Wind Energy Analysis, Utilizations, And Economic Viability For Different Applications In Iraq

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Abstract:

Thirty years of wind data, for ٢٢ stations and a experimental locations inside Iraq, were used to calculate the potential of wind energy in Iraq. A full statistical analysis has been carried out for five selected stations which involved hourly wind speed, monthly average speed, annual values of shape and scale parameters of normal and weibull distribution. Frequency distribution, speed distribution, with their individual and cumulative probability pattern, are analyzed. It can be seen that ٢٤٪ of the country enjoys monthly wind speed greater than ٤ m/sec. Therefore, wind energy is sufficient for water pumping or electricity supply for remote areas in Iraq. Here we examine the viability of utilizing wind energy to supplement solar energy by comparing the supply and demand for different utilizations. The economic viability of wind energy visa vis traditional energy resources is also discussed.

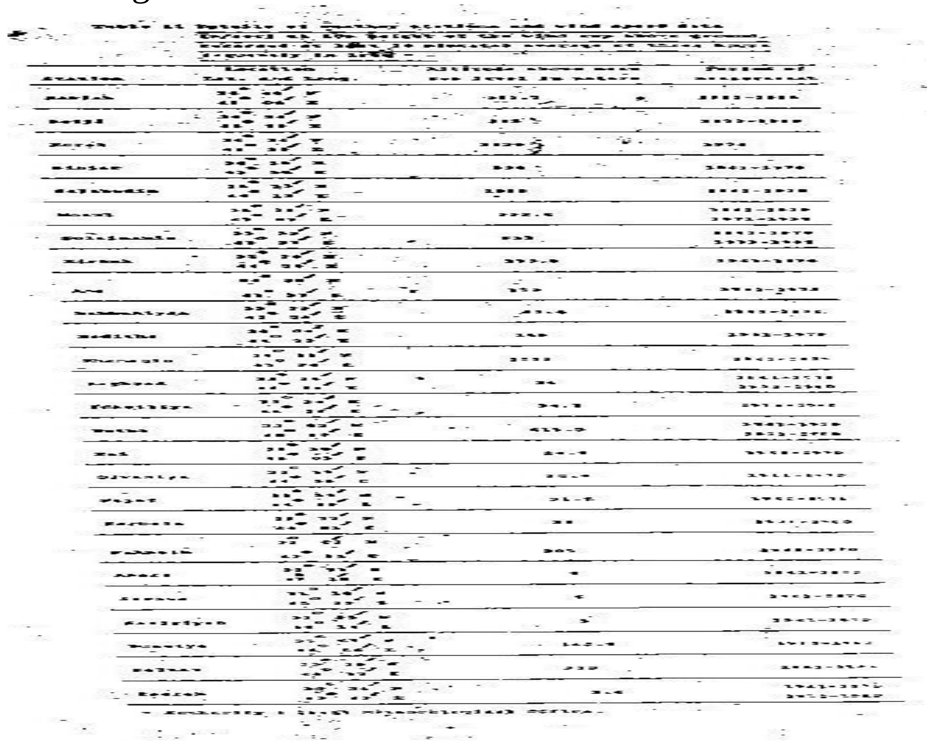
١. Introduction:

Iraq is situated in the north eastern corner of the Arabian peninsula, its area is about ٤٥٠,٠٠٠ km. It occupies a unique location comprising the southern part of the combined valley of Tigris and Euphrates. The topography shows mild elevation westwards and a rather steep elevation to the east, where it is bound by the Iranian plateau and the heights of Asia minor. Geographically, Iraq roughly extends between latitude ٢٩ N and ٣٨ N and Longitude ٣٨ E and ٤٨ E. Therefore it occupies a very interesting location with respect to the general atmospheric circulation.

Iraq has about ٣١٣٣ hours of sunshine per year and an average solar radiation intensity of ٢٤٠ w/m^٢ [١], with maximum radiation (٩٥٠ w/m^٢) occurring mostly in June and part of July. But maximum diffuse radiation (٢٠٠ w/m^٢) occurs in March [٢]. A Limited number of wind energy assessment studies in Iraq [٣, ٤, ٥, ٦, ٧, ٨, ٩, ١٠, ١١] have been conducted. In the last few decades meteorologists started to collect sufficient observational data to carry out research work in this domain aiming seriously to solve many of the problems for new and renewable energy application. Table ١ shows the geographical data for the meteorological stations and the geographical data for different remote areas throughout the territory (Korek, Fdhailiya Rabeah, Ksheety, Fhidah, Kasrah, Amje and Rutba). A map of regional distribution of annual wind energy in Iraq has been drawn, in Fig.١, within a range (١٥,٢ – ١٣١,٤) KJ/Hr up to ٤٧٨ KJ/Hr at Korek and ٢,٥ x ١٠٨٣ – ٣,٣ x ١٠٨٣ KJ/Hr at Sulman and Busaiya, respectively. Figure ٢ represents the typical monthly mean surface wind speed for July during the period (١٩٧١-١٩٨٠). A mean wind speed of ٤ m/sec or more is centred in the middle region. Around Amara, Ana, Haditha, Ksheety, Amje and Najaf the mean wind speeds are slightly more than ٥ m/sec while the range (٦,٩٥ – ٨,٩٦) m/sec is divided in to various parts of the country particularly in the Korek mountain and the south surrounding sulman and Busaiya station, respectively. The prevailing wind speed in most of the stations is North-West as shown in Fig.٣.

