Data Logger Information and Installation Guide

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Contents

Overview

This is a guide for the set-up, installation, maintenance and data analysis for a wind speed, direction and irradiance data-logging system.

When looking at installing a renewable energy generator you need to be confident of the resource (solar, wind, water etc) at your particular location as this affects the energy generated at the site and hence the economics of the installation.

The solar resource can be monitored using a photovoltaic irradiance sensor. Solar resource data can be found quite accurately on-line, with some real irradiance levels used to confirm the results and calibrate for any shading issues there may be.

The wind resource is incredibly variable and depends upon the exact topology of the area. Houses, tree and valleys can all affect the local wind resource.

For this reason wind speed data is collected at a potential wind turbine installation site. This gives real data which can be used to assess the wind speed.

If a developer is installing a number of very expensive large wind turbines then they must be VERY confident about the wind speed data. The data must be robust and reliable and the developer will be willing to spend a lot of money on accurate industrial equipment to have lots of confidence in the data. For a large wind farm the wind speed sensor is generally installed on a wind-up tower with remote data logging equipment to store and send data via GPRS (mobile phone) data.

Generally at least 6 months of data is required; if possible a whole year or more to get seasonal variations. This means collecting data for a large wind farm is an expensive business, but necessarily so as there are large sums of money being invested.

In a remote rural location it might be that just a single small wind turbine could provide low but vital levels of electrification. These turbines cost in the region of a few hundred dollars, so the expense of taking wind data readings would not be a sensible investment. Hence wind data is not usually recorded - the cost of recording the data outweighs the cost of the turbine.

This can lead to turbine being installed in low wind areas, due to a lack of real local data.

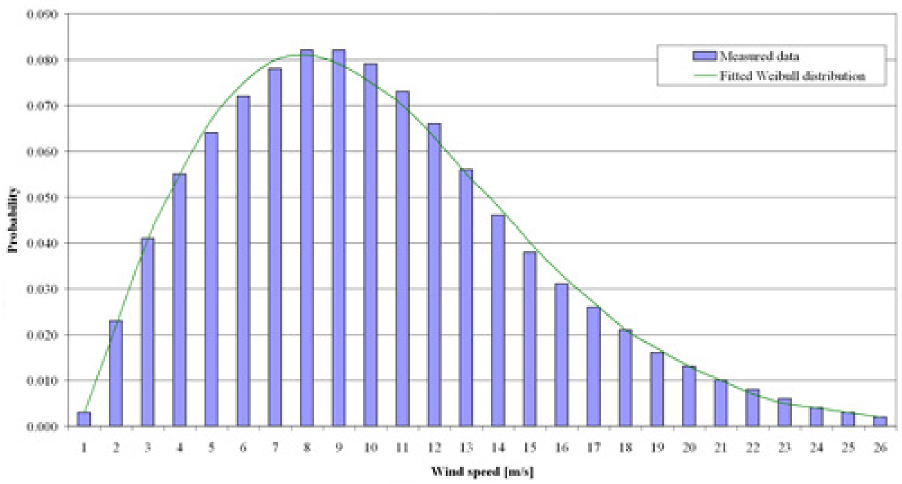
Knowing the frequency at which wind speeds occur is also very useful. A site might have a high average wind speed, but it could be that there is a very high wind for a short time (which would be difficult for the wind turbine to capture) and the rest of the time the wind speed is too low for the turbine to function.

For this reason it is good to know the wind speed against the frequency that the wind speed occurs.

To do this we 'bin' the data into different data range bins.

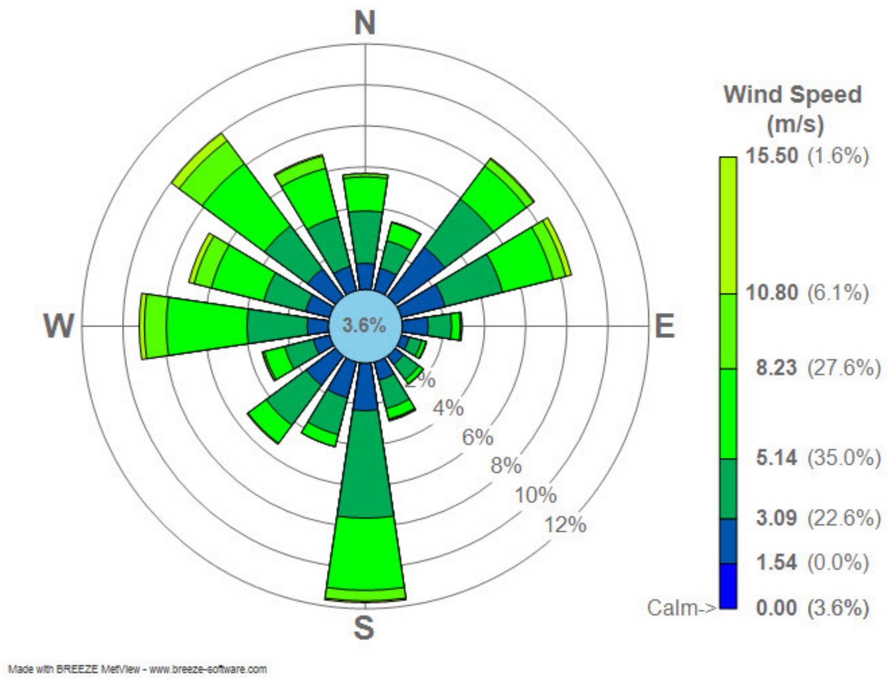
For example, if the wind has been 4m/s for 10 hours and then 10m/s for 1 hour, we would bin 10 lots within the 4m/s bin and 1 lot within the 10m/s bin. This creates a wind speed frequency graph.

