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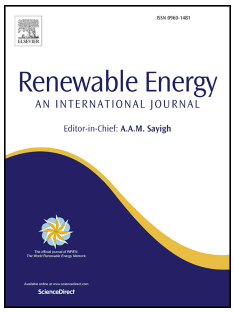

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Guido Cervone, Laura Clemente-Harding, Stefano Alessandrini, Luca Delle Monache

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Short-term Photovoltaic Power Forecasting Using Artificial Neural Networks and an Analog Ensemble

Guido Cervone[a,b,*], Laura Clemente-Harding[c,a], Stefano Alessandrini[b], Luca Delle Monache[b]

[a] *Geoinformatics and Earth Observation Laboratory*
Department of Geography and Institute for CyberScience The Pennsylvania State University, University Park, PA
[b] *Research Application Laboratory National Center for Atmospheric Research, Boulder CO*
[c] *Geospatial Research Laboratory Engineer Research and Development Center, Alexandria, VA*

Abstract

A methodology based on Artificial Neural Networks (ANN) and an Analog Ensemble (AnEn) is presented to generate 72-hour deterministic and probabilistic forecasts of power generated by photovoltaic (PV) power plants using input from a numerical weather prediction model and computed astronomical variables. ANN and AnEn are used individually and in combination to generate forecasts for three solar power plants located in Italy. The computational scalability of the proposed solution is tested using synthetic data simulating 4,450 PV power stations. The NCAR Yellowstone supercomputer is employed to test the parallel implementation of the proposed solution, ranging from 1 node (32 cores) to 4,450 nodes (141,140 cores). Results show that a combined AnEn + ANN solution yields best results, and that the proposed solution is well suited for massive scale computation.

Keywords: Solar Power, Numerical Weather Prediction, Artificial Neural Networks, Uncertainty Estimation, Ensemble Modeling, Parallel Computing

1. Introduction

Building a sustainable society requires providing solutions that meet societal needs and will last for generations to come. The current reliance on finite environmental resources to meet the power needs of the world's expanding population and economy is not sustainable in the long term (Lewis and Nocera, 2006). Renewable energy sources provide a potential sustainable solution to meet societal power needs. This article describes a methodology for generating deterministic and probabilistic forecasts of photovoltaic (PV) power generation, which are specific tasks required to rely on renewable sources for a portion of the energy production requirements.

Becker et al. (2014) analyzed 32 years of weather data investigating the feasibility of U.S. reliance on wind and solar power to satisfy the country's power requirements. They concluded that the U.S. has adequate meteorological and terrain characteristics to suggest that renewable sources can be successfully implemented. The Renewable Electricity Futures Study (RE Futures) used two power generation models to conclude that up to 80% of U.S. electricity demand could be met through renewable resources (Hand et al., 2012). Arent et al. (2014) drew upon RE Futures results to conclude that a high reliance on renewable sources necessitates a number of structural modifications that positively affect both supply chains and the environment. With respect to PV production in the U.S. the southwest has the highest solar radiation and most areas of the country are viable candidates, including regions like PA and NJ where the solar radiation is comparable to northern Spain.

Brazil is an example of a country with significant potential for PV penetration (Lima et al., 2016). Distributed PV power can provide energy to mitigate peak loads when air conditioning is greatest urban areas and minimize the energy loss caused by energy traveling longer distances. PV presents an opportunity in the Brazilian Amazon where connectivity to a main grid is not available and Diesel generators are the main power source for independent mini-grids.

Specifically, Lima et al. (2016) studied Northeastern Brazil using numerical weather prediction (NWP) model output, ground observations, and a series of ANN to develop a methodology for improving 24-h solar irradiance forecasts in the Northeastern region of Brazil. This methodology resulted in the identification of spatial patterns in the data and an improvement in the solar irradiance forecasts when using ANN where the ANN reduces the general overforecasting of solar irradiance in the NWP output.

Deep penetration of renewable energy in the existing power grid, especially distributed PV systems, is needed

*Corresponding author
Email addresses: cervone@psu.edu (Guido Cervone), laura@psu.edu (Laura Clemente-Harding), alessand@ucar.edu (Stefano Alessandrini), lucadm@ucar.edu (Luca Delle Monache)