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Wind energy in the Gulf of Tunis, Tunisia

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ABSTRACT

This paper presents a study of wind resource in the Gulf of Tunis. During 2008, an experimental measurement of wind speed and wind direction at 20 m and 30 m, were conducted using a 10-min time step. The statistic treatment of results permitted us to evaluate the most characteristics of wind energy in the studied site. An extrapolation of wind speed is, also, carried out using the deduced power law exponent. The annual production of the wind turbine Enercon E82 is estimated at a height of 100 m above ground level. The obtained results can be used to perform wind park project and confirm that the Gulf of Tunis has promising wind energy potential.

Contents

1. Introduction

During the last decades, oil price fluctuation caused an important problem in the economies of the importing countries. In fact, the vulnerability of oil-importing countries to higher oil prices varies distinctly, depending on the degree to which they are net importers and the oil intensity of their economies. To cure this problem, Tunisia decided to invest in the field of renewable energy and essentially the wind energy since it is localized in windy area. In 2000, the first wind farm in Tunisia was implemented in Sidi Daoud site, thanks to a financial support of the Global Environment Facility (GEF) and the United Nations Development Program (UNDP). Recently the Tunisian Company of Electricity and Gas (STEG) has signed a contract of 190 million Euros with the Spanish

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company Gamesa specialized in the construction of wind turbine, for the implantation of three new wind parks project in the site of Metline and Kechabta in the north Mediterranean coast [1]. In the end of 2009, the total power installed will reach a total capacity of 200 MW, which represents about 4% of the total electric power produced by STEG.

In this general context our study is devoted to the evaluation of wind energy potential in the central coasts of the Gulf of Tunis. Many researchers have shown interest in the estimation of the wind energy potential of several sites over the world. For example in Africa, we found the work of Ahmed Shata and Hannitch [2], which presents a data bank of electricity generation and wind potential assessment of Hargada in Egypt. Also, we found the study of Omer [3], which has estimated the wind energy resources of Sudan using the data collected over the country and proposed a study of wind pump profitability in the Soba site. In Europe, an estimation of wind resource in six locations of Hungary was conducted by Radics and Bartholy [4]. Migoya et al. [5] have also estimated the wind energy resource in Madrid region in Spain using the data collected by the Spanish National Meteorological Institute. In Asia, Rehman and Al-Abbadi [6] have interest in the turbulence intensity and wind shear coefficient in the site of Dhulom and their effect to the wind energy potential for the period of 4 year. An overview of the current state and future perspectives of the wind energy in China was presented in the work of Changliang and Zhanfeng [7]. In America, Wichsera and Klinkb [8] have collected the wind data in Minnesota over 3 years and evaluated the wind power potential in this part of the United States of America. In the Waterloo region in Canada, an investigation of wind characteristics and assessment of wind energy potential was presented by M. Li and X. Li [9]. In Tunisia, Elamouri and Ben Amara [10] purposed a study of 17 synoptic sites distributed on all the territory of Tunisia. Using the hourly meteorological data provided by the Meteorology National Institute (INM), they have evaluated the wind speed characteristics and the wind power potential at a height of 10 m above ground level. Ben Amar et al. [11] have presented the energy assessment of the first wind farm section of Sidi Daoud. The energetic and aerodynamic characteristics of aerogenerator Made AE-32 installed on site were also studied over 4 years.

In this study, measurements of wind speed and wind direction are conducted during the year of 2008, using a 10-min time step. The treatment of 52 704 observations, permitted us to evaluate the most important characteristics of wind energy in the studied site: the mean wind speed, the standard deviation of wind speed, the turbulence intensity and the mean wind power density. Wind rose, wind power rose and wind turbulence rose are also estimated.

2. Site description and experimental design

Tunisia is located in North Africa. It is bordered by Algeria to the west and Libya to the southeast. It is the northernmost country on the African continent, and the smallest of the nations situated along the Atlas mountain range (Fig. 1). The country is divided in two regions, the well-watered north and the semi-arid south. An abrupt southern turn of its shoreline gives Tunisia two faces on the Mediterranean sea with 1298 km coastline.

The experimental design is a NRG weather station installed in 36°43′04″N latitude and 10°25′41″E longitude (Fig. 2). It permits the measurement of wind speed, wind direction, ambient temperature and the solar flux in the Gulf of Tunis. This station is equipped with an acquisition system that record, every 10 min the average, the max, the min and the standard deviation values for each sensor.

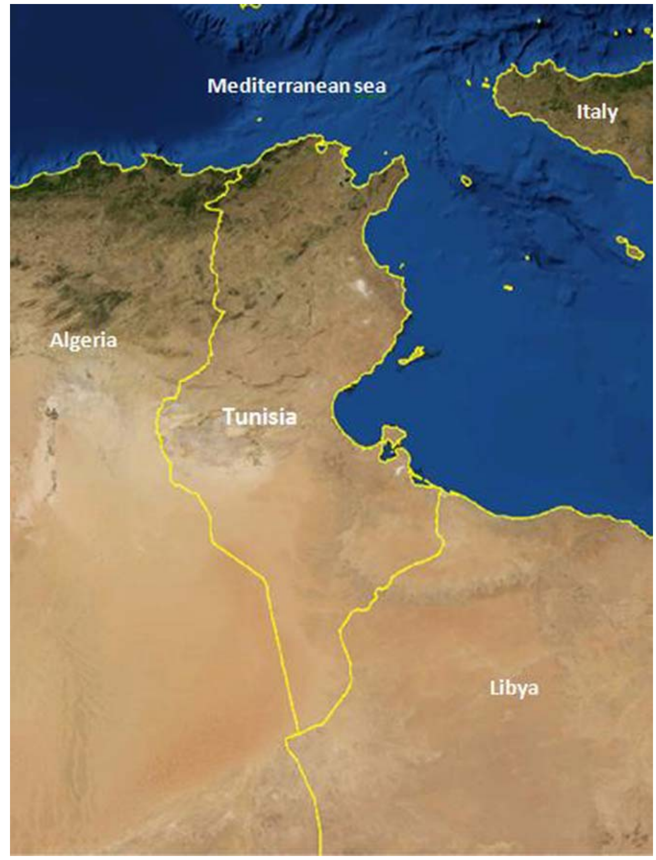

Fig. 1. Geographic position of Tunisia.

3. Theoretical model

For a better understanding the wind speed variability, the data are usually presented in the form of frequency distribution. This gives us the information on the percent of time for which the velocity is within a specific range. Various probability functions can be suitable for statistical distributions of wind regimes. According to Gumbel [12], Weibull distribution is the best one, with an acceptable accuracy level. This function has the advantage of making it possible to quickly determine the average of annual production of a given wind turbine.

3.1. Weibull distribution

In Weibull distribution, the variations in wind velocity are characterized by the two functions:

- The probability density function.
- The cumulative distribution function.

The probability density function $f(V)$ indicates the percent of time for which the wind flows with a specific wind speed. It is expressed as

$$f(V) = \frac{k}{A}\left(\frac{V}{A}\right)^{k-1} \exp\left(-\left(\frac{V}{A}\right)^{k}\right) \tag{1}$$

A and k are, respectively, the scale and the shape parameter. In order to determine the values of these parameters, the maximum likelihood method [13] can be used to fit a Weibull function to a measured wind speed distribution.