Renewable Energy xxx (2016) 1–11

Contents lists available at ScienceDirect

Renewable Energy

journal homepage: www.elsevier.com/locate/renene

Estimation of power generation capacities of a wind farms installed in windy sites in Algerian high plateaus

Djamila Abdeslame [a], Nachida Kasbadji Merzouk [b, *], Said Mekhtoub [a], Mohamed Abbas [b], Mokrane Dehmas [c]

[a] Ecole Nationale Polytechnique, El Harrach, 16131, W. Alger, Algeria
[b] Unité de Développement des Equipements Solaires/UDES, Centre de Développement des Energies Renouvelables/CDER, 42415, W. Tipaza, Algeria
[c] Institut de Génie Electrique et Electronique, Université M'Hamed Bouguerra de Boumerdés, 35000, W. Boumerdés, Algeria

ARTICLE INFO

Article history:
Received 11 August 2015
Received in revised form
18 August 2016
Accepted 30 October 2016
Available online xxx

Keywords:
Atlas wind
Wind resource assessment
Wind turbine
Annual electrical output
Regional wind climate

ABSTRACT

The data of the wind data (speed and direction) measured over one period 10 consecutive years, of four sites located in the Algerian high plateaus, were used to determine the regional atlases of wind speed and the power densities of the areas. The results allowed the estimate of the optimal production of wind farm composed by four wind turbine adding up a rated capacity of 8 MW. The Weibull parameters, the mean wind speed and the power density according to different values of heights and roughness factors were calculated for the considered sites. The effects on the annual electrical output production in function of the RIX factor that determines the best site of the wind farm in the area and the wake effects were analyzed. The results show that the two regions, Tiaret and M'Sila are more profitable and are adapted for wind farms installation comparing with the others.

1. Introduction

The Algerian's renewable energy capacities have shown rapid growth over the last three years. The total installed capacity is estimated to 39.24 MW in the second quarter of 2013. An analysis of the installed renewable electrical energy capacity excluding hydropower facilities shows that the contribution of solar and wind powers account for respectively more than 70% and 25% of the installed global capacities, [1].

The same year, Ouhib [2], has updated the available data and established a general overview of the sector including an inventory of the installed capacities by state and public stakeholders [2]. He showed that the installed capacity was 228 MW including, 2.5 MW of solar photovoltaic, 25 MW of concentrated solar thermal, 0.4 MW of thermal heating, 0.10 MW of wind and 200 MW of hydropower. The author concluded that Algeria has significant renewable energy resources, but its use is unfortunately still absent on the market, [2].

For better extrapolation of its non-hydro renewable energy resources, Algeria lunched a strategic plan on 2011. The objective of this ambitious and huge program is to provide 40% of the national electrical energy demand from renewable energy by 2030, [3]. This program has been updated in 2015 [4]. It consists of installing 22 GW power generation capacity from solar and wind resources between 2013 and 2030, of which 22 GW will be intended to satisfy the local electrical energy demand. It is also important to note that the share of wind energy resource will be pass from 1800 MW to 5000 MW.

The Algerian's first wind farm became operational in 2014 [5], it is a 10.2 MW plant located in the south-west of the country in the locality of Kabertene (70 km north from Adrar city). The project which extends over an area of thirty (30) hectares was initiated in 2011. The farm consist of one row of twelve (12) wind turbines facing the main wind direction. In late 2014, the plant was interconnected to the local grid network suppliying the cities of Adrar, In Salah and Timimoun. One year later, the generated power attained 1.5 GWh, [6].

The first attempt to study the Algerian wind potential has been performed by Said et al., [7] in 1984, followed by the assessment performed by Benssaad in 1985, [8]. In 1999, M. Hammouche established the first Algeria wind Atlas [9], which consists of a series of statistical results providing wind energy potentials of 37 sites (in each site is located a weather station).

* Corresponding author.
E-mail address: nkmerzouk@gmail.com (N. Kasbadji Merzouk).

http://dx.doi.org/10.1016/j.renene.2016.10.075
0960-1481/

The first Algeria wind map, based on data measured at 10 m above ground level, has been achieved by N. Kasbadji Merzouk in 2000 [10] and updated in 2006 by the same author, [11]. The atlas is obtained by interpolation of wind speeds obtained from statistical estimated of Weibull parameters. The results show that maximum mean wind speed values are reached in the localities of Adrar (Sahara) and Tiaret (high plateaus) with a peak of 6.5 m/s.

From 2008 to 2010, Himri et al. [12–14] have published several studies about wind potential assessment, in which they predicted the electrical power generated in the concerned sites using wind turbine characteristics.

In 2011, F. Chellali [15], has contributed to update the wind map of Algeria using more recent data especially those collected from Hassi R'mel region located in the south-eastern of the country. S.M. Boudia [16] has also updated, in 2013, the Algerian wind Atlas using the monthly mean wind speed estimated at 10 m above the ground. He used vertical extrapolation of wind speed at 50 m to estimate the available wind power densities and the amount of energy generated monthly by a 600 kW rated in some selected sites.

Several authors have used the Wasp software to perform analyses on wind resources and to predict wind farms performances taking into consideration various parameters related t climate and terrains, (flat, mountainous, complex, …).

