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Modeling of Wind Energy in Some Areas of Palestine

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Modeling of Wind Energy in Some Areas of Palestine

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Dedication

To my parents who gave me life, love & care.

To my sisters& brothers.

To my special friend Maryam, & faithfully friends

To all my relatives, teachers, and who gave me

encouragement to do this work.

Declaration

I certify that this thesis submitted for the degree of Master is the results of my own research, except where otherwise acknowledged, and that this thesis (or any part of the same) has been not submitted for a higher degree to any other university or institution.

Signed:…………………….

Abeer Abd Hameed Aljuneidi

Date11/06/2011

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Abstract

The daily mean wind speed data for 4 locations in Palestine over the period of 5 years (1997-2001) are collected, analyzed, and fitted to the Weibull distribution function. Weibull parameters are derived from the cumulative function of the observed data records, and used to calculate the mean wind speed and variance of the theoretical distribution, which have maximum values in summer months and minimum values in winter months, except Hebron station due to its higher elevation (1005 m) above sea level. However, Jericho station provides lower values of monthly mean wind speed (maximum, 2.56 m s^{-1}). The second order polynomial is used to fit the relationship between the wind power and the mean wind speed. The monthly mean wind power density is higher during summer and lowers during winter except Hebron which is higher in winter and lower in summer months. The highest mean power values are 32.98 W m^{-2} in January and 37.85 W m^{-2} in July for Hebron and Nablus respectively, whereas the lowest mean power is 1.66 W m^{-2} in January for Jericho. The adjusted R^2 of the polynomial fit is 99.8% for all stations except Hebron 70%.

The following recommendations for further study are :

- Manufacturing facilities for wind plant and wind turbine must be created in suitable sites.
- It should be attended in selecting an appropriate site for the wind turbine.
- In case to power generation, major problem is energy storage, we need to resolve this by linking wind generators with conventional electrical grid.
- It should encourage the researchers to develop projects in the field of wind energy.
- Where the wind speed is favorable, variety of applications of wind energy, short or long term research programmers may be undertaken for the utilization of wind energy in Palestine.

- Wind speed should be recorded in different locations of Palestine for precise studies in this field.
- Decision makers should support researchers for continual studies.

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Chapter One

Introduction and Previous Studies

Introduction

Two main issues facing the world today, one is the global climate change, which is predominantly due to the greenhouse gas emission. Major contribution of greenhouse gas is by the burning of fossil fuel such as coal and oil. And the other is the shortage of world fossil fuels reserves due to the fast growing population on the earth causes accelerating consumption of the finite petroleum resource which causing pollution in air such as carbon dioxide, sulfur and nitrogen oxides. The exploitation of the renewable energy sources plays a key role for achieving the CO_2 emissions reduction targets established by the Kyoto Protocol. At the World Summit on Sustainable Development in Johannesburg (September 2002), it was agreed that the contribution of renewable to world energy use should be substantially increased with a sense of urgency. Intermittent renewable energy can reliably provide 10–30% of total electricity supplies in the area covered by an adequately strong power grid if operated in conjunction with fuel-based power generation (Cellura *et al*, 2008).

Wind power is considered one of the most effective means available to prevent the crises of global climate change and energy security, providing a possible solution to the problems associated with volatility in the fossil fuel markets for coal, gas and oil (Bientz *et al*, 2009).

1-1 Previous Studies

In order to evaluate the potential of wind energy, many statistical models have been developed and studied for different areas. These models help the energy planner, researchers and policy makers widely. Wind power is a function of wind speed; the methodology is based on the development of a model for values of wind power estimated by applying the appropriate transformations to values of wind speed.

There is a model investigating the impact of a wind power on the dynamics of the power system to which is connected. In order to avoid the necessity of developing a detailed model of a wind park with tens or hundreds of wind turbines and their interconnections and to calculate the wind speed signal for each individual turbine aggregated wind park models are needed with their constant or variable speed wind turbines (Slootweg and Kling, 2003).

Scerri and Farrugia recorded hourly wind data for the year 1993 at Luqa International Airport in Maltese. Data are obtained at a height of 10 m above ground level and 84 m above average sea level. Wind parameters are examined assuming a Weibull distribution function for the recorded data. The assumption of a logistic distribution function as a possible alternative mode of calculating the mean wind speed is also analyzed. A comparison of the two methodologies is carried out (Scerri and Farrugia., 1996).

Shabbaneh and Hasan computed Weibull parameters of the wind speed distribution function for some weather stations in Palestine (*many of those stations are now evacuated and cancelled*). Wind potentials in kWh/m^2 yr were calculated, then contours of wind potential were drawn. Electricity from the wind can be generated, in some locations in the West Bank, at a cost of 0.07 $/kWh (Shabbaneh and Hasan., 1997).

Nfaoui et al found that the annual average wind speed for the eleven sites in the windy regions in Morocco ranged from 5 m/s to 10m/s and the average power density from 100 W/m^2 to 1000W/m^2, which might be suitable for electrical power production by installing wind farms. On an annual scale the observations of the distribution of hourly wind speed are better fitted by the Weibull hybrid distribution in contrast to the Weibull distribution. The wind power is estimated to be 1817 MW, that is to say, the exploitable wind energy is 15198 GWh, which represents theoretically 11% of the total consumed energy in Morocco in 1994 (Nfaoui *et al*., 1998).

Alnaser and Al-karaghouli studied and analyzed wind speed in Bahrain and found that the average annual wind speed equal to 4.7 m/s, which indicates the suitability to a certain extent of using only small size wind parks (blade diameter of not more than 2 m) to produce electricity to fulfill the deficient electrical power at day and night during summer season in Bahrain. The extractable power was found to vary from 36 to 160 W m^{-2}. The wind direction was found so variant which makes it unique for installation of wind parks due to limited spaces; this meets the requirement for Bahrain (area of 700 km^2). These wind parks can be installed near the sea shores or off-shores. (Alnaser and Al-Karaghouli., 2000).

Yin provides a global analysis surface wind speed based on data from 1506 weather stations across the world. It is found that the local variation in monthly normal surface wind speed can generally be captured as a sine function of calendar month. With station-specific descriptor values, the function accounts statistically for 97% of the variance in surface wind speed contained in the total data set; the corresponding root-mean-square error is 0.30m/s, or 8.2% of the surface wind speed data mean (Yin., 2000).

Celik analyzed the wind energy potential of the Iskenderun located on the Mediterranean coast of Turkey based on 1-year measured hourly time-series wind speed data. The probability density distributions are derived from time-series data and distributional parameters are identified. Two probability density functions are fitted to the measured probability distributions on a monthly basis. The wind energy potential of the location is studied based on the Weibull and the Rayleigh models (Celik., 2003).

Cellura et al analyzed the long term wind speed and direction available at the wind measurements recorded in several stations of Sicily-Italy, and were used for the spatial modeling of the wind fields over the region. A statistical analysis of the wind data estimated the parameters of the wibull distribution. The results of some traditional deterministic and geostatistical interpolation techniques are shown (Cellura *et al*., 2008).

Modeling of daily wind speed data using two parameter Weibull distribution for ten selected weather stations in Seri Lanka is represented. The daily wind speed data measured at the heights 6 m-15 m during the years 2001 and 2004. Numerical modeling using two parameter Weibull distribution function was performed to describe the wind speed frequency distributions over a two time periods. The annual values of shape parameter k and scale parameter c were estimated and found to vary between, 0.80 to 3.58 for k and 2.79 to 19.78 m/s for c. The highest seasonal values of shape parameter and scale parameter are recorded. The two parameter Weibull distribution was found to describe the daily average wind speeds with a reasonable accuracy (Fernando and Sonnadara., 2007).

In Ibadan-Nigeria, the daily wind speed data was obtained from the meteorological stations. Those data were measured continuously with a cup-generator anemometer at a height of 10 m. The results using the Weibull distribution function provide acceptable accuracy for prediction of wind energy output required for preliminary design and assessment of wind power plants (Fadare., 2008).

Ahmed Shata presented a new analytical method for calculation of the wind energy potential available along the north coast of the Mediterranean Sea and the east coast of Red Sea in Egypt and moreover, it estimates the possible electrical power generated by large wind turbines and the expected cost is 1.26 € cent/ 1 kWh. It is hoped that the data analysis will help to identify good sites in Egypt for new wind turbine installations. This evaluation is hoped to trigger the use of large wind turbines at those selected sites (Ahmed Shata., 2008).

Dahmouni et al proposed a study of wind resource in the site of Borj-Cedria in the Gulf of Tunisia. Using the data of wind speed and wind direction, are obtained. To perform wind power designs the result evaluated by using Weibull model. Wind power roses(used to determine the direction of wind) are also estimated. The functioning of two types of wind turbines is simulated and a comparison between their profitability is carried out in the considered site, which allowed them to identify the suitable site of the wind park and avoided the problems of the project (Dahmouni *et al*., 2008).

Zaharim et al investigated the probability distribution of wind speed data recorded in Faculty of Engineering, University Kebangsaan-Malaysia. The wind speed data represented in the form of frequency curves show the shape of a potential model. The two-parameter Weibull distribution and lognormal distribution are adopted in this study to fit the wind speed data. The scale and shape parameters were estimated by using maximum likelihood method. The goodness-of-fit tests based on the empirical distribution function are conducted to show that the distribution adequately fits the data. It is found that the two distributions are all suitable for describing the probability distribution of wind speed data, the two parameter Weibull distribution is more appropriate than the lognormal distribution (Zaharim *et al*., 2009).

Brahmi *et al* developed algorithm to determine the monthly wind energy potential of Sfax city- Tunisia. The monthly scale and shape parameters are calculated to evaluate the monthly wind potential. As a result the monthly wind energy distribution is obtained. However, even non conventional methods are used, wind distribution estimation presents limitation in its maximum. Hence, the introduction of a third Weibull parameter in the distribution becomes necessary (Brahmi *et al.*, 2010).

1-2 Wind and wind power

The burning of fossil fuel to obtain energy pollutes the lower layer of atmosphere, causing pollution in air such as carbon dioxide, sulfur and nitrogen oxides. These pollutants are threatening the health of the global ecosystem and climate change.

The growing environmental concern of air quality around the world has created a move to green sources of energy such as wind and solar which provide a pollution-free electricity (Jowder, 2009). Renewable energy sources including wind power offer a feasible solution to distributed power generation. It became one of the most convenient and environmental friendly ways of generating electricity. Globally, at the end of 2007, worldwide capacity of wind power generators was 94 GW, about 1% of world-wide electricity use. Wind energy is used in more than 70 countries –USA, Spain and China take the worldwide lead (http://www.wwindea.org.).

Wind is an air motion caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow is affected by the geographical conditions and character of a terrestrial surface, including various natural and artificial obstacles (Minina, 2009), bodies of water, and vegetative cover, the rotation of the earth, and heating of the atmosphere by the sun. Wind speed is affected by a number of factors and situations, operating on varying scales. These include the pressure gradient, Rossby waves and jet streams, and local weather conditions. There are also links to be found between wind speed and wind direction, notably with the pressure gradient and surfaces over which the air is found (Raman *et al.*, 2010).

Wind is a form of solar energy, about 1% of the incident solar radiation is converted into wind energy. One square meter of the earth's surface on or near the equator receives more solar radiation per year than one square meter at higher latitudes. Atmospheric pressure is the pressure resulting from the weight of the column of air that is above a specified surface area. The variations in atmospheric pressure causes the movement of atmospheric air masses. When the solar heating of different parts of the earth's surface, air expanded and become warmer, which have less dense and lighter from the cold air. The tropic region is warmer than high latitude regions, and the air movement from tropic region to the higher latitudes (Abdel-Qader, 2008).

Another factors such as topographical features and local temperature gradients alter wind energy distribution. The air between 30 North and 30 South at the equator is heated and rises and replaced by cooler air coming from the north and south. This is called the Hadley circulation at the earth surface. This means that cool wind blows towards the equator. The air that comes down at 30 North and 30 South is very dry and moves eastward due to the fact that the earth's rotational speed at these latitudes is much less than at the equator. At these latitudes, deserts are found. Between 30 N and 70 N, western winds are found predominantly. These winds form a wave like circulation, transfer cooled air southward and warm air northward. This is called Rossby circulation. On the basis of the a above circulation of wind and current knowledge about the regionally available wind resources, the potential of wind energy as power source has been studied for different regions. This is the main global system (Rameshandra *et al*, 1997).

The local wind system includes sea breezes and mountain valley winds. Land masses are heated by the sun more quickly than the sea in the daytime. The air rises, flows out to the sea, and creates a low pressure at ground level which attracts the cool air from the sea. This is called a sea breeze. At nightfall there is often a period of calm when land and sea temperatures are equal. At night the wind blows in the opposite direction. The land breeze at night generally has lower wind speeds, because the temperature difference between land and sea is smaller at night. Mountain valley winds are created when cool mountain air warms up in the morning and, as it becomes lighter, begins to rise, cool air from the valley below then moves up the slope to replace it. During the night the flow reverses, with cool mountain air sinking to the valley (Boyle, 2004). This mean that wind speed affected by the local topography and elevation. Long term measurements are needed for a good wind energy assessment.

