Wind Power Estimation for Al-Hay District (Eastern South of Iraq)

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Abstract:
In this paper the wind data that is measured for 12 months (January to December 2011) at Al-Hay district of Wasit province, southern IRAQ country has been analyzed statistically. The wind speed at heights of 10 m above ground level was measured for every 10 minutes interval. The statistical analysis of wind data was performed using WAsP software which is based on Weibull distributions. The Weibull shape and scale parameters is obtained and used in this paper statistics. The achieved results demonstrated that the study area has Annual Mean Energy Production (AMEP) about 219.002 MWh. The computations have been performed on 70m hub's height of the turbine and on Earth surface roughness length (0.0, 0.03, 0.1, 0.4, 1.5) m respectively.

Keywords: WAsP software, Weibull Distribution, Power Density, Wind Energy, Probability Density Function.

تخمين قدرة الرياح في منطقة الحي (الجنوب الشرقي من العراق)

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الخلاصة:
في هذا البحث، تم جمع بيانات سرع الرياح لفترة 12 شهر (كانون الثاني الى كانون الاول لسنة 2012) لمحطة الحي في محافظة واسط، جنوب شرق العراق. لقد تم تحليل هذه البيانات احصائيا. ان البيانات الانوائية تم جمعها وقياسها على ارتفاع 10 متر فوق سطح الارض ولفواصل زمنية 10 دقيقة. التحليل الاحصائي لبيانات الرياح قد تمت باستخدام برنامج WAsP والذي يعتمد على نموذج توزيع ويبل. لقد تم حساب معلمة الشكل والقياس لهذه البيانات. ان الناتج من هذا البحث هو المعدل السنوي للطاقة المنتجة (AMEP) بحدود 219.002 MWh . ان الحسابات قد اجريت على ارتفاع 70 m لتوربين الهواء طول الخشونة لسطح الارض (0.0, 0.03, 0.1, 0.4, 1.5 m) على التوالي.

Introduction

Wind resources are the most important factors used to select locations for wind turbines because it fits is directly proportional with the cubic power of wind speed. For simple terrain (i.e. elevation

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relatively flat and low vegetation), the farms of wind resource can be modeled well, but it is more complicated with different environments. The assessments of power production of these farms are significantly affected by the wind over difficult areas. Unfortunately, many of the effects of these types of terrain like mountain or forests are not fully understood within the wind-energy industry or even the micro-meteorological community [1].

In the current project, we will try to evaluate and validate the predictions using wind speed and directions data of previous studies that were located the promising area in Iraq [2]. The data in our present research perform the analyses using the WAsP program. The Wind Atlas Analysis and Application Program (WAsP) model is a PC program for predicting wind climates, wind resources and power productions from wind turbines and wind farms. The predictions are based on wind data measured at regional metrological stations. The program includes a complex terrain flow model, a roughness change model and a model of sheltering obstacles.

A proper analysis of statistical wind data is a very important step when performing a wind resource assessment projects. The site’s probability distribution of wind speeds determine the performance of wind turbine generators also the corresponding power curve of the turbine which affect the performance. There is several models deal with the use of probability density functions to describe wind speed frequency distribution [3]. The most often used distributions are; Gaussian distributions, exponential distributions, gamma distributions and logistics distributions that can be used to model a site’s wind speed variation [4]. In this project, the Weibull probability density function will be used to predict a site’s probability distribution of wind speeds. The Weibull distribution technique is a widely accepted and preferred method for describing wind speed variations at a given site. It is considered as the best fit for describing wind speed variations at a given site [5]. Unfortunately, the Weibull distribution cannot predict well the site’s having low mean wind speeds [6].

As many wind prediction models, WAsP is based on the hypothesis that wind speed data can be approached in statistically by the Weibull distribution (i.e. a continuous probability distribution, which is widely accepted among the wind-engineering community). The probability density for Weibull Distribution is given by the following [7]:

$$f(u) = \frac{q}{A}(\frac{u}{A})^{(q-1)} e^{-(\frac{u}{A})^q} \quad (1)$$

Where A is a scale parameter (m/s) and q the shape parameter (in case q = 1, for exponential distribution) or the (case q = 2 for Rayleigh distribution) …..etc.[8].