There is an explanation of wind speed variations from the Danish Wind Energy Association here.



A graph of wind speed characteristic - from Wind Energy - The Facts website.

Wind speed data can be combined with wind direction data to produce a **wind rose** diagram. This is a visual way of showing the prevailing wind speeds.



Wind Monitoring Sensors

Wind Speed

An **anemometer** is a device to measure the wind speed. There are two main types:

Cup anemometers

These are typically three small cups which rotate at a rate proportional to the wind speed.

A cup anemometer.

Their output can either be a **switch** (typically a 'reed' switch and magnet) or a **hall-effect sensor** (whose output varies as a magnet passes). The cheaper versions are usually reed switch type.

These have moving and rotating parts, so they are more prone to hardware failure, but the electrical output is very simple.

The electrical output is a series of pulses, the frequency of which is proportional to the wind speed.

Ultrasonic anemometers

These are 'solid state' - meaning they have no moving parts. They work by having a number of ultrasonic emitters and receivers. The wind speed will affect the time taken for the signal to go from the emitter to the receiver. With a number of these ultrasonic pairs the wind direction can also be calculated.

An ultrasonic wind speed sensor.

These are relatively expensive to buy off the shelf, so are generally not used in low cost data-logging systems.

Calibration

The anemometer used must have been calibrated to some standard so we can be confident of the output data.

For this data-logger system we are using two different anemometers. If these data points correlate then we can be more confident in the data.

InSpeed Vortex Anemometer

Low-cost but calibrated and accurate anemometers are available from http://www.inspeed.com/.

The calibration factor is 1.1176 m/s per Hz, where 1 Hz = 1 pulse/second.

(From: http://www.inspeed.com/anemometers/vortex_wind_sensor.asp)

No-brand Anemometer

This is a replacement very low-cost weather station anemometer from Maplin Electronics in the UK.

The calibration factor is 0.7 m/s per Hz, where 1 Hz = 1 pulse/second.

Wind Direction

A wind vane is used to measure the wind direction. These are mechanical units which have a large 'flap' which is pushed by the wind so the other end points towards the direction of the wind.

A wind vane.

Calibration

The wind vanes used are low-cost versions designed for use with an off-the-shelf weather station. These were ordered from PCE Instruments.

This has an array of reed switches, giving 8 separate wind directions. These reed switches are used to introduce different resistors to the output line. Hence the output is a varying resistance, which is measured using a potential divider as a varying resistance.

The conversion of resistance to direction is done within the code of the data logging unit.

Irradiance

The solar resource is measured using a small photovoltaic cell with an accurate load resistor. This gives a voltage which varies according to the current from the PV cell.

This does not give highly accurate data, as it would need to be temperature corrected and the response accurately calibrated, but it will give data about the relative sunlight level in the location, cloud issues and sunrise/sunset times to align the wind resource data.

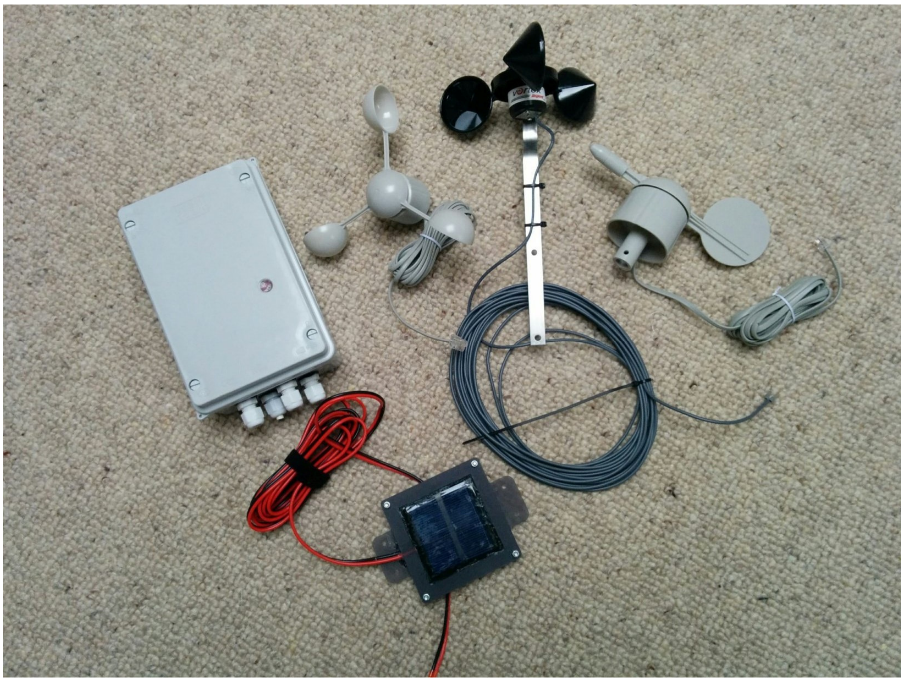
Calibration

Output voltage is proportional to irradiance with a conversion factor of 1mV = 1 W/m^2. This conversion is performed within the data-logger, so the recorded data is the irradiance. This low-cost unit is only accurate to within 10%.

