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Wind Energy Resources Assessment and Micrositting on Different Areas of Libya: The Case Study in Darnah

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***Abstract*—This paper presents long term wind data analysis in terms of annual and diurnal variations at different areas of Libya. The data of the wind speed and direction are taken each ten minutes for a period, at least two years, are used in the analysis. 'WindPRO' software and Excel workbook were used for the wind statistics and energy calculations. As for Darnah, average speeds are 10m, 20m and 40m and 6.57 m/s, 7.18 m/s, and 8.09 m/s, respectively. Highest wind speeds are observed at SSW, followed by S, WNW and NW sectors. Lowest wind speeds are observed between N and E sectors. Most frequent wind directions are NW and NNW. Hence, wind turbines can be installed against these directions. The most powerful sector is NW (31.3% of total expected wind energy), followed by 17.9% SSW, 11.5% NNW and 8.2% WNW

In Excel workbook, an estimation of annual energy yield at position of Derna, Al-Maqrun, Tarhuna and Al-Asaaba meteorological mast has been done, considering a generic wind turbine of 1.65 MW. (mtORRES, TWT 82-1.65MW) in position of meteorological mast. Three other turbines have been tested and a reduction of 18% over the net AEP. At 80m, the estimation of energy yield for Derna, Al- Maqrun, Tarhuna and Asaaba is 6.78 GWh or 3390 equivalent hours, 5.80 GWh or 2900 equivalent hours, 4.91 GWh or 2454 equivalent hours and 5.08 GWh or 2541 equivalent hours respectively. It seems a fair value in the context of a possible development of a wind energy project in the areas, considering a value of 2400 equivalent hours as an approximate limit to consider a wind warm economically profitable. Furthermore, an estimation of annual energy yield at positions of Misalatha, Azizyah and Goterria meteorological mast has been done, considering a generic wind turbine of 2 MW. We found that, at 80 m the estimation of energy yield is 3.12 GWh or 1557 equivalent hours, 4.47 GWh or 2235 equivalent hours and 4.07GWh or 2033 respectively.

It seems a very poor value in the context of possible development of a wind energy project in the areas, considering a value of 2400 equivalent hours as an approximate limit to consider a wind warm economically profitable. Anyway, more data and a detailed wind farm study would be necessary to draw conclusions.

***Keywords*—**Wind turbines, wind data, energy yield, micrositting.

I. Introduction

THIS paper presents long term wind data analysis in terms of annual and diurnal variations at different areas of Libya. The data of the wind speed and direction are taken each ten minutes for a period, at least two years, are used in the analysis [1].

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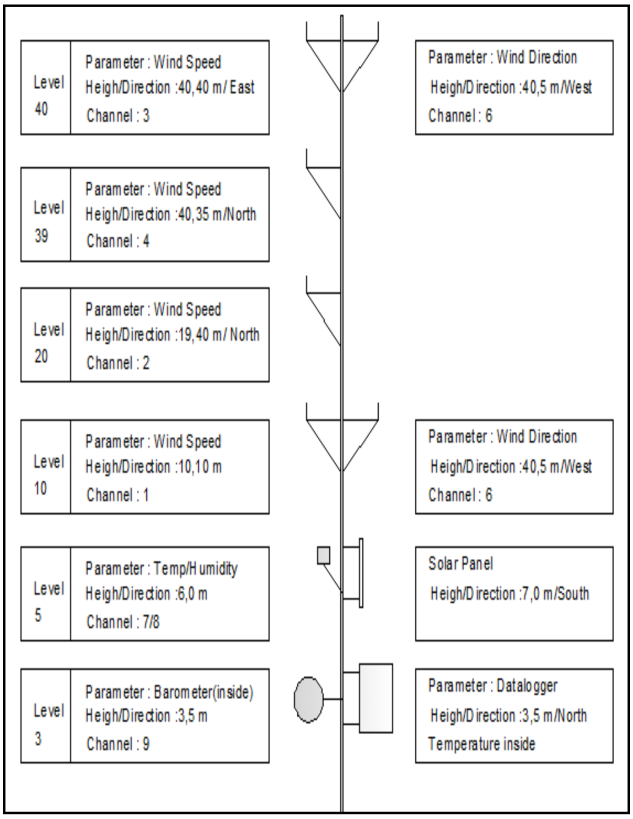

Fig. 1 Meteorological Mast in the El-Maqrun station

II. Data Collection

Details weather data concerning atmospheric pressure, temperature, humidity, and wind speed as well as the wind direction was measured at El-Magrun station by using meteorological mast. The data were recorded each 10 minutes from seven levels beginning 3.5m to 40.4m during 2002 (Fig. 1).