Onat et al., [17] and Hocaoglu et al., [18] used Wasp software to produce the wind maps and evaluate energy potential of regions in Turkey. They investigated the wind characteristics to identify suitable sites for wind farm installation. Lima et al., [19] performed a wind resource evaluation and wind energy assessment of two northeast of Brazil. They demonstrated that WAsP program is a robust and reliable tool to make wind assessment.

A validation studies have also been performed by comparing the wasp estimation with wind measurements. Bernhard et al., [20], found no significant error when comparing wasp results with measurements at different height levels in the coastal regions.

Romeo and al [21], used a numerical data to estimate a wind speeds of coastal sites in Sicily (Italy) and concluded that Wasp software produces a good results. Sua'rez et al. [22], tested the performance of the wasp package at mountainous terrain. They compared the speeds estimated by Wasp with those measured by a reference anemometer installed in the concerned region. They concluded that the results were different from one place to another depending on the interpolation slope (rising or falling). For some terrain types, the error level could be up to ± 20%. Landberg et al., [23] used measured data at six complex terrain stations in northern Portugal to compare them with those estimated by Wasp. They conclude that WAsP results are poor if the climate of reference and target sites is different. Berge et al., [24] analyzed the prediction WAsP errors in the quite complex terrain using a five 50 m measuring masts and the RIX-values differences in a mountainous site near the Norwegian coast. He concluded that the prediction errors of 10%–15% were found, due to the contribution of a coastal background station. For the measuring stations within the wind farm area only the prediction errors was estimated in the range 0%–6%, which is considered quite low taking into account the complexity of the terrain.

Indasi et al. [25] used Wasp to estimate the average annual wind speed at three sites located in Australia based on measurements obtained during one year. The results were compared with those measured during two weeks by A Tarcer Wind Lidar and indicate that data observed by a single mast are sufficient to achieve accurate micro-scale modeling using WAsP.

Only few microclimate wind energy studies were conducted in Algeria. Some authors have not considered relief aspects when horizontal interpolation of wind data from the measuring point to the wind farm location is performed. Among these studies, one can mention those done by Boudia et al. [26] and Bencherif et al. [27]. Concerning the high plateaus region, we note contribution in the estimation of wind turbine performances based on wind data measured at weather stations installed in the concerned localities, [28]. The monthly wind mean speeds were extrapolated at the turbine height using empirical models and the generated power was estimated based on the wind turbines characteristics. However, the topography was not considered in the analyses and the roughness was introduced just for wind speed extrapolation.

Abdessalem et al., [29], used Wasp in 2011 to analyses the use of wind energy resources of microclimate site for seawater reverse osmosis desalination (SWRO). The study was performed assuming a wind farm consisting of 5 Bonus type 2-MW wind turbines. It was found that wind energy can be used successfully to supply an SWRO desalination plant in the involved region. Djemai et al. [30] investigated the possibility of installing a 10 MW wind farm in Adrar, a region located in the south of the country. Boudia et al., [31] produced a wind assessment of coaastal area using Wasp software without consideration of the accuracy of the interpolation. He also compared the electrical output production of farms composed with different kind of turbines installed in the same area. Bel Abbes [32], determined the cost of electricity production of wind farms installed in northern part of Algeria. He used the Wasp software to estimate wind energy potential of the investigated sites. .A Wasp model was also used for a detailed analysis of available wind potential and production of wind maps of two sites located at high plains region, [33,34].

In the present work, a wind microclimate assessment of four selected sites located in the high plateaus region is carried out. The analysis evaluates and compares power generation performances of assumed similar wind farms installed in the selected sites namely Tiaret, Ksar El Chellala, M'Sila and Setif.

The Wind Atlas Analysis and Application Program (WAsP) package is used in the analysis. It is a powerful software tool for horizontal and vertical extrapolation of wind climates and for estimation of the Annual Energy Production (AEP) from wind turbines and farms developed by Riso National Laboratory of Denmark [35,36]. It includes required tools and models to perform all steps of the process from wind resources assessment to wind turbines AEP.

WASP contains several physical models to describe the wind resources over different terrains and close to sheltering obstacles. In addition, the simulator includes a wake model for wind farm effects and an orographic performance indicator (RIX) to show the stability model for the average heat flux conditions, [35]. Furthermore, if the terrain is complex and steep, it allows an easy access to a state-of-the-art CFD model.

The data used by WASP for wind resource and AEP assessments can be input from different sources. The wind-climatological input comes from wind measurements at a nearby meteorological mast or may be derived from mesoscale modeling results. The topographical description can be obtained from space shuttle elevation data or from other data sets, while the land cover description and nearby sheltering obstacles can be extracted from topographical maps, data bases or satellite imagery (ex: Google Earth), [36–38].

2. Method and data

As stated in the previous section, Algeria has a huge wind potential. To select appropriate sites for wind farms installation, it is obvious that the most accurate evaluation of a site, wind resource is through on-site measurement using an anemometer and a wind vane. However, this process is costly and time consuming.

The wind velocities can also be modeled using computer programs, describing effects of some parameters on the wind, such as