The probability density function (PDF) of the wind speed is given by:

$$f(v) = (\frac{K}{A})(\frac{V}{A})^{(K-1)} e^{-(\frac{V}{A})K} \quad (2)$$

Where: f(v) is the probability density function of the wind speed; A is the Weibull scale parameter; and K is the dimensionless Weibull shape parameter.

In the layers that have altitude below 1 kilometer, the atmosphere, however, wind speeds are affected by the friction against the surface of the earth. In the wind industry one distinguishes between the roughness of the terrain, the influence from obstacles, and the influence from the terrain contours, which is also called the orography of the area. In the wind industry, people usually refer to roughness classes or roughness lengths, when they evaluate wind conditions in a landscape. The term roughness length is really the distance above ground level where the wind speed theoretically should be zero [9].

The Study Area

The study area as shown in figure-1a, is a square region of 100km^2, its centre point located at coordinates (E602013 m, N3572356 m) at zone 38N for UTM projection coordinate system. It is known ‘Al_Hay district' Eastern south of IRAQ belong to Wasit province illustrated in figure-1b. Figure-1c, represents the Digital Elevation Map 'DEM' of 30 m resolution for the study area. The observed wind climate data has been collected at the meteorological station located at a site of elevation 12.5 m above sea level (a.s.l.).

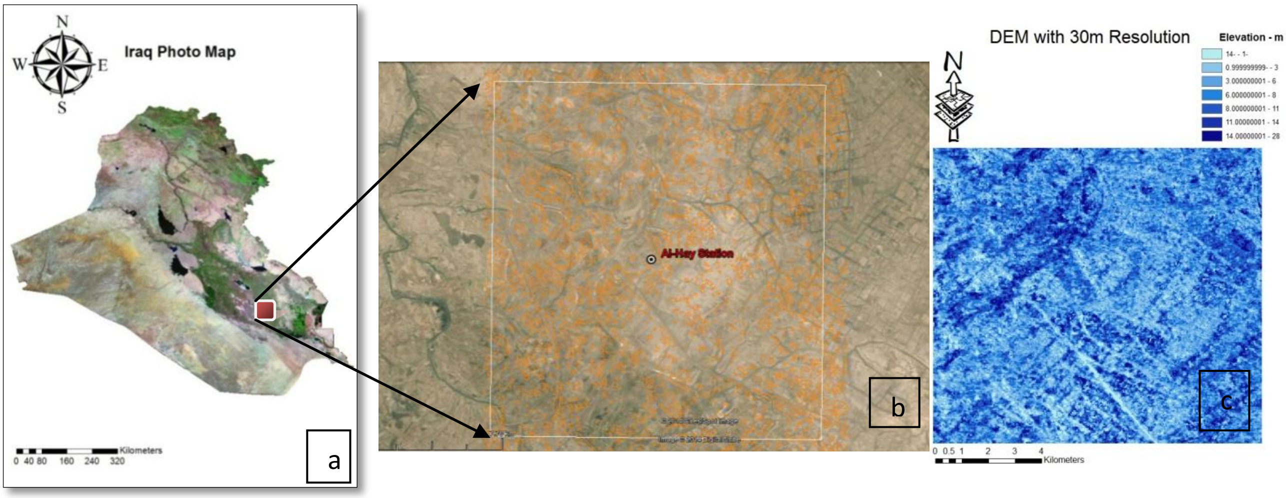

Figure 1-a)Satellite photo map of Iraq observed by Landsat-7 sensor, b) Site of the study area, and c) DEM of the study area (30m Resolution)

Methodology

The parameters that were involved in the computation of the wind power for a specified region has been computed and extracted from multiple sources. The first source is the Metrological stations which were a data bank for wind speed measurements through decades (They provide measurements every 10 minutes). The second source is the DEM of the region to produce contour map use to calculate the roughness of the study area. The third source is a high resolution photo map for viewing the study region and locating local obstacles (e.g. power transmission lines, roads, buildings, wet lands etc.). The air density which is adopted in this research was 1.225kg/m3 used to calculate the mean power density. This approach facilitates the final calculation of wind assessment because it does not correlate the wind power and the influences air temperature and altitude values.

We have divided the compass into 12 sectors, one for each 30 degrees of the horizon. (A wind rose may also be drawn for 8 or 16 sectors, but 12 sectors tend to be the standard set by the European Wind Atlas. The radius of the 12 outermost, wide wedges gives the relative frequency of each of the 12 wind directions, i.e. how many per cent of the time is the wind blowing from that direction. The second wedge gives the same information, but multiplied by the average wind speed in each particular direction. The result is then normalized to add up to 100 per cent. This tells you how much each sector contributes to the average wind speed at our particular location. The methodology followed in this research is summarized by the block diagram shown in figure-2.

