

On-site measurements of Power and Power Quality

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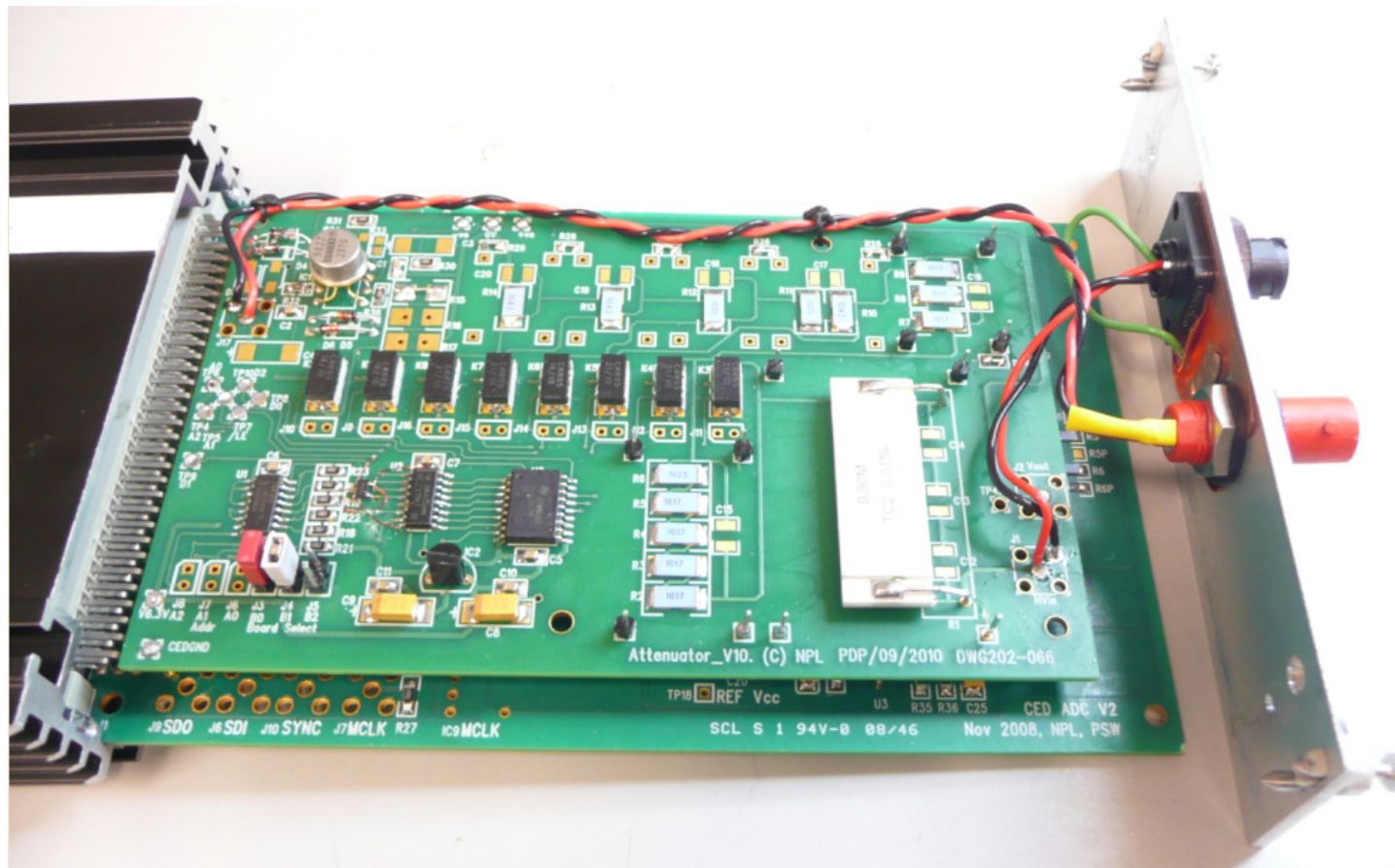
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Target Sites

- 1) Government Agency building with renewables
Agency abolished by government
- 2) Smart Grid Trial in Liverpool
Delays in funding - delays in project
- 3) NPL Local sub-station
7 day test completed
- 4) Trial in sub-station owned by UK DNO
1 day test completed
- 5) High penetration PV network owned by same UK DNO
Scheduled April 2011

Voltage Transducers

- LV measurements – 415/230V 3 Phase
- Retro-fitted ranging amplifier (one for each channel)
- Relay selected ranges: 440,220,110,63.5,20,10,1V



