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ASSESSMENT OF WIND ENERGY POTENTIAL IN EAST AZARBAIJAN PROVINCE OF IRAN (CASE STUDY: SAHAND STATION)

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ABSTRACT

Today's world requires a change in how the use of different types of energy. With declining reserves of fossil fuels for renewable energies is of course the best alternative. Among the renewable energy from the wind can be considered one of the best forms of energy can be introduced. Accordingly, most countries are trying to identify areas with potential to benefit from this resource.

The aim of this study was to assess the potential wind power in Sahand station of Iran country. Hourly measured long term wind speed data of Sahand during the period of 2000-2013 have been statistically analyzed. In this study the wind speed frequency distribution of location was found by using Weibull distribution function. The wind energy potential of the location has been studied based on the Weibull mode. The results of this study show that mean wind speed measured at 10 m above ground level is determined as 5.16 m s^{-1} for the studied period. This speed increases by, respectively, 34.78 % and 41.21 %, when it is extrapolated to 40 and 60 m hub height.

Long term seasonal wind speeds were found to be relatively higher during the period from January to September. At the other hand, higher wind speeds were observed between the period between 06:00 and 18:00 in the day. These periods feet well with annual and daily periods of maximum demand of electricity, respectively.

Keywords: Iran, wind power, Weibull distribution, Sahand station.

1. Introduction

Climate and weather conditions are the main factors affecting human life, his work and life in general can be regarded as organisms. Among the climatic variables, wind is a special place. The round earth and physical characteristics, the amount of radiation in different parts of the surface are not equal. Even assuming equal received solar radiation in different regions of temperature and consequently do not show the same pressure. When solar radiation reaches the Earth unequally uneven surfaces may cause changes in pressure and temperature and the effect of wind variations may occur. Many meteorological parameters are moved by air currents. In fact, because of the winds role in the transmission of physical and meteorological parameters of the atmosphere is quite important. In addition, the force of the wind as a source of new and inexhaustible energy in many countries is considered.

Wind energy has many advantages and therefore Today, however, become a source of energy is rapidly growing in the entire world. Research efforts on identifying challenges in the context of the wider use of wind energy are concentrated. Wind energy is a renewable energy source that does not pollute the environment like fossil fuels. Unlike thermal power plants that work with fossil fuels, wind energy does not pollute the air. Wind turbines produce any polluting substances into the atmosphere and thus do not cause acid rain or greenhouse gases. Wind energy relies on the renewable power of the wind is inexhaustible.

Wind-generated electricity is attracting the interest of farmers, ranchers, and other landowners across the country. People find wind energy attractive for a variety of reasons, including its lower impact on the environment than other fuels and its potential economic benefits. In some situations, wind-generated electricity can help farmers and ranchers reduce their energy costs. This publication introduces small-scale wind energy to help farmers and ranchers decide whether wind energy is the right option for them.

The various studies on wind resource assessment and prospects of wind power plant have been carried out for the Middle East and African countries (Ammari *et al.*, 2003 ; Buflasa *et al.*, 2008 ; Buhairi, 2006 ; Elamouri and Amar, 2008 ; El-Osta and Califa, 2003 ; Essa and Mubarak, 2006; Marafia and Ashour, 2003; Ahmed and Hanitsch, 2006). El-Osta and Califa, (2003) carried out feasibility study for a wind farm of 6.0 MW capacity in Zwara, Tripoli, Libya. The results of the study showed that the project is economically feasible (El-Osta and Califa, 2003). Ammari and Maaitah (2003) presented feasibility study of utilization of wind energy for power generation in Jordan. Their data analysis showed that the annual mean wind speeds at a height of 24 m could reach as high as 7.6 m s^{-1} and available wind energy density close to 3 MWh/m^2/year (Ammari and Maaitah, 2003). Marafia and Ashour (2003) carried out an economic feasibility study and assessment of the potential of off-shore/on-shore wind energy as a renewable source of energy in Qatar. The results of the study indicate the suitability of utilizing small- to medium-sized wind turbine machine (Marafia and Ashour, 2003). Essa and Mubarak, (2006) carried out wind resource assessment for 18 different locations in Egypt, located mainly in Mediterranean, Inland, and Red Sea zones(Essa and Mubarak, 2006). Shata and Hanitsch (2005) carried out study on the wind energy potential for electricity generation on the coast of Mediterranean sea in Egypt. The study found out that the best locations are Sidi Barrani, Mersa Matruh, and El Dabaa where the annual mean wind speed was greater than 5.0 m s^{-1} (Shata and Hanitsch, 2005).