The paper describes the assessment of wind energy conversion systems (WECS) as a viable energy source requiring an evaluation of the statistical characteristics of the wind, in particular, wind speed, its duration and the probability distribution of wind speed. The analysis is rather complicated and requires a large data base which is often lacking for prospective WECS sites. These data are actually nominal ten minutes average speeds sampled once every ٣ hours, at a ١٠-m height. The records are of hourly data taken at Baghdad Fdhailiya (using automatic weather station) and at the remote areas mentioned above.

Hourly surface wind speed records at Mosul, Sulaimania, Baghdad, Rutba, Basrah, and the eight remote areas mentioned



before were analyzed for the period (١٩٧١-١٩٨٠) in order to establish characteristics relevant to the wind energy assessment. The majority of annual mean speeds fall within ± ٩٠٪ of the long term mean. The monthly mean wind speed is higher in the summer than in the winter by ٥-٧٦٪ and it is higher in the day time than in at night time by ١٠-١٥٪. The monthly means within an error of estimate ٠,٣١-٢,٣٢ are presented in Fig.٤.

Availability of winds with time of the day for a typical site is shown in Fig.٥. The probability of wind speeds greater than ٣ m/sec has a maximum of ٧٠٪ at ٣ P.M. local time and the minimum is ٣٠٪ at ٦ A.M., on the other hand, calm conditions are rare. The relative and cumulative wind speed probability, based on the corresponding number of observations in individual ranges, for two representative typical western and northen sites (for a typical month July) are shown in Fig.٦ and Fig.٧ respectively. A typical frequency of occurrence of wind speeds at a typical site is shown in Fig.٨ in histogram form.

٢. Mathematical Analysis:

In order to develop a model for generating wind speed at a point, the generating mechanism must be known. This may be inferred from the structure of wind speed at the particular location. Once the probability distribution of wind speed is known, a Monte Carlo data generation method may be used. The criteria for selecting the appropriate probability distribution are:(١) The goodness of fit of the data: (٢) The ease of estimating the parameters of the distribution and the economy in the number of parameters and (٣) The ability of obtaining the inverse transformation of the distribution so that new data may be generated. If the data is normally distributed, or may be transformed into a normal distribution, it will satisfy the criteria set forth above.

The variation of wind speed may be approximated by a Truncated normal distribution. The probability density function of a continuous, normally – distribution random variable, Z, is given by:

$$P(z) = \frac{1}{\sigma\sqrt{2\pi}} \exp\left[-\frac{1}{2}\left(\frac{z-\mu}{\sigma}\right)^{2}\right] \quad \ldots (١)$$

Where μ is the expected value (the mean) and σ is the standard deviation of the distribution. The distribution of wind speed is actually a mixed distribution containing both discrete and continuous variable values. For any given period (month or time of day) there is a finite probability of zero wind speed while the distribution of wind speed values greater than zero must be described by a continuous probability density function. This paper considers wind speed at a location as a sample from a Truncated normal distribution. Zero values may then be considered as negative of unknown quantity. The integral of the normal distribution from - ∞ to zero is the probability of zero wind speed, and the reminder of the distribution function describes the distribution of nonzero wind speed values. This concept is illustrated by the frequency function and histogram of observed values shown in Fig.٩. The area under the curve to the left of the zero is the probability of zero wind speed. The remaining area is the probability of nonzero values.

Data for the eight daily periods of each month were analyzed as a whole and separately for each time period within the day and a truncated normal probability distribution was fitted to each group. Details of the results, are illustrated in Fig.١٠ which shows the cumulative truncated normal probability distribution, and Fig.١١ which shows the truncated normal probability density functions of frequency histograms for a typical month April at a typical location. Chi square values were slightly high and goodness of fit could not, in some instances, be accepted at the ٩٥٪ level. Visual inspection of Fig.١٠ however, reveals a close fit for values greater than ٢ m/sec. Since this is the range of wind speeds that is of concern for WEC systems it is felt that the choice of truncated normal probability distribution is quite satisfactory.