The longer the period of collected data the more reliable are the estimated wind potentials (Youm *et al*, 2005).

Wind energy is a free, renewable resource, and it is a also a source of clean, non-polluting, electricity. It has the advantage of being harnessed on a local basis for applications in rural areas and remote areas. Water pumping for agriculture and plantation is probably the most important application that contributed to the rural development through multiple cropping (Ramachandra *et al*, 1997).

Wind power is the conversion of wind energy into a useful form of energy, such as using wind turbine to generate electricity, by converting the kinetic energy in the wind into mechanical power**.** It is one of the more promising alternative energy sources to produce, although it is intermittent power because the direction and strength of the wind varies. If wind conditions are favorable, wind energy system can provide communities with electricity at lowest cost. Wind power is clean and inexhaustible fuel; it produces no emission and is not depleted over time. A single one megawatt wind turbine running over one year can displace over 1,500 tons of carbon dioxide, 6.5 tons of sulfur dioxide, 3.2 tons of nitrogen oxides, and 60 pounds of mercury (Reeves, 2003).

By comparison with other renewable energy sources, wind energy is associated with one of the lowest costs of electricity production; the fuel for wind farms is free. This means that the future cost of wind energy will not be affected by increasing fossil fuel price or the cost of green house gas emissions. There are other costs of generating wind energy into electricity system, but these costs are estimated to be less than the costs associated with continuing to rely on thermal generation. Even though the wind power technology requires a higher initial investment than fossil-fueled generators, and wind power plants have relatively little impact on the environment compared to fossil fuel power plants, there is some concern over the noise produced by the rotor blades (Andersen, 2007).

Generally, the wind energy is characterized by a high variability both in space and time. It is therefore very important to describe the variation in wind speeds for optimizing the design of the systems in order to reduce energy-generating costs (Akpinar and Akpinar, 2004).

The distribution of wind speeds is important for the design of wind farms, power generators and agricultural applications like irrigation. Accurate information about wind speed is important in determining best sites for wind turbines. Wind speeds must also be measured by those concerned about dispersion of airborne pollutants (Zaharim *et al*, 2009).

Wind power is a technology set to change the way the world lives, with many countries soon likely to find it the cheapest way of producing electricity. Global wind generating capacity, now stands at 9600 MW a 26% increase from December 1997. Wind turbines generated 21 billion KWh of electricity in 1999, which is enough power for 3.5 million suburban homes (Alnaser and Al-Karaghouli, 2000). Despite the wind power provides less than 1% of the world's electricity at present, growth rates could make wind a major power supplier soon. Wind power is also one of the world's most rapidly expanding industries.

Most commercial wind turbines operating today are at sites with average wind speeds greater than 6 m/s or 22 km/h. A prime wind site will have an annual average wind speed in excess of 7.5 m/s (27 km/h) (www.uneptie.org).

1-3 Case Study

The main objectives of the present study are to:

1. model the wind speed variation using the Weibull distribution function and to predict the wind energy output of wind power systems for some areas in Palestine, namely: Hebron, Jenin, Jericho, Nablus, and determine the two parameters, k and c, of a Weibull function that can describe the wind speed distribution.

2. Obtain and make a survey for different locations to measure the speed of wind at different times of the day.

3. And make economical study for the wind energy in these places.

The maximization of the wind energy extraction can be obtained from different places depending on some conditions such as: the geographic position, temperature, humidity, which is related to the speed of wind. Since the surface of the earth is neither flat nor homogeneous, the amount of heat energy that is absorbed varies spatially as well as temporally. Consequently, this creates temperature, pressure and density (specific mass) differences, which, in turn, create forces that enable air to move from one place to another. It is evident that, depending on the surface feature (morphology) of the earth, some areas would be preferable to others for extracting kinetic energy from the wind in the boundary layer of the atmosphere (Alghoul *et al*, 2007).

1-4 Hypothesis

The maximization of the wind energy extraction can be obtained from different places depending on some conditions such as: the geographic position, topographic characteristics, temperature, humidity, and pressure, which is related to the speed of wind.

The study area is small; we obtain the pressure, the geographic position, and topographic characteristics, and see how they affect the wind speed.

Two issues can be resolved:

1- Determining the exact potential of wind energy by installing more modern computerized stations in all regions of Palestine.

2- Considering the market penetration barriers financing the project, by processing or bring the land for installation of turbine, availability of electrical network in project area, and lack of experience in the wind energy field.

Chapter Two

Study Area and Dataset

2-1 Study Area

Palestine is located on the western coast of Mediterranean Sea, West of Jordan. Elevation ranges from 350 m below the sea level in the Jordan Valley to the sea level along Gaza strip seashore, exceeding 1000m in some locations in the West Bank. Geographical coordinates between 34 20˚-35 30˚ E and 31 10˚-32 30˚ N. West Bank area is about 5665 km^2. Climate conditions vary widely. In hilly areas of West Bank, cold winter and mild summer with relative humidity 51%- 83%. In Jordan Valley and Jericho hot summer and warm winter.

For the Palestinian case, the daily average of solar radiation intensity on horizontal surface is about 5.4 kWh/m^2 per day, while the total annual sunshine hours amounts to about 3000 (Abdel-Qader, 2008), the day time temperature ranging on the average from 14°to 26°.

The demand on energy is growing rapidly in Palestine due to rapid population growth, urbanization and socioeconomic development. Many factors and processes interact to determine the surface wind speed at a given point on the Earth's surface and therefore in Palestine. The regions of study are influenced by the Mediterranean Sea. As is well known, the different heat capacity of land and water strongly influences the temperature variability. Particularly, the northern cities (Nablus, and Jenin) are more influenced by the temperature gradient caused by the Mediterranean Sea because the linear distance to the Sea is not large. For Ramallah and partially for Hebron cities with higher altitudes above the sea level, it is well known that temperature typically decreases with elevation which creates temperature laps rate and then wind. For Jericho city, the effect of the Dead Sea must be taken into account, since specific heat for the water more than the specific heat of the land which creates temperature difference, as well as the air density in this city due to the pressure effect.

Palestinians need energy for achievement the sustainable development, and there are many problems facing them, namely: political, economical, social, and environmental problems. They take energy demand from fossil fuel resources. Palestine import all its needs of petroleum from Israeli market and about 92% of electrical energy from the

Israeli Electrical Corporation. Renewable energy market is strongly affected by the political stability in the region, economic situation of the people, rising demand on energy and availability of the indigenous resources. Generating electricity from the wind does require a wind speed, based on the available data and topographical features of Palestine, potential of wind energy seems to be limited to the mountains elevation about 1000 m above sea level; regions of Nablus, Ramallah, and Hebron where the speed surpass 5 m/s as predicted. Hebron city is suitable for operating a wind turbine for wind power generation, Al-Ahli Hospital is located in the south-western part of Hebron at 1000 m above sea level on a site of 27500 m^2. The proposed and required wind turbine to be installed at Al-Ahli Hospital is expected to give about 700 kW total power production capacity. Utilization of wind could be feasible in some locations for cutoff electricity production (Yaseen, 2007).

2-2 Dataset

For the investigation of large-scale wind power in this study, wind speed data are obtained from the Palestinian Meteorological Stations Network office, wind speed are collected 8 times a day then to take the average over a day. All measurements were obtained at an anemometer height of 10m above the ground level.

Wind observations are generally collected in the form of very large numbers of points. It is remarkably useful that a wide range of wind characteristics can be summarized by specifying only two parameters via shape factor, k and scale parameter, c. These two parameters are sufficient to specify the available wind and to enable assessments and evaluations of the wind power to be produced (Lun and Lam, 2000).

In Jericho station there is missing data of the February, the average of the four years taken for this month. In Jenin station the data available only four years, we used it.

Those data are shown below and analyzed. The monthly average values were computed based on the weibull distribution function.

Table 2.1: Observed average monthly wind speed (m/s) in Hebron.

Year / Month	1997	1998	1999	2000	2001
January	3.36	3.85	3.45	4.13	2.39
February	4.16	2.63	3.65	3.73	3.60
March	4.24	2.35	3.86	3.76	3.39
April	4.09	2.04	3.88	3.36	3.45
May	3.20	1.88	3.91	3.35	3.92
June	3.45	2.11	3.91	4.08	3.87
July	3.74	2.92	4.07	3.79	3.22
August	3.41	3.80	3.79	3.79	3.55
September	3.43	3.63	3.59	3.43	3.21
October	2.64	3.09	3.66	3.64	3.11
November	3.39	3.02	3.59	3.25	3.49
December	3.5	3.8	3.4	3.5	3.7

Table 2.2: Observed average monthly wind speed (m/s) in Nablus.

Year / Month	1997	1998	1999	2000	2001
January	2.23	2.84	2.33	2.94	2.13
February	2.91	2.69	2.73	2.55	3.01
March	3.38	3.32	3.06	3.00	2.81
April	4.15	3.12	3.28	2.81	3.06
May	3.81	3.35	3.53	2.97	3.52
June	3.37	3.81	4.16	3.61	3.80
July	4.05	3.84	4.31	2.90	4.05
August	3.81	3.62	3.49	2.96	3.69
September	3.27	3.26	3.38	2.75	3.52
October	2.20	2.61	2.65	2.90	2.24
November	2.25	2.25	2.33	1.75	2.10
December	2.42	2.17	2.33	2.41	3.86

Table 2.3: Observed average monthly wind speed (m/s) in Jericho.

Year / Month	1997	1998	1999	2000	2001
January	1.28	1.13	0.55	2.07	1.31
February	1.46	1.58	0.80	1.76	1.73
March	1.75	2.36	1.08	2.10	2.14
April	2.89	2.39	1.14	2.36	2.45
May	3.37	2.55	1.21	2.36	2.86
June	2.67	2.49	2.50	2.41	2.61
July	2.47	2.41	2.34	2.42	2.68
August	2.35	2.24	1.89	2.32	2.64
September	1.95	1.86	1.91	2.26	1.97
October	1.47	1.31	1.54	2.21	1.74
November	1.24	0.96	1.28	1.40	1.53
December	1.04	1.56	1.21	1.56	1.36

Table 2.4: Observed average monthly wind speed (m/s) in Jenin.

Year / Month	1998	1999	2000	2001
January	1.80	1.46	2.67	1.40
February	1.92	1.48	1.86	2.16
March	2.55	1.99	2.12	1.92
April	2.03	2.26	2.17	2.16
May	2.46	2.35	2.43	2.71
June	1.80	3.20	3.00	3.15
July	3.17	3.43	3.25	3.21
August	2.69	2.71	2.87	2.82
September	2.26	1.10	2.51	2.79
October	1.73	1.72	1.31	2.43
November	1.64	1.47	1.40	1.78
December	1.91	1.40	1.83	1.71

2-3 The Weibull distribution function

Numbers of papers have been published to found an adequate statistical model for describing the wind speed frequency distribution. The wind speed variation on a wind turbine is very complex and demand sophisticated techniques to optimize the power extraction (Costa *et al*, 2006). The Weibull distribution approach can provide a simple method to predict wind energy output required for preliminary design and assessment of wind power plants. It is the most widely used and accepted in the specialized literature on wind energy and other renewable energy sources. Using wind speed observation, it is shown that this model generally gives a more reliable fit to the empirical wind speed frequency data than the density function with one or two parameters wind power density.

The Weibull distribution provides a close approximation to the probability laws of many natural phenomena. As seen from literature, much attention has been given to the Weibull distribution because it is found to give a good fit to the observed wind speed data. It is a useful tool for both the estimation of wind speed at different heights above the ground and the evaluation of wind energy (Nfaoui *et al*, 1998). Justus et al. concluded that the Weibull distribution gave the best fit to wind speed data for more than 100 stations of the United States National Climate studies have been carried out to create an adequate statistical model for describing wind speed frequency distribution (Justus *et al*, 1976). In a study conducted in Denmark, Petersen et al. found that Weibull distribution gave an excellent fit to the wind speed distribution (Petersen *et al*, 1981). And as shown in the Kumta and Sirsi in India where hourly wind speed recording is available (Ramachandra, 1997). A number of empirical studies have demonstrated that surface wind speed distributions over both land and sea can be well represented by the two-parameter Weibull distribution (Monahan, 2006; Morgan et al, 2011).

The most utilized model was the Weibull distribution function it is found to fit a wide collection of experimental wind data (Lun *et al*, 2000). This model has been used widely both in wind speed and wind energy analysis. The Weibull function has been employed almost unanimously by researchers involved in wind speed analysis for many years. Furthermore, since the Weibull probability density function leads to a Weibull model for the distribution of the cube of the wind speed, it has also extensively been used in wind power analysis for many decades and predicts the mean wind speed better (Celik, 2003).

