Analysis of Wind Energy Data in Arizona

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Introduction:

In 2003, Northern Arizona University acquired a wind resource map which spurred interest in investigating wind development across Arizona. By 2004, NAU began installing several meteorological (met) towers, to measure the wind speed, direction and other relevant data at several locations across Arizona in order to evaluate the wind energy resource at the various locations. The locations of the met towers are shown in Figure 1. The analysis of the data consists of assessing the suitability of the wind resource for wind energy development and to understand the general characteristics of the wind for a given geographical region. To accomplish this analysis, NAU uses a commercially available software package, WindPro, to examine the statistics describing wind speed, wind direction, time series plots, diurnal distribution, seasonal distribution, turbulence intensity and Weibull distribution. The purpose of this research is twofold, one aspect being to summarize and present the characteristics of the wind data pertaining to wind energy as well as to compare the wind data to that predicted by the high resolution Arizona wind map.

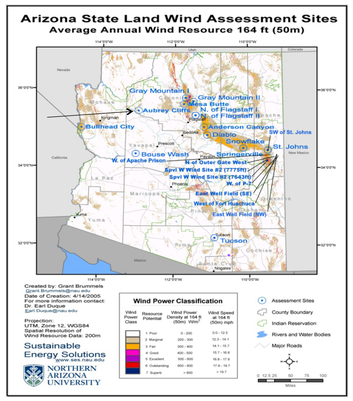


Figure 1: Wind Resource Map

Process and Methods:

The first step in evaluation the wind resource is to choose a suitable location for a met tower, typically using the Arizona wind resource map as a guide in finding a site. The key wind tower instrumentation, shown in Figure 2, are used to record ten minute averaged data which summarize the macroscopic characteristics of the wind in a given area. The data is then stored on a data chip in the data logger and later converted to a ASCII text file format.

Most of the NAU met towers are 30-meters in height, as shown in Figure 3, with a few 50-meter towers. Every two months, each data chip is collected and downloaded on the NAU computer system. The wind data is then run through a data quality check, converted into text files, analyzed with WindPro, then posted at the NAU Sustainable Energy Solutions web site (wind.nau.edu) for general access. It has also been used to compare and contrast with the AWS TrueWind wind map.

This poster will describe the basic aspects of the wind characteristics, and will include a comparison between the wind map and wind data for the following:

- Average wind speed
- Diurnal (daily) variation of wind speed
- Monthly/seasonal variation of wind speed

Wind Anemometer

Wind Vane

Data Logger

Figure 2: Wind Tower Instrumentation

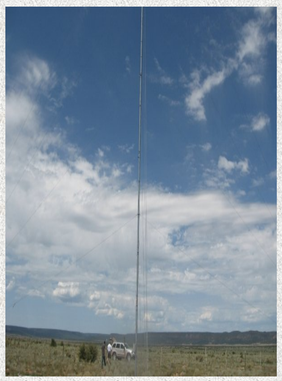


Figure 3: A 30-m tall met tower installed in Anderson Canyon.

Results:

WindPro 2.5 , a commercially available software package, is a major influence in this wind energy analysis to the extent that it amasses large quantities of wind data to ultimately summarize the characteristics of the wind pertaining to wind energy. WindPro is a powerful and user friendly tool in the sense that it outputs both graphical and numerical statistics based solely on a series of numerical wind speeds and wind directions. For a given tower location, Figure 4 outlines general wind characteristics describing, averaged monthly wind velocities, diurnal and monthly distributions as well as wind speed, direction and turbulence intensity plots. The actual data from figure 4 can be further analyzed by comparing the estimated seasonal wind speeds, shown in Figure 5. A cumulative WindPro report would include the following information:

- Statistics for time series
- Time series overview graph
- Time series detailed graph
- Table data
- Table data overview graph
- Table data sector wise turbulence graph
- Weibull data overview

The wind data from the WindPro report specifically refers to 30-m met data from the Aubrey Cliffs wind site, see arrow in Figure 1. Figure 4 highlights many important aspects related to this wind analysis, the most prominent being that the wind rose, Figure 4A, shows that the dominant wind velocities come form the SSW direction because the wind speeds are most abundant around this region. The report also emphasizes average wind velocities, Figure 4B, to the extent that it provides averaged monthly wind speeds. This numerical and graphical data can be compared to the graphical estimates presented by Figure 5 which compares the wind energy resource with respect to each season. The graphical comparison shows a direct correlation between the actual and approximated graphical distributions showing high wind speeds in the winter and low wind speeds in the summer .

