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hort Interval Data Logging Embedded System For Microgeneration Monitoring and Control

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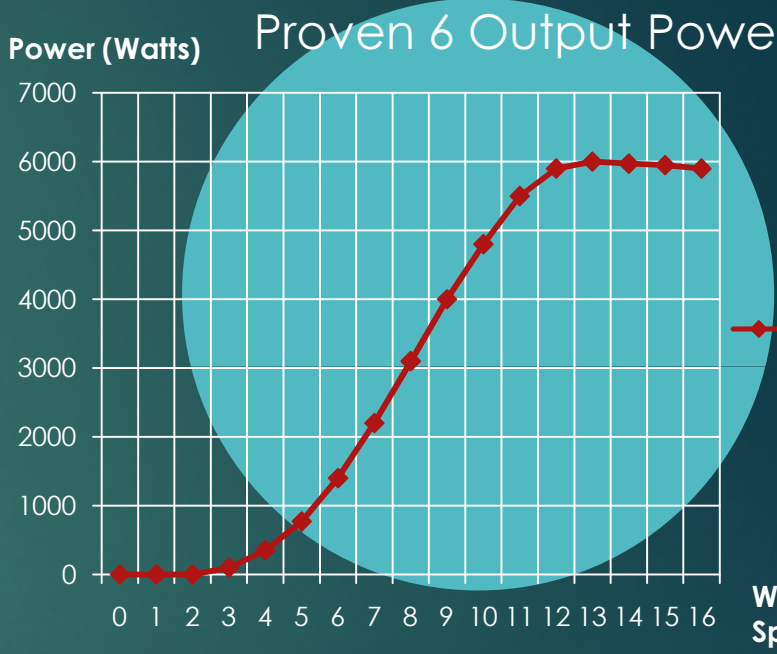
Motivation

- Investigate turbine under-performance
- Accurately create a wind profile for the site
- Desire for fast data to potentially catch any subtle short interval behaviour… Is there something we are missing ?
- Identify ,if any, the advantages of faster sampling (> 1Hz)
- Provide a tool to cater for further research in the fields of turbine modelling and control. Cost appropriate !
- Investigate applicability of low cost hardware in this field

Site Description

- Proven 6kW turbine installed on Tallaght campus
  Coordinates 53.291347, -6.365488
- Height = 15m Diameter = 5.5m V_rated = 12m/s
- Site Average Wind Velocity approximately
  5 m/s and quite gusty
- Met mast in close proximity to turbine
- Turbine grid connections in main building
  (Rectifier and two paralleled SMA 3kW Invertors



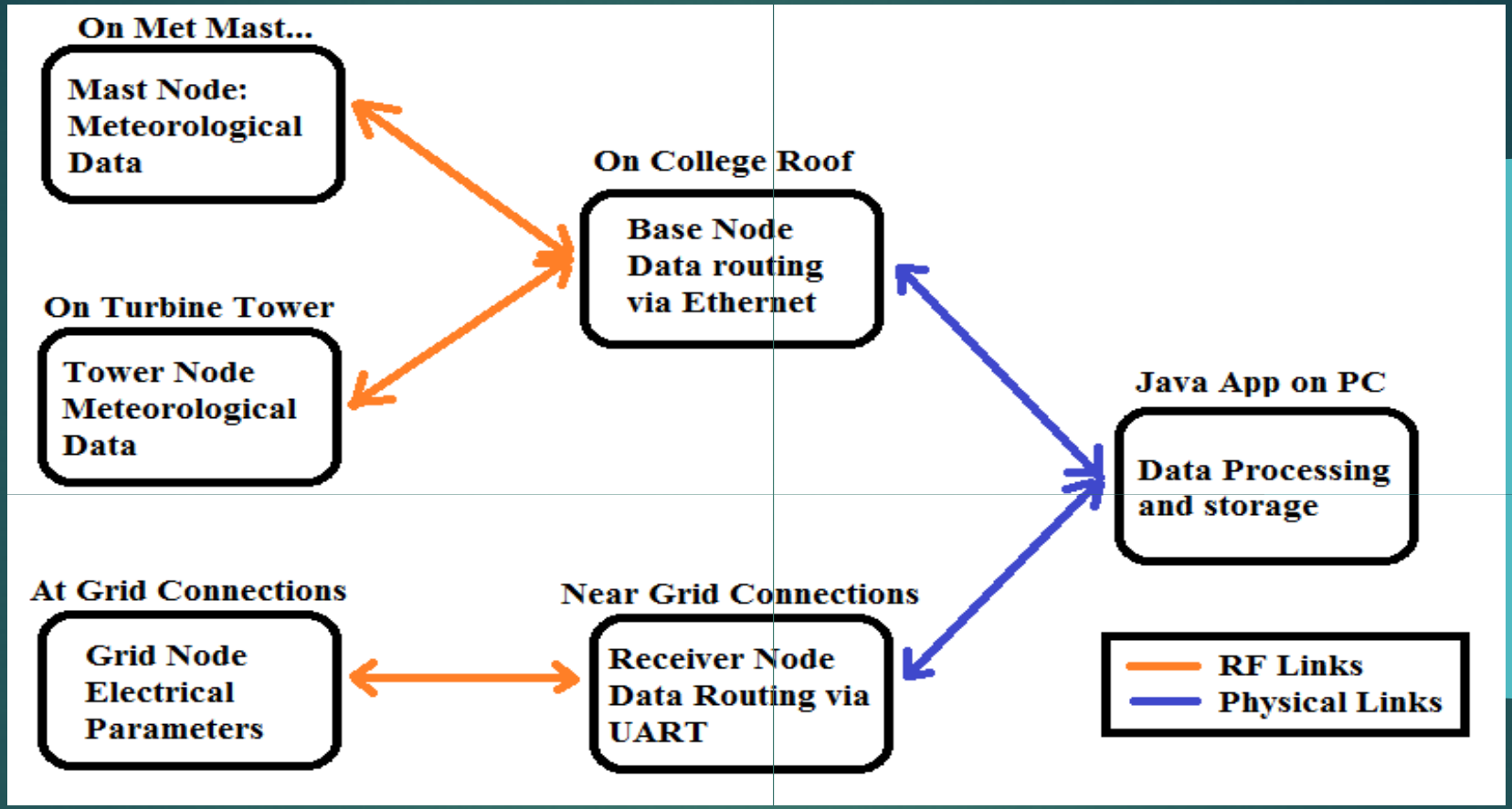
Background Research

- Research into WTG monitoring, modelling and control yielded the ideal metric set. Which metrics and how.
- Necessary sample rate of each metric. Same sample rate of each metric ?

