EVALUATION OF WIND TURBINE PERFORMANCES LOCATED IN TWO SITES OF THE ALGERIAN SAHARA

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Abstract- This work deals with a study of wind power generation applied to two sites located in southern Algeria (Adrar and Tamanrasset). First, the wind potential available in bothsites was evaluated using the OWC utility of the Wind Atlas Analysis and Application Program (WAsP software) based on the Weibull statistical distribution. The wind data used are six years records of measurements made by the National Meteorological Office (ONM) during the period 2010 – 2015. Then, the performances of wind farms located in two selected areas in the study regions were evaluated. The wind turbines used were similar to those of the existing 10.2 MW wind farm of Kaberten (Adrar).

Keywords— wind Park, resource assessment,wind farms,WAsP.

1. Introduction

Nowadays, the electrical energy generated from wind is very promising, given the huge wind resource well distributed in almost every region of the world. This type of renewable energy is inexhaustible and addresses the environmental concerns raised by the use of fossil fuels. Wind power is in full development in terms of installed capacity in the world; several factors have contributed and continue to contribute to its growth. Wind energy is clean and does not produce any pollution; it does not reject any hazardous substances in the environment and does not generate waste. The use of a turbine of 1000 kW, under normal conditions, prevents an Annual rejection of 2000 tons of carbon dioxide emitted from other sources of producing conventional electricity, such as coal power plants. Small standalone wind systems could be the solution to electrification and irrigation in remote rural areas. The recent studies have shown the existence of a significant wind resource. In addition, in other international studies, it has been reported that Algeria is among the countries with the best wind resources in Africa. In 2015, the Algerian Government recently adopted an ambitious program of energy development and energy efficiency in order to have a share of 27% of renewable origin. In this program, wind energy should reach 5 GW in 2030 [1] and the installation of wind farms in southern Algeria is planned. Wind resource assessment and wind energy cost evaluation is an important step before the development of any wind farm project. In this work, the wind energy potential available in two sites located in south Algeria is evaluated. The selected sites are:Adrar and Tamanrasset, and the wind data used are records of measurements made by the National Meteorological Office (ONM) during the period 2010 - 2015. The wind potential evaluation is performed using the WAsP OWC utility based on the Weibull statistical distribution. Then, the performance of two wind farms located in the selected sites is evaluated.

2. Materials and method

The WAsP allows spatial interpolation from ground-based data while taking into account topography, roughness and obstacles. It has been used to establish wind atlas of several countries and the European wind atlas [2]. The Auteurs reported that the prediction model of the wind resource implemented by the WAsP software is the standard method for both on-shore and offshore wind resource forecasting. It

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is one of the preferred tools of wind turbine manufacturers for the analysis of wind potential and it has been validated intensively for onshore installations.

2.1. Wind data analysis

The OWC utility of the WAsP software is based on the statistical Weibull function for the generation of wind speeds frequency distributions. The Weibull Probability model is described by the probability density function of the wind speed f(v) is given by the following equations [3] and [4];

$$f(v) = \left(\frac{K}{A}\right)\left(\frac{V}{A}\right)^{K-1} \exp\left(-\left(\frac{V}{A}\right)^{K}\right) \qquad (1)$$

Where V is the wind speed, A is the Weibull scale parameter and k is the dimensionless Weibull shape parameter.

2.2. Wind turbine performance analysis

The expected annual production (AEP) of the wind turbines are evaluated using the WAsP software, the wind turbine power curves given by the manufacturer and the results of the statistical wind data analysis. Power loss considered in the WAsP software is only due to wake loss. However, according to the European Association for wind energy [4] power loss are also due to blade soiling, electrical losses, and machine downtime and yaw mechanism. The wind turbine capacity factor (CF) is defined as the ratio between the wind turbine annual production and one-year theoretical wind farm production [5]:

$$C_f = \frac{AEP}{8760 \cdot P_n} \qquad)$$

Where P_n the wind turbine is rated power

The wind turbine full load hours (NH) is calculated using the following relationship [6]:

$$NH = \frac{AEP}{P_n} \qquad (3)$$

2.3. Used data

The data used in this work are wind turbine data, wind speed and direction data, digital elevation maps and roughness lengths for each region.