A. Climate Conditions in Libya.

Due to the lack of natural barriers, the climate is greatly influenced by the desert to the south and the Mediterranean Sea to the north. The coastal regions have a Mediterranean climate with moderate temperatures and enough rain during the winter months for grain farming.

In Tripoli average temperatures are 30 deg C (86 deg F) in summer and 8 deg C (46 deg F) in winter; annual precipitation averages 380mm (15 in) and falls mainly in winter. The mountains of the Jabal Al-Akhdar attract considerably more reliable rainfall in winter and early spring, while in summer the heights are cooler than the surrounding plains. Semiarid conditions predominate in the AL MARJ and JAFFARA plains, and in the southern deserts frequent periods of drought occur. A scorching wind called the "GHIBLI" which is a hot, very dry, sand laden wind which can raise the temperatures in a matter of hours to between 40 deg C and 50 deg C, occasionally blows into the usually humid coastal towns.

Extreme temperature and humidity conditions can be observed in Libya. These factors, together with the particular characteristics of de desert -especially dust-, must be taken into account by the manufacturers of wind turbines in order to select the model of wind turbine to use and to take appropriate measures to prevent damage on it [2].

III. Results and Discussion

This section covers the long term annual, seasonal and diurnal variation of mean wind speed; the wind availability in terms of frequency distribution, energy calculations using Excel workbook in wind turbine machines of different rated powers and capacity factor estimation and its variation with wind machine size and hub height. Lastly, the energy output from a wind farm of 60 MW installed capacity is discussed with wind size and hub height.

A. Long Term Wind Speed Variation

The long term yearly variation of wind speed provides an understanding of the long term pattern of wind speed and also confidence to an investor on the availability of wind power in coming years. In order to study the annual behavior of the wind speed, daily mean values of wind speed were used to get yearly mean values for a period of 2 years, between 2002 and 2004. The year-to-year change in the mean wind speed at 10m, 20m and 40m above the ground is shown in Figs. 2-4 [3].

TABLE I
METEOROLOGICAL STATION OF DARNAH

Period:annual			
Average rate (min)10			
Numberregisters32677			
Start30/10/200212:10 h			
End13/05/200420:40 h			
Function transfer. U (m/s) = 0.0481 * Hz + 0.1924			
Hub altitude	40 m	20 m	10 m
Average wind speed (m/s)	8.09	7.15	6.52
Maximum avg wind speed (m/s)	990	810.	316.8
Gust wind speed (m/s)	26.94	26.46	25.49
Average power density (W/m2)	555.7	449.1	302.3
Average Iu horiz.	0.066	0.075	0.081
Average sq (deg)12.77			
Calm frequency, spd=0 (%)	0.05	0.24	0.08
Average temp. (ºC)28.5			
Average humidity (%)43			
Std. density (Kg/m3)1.225			