Sulaiman et al. analyzed wind data from four stations in Oman. Data are fitted to the Weibull distribution function. Weibull parameters are derived from the empirical cumulative function and used to calculate the mean wind speed and variance of the theoretical distribution. The goodness of representing the observed distribution with the Weibull distribution is determined using the Kolmogorov– Smirnov (K–S) test. At the 1% and 5% levels of confidence the observed data are well represented by the Weibull distribution. The annual mean values of the wind speed of the observed and theoretical distributions respectively are 2.57 m s^{-1} and 2.53 m s^{-1} for Seeb, 2.85 m s^{-1} and 2.68 m s^{-1} for Salalah, 5.06 m s^{-1} and 5.03 m s^{-1} for Masirah and 5.52 m s^{-1} and 5.40 m s^{-1} for Sur. In general wind speed is higher during the summer months, notably June, July and August, and is lower during the winter months of October and November. The monthly mean wind power density varies from 9.71 W m^{-2} for Seeb in the month of November to 520.85 W m^{-2} for Sur in the month of August. Both Sur and Masirah have good wind energy potential (Sulaiman *et al*, 2002).

Celik has estimated monthly wind energy production using Weibull representative wind data for a total of 96 months from five different locations in the world (Cardiff, Canberra, Davos, Athens, Ankara). The Weibull parameters were determined based on wind distribution statistics, calculated from measured data, using the gamma function. The wind data in relative frequency format was obtained from these calculated Weibull parameters. The wind speed data in time series format and the Weibull representative wind speed data were used to calculate the wind energy output of a specific wind turbine (Celik, 2003).

Alghoul et al. collected and analyzed the daily mean wind speed data for 5 locations in Jordan over a period of 9 years. Data are fitted to the Weibull distribution function. Weibull parameters are derived from the cumulative function of the observed data records (1989-1997), and used to calculate the mean wind speed and variance of the theoretical distribution. The goodness of representing the observed distribution with the Weibull distribution is determined using the Kolmogorov-Smirnov (K-S) test. At the 1% and 5% levels of confidence the observed data are well represented by the Weibull distribution. The annual mean values of the wind speed of the observed and theoretical distributions are 6.10 ms^{-1} and 6.26 ms^{-1} for Ras.Monief, 4.79 ms^{-1} and

4.77 ms^{-1} for Aqaba, 3.07 ms^{-1} and 3.15 ms^{-1} for Amman and 3.09 ms^{-1} and 3.13 ms^{-1} for Irbid and 2.34 ms^{-1} and 2.40 ms^{-1} for Der Alla respectively. Based on the annual wind speed, wind resource for Ras.Monief, Aqaba, Amman, Irbid and Der Alla are varied from very good to poor. The annual mean power density of Ras.Monief, Aqaba, Amman, Irbid and Der Alla are 261.76 Wm^{-2}, 118.95 Wm^{-2}, 57.45 Wm^{-2}, 40.95 Wm^{-2}, and 24.97 Wm^{-2} respectively. Values of the power density obtained from the manufacturer's power distribution curve of a 300 MW wind turbine at a hub height of 10 meters are also given for comparison. The result of the analysis showed that only Ras.Monief and Aqaba have good wind energy potential (Alghoul *et al*, 2007).

Jowder measured the hourly wind speed data for the years 2003–2005 at elevations of 10 m, 30 m and 60 m height for Kingdom of Bahrain and statically analyzed them to determine the potential of wind power generation. Extrapolation of the 10 m data, using the Power Law, has been used to determine the wind data at heights of 30 m and 60 m. Weibull distribution parameters have been estimated and compared annually and on monthly bases using the graphical method and another method, which depends on the standard deviation and average wind speed. The maximum power density for 10 m, 30 m and 60 m heights were found to be 164.33 W/m^2, 624.17 W/m^2 and 1171.18 W/m^2 in February, respectively while the minimum power density were 65.33 W/m^2, 244.33 W/m^2 and 454.53 W/m^2 in October, respectively. The average annual wind power density was found to be 114.54 W/m^2 for 10 m height, 433.29 W/m^2 for 30 m height and 816.70 W/m^2 for 60 m height. Weibull probability function, using Weibull parameters estimated from the approximated method, has shown to provide more accurate prediction of average wind speed and average power density than the graphical method. In addition, the site matching of wind turbine generators at 30 m and 60 m heights has been investigated by estimating the capacity factors of various commercially available wind turbines generators. The monthly and annual variation of capacity factors have been studied to ensure optimum selection of wind turbine generators (Jowder, 2009).

As seen before, much attention has been given to the Weibull distribution because it is found to give a good fit to the observed wind speed data (Rehman,1994). The most utilized model is the Weibull distribution function it has been found to fit a wide collection of experimental wind data (Lun and Lam, 2000). The general form of the Weibull distribution function for wind speed is given by (Spera, 1985):

$$f(v) = \left(\frac{k}{c}\right)\left(\frac{v}{c}\right)^{k-1} \exp\left[-\left(\frac{v}{c}\right)^{k}\right], \qquad (1)$$

where *f(v)* is the probability of observing wind speed *v, k* the dimensionless Weibull shape parameter, and c reference value in units of wind speed (so-called Weibull scale parameter).

The cumulative distribution function is given as (Ulgen and Hepbasli, 2002; Persaud *et al*, 1999):

$$F(v) = 1 - \exp\left[-\left(\frac{v}{c}\right)^{k}\right], \qquad (2)$$

Determination of the parameters of Weibull distribution requires a good fit of equation (2) to the recorded discrete cumulative frequency distribution. Taking the natural logarithm of both sides of equation (2) twice, gives:

$$\ln\left(-\ln\left[1 - F(v)\right]\right) = k\ln(v) - k\ln c, \qquad (3)$$

A plot of *ln(-ln[1-F(v)]) versus ln(v)* presents a straight line. The gradient of the line is *k* and the intercept with the Y-axis is *–klnc*. The linear least square algorithm was used to fit the Weibul distribution to the measured wind speed data (Spera, 1985) .

The two significant parameters *k* and *c* are closely related to the mean value of wind speed v_w as (Mayhoub and Azzam, 1997):

$$v_w = c\Gamma(1 + \frac{1}{k}), \qquad (4)$$

where Γ is the gamma function which is an extension of the factorial function, with its argument shifted down by 1, to real and complex numbers. That is, if *n* is a positive integer: $\Gamma(n)= (n-1)!$

2-4 Power

The energy contained in the wind is its kinetic energy (E_{Kin}) and is equal to:

$$E_{Kin} = 1/2 * m * v^2 \tag{5}$$

where (m) is the mass of air in kilograms and (v) is the speed of air in meters per second.

kinetic energy in the wind per second which is the power (P) in watts**.**

The power density of the wind is given as:

$$P = \frac{1}{2}\rho * v^3 \tag{6}$$

where ρ is the air density. The latter is a function of the air pressure B and the air temperature T thus (John and Nicholas, 1997).

$$\rho = \rho_0(\frac{288B}{760T}), \tag{7}$$

where ρ_0 is the density of dry air at standard temperature and pressure (1.226 kg m^{-3} at 288 K, 760 mm Hg).

Equation (6) shows the power as a function of the cube of the wind speed. Using the monthly mean wind speed, whether actual or derived from a Weibull fit gives an underestimation of the true mean power density, and this will not yield the right picture as far as the power density is concerned. The wind speed value varies over time; hence wind speeds are distributed over the low and high wind speed ranges. This illustrates that the average of the cube of different wind speeds will be much greater than the cube of the average speed (Gripe., 1993) our results as in tables 3.2-3.5 proves this prediction. Hence one must introduce another parameter known as the Energy Pattern Factor (EPF) or cube factor (Farrugia and Scerrii, 1997) which adjusts the mean power density in eq. (6) by introducing a correcting factor. This factor is known as the EPF and can be deduced from the following:

$$EPF = \frac{Total\ amount\ of\ power\ available\ in\ the\ wind}{Power\ calculated\ by\ cubing\ the\ mean\ wind\ speed}$$

Or

$$EPF = \frac{Mean\ power\ density\ for\ the\ month}{Mean\ power\ density\ at\ the\ monthly\ mean}$$

A more realistic monthly mean power density is then given as,

$$P = \frac{1}{2}\rho(EPF)v^3, \qquad (8)$$

In this work, the Weibull monthly mean wind speed is used to calculate the monthly mean power density of eq (8).

Chapter Three

Results and discussion

In this work, the daily mean wind speed data for four locations in Palestine over a period of 5 years (1997-2001) were collected and analyzed. Geographical coordinates of stations are found in table 3.1. However, there are some missing data, less than 2%, due to machine calibration, servicing, malfunction machine and political problems.

Table 3.1:- Latitude, longitude and elevation of the stations used in the study.

Station	Latitude N	Longitude E	Elevation (m)
Nablus	32º13	35º15	570
Jenin	32º28	35º18	178
Hebron	31º32	35º06	1005
Jericho	31º51	35º27	-260

Windographer software plots the Weibull distribution curves on the frequency histogram of the actual measured data. The least squares algorithm used to fit a Weibull distribution directly to the measured wind speed distribution. As a result, the figures show that the Weibull distribution approximately matches the histogram of the actual wind speed distribution.

Although fig 3.3 describing the wind speed in Jericho has some exceptional data, which is well known in the area of Jericho to have such frequency at some times of the year. Other stations show a good fit with Weibull distributions as shown in figures 3.1,3.2 and 3.4.

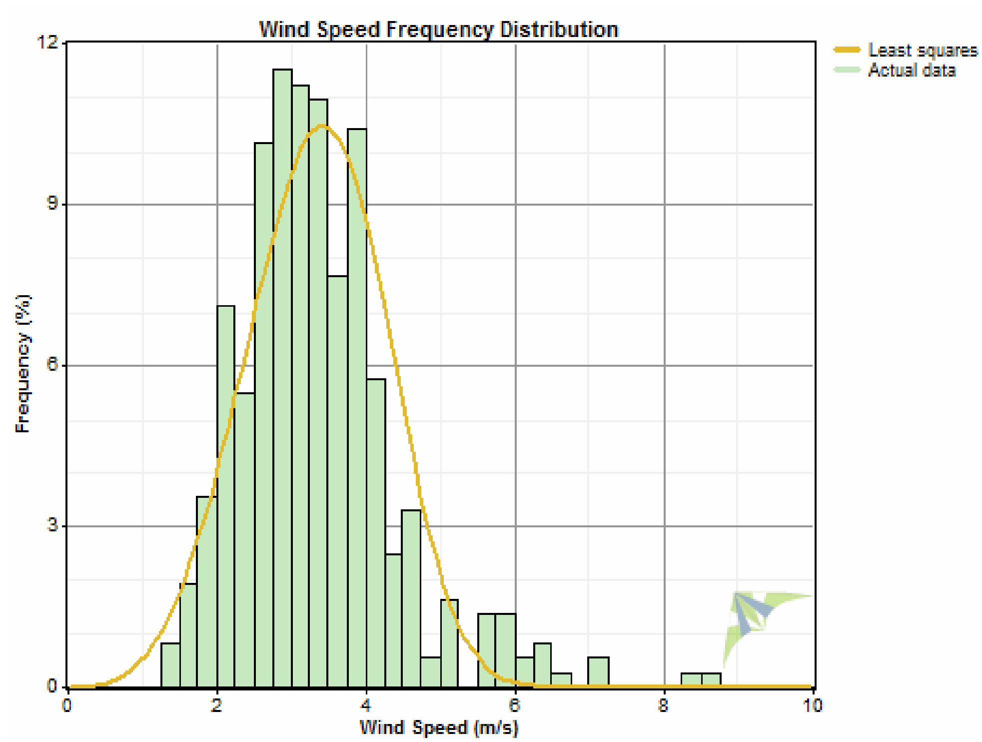

Fig 3.1: Wind speed frequency distribution for Hebron.

