Determine Wind Frequency Distributions Through the Surface Layer of Baghdad City

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ABSTRACT

This study is made for determining wind speed frequency distributions at any height within Surface Layer SL (SL has height about 250m above ground) ,where wind speed is measured at low reference level (usually 10m) which is considered a routine meteorological data recorded hourly. This study needs to know in detail the roughness characteristics of the terrain surrounding the location study, that important to calculate the rate of growth of internal boundary layers resulting from discontinuities in roughness as well as the shape of wind profile in various layers. The shape characteristics of the wind profile are determined as a function of roughness length and stability and the result of this profile is compared with measurements from radiosonde, at height 10, 50,100,150, 200m. This study tested frequency percent for wind speed at 10m, 50m, 200m for the observed and calculated at July– month 1990 and at the 12:00 hour only. The calculated wind frequency has weak at 10m wind speed and all the frequency is concentrated at the (2-6) m/s, while the observed has high frequency at the wind speed reached to 8m/s. This case is changed at the height 50m, and 200m where the calculated have high frequency at the wind speed concentrated at (6-10) m/s. This study refers to the possibility of installing turbine in this layer to generate electricity at least in this period of this year.

Keywords: Wind Speed Frequency, Surface Layer, Turner Stability classes, power law.

INTRODUCTION

The energy crisis has awakened interest of wind energy in many countries in the world . A question of prime importance, when are the potentials of wind energy being actually available in the natural wind field at high interval height for the energy-producing devices. On the other hand, direct measurements from towers extending to this height are not very numerous. Instead we need routine measurement of wind speed at heights above the ground (overall 10m) is available and depends on a number of physical factors to known this data. One of these is the roughness of the underlying ground. The effect of a roughness change can be characterized by An Internal Boundary layer (IBL) developing over the new surface, growing in height with increasing distance downwind from the change, and also a development wind profiles, shear stress within this internal boundary layer as the flow adjusts to the new surface [1]. In actual fact the roughness characteristics of a certain upwind path length is the significant parameter, the length of this characteristic path increases rapidly with increasing height of the measuring point. As will be shown later, the characteristic length of the relevant upwind path for a measuring height of, say, 150m is several kilometers, so that the characteristic roughness for the 10m and the 100m levels may differ widely [2]. The wind speed profile and frequency of occurrence in surface layer is kind of statistic that is needed in many applications other than wind energy, e.g., aircraft operations, air pollution studies (emission from high chimneys in particular) or building aerodynamics [3]. This study describes a simple model which in a crude way takes into account the effects of change of terrain characteristics and

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stability on the wind profile in the lowest 100m or 250m at the atmospheric surface layer of Baghdad city (location near to Baghdad airport station). The model is not primarily intended for giving exact individual profiles but rather for producing statistics of wind speed at levels in the height range below, say, 250m. It must be noted, however, that this study is concerned with rural and suburban conditions only.

The Model

Wind profile in surface layer:

The wind profile in the atmospheric boundary layer at a given site at a given time depends on a number of physical factors, such as the speed of the wind above the friction layer, mechanical and other properties of the underlying ground (at the local site as well as upwind), heat flux at the earth interface, the presence of clouds in the boundary layer, and the state of the boundary layer during the previous 6h or so. In this study, we shall restrict ourselves to the lowest 250m or so. This is generally far too deep layer to be considered a constant flux layer, but it is shallow enough to have a characteristic time scale of the order of minutes in most cases. Thus, it is reasonable to assume that the wind profiles below 200m are in approximate equilibrium. Knowing the wind speed at some reference level (usually 10m) leaves the profile to be determined largely by two external factors: the surface heat flux and the surface roughness over a certain upstream distance. In many cases, the terrain characteristics change discontinuously, e.g., at boundaries between grass field, forest, sea, etc. At every such discontinuity, an internal boundary layer starts to build up. It grows vertically at a rate which is determined by the degree of turbulence. In this way, a 200m deep vertical profile may consist of two or more layers with distinct physical characteristics. When air flows over an area of uniform terrain characteristics a wind profile develops that is uniquely determined by the local roughness length z_o and the fluxes of heat H and momentum at the earth interface. When it encounters an area with different characteristics a new boundary layer develops with a profile that is determined by the new values of z_o, H and τ. This phenomenon has been studied both theoretically and experimentally [2][3]. And accurate experimental data that can be used to check the theoretical predictions have been supplied firstly by Bradley (1968) and by Peterson et al. (1976) [4][5]. The general situation is schematically depicted in Fig.1; the air that flows from surface 1 to surface 2 is gradually being modified from below. This influence extends to the top of the internal boundary layer $\delta(x)$. Local equilibrium with surface 2 is attained in a relatively shallow layer, the "new equilibrium layer," the depth of which is given as h(x) in Fig.1. The layer between h (x) and $\delta(x)$ is a transition zone, for the purpose of our present model (which will be described in detail in the next section) we will make the important simplification that the equilibrium profile of the new layer extends to the upper edge of the internal boundary layer where it connects with the profile of the "old layer."