It has been shown in the references [١٢, ١٣, ١٤] that the weibull distribution is quite capable since it has a good match with the recorded data, it is defined in terms of two parameters the shape parameter K (unitless) and the scale parameter C (m/sec) as a cumulative distribution function F (V):

$$F(V) = ١ - \exp\left(-\left(\frac{V}{C}\right)^{K}\right) \qquad ……… (٢)$$

C and K parameters are chosen to fit the data. Equation (٢) is equivalent to:

$$\mathrm{Ln}\left[-\mathrm{Ln}\left(١ - F(V)\right)\right] = K\,\mathrm{Ln}V - K\,\mathrm{Ln}C \qquad …….. (٣)$$

Therefore, observed values of [– Ln (١ – F(V))] were plotted versus LnV and a straight line was fitted to the points in order to obtain the parameters C and K, since the slope is K and the intercept on the vertical axis is – K LnC. It is observed that the daily values for Baghdad for the period April to July ١٩٨٢ follew the patern of Fig. ١٢ with K = ٢ within the accuracy of estimation ± ٠,١٣٢ and C = ٤,٤٥ m/sec which the accuracy estimated to be about ± ٠,٠٤.

The general expression of different heights on wind speed can be used by[١٥]:

$$\frac{V}{VO} = \left(\frac{H}{HO}\right)^{N}$$

Where V = is the wind speed at height Ho of ١٠m above ground level.

V = wind speed at height H above ground level.

N = Roughness factor.

The N for Baghdad is calculated to be ٠,٠٣٣ for wind speeds up to ١٠ m/sec and is equal to ٢,٦١٣ for wind speeds > ١٠ m/sec. the turbine wind power P (watt) is :

$$P = ١/٢\ \rho A V^{٣} Cp \qquad ……….. (٥)$$

Where ρ = Air density ١,٢٢٥ (Kg/m^٣).

A = swept area (m^٢)

V = wind speed (m/ sec)

Cp = is the power coefficeient

Figure ١٣ and Fig. ١٤ show a wind speed duration curve and a power duration curve at Baghdad, the latter being commonly of monotonic slope even if the former is S shaped. There are other features of these two diagrams that are useful in showing performance in a convenient fashion. These are the cut – in, cut – out, and rated speeds. The cut-in speed is the lowest wind speed ٣ m/sec at which useful power is being delivered, lower values being capable of only just balancing mechanical and aerodynamic losses or for which the rotor vanes are stalled this is ١ – <٣ m/sec and is a matter of some importance in rotor design. The cut-out speed ٣٠ m/sec is that speed at which the wind may causes structural damage with the mill in a normal operating attitudes. The rated speed is that wind speed at which the system is delivering the maximum output for which it is designed, and some power shedding mechanism must be operative to prevent overloading. The rated speed and rated power is a most important parameter for economical operation. The power output is constant for all speeds higher than the rated speed, and the area under power duration curve between the cut-in and rated power points represents the total annual energy output. The annual plant load factor or capacity factor [١٦] is the ratio of this energy output to that which the system would deliver if it is operated continuously at the rated wind speed (the latter is represented by a surrounding broken line rectangle), and it is calculated from Fig.١٤ to be ٠,٦٨ at cut-in wind speed and ٠,٣٥ at rated wind speed.

٣. The Economic Viability of Using Wind Mills:

Taking the traditional from the grid station, as an example, the cost of KwHr of electricity ٠,٠٤$ [١٧], and the cost of ١ km of grid extension is ١٢٠٠$ [١٧]. So the actual cost at this site = ١٢٠٠ × ٦٠٠ = ٧٢٠٠٠٠$. With ٢٠ years of the mill lifetime, the annual cost rate = ٧٢٠٠٠٠ / ٢٠ = ٣٦٠٠٠$. Since the annual rated output needs at this site is ٦١,٤ KW [٧], so the cost of KwHr of the grid extension = ٣٦٠٠٠ / ٦١,٤ = ٥٨٦,٣٢$. Since the real cost of producing one KwHr of electricity = ٠,٠٤$. So that the actual cost of producing energy for one KwHr together with the extension cost = ٥٨٦,٣٢ + ٠,٠٤ = ٥٨٦,٣٦$

On the other hand using diesel for pumping instead of grid extension; the actual cost to produce KwHr = ٠,٢٣٤$ [١٧] and by assuming the transportation cost is ٠,٢٣٤$ to produce one KwHr; and the inflation rise is ٠,١٥ [١٨], so the cost of one KwHr of diesel is ((٠,٢٣٤ + ٠,٢٣٤) × ٠,١٥) + ٠,٤٧ = ٠,٥٤$. The (m^٣ or KwHr) cost produced by wind mill is given by [١٥]:

$$C = \frac{\text{Total Capital Cost (\$)}}{\text{Output power at rated wind speed} \times \text{٨٧٦٠ Hr/yr} \times \text{٢٠٠ yr}} \quad (٦)$$

Depending on the hourly actual demand of water ٠,٣٢٨٣, total pumping head ٢٣٠m [٧] and the rated wind speed from Fig.٢, the cost of KwHr to produce m^٣ of water using wind energy is ٠,٤٨$. While the cost of KwHr to produce KwHr of electricity using wind energy is ٠,٣٥$ depending on the ٩٨,٥٦ KwHr of daily demand [٨].

