Mausam, (1981), **32**, 1, 55–58

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Wind analysis for wind power : Part I

S. I. T. THOMAS

Meteorological Office, Ahmedabad

(*Received 28 December 1978*)

ABSTRACT. Utilisation of energy from the winds has assumed significant importance in the context of the energy crisis which is one of the challenging problems facing the world today. In India there is much scope for making use of the wind power. In planning the locations, the type and design of the most suitable types of wind mills information on winds at the desired locations is very valuable. In this paper, the author has made a frequency analysis of hourly values of winds from the records of the Dines Pressure Tube Anemograph at Ahmedabad during the five year period 1973-77. The frequency distribution of hourly values of winds in the four ranges 0-9 kmph, 10-14 kmph, 15-19 kmph and 20 kmph and above has been determined. Monthwise frequency distribution is also presented.

1. Introduction

Energy crisis is one of the challenging problems facing the world today. With fast depleting fossil fuels and a frightening note of the possibilities of exhausting the world's oil resources, all eyes are now turning towards harnessing the seemingly inexhaustible power from the sun.

Winds experienced by us are themselves a form of solar energy. A few countries have gone ahead in the utilisation of energy from wind power. For example the USSR proposes to install as many as 200,000 wind driven generators with an output of 30 kw during the next few years. Strong prairie winds, for years nuisance to the small town of Clayton, New Mexico, USA, are now helping to supply the town with upto 15 per cent of its electric power. A French company has developed three types of machines for (*i*) areas of light winds, (*ii*) areas of moderate winds and (*iii*) areas of high winds.

The power of the wind in kilowatt (P) may be given by the formula:

$$P = 2.14\ \rho A V^3 \times 10^{-3}$$

where, P = Power in kilowatt,

ρ = Density of the air, in slugs per cubic foot,

$= M/g \cdot \text{ft}^{-3}$ (a slug is a unit of mass equal to the weight divided by the acceleration of gravity),

A = The projected area swept by the turbine,

V = Wind velocity in miles per hour.

It may be noted here that the power in the wind is proportional to the third power of wind velocity and hence the significant advantage of relatively strong winds.

In India there is much scope for making use of the wind power. There is much to be done in India for rural development. As such the most fascinating thing is that small units (upto 20 kw) can be located practically anywhere where there is a fair wind and the power produced can be of use to people in far flung and remote rural areas by way of generating electricity, pumps for irrigation, flour mills etc.

This task of establishing a network of wind mills for optimum benefits will have to be tackled by proper planning. This planning will involve taking into consideration the following factors : (*i*) Wind data for the locality, (*ii*) On the wind data, the type and design of the wind mill.

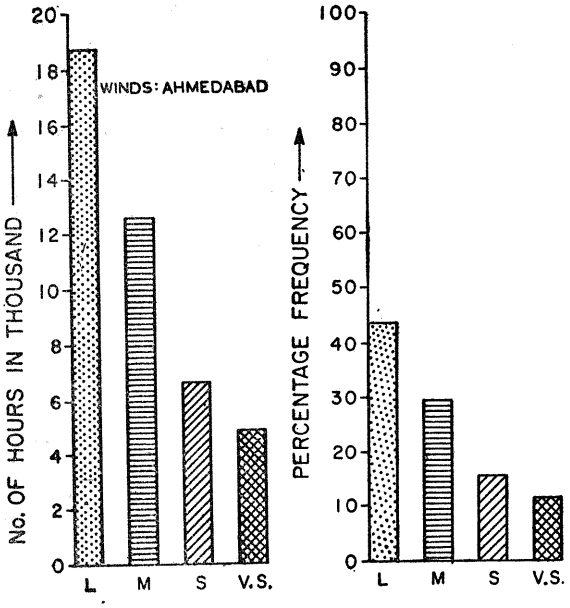

Fig. 1. Winds at Ahmedabad for the period 1973-1977 (L=0-9, M=10-14, S=15-19, V. S.=20 and above in kmph)

In this study the author has analysed the winds for Ahmedabad for determining the number of hours when the strength of wind is in the ranges 0-9 kmph, 10-14 kmph, 15-19 kmph and 20 kmph and above.

It may be mentioned here that although some work on wind analysis has been done by some earlier workers, they are all based on 24 hour average winds. Such information is hardly useful for planning in the utilisation of wind mills whereas hourly values of winds give far more useful information for determining hours of availability of useful winds.