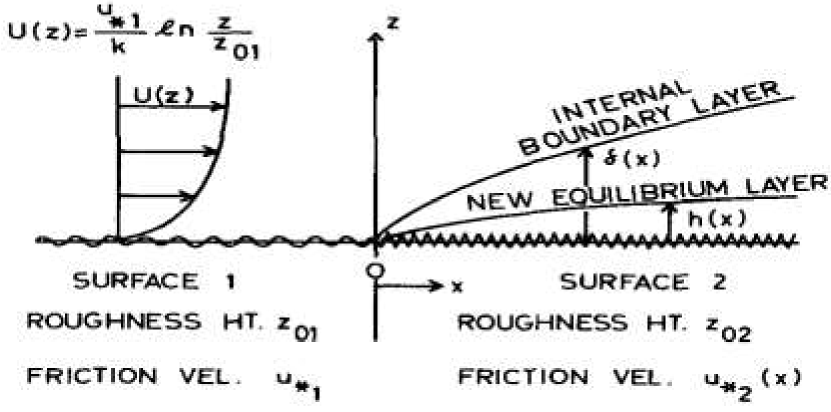


Figure (1): Schematic diagram of the internal boundary layer at the change of surface roughness, where u_*, z_o is friction velocity and surface roughness respectively [4][5].

Determine stability by Turner classification:

Pasquill used meteorological data at the surface for the characterization of surface atmospheric stability and derived six stability classes from A for extremely unstable to F for extremely stable conditions [6]. Turner improved this scheme by introducing Net Radiation Index (NRI) as indicator of insolation. This produced a new version of Pasquill's algorithm in which radiation is categorized into classes related to solar altitude, cloud cover and cloud height [7]. The method is generally acceptable for studies of atmospheric pollution, even if it overestimates the neutral stability class [8]. When the solar altitude is higher than 60 degrees, i.e. in the afternoon summertime, then the atmosphere is unstable. Moderate instability occurs during a summer day with a few clouds. Weak atmospheric instability happens usually in the afternoons of autumn or summer days with few low clouds. The neutral category governs during cloudy days and nights. Finally, the creation of inversions during nights with clear sky indicates stable atmosphere [9]. Stability class in Pasquill Turner Method (PTM) is determined according to the NRI and the wind speed, as it is shown in Table 1. In urban areas, during the day, surfaces are more reflective and become hotter and thus, producing more convective eddies. As a result, convective turbulence in an urban area is more significant than it is in the rural and suburban areas and urban areas are rarely as stable. Therefore, while using PTM for urban areas, like this study, it is possible to combine stability categories 6 and 7 into one category [9].

Table (1): Stability classes as a function of NRI and wind speed

Wind speed (m/s)	Net radiation index (NRI)						
	4	3	2	1	0	-1	-2
$0 \le u < 1$	1	1	2	3	4	6	7
$1 \le u < 2$	1	2	2	3	4	6	7
$2 \le u < 3$	1	2	3	4	4	5	6
$u = 3$	2	2	3	4	4	5	6
$3 < u < 4$	2	2	3	4	4	4	5
$4 \le u < 5$	2	3	3	4	4	4	5
$u = 5$	3	3	4	4	4	4	5
$5 < u < 6$	3	3	4	4	4	4	4
$u \ge 6$	3	4	4	4	4	4	4

The main methodology of this study consists of two parts , first part calculate solar altitude where solar altitude is calculated by means of the equations needed geographic latitude , solar declination angle , solar hourly angle and the number of days of study's years [10][11] .Where Orbital elements such as mean distance from sun, eccentricity, etc. are calculated using the number of days [12], these elements results in measurement of solar altitude in time and location of interest. Second Part: Stability Class Determination This part uses solar altitude obtained from the first part and meteorological data include wind speed, cloud cover, to determine turner's stability class for specific time and location according to PTM algorithm.

Determination of the rate of growth of the internal boundary layers:

Pasquill (1972) has calculated the rate of growth of internal boundary layers for two roughness cases z_0 = 3cm and 1m, respectively, the values referring to the rougher of the two surfaces at a discontinuity and at three stability classes (neutral, stable and unstable) [13]. The height z_i of boundary layer as a function of distance x, constants a and b have been taken from Pasqual's Table (2) and plotted in log-log representations. Fig (2) shows the curves for z_0 =1m As seen from the figure straight lines of Log(z) against Log(z) are fair representations for the layer of interest here (z < 200m) . And we could write equation between z and landscape distance x as:

$z = \alpha x^b$ ….(1)

Where

α and b are functions of z_0 and stability. From the diagrammatic representations of Pasquill's data α and b were determined for his six cases. We can get values for other z_0'from Table (3) .