If a photovoltaic system is used to supply the demand depending on the cost of ١ m^٢ = ٧,٥$; the cost of storage batteries of one Kw capacity = ٥٠ $ and the installation and maintenance cost = ١٥٪ of the total cost of the system (١٥٠٠٠٠) with area of ٢٠٠ m^٢ and the capacity of batteries for three cloudy days = ٤٩٠ KwHr; the cost of one KwHr produced by using a photovoltaic system [٨] is ١٠,٥٤$. This comparison shows that the cost of KwHr or m^٣ produced by using wind energy is quite profitable for use in remote areas.

٤. Conclusions:

١- The monthly mean wind speed in Iraq is higher in the summer than in the winter by ٠,٩ – ١,٧٪. Wind energy in Iraq has a very good prospect. Iraq can be divided into five zones, ٥٠٪ of the country has an average wind speed of ٣ – ٤ m/sec, ١٨٪ has an average wind speed of ٢ – ٣ m/sec and ١٥٪ of the country has a relatively high average speed of greater than ٥ m/sec.

٢- If wind machine technology develops further and the cut-in wind speed is brought down close to ٢ m/sec, the western, southern and mountain regions of Iraq (represented by Rutba, Ana, Basrah and Korek) are likely to be the first to have economically viable wind machines.

٣- The attempt to arrive at a probability distribution for wind speed that is suitable for use in the Monte Carlo model of wind speed data generation satisfies this condition especially for the wind speed range of interest in wind energy conversion. On the other hand the weibull distribution function has also been shown to be applicable to give a reasonable fit.

٤- The cost of KwHr produced from a wind mill as a renewable system for energy production is economical, in comparison with the traditional energy presently used, such as national grid electricity and generated. Furthermore it should be economical in comparison with a photovoltaic system. A hyprid system would be very useful.

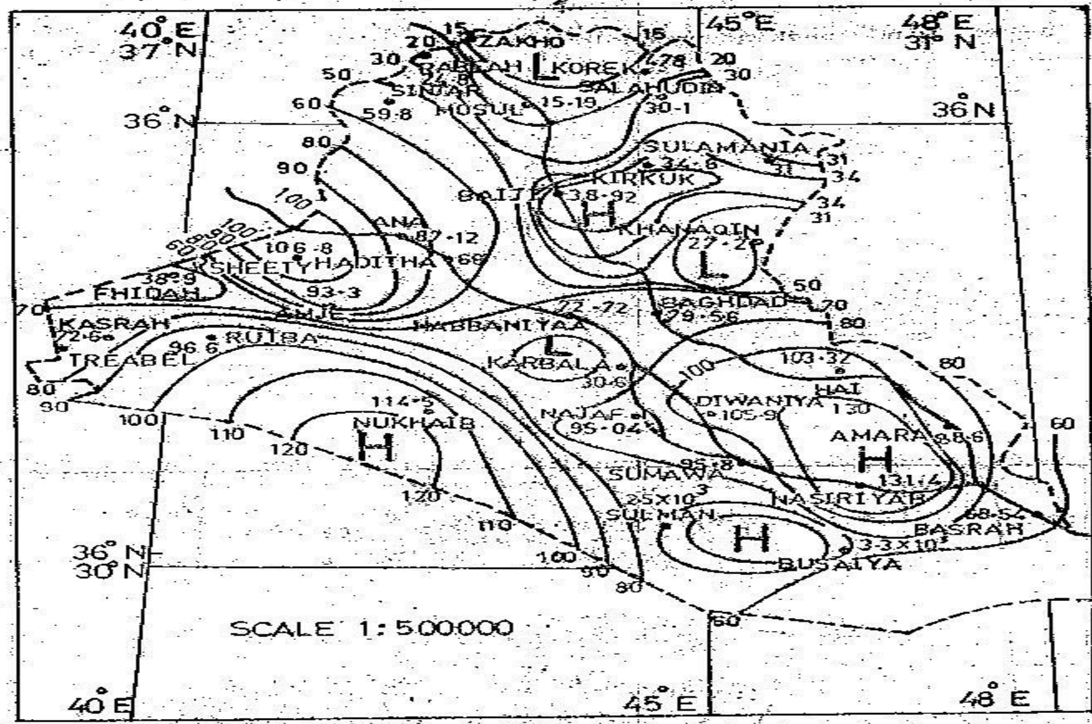


Fig. 1. Annual wind energy (KJ/Hr) isoplathes.