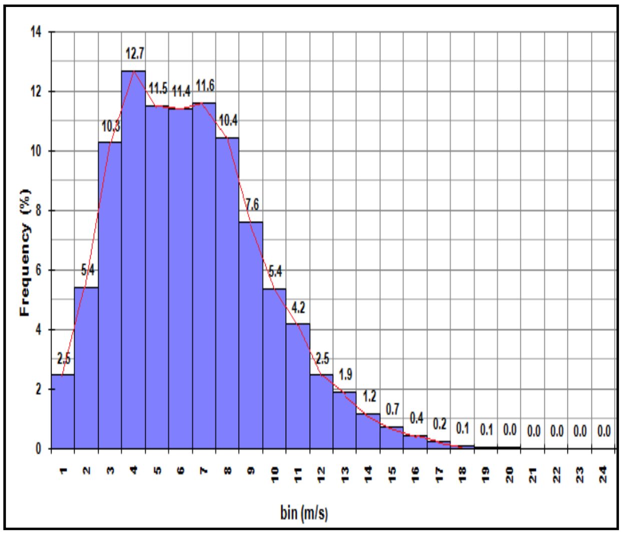

Fig. 2 Wind Speed Distribution

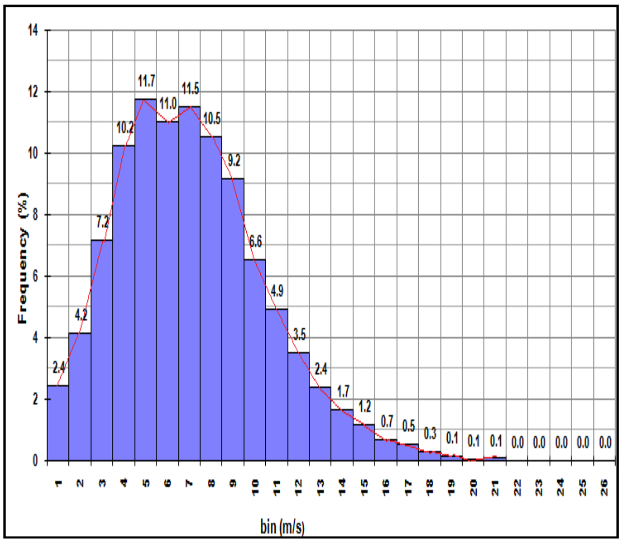

Fig. 3 Wind Speed Distribution 20m

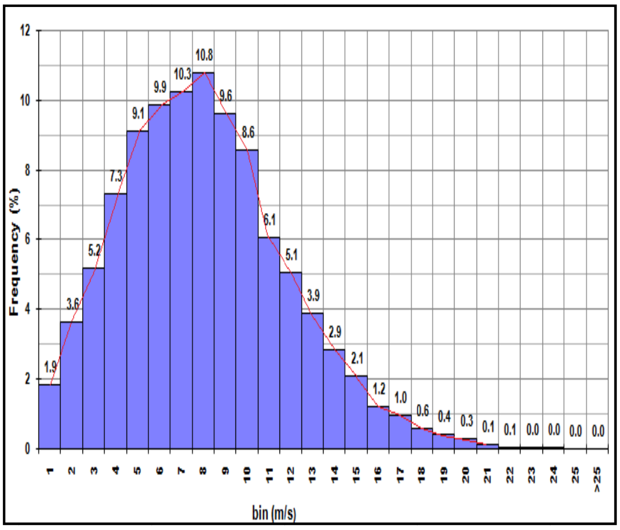

Fig. 4 Wind Speed Distribution 40m

B. Wind Availability Analysis

The wind rose provides information about the occurrence of the number hours or percentage of time during which the wind remained in a certain wind speed bin in a particular wind direction. Wind roses are constructed using hourly mean wind speed and corresponding wind direction values. Like wind speed, wind roses also vary from one location to another and are known as a form of meteorological fingerprints. Hence, a close look at the wind rose and understanding its message correctly is extremely important for sitting wind turbines. So, if a large share of wind or wind energy comes from a particular direction then the wind turbines should be placed or installed against that direction [4].

C. Results and Discussion

Average speeds of Darnah are 10m, 20m and 40m, and respectively 6.57m/s, 7.18m/s, and 8.09m/s. Highest wind speeds are observed at SSW, followed by S, WNW and NW sectors. Lowest wind speeds are observed between N and E sectors. Most frequent wind directions are NW and NNW. Hence, wind turbines can be installed against these directions. The most powerful sector is NW (29.4% of total expected wind energy), followed by 19.9 % SSW, 11.9% NNW, 8.6% WNW and 8.2% S. Furthermore in Al-Maqrun: The most powerful sector is W (26.8% of total expected wind energy), followed by 12.3% WSW and 9.5% WNW. While in Goterria: The most powerful sector is S (14.8% of total expected wind energy), followed by SSE, SE and WSW. And Misalatha: The most powerful sector is S, by far represents 28.5% of the expected power, followed by SSE and SE. As for Tarhuna, it is by far SSE and SE, representing each one two times the expected energy of the third powerful sector (NW). In Al-Asaaba: It is SSE by far represents 50% of the expected power, followed by S. It can to be noted that the high frequency of the south direction winds, that come from the desert could cause a high frequency of dust episodes. This fact then should be taken into account in order to take appropriate measures to prevent wind turbine deterioration [5]-[6].