Data logger unit

Overview of equipment

This is data logger equipment for installation:



This shows the data logger unit, 2 x anemometers, wind vane and irradiance sensor.

Internally to the data logger there is an 8 Gb SD card for data storage.

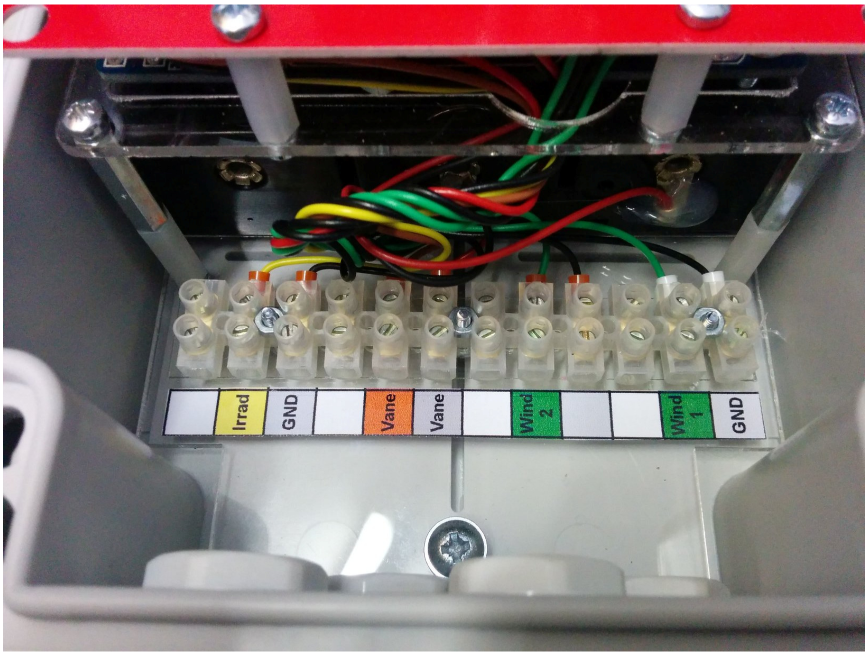
Tools required:

- 3mm flat headed screwdriver
- 5mm flat headed screwdriver
- No 1. Posidrive screwdriver
- 3 x D Cell Batteries

Connections

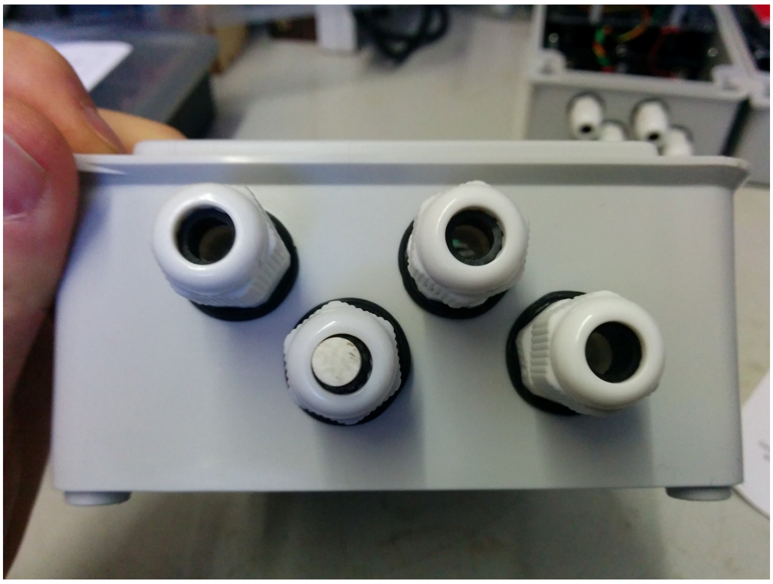
The unit is opened using the four flat head screws on the corners of the enclosure.

Use the large flat head screwdriver to open the case. These only require 1 turn to undo.



The various sensors connect to the screw terminals.

The anemometer cables pass through a compression gland.

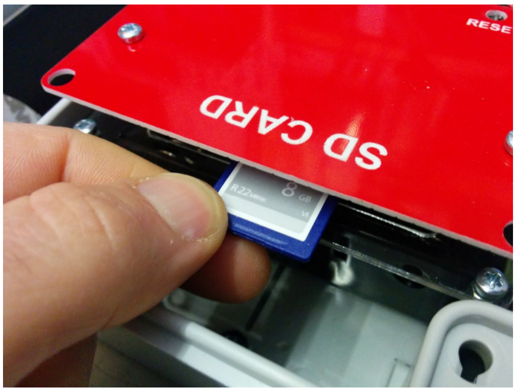


When enough cable is fed through, tighten the gland to create a waterproof connection.