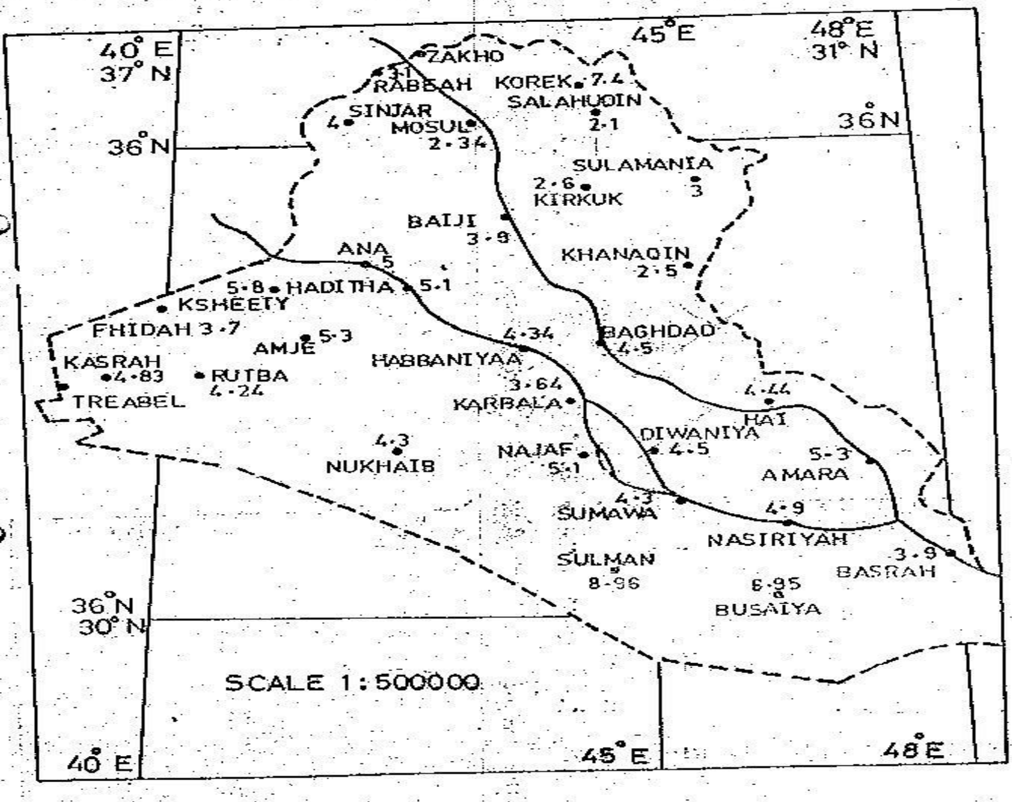


Fig. 2. Monthly mean wind speed, July (1971–1980).

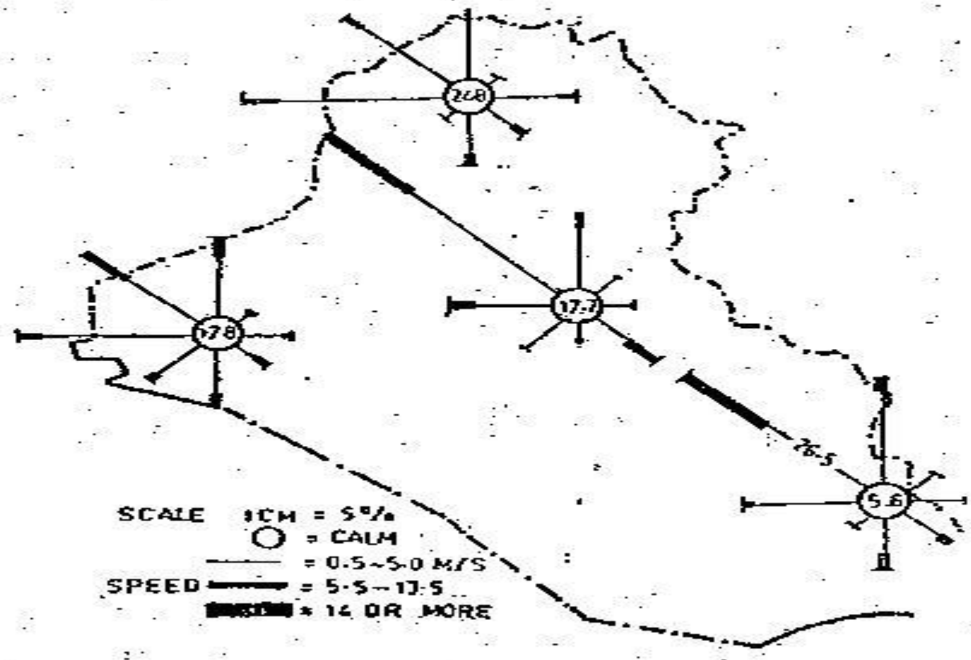


Fig. 3. Wind rose.

