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Wind resource assessment in Algeria

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ABSTRACT

In this work the Algerian wind resource assessment is made using statistical analysis based on the measured wind speed data in the last decade from 63 meteorological stations distributed over the Algerian territory and 24 in neighboring countries close boundaries. Weibull distribution is used to study the monthly, seasonal and annual wind power potential over the country. Technical and economic evaluations of electricity generation from different commercial wind turbines, ranging between 200 kW and 2 MW are examined for four selected locations in Algeria for their greatest wind potential. The results led to the actualization of the wind map in Algeria which gave an enhancement of wind energy potential in the eastern region of the Sahara, the occidental Highlands region, three coastal regions open to the Mediterranean Sea and the extreme south of the country, while it has been downgraded in two regions situated in the north. The temporal study gives spring as the windiest period over the largest part of the country. The energy cost analyses show that the four windiest sites have good economic potential where the minimum cost per kWh is about 2.8 c$/kWh, assessed at the site of Hassi R'mel using the Gamesa G80/2000 wind turbine of 2 MW rated capacity, which generates the highest annual energy of 5.46 GWh with a capacity factor of 0.31.

1. Introduction

Since 2011, Algeria has engaged in a new phase of sustainable energy use, the government program consists to install 22 GW of power generated from renewable sources by 2030 (Stambouli, Khiat, Flazi, & Kitamura, 2012). Despite its relatively low potential assessed until now, wind energy is not excluded from the new program, as it constitutes the second axis of development with an electricity production expected to reach about 5 GW in 2030 with 1 GW which must be achieved by 2020 (CREG, 2015). Although Africa is beginning to exploit its enormous wind power potential, energy produced in 2012 was still small, with just 1 GW installed across the continent. Since Africa's wind resource is best around the coasts and in the eastern highlands, at the end of 2012, the continent's almost total wind installations can be found only across three countries – Egypt (550 MW), Morocco (291 MW) and Tunisia (104 MW) (Sawyer & Rave, 2010). This wind energy evolution in Africa, sets Algeria at the bottom of the global installed wind power capacity table in the region. After taking several years, the installation of the first wind power plant of only 10 MW has been issued in June 2014, at Adrar in South of the country. The choice of this site is in adequacy with several wind resource assessment studies, which place the south of Algeria in the Sahara as the windiest (Boudia, 2013; Chellali, Khellaf, Belouchrani, & Recioui, 2011; Diaf & Notton, 2013a; Himri, Himri, & Stambouli, 2009; Himri, Stambouli, & Draoui, 2009; Himri, Stambouli, Draoui, & Himri, 2009; Merzouk, 2000; Merzouk, 2006), and would give the best resources.

An important step in using wind energy is to have information on the carrying capacity of the local wind to drive wind turbines. Thus, several researchers have assessed the potential for wind energy and wind energy potential has been evaluated in many parts of the country.

In this research axis, one may cite studies of Himri, Himri, et al. (2009), Himri, Rehman, Setiawan, and Himri (2012), Himri,

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Himri, and Stambouli (2010), Himri, Stambouli, Draoui, et al. (2009), Himri, Rehman, Draoui, and Himri (2008), Himri, Stambouli, and Draoui (2009) that were among the first to give a statistical analysis of wind speed at different regions in Algeria. The works in the assessment of wind resource at different sites in the Algerian Highlands (Boudia, Benmansour, Ghellai, Benmdjahed, & Tabet Hellal, 2012a, Boudia, Benmansour, Ghellai, Benmedjahed, & Tabet Hellal, 2012b) and in the Algerian Sahara (Boudia, Benmansour, Ghellai, Benmedjahed, & Tabet Hellal, 2013; Boudia, Benmansour, Ghellai, Benmedjahed, & Tabet Hellal, 2012c; Boudia, Benmansour, & Tabet Hellal, 2014). However, few research works in Algeria have been carried out for a technical and economic analysis of wind energy, as the studies of Diaf and Notton (2013a, 2013b).

In the field of the establishment of Atlases and maps of wind in Algeria, a preliminary work was given by Ibrahim (1984), followed by the study of Bensaid (1985). Five years after, Hammouche (1990) published the first wind atlas of Algeria including the classification of wind parameters on the basis of the month and the wind direction for 37 meteorological stations using the WAsP software. This database was mainly used by Merzouk (2000) to map the wind atlas at 10 m, where wind data of 48 stations have been used, covering almost all the topographic zones of the country and to refine the tracing of the borders map, yearly mean wind speeds of 16 stations located in neighboring countries have been used. Aiche-Hamane and Khellaf (2003) give the mapping of the monthly mean wind speed from 75 meteorological stations in Algeria. Merzouk (2006) resumed the preceding work by refining results to plot a new Wind Atlas. Chellali et al. (2011) contributed to the actualization of the wind map of Algeria by performing a spectral analysis to study the cyclical wind, using daily mean wind speed collected over 37 meteorological stations between 2004 and 2009. Where the site of Hassi R'mel in north of the Sahara was introduced, which has a good wind potential, but has been underestimated due the fact that it was located between two less windy regions.