System Design Criteria

- Off the shelf hardware in novel configuration
- System should measure appropriate metrics for WTG modelling and control.
- Fast data (1Hz or greater) gathered and time-stamped in a raw format to allow for post-processing.

stem Functional Topology



- **Two Types of Node:** Data Gathering and Intermediate
- **Intermediate Nodes** simply enables data to be routed to/from PC
- **Data Gathering Nodes** actively poll sensors and report data via RF

Slide 5

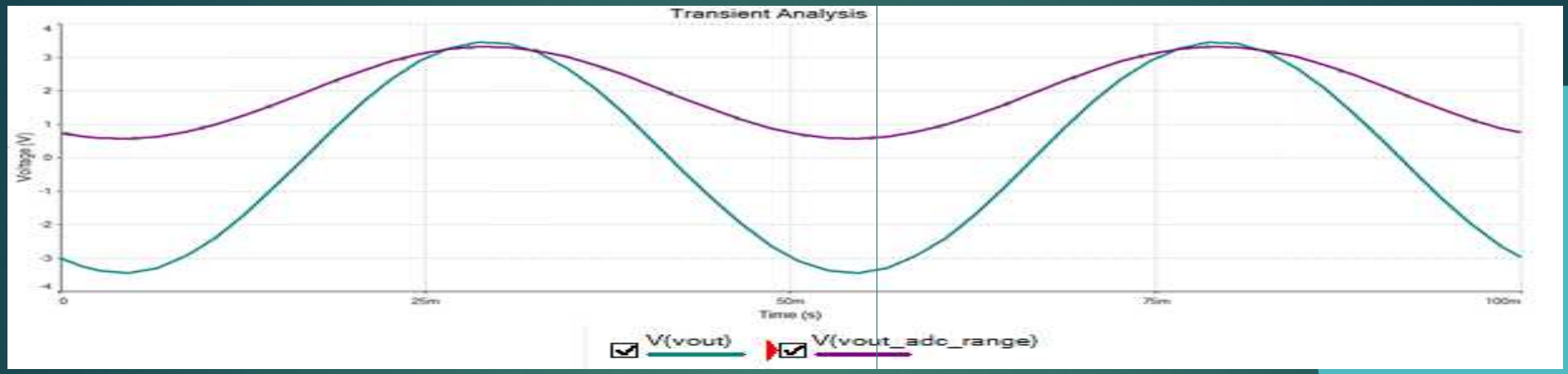
JL1 Make sure to mention what the nodes actually are .. dev boards interfacing with peripherals
Jay Long, 18/02/2015

ample: Grid Connections Node

- Novel hardware designed to allow for the safe and accurate measurement of the turbines Wild AC characteristics
- Node Measures the turbines raw output characteristics (Voltage , Current and Frequency), the magnitude of the rectifiers DC output and the invertors output power.
- Passive Diode Rectifier Ballast complicates the measurement of Voltage and Current… (Ryu 2011, Kooning *et al.* 2013) .. RMS Values required.. Power Factor
- Isolated from user via RF link and opto-isolation
- 2 embedded boards used. Master and Slave
  > Time /CPU intensive tasks delegated to slave
  (Wild Current and Voltage Signals Sampled at >6kHz)
  > Control board can then monitor other metrics accordingly

d Node: Wild AC Signal Info

ardware to scale and condition high level voltage



ffect of ballast on rectifier output on current and voltage expected.

Measurement of the true RMS value of the output voltage and current can yield nformation about entire grid side set up.

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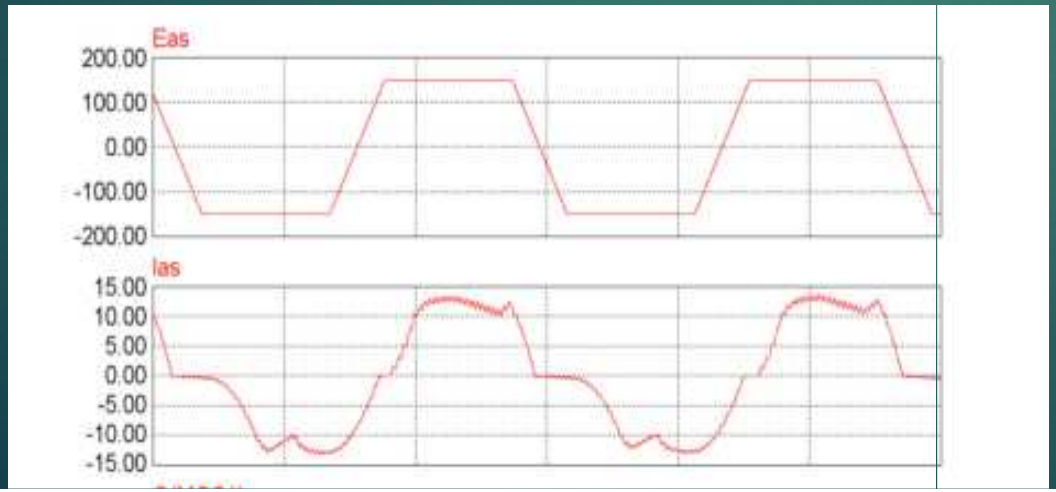
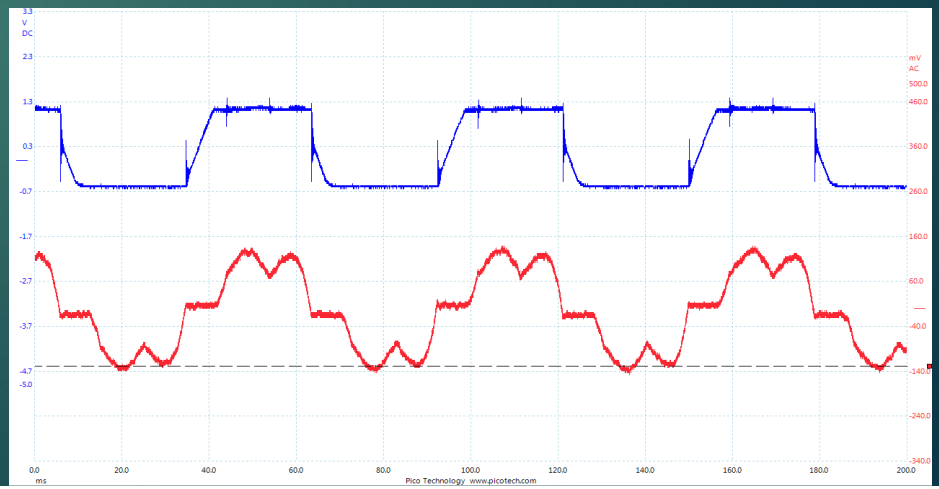
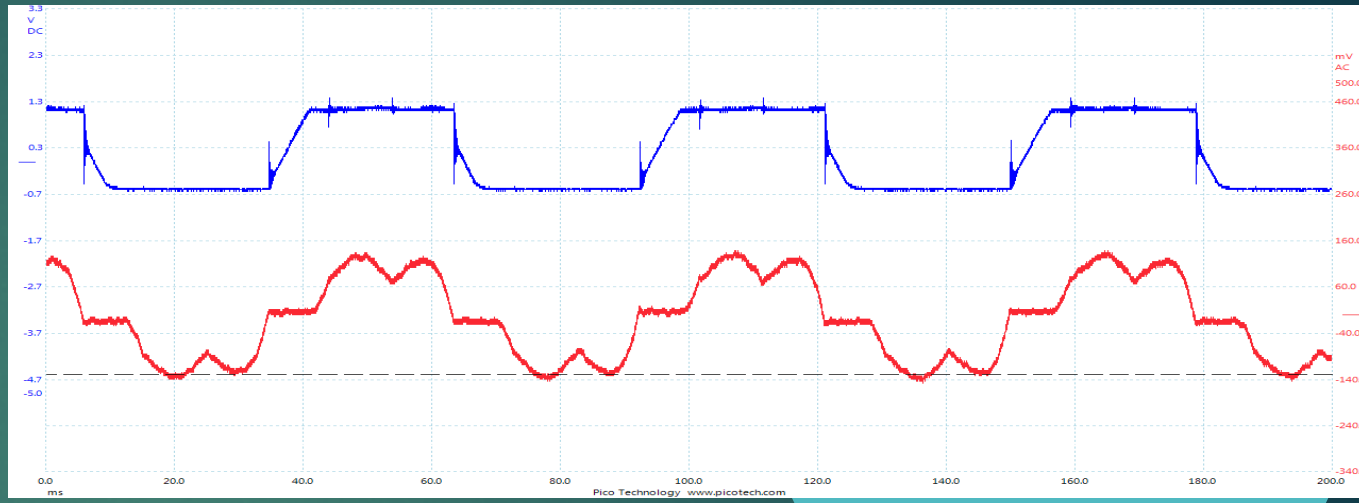