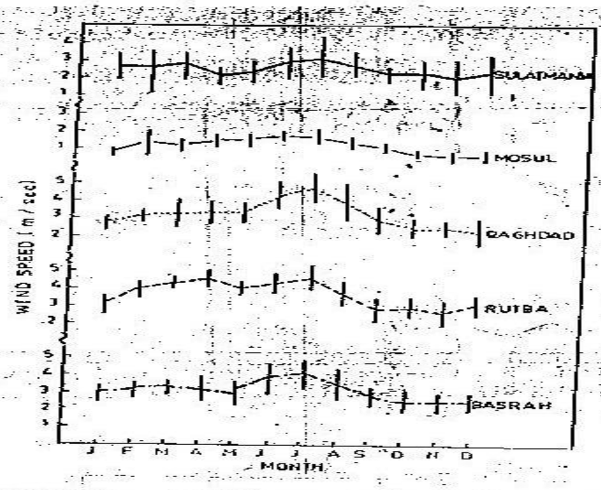


Fig. 4. Climatic monthly mean wind speed and standared deviation (1971-1980) at Sulaimania, Mosul, Baghdad, Rutba and Basrah.

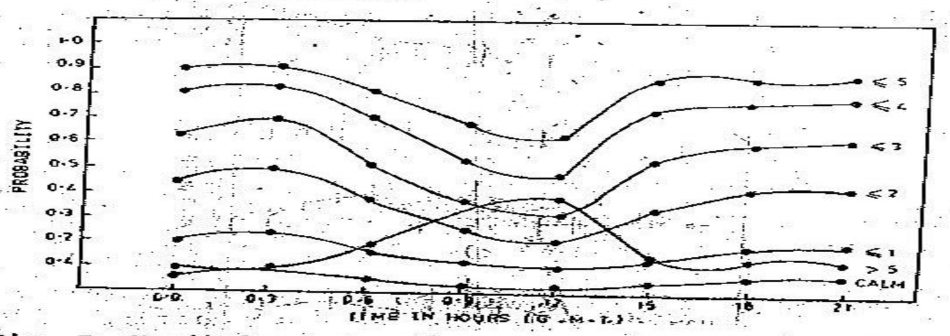


Fig. 5. Variation of wind speed probability with time of the day for typical site (1971-1980).

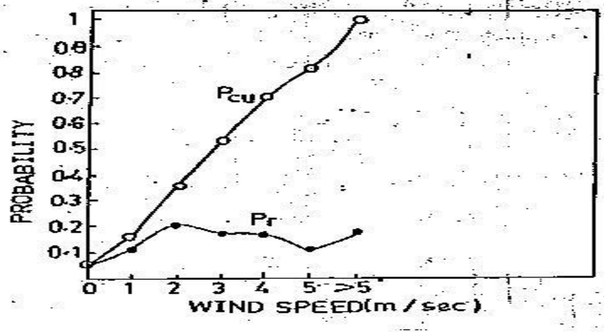


Fig. 6. Relative and cumulative wind speed probability (Pr and Pcu) for typical site (1971-1980).

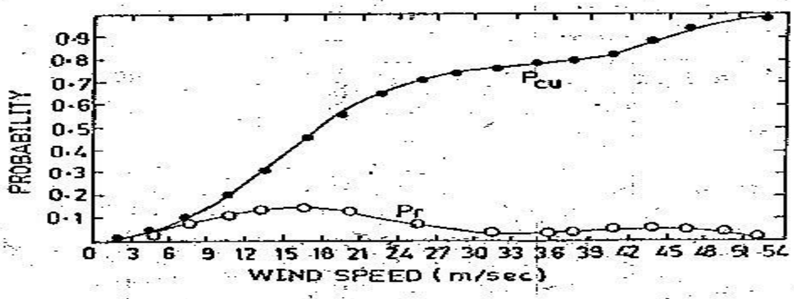


Fig. 7. Relative and cumulative probability distribution (Pr and Pcu) for winds at a typical site, July (1978).

