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Wind-resource atlas of Venezuela based on on-site anemometry observation

Francisco González-Longatt [a,*], Javier Serrano González [b], Manuel Burgos Payán [b], Jesús Manuel Riquelme Santos [b]

[a] School of Electronic, Electrical and Systems Engineering, W2.63, Loughborough, LE11 3TU, United Kingdom
[b] Department of Electrical Engineering, University of Seville, 41092 Seville, Spain

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ABSTRACT

This paper presents a wind-resource atlas of Venezuela based on wind observations recorded from on-site meteorological stations. Meteorological datasets of 32 weather stations located over northern Venezuela are used in the development of the maps of three main regions in Venezuela: West, Central and East. Hourly observations of wind speed and direction at each anemometer mast, recorded during the period 2005–2007, have been analysed in order to define the statistical description of the wind resource in the studied area. This processed data along with information on elevation and roughness length is used to model the horizontal and vertical extrapolation of wind data and the estimation of the wind resource. An implementation of *Mass-conservation Wind-Flow Model* in OpenWind software is used to calculate the wind resource at each anemometer mast. A distance-squared interpolation method is proposed as the post-processing procedure and blending technique to create each map upon which a Venezuelan wind atlas is then built. Simulation results include two main wind-resource atlases obtained at 80 m height above ground: (i) a traditional map of mean wind speed for each direction; and (ii) a map of power density. Results show that the best wind-energy resources are located in the northern coastal area of Venezuela.

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* Corresponding author.
E-mail addresses: fglongatt@fglongatt.org (F. González-Longatt), javierserrano@us.es (J. Serrano González), mburgos@us.es (M. Burgos Payán), jsantos@us.es (J.M. Riquelme Santos).

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1. Introduction

The Bolivarian Republic of Venezuela is a country located at the northernmost end of South America, and covers a total area of 916,445 km^2 and has a land area of 882,050 km^2. Shaped roughly like an inverted triangle, the country has a 2800-km coastline, and is bounded to the north by the Caribbean Sea and the Atlantic Ocean, to the east by Guyana, to the south by Brazil, and to the west by Colombia (details are shown in Fig. 1) [1,2]. Venezuela is located within the latitude and longitude of 8°00'N and 66°00'W.

Venezuela has the largest electricity consumption in South America (4018 kWh/year per capita) and its electric power system provides electricity to 95% of the Venezuelan population. The peak demand value varies between 16,500 MW and 18,200 MW depending on seasonal conditions. Electricity consumption rises between 4% and 7% per year, and is expected to increase at the same or higher rate over the next 10 years. Total generation capacity installed is 26,550 MW and the generation mix is 65% hydropower, 32% thermal power plants and 3% distributed energy resources. Although the proven oil reserves in Venezuela are claimed to be one of the largest in the world, more aggressive policies on the use of environment friendly electricity generation have been established in recent years in Venezuela. Several academic projects have been reported to promote *renewable-energy resource* installations in numerous areas of Venezuela [3–5], especially for wind power. Several small-scale and off-grid wind-power projects have been developed and two utility-scale wind farms are presently under development in mainland Venezuela: La Guajira (25 MW) [3], and La Peninsula de Paraguaná (100 MW) [2].

A wind-energy map can stimulate wind-energy projects and promote the exploitation of the wind for various applications, including electricity generation, and water pumping for irrigation. It can also become a tool to help decision-makers seek potential investors in this relatively unexploited field. In many countries, government agencies provide wind maps and wind-resource data, but there remain a number of countries where this kind of study has yet to be performed. In this case, independent researchers have conducted such studies and the results have been presented in several scientific papers: Alamdari et al. [6] presented a wind map of Iran based on observed wind-speed data and geographical interpolation, İlkiliç [7] conducted a similar study in Turkey, Đurišić and Mikulović [8] analysed the South Banat region in Serbia, Ahmed analysed the wind resource in South Egypt [9], and Jervase and Al-Lawati [10] presented a similar study for the Sultanate of Oman.

A large-scale wind-power assessment using reanalysis of wind data in the Caribbean region is presented by Chadee and Clarke [11]; this analysis is valid for a global energy assessment, but the level of detail renders it unsuitable for local assessment in Venezuela. There is a wind-speed map of Venezuela currently in existence, which has been publicly available since the 1960s, but there is no information about the data source, quality and relevant information to make this map useful. Other wind maps have been developed in last decade using reanalysis [5], and satellite data [12], and more recently the Venezuelan Government has contracted LNEG – *Laboratório Nacional de Energia e Geologia* [13] to develop a full wind-energy assessment and wind map, but it remains incomplete at the time of writing this paper. Finally, a wind-resource map of Venezuela using on-site hourly-observation anemometry is not currently available and this paper fulfils this lack of information.

This paper is organized as follows: Section 2 briefly describes the analysis method for a wind-resource map; Section 3 presents the input data used to perform the presented study; while Section 4 presents the results obtained and a discussion of their significance. Finally, in Section 5, the conclusions of the performed analysis are provided.

2. Analysis method

A regional assessment of wind and energy resources over a large area must predict the mean wind behaviour in terms of *wind speed* and *direction* and total *annual energy production* (extractable wind energy) for a specific wind turbine at a particular site. Wind-resource

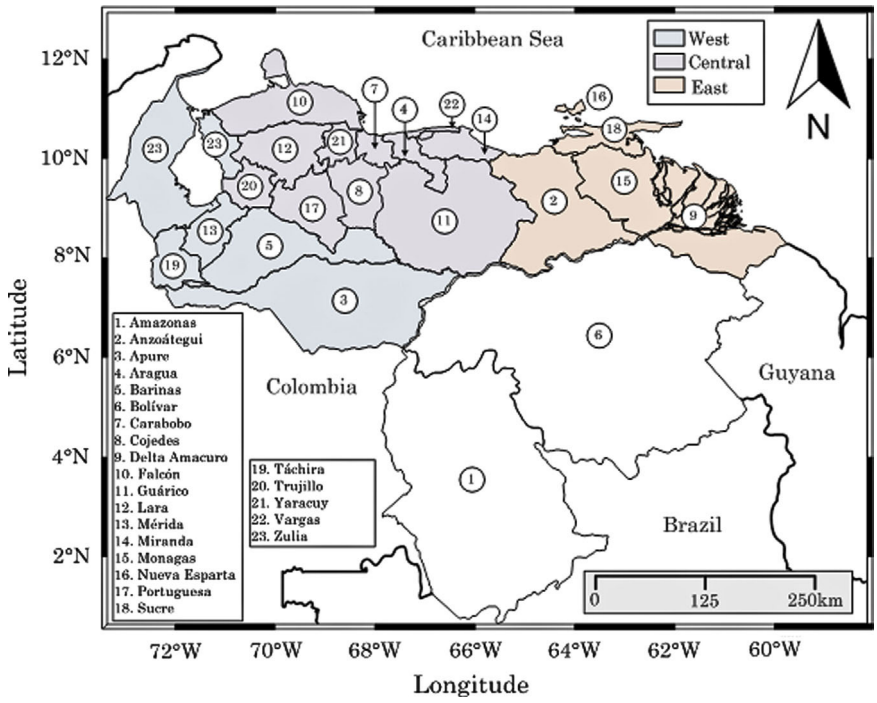

Fig. 1. Geographical location of Venezuela and Political Division.