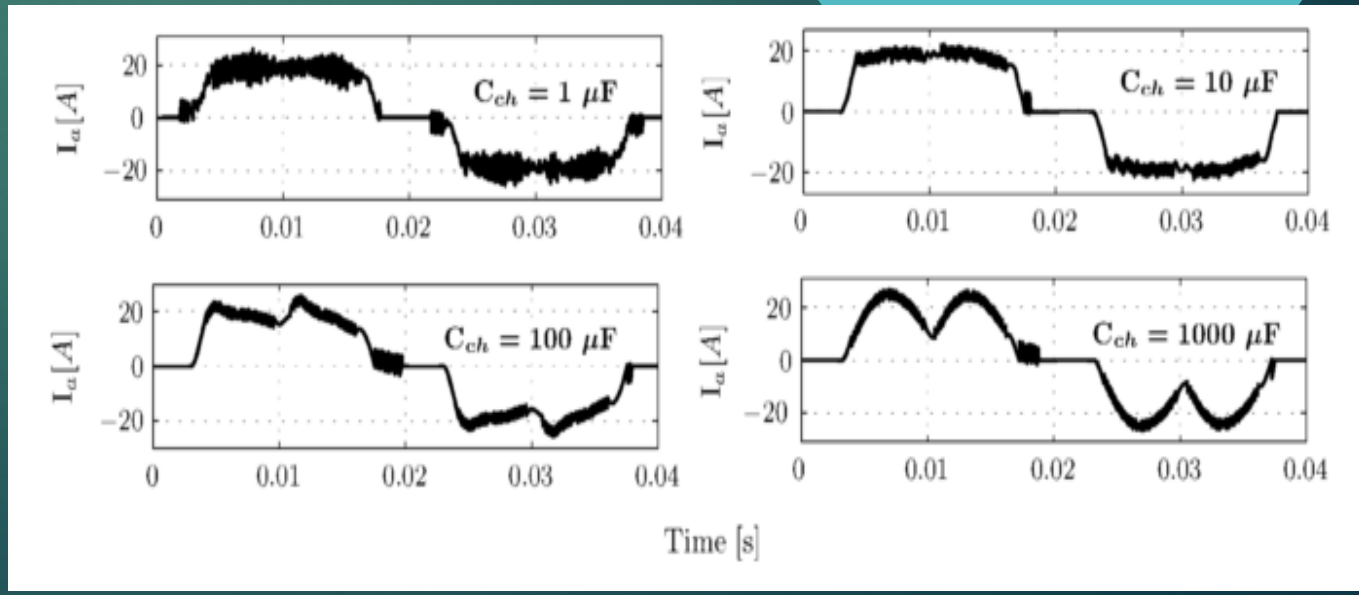


Possible Uses for This Functionality

The envelope of the current signal is telling here:



If we examine Kooning *et al.*'s experiments on the effect of capacitive ballast at rectifier output….. This hurts our Power Factor !



Other Network Components:

- The following outline other nodes, all programmed in Embedded C, used in the networ All nodes have unique RF address to allow for remote calibration etc.

Data Gathering Nodes:

- **Mast/ Tower Node:** Gather data and sends this data each second to an Ethernet base node on the roof. Atmospheric data. Wind velocity, temperature etc.

  Renewably powered (Solar PV)

- **Grid Node:** Powered by mains connection. Outlined previously

Intermediate Nodes:

- **Base Node:** Mentioned above. Receives data from remote RF nodes and forwards dat onto PC via an Ethernet connection. Vice Versa
- **PC Grid Data Receiver Node:** Isolates PC, thus the user, from any potentially harmful gri level signals.

Logging The Data

- Custom app written in Java
- GUI app that allows user to easily connect to:
  > Mast and Tower Nodes Via Ethernet and Base on roof
  > Grid connections node via UART to RF receiver node
- Self Healing, multithreaded app that receives data packets from each node at 1Hz and logs in CSV (One per day)

Sample Data:

- Logged Against Time Stamp (Note this is an Excerpt!)