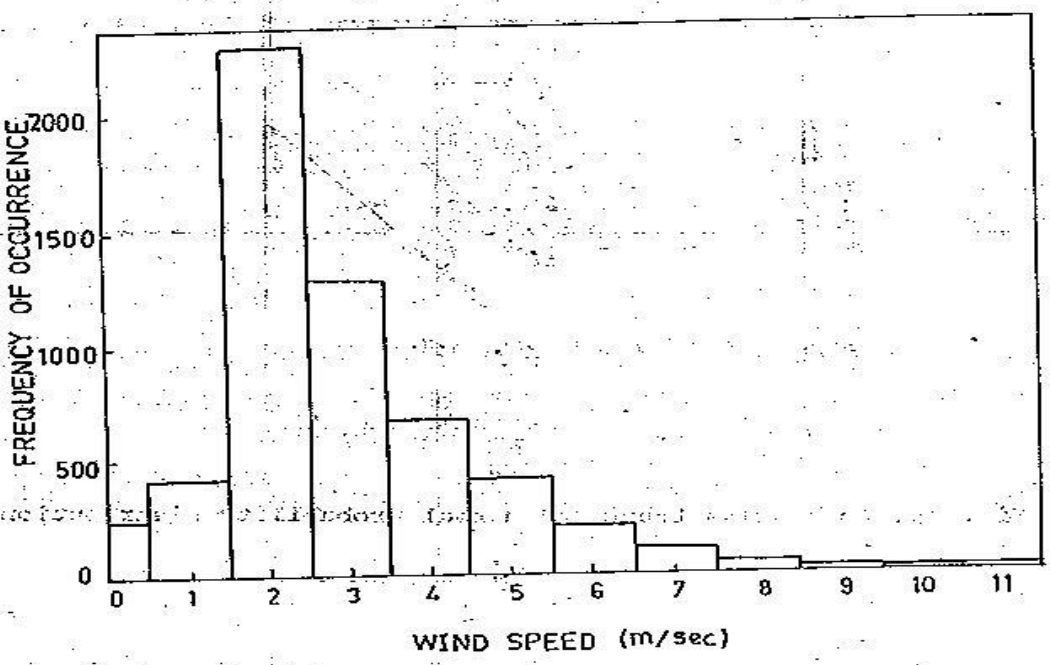


Fig. 8. Frequency of occurrence of wind speeds at a typical site.

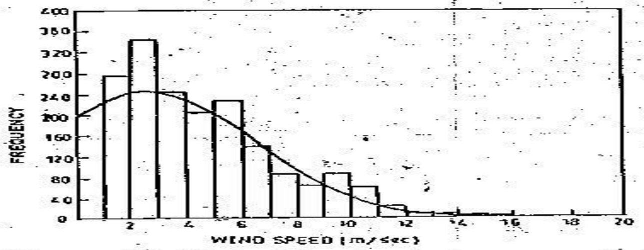


Fig. 9. Frequency function and histogram of observed values.

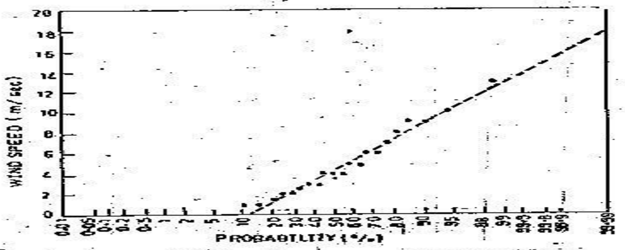


Fig. 10. Cumulative truncated normal probability distribution.

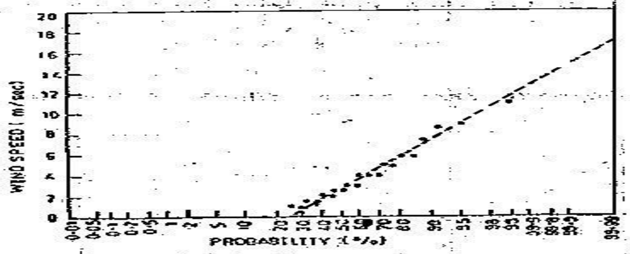


Fig. 11. Truncated normal probability density functions of frequency histograms, April, Basrah.

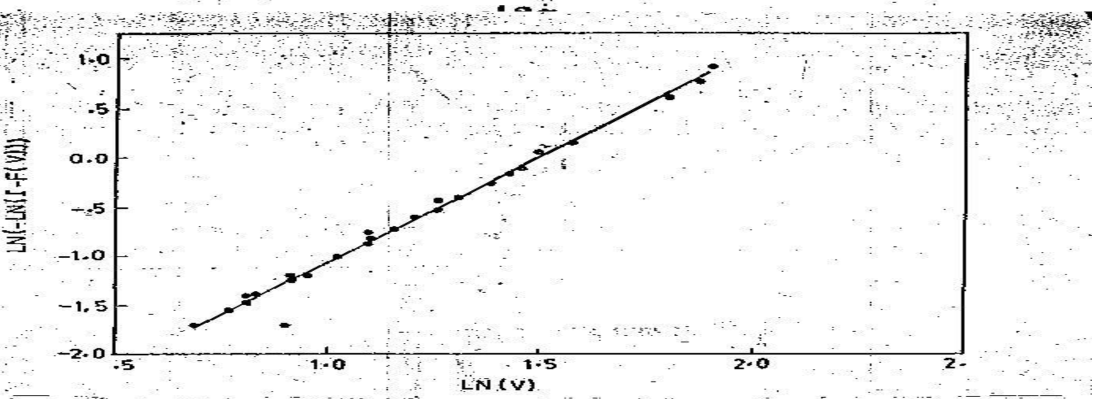


Fig. 12. The observed values of LN(-LN(1-F(V))) are plotted against LN(V).

