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Investigation of wind characteristics and wind energy potential at Ras Ghareb, Egypt

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ABSTRACT

To study the structure of a coastal location «Ras Ghareb» on the Red Sea in Egypt, a measurement station with mast of 24.5 m has been established in a built-up area, near the seashore. First, a statistical analysis of the measured data over the period 2000–2005 was performed, including calculation of the wind speed power law index which was found to be 0.18 for Ras Ghareb area. Then, wind speed data was expressed at the height of (usually 10 m) which makes it directly related to the objective of those people working in the renewable energy sector. Therefore, the mean wind speeds, availability of data, seasonal variation and the distribution by the wind direction were studied to ascertain its potential for wind energy development.

The annual wind speed over this site varies from 8.3 to 9.8 m/s at 10 and 24.5 m heights, respectively. Most of the time 73% the mean wind speed in the ranges 5–10 and 10–17 m/s at 10 m. Also, higher winds of the order 10 m/s and more observed during summer months. The main wind direction is north–northwest sector (330°) for about 51% of the times during the year that makes it unique for installation of wind parks.

Second, numerical estimations to determine the seasonal power law coefficient and Weibull parameters at different heights from 10 to 100 m were carried out.

Finally, Rayleigh distribution and our method stated in Ref. [3] were adopted for defining the monthly wind power available at 10 m height for this region. It is emphasized that Rayleigh model is not appropriate and our method is more efficient for Ras Ghareb area. Where the expected mean of wind power density was found to quite high 360 W/m^2 per year at 10 m hub height, which makes this station likely candidates for wind power utilization.

It is appear from our analysis that Ras Ghareb region can be explored for generating the electricity. Where the monthly and annual pattern of wind speed matches the electricity load pattern of the location.

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1. Introduction

The wind energy resource is very large and widely distributed throughout the world as well as in Egypt. To begin with, any country considering using wind electricity technologies must first evaluate its own wind regime to assess the potential of the installation of wind–electricity generation. It has long been recognized that the wind energy potential along the Gulf of Suez and the Red Sea is markedly higher than in other parts of Egypt – and most other parts of the North African deserts as well. Egypt has vast areas with wind conditions which are suitable for wind energy development. There are generally only scattered populations in these areas. The main obstacle for development, there is no industrial manufacture of wind turbines in Egypt so equipment and expertise must be

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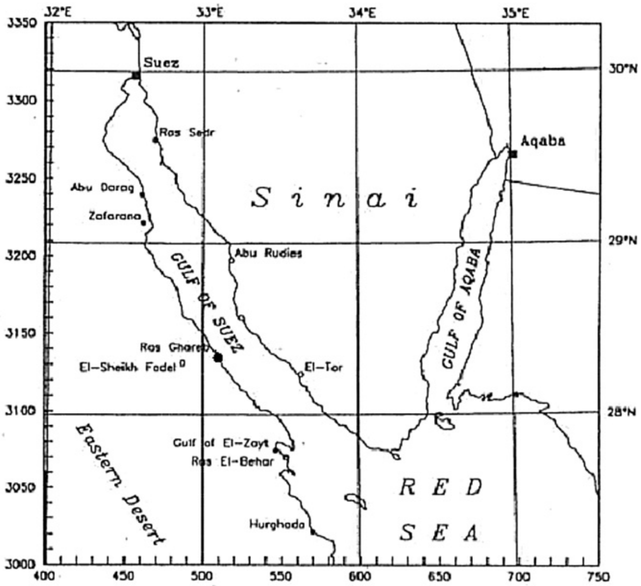

Fig. 1. Location of the measuring meteorological stations over Gulf of Suez and the northern Red Sea in Egypt; (•) indicates the location of Ras Ghareb station.

imported from other countries. Currently, Egypt produces electricity using wind farms at Zafarana, Gulf of El-Zayt and Abu Darag stations, which are located in the northern part along the Red Sea. Their electricity production presented to the country and due to an increase of needs Egypt exported these electricity to Jordan [1–3].

This note presents a first analysis of wind data for Ras Ghareb region on the east coast of Red Sea in Egypt, and provides a basis for a preliminary evaluation of wind power potential in the region.

