Short-Term PV Power Forecasts Based on a Real-Time Irradiance Monitoring Network

Antonio T. Lorenzo*, William F. Holmgren†, Michael Leuthold‡,
Chang Ki Kim‡, Alexander D. Cronin†, Eric A. Betterton‡

*College of Optical Sciences, University of Arizona, Tucson, AZ, United States
†Department of Physics, University of Arizona, Tucson, AZ, United States
‡Department of Atmospheric Sciences, University of Arizona, Tucson, AZ, United States

***Abstract*—We built an irradiance sensor network that we are now using to make operational, real-time, intra-hour forecasts of solar power at key locations. We developed reliable irradiance sensor hardware platforms to enable these sensor network forecasts. Using 19 of the 55 irradiance sensors we have throughout Tucson, we make retrospective forecasts of 26 days in April and evaluate their performance. We find that that our network forecasts outperform a persistence model for 1 to 28 minute time horizons as measured by the root mean squared error. The sensor hardware, our network forecasting method, error statistics, and future improvements to our forecasts are discussed.**

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

I. Introduction

The demand for high accuracy solar power forecasting services is increasing as electric utilities and independent service operators add more variable and potentially destabilizing solar power generation. Numerous forecasting methods are being actively developed including those based on artificial neural networks [1], total sky imagers [2]–[5], irradiance sensor networks [6], [7], satellite derived irradiance [8], numerical weather models [9], and hybrid methods [10]. Each method has an optimal forecasting horizon; often, total sky imagers and irradiance sensor network forecasts perform best for very short (5-30 minutes) time horizons, satellite forecasts perform best for short- to mid-term horizons (1-4 hours), and numerical weather models perform best for longer horizons (>4 hours). The optimal horizon for neural networks and hybrid methods varies.

In our 2013 study [6], we made retrospective forecasts using 15 minute data from rooftop PV systems that performed optimally for 45 minute time horizons. In this paper, we describe our *operational* forecasts that are made using an improved sensor network that reports in real-time. We evaluate forecasts from 26 days in April that were made retrospectively. Our network forecasts outperform a persistence forecast for 1 to 28 minute time horizons. We attribute differences in performance compared to our earlier study to the smaller network and finer (1 minute) time resolution of the real-time sensors used in the present study.

In Section II, we describe our irradiance monitoring network and the sensors we developed. Then, we explain our method to generate irradiance network forecasts in Section III. Error statistics are presented in Section IV, and conclusions and future work are discussed in Section V.

II. Irradiance Monitoring Network

A major barrier to making irradiance network based PV power forecasts is obtaining irradiance data in near real-time with high spatial and temporal resolution. We currently have a network of 55 sensors throughout the Tucson region that we use to make operational network forecasts. In this concentrated study, we use a subset of 19 sensors near the University of Arizona Science and Technology Park (UASTP). Our sensors are made up of irradiance network nodes (INNs) that we developed, rooftop PV system power data direct from monitoring equipment, and utility-scale PV power data. We now describe the INN hardware we developed to make network forecasts, the central database where all irradiance data is stored, and the network used in this study.

A. Sensor Hardware

To make high-quality network forecasts, we need reliable sensor hardware that reports in nearly real-time. We chose to design our own hardware after researching existing solutions in the market and finding them unsuitable or too expensive. Our sensor hardware is relatively cheap, uses reliable Linux microcomputers, and requires minimal maintenance. Our current sensors are not meant to be accurate global irradiance sensors, although with careful mounting and a suitable pyranometer, they can be. A summary of the sensor hardware is presented in Table I.

TABLE I
Summary of Irradiance Network Nodes

Model	**Comms. Backend**	**Sensor Type**	**Processing Unit**	**Collection Period**
Saguaro	Cellular data network	Pyranometer or photodiode	iMX233-OLinuXino-MICRO	1 second
Prickly Pear	Ethernet internet connection	Rooftop PV power measurement	Raspberry Pi	10 seconds
Yucca	Ethernet internet connection	Pyranometer or photodiode	Raspberry Pi	1 second