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Wind power potential over Delhi

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सार – दिल्ली के ऊपर पवन शक्ति विभव का आंकलन और उसका विभिन्न गति श्रेणियों में पवनचक्कियों के प्रभावशाली प्रयोग के द्वारा प्रकृति में उपलब्ध पुनःआवर्तित पवन ऊर्जा श्रोत के क्षेत्र में अनुसंधान करने का इसमें प्रयास है। आवृत्ति तथा पवन गति सूक्ष्म मानावली विश्लेषण यह दर्शाती है कि उपरितन मंद पवन श्रेणी (6 से 8 कि॰मी॰ प्रति घंटा) के लिये निर्मित पवनचक्कियों को दिन में 8-12 घंटों के लिये प्रभावशाली ढंग से चलाया जा सकता है, समय, महीने और उस पवन गति श्रेणी पर निर्भर करता है जिस पर कि पवनचक्की चलायी जा सके। दिल्ली में अधिकतम पवन शक्ति विभव 720 वाट घंटे प्रति मी॰^{2} प्रतिदिन मार्च में और न्यूनतम 130 वाट घंटे प्रति मी॰^{2} प्रतिदिन नवम्बर के बीच रहता है।

ABSTRACT. An attempt is made to investigate in the field of renewable source of wind energy available in nature by estimating the wind power potential over Delhi and its effective utilisation for windmills for different speed ranges. Frequency and wind speed fine spectrum analysis indicates that windmills designed for upper light wind range (6 to 8 km/hr) can be effectively put into operation during the daytime for about 8-12 hrs., the time depending upon the month and the range of the wind speed at which the windmill can be operated. The max. power potential over Delhi varies from 720 watt hr/m^2/day during the month of March to min. of 130 watt hr/m^2/day in the month of November.

Key words :- Wind analysis, Wind power, Wind potential, Wind energy utilisation, energy from wind.

1. Introduction

The accelerating depletion of fossil fuels is leading to the energy crisis all over the world and is compelling the mankind to turn its attention on tapping the non-conventional and renewable sources of energy available in nature in the form of solar wind and tidal energy.

Wind, which is also a form of solar energy, has enormous potential for work. A WMO report (1954) reveals that 1.75×10^{14} kwh of wind energy is available over the entire world that can be utilised for betterment of human race. It is the demand of time for developing countries, like India, to investigate and launch plans for tapping energy in the field of renewable energy sources. Bearing this in mind, an attempt is made for assessment of mean wind power potential over Delhi during the year and also the periods during the day when windmills/irrigation pumps could be effectively put into operation for different wind speed ranges (Jagdish and Varshney 1982).

2. Data

For wind spectrum analysis, continuous data of Dines Pressure Tube Anemograph recorded at Meteorological Office, Safdarjung in Delhi during the year 1972 to 1981 are utilised. The Dines Pressure Tube wind sensor is fixed at a height of 19.8 m a.g.l., and the wind data from it is taken as representative for the union territory of Delhi for the windmill purposes. This data is supplemented from current weather records for a few days for which continuous records (anemograms) are not available. The cup anemometer for recording current weather observations of Safdarjung is fixed at a height of 16.1 m a.g.l.

3. Procedure and analysis

Monthwise average hourly values of winds are worked out for each hour of the day by taking arithmetic mean and are considered representative of the wind speed at the corresponding hour. The direction of wind is not taken into consideration as windmills can be kept facing the wind (Thomas 1981). The values during squalls are also not taken into consideration as they do not represent the general flow. The data is represented in Fig. 1 where isopleths are drawn.

3.1. Wind frequency analysis of mean hourly wind speed for the class interval, (*i*) 1-4 km/hr, (*ii*) 5-8 km/hr, (*iii*) 9-12 km/hr, (*iv*) 13-16 km/hr and (*v*) greater than 16 km/hr is carried out. The number of occasions in each month when the average wind speed at each hour falls in the classified group is obtained. The procedure is repeated so as to get the total number of occasions in each of the groups for the period under study and for all the months in order to work out the percentage frequencies. Data is presented in Fig. 2(a).