Records from the Dines Pressure Tube Anemograph are ideal for a study of this nature for the following reasons. Firstly, although it is the surface wind that needs to be considered, the height of the sensor above ground level in the case of these anemographs is such that the winds at that level are more representative of the requirements for wind mills (some of the wind mills in use have their rotors at a height of about 15 to 20 metre above he ground). Secondly these anemographs give a continuous record of the winds on charts so that a ten minute average of the wind at every hour is easily obtainable. Thirdly, the data obtained from the Dines Pressure Tube Anemographs are very dependable.

In case the height above ground level of the rotor of the wind mill proposed to be installed is appreciably different from the height above ground level of the sensor of the anemograph the data of which is taken into consideration, then

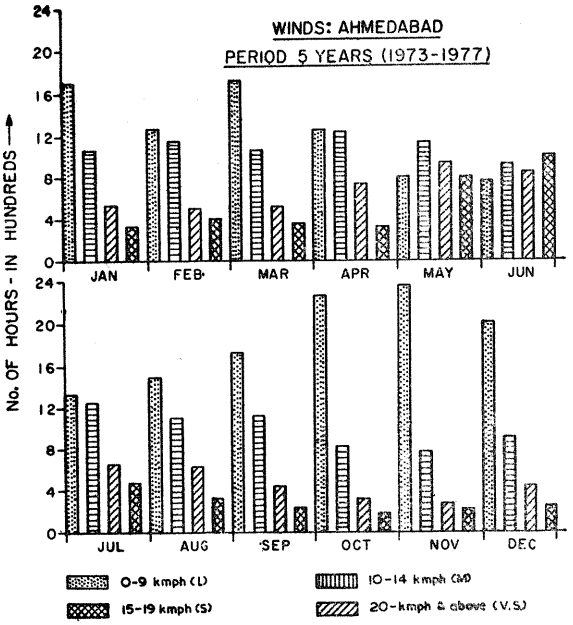

Fig. 2

suitable correction can be introduced making use of the logarithmic relationship between the wind velocity and height above ground level within the surface boundary layer of the atmosphere. The relationship is given by the formula:

$$\frac{\bar{u}}{u^*} = \frac{1}{k} \ln \left(\frac{u^* z + N}{N + \nu/9} \right)$$

where, $\bar{u}$ = velocity at height z

u^* = friction velocity

k = 0.4

N = $u^* z$ (= macroviscosity)

ν = kinematic viscosity

(N.B.—For smooth surface $N = 0 \neq u^* z$)

In the Gujarat State there are five stations which are equipped with Dines Pressure Tube Anemograph. They are Ahmedabad, New-Kandla, Veraval, Jamnagar and Baroda.

2. Procedure

The Dines Pressure Tube Anemograph at Ahmedabad is located in the Meteorological Office situated at the Ahmedabad Airport. Its sensor is at a height of 14.7 metre above ground level.

From the records of the Dines Pressure Tube Anemograph at Ahmedabad ten minute average wind speed values for each hour (ten minute ending at the full hour) for all the 24 hours of the day were tabulated. These values are representative of the wind speed at the corresponding hours. These tabulated values for a period of 5 years, *viz.*, 1973 to 1977 have been analysed. The direction of the wind has not been considered because the wind mills can be so constructed that they can turn so as to always face the wind.