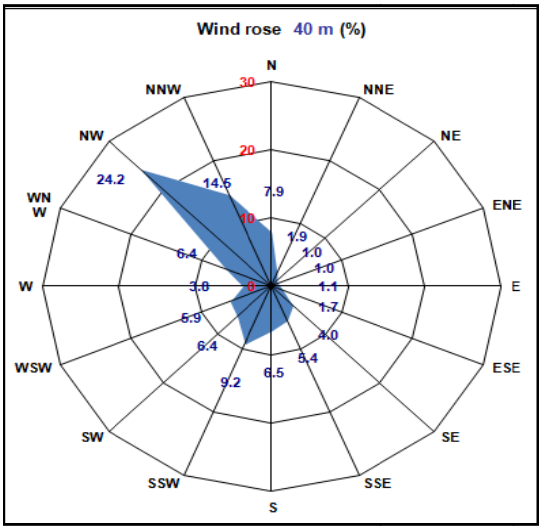

Fig. 5 Wind Rose at 40m Height (%)

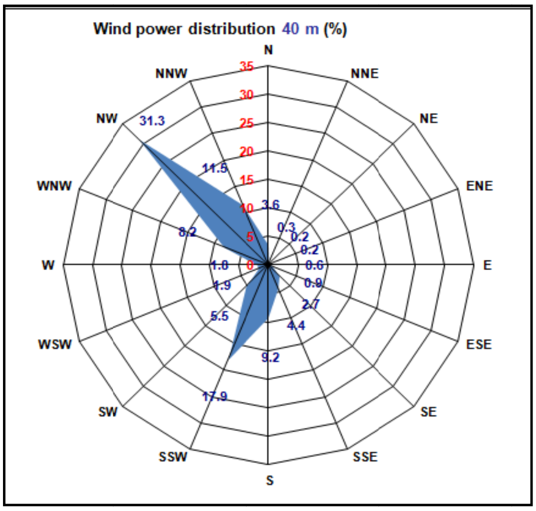

Fig. 6 Wind Power Rose Distribution 40 m(%)

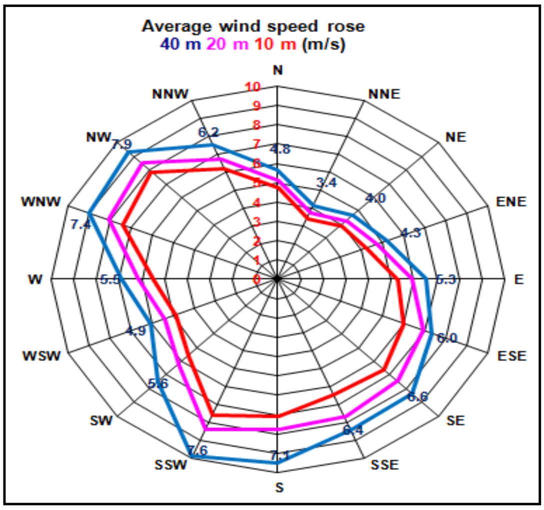

Fig. 7 Rose Wind Speed

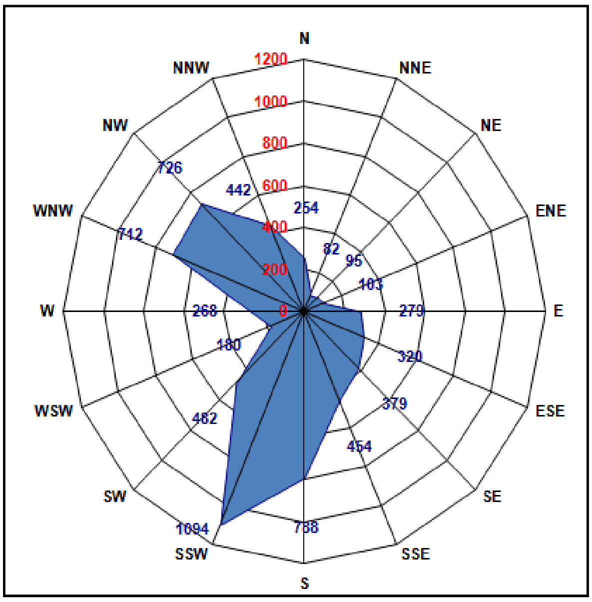

Fig. 8 Wind Power Density 40 m (W/m2)

IV. Assessment of Energy Output

A Case Study (Darnah, Years from 2002 to 2004).

Darnah city was selected because the wind speed is acceptable and it was proposed a project of construction of wind resource analysis tender Derna farm. The M.TORRES (TWT 1.65/82) is the industrial wind turbine used for this project. This project was intended to study the wind resource affecting Tender Darnah wind farm in Libya. The project consists of three possible scenarios: 60MW (37WTG), 70MW (43WTG) and 120MW. Tender Darnah Wind Farm will be located one kilometre away from the coast, in the surrounding of Darnah, Libya Fig. 9.

