ANALYSIS OF WIND ENERGY AT CHANDANA, GAZIPUR, DHAKA BASED ON ACTUAL FIELD DATA

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Abstract Continuous wind speeds were measured at Chandana, Gazipur, Dhaka during August 1997 to July 1999. Based on these actual wind speeds data, rated wind speed for different months of the year are determined This takes into account, the capacity factor which in tern depends on Weibull Shape factor, Scale factor, cut-in wind speed, rated wind speed and furling wind speed. Combined efficiency for the system was considered between 10% to 20%. This includes gear efficiency, generator efficiency and turbulence effect. Capacity factor for rated wind speeds 4 m/s to 8m/s were calculated and the rated wind speeds were considered for capacity factor more than 20%. A system was developed considering cut-in speed 2m/s, rated speed 6 m/s. and furling wind speed 12 m/s. At different combined efficiency balance energy is determined which is used to charge batteries. Although the 2nd year's wind speed data were found better than that of the 1st year's, the variation pattern is similar. It was found that the maximum rated wind speed were available during the month of May and June and minimum in September and October. During November to February the capacity factor is found less than 20%.

Keywords: Wind Energy System Design

INTRODUCTION

Three design speeds, the velocity availability factor, velocity duration curve and velocity frequency histogram are very important to design a system of utilization wind energy. But above all the capacity factor and its significance is also very important to design a system for optimum utilization of wind speeds at a site. The rated speed is chosen at the minimum 20% capacity factor. Capacity factor for different months at Chandana, Gazipur is calculated and chosen the three design speeds. After determining the rotor diameter of the wind turbine, three cases are theoretically studied with available wind energy at Chandana and finalized the decision.

CAPACITY FACTOR

The capacity factor (CF%) is the ratio of actual energy generation to the installed capacity (rated capacity) times No. of hrs. in the month or in the Year. It is uneconomical if the value of CF% is less than 20%. The higher the CF% the higher feasible is. The formula for the CF is

$$CF = \frac{e^{-\{\frac{v_c}{C}\}^k} - e^{-\{\frac{v_r}{C}\}^k}}{\{\frac{v_r}{C}\}^k - \{\frac{v_c}{C}\}^k} - e^{-\{\frac{v_f}{C}\}^k}$$

Where v_c = Cut in speed (m/s)
v_r = Rated speed (m/s)
v_f = Furling speed (m/s)
C = Weibull scale factor
k = Weibull shape factor.

Table 1: Month wise Capacity Factor
(Considering cut-in speed V_c = 2 m/s, rated speed V_r = 4,5,6,8 m/s and Furling speed V_f = 12 m/s)

Months	Vr=4 m/s	Vr=5 m/s	Vr= 6 m/s	Vr=8 m/s	Vr
	CF	CF	CF	CF	
Aug.97	0.38	0.27	0.206	0.12	5 m/s
Sep.97	0.332	0.231	0.168	0.097	5 m/s
Oct.97	0.098	0.054	0.034	0.017	-
Nov.97	0.084	0.046	0.028	0.14	-
Dec.97	0.111	0.057	0.034	0.015	-
Jan.98	0.168	0.093	0.057	0.027	-
Feb.98	0.158	0.081	0.047	0.021	-
Mar.98	0.335	0.221	0.149	0.076	5 m/s
Apr.98	0.404	0.257	0.163	0.075	5 m/s
May.98	0.441	0.317	0.225	0.12	6 m/s
Jun.98	0.721	0.586	0.45	0.24	8 m/s
Jul.98	0.599	0.417	0.271	0.117	6 m/s
Aug.98	0.499	0.39	0.301	0.181	6 m/s
Sep.98	0.384	0.298	0.232	0.147	6 m/s
Oct.98	0.254	0.176	0.126	0.073	4 m/s
Nov.98	0.229	0.129	0.078	0.036	4 m/s
Dec.98	0.179	0.089	0.05	0.021	-
Jan.99	0.347	0.194	0.113	0.047	4 m/s
Feb.99	0.412	0.252	0.153	0.067	5 m/s
Mar.99	0.508	0.256	0.242	0.118	6 m/s
Apr.99	0.707	0.575	0.446	0.25	8 m/s
May.99	0.704	0.563	0.426	0.277	8 m/s
Jun.99	0.781	0.65	0.509	0.277	8 m/s
Jul.99	0.537	0.339	0.201	0.08	6 m/s
Annual-1	0.349	0.25	0.181	0.103	5 m/s
Annual-2	0.485	0.369	0.277	0.16	6 m/s