Figure 4C graphically represents a diurnal distribution of how the wind velocities are distributed over a 24 hour time period of a given day. It specifically shows that the highest wind speeds are most apparent in the late afternoon for the Aubrey Cliffs location. Figure 4D, represents the turbulence intensity of the site over a given time plot which is computed by dividing the average wind speed by the standard deviation over a given time.

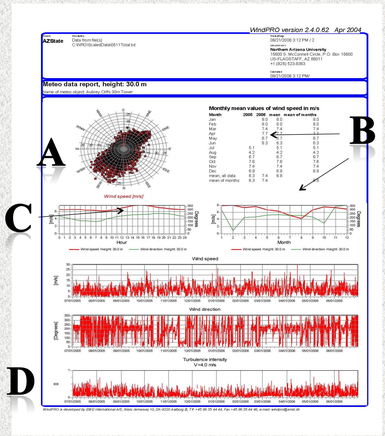
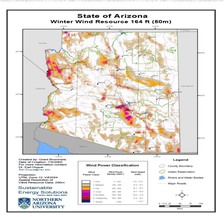
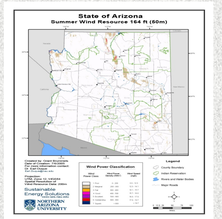
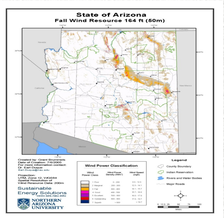


Figure 4: WindPro Report







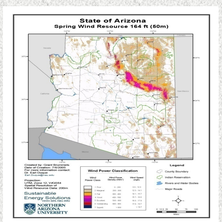


Figure 5: Seasonal Wind Speed Estimates

Weibull Analysis:

An overall description of the wind resource for wind energy is quantified using a Weibull distribution, which graphically plots the probability distribution versus wind speed for a given location. A Weibull distribution is dependent on the dimensionless shape parameters A and K where A describes the shape of the curve and K describes the height. Figure 6a, is an example of probability curve estimating the SSW wind speed histograms relative to probability. The statistics relating to Figure 6a show an A value of 7.7 m/s, a height of 1.58 m and average wind speed of 6.9 m/s. The overall Weibull distribution evaluates the probability curves for each wind direction, the most relevant being the red line that represents a cumulative the overall probability distribution. Again the curves are derived form the A, K and wind speed values at the bottom of Figure 6b. Ultimately, the Weibull data can be converted to estimate the power output for a given wind site.

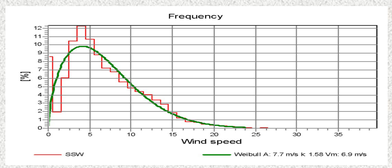


Figure 6a: Wind Speed Probability Distribution

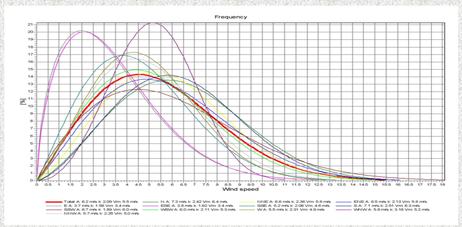


Figure 6b: Overall Weibull Curve Distribution

Conclusion:

This report has emphasized the key aspects in analyzing wind energy relating specifically to average wind speed, diurnal variation of wind speed and monthly variation of the wind speed. As a result, both graphical and numerical wind data resources have been used to understand the general characteristics of wind resources relative to specific geographical regions across Arizona. Essentially, this research provides first step in statistically evaluating wind data and ultimately leading to a detailed comparison between the tabulated wind data and the high resolution Arizona wind map.

References:

- Renewable Energy Resources 2nd Ed.
  - John Twidell & Tony Weir
- NRG Systems Website: http://www.nrgsystems.com/
- Sustainable Energy Solutions Website: www.wind.nau.edu