The main objective of the present study is to perform detailed analysis of a wind energy capacity in Sahand station (Iran). The specific objectives of the study are to assess the wind power, air density, air turbulence intensity (TI), energy yield and effect of hub height on energy yield for an isolated site in Sahand station of Iran.

2. Material and Methods

In terms of location, Sahand is situated between 37° N latitude and 46°7°E longitude. The average height of this station is 1671 meters. This station located in North West of Iran in west side of East Azarbaijan province (fig.1).

Wind data was collected every 3 h at 10m above ground level in the meteorological station of Sahand located near Tabriz and during 13 years (from 2000 to 2013). Wind speed and direction were measured, respectively, using a cup-type anemometer and weathercock. Windographer software was used to analyze raw wind data. It reads the data of almost all the data recorders, products good graphs and carries out elaborate statistical treatments. Sahand annual average of wind speed was found to be 9.05 m s^{-1} for the studied period.

Long term seasonal wind speeds were found to be relatively higher during the period from January to September (Fig. 2). We in this period correspond roughly to a period of maximum demand of electricity. In this study notice that, approximately, higher wind speeds were observed between 06:00 and 18:00.

Considering the fact that rotors of the actual wind turbines are placed at heights varying between 40 and 110m AGL and in order to choose the height of the pylons handling the wind turbines, it is necessary to know the variations of wind speed with altitude (Fig.2).

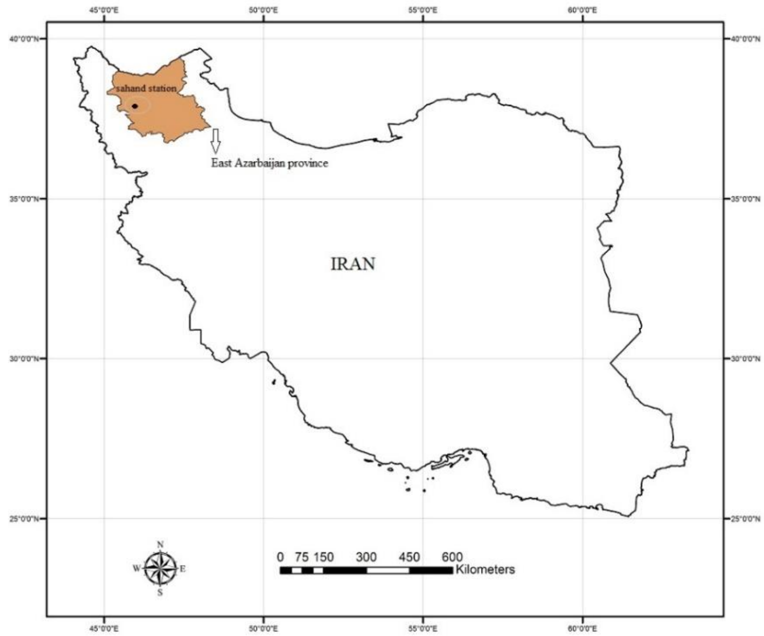

Figure 1. Geographic location of Sahand station

The variations of wind speed with altitude can be estimated using the following equation (Vosburgh, 1998):

$$v_2 = v_1 \left(\frac{z_2}{z_1}\right)^a \quad (1)$$

Where, in m s^{-1}, is the calculated wind speed at height, is the observed wind speed at height and Z2, V1 is the observed wind speed height Z1 and α is the wind speed power law exponent.