Table (2): calculated values for α (upper value) and *b* (lower value) of the approximate relation for the growth of internal boundary layers , the roughness values refer to the rougher of the two surfaes at a discontinuity [2] .

Stability class	Roughness length				
	z_0>1.5	0.5<z_0<1.5	0.2<z_0<0.5	0.06<z_0<0.2	z_0<0.06
2,3	0.77	0.64	0.49	0.35	0.2
	0.82	0.92	0.95	0.98	1.02
4	0.83	0.73	0.55	0.38	0.2
	0.73	0.75	0.79	0.83	0.81
5	0.73	0.65	0.5	0.34	0.2
	0.68	0.7	0.74	0.77	0.81
6	0.69	0.56	0.45	0.32	0.2
	0.65	0.65	0.69	0.71	0.84
7	0.5	0.44	0.36	0.29	0.20
	0.59	0.6	0.62	0.63	0.65

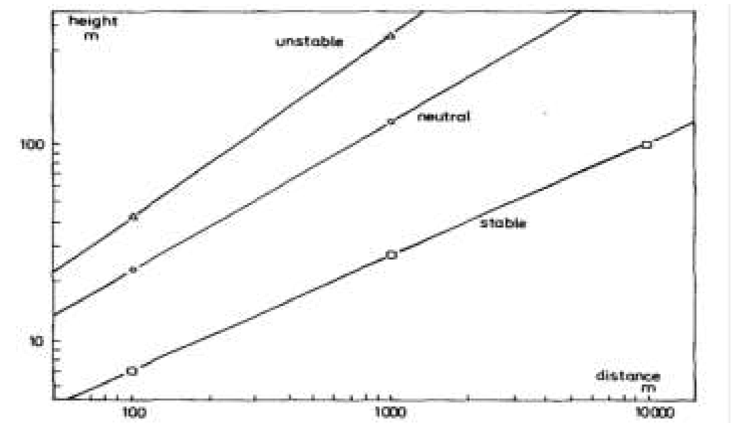


Figure (2): The growth of internal boundary layers as a function of distance from the discontinuity for three stability classes . z_0= 1m for the rougher surface [12] .

Wind Power low:

If we assume that a wind profile is made up of N layers, representing N internal boundary layer, each one of which can be traced back to a definite terrain discontinuity in the upwind direction. We can approximate the wind profile in each of the layers by a power law:

$u(z) = u(z_{ref}) (z/z_{ref})^{\alpha}$ …(2)

Where

z_{ref} is reference height (usually 10m). Thus wind profile is completely determined if the following parameters are specified: $u(z_{ref})$, $z_1, \ldots, z_N$, $\alpha_1, .., \alpha_N$. If the terrain up wind of the site is homogeneous for a long enough distance there will be just one z_i (~200 m) and one α_i . Overall, we expect the α_i to be a function of the local values of the roughness length $z_\circ$ and of the fluxes of heat H and momentum τ at the earth interface. The parameter H and τ are conveniently combined to form the Monen-Obukhov Length $L= -(u_*^2T)/k(H/\rho c_p)g$, where $u_* =\sqrt{\tau/\rho}$, ρ is the density of the air, T the air temperature (K), k the von kármán's constant, c_p the heat capacity of the air at constant pressure and g the acceleration . u_* must not be specified explicitly when z_{ref} is measured. This means that α is a function only of L and z_0. In order to evaluate the wind speed at level z the heights z_i of the internal boundary layers must also be determined. From similarity arguments it follows that