SD Card Installation

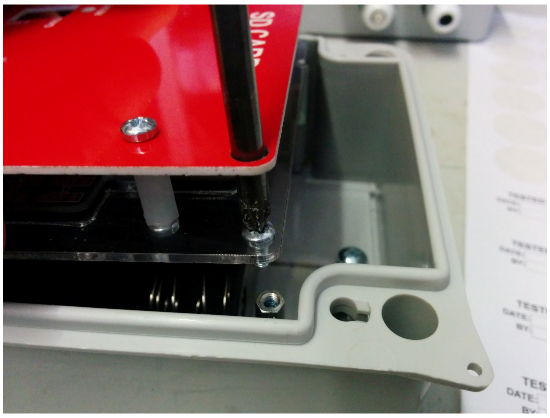
The data logger records data to a removable SD card. This can be any capacity from 2-8Gb, but larger cards will last longer, so 8Gb SD cards are supplied.

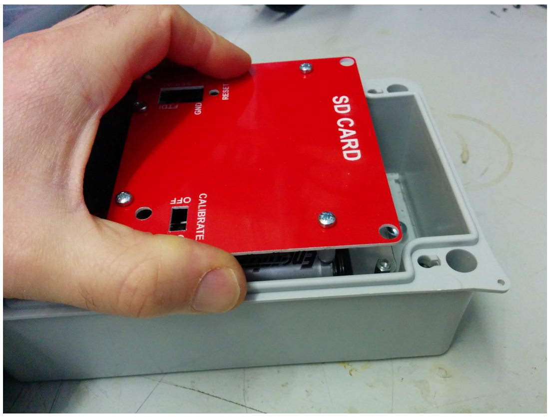
To insert/remove the SD card, push the card in slightly and it will spring out or click in.



Battery Installation

The batteries are changed by removing the four screws holding the top plate. This can be carefully moved to the side and the battery holder accessed.





Status LED Indicator

There is a red status LED which is visible from the front of the enclosure, near the calibrate switch when the unit is opened:

Normal operation will be shown by the LED status indicator on the front of the unit.

- Once every 10 seconds – Everything OK and recording data
- Twice per second – In calibrate mode (for calibration and configuration)
- Fast flash every second – No SD card inserted

Calibration Mode

This is done by pushing the switch marked 'CALIBRATE' towards the ON markings.

Calibrate mode is only used for setting up the Data Logger. See the Calibrate and Set-up section for more information. This is for high-level users only.

Data Logger Installation

SAFETY

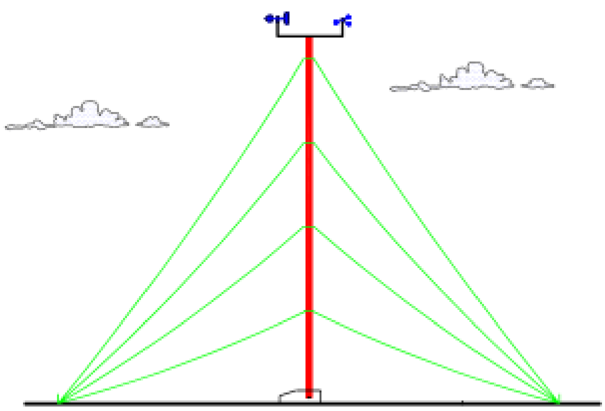
WARNING: The monitoring station installation process has inherent dangers, some of them life-threatening.

There are risks associated with falling towers, falling from towers, falling equipment, and electrocution.

Having experienced staff, following manufacturers' recommendations and ensuring good communication between the installation team members will minimize these risks.

Installation of anemometer and vane

This anemometer can be installed on a relatively simple construction, such as a long pole. This will be held upright with 4 guy roles which are pegged into the ground.



From: http://www.nrel.gov/wind/pdfs/22223.pdf

The wind speed equipment will be mounted at the top of the mast at a known height.

We need to ensure that the sensors nor the mast do not affect the data (for example: Tower shadow).

To do this we use booms from which to mount the sensors.