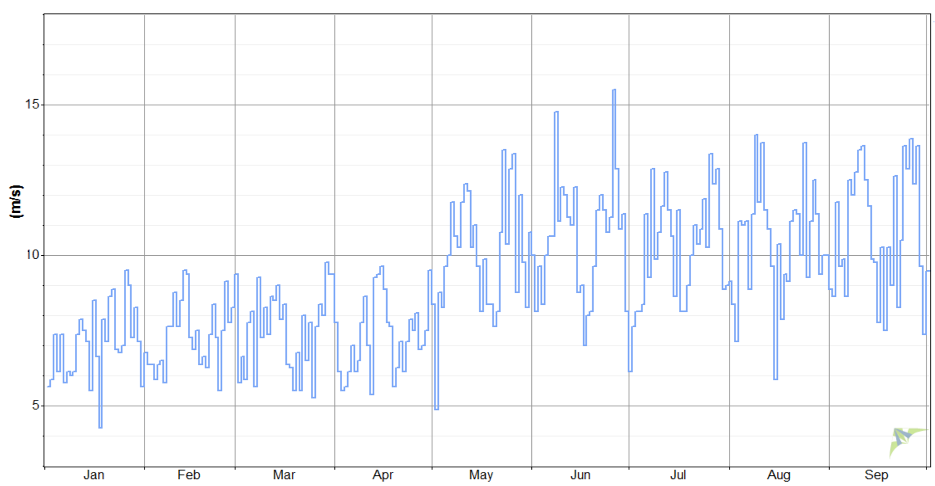

Figure 2. Monthly variation of long-term mean wind speed

The only factor to estimate for this formula is the value of the power law coefficient. It varies following the roughness of the location. The formula that calculates α is:

$$\alpha=\frac{1}{\ln\bar{z}/z_0}-\left[\frac{0.0881}{1\text{-}0.0881\ln z_1/10}\right]\times\ln\left(\frac{V_1}{6}\right) \quad (2)$$

With:

$$\bar{z}=\exp\left[\ln z_1+\ln z_2\right]/2 \quad (3)$$

Z0 is the roughness of the location.

After analysis, a value of α= 0.14 was found as the power law exponent factor for the station of Sahand where (roughness of the location) value is equal to 0.01 m.

Thereby, the collected wind speed data was calculated at 40 m and 60 m hub height using {Eq. (1)}. At these heights the annual average of wind speed became 8.44 m s^{-1} and 8.56 m s^{-1}, respectively, while it was only 5.16 m s^{-1} at 10 m AGL, this corresponds to increases of, respectively, 34.78 % and 41.21 % from the 10 m average annual wind speed, (Fig. 3).

Knowledge of wind speed frequency distribution is a very important factor to evaluate the wind potential in windy areas. The Weibull distribution is the most commonly used model. It is a good match with the experimental data. The idea is that only annual or monthly average wind speeds are sufficient to predict the complete frequency distribution of the year or the month (Ahmed and Hanitsch, 2003).

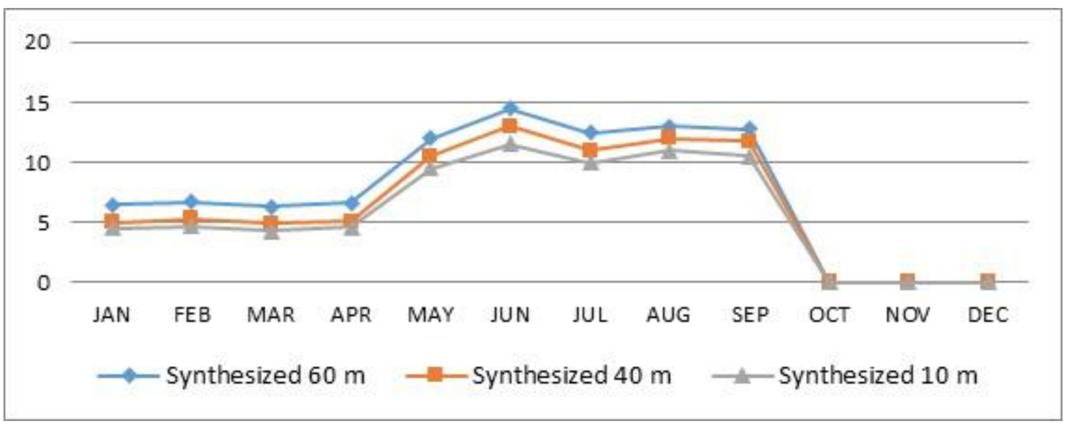

Figure 3. Monthly wind speed profile (at 10 m and extrapolation to 40 m and 60 m)

The Weibull probability density function is written as:

$$\bar{z}=\exp\left[\ln z_1+\ln z_2\right]/2 \quad (3)$$

$$f(V)=\frac{k}{c}\left(\frac{V}{c}\right)^{k\text{-}1}\exp\left[-\frac{V^k}{c}\right] \quad (4)$$

K (dimensionless) and (m s^{-1}) are the shape and scale parameters of this distribution deduced from the experimental wind data, respectively. In this study, we found that ck = 1.61 and = 4.91 m s^{-1}. c

The frequency distribution of wind speed shows in the case of Sahand location that wind speed remained at the modal value 6.5 m s^{-1} and below it for about 19 % of time during the entire year and above it for the rest of the period, (Fig. 4).