Current Transducers



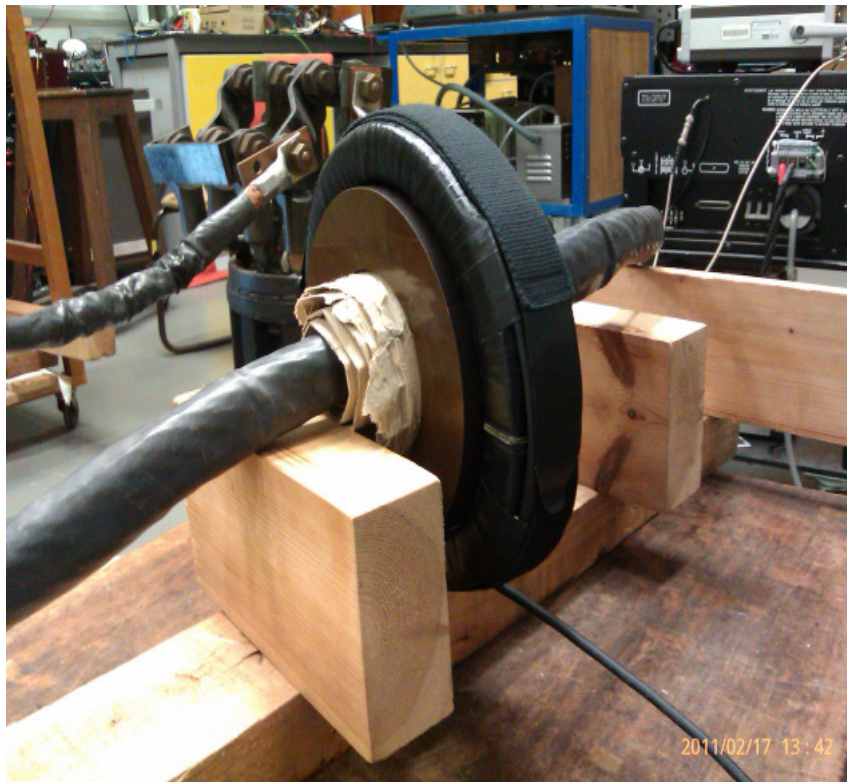
Rogowski 1 of 3

Protection Box

Current Channels
with retro-fitted
integrators

- 10A, 100A, 1KA, 10kA ranges on retro card
- Split core rigid Rogowski Coils from Rocoil Ltd.

Uncertainties



Rogowski Coils + Integrators at 50Hz

<i>Contribution</i>	<i>Uncertainty ppm</i>
Calibration Uncertainty	53
Repeatability	50
Temperature	289
Linearity	50
Rotational effects	130
End Effects	150
Positional Sensitivity	289
Cross phase interaction	60
Total at 50Hz (k=1)	463

Phase (μRad) | 70


Voltage Ranging Amplifiers at 50Hz

Calibration Uncertainty	10
Repeatability	10
Temperature	50
Linearity	2
Total at 50Hz (k=1)	52

Phase (μRad) | 23

Safety Codes

BS EN 61010-1:2010

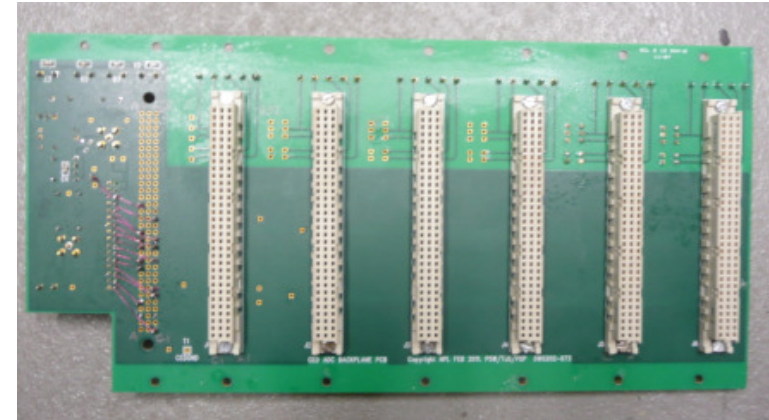


BSI Standards Publication

Safety requirements for electrical equipment for measurement, control, and laboratory use