2.3.1. Wind turbine data

The wind turbines selected are similar to those of the Kaberten wind farm of Adrar. This wind park consists of 12 GAMESA G52-850 kW Wind turbines. The main wind turbine characteristics are summarized in Table 1. The maximum ambient operating temperature is 46◦C.

Table 1. Technical specifications of the G52-850kW GAMESA wind turbine

Nominal power: Pn [KW]	850
Rotor diameter: D [m]	52
Hub height: H [m]	55
Cut-in wind speed: Vd [m / s]	4
Rated wind speed: Vn [m / s]	15
Cut-out wind speed: Vs [m / s]	25

2.3.2. Meteorological data

Wind data used in this work were collected from Meteorological stations of the Office National de la Meteorology (ONM) whose coordinates are summarized in Table 2. Both meteorological stations are located at 10m above the ground level. Wind data are collected for the period 01/01/2010 to 31/12/2015.

Table 2. Locations of the meteorological stations

ONM stations	Longitude	Latitude	Altitude[m]
Adrar	27°49 N	00°11 W	279 m
Tamanrasset	22°48 N	05°26 E	1362

2.3.3. Topographic and Roughness maps:

The topographic maps are based on a digital terrain model (DTM) derived from satellite data SRTM (Shuttle Radar Topography Mission) in geographic coordinates at up to 90 m (3-arc-sec) resolution. The topographic maps of the study areas are depicted in figure 1. The roughness maps of the study area are generated using WAsP sMap Editor and Google Earth software. Roughness lengths adopted in this study are 0.5m for palm grove and cities, 0.3m for farmland with few buildings and 0.01 for sand surfaces.

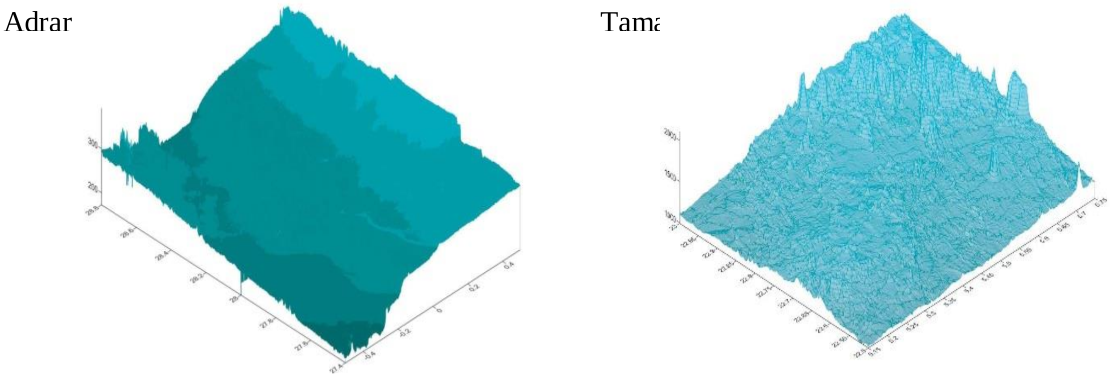

Figure 1. Topographic maps of the study areas.

3. Results and discussions

3.1. Wind data statistics

The statistical analysis of data recorded at 10m height above the ground level show that at Adrar area, the average wind speed is about 5.24 m/s,Northeast is the dominant direction and the wind power density is 173W/m^2.For the site of Tamanrasset, the average wind speed is 4.07m/s and East is the predominant direction. Figure 2 illustrates the histograms of the annual variations of the mean wind speed and the mean power density, at 10 m above the ground level, for both regions. It is found that during the period (2010-2015), the average wind speeds differ from year to year. In Adrarregion, a slight decrease of the available wind potential is observed: the average wind speed varies from 6.12 to 5.19 m/s, and the power density varies from 222 to 163 W/m^2. For the site of Tamanrasset,the average wind speed varies slightly from 4.12 to 4.19 m/s, and the power density varies from 95 to 110 W/m^2.

