Data management group exercise

February 2025

Introduction

In this group exercise, you will load some raw data from a file, perform some scaling and manipulations, calculate the 10 minute statistics and write these out to a database. You can write the data either to a MySQL SQL database or to an Influxdb timeseries database (or both!). The point is to introduce you to some typical wind and turbine data, give you some experience of databases and get you to think critically about the data.

Our dataset *2023072014-17.csv* contains 3 hours of 50Hz data for a few of the many channels from the data acquisition on our V52 wind turbine and its mast. All the data are as they have arrived from the data acquisition system. Most are already scaled in the data acquisition to the units you will need. The channels in the file are:

Channel	**Parameter**	**Units**
Date-time	Time stamp (UTC)	Yyyy-mm-dd hh:mm:ss.ms
Wsp_18m	Cup wind speed from metmast at 18m	m/s
Wsp_44m	Cup wind speed from metmast at 44m	m/s
Wsp_70m	Cup wind speed from metmast at 70m	m/s
Wdir_41m	Wind direction from wind vane at 41m	degrees
X_44m	N component of sonic wind speed at 44m	m/s
Y_44m	W component of sonic wind speed at 44m	m/s
Z_44m	Z component of sonic wind speed at 44m	m/s
T_44m	Temperature from sonic at 44m	Degrees C
AirAbs_18m	Absolute air temperature at 18m	Degrees C
AirAbs_70m	Absolute air temperature at 70m	Degrees C
Press_enc_2m	Barometric air pressure at 2m	hPa
MxTB	Tower bottom bending moment X component	mV/V
MyTB	Tower bottom bending moment Y component	mV/V
ROT	Rotor speed	rpm
ActPow	Active power from turbine SCADA	kW
Yaw	Nacelle yaw direction	degrees

Load the data into the analysis software you use. I recommend Python and have prepared a Jupyter Notebook to get you started.

Working with the fast-sampled data

First perform the following tasks on the fast sampled data:

1) Make time plots of each channel (you may combine them when this makes sense). Make the plots as wide as possible so you can see as much detail as possible.

2) The sonic anemometer has 3 orthogonal speed components X, Y and Z as you can see from the table above. The X and Y components lie in the horizontal plane with the Z component being the vertical speed. Using Pythagoras, calculate the instantaneous horizontal speed for the sonic (i.e. once for each scan). Add this as a column to your dataset.

3) The wind direction from the sonics can be obtained from the formula:

$$\theta = atan2(-X\,,-Y)$$

   You will get the result in radians and will need to convert it to the domain 0-360°. Atan2 functions vary in their definition (order of the arguments) so be warned! Add the sonic wind direction as a column to your dataset. Can you get the sonic direction to more or less agree to the wind vane direction at 41m?

4) The tower bottom bending moment signals come from two strain gauge bridges installed at the base of the tower. These signals are measured in mV/V but we need to convert them to kNM before we can make sense of them. Reading the calibration report, I have found several relevant pieces of information.

   The first is that these channels are SWAPPED so that what appears in the dataset as MxTB is actually MyTB and vice versa. Getting the channels mixed up is not so uncommon (there can be several hundred channels in a typical campaign) so be aware of this (be careful if you are making the measurements and be skeptical if you are using them).

   I have also found the gains and offsets you need to convert the signals from mV/V to kNM. They come from a combination of theoretical calculations and physical tests. The constants you need are:

Channel (true one!)	**Gain [kNM/(mV/V)]**	**Offset [kNM]**
MxTB	15953.4	1230.8
MyTB	15953.4	-3349.4

   Apply these values and calculate the signals MxTB_cal and MyTB_cal. These will have the units kNM.

Writing 10 minute statistics to the database

Now calculate the 10 minute means, standard deviations, minimums and maximums for each of the channels, including the ones you have derived. Tip: If you are using Pandas you can use the resample() method to do this very easily.

Calculate the turbulence intensity (for each ten minute period) for each of the cup anemometers and also for the sonic anemometer. Make a separate dataframe (table) for these results.

Choose a database type (MySQL or InfluxDB) and write the 10 minute statistics and the turbulence intensities to this database as five separate tables (or "measurements "in Influxdb). If you are using python, you can see some examples of how to do this on DTU Learn. We will provide you with the login details that you need.

Some questions to work on

Using either the fast sampled data or the 10 minute data as a basis, answer some of the following questions

5) You previously calculated the instantaneous sonic horizontal speeds and now have the 10 minute mean values for these. Since we now have the mean sonic X and Y values for each 10 minutes, we can calculate the mean speed from these as well. How do these values compare to the means of the instantaneous values?

6) Wind speed profiles are often characterised using a power law profile:

$$\frac{V_h}{V_{h0}} = \left(\frac{h}{h_0}\right)^{\propto}$$

Make one or more estimates of the wind shear index ∝ from the means of the wind speeds you have just calculated.

7) Why are there two absolute temperature sensors? Do the values have the relationship you would expect? The sonic also measures temperature but not very accurately. Does its value fit with those from the other two sensors?

8) Comment on the temporal resolution of the three different temperature signals. Do you know what the sonic temperature signal is especially useful for?

9) The thrust T on a wind turbine is given by

$$T = \frac{1}{2}\rho A C_T V^2$$

where ρ is air density, A is the swept rotor area, C_T is the thrust coefficient and V is the free wind speed. This thrust acts on the rotor shaft and causes a bending of the tower. The bending moment due to the thrust at the tower bottom is simply the product of the thrust and the tower height, TH. There are other contributions to the tower bottom bending moment but make this calculation and see if the measured bending moments are of the right sort of size. Because the turbine is close to full power, the thrust coefficient C_T will probably be about 0.8. What is your conclusion?

10) All the signals were sampled and stored at 50Hz. Was this sensible or necessary?