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DETERMINATION OF THE OPTIMUM RATED SPEED OF A WIND MACHINE FOR CHITTAGONG

In our earlier study (Hussain *et al.* 1986) on 'Wind speeds and wind energy availability in Bangladesh' we found that the average wind speed is 2-3 kt (1 kt= 1.852 kmph) with the exception of the coastal station, Chittagong, where the average speed is 7.2 kt. There is no hourly wind speed data of our off-shore islands. It is reported by Mani and Mooley (1983) that the average wind speed of Sagar Islands which is very near to B ngladesh is 10.3 kt. So it is likely that our off-shore islands should have wind speeds at least equal to that of Chittagong. To extract maximum wind power at the minimum cost, the characteristics of wind machines such as cut-in, rated and furling speeds should match with the wind speed behaviour of that particular location where the machine is to be installed. In this note, taking the data of Chittagong as a representative of the coastal region, an attempt has been made to find out the most suitable rated speed of a wind machine for the maximum energy output. The rated speed corresponding to the minimum cost of energy production was also determined.

The hourly wind speed (in kt) data of Chittagong have been collected from the Meteorological Department of Bangladesh for the years 1978-1981. From these data, the frequency distribution of wind speeds over a year was computed and shown in Table 1. It is known that the power P extracted from wind is given by :

$$P = \tfrac{1}{2}\, c_p\, \rho A\, V^3 \quad \text{watts} \qquad (1)$$

where, c_p, is the dimensional power coefficient (=. 12), ρ is the densiy of air (1.18 kg/m^3), A is the swept area of the wind rotor (m^2) and V is the wind speed (m/s). If V_c, V_r and V_f are the cut-in, rated and furling speed of a wind machine, the power P_i can be expressed as :

$$P = \begin{cases} 0 & \text{for } V_i < V_c \\ \tfrac{1}{2} c_p \rho A V_i^3 & \text{for } V_c \leqslant V_i \leqslant V_r \\ \tfrac{1}{2} c_p \rho A V_r^3 & \text{for } V_r \leqslant V_i \leqslant V_f \\ 0 & \text{for } V_i > V_f \end{cases}$$

If f_i is the frequency corresponding to wind speed V_i, the annual energy output :

$$E_i = \Sigma\, f_i\, p_i\, h_i \quad \text{watt-hour} \qquad (3)$$

where, h_i is the number in hours for which the wind speed V_i was prevailing. In the case of hourly wind speed data, $h_i = 1$ (as in the present case).

Normally it is assumed that the power required to start a machine is 15% of the rated power, *i.e.*,

$$\frac{P_c}{P_r} = \cdot 15$$

$$\text{or} \quad \frac{V_c}{V_r} = (.15)^{\frac{1}{3}} \qquad (4)$$

From the characteristics of different wind machines (Furlan *et al.* 1985), it is found that the minimum value of the cut-in speed is 7.2 kmph (3.9 kt). As we have rather low wind speed, so for the present computational work, the starting value of the cut-in speed was taken to be 4 kt (7.4 kmph) which according to Eqn. (4) corresponds to a rated speed of 7.5 kt (13.9 kmph). Taking the furling speed to be 27.0 kt (50 kmph),

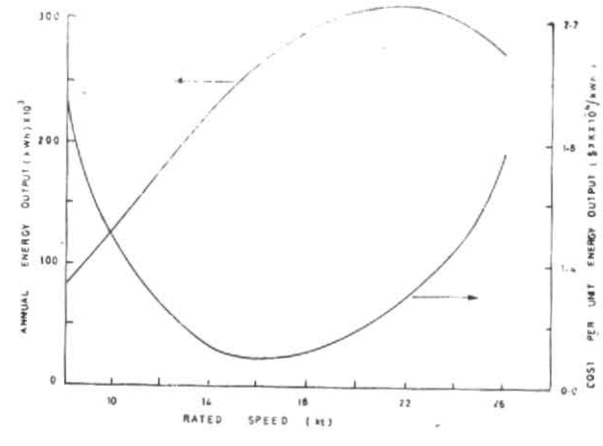

Fig. 1. Variation of annual energy output (left scale) and cost per unit energy produced (right scale) with the rated speed of wind machine for Chittagong

TABLE 1

Annual frequency distribution of the hourly wind speeds (in kt) of Chittagong

Wind speed (kt)	Freque-ncy)	Wind speed (kt)	Fre-quency	Wind speed (kt)	Fre-quency
0	1676				
1	5	16	105	31	0
2	455	17	142	32	2
3	621	18	105	33	1
4	129	19	116	34	0
5	1654	20	119	35	6
6	146	21	24	36	0
7	439	22	48	37	1
8	310	23	30	38	1
9	564	24	10	39	0
10	602	25	55	40	1
11	44	26	5	41	0
12	369	27	6	42	0
13	370	28	5	43	0
14	147	29	2	44	0
15	441	30	3	45	1

the annual energy output were calculated for different rated speeds and shown in Fig. 1 (the scale is on the left hand side).

It has been shown (Pandey and Chandra 1986) that the cost (in US dollars) per unit energy output C_r is given by :

$$C_r = \$ \frac{KE_r}{V_r} \tag{5}$$

where K is a constant and E_r is the annual energy output at a rated speed of V_r. Using Eqn. (5), the value of C_r were calculated for different values of V_r and displayed in Fig. 1 (the scale is on the right hand side). The nature of both the curves agree well with those of Pandey and Chandra (1986).

It is evident from Fig. 1 that for Chittagong, the optimum rated speed for the maximum power generation is around 22 kt (40.7 kmph) and for the production of energy at the minimum cost, the optimum rated speed is 16 kt (29.6 kmph). So a figure in between the two values should be a good compromise between these two conditions.

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