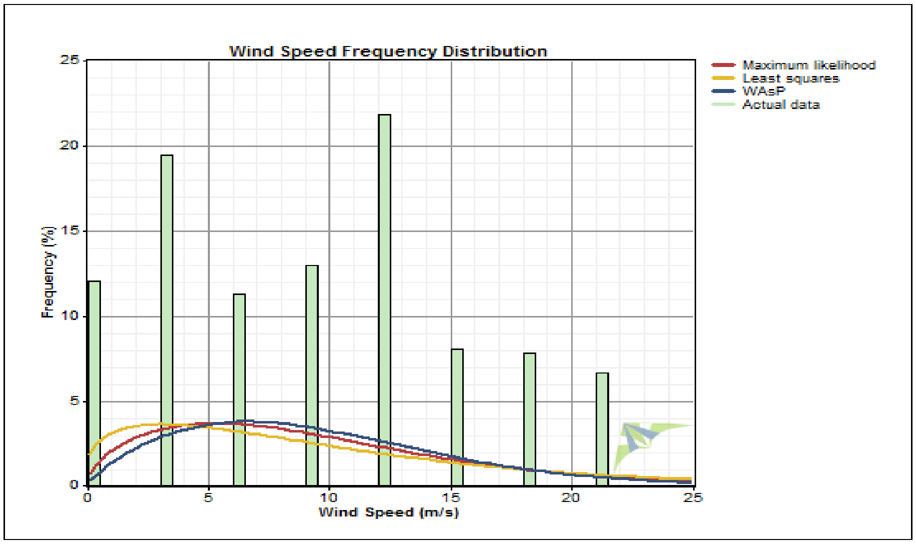

Figure 4. Probability distribution function

3. Results

Wind energy is the kinetic energy of the moving air mass. The power available, Pa (in watts), possessed by wind blowing with a speed of V (in m s^{-1}) is directly proportional to the rotor swept area A (in m^2), and to the cube of the wind speed. It is given by:

$$P_a=\frac{1}{2}\rho AV^3 \tag{5}$$

The area a perpendicular to the direction of flow can be calculated by this relation:

$$A=\pi\left(\frac{D}{2}\right)^2 \tag{6}$$

Wind turbine cannot utilize all the available power. The amount of power which can be extracted (power output, P) is, in realty, inferior to Pa and it is given by the following relationship:

$$P=C_p\times P_a \tag{7}$$

Where Cp is a power coefficient, its evaluation is based on Rankin-Froude theory [5-10]; it is given by this formula:

$$C_p=4a(1-a)^2 \tag{8}$$

When the variable a=3/1a=, Cp reaches its maximum which is called Betz limit (0.59). So, we can say that the maximum power output is:

$$P=0.59\times P_a \tag{9}$$

The average wind power density is calculated as the integral of the wind power (Tony *et al.*, 2008):

$$\int PdV=C_p\int P_a\,dV=C_p\int\frac{1}{2}\rho AV^3dV \tag{10}$$

It is used to determine the annual and seasonal wind power densities.

The electric energy produced by a turbine over the year is given by the following relationship:

$$E=N_h \int PdV=N_h C_p \int \frac{1}{2}\rho AV^3 dV \quad (11)$$

Considering the Weibull distribution {Eq. (4)}, we can write the Equation (11):

$$E=N_h C_p \frac{1}{2}\rho A \int V^3 f(V)dV \quad (12)$$

Using the Equation (6), we can write Equation (12) as:

$$E=N_h C_p \frac{1}{2}\rho\pi \frac{D^2}{4} \int V^3 f(V)dV \quad (13)$$

This equation calculates the maximum yearly mean wind energy per unit cross sectional area. Thereby, this entity was estimated for wind energy extracted at different heights: 10 m, 40 m and 60 m (Fig. 5). As expected, mean wind energy is proportional to hub height.