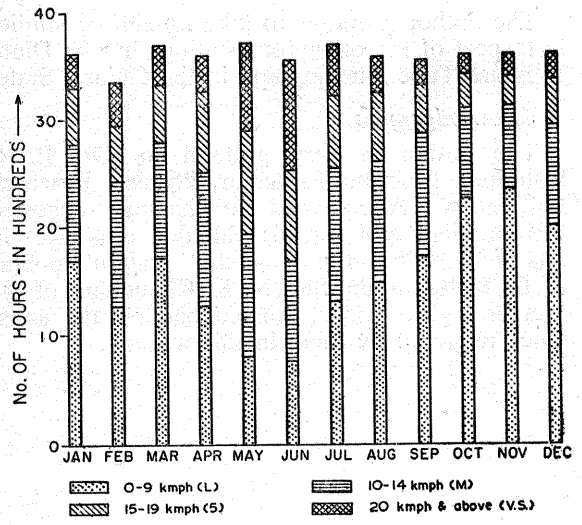

Fig. 3. Histograms of winds at Ahmedabad for the period 1973-1977

For the purpose of this analysis wind speeds have been classified into four groups as follows. Wind speeds of 0-9 kmph (kilometre per hour) have been classified as Light, denoted by L, 10 to 14 kmph as Moderate, denoted by M, 15 to 19 kmph as Strong, denoted by S and wind speeds of 20 kmph and above as Very Strong, denoted by V.S. The reason for making such classification is that when the winds are light, *i.e.,* 0-9 kmph, wind mills are practically inoperative. The frequencies of occurrence of winds in the other three groups will be helpful in deciding upon the type and sturdiness of the windmill to be employed and in deciding upon the uses to which the wind power thus derived could be put.

The number of days in a month when the wind Speed at each hour was falling in each of the above four groups was determined. (For example, in a month of 30 days, at 0100 hr, there could be 20 occasions under group L, 5 occasions under group M, 3 occasions under group S and 2 occasions under group V. S. making a total of 30). This was done in respect of all the 24 hours. Thus the classification was made for one month. In the same manner classification for all the months for all the above mentioned five years was made. Thus the frequency distribution according to the four groups L, M, S, and V. S. in respect of each hour for all the months for all the five years was got prepared. Wth this fund of information various kinds of analysis could be made.

TABLE 1

Frequency distribution of winds

(Period : 5 Years 1973-77)

Month	Group			
	L	M	S	V.S.
Jan	1699	1078	525	320
Feb	1281	1158	508	406
Mar	1726	1074	533	356
Apr	1273	1248	745	324
May	807	1143	949	812
Jun	766	925	841	1011
Jul	1324	1250	648	471
Aug	1496	1112	635	329
Sep	1739	1131	441	233
Oct	2266	830	316	175
Nov	2355	765	270	205
Dec	2015	910	435	240

3. Frequency analysis and results

The first type of analysis made was to find the frequency distribution in the four groups of all the winds for all the hours, for all the months and for all the five years put together. For this the number of occasions under each group for all hours for all months and for all the five years were just added up. This is meant to give an idea of the proporation of each group of wind speeds for the five year period. It was thus found that there were 18,747 hours of light wind, 12,624 hours of moderate wind 6,646 hours of strong wind and 4,882 hours of very strong wind during the five year period. This is graphically indicated in Fig. 1 (For about 300 hours during this five year period data were not available due to some break in the records or unserviceability of the instrument). This frequency distribution expressed as percentage distribution is represented in Fig. 1. It can be inferred from Fig. 1 that light winds prevail for 43.7 per cent, moderate wind for 29.4 per cent, strong wind for 15.5 per cent and very strong wind for 11.4 per cent of all the hours in a year at Ahmedabad. In other words, for 56.3 per cent of the hours in a year the winds are above 9 kmph. That is, broadly speaking wind mills could be effectively operative for well over half the period in a year at Ahmedabad. It may also be stated here that as most of the light winds are at night times, the hours when windmills could be effectively operative in day time alone will have a much higher percentage.

The second type of analysis made was to classify the wind speeds into the four groups monthwise. The number of occasions under each group for all hours for each month for all the five years were added up. This gives the frequency distribution in the four groups of all the winds for all the hours for each month for all the five years. The results are shown in Table 1. The results are also graphically represented in Figs. 2 and 3 (two ways of representing by histograms). These give useful information as to which are the months when windmills could be used with the best advantage. It can be seen from the figures that the more favourable months are February, April, May, June and July and the least favourable months are October and November. Thus where energy from the wind is to supplement energy from other sources, the quantum of energy from the wind that would be available being known for different months, a more realistic planning for other energy sources and projects utilising wind power for the different periods or seasons of the year becomes feasible.

The author proposes to take up similar studies in respect of the other four stations having Dines Pressure Tube Anemograph in the Gujarat State.

Acknowledgement

The author is very grateful to Dr. P. R. Pisharoty, Emeritus Professor, Physical Research Laboratory, Ahmedabad for having suggested this problem and for his valuable guidance in this study. The author is also grateful to Shri R. G. Kulkarni and Shri N. K. Chaudhary of the Meteorological Office, Ahmedabad for the assistance rendered by them in this work.