The MDA Solar Forecasting System: Sub-hourly variability and behind-the-meter generation

Overview

MDA Information Systems, LLC is predicting electric power generated from solar energy for individual sites and for regions. Two years ago at this same meeting, we presented about MDA’s state-of-the-science irradiance forecasting system utilizing the REST2 clear sky model, AERONET aerosol observations, and a variety of other public sources and proprietary site data.

Last year, we presented about MDA’s solar power forecasting system, highlighting challenges we met predicting hourly electric power generation for a single-foil PV farm in a challenging location bound by synoptic and local storms as well as sunny day cumulus. This year, we highlight prediction of sub-hourly variability for irradiance and power at individual sites and real-time calculation of aggregate distribution generated from the websites of thousands of sites in California.

MDA Solar Power and Solar Irradiance Forecasting

MDA Information Systems, LLC has developed a solar forecasting system
- Individual sites or collections of sites
- Distributed generation
- Panels of any tilt or sun-tracking
- All forecast lead times
- Prediction of solar power generation
- Global horizontal irradiance (GHI)
- Direct Normal Irradiance (DNI) and Direct Horizontal Irradiance (DHI)
- Irradiance incident on panels (plane of array)
- Sub-hourly variability for irradiance and power and irradiance
- MDA predictions of PV electric generation outperformed competition during our only head-to-head match-up for 2011

Our user interface shown here
- Is integrated into the wind power forecast display with the same features
- Allows viewing of forecasts for regions or individual farms
- Allows comparing historical forecasts and reported actuals to present forecasts
- Allows viewing of error statistics from recent forecasts
- In addition to the MDA power forecast, overlays model irradiance forecasts onto a map indicating power installation density, allowing the user to get a sense of the spatial and temporal distribution of incoming solar energy and its juxtaposition with electric generation capacity

An improved user interface with more flexibility is coming soon!
- Combined administrator power will be available for regions having large wind and solar capacity
- Skill is dominated by prediction of clouds. Predicting evolution beyond the first few hours requires use of numerical weather prediction (NWP) models
- Cloud prediction is a weak point in NWP
- Time-averaged, not instantaneous, values of surface shortwave flux are needed
- Output frequency for most major NWP models is insufficient
- Surface shortwave fluxes from NWP models need complex bias correction (function of other variables)
- Most NWP models do not output direct beam irradiance (DNI or DHI) and those that do provide it have little skill independent of other variables
- Mixed surface types and complex topography play a role in sub-hourly variability and uncertainty
- Our user interface shown here

MDA Information Systems, LLC has developed a solar forecasting system utilizing empirical power curves for this site. Hourly averaged irradiations were used to generate power curves. “Steady” values are based on the hourly averaged values, while “variable” 1-minute values utilized the stochastic method described above. The difference is plotted as a function of hourly averaged measured power. The steady values are systematically higher than the variable values when the PV installation is operating near its rated capacity, but not at other times.

A sample partly-cloudy day from this experiment is shown in the 6-panel figure. Calculated plane-of-array irradiance based on observations of direct and diffuse irradiance are shown in white while the hourly results from using the steady assumption are shown in green and the stochastic values are in blue. For comparison, the observed values for the next day, a cloudy day, are shown in black. Both 1, 2, or 3 fixed panel orientations and sun-tracking orientations were used for each site. The steady assumption was used, with results from the merged statistics combining all sites.

The steady assumption was used, with results from the merged statistics combining all sites. The steady values are systematically higher than the variable values when the PV installation is operating near its rated capacity, but not at other times. The corresponding shading in the 6-panel figure shows the clear sky values. The corresponding shading in the 6-panel figure shows the clear sky values.

Distributed Generation – How many sites need separate forecasts? The California Solar Initiative (CSI) lists over 140,000 active sites totaling almost 2 GW of installed PV capacity, mostly behind-the-meter with no visibility to utilities or public sources. How many of these sites does an aggregate forecast need to account for to make a climate approximation of all 140,000 sites? This address this question by envisioning hypothetical solar owner, partly cloudy, and cloudy days in each season using one individual site and comparing the results to the 140,000 sites using the same day.

The CSI database lists the capacity and CEC-certified addresses for individual sites and the fixed panel orientation or number of sun-tracking axes for most sites. We applied measured direct, diffuse, and upwelling irradiance at the Desert Rock, NV SURF/PAD site from selected days to create tilted panel plane of array irradiances for each CSI site. Plane-of-array irradiance was computed using a simple power tracer (corrected at 1000 W/m²). The CSI sites were then aggregated by zip code and grouped into dominant orientations. The 382 GBT, 371, and 345 sites that were used included in each

The steady assumption was used, with results from the merged statistics combining all sites. The steady values are systematically higher than the variable values when the PV installation is operating near its rated capacity, but not at other times. The corresponding shading in the 6-panel figure shows the clear sky values. The corresponding shading in the 6-panel figure shows the clear sky values.

Sub-hourly Variability - Irradiance

Predictability of the times when cloud patches will pass in front of the sun is near zero beyond the first hour or two. However, predictability of variability has promise.

We can predict the presence of a cumulus cloud field that will result in sub-hourly irradiance fluctuations and back the meter.“Steady” values are based on the hourly averaged values, while “variable” 1-minute values utilized the stochastic method described above. The difference is plotted as a function of hourly averaged measured power.

The steady values are systematically higher than the variable values when the PV installation is operating near its rated capacity, but not at other times.

The steady assumption was used, with results from the merged statistics combining all sites. The steady values are systematically higher than the variable values when the PV installation is operating near its rated capacity, but not at other times. The corresponding shading in the 6-panel figure shows the clear sky values. The corresponding shading in the 6-panel figure shows the clear sky values.

The Way Forward

- Sub-hourly variability of solar power is vitally important to the energy industry and has higher predictability than sub-hourly power.

- Behind-the-meter generation from rooftop solar installations is ramping up to meaningful amounts in many areas, presenting a blind spot to load management. Forecasting this power more accurately than forecasting for every site is a goal that is getting closer.

- Accurate solar power forecasts rely on high-quality co-located irradiance and power data at high temporal resolution. More is needed.