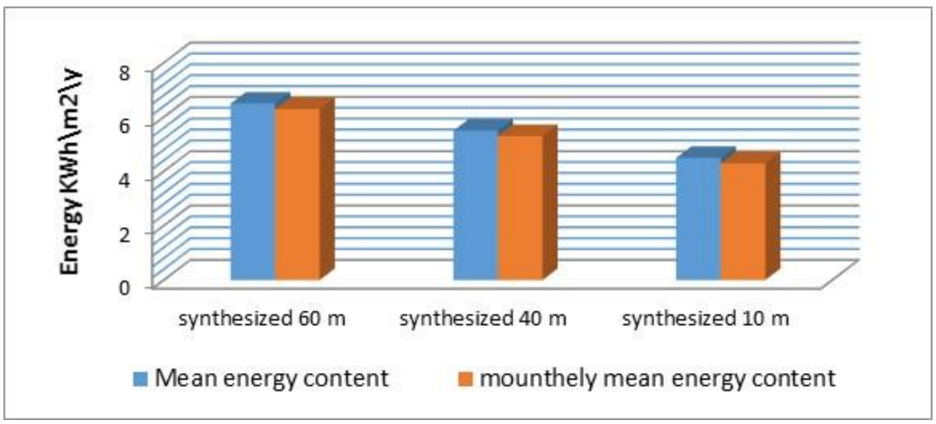

Figure 5. Maximum yearly mean wind energy per unit cross sectional area

There is a large variety of wind generators produced by many manufacturers over the world. Considering the socio-geographical features and wind potential of the region of Sahand, and looking for machines with good performance and reasonable cost, four types of wind turbines (3 blades) from different manufacturers have been chosen: Bergey Excel-R, Bergey Excel-S, Enercon E33 and Fuhrländer FL 100.

All these turbines have a "cut-in wind speed" that is inferior to the mean wind speed observed in Sahnd as shown in Table 1.

This table shows also other features of the chosen turbines: nominal (or "rated") speed and the corresponding nominal (or "rated") power which is the nameplate capacity of the turbine (the amount of power it produces under the wind speed and air density conditions at which the manufacturer rates the turbine). The diameter and the number of blades of each machine are also given. The wind power curves of the different wind turbines are given in fig. 6.

The power output can divide the selected turbines in tow groups. This is another criterion added to the raison of our choice. Indeed, Bergey wind turbines used in combination with a back-up diesel generator, and with optional photovoltaic, provide a cost-effective and reliable alternative to conventional methods of electricity supply in remote areas. This fits well with the aim of this study.

Table 1: Main characters of four different commercial wind turbines

	Hub	Hub Height	Time At	Time At	Mean Net	Mean Net	Net Capacity
	Heig ht	Wind Speed	Zero Output	Rated Output	Power Output	Energy Output	Factor
Turbine	(m)	(m s^{-1})	(%)	(%)	(kW)	(kWh/yr)	(%)
Bergey Excel-R	43	10.78	25.57	21.06	2.7	23,770	36.2
Bergey Excel-S	43	10.78	25.55	22.48	3.8	33,137	37.8
Fuhrländer FL 100	35	10.26	12.3	34.59	53	464,473	53
Enercon E101	99	14.26	28.98	37.54	1,166.40	10,217,406	38.9