$$z_i= z_i (x, L , z_0) \quad \ldots (3)$$

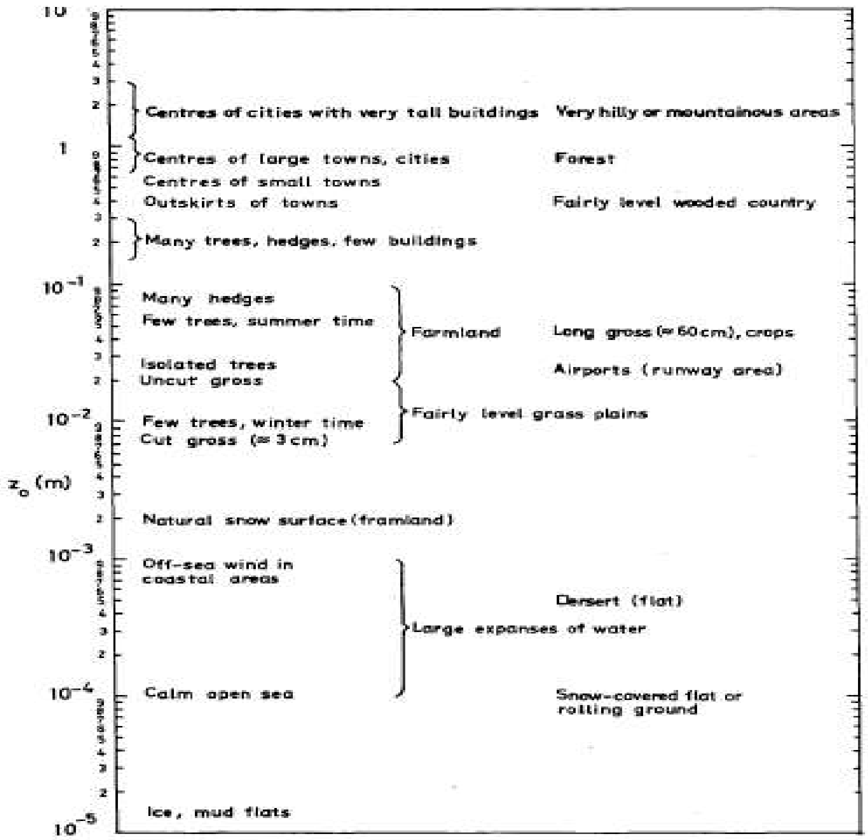
Where

x is the distance between the site and the terrain discontinuity, measured along the wind direction. In the application of this model to be demonstrated below routine meteorological observation data will be used throughout. Thus L will not be determined explicitly for the different terrain areas for each case. Instead each case will be characterized by one single stability index, based on the Turner classification scheme [7]. Thus the most unstable Turner category 1 represent very unstable. The other two unstable categories 2 and 3 are taken together. The neutral class 4 and the stable classes 5-7 are the same as in Turner's original scheme, although the details of the procedure for the determination of the class differ in certain details. By comparison with measured stability at one site, and wind profile resulted from applied of power low with wind profile result from observed radiosonde at the Baghdad station.

The Site and data Used:

For a geographical area like Iraq (specifically Baghdad city), information available from surface boundary layer that obtain from a few towers and radiosonde released is not adequate for a realistic appreciation of the national wind energy potential. On other hand Building tower measurements is not realistic-the costs and times required to get reasonably representative data sets are prohibitive. Instead, routinely available meteorological data must be used in combination with some kind of physical model of the atmospheric surface boundary layer. The data used in this study obtained from the internet sites from ECMWF (European Centre For Medium-Range Weather Forecasts). After determined longitude and latitude of any site, it's covered the mid area of Iraq, where its obtain as a grid of twelve points extends from (30°-30.75°) N latitudes and (42°75'- 45°) E longitudes with a uniform grid interval of 0.7° degrees longitude and 0.7° degrees latitude through July (summer) of 1990 and for the time (00 , 06 , 12 and 18) UTC. The area of study is located at the grid point 30° N latitudes and 44°25'E longitude ,this point located south- west of Baghdad city center, Figure (3) shows the Space image taken from Google earth . This image also shows the locale zone soured it from the eight sector (N , NE , E , SE, S , SW, W , NW). The input data consists of the horizontal wind velocity (u) m/s and total cloud cover and low cloud cover from the ECMWF (European Centre For Medium-Range Weather Forecasts). It should be noted that The ECMWF values are not really observed, of course, but from a numerical model. Generally we can used this electronic site data in scientific research , through intersection of latitude and longitude lines on maps , and at different method to display this , figure 4 show one of these mode where y axis represent latitudes, and x axis represent days and hours that taken every 6 hour for the record wind speed variation at 10m .

Table (3): Roughness lengths values for typical terrain types [14] .



