-windows that must individually contain recognizable features, and creates a discrete set of vectors based on them.

We present advancements in our algorithm and compare results with a persistence forecast for both solar irradiation and substation PV power in Germany calculated using Fraunhofer IEE's Solar Prediction System, a probabilistic regional power model (Y.M. Saint Drenan et al., 2016).