Part 1: General requirements

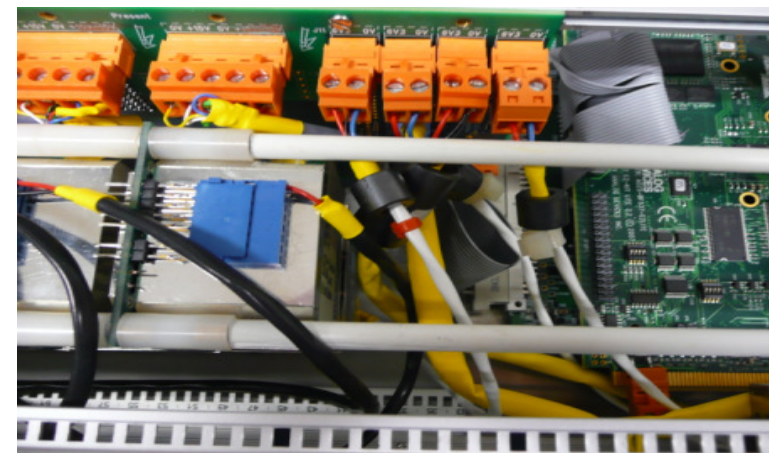
Improved PCB Clearances



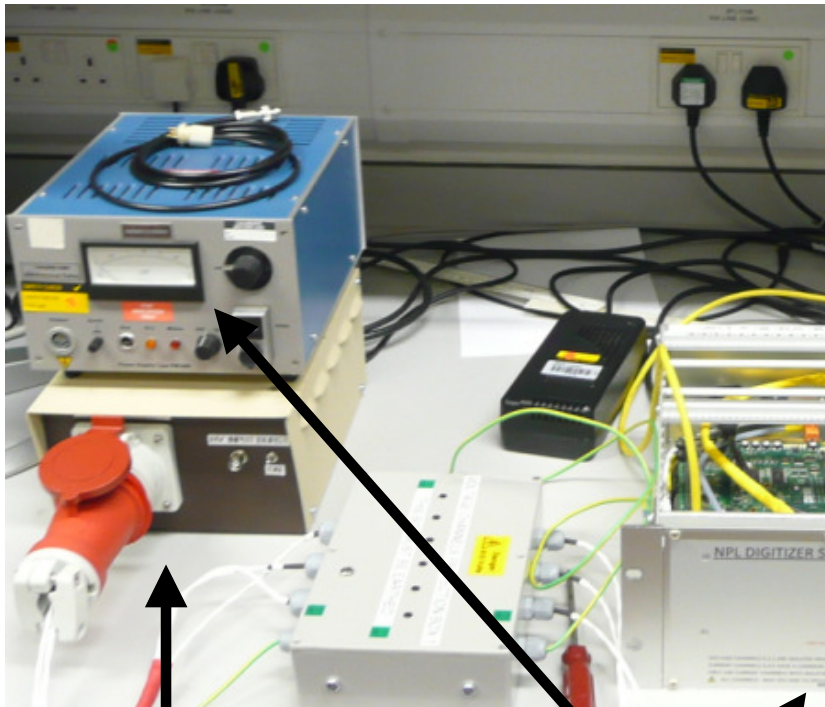
Protection



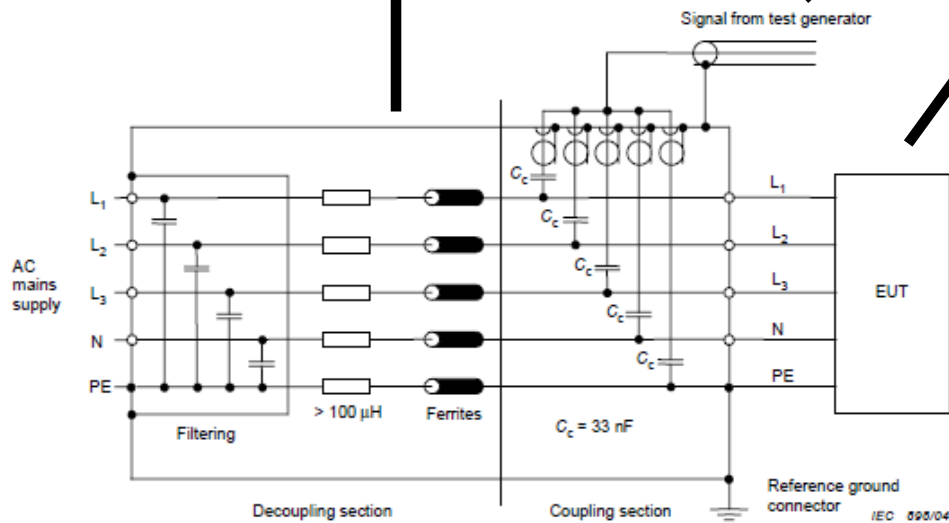
Improved Insulation



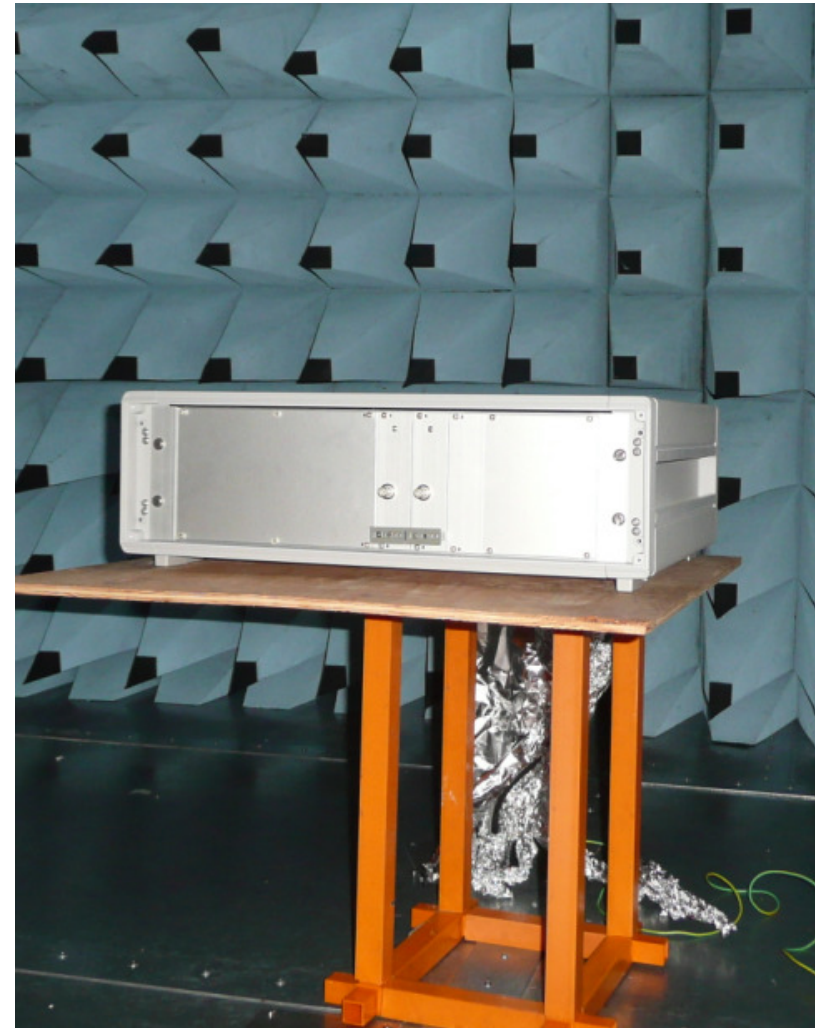
EMC Testing



BRITISH STANDARD	BS EN 61000-4-4:2004
Electromagnetic compatibility (EMC) —	
Part 4-4: Testing and measurement techniques — Electrical fast transient/burst immunity test	



EMC Radiated Emissions – GTEM Cell



Software & Data Processing

9.2M samples per minute – capture of samples with post processing is not practical !

