Atmósfera 27(1), 77-89 (2014)

On the wind power potential in the northwest of the Yucatan Peninsula in Mexico

BERNARDO FIGUEROA-ESPINOZA and PAULO SALLES
Instituto de Ingeniería, Laboratorio de Ingeniería y Procesos Costeros, Universidad Nacional Autónoma de México, Puerto de Abrigo s/n, 97351 Sisal, Yucatán, México
Corresponding author: Bernardo Figueroa-Espinoza; e-mail: bfigueroae@ii.unam.mx

JORGE ZAVALA-HIDALGO
Centro de Ciencias de la Atmósfera, Universidad Nacional Autónoma de México, Circuito de la Investigación Científica s/n, Ciudad Universitaria, 04510 México, D.F.

Received March 26, 2013; accepted November 26, 2013

RESUMEN

La densidad de potencia, los perfiles verticales de velocidad y otras características del viento se establecieron por medio de una torre meteorológica de 51 m localizada muy cerca de la línea costera en el noroeste de la península de Yucatán, ubicada en el golfo de México. Se llevó a cabo un estudio comparativo de la densidad de potencia del viento utilizando información obtenida de septiembre de 2010 a septiembre de 2011. Se encontró que la función de densidad de probabilidad para la velocidad del viento es bimodal a causa de las brisas que soplan de mar a tierra, característica menos evidente a medida que aumenta la distancia vertical al suelo. La diferencia entre estos dos regímenes de viento se utilizó para ajustar la curva de Weibull-Weibull usando un criterio de mínimos cuadrados lineales en los parámetros. Adicionalmente, las simulaciones numéricas de un modelo de mesoescala concuerdan con las mediciones por arriba de z = 50 m (z es la distancia vertical al suelo). Esto sugiere que algunas simulaciones de mesoescala pueden servir como herramienta preliminar para valorar la energía del viento en zonas costeras con extensas áreas bajas.

ABSTRACT

Wind power density, vertical velocity profiles, and other wind characteristics were established using a 51 m meteorological mast located very close to the shoreline on the northwest of the Yucatan peninsula in the Gulf of Mexico. A comparative study of the wind power density was carried out using information obtained between September 2010 and September 2011. The wind speed probability density function was found to be bimodal due to sea-land breezes, a characteristic that becomes less evident as the vertical distance to the ground increases. The distinction between these two wind regimes was used to fit the Weibull-Weibull curve using a linear least-squares criterion in the parameters. In addition, numerical simulations from a mesoscale model are in close agreement with measurements above z = 50 m (z is the vertical distance to the ground). This result suggests that some mesoscale simulations may serve as a preliminary wind energy assessment tool in coastal zones with extended low-lying areas.

Keywords: Wind power density, bimodal probability density function, coastal zone, mesoscale model.

1. Introduction

Wind power technology has been evolving through the history of mankind for at least 3000 years (Sathyajith, 2006). During the last decades, it has experienced unprecedented growth rates due to the transition to sustainable development, triggered in the 1970s by several factors: the oil crisis of 1973 and 1979, the discovery of the ozone layer depletion caused by chlorofluorocarbon aerosols in the upper atmosphere (Molina and Rowland, 1974) and the global warming due to the greenhouse effect related to some gaseous emissions like CO_2 or CH_4 to the atmosphere (Broecker, 1975). This tendency has been reinforced by the development of a gradual ecological consciousness and important international actions such as the Kyoto Protocol in 1997 and 2005. Between 2004 and 2009 the worldwide cumulative wind power capacity grew in average 27% (REN21, 2010).

The efforts to transform the energy and industrial sectors to use renewable energy have been successful in some countries like the United States of America, China, Germany and Spain. In developing countries an important growth is also observed, notwithstanding the economical difficulties. Mexico is not an exception to this trend, and in 2005 an 83 MW wind farm was built in La Venta, on the Tehuantepec Isthmus in the state of Oaxaca, Mexico. A total installed power of more than 580MW is projected by the end of 2012 in that same region (SENER-CFE, 2009).

Considering other regions, the wind potential in Mexico is not particularly abundant with the exception of some particular locations known to have strong winds all year round, according to data collected by standard meteorological stations throughout the country. There are few studies that estimate the power density (power/unit of area), whose results are based on experimental facilities specialized on wind energy assessment (Saldaña and Miranda, 2005). In the case of Sisal, Yucatan, there is a previous work (Saldaña and Miranda, 2009), where the power density was established using a mast equipped with cup anemometers at z = 20 and 40 m. Wind data was collected during the period comprised between January 2005 and September 2007. Information about the wind roses, Weibull curves and their corresponding parameters, as well as wind speed averages are available for direct comparison. The power density was estimated to be D = 222 and 298 W/m^2 at 20 and 40 m, respectively, and a projection for 80 m was also obtained using a power law fit for the vertical wind speed profile. To our best knowledge, this is the only previous study in Sisal; however, there are other previous investigations in Yucatan (Soler-Bientz *et al.*, 2011) where the offshore potential and temperature profiles were studied, as well as the wind shear patterns on an inland site near Merida, 50 km away from Sisal (Soler-Bientz *et al.*, 2009).

All these contributions mention the strong influence of the coastline on the weather and wind patterns, which result from strong temperature and humidity gradients, as well as the sudden roughness step found at the shoreline. Some aspects of these complex interactions, such as the correct scaling that describe atmospheric stability near internal boundary layers still present an important challenge for scientists and engineers, who require a precise assessment of the wind resource.

The evaluation of the wind power potential can be achieved using rather standardized techniques (Rohatgui and Nelson, 1994), which work well in a variety of situations and terrain characteristics. The usual viewpoint is to evaluate the power density (in W/m^2) by means of the wind speed probability distribution function (PDF). If the data is collected for a long period of time (larger than one year) this PDF can be approximated to a theoretical curve, like the Rayleigh or Weibull PDF (Justus *et al.*, 1978). However, this is not feasible for some complex terrains, as was documented by Romero *et al.* (2003) and Jaramillo and Borja (2004) for La Ventosa, located in the state of Oaxaca, Mexico. It was observed that the PDF is bimodal, with high wind speeds coming from the north-northwest as a result of wind channeling from the Gulf of Mexico to the Pacific Ocean through the Isthmus of Tehuantepec, mainly driven by pressure differences between the two basins. Winds from other directions, as well as local effects (such as the ocean breeze) contribute to the second peak of the PDF (at lower wind speed).

Other types of PDF can be fit to bimodal data, such as the so-called MEP (minimum entropy principle) type distribution described by Li and Li (2005) and used in a comparative study (Chang, 2010) where different PDF's were tested with experimental data. The Weibull-Weibull (WW) curve, as well as the MEP-type distributions proved to be well suited for some wind regimes found over complex terrain. The WW curve was chosen for the characterization of wind speed PDF in this study for two reasons: as already stated, it is well adapted for the description of bimodal wind regimes, and for simplicity, as will be shown in section 3.

2. Objectives and limitations

The present study was motivated by a collaborative effort between different research and industrial