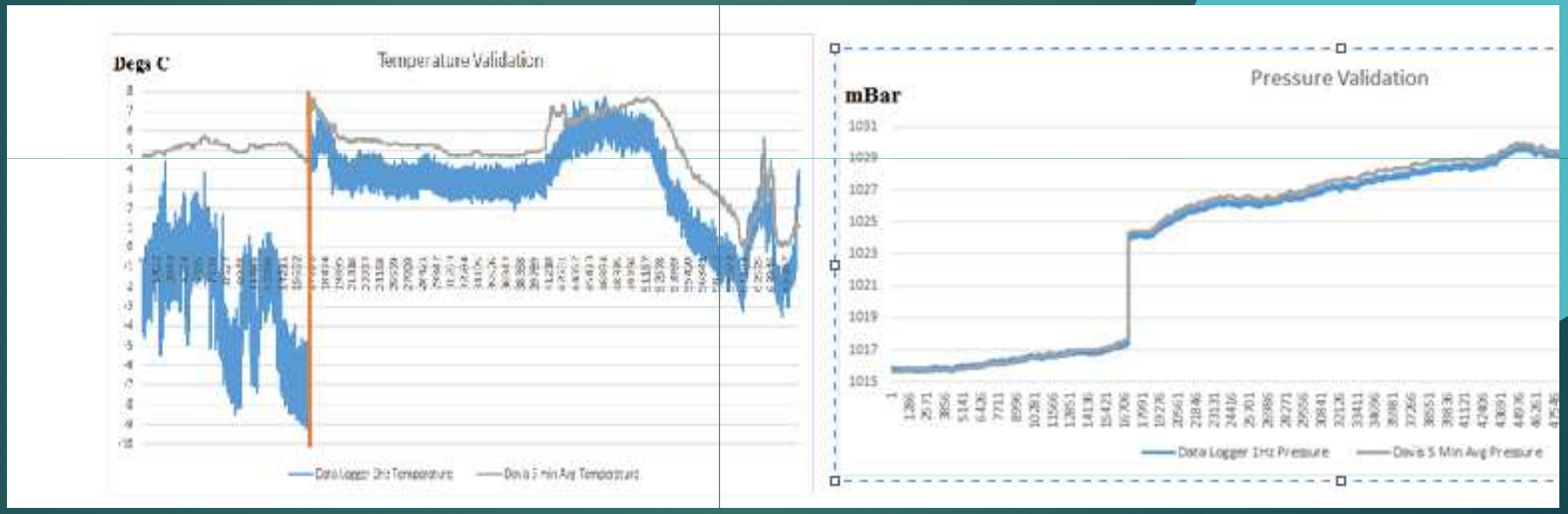
me_Stamp	Mast WS Avg High (m/s)	Mast WD Avg High (Degs)	Temp (Degs C)	Pressure (mBar)	Voltage (RMS)	Current (RMS)	Frequency (Hz)	Udc (Volts)	Pwac(atts)
015-01-07 03:15:16	8.454	320.6206	7.3	1013.1	264.3799	11.0083	19.26	303.0404	2910.3
015-01-07 03:15:17	8.5926	321.1493	7.3	1013.2	259.8511	9.9902	18.58	298.6427	2595.9
015-01-07 03:15:18	8.454	321.6779	7.3	1013.1	248.4863	8.7744	18.05	294.6448	2180.3

- What is not shown is the various other wind velocity/direction sensor readings, and the fact that the raw 6Hz (Why 6Hz?) values are also stored

Time_Stamp	Mast WS Avg High (m/s)	M_WS_H_1	M_WS_H_2	M_WS_H_3	M_WS_H_4	M_WS_H_5	M_WS_H_6
2015-01-07 03:15:16	8.454	10	11	10	10	10	10

System Validation

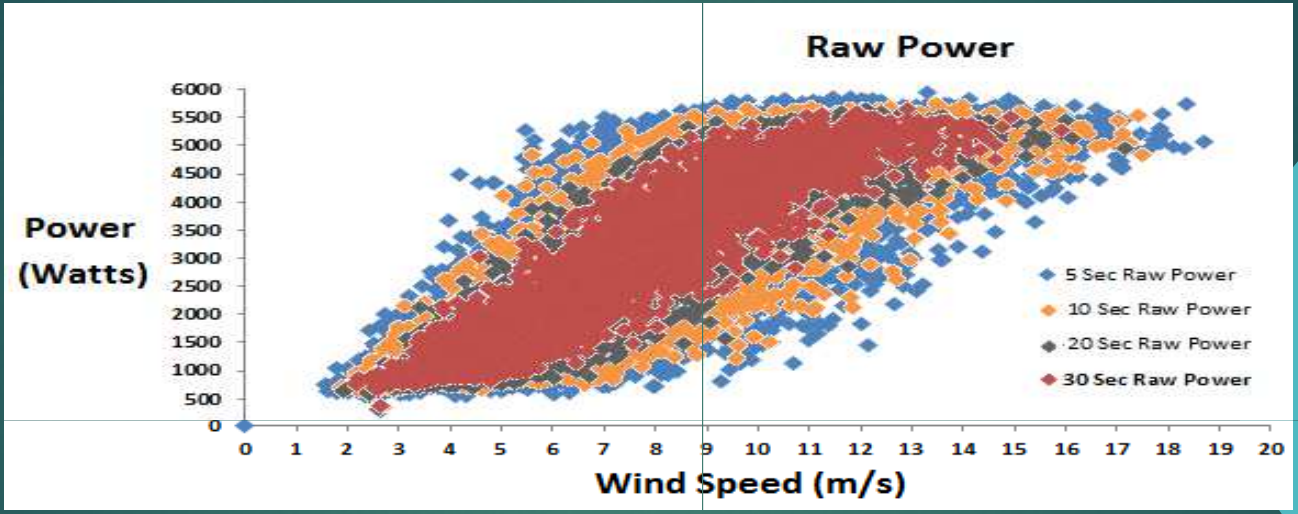
- Currently underway by placing our nodes versus professional sensing equipment
- Davis Weather Station, for wind speed/direction temperature and pressure.
- Sample Findings:



- Planning to use various watt meters and multi-meters to validate grid side in coming days

me Basic Analysis (Pending Post Imp. Positive Validation)

Does our data make sense so far?



