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Investigation of wind power potential at Oran, northwest of Algeria

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ABSTRACT

In this work, ten years of wind data from Oran meteorological station have been used to evaluate the potential of wind power on the Oranie region, in the North-western part of Algeria, open on the Mediterranean Sea. The WAsP program was used to analyze the wind Atlas of the region to find the windiest areas. Three regions were chosen for their great wind potential. The study proposes to assess wind power cost per kW h of electricity produced using six types of WECs. The investigation at 10 m above ground at the location of the meteorological station shows that Oran has an average wind potential, with an annual mean wind speed equal to 4.2 m/s and an annual mean power density of 129 W/m^2. The temporal study shows that spring period is the windiest with 4.9 m/s. In terms of energy production, the results show that the second site is the best location for harnessing the wind power to generate electricity. The minimum cost per kW h of electricity generated in that location is about 0.0181$/kW h with a capacity factor equal to 51.36% for an annual energy production equal to 11.14 GW h, given by the Power Wind 90 wind turbine of 2.5 MW power rated capacity.

1. Introduction

The geographical location and climate conditions of Algeria procure a great renewable energy potential and theoretically, some of electrical energy needs can be produced by renewable energy [1,2]. The new Algerian program consists to install 22.000 MW from renewable source by 2030, which represent 40% of total energy consumption [2].

Apart from a few hydroelectric power plants that were built in the 50s, and the 150 MW Hassi R'mel integrated solar combined cycle plant, of which 30 MW are generated from CSP, national electricity generation depends heavily on fossil fuels, mostly natural gas and this situation cannot continue considering the global and environmental problems such as CO_2 emissions, as well as air pollution. Since North African's countries have high levels of direct solar radiation, generating electricity bundled by wind, CSP and large scale PV is the most feasible option for North Africa [3]. Despite its relatively low potential, wind energy is not excluded from the new program as it constitutes the second axis of development with a share in electricity production expected to reach about 3% in 2030 [4]. Although most of wind resource assessment studies give the south of Algeria in Sahara as windiest [5–8], thereby the southwest region, which is a remote area and sparsely populated would give the best resources.

However, the country has a coastline of about 1200 km, and wind energy can be produced on a large part of the coastline, as the assessment of a significant wind resource on some microclimates, as Ténès, Algiers, Béjaia and El-Kala [5,8,9]. By these promising wind resource assessments, large areas in coastline of Algeria can be potentially well-suited for wind energy development and worthy of further investigation.

In the general-purpose measurements implemented by National Meteorological Office (ONM) in Algeria, wind parameters in terms of speed and direction are collected at 10 m above the ground, the measurement stations are mostly installed in airports intended for aeronautics. Furthermore, Electricity & Gas National Enterprise (SONELGAZ) had been equipped in last decade by automatic climatological recording stations where wind data are measured at 17 m above the ground, and the data acquisition system was programmed to an average recording interval of 10 min [10,11]. Several scientific and technological institutions, as such research centers and universities have installed their own measurement masts for meteorological data collection, for example the first station of CHEMS network was installed at the Renewable Energy Development Center situated on the heights of Algiers [12], with an interval of 5 min for the measurement data.

As a first step, wind resource studies can be assessed at the measurement points, but works must be thorough because the weather stations' locations are not well adequate to characterize

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Nomenclature

$f(v)$	Weibull distribution function	V_1	wind speed at anemometer height (m/s)
v	wind speed (m/s)	V_2	wind speed at hub height (m/s)
k	Weibull shape parameter	Z_1	anemometer height (m)
A	Weibull scale parameter (m/s)	Z_2	hub height (m)
V_m	average wind speed (m/s)	ρ	air density (kg/m^3)
Γ	gamma function	V_{mp}	most probable wind speed (m/s)
σ	standard deviation (m/s)	$V_{\max E}$	wind speed carrying maximum energy (m/s)
n	lifetime of a wind turbine in years	CF	capacity factor (%)
i	inflation rate (%)	AEP	annual energy production (GW h/year)
r	interest rate (%)	CPU	unit energy cost ($/kW h)
S	salvage value ($)	PVC	Present Value Cost ($)
P	wind power density (W/m^2)	I	investment of an amount ($)
Z_0	roughness (m)	C_{OMR}	operation, repair and maintenance costs ($)
Sk	skewness	S_w	blade sweep area (m^2)
Kt	kurtosis	$WECs$	wind energy conversion system
E	wind energy density (W h/m^2)		