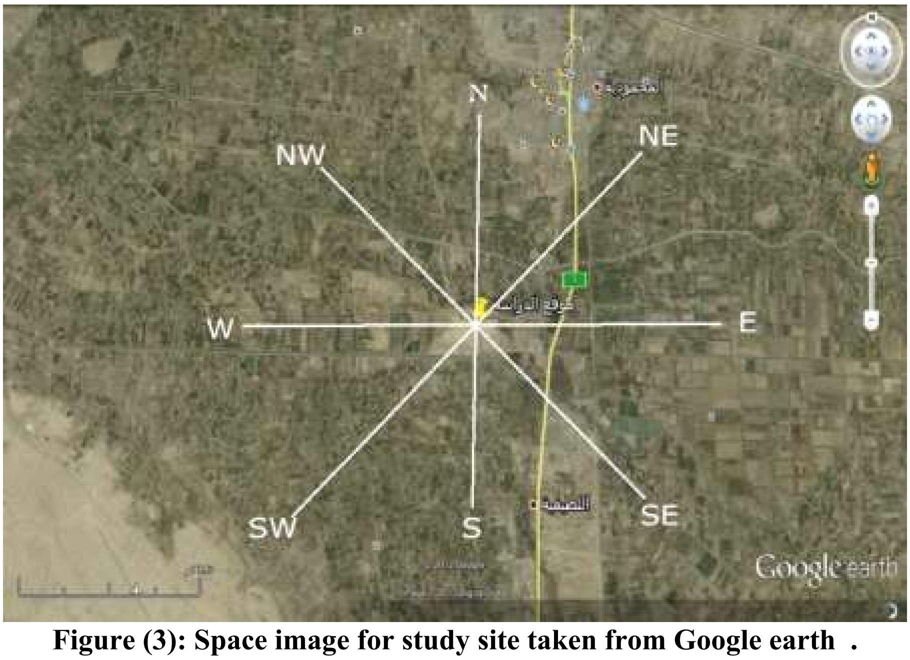


Figure (3): Space image for study site taken from Google earth .

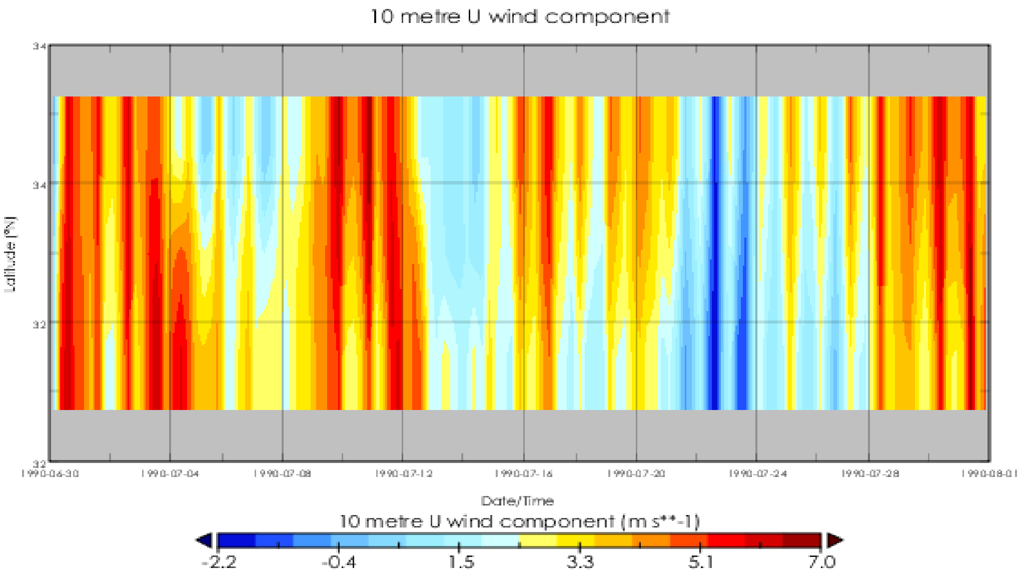


Figure (4) : One of methods to display (ECMWF) data ,for wind speed 10m at July month.

Results and Discussion

Applications of the model

The model has been used to determine wind speed frequency distributions for heights 50, 100 ,150 and 200 m for a site of study. Frequency distributions of immediate wind speed values and wind direction values were evaluated for each of the seven stability classes of Turner. Observations every 6 hour during a July month for year (1990) were used. This month is selected because its windy over all the year , figure 5, show average monthly wind speed at the area of study , where we see from this figure that the months June and July formed the highest average value of wind . This months can be used to comparison the calculated wind speed variation with height up to 250m (surface layer) and that observed variation of wind speed with height recorded by radiosonde, we taken its old year, because we haven't any continues radiosonde data in Iraq after 2003, this can be return to the condition of country after the last war in 2003. Overall, The terrain characteristics round the site were investigated in detail, and the corresponding z_0 values were estimated with the aid of the table 3, and the termed "roughness sectors" were identified; that is, sectors which can be described by z_0 . After we fixed the site of study the following computations were performed on the data recorded:

1. Estimate stability classes by used routine meteorological observations (cloudiness, wind speed ...etc.) that needed for the evaluation of the modified turner class, where the unstable class 1, 2,3 could safely be attributed to clear summer days , the neutral class 4 to overcast and windy winter periods , for the stable cases there is three classes 5,6,7 where the cases were classified as either slightly stable 5 or very stable,.
2. The stability classes was used together with roughness length z_0 to determine from table 1 , the relevant values for a and b to be used to determine the height of internal boundary layer separation from eq. 1 , this was only done for uniform surface (suburban) figure 6.
3. From the stability classes , we can find the a value for each layer of boundary layer calculated by used of table 2 ,and the empirical second order polynomials equation can driven as: $\alpha = c_0 + c_1 \log z_0 + c_2 (\log z_0)$ where c_0 , c_1 ,c_2 is constant .
4. Then the u(z) could be calculated at levels 50 , 100 , 150 , 200 in the surface layer with aid of equation 2 ,and table 4.
5. Stability and wind speed at the reference level $u(z_{ref.})$ were used together with the above result to calculate wind speed frequency at the levels mentioned above in the surface layer .