3.2. Annual speed duration analysis is carried out by calculating the number of hours for which a wind of particular speed blows over the station. The speed

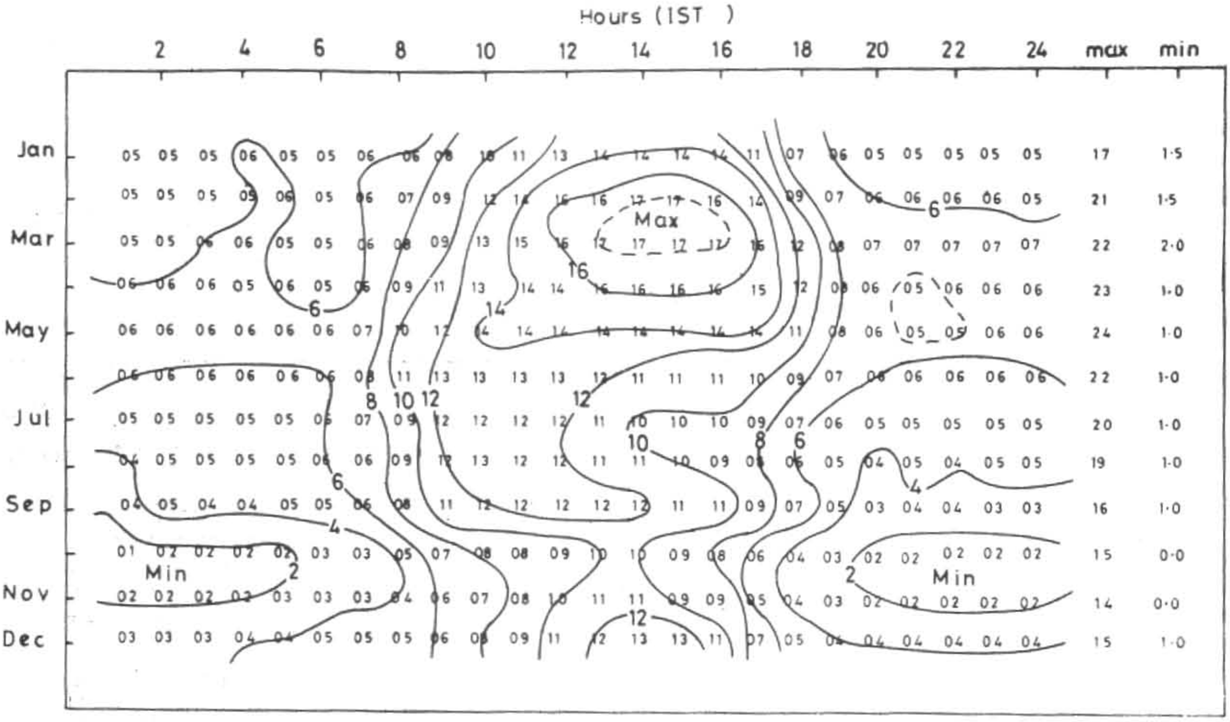
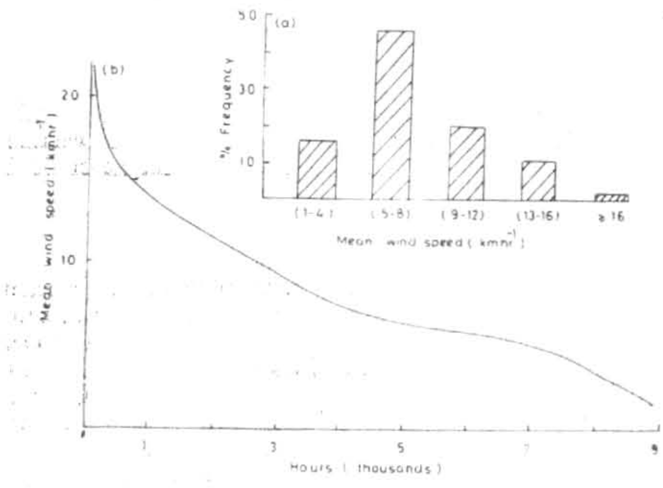