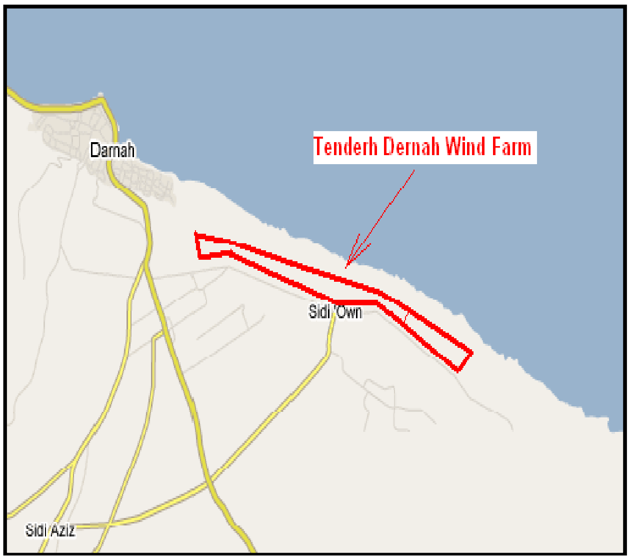

Fig. 9 Darnah Wind Farm

A. Wind Power Density

The wind power density was calculated from

$$P = \frac{1}{2}\rho V^3 \qquad (1)$$

This has rendered possible to design the diagrams of average wind speed duration (V) Fig.10, and of the specific power (P') Fig. 10, according to a coefficient of the conventional use of time u = h/8760 % [7].

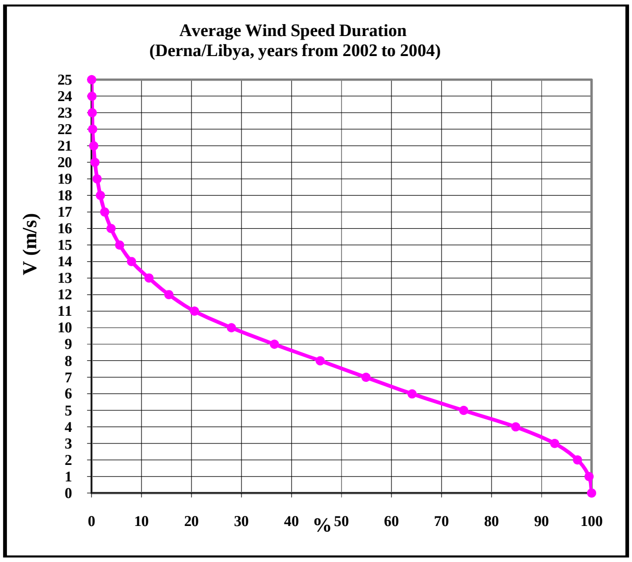

Fig. 10 Duration of Average Wind Speed

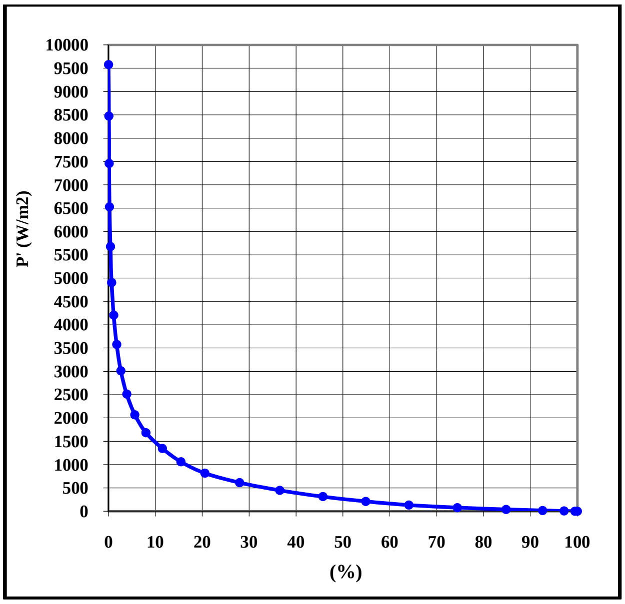

Fig. 11 Specific Power Durations Darnah- Libya

B. Load Factor and Energy Yield

The annual energy and annual capacity factor were calculated at 80m height based on specification of wind turbine known as **mt**ORRES (TWT 1.65/82) wind turbine which has a power curve as shown in Fig. 12 and its curve of load factor is shown in Fig. 13. Where the air density ρ=1.225 kg/m^3. The power curve of an industrial wind turbine shows the typical trend of the wind speed. The power was equal to zero up to a speed of about V=3.0 m/s and reached 100% at speed V=15.0 m/s and the cut-out speed is 25.0 m/s.