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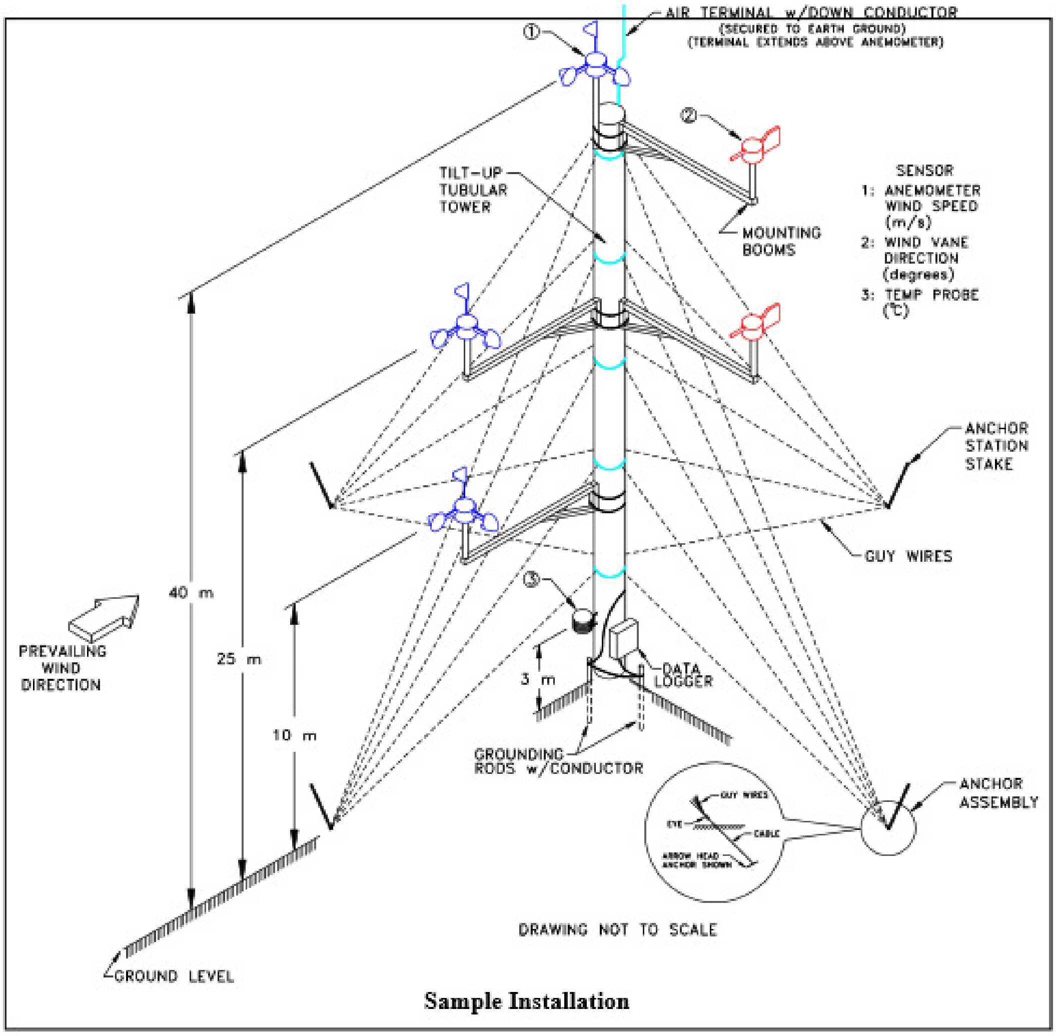
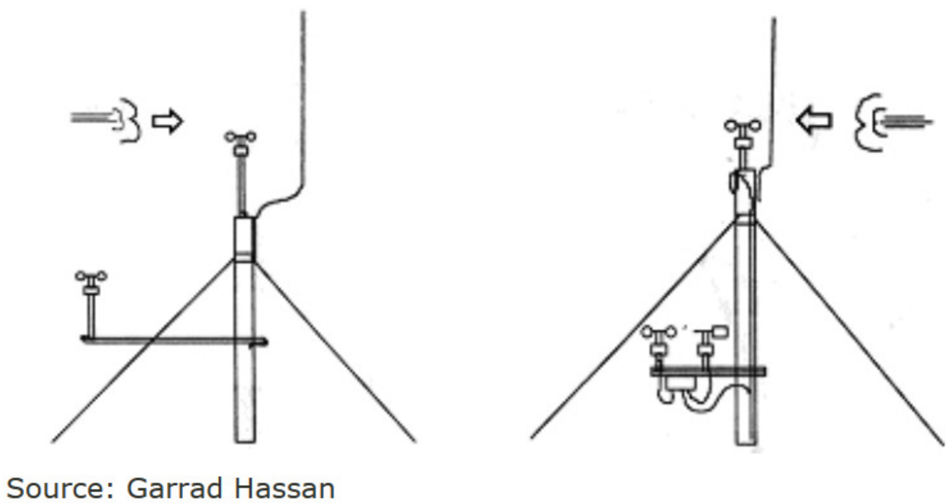


A sample installation. *From: http://www.nrel.gov/wind/pdfs/22223.pdf*



Good (left) and Bad (right) sensor installation.

From: http://www.wind-energy-the-facts.org/best-practice-for-accurate-wind-speed-measurements.html

Parts required

- Long pole
  - Bamboo or other straight pole
  - Need to know the length of the pole
- Guy ropes
  - Nylon rope can be used for temporary installation
  - Rot-proof
  - Need at least 4 x length of pole
- Anchors
  - Good metal pegs
- Wooden board
  - For the data-logger unit
- Cable ties
  - Outdoor rated
  - Nylon rope may also work
- Hammer
  - For pegs
- Spirit level
  - For alignment of pole vertically and horizontally
- Compass
  - For alignment of the wind vane
- Screwdriver
  - For terminal connections

This anemometry mast should be mounted as close as possible to the potential wind turbine site. It should be mounted as high as possible (if possible at the proposed hub height of the wind turbine).