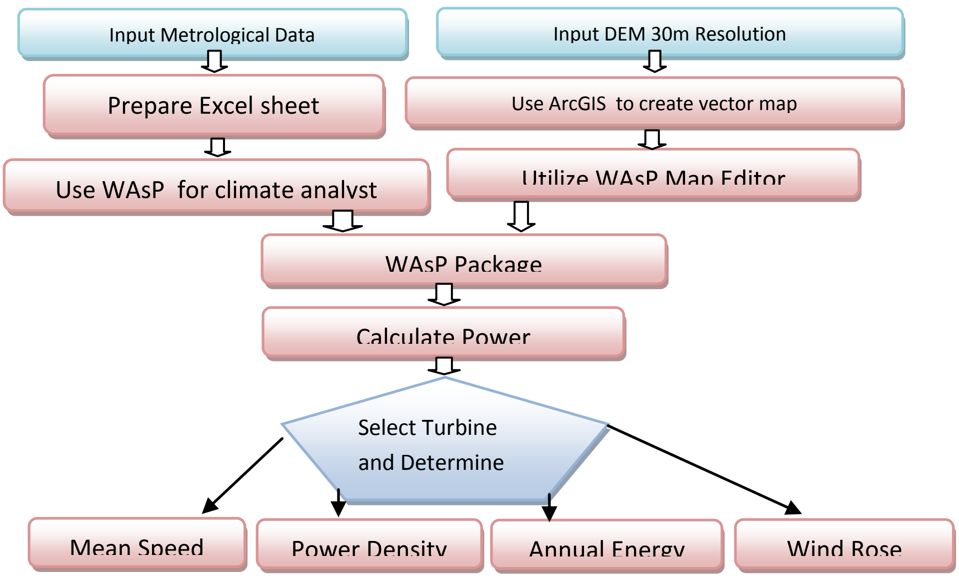

Figure 2-Block diagram summarizes the methodological steps followed in this project.

Results and Discussions

The wind turbine selected for this study is a **V82 -1.65 MW- Vestas** it has a blade diameter 82m, cut-in wind speed of 3.5 m/s, and cut-out wind speed of 20 m/s. Only three wind turbines are suggested to be installed in the wind farm. The **V82 -1.65 MW- Vestas** has the following specification; it is a pitch regulated, upwind turbine with active yaw and a high speed rotor with three blades. The medium size of this turbine is suitable for powering large farms; its energy capture is exceptionally good across a wide range of wind speeds, installed on a 70m hub height for maximum energy capture, withstanding harsh conditions, and of design life exceed 20 years. As has been illustrated in the block diagram figure-2, the first step was to produce a contour vector map for the DEM image shown in figure-1c of the study region by utilizing the Arc GIS, present in figure-3.

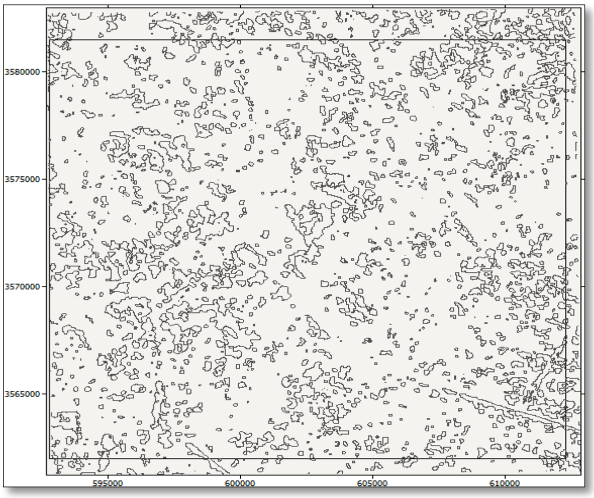

Figure 3-Vector contours map for Al-Hay district.

The mean wind speed for 12 sectors within the study area is illustrated in figure-4.

