Available online at www.sciencedirect.com
ScienceDirect
Mathematics and Computers in Simulation 131 (2017) 88–100
MATHEMATICS AND COMPUTERS IN SIMULATION
www.elsevier.com/locate/matcom

Original articles

Analysis and validation of 24 hours ahead neural network forecasting of photovoltaic output power

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Received 20 October 2014; received in revised form 12 February 2015; accepted 26 May 2015
Available online 15 July 2015

Highlights

- We propose an artificial neural network for photovoltaic energy forecasting.
- We analyze its sensitivity with respect to the input data sets and error definitions.
- Data are taken from experimental activities carried out on a real photovoltaic plant.
- The hourly energy prediction covers all the daylight hours of the following day.

Abstract

In this paper an artificial neural network for photovoltaic plant energy forecasting is proposed and analyzed in terms of its sensitivity with respect to the input data sets.

Furthermore, the accuracy of the method has been studied as a function of the training data sets and error definitions. The analysis is based on experimental activities carried out on a real photovoltaic power plant accompanied by clear sky model.

In particular, this paper deals with the hourly energy prediction for all the daylight hours of the following day, based on 48 hours ahead weather forecast. This is very important due to the predictive features requested by smart grid application: renewable energy sources planning, in particular storage system sizing, and market of energy.

Keywords: Artificial neural network; Energy forecasting; Photovoltaic system

1. Introduction

The electricity produced by renewable energy sources (RES) is constantly world-wide increasing thanks to government policies and technical progress. Europe has experienced one of the largest growths: in the last five years the electricity generation by RES, and in particular by photovoltaic (PV) and wind plants, is doubled. However, the RES energy productions are characterized by fluctuating output, because they are influenced by meteorological conditions.

Challenges of controlling and maintaining energy from inherently intermittent sources in grid-connected systems involve many features: efficiency, reliability, safety, stability of the grid and ability to forecast energy production. In

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http://dx.doi.org/10.1016/j.matcom.2015.05.010

Nomenclature

G	global solar radiation on module surface (W/m^2)
P	PV output power (W)
REL	Reliability Coefficient
e	error (W)
NMAE	Normalized Mean Absolute Error
WMAE	Weighted Mean Absolute Error
nRNSE	Normalized Root Mean Square Error
C	Rated power (W)
k	Generic time sample
CSRM	Clear Sky Radiation Model
STC	Standard Test Conditions
m	measured
p	predicted
1/4 h	quarter of hour
h	hour sample
N	total number of considered samples (daylight hours)
i	single trial of ensemble method of ANN
n	number of trials of ensemble method of ANN

particular, PV and wind power forecasting, as an estimation of the expected power production, is crucial to help the grid operators to better manage the electric balance between power demand and supply, and to improve the penetration of distributed renewable energy sources. Furthermore, in countries with a day-ahead electricity market, large power plants based on RES can act, as any other electricity producer, providing power generation sale offers (bids) to the market. In electricity markets, when a power producer does not follow the scheduled bid it will be penalized with retributions lower than those established in the market for those hours with deviation between the electric energy actually produced and that presented in the bid [15,24].

These technical and economic reasons have driven the development of power forecasting models for wind farms and relatively large grid-connected PV plants, with the aim to predict the hourly output power up to 24 h ahead and even more.

In recent years several power forecasting models related to PV plants have been published. The existing solutions can be classified into the categories of physical, statistical and hybrid methods. Some of these models were at first oriented to obtain solar radiation predictions [14,18] while other works present models specifically dedicated to the forecasting of the hourly power output from PV plants [12,20]. Nowadays the most applied techniques to model the stochastic nature of solar irradiance at the ground level and thus the power output of PV installations are the statistical methods; in particular regression methods are often employed to describe complex non-linear atmospheric phenomena for few-hours ahead forecast and specific soft-computing techniques based on artificial neural network (ANN) are used for few-hours power output forecast [17]. Some other papers use physical methods [15,23,21]. Some papers report the comparison of the results obtained with different models based on two or more forecasting techniques [17,18,15]. Nowadays the most important forecasting horizon is 24 hours of the next days. Only a few papers describe forecasting models used to predict the daily irradiance or directly energy production of the PV plant for all the daylight hours of the following day [24,15,25].

In order to define the accuracy of the prediction, some error indexes are introduced to evaluate the performances of the forecasting models. Some of these definitions come from statistics while others originate from regulatory authority for market issues [1].

This paper uses a model based on ANN accompanied by clear sky model for input data validation for next-day energy forecasting of a PV plant with the aim to evaluate its sensitivity. It has been assessed by changing the size of the training data sets in input, the number of iterations and launching single-/multiple-runs. Different error definitions are also calculated and analyzed in order to evaluate the results. The analysis is based on experimental activities carried out by a real PV power plant.