Try to ensure that there are minimal obstructions to the wind, such as trees.

The anemometer must be as vertical as possible. Use the spirit level to ensure this.

Ensure correct orientation of the wind vane using the compass. Wind vane must be oriented towards North. This is marked on the side of the vane.

Installation of irradiance sensor

The irradiance sensor should be installed horizontally. This means we can compare the data with other horizontal irradiance data.

This can be checked with a spirit level.

Installation of the data logger

This can be mounted outside, but should be mounted out of direct exposure to weather conditions.

If possible this should be mounted on a wall with a roof overhang.

If not possible then use the wooden board attached to the base of the pole.

Add a cover using the wooden board to protect against very heavy rainfall.

Installation log

We need to keep good records of the installation, as this will be left in the remote location for a length of time.

Here is a sample installation log sheet:

Installation Log

Site Description	
Site Location:	
Longitude:	
Latitude:	
Elevation:	
Installation/ Commission Date:	
Commission Time:	
Soil Type:	
Surroundings Description:	
Prevailing wind direction:	
Notes:	

Equipment Details					
Description	*Serial No*	*Mounting Height*	*Sensor Calibration*	*Data Logger Ref*	*Notes*

Local Contact Details	
Name:	
Address:	
Phone:	
Other:	

Installer Contact Details	
Name:	
Address:	
Phone:	
Other:	

Operation and Maintenance

Status LED

Normal operation will be shown by the LED status indicator on the front of the unit.

- Once every 10 seconds – Everything OK and recording data
- Twice per second – In calibrate mode (for calibration and configuration)
- Fast flash every second – No SD card inserted

Battery Life

The unit takes 3 x D cell batteries.

Good quality batteries should last in the region of 2-4 months.

The battery voltage is monitored and recorded. If this is below 3.3V then the batteries are empty and the data cannot be trusted.

Ensure the batteries are checked at least every month.

General Maintenance

Two or three local operators should be trained on checking the unit. They will be in charge of checking the loggers every week.

A notebook should be used to record the operation of the data-logger units.

The unit should be checked at least once per week.

- Water ingress should be checked.
- Battery voltages should be checked.
- Connections should be checked.

Site Visit Checklist

Site inspections are sensible throughout the data logging period to ensure the correct functioning of the equipment.

Here is a simple site visit checklist:

Site Visit Checklist

Site:	
Date:	
Assessor:	
Notes:	

Y/N?	***Task***
	Area free from vandalism?
	Tower straight?
	Guy ropes taut and undamaged?
	Anchor points secure and undamaged?
	Anemometer spinning freely?
	Direction sensor spinning feely?
	Irradiance sensor horizontal and clean?
	Wires secure and undamaged?
	Data Logger unit secure and undamaged?
	Batteries tested? Battery voltage and date:
	Batteries replaced? Note brand and date:
	Download of data performed?
	Check of data from download. Is it OK?
	SD card replaced?
	Check new data recording correctly?

Data Analysis

Once the unit has been left to collect data, we need to return to the unit to record and analyse the data.

The data is stored as a new .csv file every day. It is designed to be human readable, with headings written in a human readable format. Data is taken every sample period (set by the user, but 1 min averages are the standard for small wind turbines (10 min averages for large wind turbines)) and stored to the SD card.

Data Download

To obtain the data, the SD card is removed.

It is then plugged into a computer with an SD card reader.

The data will be as a series of daily files each with data points.

These are as .csv files with the titles of the file made from the date.

For example "D160113.csv" is data from the 13th (13) of January (01) from the year 2016 (16).

Copy the files to a suitable location.

Example data

Here is some example data. It should be in human readable format.

Ref	Date	Time	Wind 1	Wind 2	Direction	Irradiance Wm-2	Batt V
BB	13/01/2016	11:19:47	0	0	E	38	4.59
BB	13/01/2016	11:20:47	0	0	E	38	4.59
BB	13/01/2016	11:21:47	0	0	E	38	4.57
BB	13/01/2016	11:22:47	2	0	N	38	4.57
BB	13/01/2016	11:23:47	3	0	NW	41	4.57
BB	13/01/2016	11:24:47	15	0	NW	41	4.57
BB	13/01/2016	11:25:47	43	0	W	41	4.57
BB	13/01/2016	11:26:47	3	0	N	41	4.57
BB	13/01/2016	11:27:47	0	0	N	38	4.57
BB	13/01/2016	11:28:47	12	0	W	38	4.57
BB	13/01/2016	11:29:47	24	0	W	38	4.57
BB	13/01/2016	11:30:47	2	0	N	35	4.57
BB	13/01/2016	11:31:47	0	0	N	35	4.57
BB	13/01/2016	11:32:47	5	0	N	32	4.57
BB	13/01/2016	11:33:47	0	0	N	32	4.57
BB	13/01/2016	11:34:47	6	0	SE	32	4.57
BB	13/01/2016	11:35:47	8	0	E	32	4.57
BB	13/01/2016	11:36:47	7	0	N	32	4.57
BB	13/01/2016	11:37:47	8	0	N	35	4.57
BB	13/01/2016	11:38:47	13	0	NW	35	4.57
BB	13/01/2016	11:39:47	29	0	W	35	4.57

Ref

This is a 2-byte variable which can be used as an ID for the data-logger.