WIND POWER

Wind energy conversion is ruled by several basic principles, which determines how much energy can be extracted from the wind as well as the electricity extraction capabilities of various types of generator. Any generator can't extract 100% of wind power. It has been established by A. Betz that the maximum power can be extracted from wind is 59% theoretically. There are many factors that effect on power extraction. These are power coefficient of blade(C_p), power transmission efficiency (η_t), generator efficiency ((η_g), and fluctuation of wind energy (η_f). If the power is denoted as P (w) and combined efficiency as η_c, wind speed as v m/s and rotor area as A (m^2) , the power equation is shown as

$$\mathbf{P = 0.59\, C_p\, \eta_t\, \eta_g\, \eta_f\, v^3\, A\ (watt) = \eta_c\, V_r^3\, A\ [watts]}$$

Where

C_p = 0.35- 0.45	for horizontal turbine	
0.2-0.30		for vertical turbine
η_t = 0.70 – 0.9	gear transmission efficiency	
η_g = 0.80 – 0.95	generator efficiency	
η_f = 0.9	wind fluctuation efficiency	
η_c = 0.10 – 0.23	combined efficiency	

From the power equation it is seen that the power is directly proportional to rotor area or square to diameter (D^2) or radius (R^2). The higher the radius, the higher the power and it need higher starting torque or higher cut – in speed (V_c) . If we generate higher power, we can provide much energy to the consumers. However, everything is depended on wind speed of that site. A designer can not chose a rotor radius as he wishes. He has to look into the wind data, aerodynamic properties of the rotor shape. He has also to consider all parameters of wind energy conversion system (WECS) to chose the rotor radius.

The determination of rotor radius (R) from the rated power equation is shown below.

Where $P_r = \eta_c v_r^3 A = \eta_c v_r^3 \pi R^2$

$$R = \sqrt{\frac{P_r}{\pi \times \eta_C \times v_r^3}}$$

SYSTEM DESIGN

Energy needed to the system:

Suppose we choose a system units consists of three 6-watt bulbs and one 15 watt for 14 inch TV (b/w) per family and it will be operated for 6 hrs daily. (6 PM to 12 PM) . Then the total power needed per family is

$$P_n = 3 \times 6 + 15 = 33 \text{ watts}$$

Considering the battery discharge able rate is 70 % and line loss is 10 % . So, the actual power needed per family from the source is

$$P_n = 33/(0.70 \times 0.90) = 52.38 \text{ watts.}$$

Therefore we can choose a system of 60- watts per family and will run for 6 hours per day. Then the demand energy E_n is

$$E_n = 6 \times 60 = 360 \text{ Wh/day.}$$

In the following, it will be discussed on how many families we can provide. We have designed three systems, those are

i) Case-1
ii) Case-2
iii) Case-3

Case-1 :

Each family demands 360 Wh /day

Cut –in speed V_c = 2 m/s
Rated speed V_r = 6 m/s
Furling speed V_f = 12 m/s
Family No. = 5
Total Demand = 1800 Wh/day.
We have to select approximate size of turbine by error and trial method
Rated power , P_r = 300 watt
Rotor radius R = 1.81 m = 6ft,
A = 10.29 m^2 η_c=10%

Case-2 :
Unit family demands 360 Wh /day
Cut –in speed Vc = 2 m/s
Rated speed Vr = 6 m/s
Furling speed Vf = 12 m/s , Family No. = 5
Total Demand = 1800 Wh/day.
We have to select approximate size of turbine by error and trial method
Rated power , Pr = 900 watt ηc=15%
Rotor radius R = 3 m = 10ft, A = 28.27 m2

Case-3 :
Unit family demands 360 Wh /day
Cut –in speed V_c = 2 m/s
Rated speed V_r = 6 m/s
Furling speed V_f = 12 m/s, Family No. = 5
Total Demand = 1800 Wh/day.
We have to select approximate size of turbine by error and trial method
Rated power , P_r = 600watt η_c=15%
Rotor radius R = 2.42 m = 8ft, A = 18.4 m^2

Table 2: Wind Energy System Design (for case-1)