Fig. 1. Monthwise average hourly values of wind speed (km/hr)



Figs. 2 (a&b). (a) Percentage frequency of wind in various speed ranges and (b) Annual speed duration curve

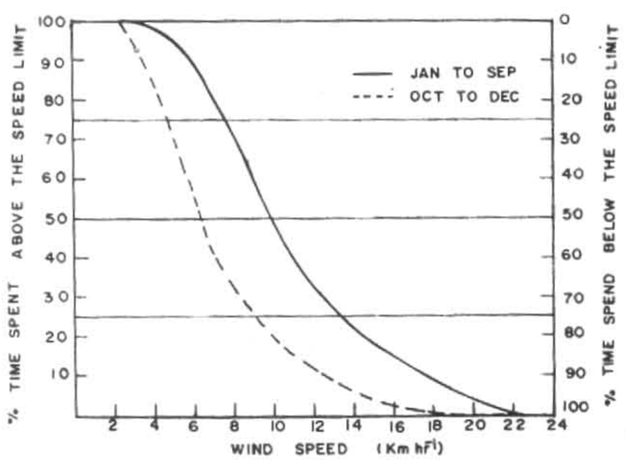


Fig. 3. Cumulative frequency diagram

duration curve is obtained by a horizontal plot of the duration in hours against the mean wind speed as shown in Fig. 2 (b). This curve is prepared for estimating the actual number of hours in a year for which a particular wind speed greater than or equal to that of a specified value is available at the station.

3.3. Monthwise speed duration analysis is also carried out by calculating the percentage time spent in each wind speed band. This monthly analysis is employed to assess the wind power.

The kinetic energy associated with a wind flow of mass m and speed v is given as $1/2\, mv^2$. If ρ be the density of air passing normal to the area A, the mass of air is ρAv. Thus K.E. per unit time or the power of the wind is :

$$P = 1/2\, \rho\, A\, v \times v^2$$
$$= 1/2\, \rho\, A\, v^3$$

TABLE 1

Percentage time spent in various speed class intervals

Speed class (km/hr)	1-4	5-8	9-12	13-16	17-20	21-24	Power (kwh/m²/d)
Jan	16.7	43.3	15.8	18.0	6.2	0.0	0.55
Feb	15.6	44.8	14.1	17.7	7.8	0.0	0.64
Mar	2.3	52.3	11.6	22.2	10.6	1.0	0.72
Apr	15.4	34.2	16.7	26.2	7.5	0.0	0.71
May	16.7	34.3	26.4	12.0	10.2	0.4	0.65
Jun	11.3	43.7	31.3	10.4	2.9	0.4	0.46
Jul	24.5	38.4	27.8	5.5	1.9	1.9	0.41
Aug	25.4	41.3	21.4	10.9	1.0	0.0	0.33
Sep	33.3	28.7	26.9	9.7	1.4	0.0	0.20
Oct	60.2	19.9	17.6	2.3	0.0	0.0	0.14
Nov	63.0	18.0	17.6	1.4	0.0	0.0	0.13
Dec	39.4	35.6	15.7	9.3	0.0	0.0	0.25