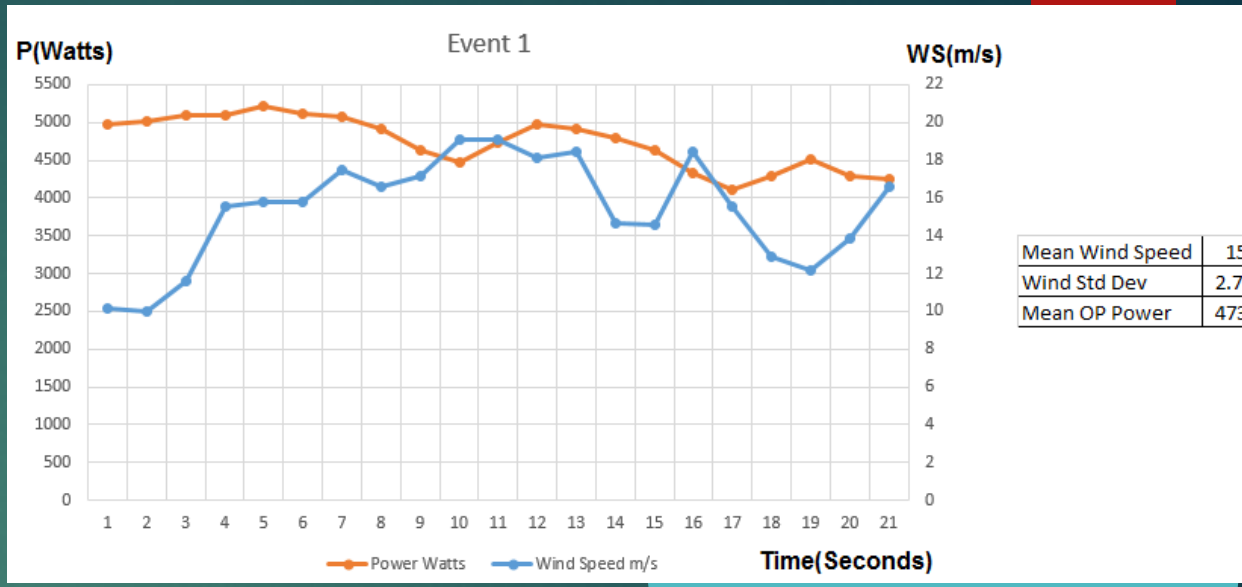
Does the System Function as a research tool ?

Faster/ raw data allows for the investigation of different analysis techniques (Sample rate . Data processing)

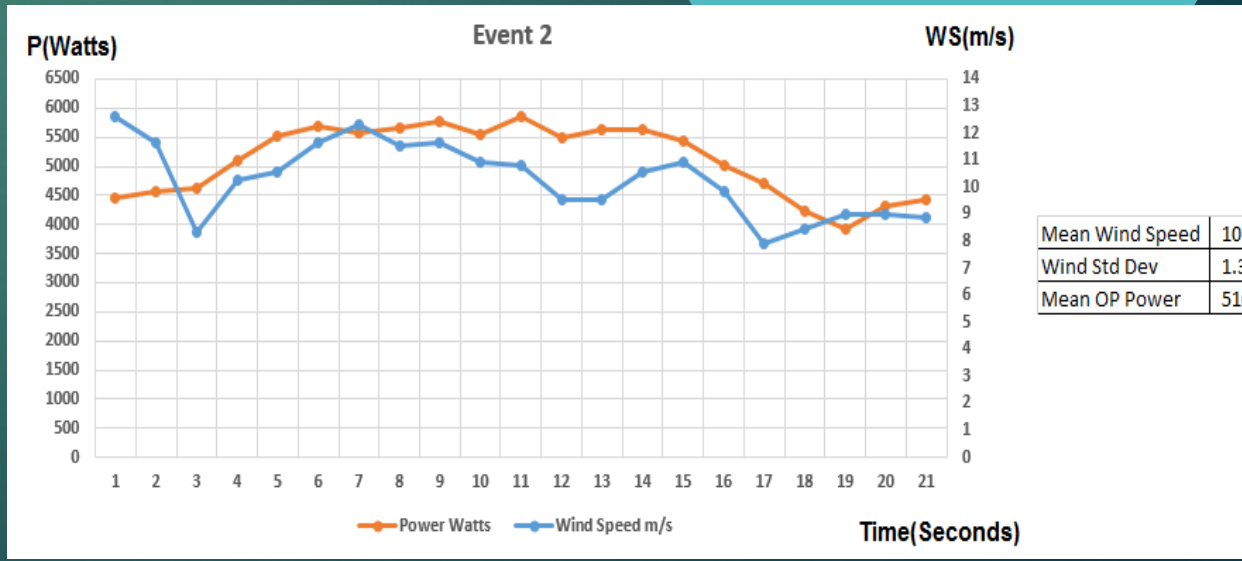
s there added value by going reporting data faster than tried and tested averaging ntervals (1 min … 10 min) ?

Continued …

- Short interval turbine performance analysis:
- Close Examination of defined time intervals thanks to time-stamp
- System allows for in depth analysis of the effects of how we treat our data, (Sampling Rates, Averaging Periods etc.)