In this work, we propose to assess the wind potential in Algeria, according to the months, seasons and whole years' data, and contribute to the updating of the wind map at 10 m from the ground, using more recent meteorological data, collected from a larger number of measurement points. Thus, daily mean wind speeds collected in the last decade from 87 stations, 63 of which are located in Algeria and 24 in neighboring countries have been used to update the distribution cartography of wind speed in Algeria at a height of 10 m. In the first part, the wind data analysis was done by using the Weibull function at the anemometer height. After the statistical analysis which include several fundamental properties, such as the Weibull parameters, mean wind speed, skewness, kurtosis, standard deviation and power potential variations, the temporal evolution of mean wind speed, the annual mean value of shape factor and mean power density were mapped. In the second part, the performance of six chosen commercial wind turbine models, designed for electricity generation is examined, located at the four windiest sites of this study, with an economic evaluation of the wind energy.

As for the project in Copenhagen, leading to produce energy for the city and which took part in 2000 in a large offshore wind farm project called Middelgrunden (Larsen, Soerensen, Christiansen, Naef, & Vølund, 2005) two kilometers off the city's coastline, or for the total of 200 MW installed wind turbine capacity in the port of Rotterdam (Port of Rotterdam, 2016), the wind energy which could be eventually produced locally in the Algerian Sahara can be used for the national consumption. In this case, the present study may support the idea that cities can be visionary and produce energy themselves.

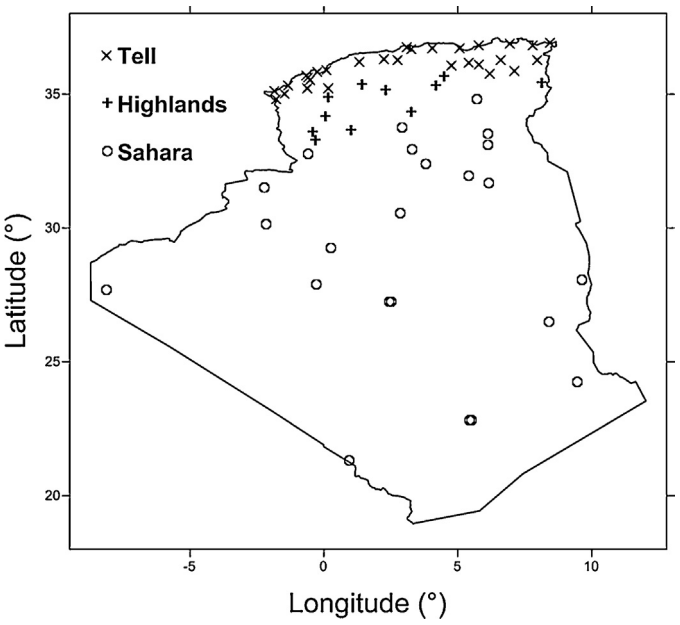

Fig. 1. Distribution of meteorological stations over Algeria.

2. Methodology

In the perspective to prove that some cities can optionally produce their own energy, this study includes two major aspects which are:

- The updating of the wind map in Algeria, using most recent meteorological data collected at ports and airports, near cities,
- The technical-economic assessment of the wind energy production at the windiest cities.

For this purpose, the present section involves to:

- Introduce the wind data used in the study, with the specific probability distribution function used to describe and analyze the wind speed frequency,
- Present the mathematical models used to assess the wind potential at the wind turbine hub height and the wind energy produced at the output of a given wind turbine,
- Define the assumptions relating the method used to determine the present value of costs of electricity produced per year.

In addition, the software packages Matlab and Surfer were exploited.

2.1. Wind data

This work is based on daily mean wind speeds collected in the last decade at a standard height of 10 m from the ground for 63 meteorological stations distributed over Algeria (Fig. 1) belonging the network of National Meteorological Office (ONM). The geographical coordinates of these meteorological stations and measurement periods are given in Table 1.

In addition, daily mean wind speeds of 24 stations located in seven neighboring countries close boundaries have been exploited to refine the tracing of the borders map. The data used were measured over a period of five (05) years from 01/01/2006 until 31/12/2010. Geographical coordinates are given in Table 2.