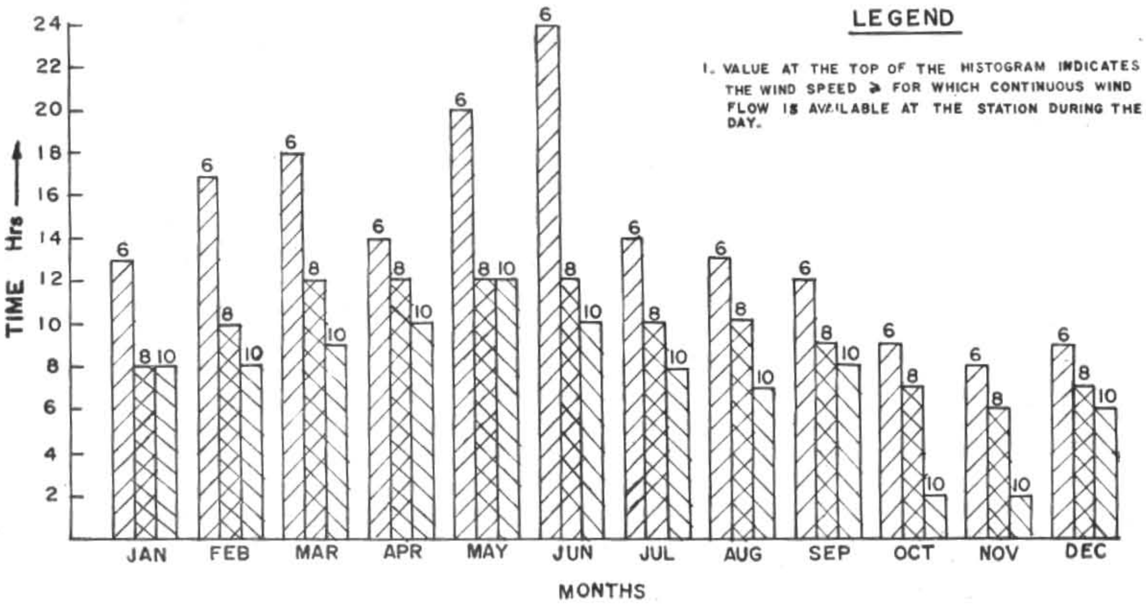


Fig. 4. Annual variation of continuous wind flow above different speed limits

This is the total power which can be extracted by a windmill. As the power is proportional to the wind speed cubed, the wind speed plays a dominant role in power generation by the wind flow.

While computing the wind power, the density of air is taken as 1.29 kg/m^3. Small variations on account of pressure and temperature changes is not taken into consideration as these changes are quite small as compared to fluctuations in *v*. The results are presented in Table 1 which depicts the percentage time spent in each wind speed band and the average wind power density monthwise.

3.4. Cumulative percentage time spent above a given wind speed band is extracted from Table 1 for each month and ogive is constructed which is represented in Fig. 3. For this two curves smoothed out for mean positions for (*i*) January to September and (*ii*) October to December are drawn since there are marked departures in the cumulative values of these groups. This is considered useful for estimating the frequency of percentage time spent above a given wind speed at which windmill can be effectively put into operation.

3.5. Classification of wind speeds greater than a given value for which continuous average wind flows available against the hours of the day is carried out. This is diagramatically represented in Fig. 4 where histograms for continuous flow of wind in the various speed ranges (greater than or equal to 6, 8 and 10 km/hr) are drawn. This is done in order to obtain actual specific hours when wind speed greater than or equal to a given value could be used for operation of windmills.

4. Results and discussion

Isopleth analysis of Fig. 1 reveals that strongest average winds occur in the months of February to April in the afternoon and weakest in October to November in the night hours. Further winds during the day are generally stronger.

4.1. *Fine frequency analysis*

Though windmills are generally inoperative when the winds are in the light range (1-9 km/hr), they have been tried with some success when the winds are in the upper light range (6-8 km/hr), Tiwari (1978). Keeping the above in view, the fine frequency analysis of the wind spectrum as given in Fig. 2(b) indicates that there are 4044 hrs on an average in a year when wind speed lies between 5 and 8 km/hr. The percentage frequency of average number of hours in a year is 46% for wind speed lying between 5 and 8 km/hr. As stated earlier wind speed generally decreases during the night hours, the percentage frequency for optimum wind speed lying between 5 and 8 km/hr is bound to be higher if windmills are to be operated during the day.