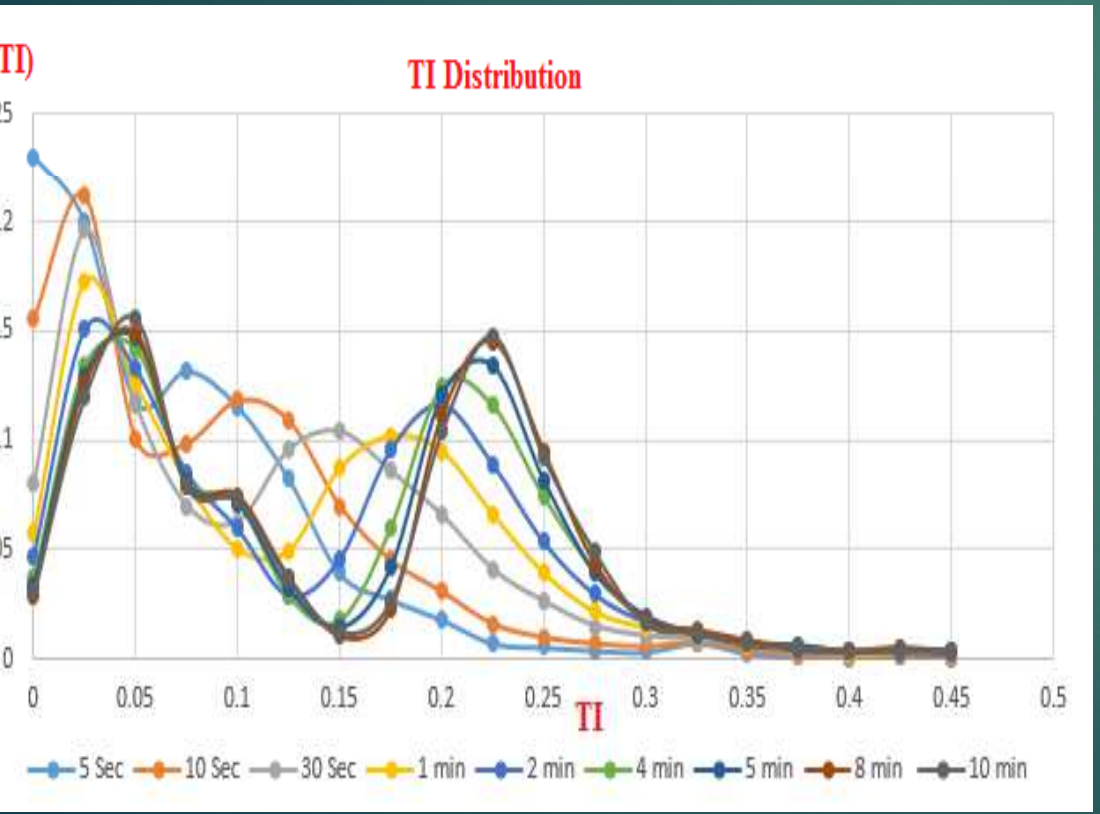
Mean Wind Speed	15
Wind Std Dev	2.7
Mean OP Power	473



Mean Wind Speed	10
Wind Std Dev	1.3
Mean OP Power	51

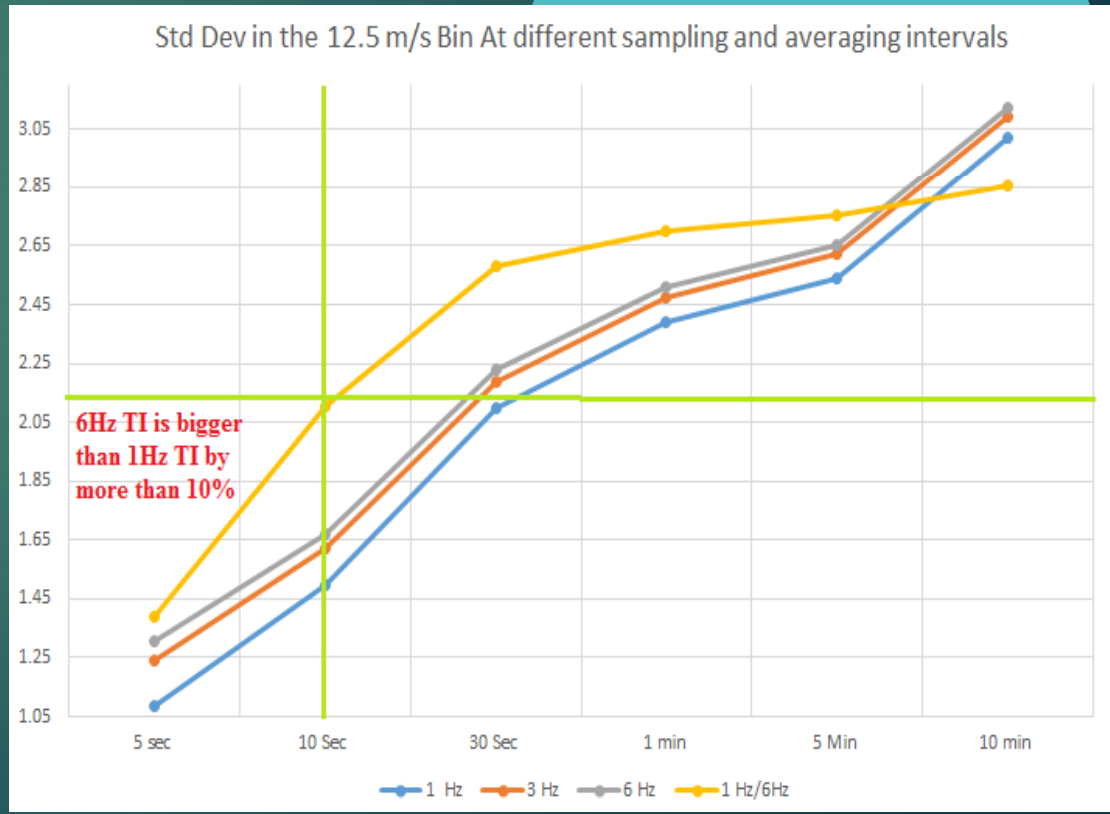
ct Of Averaging Period:

Particularly interesting in the use of analysis he effects of wind speed deviation on the urbines behaviour



Effect Of Sampling Rate:

- Higher sample rate yields higher TI in narrow averaging interval research, but effect lessons with averaging window width



Wrapping Up

Issues Remaining:

- *Data Validation, is the data lying, establishing error bounds.*
- *Minimising packet drops by smarter handling of calibration cycles*
- *Unable to devise a way of orientation monitoring (Logistics)*

Results & Conclusions thus far:

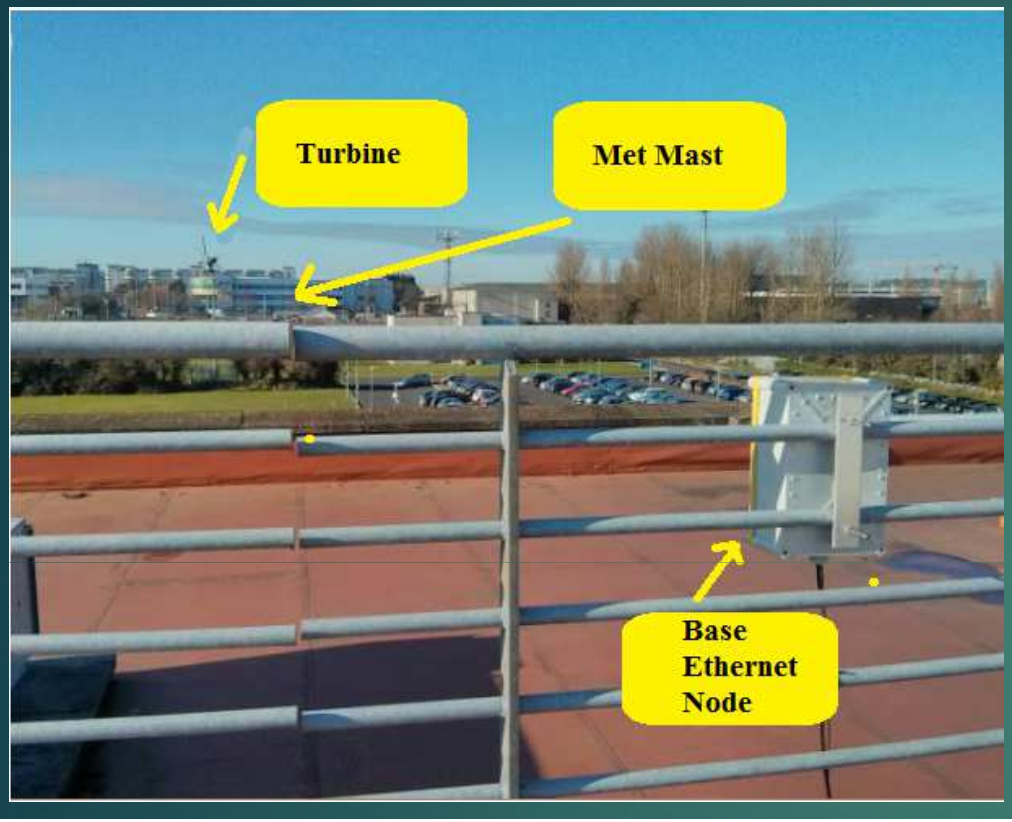
- *Initial findings seem to suggest that the system is indeed a viable research tool*
- *System uses significantly reduced cost hardware… overall cost less than €1500 ex*
  Met mast and labour for installation (= one ultrasonic anemometer .. If you're lucky
- *Will drive labs and further research in the institute*

Thanks for your time and the opportunity to speak today …. Q&A

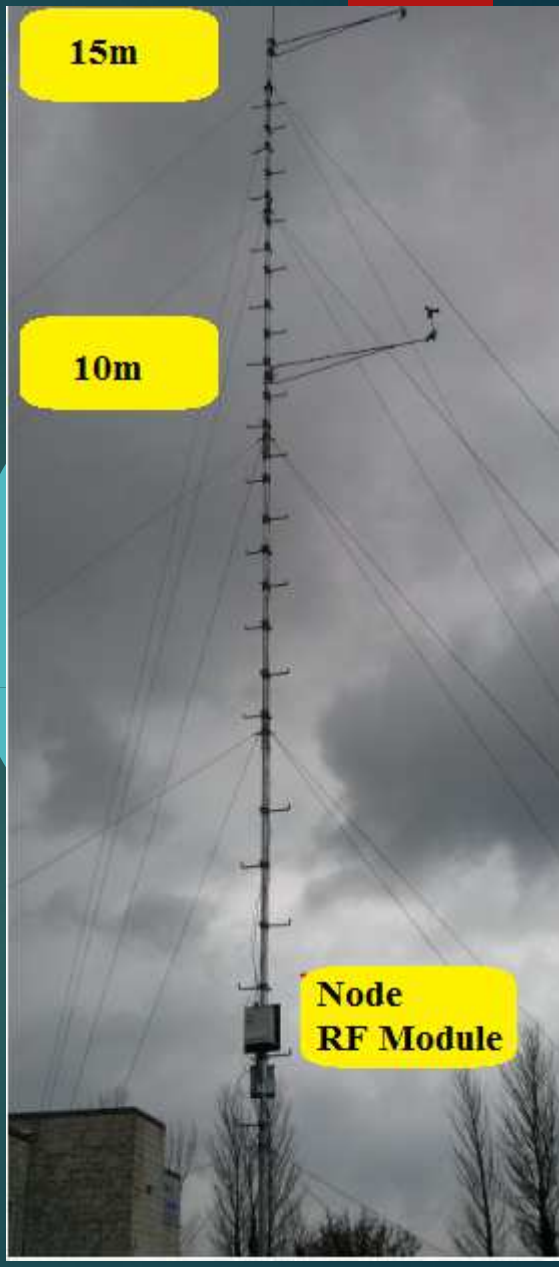
References:

- H.-M. Ryu, "Highly Efficient AC-DC Converter for Small Wind Power Generators," *J. Power Electron.*, vol. 11, no. 2, pp. 188–193, Mar. 2011.
- J. D. M. De Kooning, J. Van De Vyver, T. L. Vandoorn, B. Meersman, and L. Vandevelde, "Joule Losses and Torque Ripple Caused by Current Waveforms in Small and Medium Wind Turbines," no. July, pp. 889–896, 2013.
- D. Elliot, D. Infield, "An Assessment of the Impact of Reduced Averaging Time on Small Wind Turbine Power Curves, Energy Capture Predictions and Turbulence Intensity Measurements", 2014