This is useful if the loggers are placed in different locations but the data will be processed on the same machine as it is easy for data mix-ups.

Date

The date in the format DD / MM / YYYY.

This is stored by an on-board real time clock and should stay correct within 1min for 1 year.

Time

The time in the format hh:mm:ss. These have been set to UK GMT.

This is stored by an on-board real time clock and should stay correct within 1min for 1 year.

Wind 1

This is the number of pulses from the anemometer connected to the Wind 1 input. This is a count of pulses from the previous time sample.

These pulses need to be converted into a wind speed using the anemometer calibration factor.

Eg:

With the data and the calibration factor of 1.1176m/s per Hz for Wind 1:

BB	13/01/2016	11:28:47	12	0	W	38	4.57
BB	13/01/2016	11:29:47	24	0	W	38	4.57
BB	13/01/2016	11:30:47	2	0	N	35	4.57

Then the wind speed data would be for the shaded data:

24 pulses between 11:28:47 and 11:29:47

This is 24 pulses in 60 seconds so an average output of 24/60 = **0.4Hz**.

This equates to a wind speed of 0.4 * 1.1176 = **0.447m/s**.

Wind 2

This is the number of pulses from the anemometer connected to the Wind 2 input. This is a count of pulses from the previous time sample.

These pulses need to be converted into a wind speed using the anemometer calibration factor.

See example in Wind 1.

Direction

Wind direction is a human readable indicator of the wind direction with a resolution of 8 segments.

This would be N, NE, E, SE, S, SW, W, NW.

Irradiance wm-2

This is an irradiance value in W/m^2. This has already been converted so the reading here is the

Batt V

This is the battery voltage in volts DC.

When the unit reads 3.3V then the batteries are totally flat and the data recorded cannot be trusted, although it is still recorded if there is energy available within the batteries.

If this reads 3.3V or below then the data should be disregarded from any a analysis.

This is for operation and maintenance.

Data Analysis Program - Winda

There will be many files on the SD card. One for each day the unit has been installed. With one minute averaged data then there will be 1440 data records per day.

This makes data analysis difficult, especially with file length restrictions in spreadsheet programs like Excel.

A Python script has been produced to analyse the .csv files.

NOTE: This is a work in progress and updates will happen to this code

1. Download Python

This will need Python 3.4 to be installed from the link:

https://www.python.org/download/releases/3.4.0/

2. Download Winda

You will also need the Winda windows install which is available here:

https://github.com/matthewg42/winda/raw/master/win32/winda.zip

3. Unzip to a convenient location
4. Copy CSV files to the folder where winda was unzipped
5. Open cmd
6. cd into folder
7. in cmd shell
    a. Add files to database:

       c:\whatever\> winda add D160115.CSV

       c:\whatever\> winda add D160116.CSV

       c:\whatever\> winda add D160117.CSV
    b. Dump of processed data:
    c. c:\whatever\> winda export

d. Get speed probability CSV data for graphing with various filter options and the option to split by wind direction:

   c:\whatever\> winda speeds > somefile.csv

   c:\whatever\> winda speeds --direction > somefile.csv

   c:\whatever\> winda speeds --date 2016-01-16

   c:\whatever\> winda speeds --from "2016-01-16 12:30" --to ""2016-01-16 14:30""

e. Rest the database:

   c:\whatever\> winda reset

Create Wind Speed Distribution

The data files can be converted into a wind speed probability distribution using the following command:

c:\whatever\> winda speeds

This will create a .csv file with the wind speeds listed with their relative probability.

This .csv file can be used to produce relevant graphs.

Create Wind Rose

The data files can be converted into a wind speed probability distribution for EACH direction using the following command:

c:\whatever\> winda speeds --direction

This will create a .csv file with the wind speeds listed with their relative probability for each of the 8 wind directions.

This .csv file can be used to produce relevant graphs.

International Standards

At present there is no international standard for wind resource analysis.

Recommendations provided by the International Electrotechnical Committee (IEC), the International Energy Agency (IEA) and the International Network for Harmonised and Recognised Wind Energy Measurement (MEASNET) provide detail on minimum technical requirements for anemometers, wind vanes and data loggers.

IEC 61400

https://en.wikipedia.org/wiki/IEC_61400

This is an international standard for assessing wind turbine power performance.