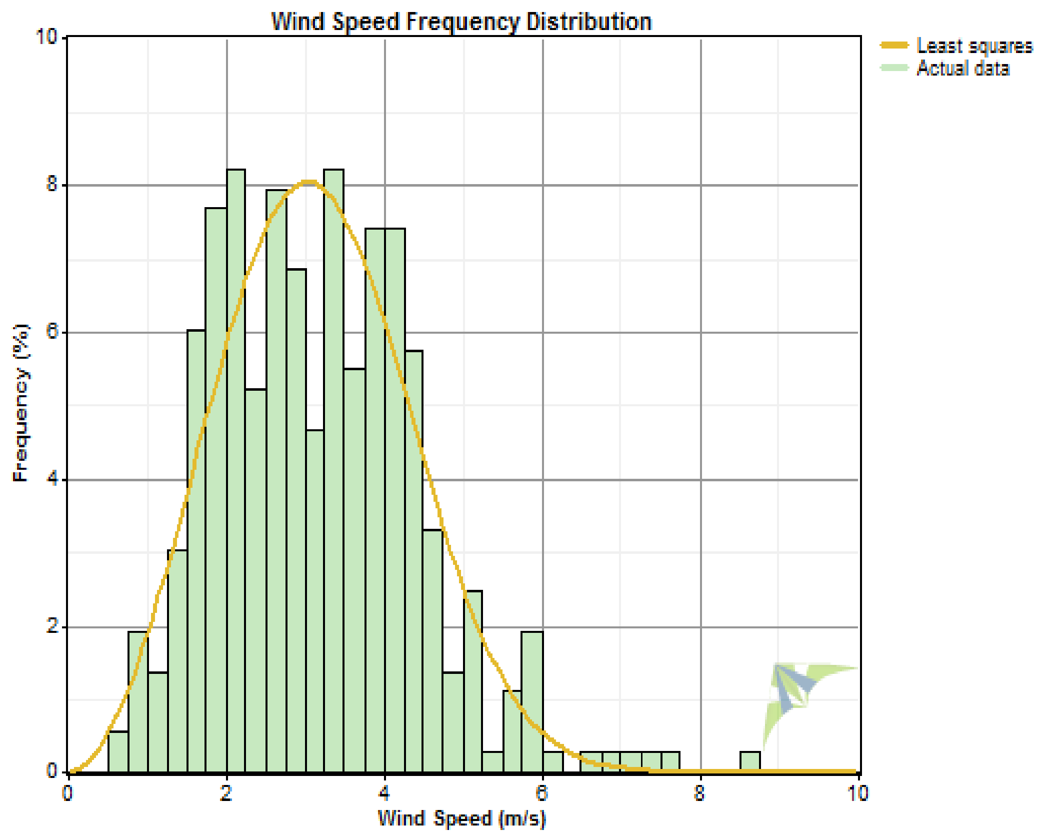

Fig 3.2: Wind speed frequency distribution for Nablus.

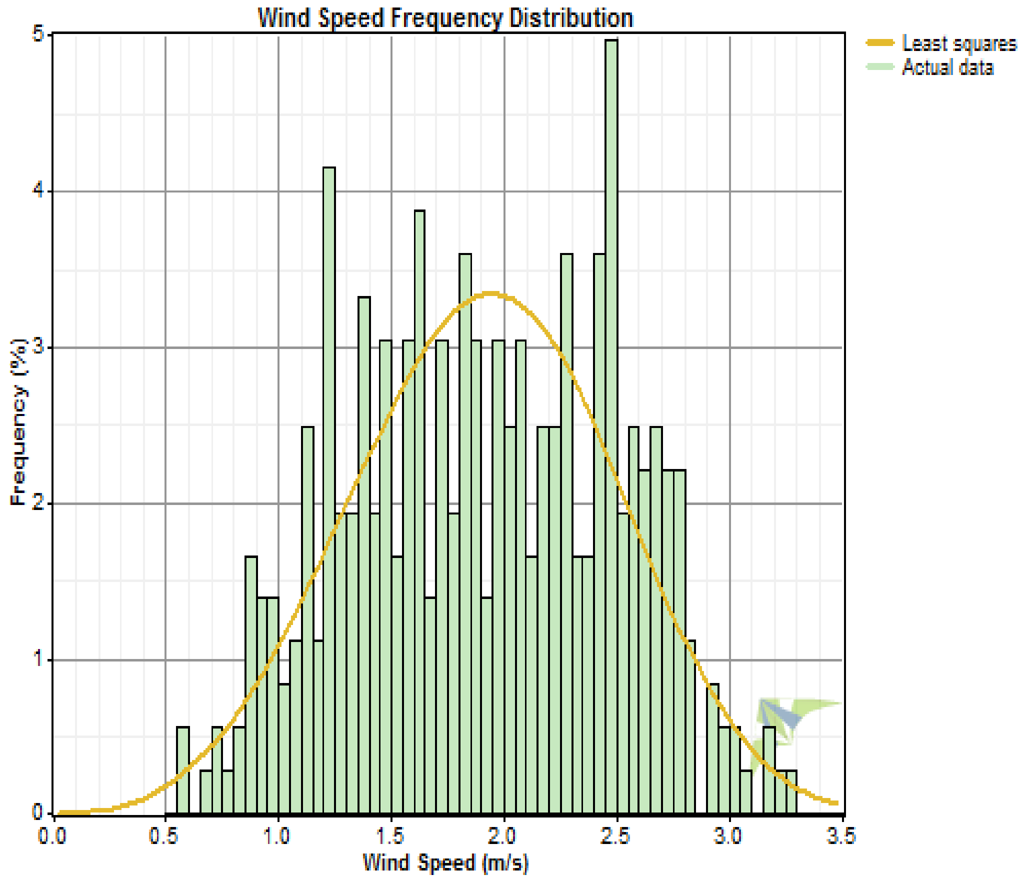

Fig 3.3: Wind speed frequency distribution for Jericho.

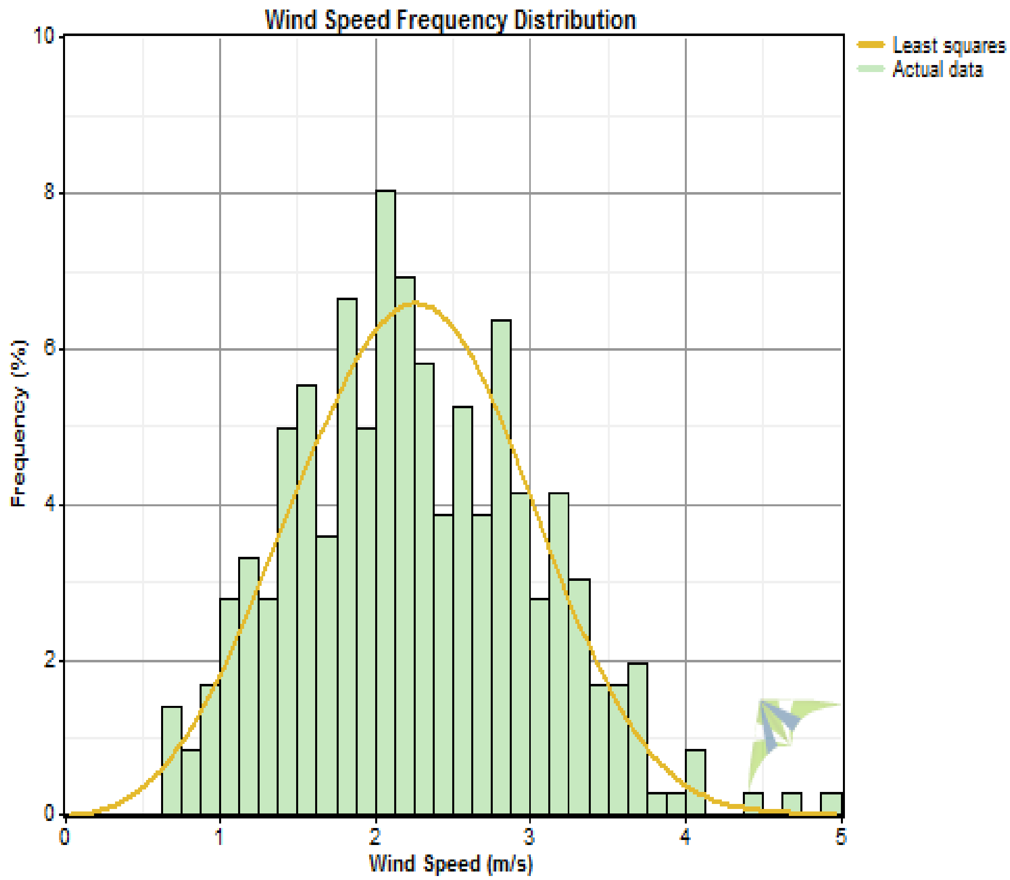

Fig 3.4: Wind speed frequency distribution for Jenin.

The cumulative distribution function represents the probability that a variable is less than or equal to a particular value. The figures 3.5-3.8 presented the cumulative frequency for the measured wind speed data for each station.

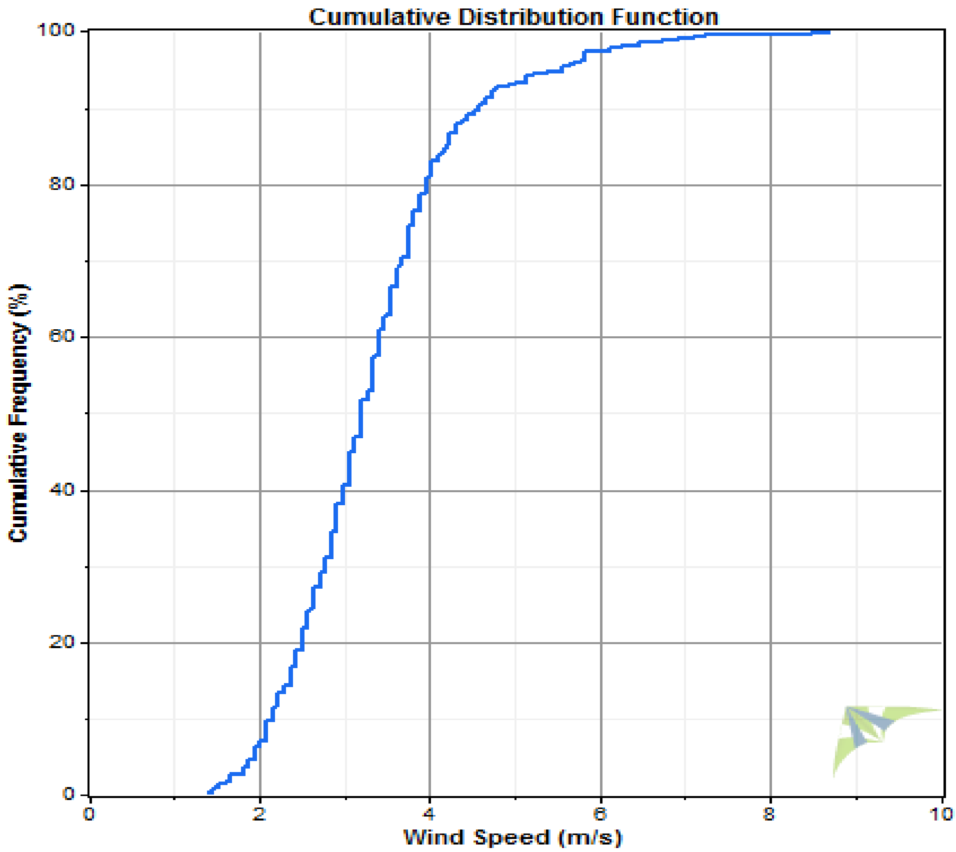

Fig 3.5: Wind speed cumulative frequency in Hebron.

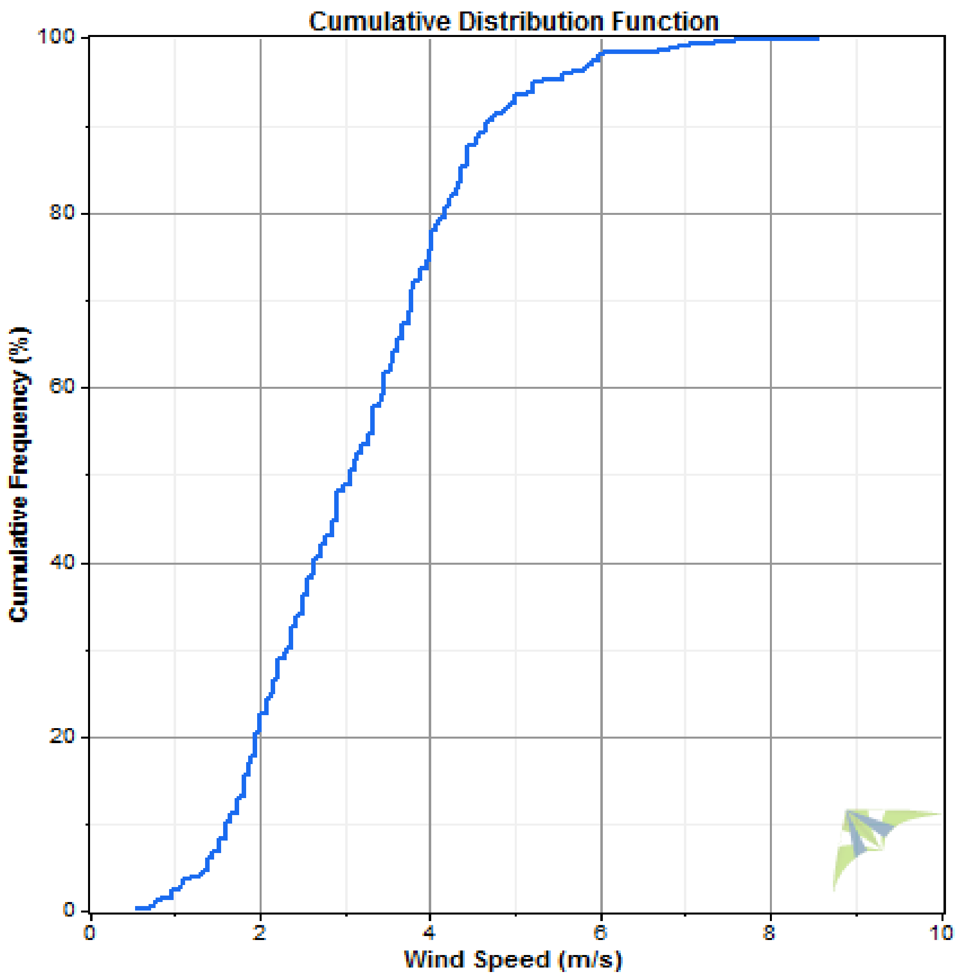

Fig 3.6: Wind speed cumulative frequency in Nablus.