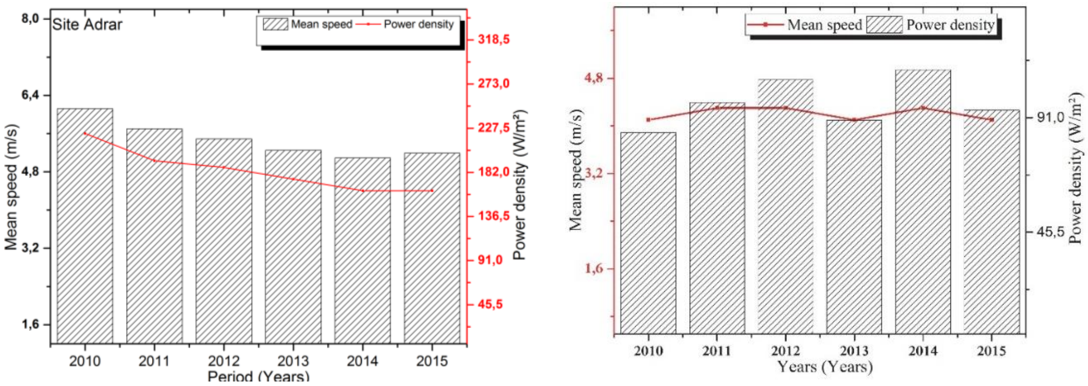

Figure 2. Annual changes in the average wind speed at 10 m a.g.l.

3.2. Wind maps

Figures 3 and 4 illustrate the wind speed maps at 55 m above ground level (i.e. at the hub height), and the location of the wind turbines. The wind speed maps depicted in Fig. 4 show that at 55 m, in Adrar region, the average annual wind speed varies from 6.7 to 7.41m/s. At Tamanrasset, the average annual wind speed varies from 4.51 to 9.71 m/s (Fig. 4).