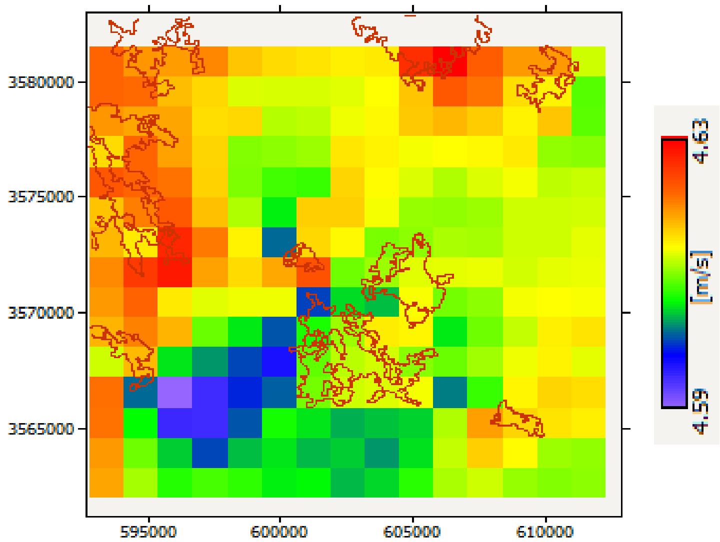

Figure 4-Mean wind speed map of 12 sectors within the study area.

As it is obvious, the mean wind speed varies between 4.59 (at point of coordinates E604288, N3581365) to 4.63 m/s (at point E595188, N3572265), the mean value is 4.62 m/s.
Figure-5, presents the assessment power density produced by the 12 sectors, range between 108 (at point E604288, N3581365) to 110 W/m^2 (at point E610788, N3581365), the mean value is 110 W/m^2.

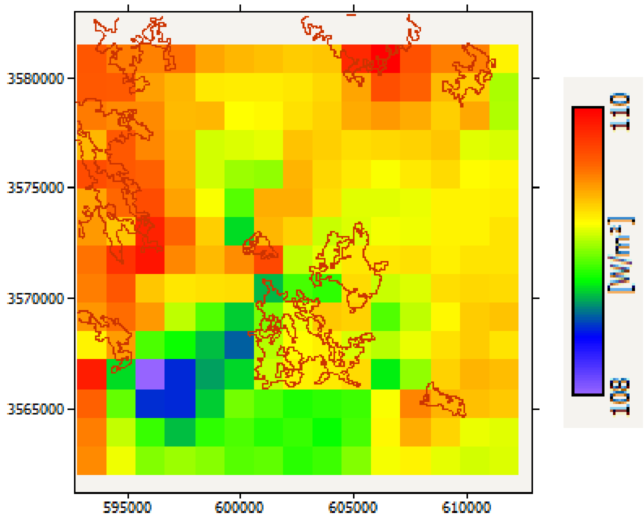

Figure 5-The power density produced by the wind for the 12 sectors.

The Annual Energy Production (AEP) has been calculate for the 12 sectors of study area and illustrated in figure-6. As it is obvious, the produced AEP varies between 214.479MWh (at point E604288, N3581365) to 220.596MWH (at point E595188, N3572265), the mean value 219 MWh).

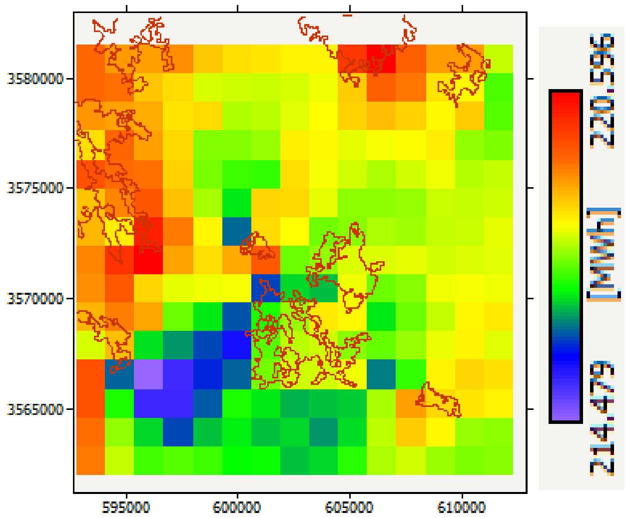

Figure 6-The Annual Energy production for the 12 sectors of the study area.