the real wind potential. In order to make a reliable estimate of the wind resource assessment it is required to know the vertical and horizontal profiles of the wind speed on the studied site. For this, we could use different software such as the Wind Atlas Analysis and Application Program (WAsP) [13] of the European Wind Atlas [14] which is one of the most preferred packet programs by commercial firms in wind potential analysis. As reported by Bernhard et al. [15] the wind resource prediction model WAsP is the standard method for wind resource predictions on onshore as well as offshore. It has been validated extensively for land conditions. A validation study for coastal stations was performed by inter-comparisons of wind measurements at different heights from high meteorological masts close to the sea [16] where no significant deviation was found.

In the field of statistical analysis of wind potential in Algeria using WAsP program, we can cite the study of Hammouche [17] who published the first wind Atlas of the country, giving the results of the statistical study of 37 locations. The works of Himri et al. [10,18] that give a statistical analysis of wind speed at different regions in Algeria. Dehmas et al. [9] and Djamai et al. [19] have provided a detailed analysis of wind energy resources at Ténès and Adrar regions respectively, where wind potential Atlas were plotted at selected areas. WAsP takes into account the sheltering effects due to nearby buildings and other obstacles surrounding the wind mast. The position of the close environmental barriers around it must be defined [20–22]. Thereafter, suitable sites to install wind turbines optimally can be selected according to the created wind power and wind speed maps [23–25].

To obtain the initial feasibility of generating electricity from the wind power through a wind farm, in a given region, WAsP was also used in several studies in the world, among which, the following research. Onat et al. [23] used the software to determine the characteristics of wind climate and energy potential and produced detailed analyses on three regions in Turkey namely Samandag, Amasra and Güney. Fang [26] made a study which had the purpose to produce a high resolution wind energy assessment for the potential offshore wind farm area of Taiwan west coast and Penghu archipelago to help the development of Taiwan offshore wind power. Sahin et al. [27] investigated the wind characteristics in the Belen-Hatay province situated in southern Turkey for future wind power generation projects. Hocaoğlu et al. [24] give the wind energy potential and wind maps of the region of Es-kisehir in Turkey and according to the created wind power and wind speed maps, suitable sites to locate wind turbines optimally were selected.

The statistical analysis of wind potential includes seasonal wind speed assessment and diurnal peak periods, in fact, temporal variation of long term mean wind speed provides an understanding of the long term pattern of wind speed and also gives confidence to an investor on the availability of wind power in coming years [28,29].

In this study, wind energy potential has been investigated on the coastline of Oran situated in the northwest of Algeria, open to the Mediterranean Sea by using meteorological data provided from the measurement station within Sénia Airport. Before the assessment of cost and economical aspects, several fundamental properties in the region, such as land topography, rougher surfaces, wind speed probability distribution, wind direction frequency distribution, Weibull parameters, mean wind speed, skewness, kurtosis, standard deviation and power potential variations were determined for ten years. The wind characteristics were also studied according to the wind directions, years, seasons, and hours of the day. According to the simulations, wind speed distribution map of the region is obtained and the three most suitable sites for wind farms are determined. In addition, the performance of six commercial wind turbine models designed for electricity generation located at these sites is examined and economic evaluation of the wind energy in the selected sites is performed.

2. Methodology

The purpose of this study is the wind resource assessment. Wind data and the mathematical models used in the study as well as the cost analysis model are presented. The software packages WAsP, Surfer and Matlab were used.

2.1. Data

The three hour data of the wind speed and direction collected at 10 m from the ground at the meteorological station of Sénia, situated in Oran, were used in this work. The geographical coordinates of the meteorological station with the measurement period are given in Table 1.

The digital terrain map based on a resolution of 90 m derived from the free NASA SRTM (Shuttle Radar Terrain Mission) downloaded from the Jet Propulsion Laboratory [30] was used to prepare the necessary digitized topographical (Fig. 1), sheltering obstacle data (Fig. 2) and roughness.