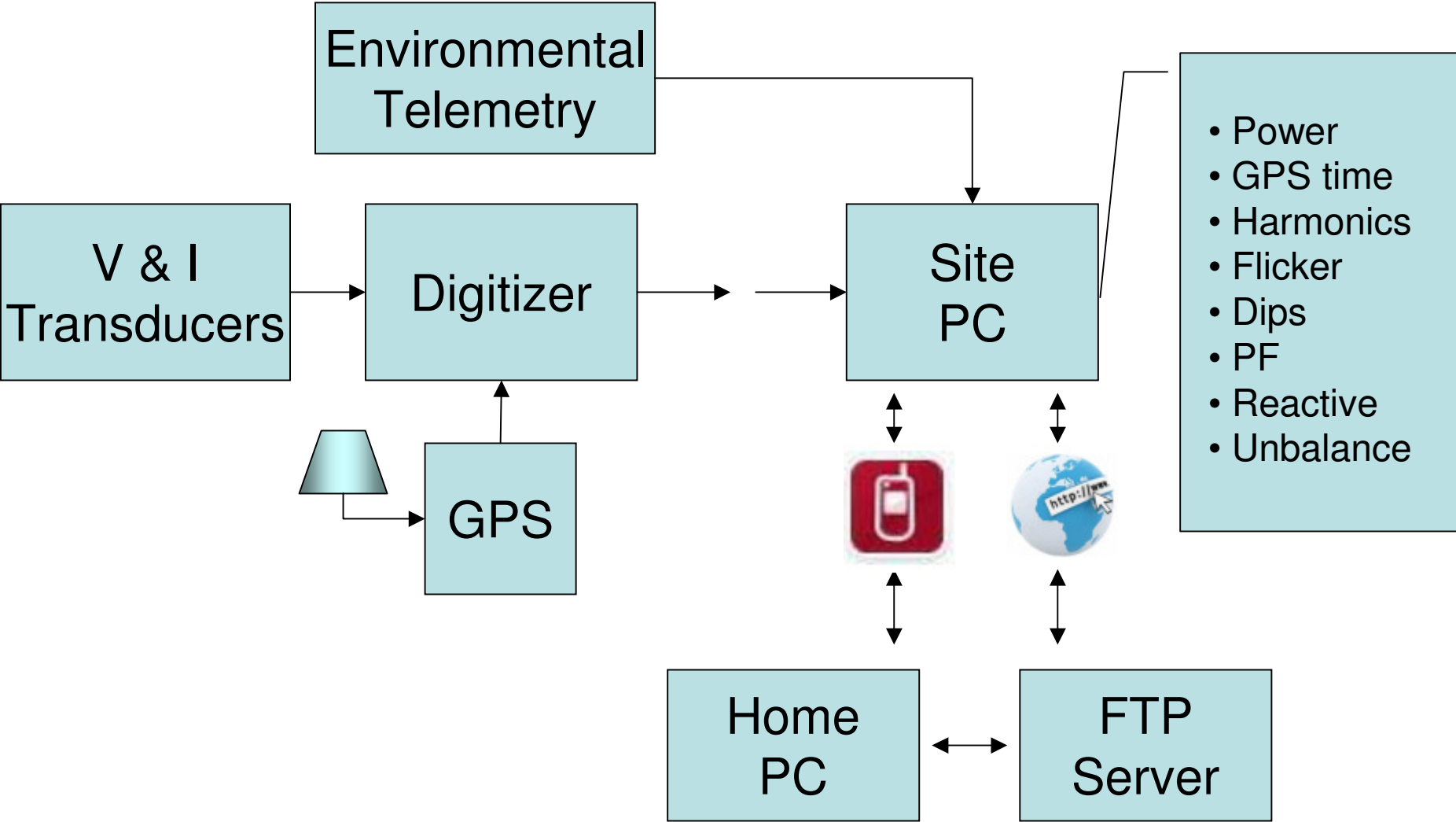
Real Time PQ processing is essential

Name	Size	Modified
FlickerCh2 MeasurementLog 20110224 114037 Part 2.csv	8,371	24/02/2011 18:56:30
FlickerCh2 MeasurementLog 20110224 114037 Part 3.csv	8,734	24/02/2011 22:33:42
FlickerCh2 MeasurementLog 20110224 114037 Part 4.csv	8,448	25/02/2011 02:11:14
FlickerCh2 MeasurementLog 20110224 114037 Part 5.csv	8,092	25/02/2011 05:48:52
FlickerCh2 MeasurementLog 20110224 114037 Part 6.csv	8,343	25/02/2011 09:20:24
FlickerCh2 MeasurementLog 20110224 114037 Part 7.csv	791	25/02/2011 05:48:56
FTAmplitudesCh0 MeasurementLog 20110224 114037 Part 1.csv	54,973,883	24/02/2011 15:18:52
FTAmplitudesCh1 MeasurementLog 20110224 114037 Part 5.csv	55,174,690	25/02/2011 05:48:52
FTAmplitudesCh1 MeasurementLog 20110224 114037 Part 6.csv	55,029,375	25/02/2011 09:25:20
FTAmplitudesCh1 MeasurementLog 20110224 114037 Part 7.csv	594	25/02/2011 05:48:52
FTAmplitudesCh2 MeasurementLog 20110224 114037 Part 1.csv	55,101,120	24/02/2011 15:18:52
FTAmplitudesCh2 MeasurementLog 20110224 114037 Part 2.csv	55,154,282	24/02/2011 18:56:30
FTAmplitudesCh2 MeasurementLog 20110224 114037 Part 3.csv	55,140,473	24/02/2011 22:33:42
FTAmplitudesCh2 MeasurementLog 20110224 114037 Part 4.csv	55,132,741	25/02/2011 02:11:14
FTAmplitudesCh2 MeasurementLog 20110224 114037 Part 5.csv	55,117,483	25/02/2011 05:48:52
FTAmplitudesCh2 MeasurementLog 20110224 114037 Part 6.csv	54,760,097	25/02/2011 09:24:42
FTAmplitudesCh2 MeasurementLog 20110224 114037 Part 7.csv	594	25/02/2011 05:48:52
FTAmplitudesCh3 MeasurementLog 20110224 114037 Part 1.csv	55,431,062	24/02/2011 15:18:52
FTAmplitudesCh3 MeasurementLog 20110224 114037 Part 2.csv	55,282,483	24/02/2011 18:56:30
FTAmplitudesCh3 MeasurementLog 20110224 114037 Part 3.csv	55,214,217	24/02/2011 22:33:42
FTAmplitudesCh3 MeasurementLog 20110224 114037 Part 4.csv	55,380,777	25/02/2011 02:11:14
FTAmplitudesCh3 MeasurementLog 20110224 114037 Part 5.csv	55,357,944	25/02/2011 05:48:52
FTAmplitudesCh3 MeasurementLog 20110224 114037 Part 6.csv	54,801,835	25/02/2011 09:24:08
FTAmplitudesCh3 MeasurementLog 20110224 114037 Part 7.csv	600	25/02/2011 05:48:54
FTAmplitudesCh4 MeasurementLog 20110224 114037 Part 1.csv	55,736,353	24/02/2011 15:18:52

Results in various log files split into parts – still gives lots of data.

Result visualization and interpretation is a major task.

Remote Data Communications



Logistics



Site Testing Equipment Check List

Primary Equipment
Digitizer
24V Power Supply
IDC mains lead
Current Fuse Box
Voltage Fuse Box
Current Extension leads (x3) + couplers

Rogowski Coils (x3)
large heat shrink for Rog Coils padding

PC
Mouse
Monitor
keyboard
IDC mains leads (x2)
5m screen crossover Ethernet cable

