Project 10

In the project description we sketch the analysis of the problem we expect you to do. (Obviously you are welcome to do more.) To pass the project a short report should be written and handed in to the project supervisor. In addition the group should present their results in class. The presentation should take about 15 minutes. Please include a short introduction which will facilitate for other students to understand the results of the project. (Do not assume that the audience knows the subject.)

1 Introduction - Wind energy harvesting.

As a result of the increased concern about the drawbacks of conventional energy sources in terms of emissions of Carbon Dioxide and other Green-House Gases , renewable energy sources such as wind power attract more and more attention from governments, industry, research and the general public. Since after manufacture and installation of the wind mills does not emit any Green-House Gases, wind power is the energy source that is rapidly growing all over the world.

In this project you will address an important problems associated with wind-energy harvesting; the choice of a suitable location for wind turbine.

Choice of wind mills parks depends on many factors. One of these is the expected yearly available power P. The available power from wind is related to the cube of wind speed w, say, viz

$$P(w) = \frac{1}{2}\rho_{air} A_r\, w^3,$$

where A_r is the area swept by the rotor blades and ρ_{air} is the air density. Obviously the power output from the turbine is smaller than the available power and it is about 20%-30% of that value. In addition wind turbines cannot produce power for all wind speeds. The range in which power is produced is limited below by the cut-in speed and above by the cut-off speed. These take values between 2-4 m/s and 25-30 m/s, respectively, depending on turbine model. Since wind speed fluctuates in time and space in unpredictable way finding the expected power requires stochastic modeling of wind speeds variability.

The expected yearly available power P is computed using the so called long-term probability distribution of wind speed. Different locations will have different wind speed distributions. It is a general agreement that the Weibull model often closely mirrors the actual distribution of hourly/ten-minute wind speeds at many locations. In the project you will check this claim using specific data.

2 Expected Available Power

In the project wind measurements on Älvsborgsbron, from years 2005, 2008, available at

http://www.gvc.gu.se/Department of earth sciences/climate stations/climate-data/

will be used. The bridge is located at 57,6967 N and 11,9869 E. Average wind speeds are recorded hourly. Write few words about the data.

Load the data

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>>load Alvsborgsbron2005.mat
>>load Alvsborgsbron2008.mat
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and use the data to check the following hypothesis:

- Weibull cumulative distribution function (cdf) is a good model of wind speeds variability over a year. (Does Weibull model for 2008 wind speeds differs from the model for 2005?) Here the most important issue is whether Weibull model gives good estimates of the expected available wind power.

- It is enough to gather wind data over one year to get reliable estimates of the expected available wind power. Here you can compare estimates of the expected available wind power derived using Älvsborgsbron data measured years 2005, 2008, separately and using the Weibull model fitted to both data sets.

- Frequent measurements of wind speeds are needed to estimate the Weibull cdf. Here you can compare the Weibull estimates evaluated using whole data, i.e. winds measured hourly, with the estimates derived using recorded wind speeds every 6 or 24 hours?

Some remarks:

Weibull probability distribution is a commonly used model for wind speed W, say, variability over a year. Practically speaking the Weibull (long-term) cdf means that the normalized histogram of observed wind speeds is close to a Weibull probability density. Check how well the model works for the two data sets. (Here you could use Weibull probability paper to get a general impression about suitability of the Weibull model. Then you could fit Weibull cdf to the data using the function wblfit).

Probably you will see that the Weibull model is not accurate model of the long-term cdf over the whole range of wind speed values. However, since you are mostly interested in the estimation of the expected available power, the Weibull model can still be useful. Compare a fraction of the actual (observed) yearly available power and the one given by the Weibull model, viz. evaluate

$$\frac{1}{N}\sum_{i}^{N} w_i^3 / E[W^3].$$

If W has Weibull cdf then W^3 is Weibull distributed too (proof this). Consequently $E[W^3]$ is an explicit function of the parameters a, c. Write down the formula for $E[W^3]$ using parameters $m_W = E[W]$ and c.