Determination of α as a function of stability and roughness :

The point of study were selected at south- west of Baghdad city , this is situated in very heterogeneous terrain . In order to get reasonably clear-cut narrow sectors with well-defined terrain characteristics were chosen for the study. And table 3 can used to describe the exponent α of the wind power law was determined from the wind speed measurements for each boundary layer separately. Figure 7 show the relationship between the wind power and stability that can be express as turner classes , where the classes 1 , 2 , 3 is express the unstable conditions and class 4 is express the neutral condition , while the classes 5, 6 ,7 express the stable conditions. The exponent α has a small value in unstable condition while the largest value was in the stable case. On other hand, Fig. 8 gives the variation of α with z_0 for each one of the three stability classes. We can say that there is increases in the power exponent with the increases in the roughness length, at the transform the weather stability condition from unstable to stable.

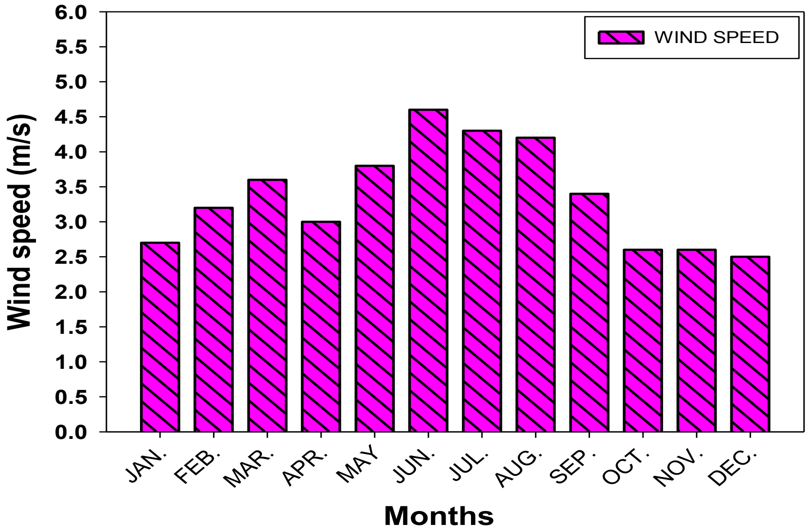


Figure (5): The average wind speed (10m) at location study in 1990.

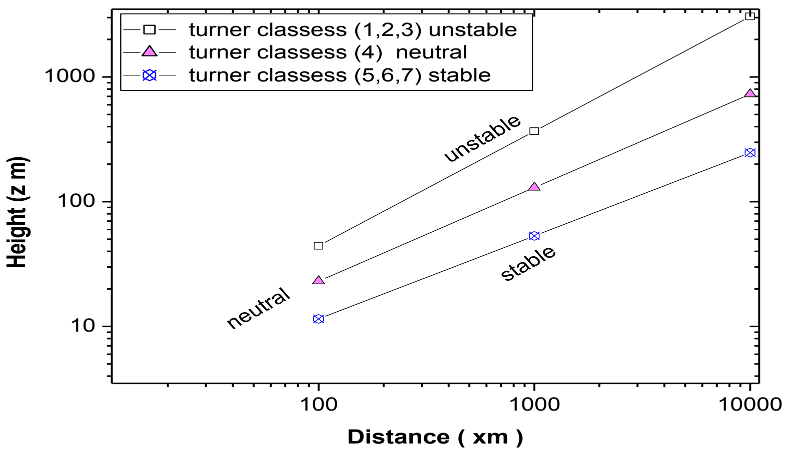
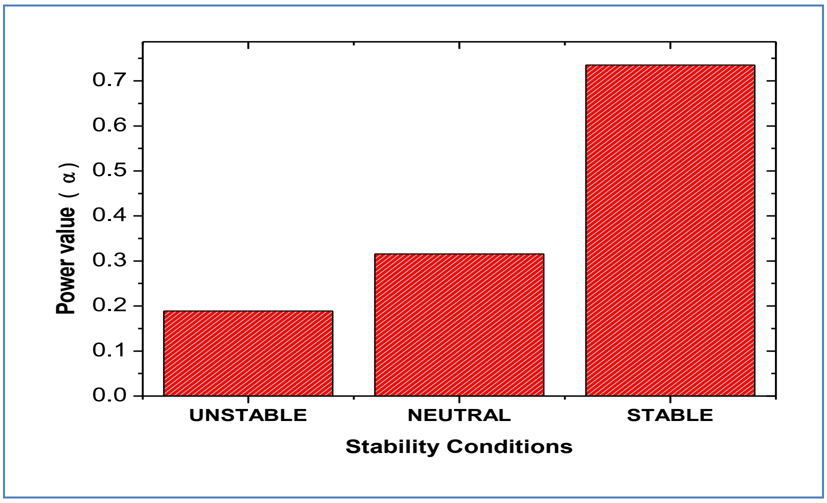


