University of the Philippines
College of Engineering
Energy Engineering Program

EgyE 205 – Energy Engineering Laboratory

Laboratory Exercise on
TECHNIQUES AND TOOLS FOR WIND ENERGY RESOURCE ASSESSMENT

Introduction

The evaluation of wind potential involves a series of steps which represent restrictions on the exploitation of the potential. The first step is to determine or estimate the theoretical potential, which is defined as the maximum wind energy output in a region. It is determined by using a reference wind turbine, available wind speed data and the available sites in that region.

Objectives:

1. Apply basic physical principles of wind on actual measurement data.
2. Gain basic skills in resource assessment of available wind energy for a specific site.

Materials and Methods:

1. One (1) month anemometer data (wind speed and direction)
2. Spreadsheet software (You may use any of your own choice).

Procedure:

Part 1: Wind energy analysis and calculations

The diurnal variation of wind speed provides information about the availability of suitable winds during the entire 24 h of the day. Hence, to study this pattern, overall hourly mean values of wind speed should be shown as in Figure 1.

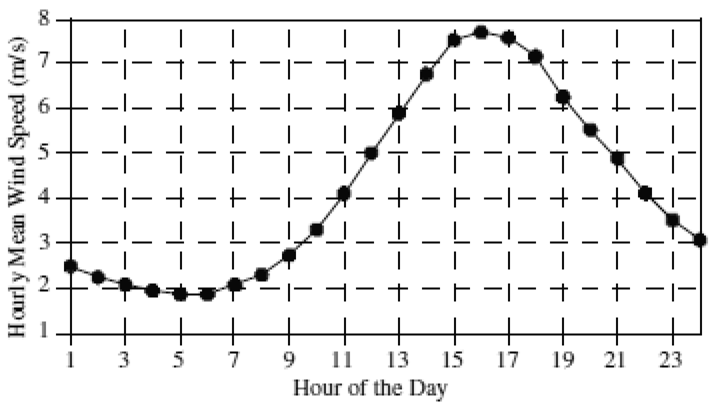

Figure 1. Diurnal variation of hourly mean values of wind speed.

One useful way of representing a wind data is the wind rose diagram (Figure 2). Wind roses are constructed using hourly mean wind speed and corresponding wind direction values. Like wind speed, wind roses also vary from one location to another and are known as a form of meteorological fingerprints. Hence, a close look at the wind rose and understanding its message correctly is extremely important for siting wind turbines. So, if a large share of wind or wind energy comes from a particular direction then the wind turbines should be placed or installed against that direction. In order to construct the wind rose and analyze the frequency distribution, all average hourly values of wind speed and wind direction can be used.

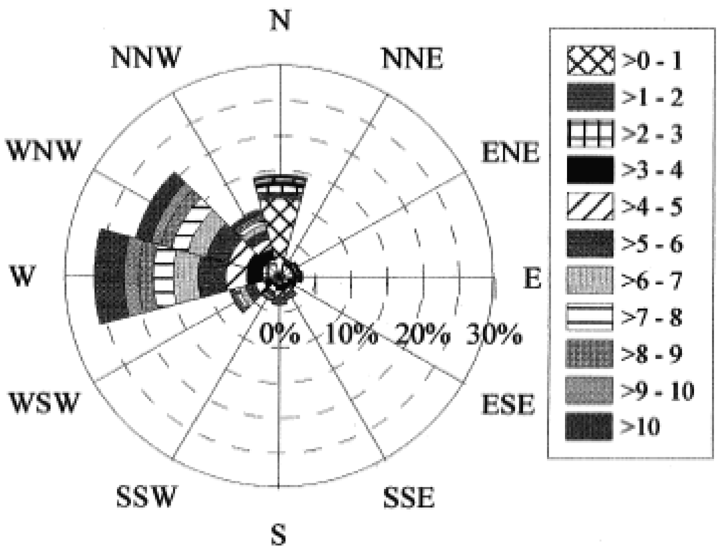

Figure 2. Example of a wind rose diagram.

Wind speed is not constant with time. Another way of assessing the availability of your wind data is the *frequency distribution*. Since most modern wind turbines usually start producing energy above 3.5 m/s, the percentage availability of wind speed above the cut-in-speed of wind turbines must be determined. To construct a wind frequency distribution, sort your wind data according to wind speed and group according to range of wind speed. In this case, use 1 m/s intervals. Count the number of occurrences per range and divide by the total number of observations. An example is given in Figure 3.

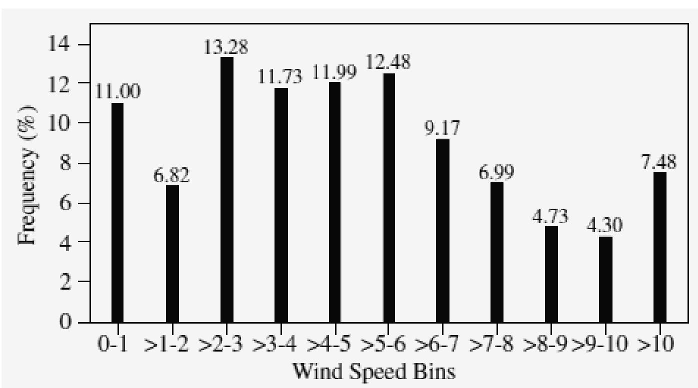

Figure 3. Percent frequency distribution of wind speed at 10 m above ground level.