Months	Energy Demand	Wind Energy (Wh/m²)	Turbine Energy Generation	Energy Balance	No. Of Charge. Batteries	Excess(+) /Short(-) Batteries
Aug'97	55800	2315.5	23826.5	-31973.5	2.13	- 2.87
Sep'97	54000	1930.8	19867.93	-34132.1	1.84	- 3.16
Oct'97	55800	417.5	4296.08	-51503.9	0.38	-4.62
Nov'97	54000	382.6	3936.95	50063.0	0.36	- 4.64
Dec'97	55800	539.5	5551.46	-50248.5	0.50	- 4.5
Jan'98	54000	815.7	8393.55	-47406.4	0.75	-4.25
Feb'98	50400	837.5	8617.88	-41782.1	0.85	-4.15
Mar'98	55800	2070.4	21304.42	-34495.6	1.91	-3.09
Apr'98	54000	2514.4	25873.13	-28126.8	2.40	- 2.6
May'98	55800	3192.6	32851.85	-22948.1	2.94	-2.06
Jun'98	54000	6897.2	70972.19	16972.2	6.57	1.57
Jul'98	55800	4712.8	48494.71	-7305.3	4.35	- 0.65
Aug'98	54000	4124.5	42441.11	-13358.9	3.80	- 1.2
Sep'98	55800	2696.9	27751.10	-26248.9	2.57	-2.43
Oct'98	54000	1252	12883.08	-42916.9	1.15	- 3.85
Nov'98	55800	1302.7	13404.78	-40595.2	1.24	- 3.76
Dec'98	54000	1025.2	10549.31	-45250.7	0.95	- 4.05
Jan'98	55800	1908.4	19637.44	-36162.6	1.76	-3.24
Feb'98	54000	2356.7	24250.44	-26149.6	2.41	- 2.59
Mar'98	55800	3775.4	38848.87	-16951.1	3.48	- 1.52
Apr'98	54000	6766.6	69628.31	15628.3	6.45	1.45
May'98	55800	6731.8	69270.22	13470.2	6.21	1.21
Jun'98	54000	6425.313	66116.47	12116.47	6.12	1.12

Table 3: Energy Demand Analysis (for case-2)

Months	Energy Demand	Wind Energy (wh/m²)	Turbine Energy Generation	Energy Balance	No. of Charg. Batteries	Excess(+) /Short(-) Batteries
Aug'97	55800	3473.25	98188.78	42388.78	8.80	3.8
Sep'97	54000	2896.2	81875.57	27875.57	7.58	2.58
Oct'97	55800	626.25	17704.09	-38095.91	1.59	- 3.41
Nov'97	54000	573.9	16224.15	-37775.85	1.50	- 3.5
Dec'97	55800	809.25	22877.50	32922.50	2.05	- 2.95
Jan'98	54000	1223.55	34589.76	-21210.24	3.10	-1.90
Feb'98	50400	1256.25	35514.19	-14885.81	3.18	- 1.82
Mar'98	55800	3105.6	87795.31	31995.31	7.87	2.87
Apr'98	54000	3771.6	106623.13	52623.13	9.87	4.87
May'98	55800	4788.9	135382.2	79582.20	12.13	7.13
Jun'98	54000	10345.8	292475.77	238475.77	27.08	22.08
Jul'98	55800	7069.2	199846.28	144046.28	17.91	12.91
Aug'98	54000	6186.75	174899.42	119099.42	15.57	10.57
Sep'98	55800	4045.35	114362.04	60362.04	10.59	5.59
Oct'98	54000	1878	53091.06	-2708.94	4.76	- 0.24
Nov'98	55800	1954.05	55240.99	1240.99	5.11	0.11
Dec'98	54000	1537.8	43473.61	-12326.39	3.90	- 1.1
Jan'99	55800	2862.6	80925.70	25125.70	7.25	2.25
Feb'99	54000	3535.05	99935.86	4953.86	9.91	4.91
Mar'99	55800	5663.1	160095.84	104295.84	14.35	9.35
Apr'99	54000	10149.9	286937.67	232937.67	26.57	21.57
May'99	55800	10097.7	285461.98	229661.98	25.58	20.58
Jun'99	54000	9637.97	272465.4	218465.40	25.22	20.22
Jul'99	55800	5611.35	158632.86	102832.86	14.21	9.21