4.2. *Annual speed duration curve*

Annual speed duration curve, Fig. 2(b) provides a useful information regarding the number of hours in a year during which the mean wind speed equals or exceeds a particular magnitude. It is seen that there are 3160 hrs in a year on an average during which wind with speed 9 km/hr is available and 7200 hrs in a year during which mean wind speed 5 km/hr blows over Delhi. Thus, windmills sensitive to the speed ranges mentioned above can efficiently be utilised during the day.

4.3. *Monthly wind power potential*

The computed values of wind power as shown in Table 1, reveal that during the month of March which is the windiest month, the wind has the highest power potential of the order of 720 watt hr/m^2/day. The wind power potential during January to May ranges between 550 and 650 watt hr/m^2/day. October and November are the months during which the wind power potential is minimum (130 watt hr/m^2/day), increasing to 250 watt hr/m^2/day in December.

4.4. *Cumulative frequency*

Cumulative frequency diagram (ogive) shown in Fig. 3 reveals that from January to September average percentage time spent above 6 km/hr speed range is 90%. It is 80%, 70%, 60% and 50% for wind speeds greater than 7, 8, 9 and 10 km/hr respectively. It is also evident from the diagram that from October to December, the percentage time spent is 55%, 40%, 35%, 25% and 20% for wind speeds greater than 6, 7, 8, 9 and 10 km/hr respectively.

4.5. *Hours of continuous average wind flow*

The availability of continuous average wind flow for optimum wind speed at which the windmill can be put into operation is considered very useful for full exploitation of wind power potential. The analysis carried out with the above in view and represented diagramatically in Fig. 4 reveals that the windmills designed for wind speeds greater than or equal to 6, 8 and 10 km/hr can be put into operation only during the day time depending upon the month of the year with slight variation in the actual hours of operation. It is evident from Fig. 1 and Fig. 4 that for wind speed greater than or equal to 6 km/hr, they can be put into operation for about 12 hrs from 0700 to 1900 IST from January to September and for about 8 hrs from 0900 to 1700 IST from October to December.

For wind speeds greater than or equal to 8 km/hr they can be put into operation for about 9 hrs from 0900 to 1800 IST in Jan-Feb, for about 11 hrs from 0800 to 1800 IST in Mar to May, for about 9 hrs from 0800 to 1700 IST in Aug-Sep and for about 6 hrs from 1000 to 1600 IST in Oct-Dec.

For wind speeds greater than or equal to 10 km/hr the choice of operation further reduces to from about maximum 10 hrs in May to about minimum of about 2 hrs in Oct-Nov.

5. Conclusions

(*i*) Strongest winds 16-17 km/hr occur in the months of February to April in the afternoon and weakest average winds about 2 km/hr in October-November during the night. The longest period of duration of max. winds about 14 km/hr occurs in May. Winds during the day are generally stronger than during the night.

(*ii*) The maximum wind power potential over Delhi is about 720 watt hr/m²/day in March and the minimum is 130 watt hr/m², day in November.

(*iii*) The windmills designed for upper light range, *i.e.*, wind speeds greater than or equal to 6-8 km/hr are considered to be most useful for exploitation of maximum wind power potential over Delhi during the daytime. There are 7200 hrs in a year (8760 hrs) during which mean wind speed greater than 5 km/hr blows over Delhi. Though average percentage time spent in above wind speed range is of the order of 50% in October-December, much higher from January to September where it is of the order of 70 to 90%.

(*iv*) Windmills designed in the upper light range (6-8 km/hr) can be effectively utilised for exploitation of maximum wind power potential over Delhi by putting them into operation for about 8-12 hrs during the day from 0700 to 1900 IST except in the months of October-December where it can be exploited for about 6 hrs from 0900 IST.

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