Solar Power Forecasting at UC San Diego

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Background

In performance-based tariff structures, the economics of solar power on the grid-scale hinges on the ability to predict and balance the impact of transient cloudiness – or intermittency – through geographical dispersion of sites or energy storage. The short term ramp rates for solar far exceed that of wind power, especially for direct electric conversion (photovoltaic). Charging and discharging of fast storage devices with relatively low power (e.g. batteries or supercapacitors) could smooth out short-period fluctuations, reduce load following capacity on the grid, and thus improve the economics of solar power. However, accurate short term forecasting of cloudiness is required for efficient operation of storage systems.

Technology

UC San Diego is uniquely capable of addressing forecasting of cloudiness through

- continuous collection of a 1 second global horizontal solar radiation data at 8 DEMROES stations located throughout the 1200 acre campus (Fig. 1).

- a Total Sky Imager (YES TSI-440, Fig. 2) that takes hemispherical sky photographs and compute cloud fraction every 30 seconds. Cloud motion vectors will be determined through pattern matching analysis of subsequent images.

- a ceilometer to record cloud height and aerosol optical depth (Fig. 3).

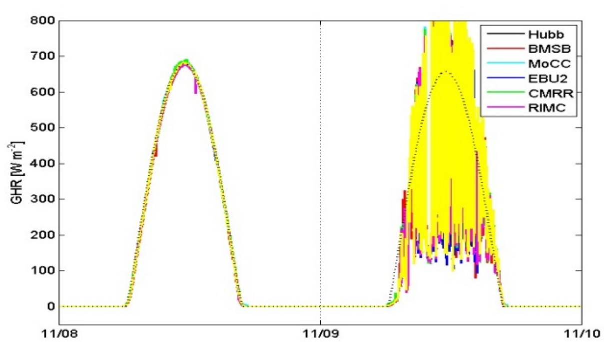

Figure 1: Timeseries of 1 second global horizontal radiation over a clear and a cloudy day in November 2008 at 6 sites at UCSD.

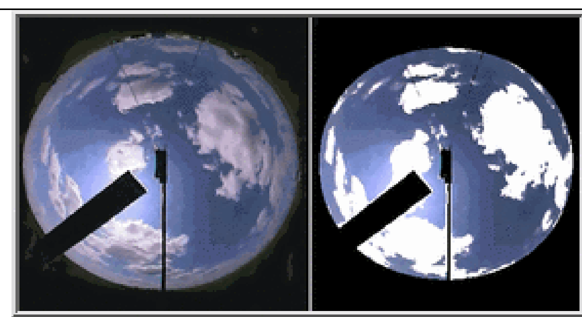

Figure 2: Hemispheric sky image showing raw sky image left and processed image with cloud identification (right). Yankee Environmental Systems

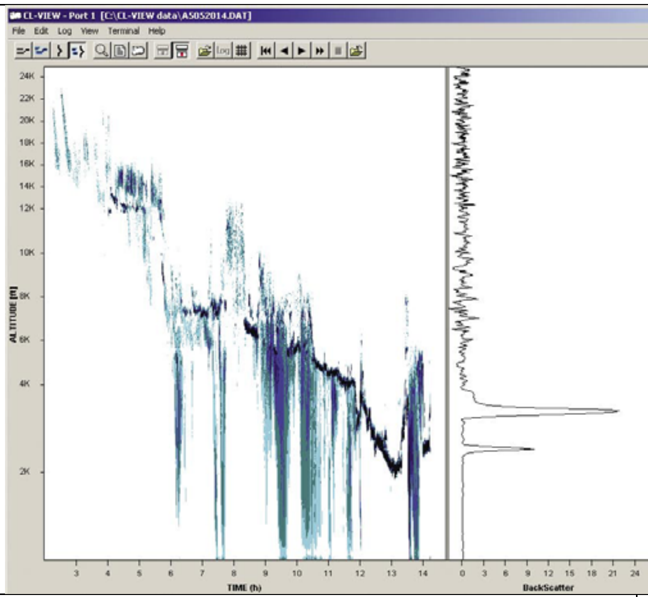

Figure 3: Ceilometer time series of cloud height (left) and current backscatter profile (right) from Vaisala Inc. The left image shows a reduction in cloud height and the peaks on the right show 2 cloud layers. Vaisala

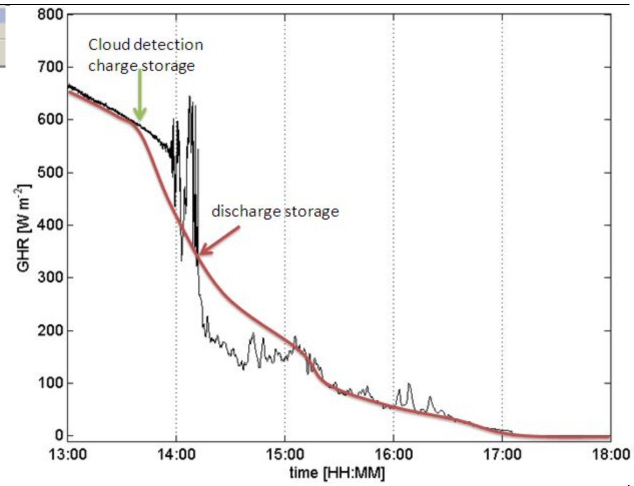

Fig. 4: Observed solar power output (black line) and simulation of applying a smart storage controller (red line). The maximum ramp rate for a virtual 1 MW plant is decreased from 3 MW/min to 70 kW/min.

Algorithm

The storage controller will respond to the cloud detection and forecast system in a multi-tiered structure:

Tier 1: Real-time cloud detection

On a clear day the detection of clouds with the Sky Imager will trigger the controller to divert some of the PV output to charge the storage system. Vice versa on an overcast day the detection of a reduction in cloud cover will trigger the controller to start discharging the storage system in anticipation of an increase in solar power output.

Tier 2: Cloud position forecast

Using pattern recognition algorithms we will derive cloud motion vector fields from subsequent sky images and forecast cloud position for the hour ahead. Cloud height will be determined from the ceilometer. Given typical cloud reductions in irradiance, the controller will compute the expected amount of storage required to smooth out the PV power production curve (Fig. 4).

Tier 3: Power output forecast

As cloud related solar radiation reductions are observed at DEMROES stations, the optical depth of each cloud will be computed and input into the cloud position algorithm to determine actual expected solar power output at each PV array over the hour ahead.