Table 4: Energy Demand Analysis (for case-3)

Months	Energy Demand	Wind Energy (Wh/m^2)	Turbine Energy Generation	Energy Balance	No. of Charg. Batteries	Excess(+) /Short(-) Batteries
Aug'97	55800	3473.25	6390.80	8107.80	5.73	0.73
Sep'97	54000	2896.2	53290.08	-709.92	4.93	-0.07
Oct'97	55800	626.25	11523	-44277	1.03	-3.97
Nov'97	54000	573.9	10559.76	-43440.24	0.98	-4.02
Dec'97	55800	809.25	14890.2	-40909.8	1.33	-3.67
Jan'98	54000	1223.55	22513.32	-33286.68	2.02	-2.98
Feb'98	50400	1256.25	23115	-27285	2.29	-2.71
Mar'98	55800	3105.6	57143.04	1343.04	5.12	0.12
Apr'98	54000	3771.6	69397.44	15397.44	6.43	1.43
May'98	55800	4788.9	88115.76	32315.76	7.90	2.90
Jun'98	54000	10345.8	190362.72	136362.72	17.63	12.63
Jul'98	55800	7069.2	130073.28	74273.28	11.66	6.66
Aug'98	54000	6186.75	113836.2	58036.2	10.20	5.20
Sep'98	55800	4045.35	74434.44	20434.44	6.89	1.89
Oct'98	54000	1878	34555.2	-21244.8	3.10	-1.90
Nov'98	55800	1954.05	35954.52	-18045.48	3.33	-1.67
Dec'98	54000	1537.8	28295.52	27504.48	2.54	-2.46
Jan'99	55800	2862.6	52671.84	-3128.16	4.72	-.028
Feb'99	54000	3535.05	65044.92	14644.92	6.45	1.45
Mar'99	55800	5663.1	104201.04	48401.04	9.34	4.34
Apr'99	54000	10149.9	186758.16	132758.16	17.29	12.29
May'99	55800	10097.7	18579.68	129997.68	16.65	11.65
Jun'99	54000	9637.97	177338.6	12333.6	16.42	11.42
Jul'99	55800	5611.35	103248.8	47448.8	9.25	4.25

CONCLUSIONS

Higher the rated speed , lower the rotor radius is. So the rated speed is also very important to determine the rotor radius. There is a general guide rule from which the rated speed can be determined using the CF(Table 1). From this table it will be wise to choose the rated speed. It is found that the rated speed (v_r) = 5 to 6 m/s. Considering the total consumers' demand we have to select the installed capacity of the turbine. By analysis the collected wind data, we can select 600 watt capacity turbine having the radius 2.42 m for Chandona, Gazipur , Dhaka. The most available energy periods are May, June and July in a year. Wind data monitoring and analysis are the imperative task before selecting a Wind Electric Generator for a site. Thorough wind speeds observation and analysis of collected wind data have been done by a data-logger for two years at Chandana, Gazipur, Dhaka. The annual mean wind speed is 2.5-3.0 m/s. The maximum frequency of wind speeds is 2-3 m/s during the time. The maximum wind energy is yield at 3 – 6 m/s. The capacity factor (CF%) is determined for each month. This value must be more than 20% i.e. The turbine must run at least 4 to 5 hrs a day. Otherwise the system will fail. The significance of CF% is very important for choosing three design speeds to select a wind electric generator. After having determined the three design speeds at Chandana, Gazipur, a system is designed to supply electricity for five Families in Gazipur. Each family needs 360 watts-hour per day. Three cases are studied and it is try to optimize the system. For case 1, most of the months 1to 2the batteries (100 AH) can be charged. So five families can not be provide. For case 2, most the months 6 to 8 batteries can be charged, which is desirable. But practically it will not be possible for bigger blade diameter .For this reason, it needs higher cut –in speed. This means the turbine will not generate any power most of the time. In case 3 it try to optimize the system design. In May, June and July 10 to 16 no. of batteries can be charged and in March, April, August and September 5 to 6 no. of batteries can be charged and in October to February 1 to 2 no. of batteries can be charged. All these values have been calculated on the basis of 600-watt capacity installed turbine. About seven months the system will operate. There will be shortfall of energy about five months in a year. So hybrid system is recommended either with diesel or solar PV system. Hence unit cost of energy will be high.

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