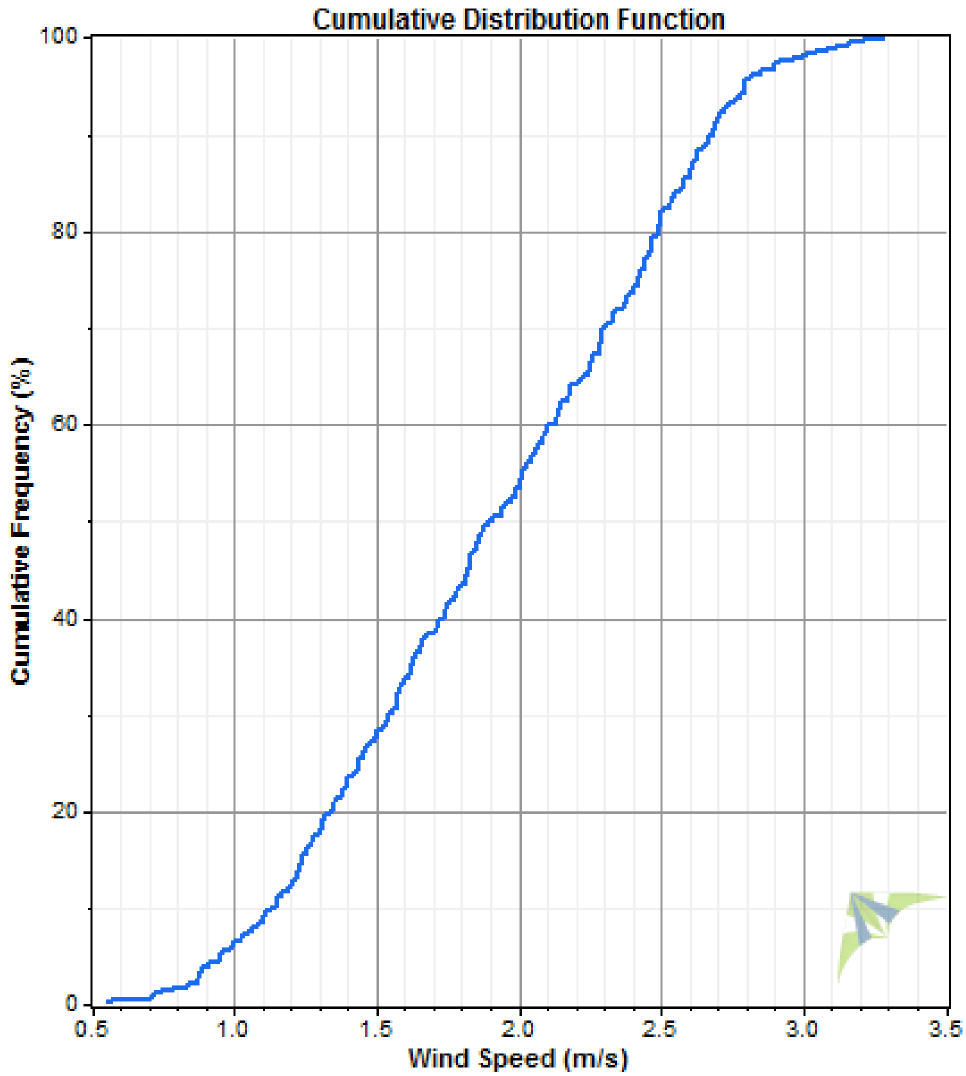

Fig 3.7: Wind speed cumulative frequency in Jericho.

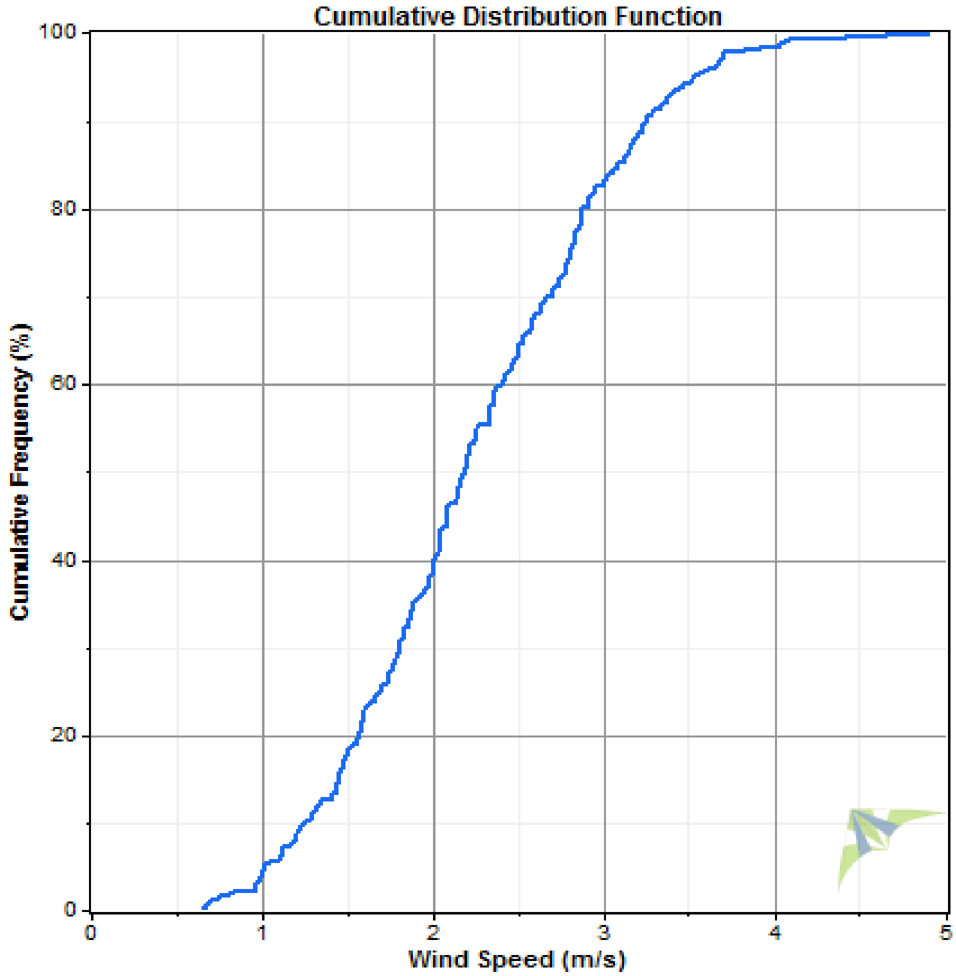

Fig 3.8: Wind speed cumulative frequency in Jenin.

The observed and theoretical mean wind speed for the four stations are presented in figures 3.9- 3.12.

As shown in figures 3.9-3.12, the model better fits the data obtained from these stations, mean while, figure 3.9 for Hebron data, shows that the monthly mean of winter months have higher actual wind speed values than that of the Weibull distribution.

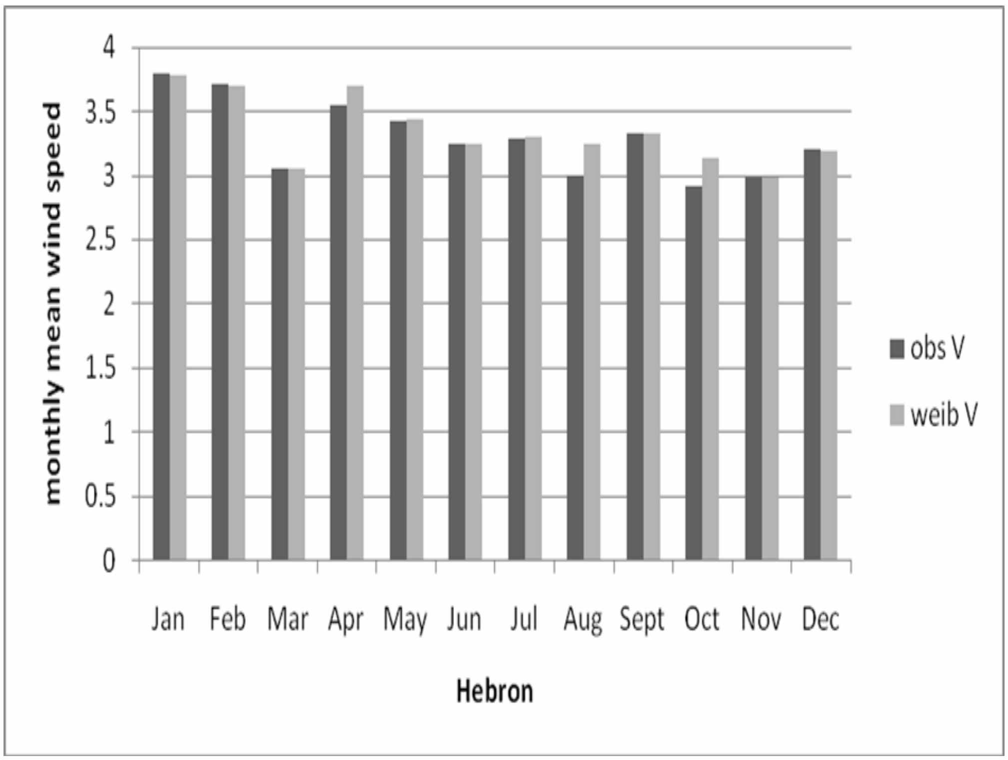

Fig 3.9: Observed and theoretical monthly mean wind speed for Hebron.

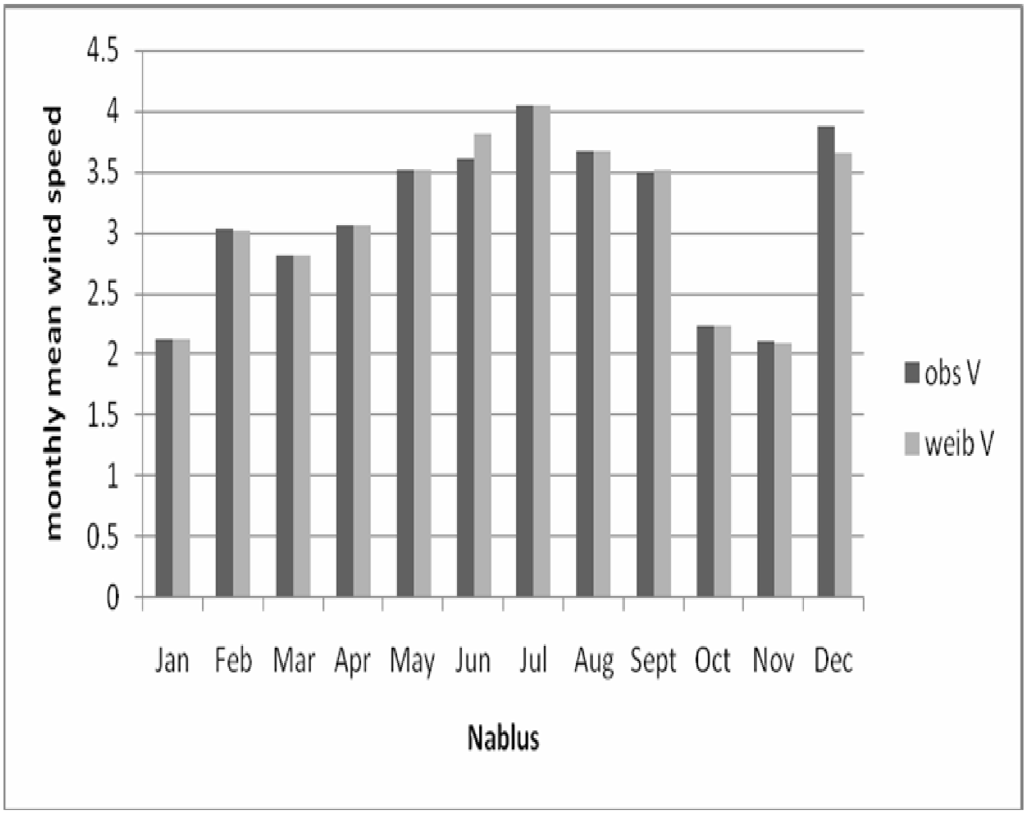

Fig 3.10: Observed and theoretical monthly mean wind speed for Nablus.