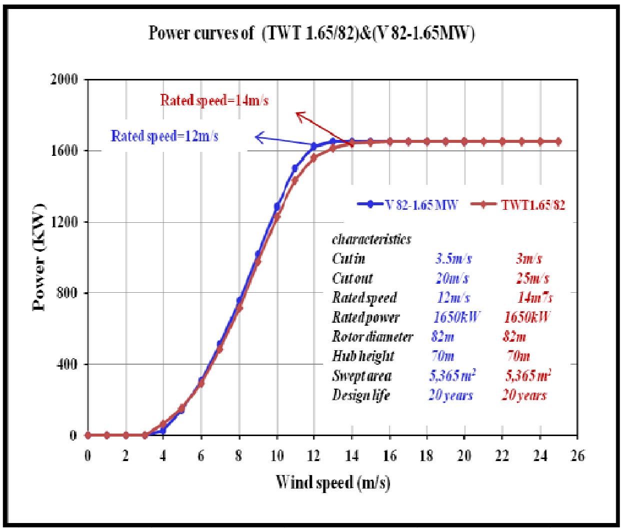

Fig. 12 Power Curves Of (TWT 1.65/82) & (V82-1.65MW)

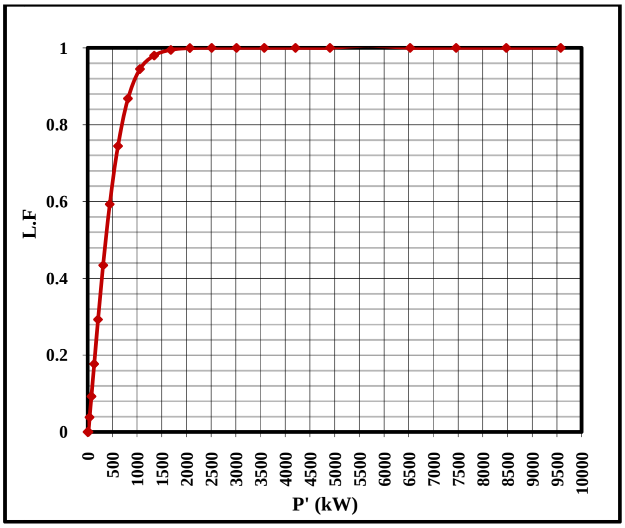

Fig. 13 Curve of Load Factor of M. Torres (TWT 1.65/82)

From the curve of Fig. 12 the load factor (L.F) was calculated (see Fig.13), which is defined as the ratio between the instantaneous power and the max. load of wind turbine, in relation the specific power P', corresponding to each wind speed (V) according to equation of wind power density. In Fig. 14 the curve of (L.F) was also superimposed on the distribution frequency of wind velocities of Darnah-Libya at 80m height. Note the proportionality between the power output and the relative frequency distribution.