Figure (6) : The height growth of internal boundary layer as a function of distance from the discontinuity for three stability classes ,and average value of roughness 1.2m



Figure(7) : The exponent α is function of stability condition

Table (4): the constant values of c_0 , c_1 and c_2 at turner classes

Stability class	c_0	c_1	c_2
1,2,3	0.18	0.13	0.03
4	0.3	0.17	0.03
5	0.52	0.2	0.03
6	0.8	0.25	0.03
7	1.03	0.31	0.03

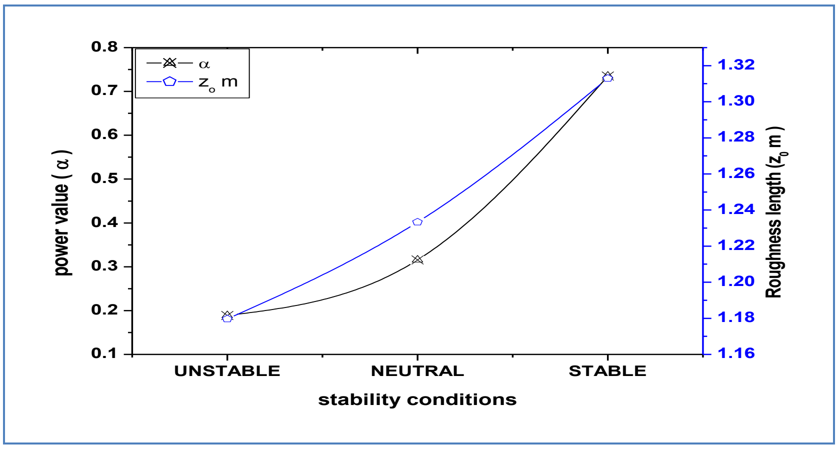


Figure (8): Show the relationship between the roughness length with stability at different stability conditions.

Wind Frequency Distribution at surface layer:

The main aim of this study we focus on is the estimation or determination of wind speed frequency distributions for 50, 100,150 and 200m, where we evaluated the frequency distributions of simultaneous wind speed values at 12:00 and at the seven stability classes. During the year 1990 and at July month were used, also terrain characteristics round the site were investigated in details and the corresponding z_0 values were estimated with aid of the Table (3). This study has shown that it's possible to describe wind profiles up to 200 and more above ground in relatively flat terrain. The result of application of this model is very important because its described wind profile in various internal boundary layer by used of power law.

There is a lot of computations to carried out to determine the exponent of the such a power law in varying surface conditions. The model determines the relevant α values for the various physical situations and then makes the correct weighting to form not only the relevant mean wind speed for 100m or 150m but also the corresponding wind speed distributions. and comparison the wind profile that obtain from the power law exponent with wind speed that observed from the radiosonde measurement, and comparison also the wind speed distribution from the observed with that calculated see figures 9, 10 and 11 that show the frequency percent for wind speed at 10m , 50m , 200m for the observed and measured at the July – month 1990 and at the 12:00 hour only . we see that wind frequency at 10m that the calculated has weak wind speed and all the frequency is concentrated at the (2-6)m/s , while the observed has high frequency at the wind speed reached to 8m/s . This case is changed at the height 50m , and 200m where the calculated have high frequency at the wind speed concentrated at (6-10) m/s . review to the figures .