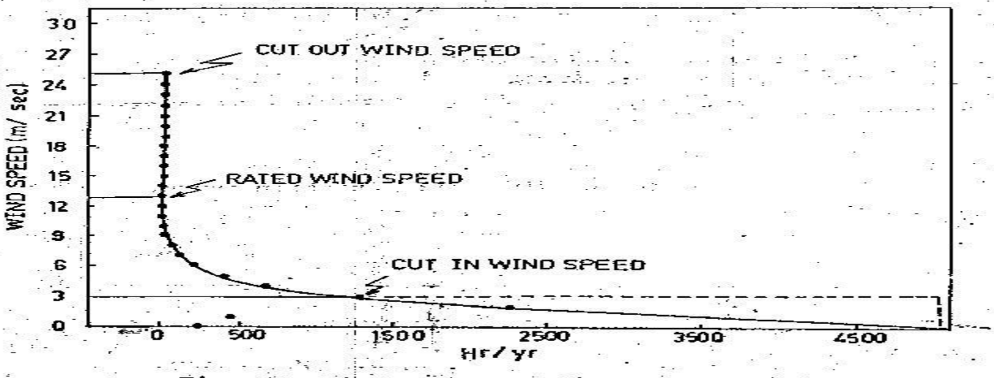


Fig. 13. Wind speed duration curve.

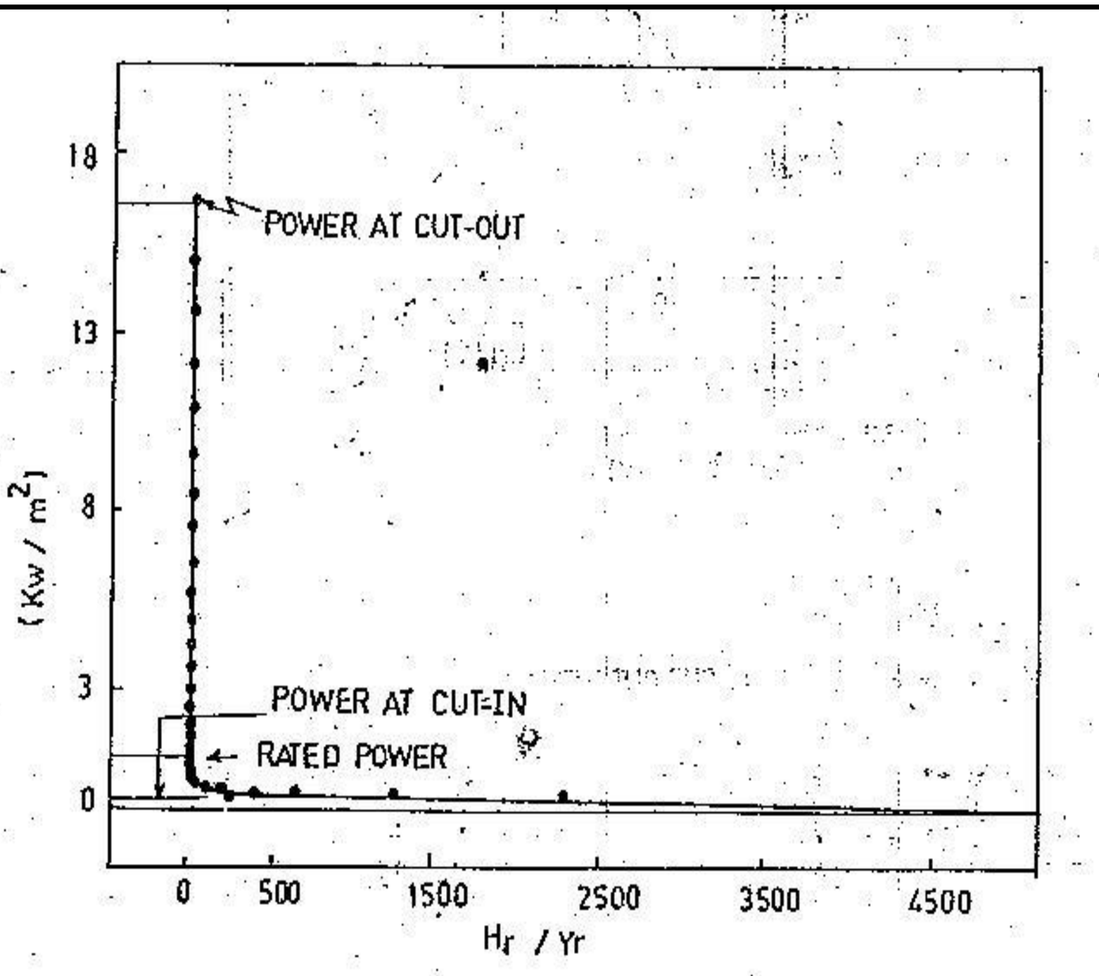


Fig. 14. Wind power duration curve.

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