

Appendix B: Interpretation of the Wind Data Charts

Introduction

This appendix is a guide to interpreting the wind data charts included in the report. Included are background information and an explanation of the meaning of the data in each chart.

The annual results given in the charts in this appendix will differ somewhat from the results given in the charts in the main body of the report. This is due to differences in how the data is processed. This is best described by using an example. Let us assume that 15 months of data was collected from a site, with the monitoring period running from 1 January 2003 to 31 March 2004. The annual average numbers given in the appendix simply provide the average of all the data collected. However this double counts the months of January, February & March. If these months tend to be windier than the rest of the year, then the wind resource will be over estimated.

The proper procedure is to average together the data from the double counted months before averaging the data to create annual averages. This is what has been done for the charts in the main body of the report.

The reason the software does not do this is that it was really designed to process multiyear data. If 9.5 years of data are processed, having 10 Januarys and 9 Julys creates negligible error. However, with only a little over a year of data, the double counted months can cause noticeable error.

Power Density versus Wind Speed

Wind turbines convert the kinetic energy of moving air into useful mechanical or electrical energy. The power of a column of moving air is given by the equation below.

$$P = 0.5\rho Av^3 \quad (\text{Equation B - 1})$$

Where

| | | |
|--------|---|---|
| P | = | power in a column of air (watts) |
| ρ | = | density of air (kg/m^3) (Roughly $\sim 1 \text{ kg/m}^3$) |
| A | = | cross sectional area of the column of air (m^2) |
| v | = | velocity of the air (m/s) |

Thus the power a wind turbine can extract from the wind is proportional to the cross sectional area of the rotor, the density of the air, and the cube of the wind velocity. At a given location the air density typically doesn't change by more than 10%. Therefore the big variable is the wind speed. Annual average wind turbine production is very sensitive to the annual average wind speed.

A wind turbine cannot extract all the energy from the air stream moving past it. A wind turbine's extraction efficiency typically varies with wind speed. In their range of maximum conversion efficiency most of today's wind turbines extract about 40% - 50 % of the wind's energy.

Power density is simply the power divided by the cross sectional area. Power density is given in units of watts per meter squared. (watts/m^2)

$$\text{Power Density} = 0.5\rho v^3 \quad (\text{Equation B - 2})$$

The cubic dependence of wind power density upon velocity underscores the importance of accurately characterizing the wind at a given location. A small uncertainty in wind speed translates to a large uncertainty in wind turbine power production. For example a 5% uncertainty in wind speed leads to a 15% uncertainty in power output. The cubic relationship also makes it more difficult to predict the long-term performance of a wind turbine. More information is needed than simply the average wind speed. For example, imagine a location where the wind speed is a constant five meters per second. The average power density of a column of air with a 1m^2 cross section is then $0.5 * 1.0 \text{ kg/m}^3 * 1.0 \text{ m}^2 * 5 \text{ (m/s)}^3 = 62.5 \text{ watts}$. Over a year the total energy of that column would be 547.5 kWh (this is found by multiplying the average power density by the number of hours in a year, then dividing by 1000 to convert to kilowatts). Now imagine a location where half the time the wind speed is 3 m/s and the other

half the time the wind speed is 7 m/s. The average wind speed is still 5 m/s but the average power density is now $0.5 \cdot 1.0 \cdot 1.0 \cdot (3^3 + 7^3)/2 = 92.5$ watts. This leads to an annual energy of 810 kWh.

Power density is listed in many of the graphs below because power density gives a better indication of wind turbine production than does wind speed alone. As can be seen from the graph titled “Speed and Power by Month,” power density correlates to wind speed, but doesn’t follow wind speed exactly.

Wind Speeds/Wind Directions

These first plots simply show the wind speed and direction for the monitoring period. Good data is shown with a solid line. Bad data is shown with a dotted line.

Speed and Power by Month

This graph gives the average wind speed and average power density for each month. This shows how the wind resource is distributed throughout the year.

Observations by Month

This graph shows the number of observations for each month. The greater the number of observations, the greater the probability the data is close to the long-term average resource.

Speed and Power by Hour

The top graph shows how the wind speeds and power densities are distributed by time of day over the whole year. The other 12 graphs show the same thing for each month. On top of each graph is an average wind speed and power density for the period in question.

Frequency and Speed by Direction

These graphs show how the winds are distributed by direction. The solid line shows the fraction of time that the wind comes from a particular direction. The dotted line shows the average wind speed of the winds coming from a particular direction. Above each graph the fraction of time that the wind is calm (below 1.0 m/s) is given. These graphs indicate the directions from which the strongest winds come. Special care should be taken to ensure the wind turbines have good exposure to winds from these directions.

Frequency of Speed and Percent of Power by Speed

These graphs show the distribution of wind speeds and power densities. The solid line indicates the fraction of time that the wind has a particular velocity. The solid line indicates the fraction of the total wind power contributed by winds at each wind speed.