When designing farm of wind's turbines, the best locations for erecting each turbine must be decided. In our present project, three sites of turbines have been selected in corresponding to the site of the local metrological station. As mentioned above, the adopted type of the wind turbine was V82-1.65 MW–Vestas. For each decided turbine site, the AEP was calculated at 70m hub height. The calculated data is presented in table-1.

Table 1- Represents the AEP for the three selected sites of the turbines.

Site	**Location [m]**	**Elevation (m)**	**Hub height (m)**	**Net AEP [GWH]**
Turbine site-1	E595814.3,N3572510.0	16	70	3.082
Turbine site-2	E595585.4,N3572052.0	15.93327	70	3.089
Turbine site-3	E596043.3,N3573120.0	15.93058	70	3.081

Table-2, presents the calculated Weibull parameters (shape and scale A & k) at 70m hub heights (H), also the calculated mean wind speed (U) and the power density (E) for each selected sites are included.

Table 2-The Weibull parameters, the wind speed, & power density of the selected sites of turbines

Site	Location [m]	H [m]	A [m/s]	K	U [m/s]	E [W/m²]
Turbine site-1	E595814.3,N3572510.0	70	6.2	2.30	5.49	170
Turbine site-2	E595585.4,N3572052.0	70	6.2	2.30	5.49	170
Turbine site-3	E596043.3,N3573120.0	70	6.2	2.30	5.48	170

The observed wind frequency for the local metrological station is illustrated in figure-7.

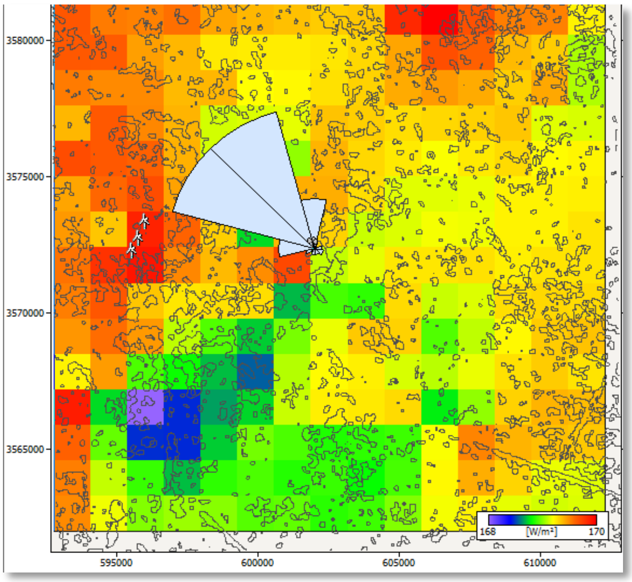

Figure 7- The observed wind frequency at the local metrological station site.

The predicted wind frequency for the three selected sites is shown in figure-8. As it is obvious, the mainstream of the wind was almost stable direction.

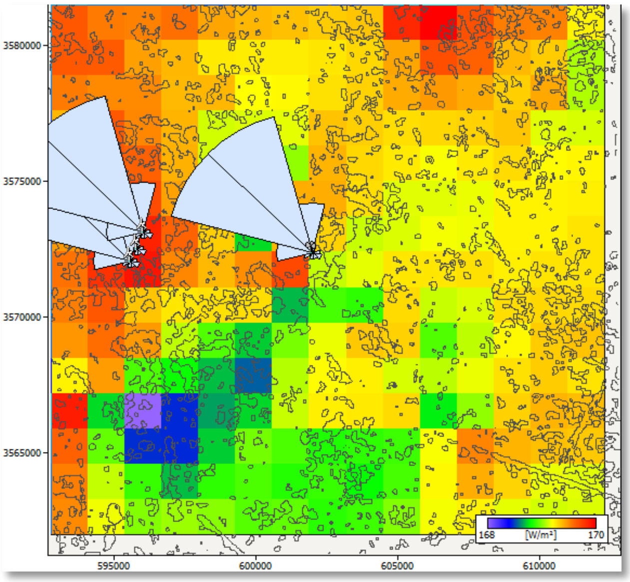

Figure 8- The predicted wind frequency at the three selected sites.

Figure-9, shows the self prediction for metrological station site.