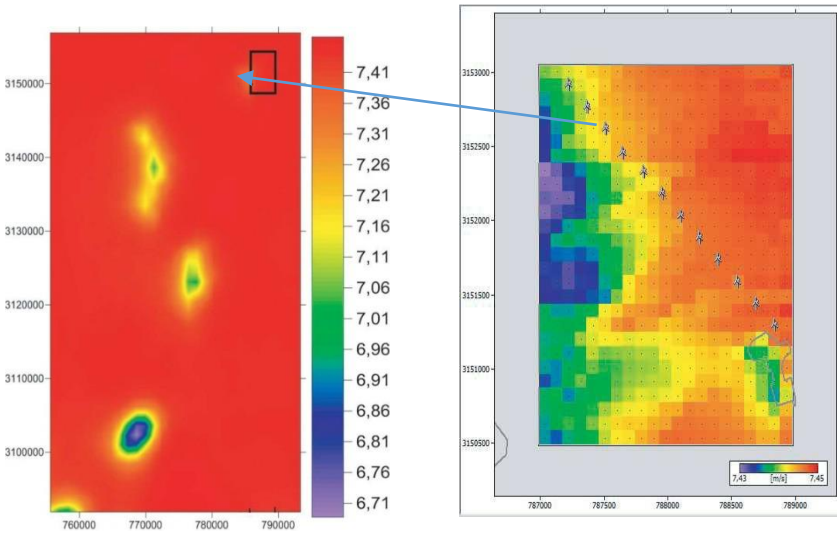

Figure 3. Wind speed maps at Adrar area, at 55 m a.g.l

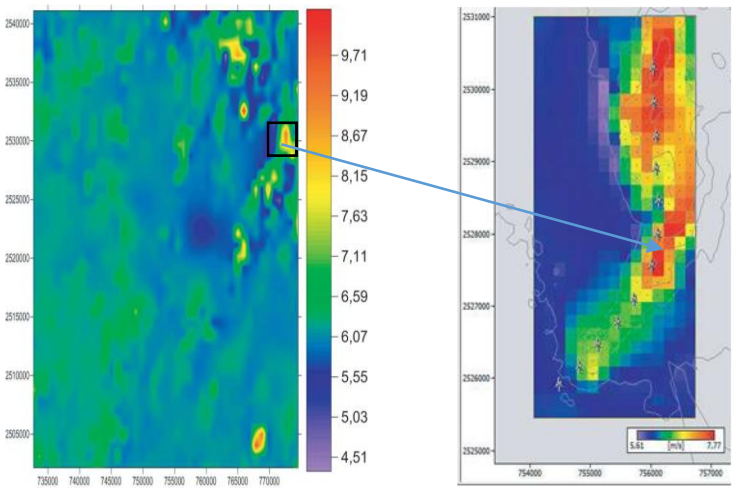

Figure 4. Wind speed maps at Tamanrasset area, at 55 m a.g.l

3.3. Expected wind farm performances

The AEP, CH and NH computed using WAsP software are summarized in Tables 3 and 4 for Adrar and Tamanrasset sites, respectively. These Tables show that the wind park AEP takes a value of 31.787GWh for Kabertene and 29.927GWh for Tamanrasset. Concerning the capacity factor, it is about 35% and 33% for Adrar and Tamanrasset wind fram respectively. The number of operating hours of the wind park is 3100 h for Kabertene 2934 h for Tamanrassetwind park.

Table 3. Expected AEP, CF and NH of Adrar wind park

Wind Turbines	VMean(m/s)	AEP (GWh)	Wake loss (%)	CF (%)	NH (h)
WT01	7.44	1.03	2.68	35.95	3149
WT02	7.45	2.653	1.9	35.63	3121
WT03	7.45	2.648	2.1	35.56	3115
WT04	7.45	2.645	2.22	35.51	3108
WT05	7.45	2.644	2.24	35.51	3111
WT06	7.45	2.642	2.29	35.48	3108

WT07	7.45	2.642	2.29	35.48	3108
WT08	7.44	2.642	2.25	35.48	3108
WT09	7.44	2.634	2.50	35.37	3099
WT10	7.44	2.646	2.07	35.54	3113
WT11	7.44	2.647	1.98	35.55	3114
WT12	7.44	2.665	1.29	35.79	3135
Wind Park	7.45	31.787	2.01	35.58	3116

Table 4. Expected AEP, CF and NH of Tamanrasset Wind Park

Wind Turbines	VMean(m/s)	AEP (GWh)	Wake loss	CF (%)	NH (h)
WT01	6.63	2.128	0.59	28.58	2503
WT02	6.68	2.151	1.07	28.89	2531
WT03	7.04	2.390	0.98	32.10	2812
WT04	7.91	2.925	1.07	39.28	3441
WT05	7.53	2.673	0.99	35.90	3145
WT06	7.50	2.658	1.18	35.70	3127
WT07	7.25	2.495	1.53	33.50	2935
WT08	7.13	2.418	1.64	32.47	2845
WT09	7.17	2.444	1.73	32.82	2875
WT10	7.06	2.376	1.65	31.91	2795
WT11	7.30	2.538	1.83	34.09	2986
WT12	7.60	2.732	1.01	36.70	3214
Wind Park	7.23	29.927	1.28	33.49	2934

4. Conclusion

Using the WASP software, we assessed the expected performance of two wind farms located in southern Algeria. First, a statistical analysis of the available wind speed was performed. The wind maps were then established at the hub level and the expected power generation was evaluated.

The results clearly indicate that the Adrar region is the most eligible area for the development of wind energy. It was found that the expected AEP is about 31 GWh, the wind turbine capacity factor, 35.79%, and the number of full load hours is 3135 hours / year.

5. References

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