Power from the wind, in turn, varies with the cube of the wind speed. Thus, for the determination of energy output and consequently, technical potential, in addition to average wind speed it is of importance to know the wind speed distribution, $f(v)$. So far, the Weibull function is the most widely used to represent the distribution of wind. This function expresses the possibility $f(v)$ to have a wind speed v during a year according to:

$$f(v) = \frac{\pi v}{2({v_m}^2)} \exp\left(\frac{-\pi}{4}\right)\left(\frac{v}{v_m}\right)^2$$

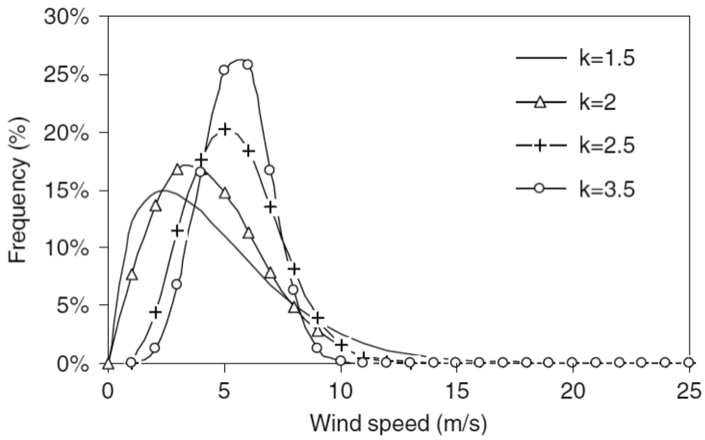

Figure 4. Wind speed frequency distributions based on the Weibull curve for a mean wind speed of 5 m/s and various k values.

With the distribution function and the power curve of a reference turbine, the periodic energy production $YEY(v_m)$ can be calculated by integrating the power output at every bin width:

$$YEY(v_m) = \sum_{v=1}^{25} f(v)P(v)8760$$

$f(v)$ is the Weibull probability density function for wind speed v, calculated for average wind speed v_m and 8760 is the number of hours in a year. $P(v)$ is the turbine power at wind speed v. This can be obtained by using a reference wind turbine with a certain power curve characteristic as illustrated in Figure 5.

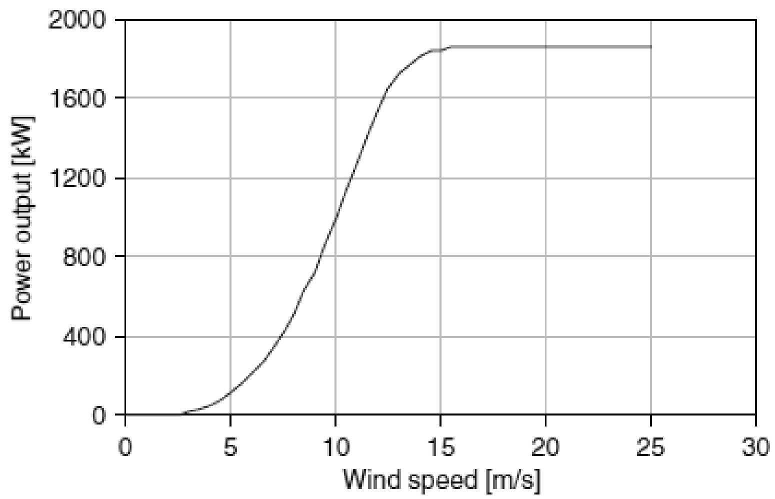

Figure 5. Power curve $P(v)$ of V66-1650kW wind turbine.

Part 2: Requirements:

Write a report about your wind data (select one month worth of data from the provided dataset), particularly the following:

1. Prepare the following graphs/diagram for your wind data
   a. Plot of averaged diurnal variation (1 graph per day – 30/31 graphs all in all)
   b. Windrose diagram for average twenty-four hours (24hrs) data (1 diagram per day – 30/31 graphs all in all)
   c. Frequency distribution of the wind intensities (1 graph for the whole month)

2. Compute the following:
   a. Basic statistics of wind speed (minimum, maximum, average). In which periods do these values occur?
   b. The Melchor Hall rooftop is approximately 84 meters above the ground. The anemometer is installed 2 m above the rooftop. What is the theoretical wind energy potential on this site if a 20 m wind turbine is installed using a mast 25 meters above the rooftop? What will be the total energy yield for a day?
   Assuming the distribution holds for the year, compute for $YEY(v_m)$.

3. Answer the following questions:
   a. Describe the directional characteristics of wind in your site. In which direction are maximum speeds dominant? In general, higher values are observed during daytime and smaller values during the evening and night hours. Is this true for your site?
   b. The Weibull function can also be represented as:

$$f(v) = \left(\frac{k}{A}\right)\left(\frac{v}{A}\right)^{k-1} exp - \left(\frac{v}{A}\right)^{k}$$

where:

$$A = \frac{2}{\sqrt{\pi}} v_m$$

Approximate the value for k using the Weibull function and the wind frequency distribution you have obtained. Explain your method of deriving or estimating k.

For submission:

- Formal report in pdf (name your file as: EgyE205_WindReport_Surname.pdf)
- Spreadsheet file of your computations (name your file as: EgyE205_WindComputations_Surname.xlsx)