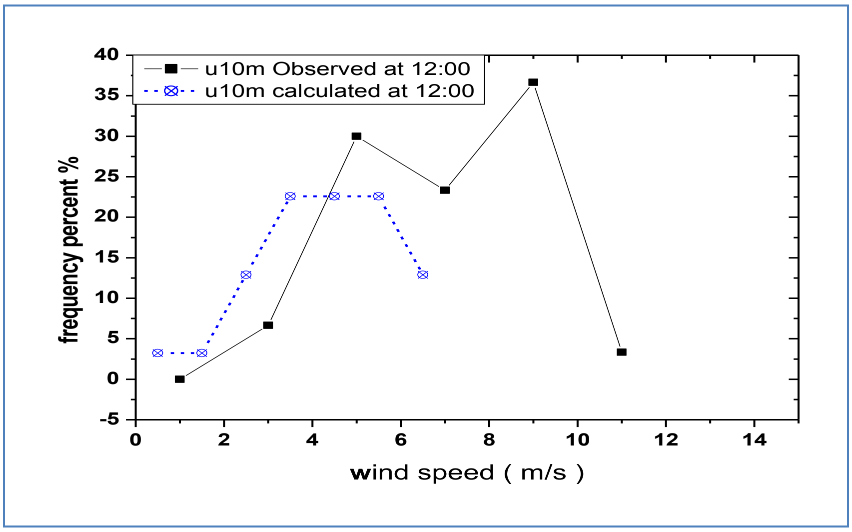


Figure (9): Show the frequency percent of observed and calculated wind speed at 10m and at July month and at 12:00

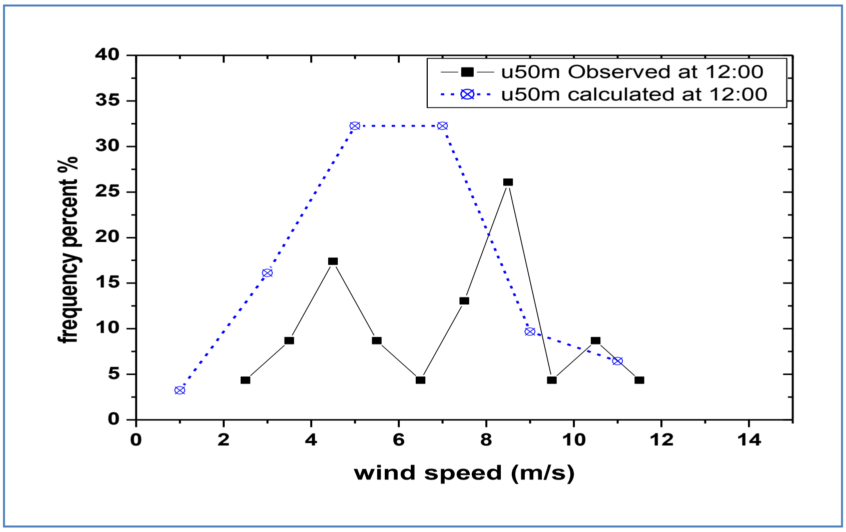


Figure (10): Show the frequency percent of observed and calculated wind speed at 50m and at July month and at 12:00

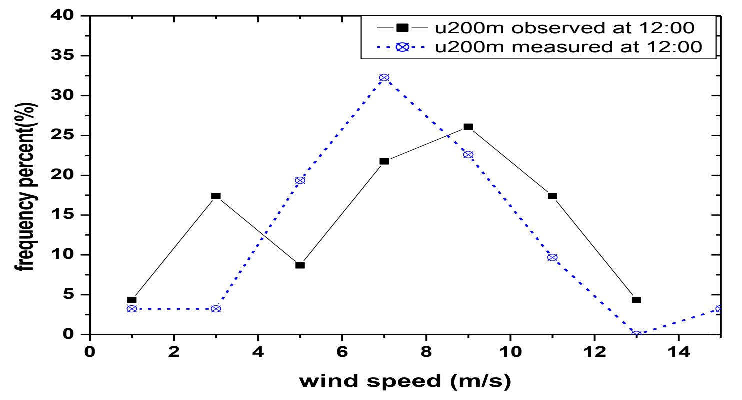


Figure (11) : Show the frequency percent of observed and calculated wind speed at 200m and at July month and at 12:00

CONCLUSION

The present study has shown that it is possible to describe with remarkable accuracy, at least in a statistical sense, wind profiles up to 200m above ground in relatively flat terrain with varying surface conditions .The input to the model is routine meteorological data, including wind at standard anemometer level, and in addition detailed information about the roughness characteristics as a function of distance and direction relative to the measuring point. The parameters that go into the model have been determined from extensive data sets from ECMWF (European Centre For Medium-Range Weather Forecasts). Overall the result of this model is quite important, because it indicates that the general approach of describing the wind profile in the various internal boundary layers as power laws. The exponent law method is compared with observed wind profile from radiosonde we notes similarity between calculated and observed at high level of surface layer , see figures 9, 10 and 11 . this refer to that frequency of wind speed through this layer can be used to generate electric wind power at least in this period from year .An important restriction to the applicability of the model is that the model ,with the numerical parameters presented here , cannot be used in urban surroundings . Overall The procedure described here requires a lot of computations in time and technique used to be carried out, and one could ask whether it would be possible to acquire in practice the same information by applying a simple power law to extrapolate the mean wind from standard anemometer level to 100 or 200m. The crucial point, however, is how to determine the exponent such as power law in case of varying surface conditions.

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