An Operational, Real-Time Forecasting System for 250 MW of PV Power Using NWP, Satellite, and DG Production data

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***Abstract* — We developed a real-time PV power forecasting system for Tucson Electric Power using a combination of high-resolution numerical weather prediction, satellite imagery, distributed generation (DG) production data, and irradiance sensors. The system provides forecasts with 10 second resolution for the first 30 minutes and 3 minute resolution out to 3 days. Forecasts out to 30 minutes are updated every 60 seconds based on new data from DG installations and irradiance sensors.**

***Index Terms* — forecasting, real-time systems, sensors, solar energy.**

I. Introduction

The need for PV power forecasting to support grid integration is well established [1-4]. We describe an operational hybrid forecasting system that utilizes input from 3 different sources: a high-resolution numerical weather prediction model, satellite imagery, and a network of distributed generation PV systems and irradiance sensors. Our forecasts are currently used at Tucson Electric Power to inform conventional generation resource allocation and to give system operators insight into behind-the-meter energy usage and generation. Our 10-second resolution short-term forecasts can help anticipate destabilizing ramp events, enable preemptive curtailment to avoid high ramp rates, and reduce the battery size needed to control ramp rates. Our long-term forecasts predict both solar and wind power production with 3-minute resolution, enabling day-ahead forecasts of the possibility of high variability. Integrating the forecasting technologies into a single hybrid forecast will improve the forecast accuracy at all time horizons and present end-users with a straightforward and simple product.

The field of solar power forecasting has quickly grown over the last several years. PV power forecasts have been made using numerical weather prediction [2, 5], satellite imagery [2, 6], total sky imagers [2, 7], and sensor networks [8]. The work we present here is, to our knowledge, the first work that combines a short-term forecasting method (i.e. total sky imagers or sensor networks) with both medium-term satellite imagery and long-term numerical weather modeling. We also emphasize that the work we present here represents the analysis of true forecasts, rather than retrospective modeling and analysis of historical data.

II. Data Sources

In this section we provide a summary of the 3 different components of our forecasting system: a WRF numerical weather model, satellite imagery, and a network of DG PV systems and irradiance sensors.

A. Numerical Weather Prediction

The backbone of our forecast is a suite of high-resolution Weather Research and Forecasting (WRF) mesoscale numerical weather models. Each day we run four different models initialized using the 6Z and 12Z GFS and NAM forecasts, plus one additional forecast using cloud assimilation from satellite imagery. The models use a 5.4 km outer domain spanning 28.5° longitude by 20.75° latitude, and a 1.8 km inner domain spanning 7.7° longitude by 5.3° latitude. The consistency, or lack thereof, of the multiple model runs provides one estimate of the uncertainty of the WRF forecasts. We typically run the 6Z forecasts out to 72 hours and the 12Z forecasts out to 48 hours. Variables directly relevant to renewable power forecasting, including GHI, DNI, 10 meter winds, 80 meter winds, and 2 meter temperature, are output every 3 minutes. Figure 1 shows WRF forecasts for a 25 MW single-axis tracker installation.

The high spatial and temporal resolution of our WRF model enables direct prediction of local irradiance and variability, rather than relying on historical correlations between irradiance, variability and other model outputs. The high spatial resolution is also essential for accurate weather and irradiance modeling in regions with rapidly changing topography and land use, such as southern Arizona.

We used the NREL SOLRMAP OASIS station at the University of Arizona [9] to compare the WRF model predictions of GHI to the measured GHI. Calculations of the daily average mean absolute error (MAE) and normalized MAE (NMAE) of the WRF model GHI predictions are shown in Table I and Table II. We only considered times of the day at which the solar altitude was greater than 10 degrees. The MAE shown here was calculated at 3-minute resolution and MAE statistics for hourly forecasts are approximately 25% smaller. Normalization was calculated with respect to the clear sky irradiance at each time bin. For this work, we restrict our analysis of the WRF model runs to the month of April so that we can more directly compare them to the network forecasting

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