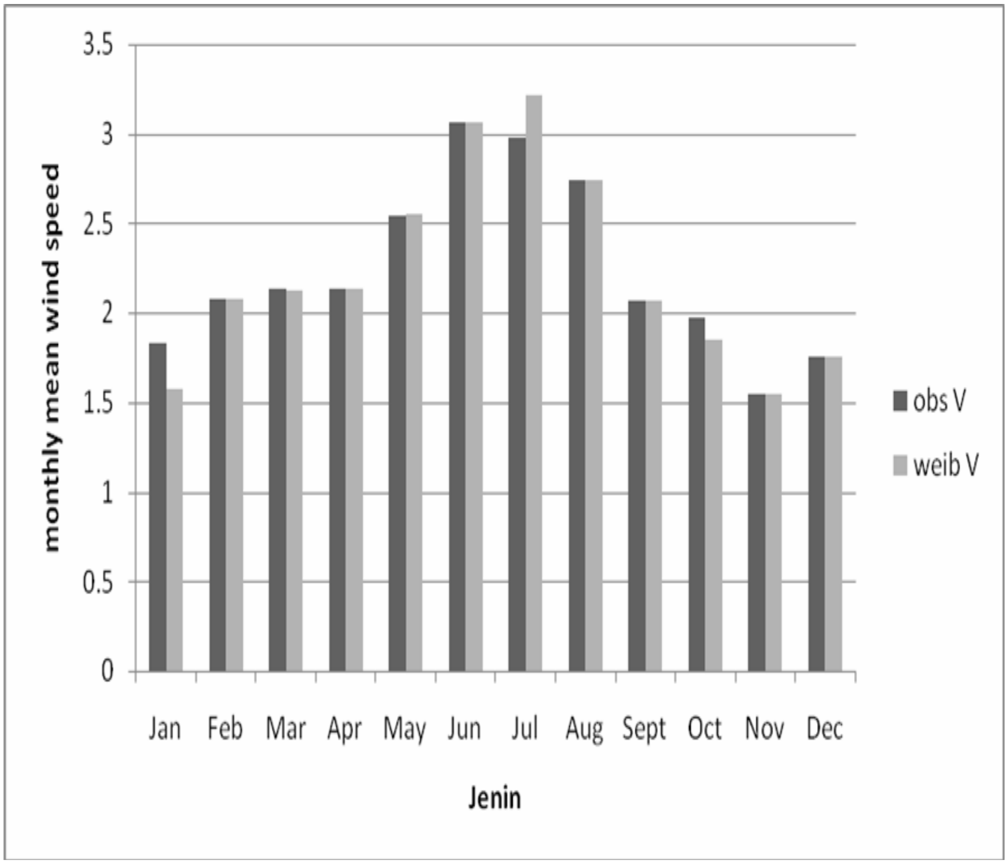

Fig 3.11: Observed and theoretical monthly mean wind speed for Jenin.

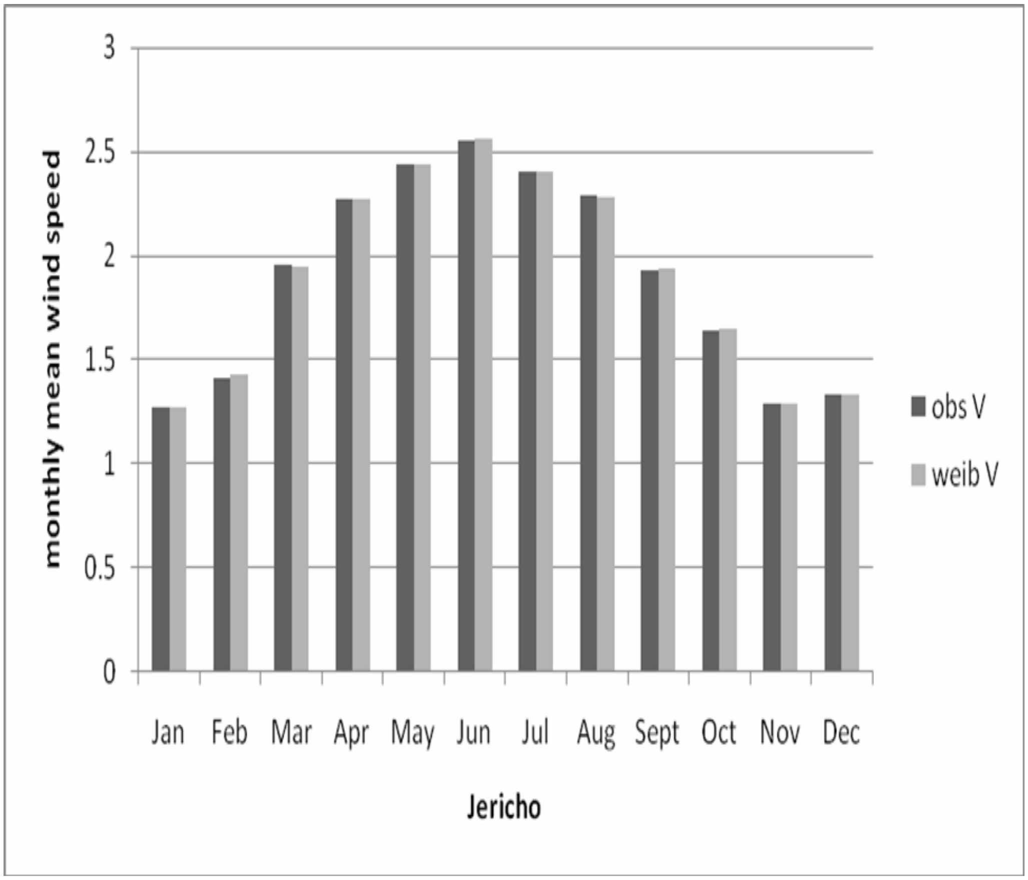

Fig 3.12: Observed and theoretical monthly mean wind speed for Jericho.

The observed and theoretical mean wind speed values in figures 3.9-3.12, present a seasonal variation along the year with maximum values in summer months and minimum values in winter months, except Hebron station due to its higher elevation (1005 m) above sea level, this station has higher observed values to vary from 2.98 m s^{-1} in November to 3.78 m s^{-1} in January. However, Jericho station provides lower values of monthly mean wind speed (maximum, 2.56 m s^{-1}), probably due to its lower elevation (-260 m) below the sea level.

Weibull parameters are derived from the graphical plot of Eq. (3) The Weibull mean speed and variance are also calculated. The monthly mean power density of the wind is evaluated using Eq. (5) taking into account the variation of air density using Eq. (6).

In Tables 3.2-3.5, the observed monthly average wind speed, Weibull wind speed, variance of the Weibull wind speed, the two Weibull parameters and the monthly mean power density are also given for all stations.

The Weibull distribution model gives a good fit to the observed monthly wind speed data. The variance values given in tables 3.2-3.5 provides maximum values of, 9.41 in April for Hebron, 1.97 in July for Jenin, 0.77 in April for Jericho and 4.11 in December for Nablus.

Table 3. 2 The main characteristic parameters of Hebron wind speed.

Months	v_{obs} ms^{-1}	v_w ms^{-1}	σ^2	c ms^{-1}	k	v^3_{avg} obs	$(v_{avg})^3$ obs	EPF	P Wm^{-2}
Jan	3.78	3.80	2.04	4.26	2.89	48.52	44.41	1.09	32.98
Feb	3.70	3.71	2.92	4.19	2.31	51.61	45.11	1.14	32.21
Mar	3.05	3.05	0.81	2.37	3.76	47.93	43.61	1.10	25.66
Apr	3.70	3.54	9.41	3.73	1.16	41	37.93	1.08	29.65
May	3.44	3.42	0.76	3.75	4.44	36.23	34.96	1.03	22.57
Jun	3.24	3.24	0.39	3.50	5.78	43.44	41.78	1.04	19.86
Jul	3.30	3.29	0.27	3.52	7.20	42.47	40.7	1.04	19.67
Aug	3.24	3.00	1.26	3.36	2.89	50.88	49.02	1.03	18.55
Sept	3.33	3.33	0.28	3.60	7.40	43	41.06	1.04	20.56
Oct	3.14	2.92	1.97	3.30	2.20	36.04	33.38	1.08	18.03
Nov	2.98	2.98	1.34	3.35	2.78	39.73	37.6	1.05	15.23
Dec	3.19	3.20	1.89	3.60	2.49	50.85	45.5	1.11	19.91

Table 3.3 The main characteristic parameters of Nablus wind speed.

Months	v_{obs} ms^{-1}	v_w ms^{-1}	σ^2	c ms^{-1}	k	$v^3{}_{avg}$ obs	$(v_{avg})^3$ obs	EPF	P Wm^{-2}
Jan	2.13	2.13	0.86	2.40	2.45	18.69	15.44	1.21	6.92
Feb	3.01	3.03	2.01	3.42	2.27	24.3	21.48	1.13	18.17
Mar	2.81	2.81	1.73	3.17	2.34	34.6	30.08	1.15	14.90
Apr	3.06	3.06	0.88	3.40	3.63	37.17	34.01	1.09	17.87
May	3.52	3.52	1.33	3.92	3.38	43.52	40.31	1.08	26.55
Jun	3.81	3.61	1.13	3.99	3.78	54.1	52.73	1.02	31.53
Jul	4.05	4.04	0.55	4.34	6.34	57.5	55.74	1.03	37.85
Aug	3.67	3.67	0.56	3.97	5.68	57.5	55.74	1.03	28.15
Sept	3.52	3.50	0.44	3.77	6.15	34.86	33.7	1.03	25.01
Oct	2.24	2.24	0.57	2.50	3.27	16.75	15.81	1.06	6.69
Nov	2.10	2.11	1.06	2.38	2.15	10.82	9.93	1.09	5.83
Dec	3.66	3.88	4.11	4.38	1.99	20.56	17.98	1.14	32.67

Table 3.4 The main characteristic parameters of Jenin wind speed.

Months	v_{obs} ms^{-1}	v_w ms^{-1}	σ^2	c ms^{-1}	k	v^3_{avg} obs	$(v_{avg})^3$ obs	EPF	P Wm^{-2}
Jan	1.57	1.83	0.90	2.07	2.02	12.39	6.02	2.05	4.86
Feb	2.08	2.08	0.53	2.32	3.14	10.42	7.3	1.42	7.77
Mar	2.12	2.13	0.38	2.35	3.85	12.59	9.66	1.3	7.50
Apr	2.13	2.13	0.19	2.30	5.70	11.04	9.93	1.11	6.42
May	2.55	2.54	0.28	2.75	5.51	17.52	15.43	1.13	10.95
Jun	3.06	3.06	0.21	3.25	7.85	28.82	27	1.06	17.60
Jul	3.22	2.98	1.97	3.32	3.26	37.63	34.64	1.08	18.90
Aug	2.74	2.74	0.21	2.93	7.10	22.83	21.25	1.07	12.59
Sept	2.07	2.07	0.25	2.26	4.73	10.43	9.12	1.14	5.92
Oct	1.85	1.97	0.17	2.01	5.11	7.77	6.64	1.17	4.34
Nov	1.55	1.55	0.32	1.73	3.00	5.44	3.94	1.38	3.05
Dec	1.75	1.75	0.45	1.97	2.88	7.36	5	1.47	4.79

Table 3.5 The main characteristic parameters of Jericho wind speed.

Months	v_{obs} ms^{-1}	v_w ms^{-1}	σ^2	c ms^{-1}	k	v^3_{avg} obs	$(v_{avg})^3$ obs	EPF	P Wm^{-2}
Jan	1.27	1.27	0.16	1.41	3.53	2.61	2	1.3	1.66
Feb	1.43	1.41	0.28	1.59	2.92	3.78	3.04	1.24	2.32
Mar	1.95	1.96	0.25	2.14	4.47	8	6.64	1.2	5.57
Apr	2.27	2.27	0.77	2.46	5.56	12.51	11.23	1.11	8.10
May	2.44	2.44	0.20	2.62	6.48	16.6	15.07	1.1	9.63
Jun	2.56	2.55	0.09	2.68	10.00	16.74	16	1.04	10.34
Jul	2.40	2.40	0.08	2.52	10.00	15.38	14.88	1.03	8.42
Aug	2.28	2.29	0.08	2.41	9.77	12.45	11.85	1.05	7.37
Sept	1.94	1.93	0.09	2.06	7.57	8.27	7.76	1.06	4.60
Oct	1.65	1.64	0.10	1.76	6.15	4.87	4.49	1.08	2.81
Nov	1.29	1.29	0.16	1.43	3.63	2.71	2.09	1.29	1.73
Dec	1.33	1.33	0.13	1.46	4.20	2.86	2.4	1.19	1.77

The minimum observed/Weibull mean wind speed values in Tables 3.2-3.5 in m s^{-1} are 2.98/2.98 in November for Hebron, 1.55/1.55 in November for Jenin, 1.77/1.77 in January for Jericho, and 2.10/2.11 in November for Nablus. Meanwhile the maximum observed/Weibull mean wind speed values in those tables are 3.78/3.78 in January for Hebron, 3.22/2.98 in July for Jenin, 2.56/2.55 in June for Jericho, and 4.05/4.04 in June for Nablus.