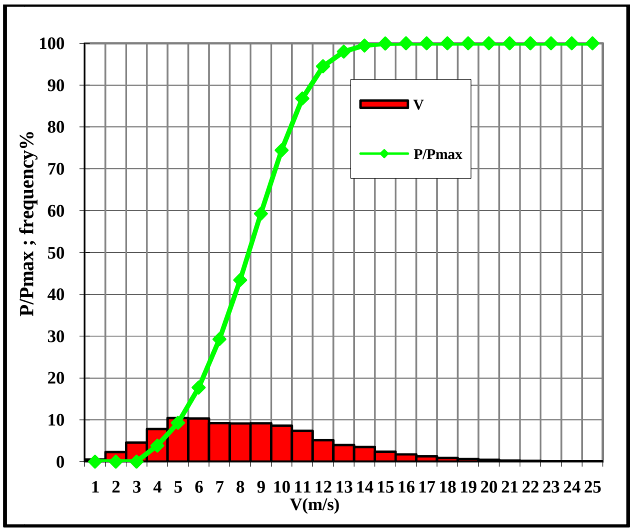

Fig. 14 Curves of Load Factor and Distribution ofWind Speeds

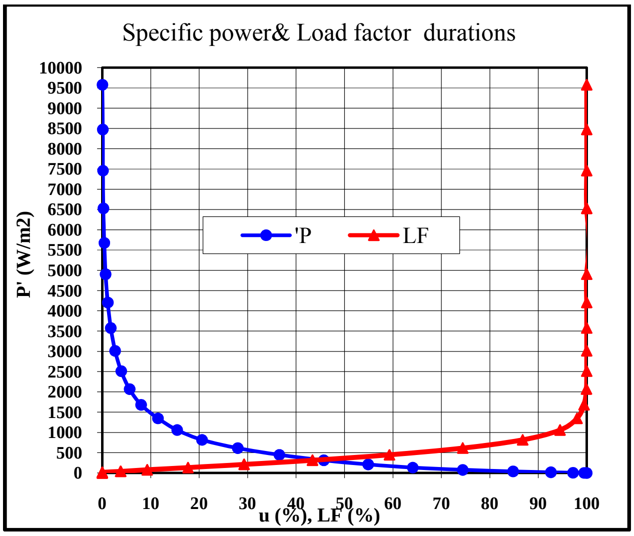

Fig. 15 Specific power and the load factor durations

The performance of load factor (L.F) according to the conventional time use coefficient (Fig. 15)has been associated with corresponding diagram of local duration of P'(u) .Multiplying each value of LF (u) for the duration (u) of the corresponding specific power P '(u) so you can be obtain a integral yield function (time): I.Y=LF * u(P') of the wind turbine (Fig. 16) product of a quantity characterizing of the machine (LF) for a quantity characterizing of the site (u (P')). It is proposed here to adopt (I.Y) as an indicator of the correct choice and dimensioning - Regardless of the value of (Cp) - of a wind turbine which has the actual performance of Fig. 12. The maximum value, the variation of the power P' reached by (I.Y) quantifies in fact the best potential of the site and identifies at the same time the specific power to be taken for the project. For Darnah location, the function of the integral yield assumes values less than 22%, insignificant for the purposes of a power installation [8].

V. Energy Output Analysis for a Wind Farm of Installed Capacity of 60 MW

Fig. 16 shows the optimal value of the integral energy yield for Darnah, which can be obtained through the corresponding value of specific power P' in around of 760W/m^2/y. It gave us the average annual energy of approximately 22% from the limit of a wind turbine generator. Therefore, the annual coefficient of the conventional use of time for Darnah was about 1927 hours (u= 0.22*8760) of the equivalent fully loaded operation. From above, it can be concluded that the energy yield was equal to the specific power (P') multiplying per coefficient of time (u). (Energy yield = 1465 kWh/m2/y), multiplying per swept area (A), the annual energy output was obtained as Eout = 7.86 GWh.

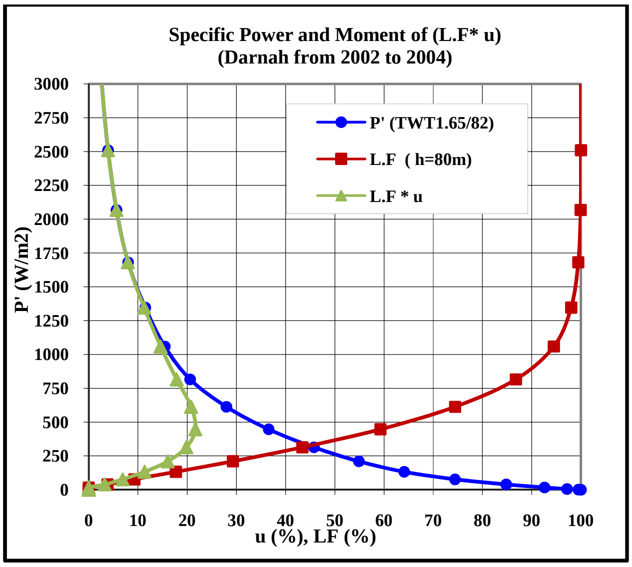

Fig. 16 (a) Specific Power And Moment Of (L.F*U)