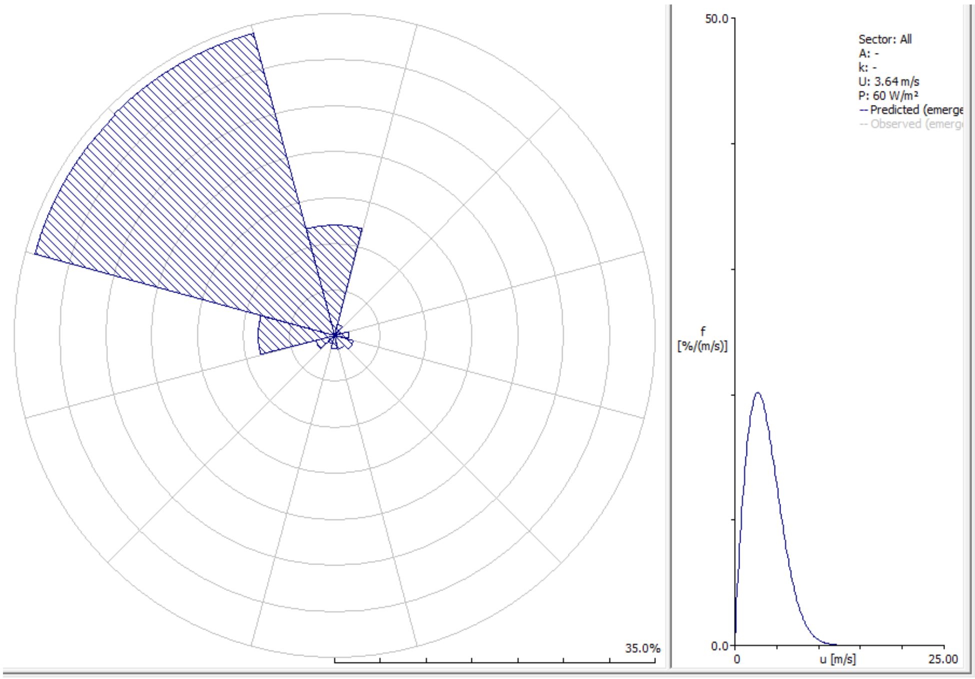

Figure 9- Illustrates the self prediction for metrological station

The wind atlas contains data for 5 reference roughness lengths (0.000 m, 0.030 m, 0.100 m, 0.400 m, 1.500 m) and 5 reference heights (10 m, 25 m, 50 m, 100 m, 200 m) above ground level. The roses of Weibull parameters have 12 sectors each. The regional wind climate summary illustrated in table-3.

Table 3- Regional wind climate summary

Height	**Parameter**	**0.00 m**	**0.03 m**	**0.10 m**	**0.40 m**	**1.50 m**
10.0 m	Weibull A [m/s] Weibull k Mean speed U [m/s] Power density E [W/m²]	5.64 2.12 4.99 138	4.10 1.89 3.64 60	3.63 1.93 3.22 41	2.86 1.92 2.54 20	1.92 1.94 1.70 6
25.0 m	Weibull A [m/s] Weibull k Mean speed U [m/s] Power density E [W/m²]	6.17 2.18 5.47 176	4.91 2.02 4.35 95	4.49 2.06 3.98 72	3.77 2.03 3.34 43	2.91 2.04 2.58 20
50.0 m	Weibull A [m/s] Weibull k Mean speed U [m/s] Power density E [W/m²]	6.64 2.23 5.88 214	5.68 2.23 5.03 135	5.27 2.25 4.67 107	4.56 2.19 4.04 71	3.74 2.18 3.31 39
100.0 m	Weibull A [m/s] Weibull k Mean speed U [m/s] Power density E [W/m²]	7.20 2.18 6.37 279	6.72 2.36 5.95 213	6.26 2.44 5.55 168	5.51 2.45 4.89 115	4.69 2.45 4.16 71
200.0 m	Weibull A [m/s] Weibull k Mean speed U [m/s] Power density E [W/m²]	7.91 2.10 7.01 385	8.20 2.28 7.27 398	7.64 2.36 6.77 313	6.76 2.37 5.99 216	5.85 2.41 5.19 139

Conclusions

The best choice for erecting wind turbine type **V82-1.65 MW–Vestas**, with hub's height 70m. The studied area Al-Hay district of Wasit province eastern south of Iraq has found to be a good area for establishing a farm of wind turbines. The low coarseness terrain of the area has been found to yield stable wind direction and represents suitable land for erecting wind turbines. The output supply power for each turbine at the study area can provide about 3GWh electric power annually.

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