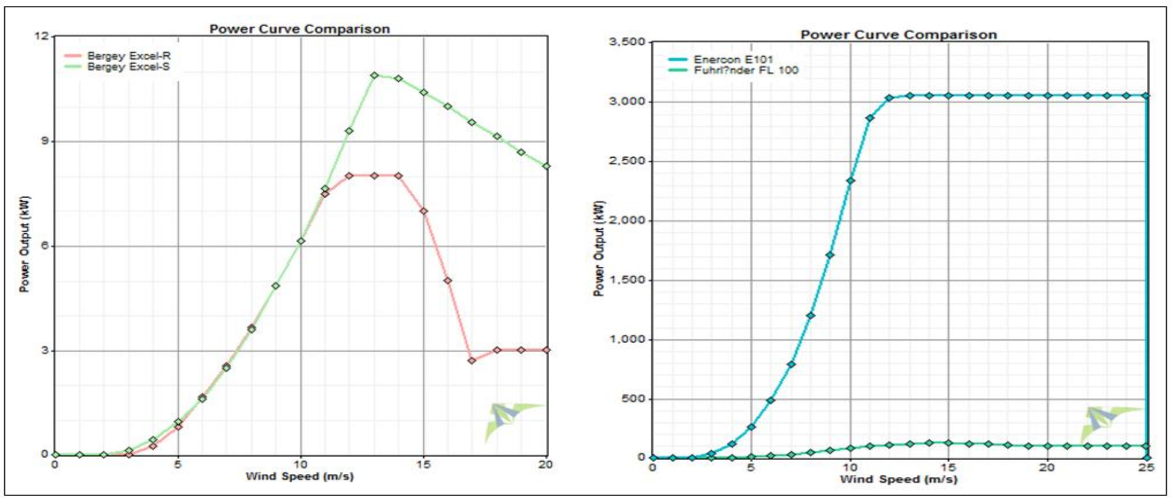

Figure 6. Wind power curve of four different commercial wind turbines

At the other hand, the Enercon E33 and Fuhrländer FL 100 turbines chosen here, operate with variable rotor speed and are thus capable of producing electric power. The output energy E of each turbine has been calculated for the region of Sahand using Windographer software.

4. Discussions

The aim of this study was to assess the potential wind power in Sahand region of Iran. Hourly measured long term wind speed data of Sahand during the period of 2000-2013 have been statistically analyzed.

The probability density distributions have been derived from long term wind speed data and the distributional parameters were identified. The wind speed frequency distribution of location was found by using Weibull distribution function. The wind energy potential of the location has been studied based on the Weibull mode. The results of this study show that

Mean wind speed measured at 10 m above ground level is determined as 5.16 m s^{-1} for the studied period. This speed increases by, respectively, 34.78 % and 41.21 %, when it is extrapolated to 40 and 60 m hub height.

Long term seasonal wind speeds were found to be relatively higher during the period from January to September. At the other hand, higher wind speeds were observed between the period between 06:00 and 18:00 in the day.

The maximum yearly mean wind energy per unit cross sectional area of standard wind turbine was estimated at different heights: 10 m, 40 m and 60 m and shows that mean wind energy is proportional to hub height. So we can vary only the rotor diameter to find the optimal wind turbine(s) for this location. Four types of wind turbines have been chosen according to the socio-geographical features and wind potential of the region of Sahand, and looking for machines with good performance and reasonable cost.

The power output of these machines was evaluated at different hub heights. This evaluation confirms that small wind turbines (Bergey Excel-R and Bergey Excel-S) can be used to supply remote regions with small electricity needs (rural zones) while bigger machines (Enercon E33 and Fuhrländer FL 100) can be used to supply those with more important electricity demand: airport, new agglomerations, military installations, telecommunication stations

g- Small wind turbines (Bergey Excel-R and Bergey Excel-S) can be used in conjunction with other energy resources (solar and/or diesel) in order to compensate wind energy output fluctuations.

References

Ahmed Shata A.S. and Hanitsch R. (2006), The Potential of Electricity Generation on the East Coasts on Red Sea in Egypt, *Renewable Energy*, **31**(10), 1597 – 1615.

Ammari H.D. and Maaitah A. (2003), Assessment of wind-generation potentiality in Jordan using the site effectiveness approach, *Energy,* **28**, 1579–1592.

Tony B., David S., Nick J., Ervin B. Wind Energy Handbook. England: John Wiley & Sons, Ltd 2001:607.

Buflasa H.A., Watson S.I. and Thomson M. (2008), Wind resource assessment for the Kingdom of Bahrain, *Wind Engineering,* **32**(5), 439–448.

Buhairi M.H.A. (2006), A statistical analysis of wind speed data and an assessment of wind energy potential in Taiz-Yemen, *Environ. Res.,* **9**(2), 13–21.

Elamouri M. and Amar F.B. (2008), Wind energy potential in Tunisia, *Renewable Energy*, **33**, 758–768.

El-Osta W. and Califa Y. (2003), Prospects of wind power plants in Libya: A case study, *Renewable Energy*, **28**, 363–371.

Essa K.S.M. and Mubarak F. (2006), Survey and assessment of wind-speed and wind-power in Egypt including air density variation, *Wind Engineering*, **30**(2), 95–106.

Marafia A.H. and Ashour H.A. (2003), Economics of off-shore/on-shore wind energy systems in Qatar, Renewable Energy, **28**, 1953–1963.

Vosburgh P.N. (1983), Commercial Applications of Wind Power', New York: Van Nostrand Reinhold Company, 455.

Shata A.S.A. and Hanitsch R. (2005), Evaluation of wind energy potential and electricity generation on the coast of Mediterranean, *Renewable Energy*, **31**(8), 1183–1202.