Referring to the Weibull parameters it is found that the values of k are generally higher than those of c for Jenin and Jericho but lower for Hebron and Nablus. The parameter c varies from 1.41 m s^{-1} in January for Jericho to 4.34 m s^{-1} in July for Nablus whereas k varies from 1.16 in April for Hebron to 10 in June and July for Jericho. In general v_w, c and k present seasonal variation, however these values increase at the beginning of the year until they reach their maximum values in June to August then decrease towards the end of the year for all stations except Hebron. The latter one is located in the south of Palestine at higher altitude and in complex topography area. Thus the monthly mean wind speed for Hebron is greater than the average speed for the other stations.

The figures below presented the relationship between the mean power versus mean wind speed fitted by using the second-order polynomial function.

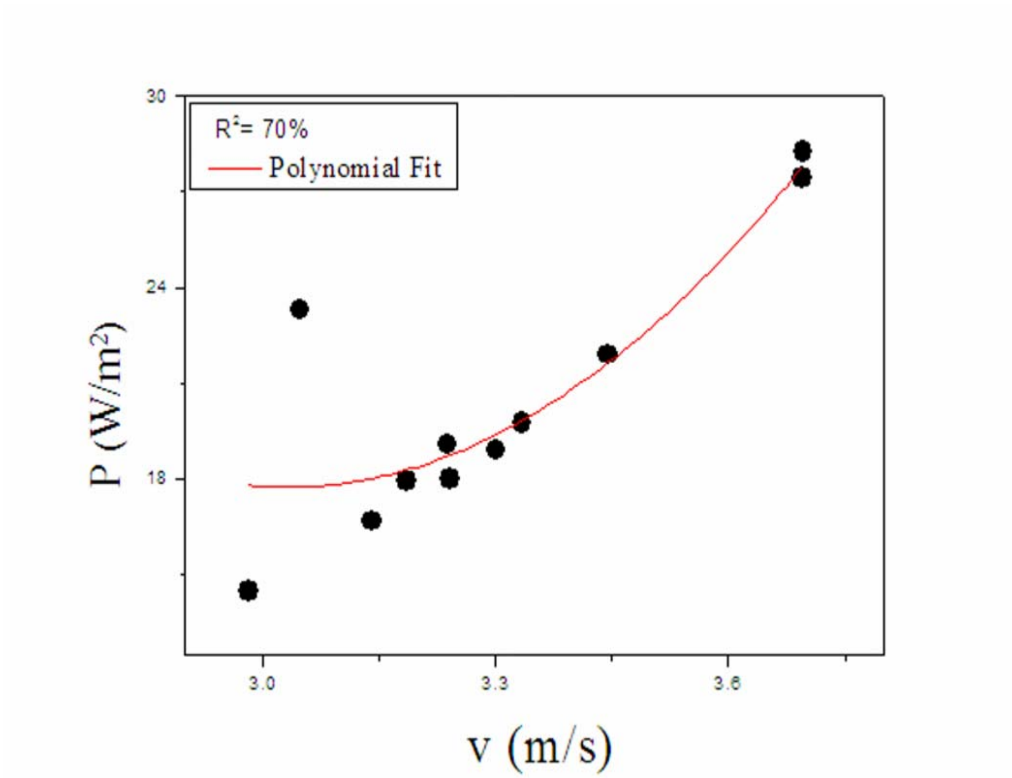

Fig 3.13: Scatter plot of mean wind power and mean wind speed for Hebron station using second-order polynomial fit.

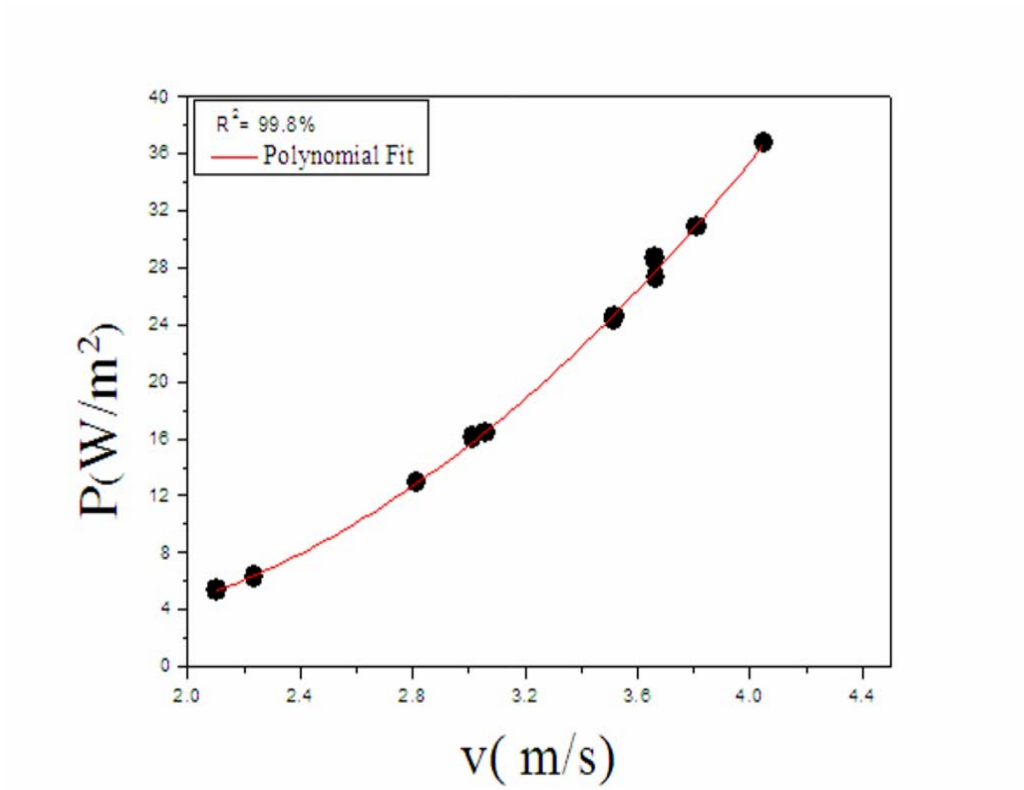

Fig 3.14: Scatter plot of mean wind power and mean wind speed for Nablus station using second-order polynomial fit.

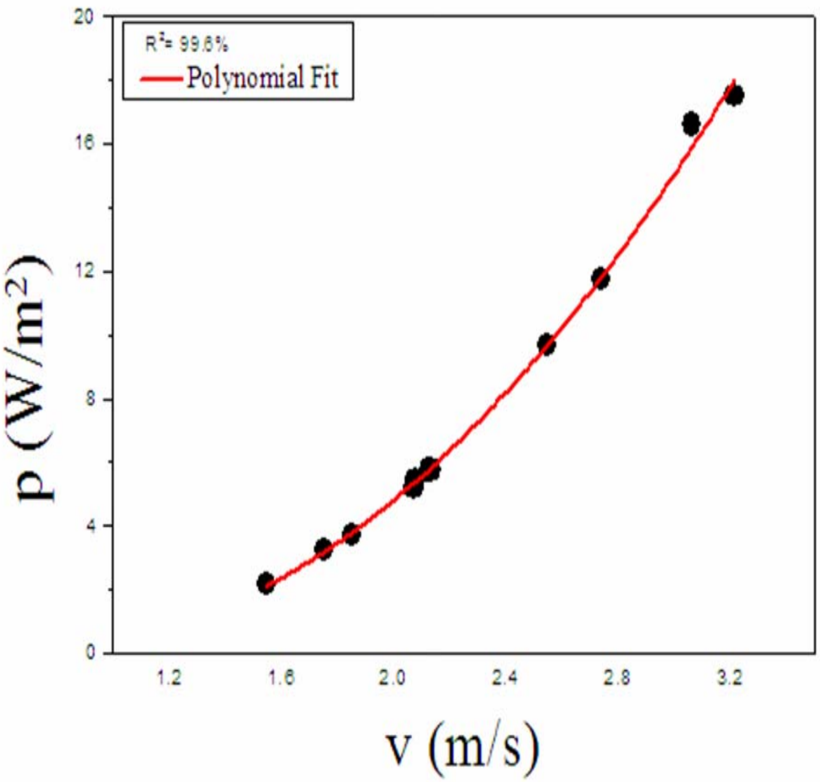

Fig.3.15: Scatter plot of mean wind power and mean wind speed for Jenin station using second-order polynomial fit.

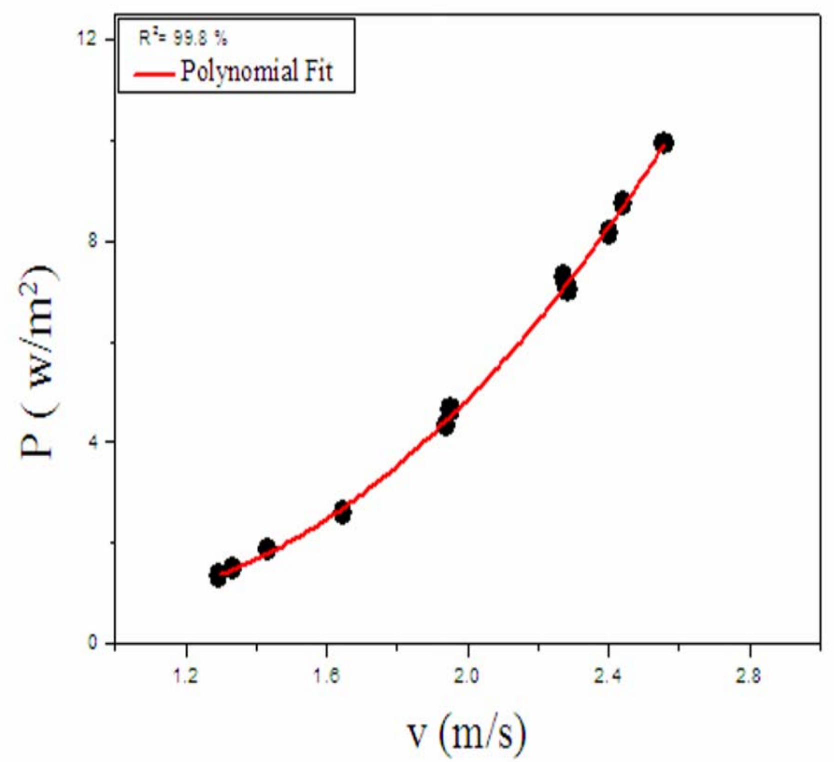

Fig 3.16: Scatter plot of mean wind power and mean wind speed for Jericho station using second-order polynomial fit.

Figures 3.13-3.16 show the second-order polynomial fit of the mean wind power versus the mean wind speed, the adjusted R^2 is more than 99% for all stations except for Hebron. The later one provides R^2= 70%, this station as said before is located in complex topography area and the wind flow is affected by sharp slopes, hills and orientations (Alsamamra, 2009) also higher wind speed values along the year, whereas the other stations are located in almost flat areas. Table 3.6 provides the polynomial fit parameters.

Table 3.6 Polynomial fit parameters.

Station Name	intercept	b_1	b_2
Hebron	226.89	-137.99	22.76
Nablus	9.64	-11.46	4.47
Jenin	2.04	-4.51	2.94
Jericho	3.45	-5.85	3.27

As seen from Tables 3.2-3.5, the monthly mean wind power density is higher during the summer and lowers during the winter except Hebron is higher in winter and lower in summer months. The highest mean power values are 32.98W m^{-2} in January and 37.85 W m^{-2} in July for Hebron and Nablus respectively, whereas the lowest mean power is 1.66 W m^{-2} in January for Jericho due to its elevation below the sea level.

Chapter Four

Conclusions And Future Recommendations

4-1 Conclusions

Wind speed is measured at a height of about 6-10 meters in meteorological stations, the collected data have been analyzed and fitted. Accordingly the following conclusions can be considered :-

- Wind speed depends on the height above earth level. Close to the earth the wind is slowed down because of the friction with the earth surface. Thus, a wind is stronger at higher levels. In addition wind speed depends also on the temperature and pressure.

- The power available from the wind is a function of wind speed, which is proportional to the cube of the wind speed.

- The monthly mean wind speed data of the four stations in Palestine are fitted to the Weibull distribution and showed a good coincidence.

- The second-order polynomial is used to fit the relation between the mean wind power and the mean wind speed.