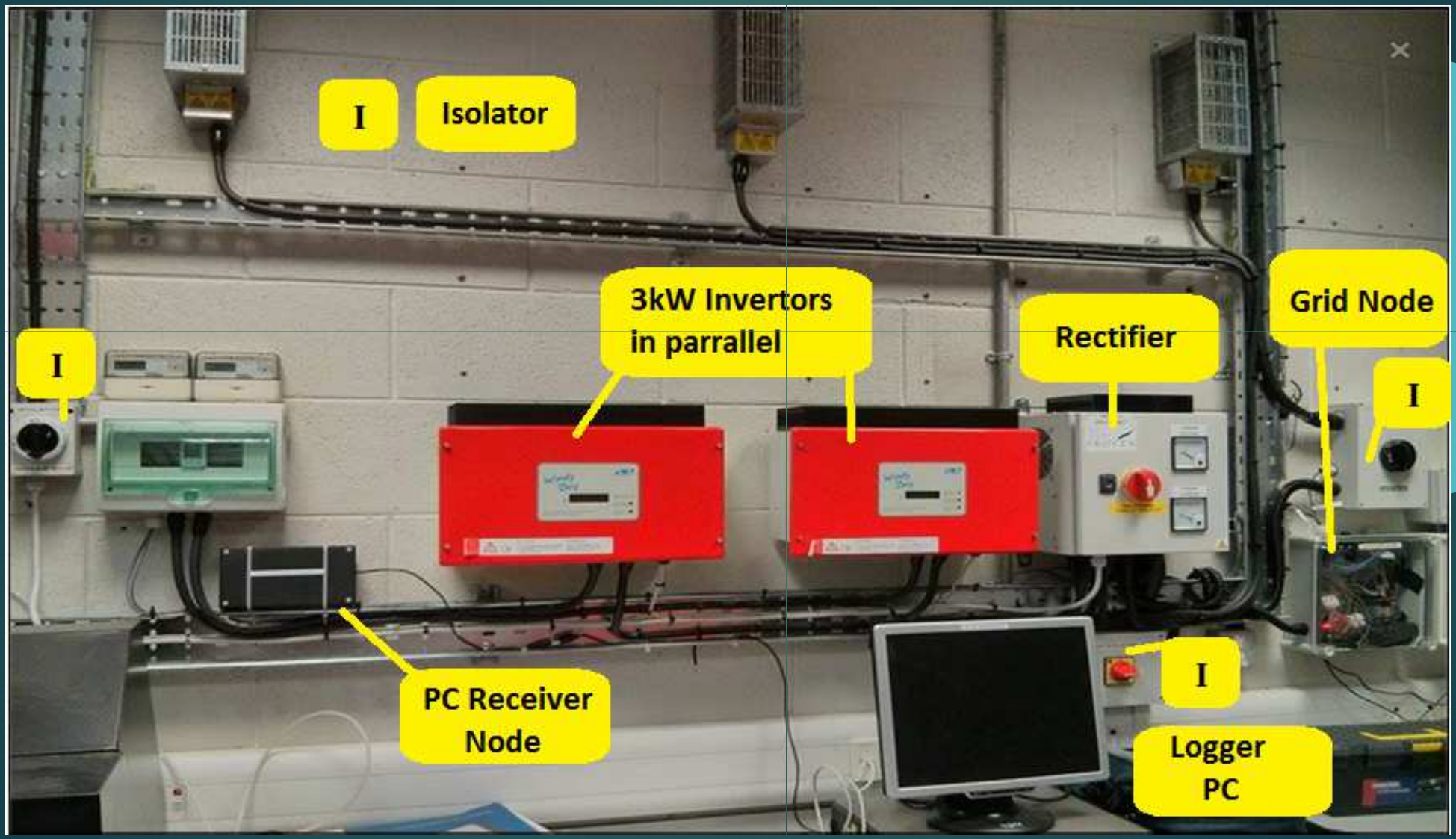
Appendices 1 .. Setup Images



Main Building
(Grid Connections
in lab on ground floor)

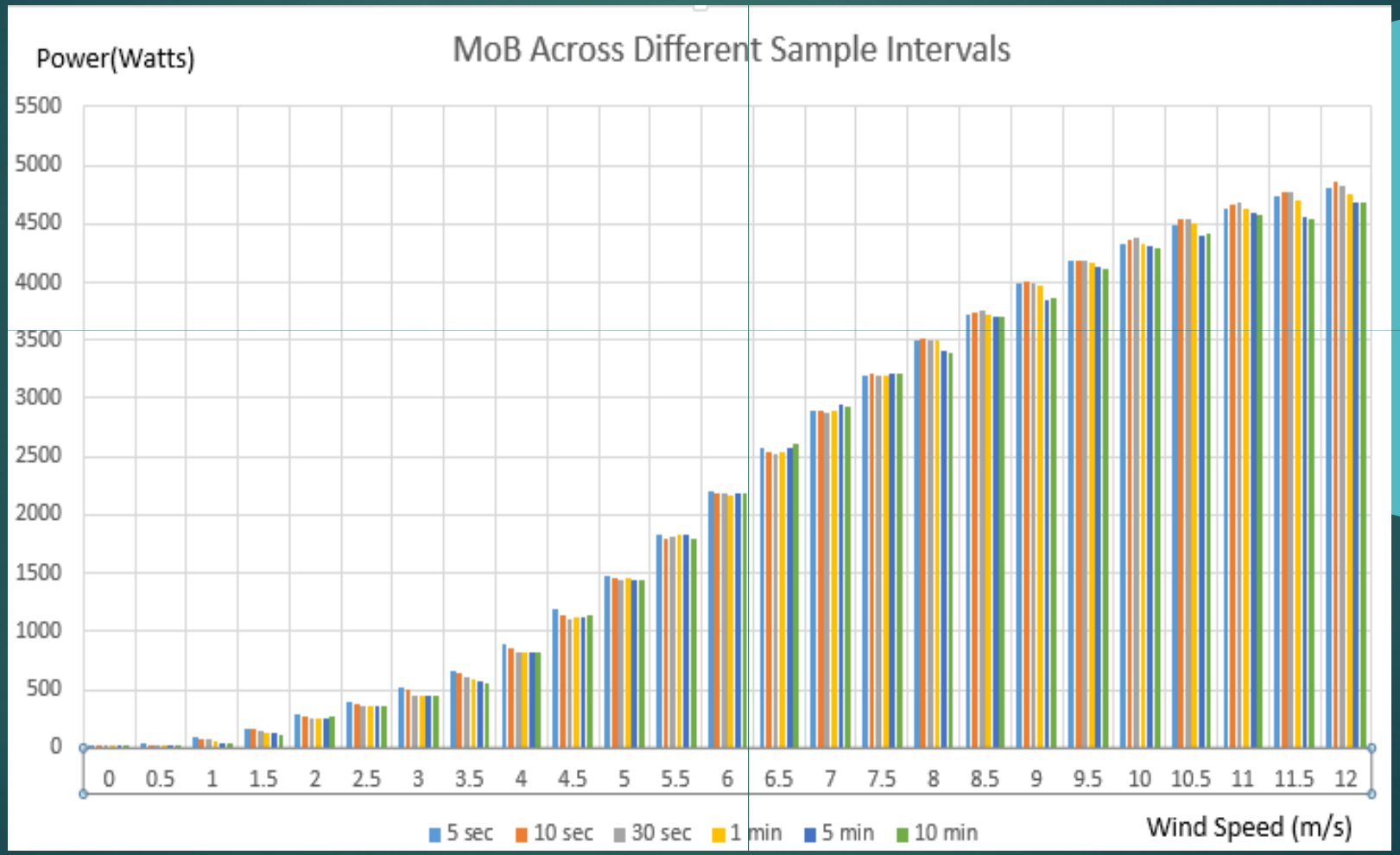


App 3… Grid Side Images



pp. 3 – Output Power Curve

urbine Power Curve Across Different Sample Intervals (0.5 m/s bins)



pp. 4 – Wind Distribution

- Site wind distribution data over a 3 week period