Information and Resources

- **NREL Wind Resource Assessment Handbook**

  Very detailed guide, for large wind resource assessment.

  http://www.nrel.gov/wind/pdfs/22223.pdf

- **Engineering in Development - Energy**

  From Engineers Without Borders UK

  Information on all technologies with a focus on small off-grid systems

  https://docs.google.com/viewerng/viewer?url=http://www.ewb-uk.org/wp-content/uploads/2015/09/EWB-ENRGY-INTERACTIVE.pdf

- **Wind Resource Assessment Handbook**

  Similar to NREL but with some more up-to-date info.

  http://www.inscc.utah.edu/~krueger/5270/wind_resource_handbook.pdf

- **Observers Handbook - Wind**

  http://www.metoffice.gov.uk/media/pdf/s/p/OH_Chapter51.pdf

Data Logger - Calibration and set-up

Note: This is for high level users only.

Programming lead

To configure this unit you will need a USB to Serial programming lead. You will need to download the relevant driver.

If we have provided the lead it will be the CH340 version:
http://www.elecrow.com/wiki/index.php?title=USB_Transformer

The driver for this is available here:

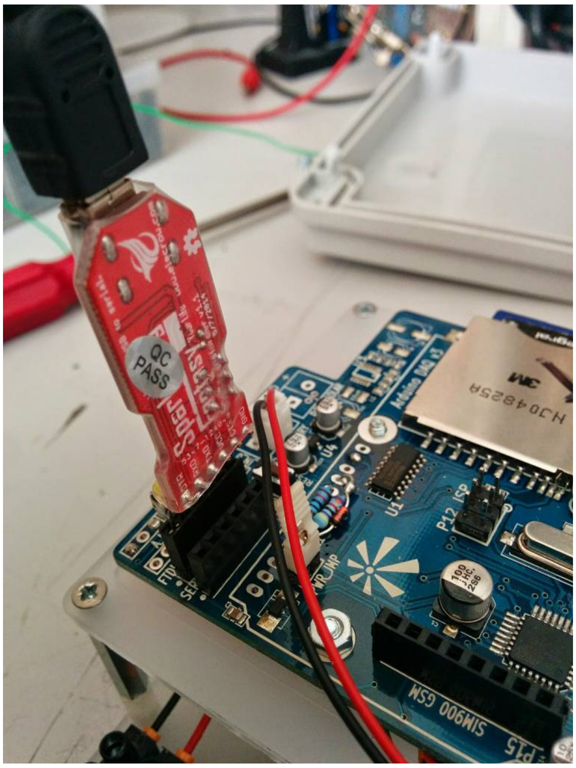
http://www.elecrow.com/wiki/images/a/a6/USB_Transformer_Drivers.zip

Open and extract the program, then run the relevant program, depending upon your operating system.

Otherwise use a standard FTDI cable.

Once the driver is installed, plug in the programming lead and you should see it install and become a COM port (on a Windows machine).

If using CH340 serial lead, plug in the programming lead into the port marked 'SERIAL' and 'P14'. ALWAYS DOUBLE CHECK THE POLARITY. The USB-Serial lead has one side which is GND (black wire) and one side which is RESET/DTR (green wire). The GND faces towards the P14 number and the RESET/DTR faces towards the small dot.



Otherwise plug in the FTDI cable to the FTDI connection marked P13. The lead has one side which is GND (black wire) and one side which is

RESET/DTR (green wire). The GND faces towards the P14 number and the RESET/DTR faces towards the small dot.

In both situations, data is transferred at **115200 baud with no parity and 1 stop bit**.

Monitor data on Computer

When the lead is plugged in this will power the unit.

Open a serial monitor program (one is built in to the Arduino IDE). Set the baud rate to 115200.

You will see a text string every so often. If the unit is NOT in calibrate mode then the text string only appears every time the data is written to the SD card (the sample time).

If you are in calibrate mode then you will see the data approximately once per second. This data will NOT be recorded to the SD card.

The data will appear in rows, in the following order:

Ref	Date	Time	Wind 1	Wind 2	Direction	Irradiance Wm-2	Batt V
BB	13/01/2016	11:19:47	0	0	E	38	4.59
BB	13/01/2016	11:20:47	0	0	E	38	4.59
BB	13/01/2016	11:21:47	0	0	E	38	4.57

These column headers will appear on the .csv file written to the SD card.

Enter Calibrate Mode

This is done by pushing the switch marked ‘CALIBRATE’ towards the ON markings.

Configure Data Logger Settings

To configure the data logger settings you will need to be in ‘calibrate’ mode, have the programming lead correctly plugged in. The programming lead will power the unit, if no external power is applied.

You can adjust the following parameters:

Reference

Type: “R??E” to change the reference, where ?? is a two digit ID number

Time

Enter the EXACT time in the format:

“T??????E”, where ?????? is the time in the format HHMMSS.

A good way to do this is to check the clock, type in a time maybe 30 seconds after that time, but do not press return. Watch the computer clock and when it is EXACTLY that time then press return to send the data.

Date

Enter the date in the format:

“D??????E”, where ?????? is the date in the format DDMMYY.

Sample Period

This is the time over which the wind and vane data is averaged. Current and Voltage are measured instantaneously when the data is recorded. This is set in seconds from 1 to 99999 seconds.

This can be adjusted using the command S?????E, where ????? is the sample period in seconds. At the end of this period data will be sampled and stored.