2. Description of the site and measurement station

To study the structure of the coastal wind field on the Gulf of Suez in Egypt, a measurement station with mast of height 24.5 m, has been established about 6 km WSW of the town of Ras Ghareb. The distance to the coastline of the Gulf of Suez is also about 6 km in an east-northeasterly distance. There are no sheltering obstacles close to the «Ras Ghareb mast». The surface consists mostly of sand and gravel with a roughness length of less than 0.01 m. The map in Fig. 1 indicates the location of the station in northern region the east coast of Red Sea in Egypt. Where its grid coordinates (latitude 28°20′, Longitude 33°01′) and elevation is 56 m above the ground level.

Wind speed is measured with cup anemometers of the Risø-70, manufactured by the Wind Energy Department at Risø, Denmark. This anemometer features a light weight 3-cup rotor and is a sturdy, yet fast-responding anemometer. The calibration is linear with an offset (‘starting speed’) of approx. 2 m/s. The distance constant is about 1.8 m [4].

3. Wind speed and frequency distribution

The wind speed behaviour of a region is a function of altitude, season and hour of measurements. Generally, five years of records and weather watching is sufficient to predict the long-term seasonal mean wind speed to within an accuracy of 10% with a confidence level of 90% [5].

For this study, wind speed recording instruments are located at 24.5 m height above the ground level for a period 6 years (2000–2005) by the Renewable Energy Authority in Cairo, Egypt. This means that the quality of the recorded and published data does not reflect the calibration factor. In addition, it was also necessary to adjust the wind speed data to a height of 10 m in order to make it directly related to the objective of those people working in the renewable energy sector.

Over the last decades the effect of different heights on wind speed has been studied by many authors [5–7], and the relationship for computing the wind speed at a height of 10 m when measurements are taken at heights other than the standard 10 m is given as:

$$V_1 = V_2\left(\frac{H_1}{H_2}\right)^{\alpha} \quad (1)$$

where V_1 = the estimated mean wind speed at 10 m height, V_2 = the mean wind speed measured by the Renewable Energy Authority, Egypt at Ras Ghareb station, H_1 = the anemometer height, 10 m, H_2 = the anemometer height at Ras Ghareb station.

Recently, α is the roughness factor, this parameter is the wind speed power law index, which is considered to be 1/7 or 0.14, for surfaces with low roughness, as given by the one-seventh power law. The value of this coefficient varies from less than 0.10 over the tops of steep hills to over 0.25 in sheltered locations. In addition, the value of α in Eq. (1) depends on the time of the day, the wind speed level, the wind stability and the surface roughness. This value varies from 0.10 to 0.40 [8–10].

The simply computed roughness factor, α, which results from the wind speed measurements, recommended by many authors was used as follow [11–14]:

$$\alpha = \frac{0.37 - 0.0881\ \ln V_2}{1 - 0.0881\ \ln(H_2/10)} \quad (2)$$

By applying the available wind data for the station under study at 24.5 m height with the Eq. (2), it is evident that the corrected roughness factor for Ras Ghareb region has been found to be α = 0.18. So, the results of the above processes on wind speed are presented in Table 1. Mean monthly for measured wind speeds at 24.5 m height of the year with estimated values at H_1 = 10 m height are plotted in Fig. 2. Analysis the data of Table 1 and Fig. 2 lead to the following:

(1) This table shows that the wind speed at Ras Ghareb is generally high. Where the annual mean wind speed of the site is 8.3 m/s at 10 m height.
(2) From March to October strong trade winds observed and the drop in the average wind speed observed from November to February. The maximum value of monthly mean wind speed is 10.2 m/s during June and the minimum value is recorded at the station with 6.4 m/s during January.
(3) On the seasonal scale: Ras Ghareb's wind climate is characterized by the trade winds during summer season in the range of 10 m/s. Additionally there are strong wind 8.3 m/s blowing at spring and autumn periods.

Table 1
Measured and calculated mean wind speed (m/s) for the years 2000–2005 of Ras Ghareb at 24.5 m and 10 m, respectively.

Mean wind speed	Month												Annual mean
	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	
v_{10}	6.4	6.6	7.9	8.3	8.8	10.2	9.5	10.0	9.7	8.5	6.6	6.6	8.3
$v_{24.5}$	7.5	7.8	9.3	9.7	10.3	12.0	11.1	11.7	11.4	10.0	7.8	7.7	9.8