GSM Modem, PSU and aerial
Reset Relay fibre transmitter box
Fibre optic cable

4-way extension board (2 off)
blue single phase round 240V plug

Temperature monitor, probes and PSU
pointer to reset temperature monitor

Trolley

O2 Hi Speed IP Dongle

Spares
HRC Fuses
24V Power Supply

spare fuse for 24V PSU
IDC mains lead
cross over Ethernet cable

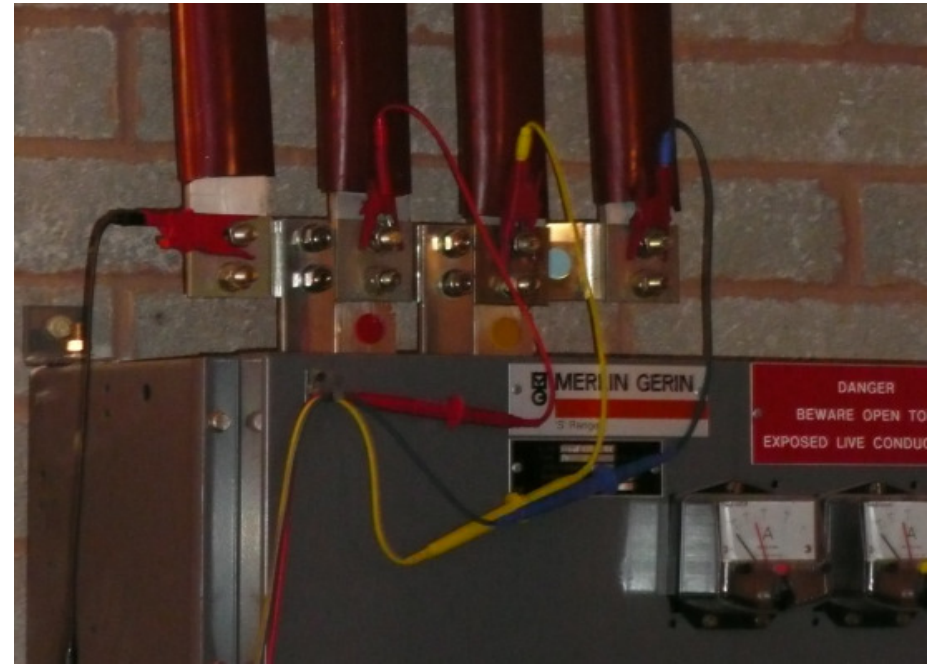
Fibre optic cable

Digitizer unit

Substation #1



Substation #2



Problems with Rogowski Coil Sizing

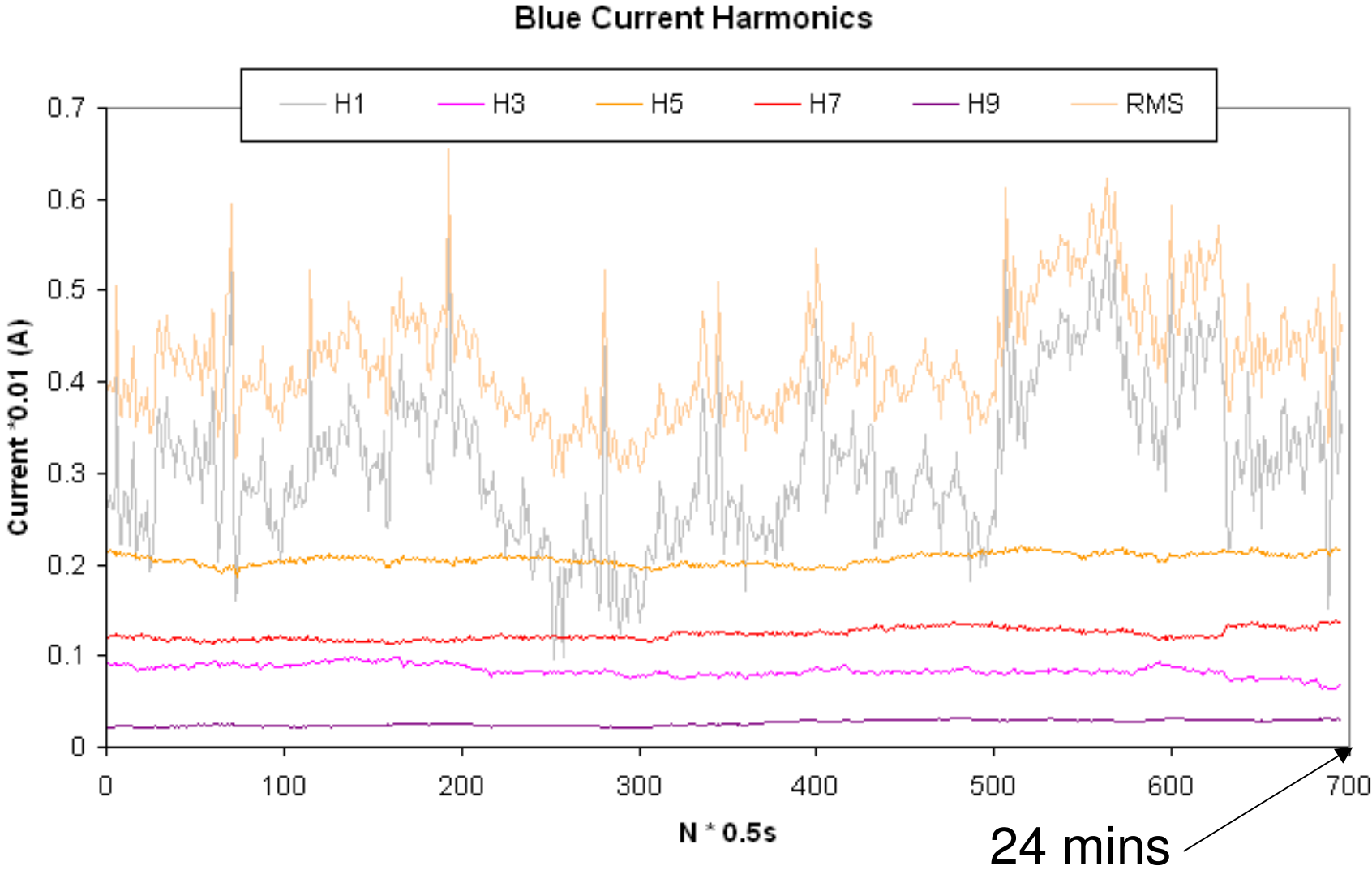
- Sub#1 -Coil too small for main busbar
- coils used on feeders instead