- Both Hebron and Nablus have higher mean wind speed values of more than 3.5 m s^{-1} average monthly and maximum wind power density of 37.85 W m^{-2} in July provided by Nablus station. The second-order polynomial provides better fit for all stations except Hebron, due to its location in complex topographical area.

- Those measured values of wind speed are at about 6-10 meters above the ground in each station, which means that at higher elevations all these values are expected to increase drastically as is shown by Shabbane and Hasan (Shabbane and Hasan, 1997).

- In Jenin and Jericho the maximum wind speed and wind power are maximum in summer months, and minimum in winter months. They have the same topography, but Jericho is located in a lower region.

- In Nablus the maximum wind speed and wind power are in June, July and December.

- In Hebron the maximum wind speed and wind power are in January, February and April.

- Wind speed frequency distribution is an important parameter for predicting energy output of a wind energy conversion system.

- Many factors including hills, buildings and trees affect wind pattern, causing actual wind measurements to vary from the wind observed. In our case the stations of measurements are located on low buildings inside the cities so the readings are surely affected.

- Local terrain features can cause the mean wind energy to vary, especially in hilly, and mountainous terrain which have high wind resource.

- This study is valuable to wind energy developers and potential wind energy user because it allows them to choose area of estimated high wind resource.

- The wind power estimates apply to areas free of local obstructions to the wind and to terrain features that are well exposed to the wind .

4-2 Future Recommendations

Due to the relative simplicity of wind energy system and availability of wind resource, wind power is expected to play a significant role in meeting some of our future energy needs. However, there are many problems to be resolved if wind resource is to be used effectively and efficiently, a deep and careful planning activity is needed by decision makers.

- Manufacturing facilities for wind plant and wind turbine must be created in suitable sites.
- It should be attended in selecting an appropriate site for the wind turbine.
- In case of power generation, major problem is energy storage, we need to resolve this by linking wind generators with conventional electrical grids.
- It should encourage the researchers to develop projects in the field of wind energy.

- Where the wind speed is favorable, variety of applications of wind energy, short or long term research programmers may be undertaken for the utilization of wind energy in Palestine.
- Wind velocity (magnitude and direction) should be recorded in different locations of Palestine for precise studies in this field, by using special digital sensors.
- Decision makers should support researchers for continual studies, and provide the laws of renewable energy.

ملخص اللغة العربية

نماذج من طاقة الرياح في بعض المناطق في فلسطين

لقد تم جمع البيانات لمتوسط سرعة الرياح اليومية لأربعة مواقع في فلسطين خلال 5 سنوات وتحليلها وتركيبها على التوزيع "ويبل". وتستمد معاملات ويبل من الدالة التراكمية للبيانات للفترة (1997-2001)، والمستخدمة لحساب سرعة الرياح ويعني التباين في توزيع النظرية، التي تحتوي على قيم قصوى في أشهر الصيف والقيم الدنيا في أشهر الشتاء، باستثناء الخليل بسبب الارتفاع العالي ، (1005 م) فوق مستوى سطح البحر. ومع ذلك، تبين محطة أريحا انخفاض القيمة الشهرية لمتوسط سرعة الريح (كحد أقصى 2،56 م /ث). يتم استخدام متعدد الحدود من الدرجة الثانية لتناسب العلاقة بين طاقة الرياح وسرعة الرياح ان زيادة طاقة الرياح في الصيف تعني سرعة أعلى وهي تنخفض خلال فصل الشتاء باستثناء الخليل لتعطي قيمة أعلى في فصل الشتاء وتنخفض في أشهر الصيف. لقد تم تسجيل أعلى قيمه للقدرة لتكون 32.98 واط/ م 2 في يناير و37.85 واط/ م 2 في تموز / يوليو عن الخليل ونابلس على التوالي، في حين أن أدنى قيمة هي 1.66 واط/ م 2 في يناير كانون الثاني لأريحا. وR^2 لتناسب متعدد الحدود هو 99،8 ٪ بالنسبة جميع المحطات بإستثناء 70% الخليل .

التوصيات التالية لمزيد من الدراسة المستقبلية :

- يجب وضع توربينات الرياح في موقع مناسب.
- المشكلة الرئيسية تتلخص في تخزين الطاقة، ونحن بحاجة إلى حل هذه عن طريق ربط مولدات الرياح مع الشبكة الكهربائية التقليدية.
- ينبغي أن يشجع الباحثين على تطوير مشاريع في مجال توليد الطاقة من الرياح.
- أن سرعة الرياح المواتية هي مجموعة متنوعة من التطبيقات من طاقة الرياح ، قصيرة أو طويلة الأجل يمكن اتخاذها للاستفادة من طاقة الرياح في فلسطين. وينبغي قياس سرعة الرياح (مقدارا واتجاها) في مواقع مختلفة من فلسطين للدراسات الدقيقة في هذا المجال باستخدام أجهزة حساسة ومتطورة.
- ينبغي على صناع القرار دعم الباحثين لإجراء دراسات مستمرة.

References

Abdel-Qader, M. 2008. Simulation of a Hybrid Power System Consisting of Wind Turbine, PV, Storage Battery and Diesel Generator with Compensation Network: Design, Optimization and Economical Evaluation. Master. thesis, Najah National University, Nablus, Palestine.

Ahmed Shata, A. 2008. Theoretical investigation and mathematical modeling of a wind energy system: Case study for Mediterranean and Red Sea. Ph.D. thesis, der Technischen Universität Berlinzur Erlangung des akademischen Grades, Berlin.

Akpinar, K., Akpinar, S. 2004. Statistical Analysis of Wind Energy Potential on the Basis of the Weibull and Rayleigh Distributions for Agin-Elazig, Turkey. Journal Power and Energy. 218, 557-565.

Alghoul, M., Sulaiman, M., Azmi, B., Abd. Wahab, M. 2007. Wind Energy Potential of Jordan. International Energy Journal. 8, P 71-78.

Alnaser, W., Al-Karaghouli, A. 2000. Wind availability and its power utility for electricity production in Bahrain. Renewable Energy 21, 247-25

Alsamamra, H. 2009. Using geostatistical techniques to obtain high spatial resolution climate maps for Andalusia (southern Spain). Ph.D. thesis, University of Jaen, Spain.

Andersen, P. 2007. Review of Historical and Modern Utilization of Wind Power. Publications. http://www.risoe.dk/rispubl/VEA/dannemand.htm.

Bientz, R., Watson, S., Infield, D. 2009. Preliminary study of long-term wind characteristics of the Mexican Yucatan Peninsula. Energy Conversion and Management. 50, 1773–1780.

Brahimi, N., Sallem, S., Chaabene, M. 2010. ANN based parameters estimation of Weibull : Application to wind energy potential assessment of Sfax, Tunisia. International Renewable Energy Congress- Sousse, Tunisia.

Boyle, G. 2004.Renewable Energy. Oxford University press.

Celik, A. 2003. A statistical analysis of wind power density based on the Weibull and Rayleigh models at the southern region of Turkey. Renewable Energy 29, 593-604.

Celik, A. 2003. Assessing the suitability of wind speed probability distribution functions based on wind power density. Renewable Energy. 28, 1563–1574.

Celik, A. 2003. Energy output estimation for small-scale wind power generators using Weibull-representative wind data. Journal of Wind Engineering and Industrial Aerodynamics. 91, 693–707.

Cellura, M., Cirrincione, G., Marvuglia, A., Miraoui, A. 2008. Wind speed spatial estimation for energy planning in Sicily: Introduction and statistical analysis. Renewable Energy. 33, 1237-1250.

Costa, P., Martins, A., Carvalho, A. 2006. Wind energy extraction and conversion: optimization through variable speed generators and non linear fuzzy control. Ewec proceedings. Info.

Dahmouni, A., Ben Salah, M., Askri, F., . Aloui, F., Ben Nasrallah, S. 2008. Wind energy potential in the site of Borj-Cedria in Tunisia. Revue des énergies renouvelables CICME'08 Sousse 101 – 108.

Fadare, D. 2008. A Statistical Analysis of Wind Energy Potential in Ibadan, Nigeria, Based on Weibull Distribution Function. The Pacific Journal of Science and Technology vol. 9, No 1.

Fernando, W., Sonnadara, D. 2007. Modeling Wind Speed Distribution in Selected Weather Station, Proceedings of the Technical Sessions Institute of Physics – Sri Lanka. 23, P1-6.

Gipe, P. 1993. Wind Power for Home and business. Chelsea, Green Publishing Co,USA.

John, F., Nicholas J. 1997. Wind Energy Technology. New York: Wiley.

Jowder, F. 2009. Wind power analysis and site matching of wind turbine generators in Kingdom of Bahrain. Applied Energy. 86, P 538-545.

Justus, C., Mikhail, A. 1976. Height variation of wind speed and wind distributions statistics. Geophysical Research Letters. VOL. 3, P. 261-264.

Lun, I., Lam, J. 2000. A study of Weibull parameters using long-term wind observations. Renewable Energy. 20, 145-153.

Martin, P. 1995. Some wind characteristics and applications of wind power on the East Coast of the Arabian Peninsula. Sol Energy; 34(1): 9-11.

Mayhoub, A., Azzam, A. 1997. A survey on the assessment of wind energy potential in Egypt. Renew Energy. 11, 235-247.

Minina, A. 2009. Technical Wind Energy Potential in Russia. Master's thesis, Lappeenranta University of Technology, Russia.

Monahan, A. 2006. The Probability Distribution of Sea Surface Wind Speeds. Part I: Theory and Sea Winds Observations. Journal of Climate. Vol.19.

Morgan, E., Lackner, M., Vogel, R., Baise, L. 2011. Probability distributions for offshore wind speeds. Energy Conversion and Management. 52, 15-26.

Nfaoui, H., Buret, J., Sayigh, A. 1998. Wind Characteristics and Wind Energy Potential in Morocco. *Solar Energy* Vol. 63, No. 1, pp. 51–60.

Palestinian Meteorological Stations Network, http//www.pmd.ps.

Persaud, S., Flynn, D., Fox, B. 1999. Potential for wind generation on the Guyana Coastlands. Renewable Energy 18:175-189.

Petersen, E., Troen, I., Frandsen, S., Hedegaard, K. 1981. Wind atlas for Denmark. A rational method of wind energy siting. Riso-R-428, Riso National Laboratory, DK-400 Roskilde, Denmark. P 229.

Raman, S., Iniyan, S., Suganthi, L., Goic, R. 2010. Wind Energy Potential Estimation in India. Clean Technology. http://www.ct-si.org/.

Ramesh, R., Udayakumar, K., Anandakrishnan, M. 1997. Renewable Energy Technologies. Narosa Publishing House, London, UK.

Ramachandra, T., Subramanian, D., Joshi, N. 1997. Wind Energy Potential Assessment In Uttera Kannada District Of Karantaka, India. Renewable Energy. Vol. 10, No. 4, pp 585-611.

Rehman, S., Halawani, T., Husain, T. 1994. Weibull parameters for wind speed Distribution In Saudia Arabia, Solar energy. Vol.53. 473-479.

Reeves, A., Beck, F. 2003. Wind Energy for Electric power. Renew Energy Policy Project.

Scerri, E., Farrugia, R. 1996. Wind data evaluation in the Maltese Islands. Renewable Energy, Vol. 7, No. 1, pp. 10-114.

Shabbaneh, R., Hasan, A. 1997. Wind Energy Potential in Palestine. Renewable Energy 11(4),479-483.

Slootweg, G., Kling, WL. 2003. Aggregated modeling of Wind Parks in Power System Dynamics Simulations, IEEE http://www. ieee.org.

Spera, D. 1985. Wind Turbine Technology: Fundamental Concepts of Wind Turbine Engineering. The American Society of Mechanical Engineers: New York; 638p.

Sulaiman, M., Akaak, A., Wahab, M, Sulaiman, A., Suradi, J. 2002. Wind characteristics of Oman. Energy 27, P 35-46.

Ulgen, K., Hepbasli, A.2002. Determination of Weibull parameters for wind energy analysis of Izmir, Turky. International Journal Of Research. 26, 495-506.

WWEA(World Wind Energy Association). 2008. http://www.wwindea.org.

http://www.uneptie.org/energy.

Yaseen, B. 2007. Renewable Energy Applications in Palestine. Palestinian Energy and Environment Research Center (PEC) – Energy Authority**.**

Yin, X. 2000. Surface Wind Speed over Land: A Global View. Journal of Applied Meteorology. Vol. 39, P 1861-1865.

Youm, I., Sarr, J., Sall, M., Ndiaye, A., Kane, M. 2005. Analysis of wind data and wind energy potential along the northern coast of Senegal. Renewable Energy. Vol. 8, P 95 – 108.

Zaharim, Z., Razali, A., Abidin, R., Sopian, K. 2009. Fitting of Statistical Distributions to Wind Speed Data in Malaysia. European Journal of Scientific Research. Vol.26, No 1, P 6-12.