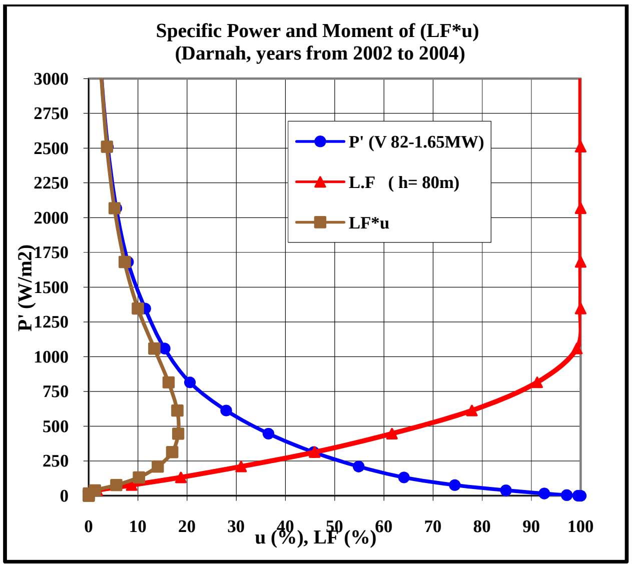

Fig. 16 (b) Specific Power and Moment of (L.F*U)

TABLE II
ANNUAL ENERGY OUTPUT AND CAPACITY FACTOR OF 16 DIFFERENT COMMERCIAL WIND TURBINES(EACH TWO OF THEM HAVE THE SAME HUB HEIGHT, ROTOR DIAMETER AND RATED POWER BUT THEY ARE DIFFERENT IN THEIR RATED WIND SPEED

TurbineModel	Hub height(m)	Rated power (kW)	Vcut inm/s	Rated Speed (m/s)	Vcut out(m/s)	Energy (kWh/y)
Enercon E40	40	600	2.5	12.5	28-34	2,219,717
AN BONUS 41	40	600	4.5	14-15	25	2,167,883
AWE52-900 kW	75	900	2	14	25	3,883,967
NM 52-900 kW	75	900	3.5	15	25	3,669,995
FL 54-1000 kW	70	1000	2.5	12.5	25	3,806,701
aaERA-1000/S	70	1000	3	14	20	3,768,736
HW77/1500 kW	70	1500	3	12	25	6,854,128
GE 77-1.5MW	70	1500	3.5	14	25	6,660,350
V82-1.65MW	80	1650	3.5	12	20	7,888,357
TWT 82-1.65	70	1650	3	14	25	7,861,646
TWT 82-1.65	80	1650	3	14	25	7,834,475
TWT 70-1.65	70	1650	3	14	25	5,426,537
DeWind D8.2	80	2000	3	13.5	25	7,341,258
V80-2.0 MW	80	2000	4	16	25	7,486,139
E101-3.0MW	100	3000	2.5	12.5	28-34	11,244,03
AW100-3.0MW	100	3000	4	11.7	25	10,804,15
V112-3.0MW	125	3000	4	14	25	13,474,35
E126-7.5MW	135	7500	2.5	12.5	28-34	16,384,24

VI. CONCLUSIONS AND RECOMMENDATIONS

As for the wind energy, so the purpose of this part is to present a new analytical method by use Excel workbook for estimation of annual energy yield and the wind statistics for different sites in Libya, which are located on the coast of Mediterranean Sea, central zone and Sahara. This new analytical method for estimation of annual energy yield and the wind statistics was used and its comparison with other methods, which has given the similar results. Furthermore the annual energy yield was estimated by large wind turbines M. Torres (TWT 1.65/82) and comparison with other machine turbine, Such as Vestas (V82/1.65MW) showed the same characteristics [9], [10]. After studying this part of work, it can be concluded that the energy output of wind machines increases with the increasing of hub height, rotor diameter and rated power. This showed that hub height and rotor diameter play a considerable role in energy generation from the wind machines. Similar types of behavior are noticed from the wind machines of other sizes. The use of a wind turbine which has a rated power greater than 1000kW at Darnah station was recommended. Then based on results, the use of a wind turbine with lower rated speed will produce more energy over a year than a wind turbine with higher rated speed. The capacity factor is greater for wind turbine with lower rated wind speeds. The choice of the best suitable wind turbine for each station was discussed. Whereas a technical and economic assessment of electricity generation from wind turbine machine "mtORRES (TWT 1.65/82)" has capacity of 1650kW considered in ten different sites along the coast of Mediterranean Sea and Sahara in Libya (Darnah station was one of them). The energy yield and capacity factor for Darnah on the coast of Mediterranean Sea was high and acceptable.

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