- Sub#2 - Coil too big – can't get 3 on safely



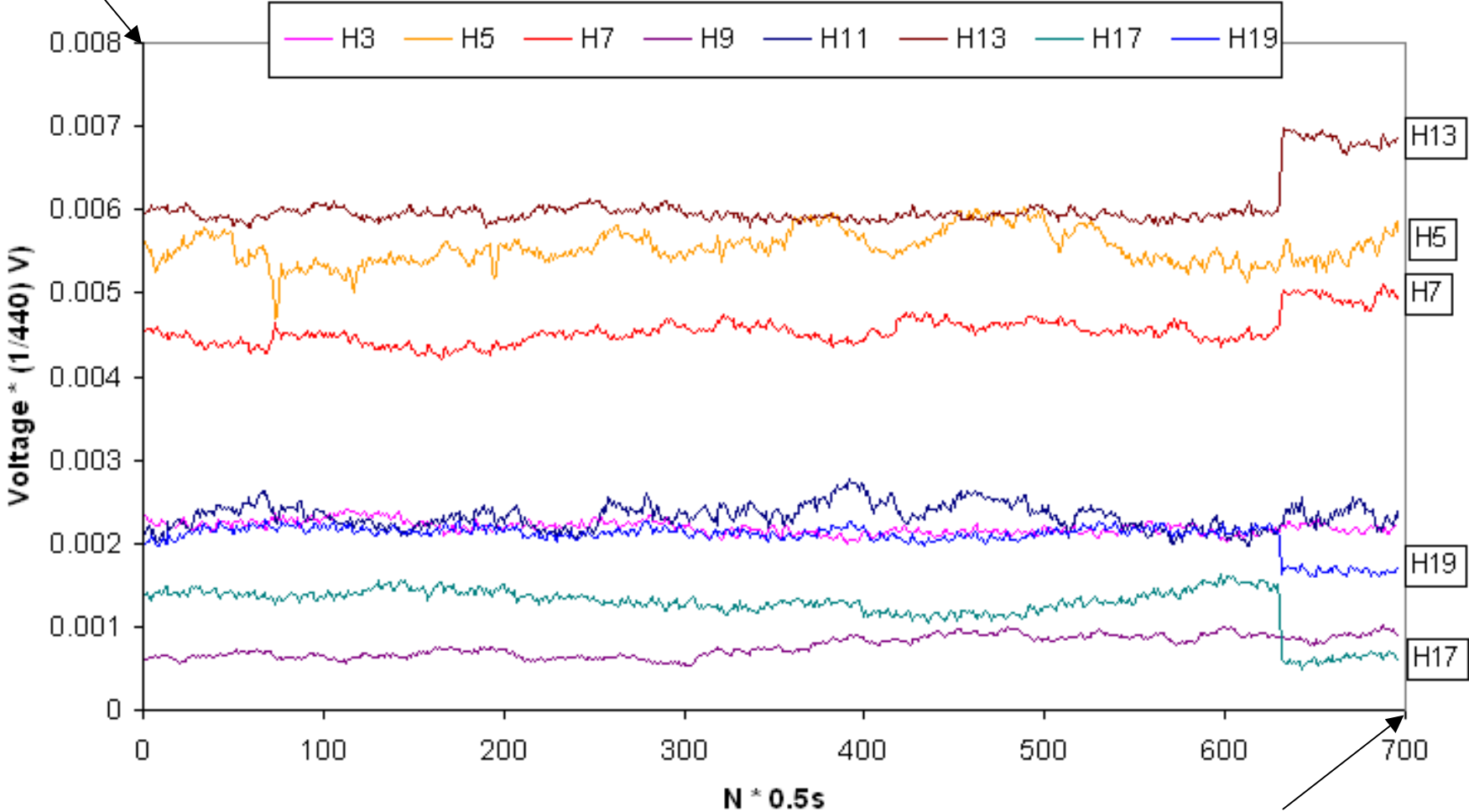
Current Harmonic Results



Voltage Harmonic Results

1.4% of Vrms

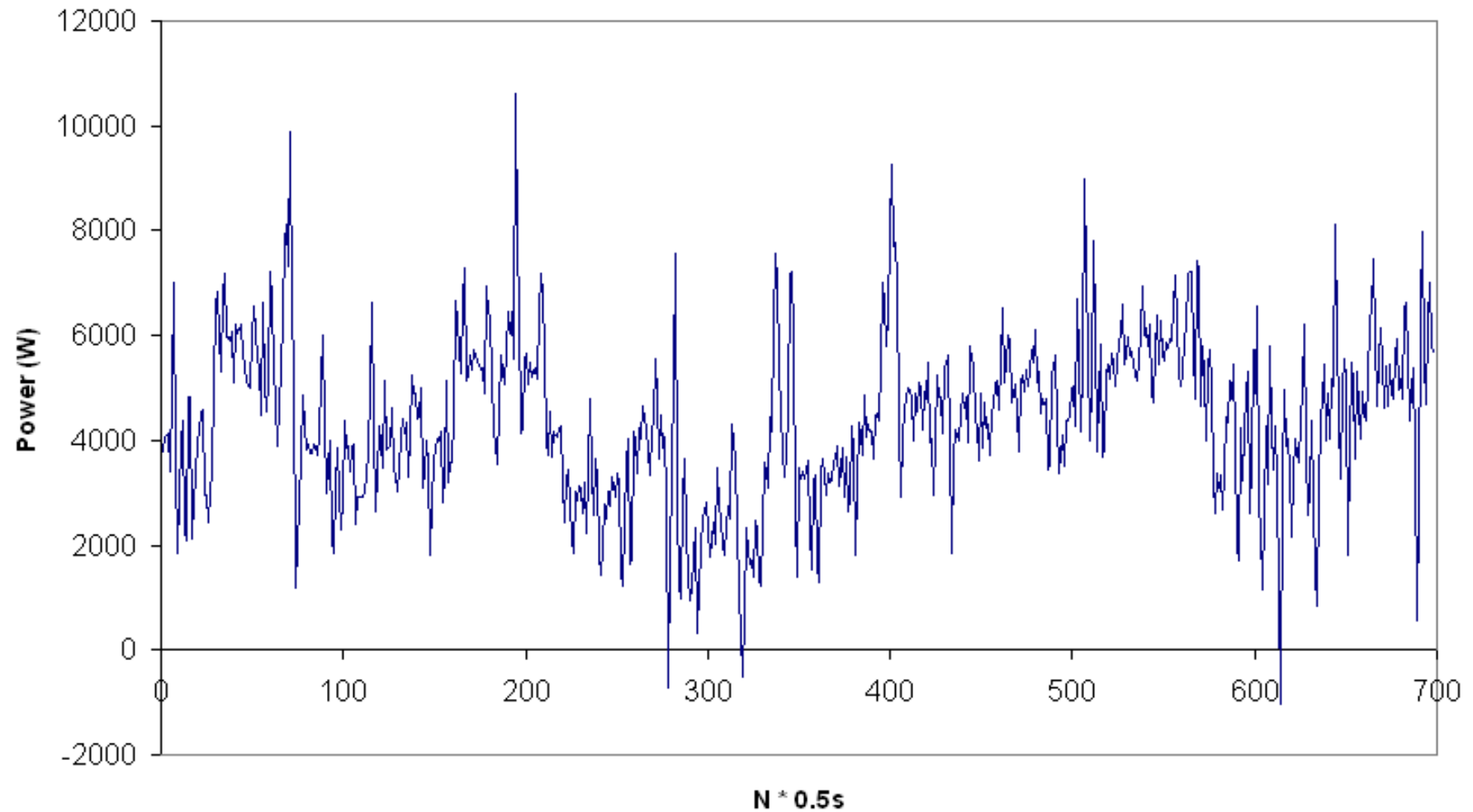
Blue Voltage Harmonics



24 mins

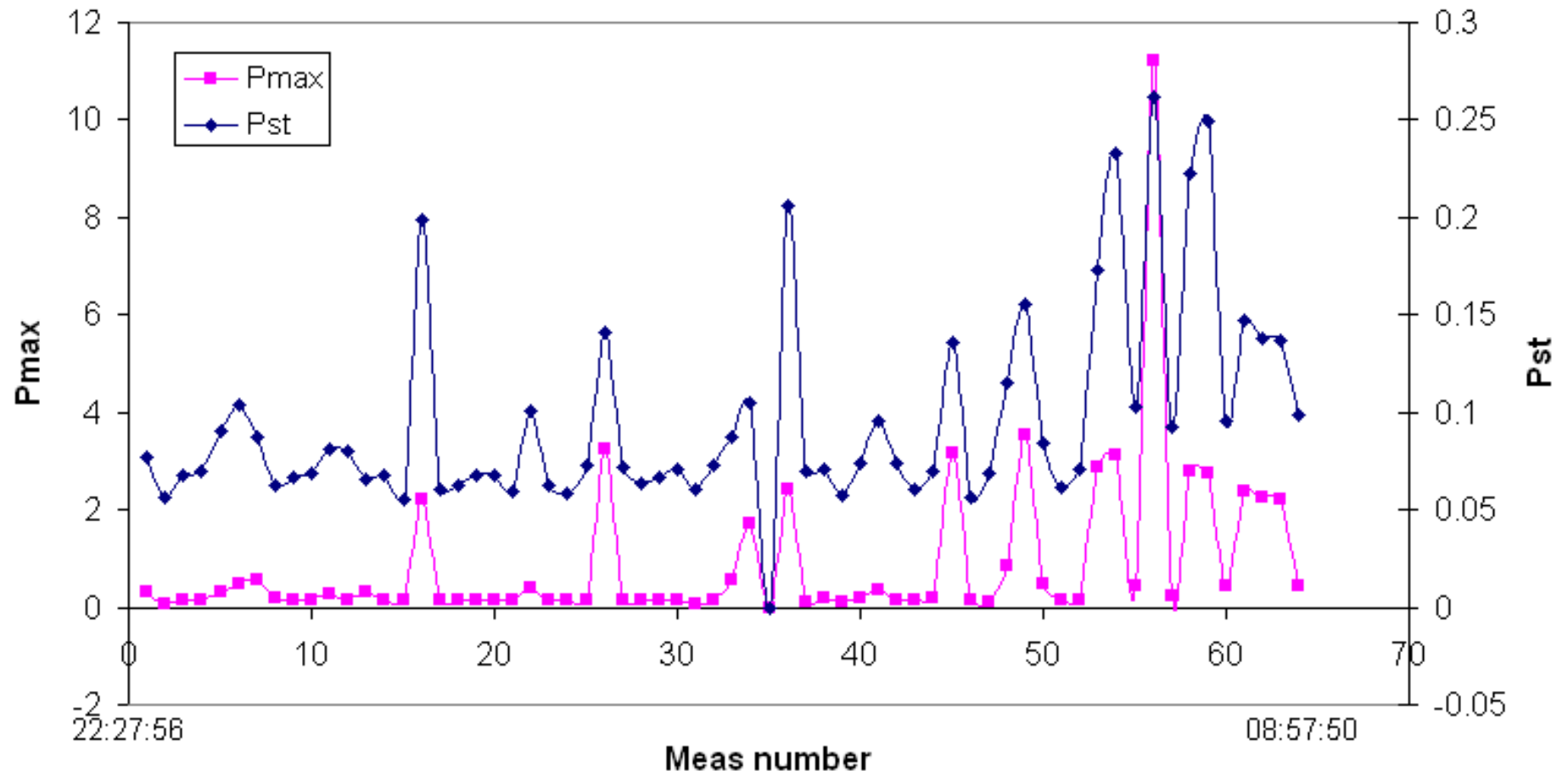
Power Measurements

Blue Phase Power



Flicker Sub#1

22/02/11 - Flicker, Red Phase



Next Measurement - PV Trial Site



- A site with high PV penetration.
- More on line in next few months.
- 2 weeks of measurements – 04/11
- DNO interested in:
 - Under/over voltage
 - dips/swells, flicker
 - inverter switching harmonics at about 3kHz

Power Quality – Field Measurements

- Smart Grid Trials – before and after studies.
- Flicker effects of Wind Turbines, verifying IEC Fictitious grid technique.
- Rail distribution grid PQ measurements.
- High voltage transmission measurements for TSOs.
- HVDC Links



Conclusions – Lessons Learned

- Huge underestimation of the time and effort taken to prepare for a site visit. It might seem trivial – is isn't!
- Does your equipment meet EN61010 – Part III – insulation, protection etc.
- Do an early site survey if possible to get an idea of busbar sizes and voltage connections – not always easy!
- Have a variety of Rogowski coils of different sizes
- Talk to network operator – understand working codes and practices, paperwork and safety requirements.
- Think about the requirements of processing the huge amounts of data.
- Expect the unexpected.