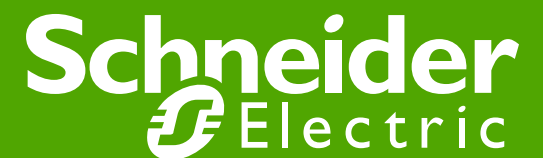


Power Quality

Brian Kingham
Utility Market Manager
Power Monitoring and Control



Agenda

- Why monitor power quality?
 - Do we need to in Canada?
 - What are the costs of poor power quality?
- 'World-class' standards
 - Compliance standards
 - Measurement standards

Do we need to focus on PQ in Canada?

- Compared to the rest of the world, Canada has 'good' power quality
- But, there are several disturbing trends...
 - Causes: More **nonlinear loads**, more DG, more sensitive equipment, more voltage unbalance, more **Wind power**...
 - Effects: More **THD**, more blown fuses, more tripped UPSs, more equipment failure, more **transmission congestion**...
- ...leading to a need for improved awareness
 - More Industrial PQ monitors with better features
 - More Utilities establishing benchmarks



Chip East / Reuters file

The Costs of Poor Power Quality

● Obvious costs

- Hourly-cost of downtime:
 - Stock-market transactions \$ 6,500,000
 - Wafer - Fab \$ 3,800,000
 - Banking-card transactions \$ 2,500,000
 - Automotive \$ 1,000,000
 - Airline reservations \$ 90,000
 - Mobile telephone systems \$ 40,000
- Equipment damage from overvoltage/transient



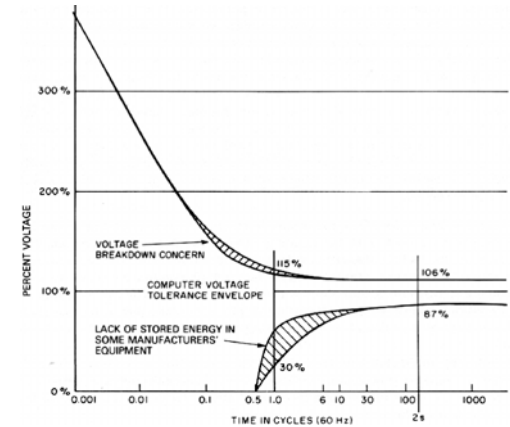
● Hidden costs

- Loss of system capacity
 - with square of harmonic
 - Premature ageing of infrastructure due to harmonics or unbalance
 - motors, transformers, insulation
 - Safety – triplen harmonics sum at neutral which may be undersized
- Europe recently estimated total cost of sags and short interruptions at 86.5 Billion Euro/year

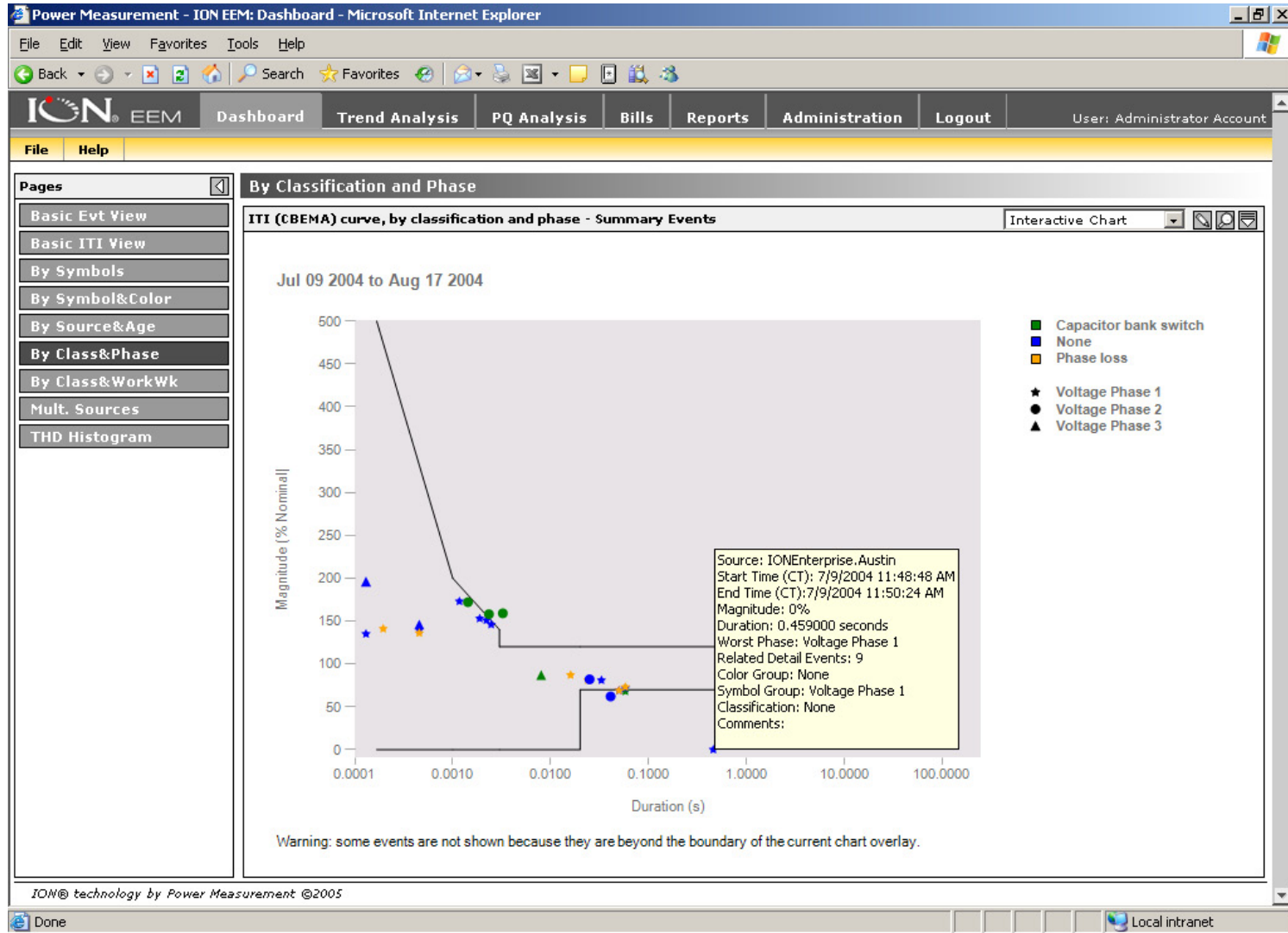
Power Quality *Compliance* Standards



- ITI (CBEMA) Curve
 - *Guideline* for power supply design
- IEEE 519
 - *Recommended Practice*
- SEMI F47
 - Compliance for semiconductor equipment
- SARFI/SAIDI/CAIFI/CAIDI...
 - Usually internal limits applied
- EN50160
 - European *Requirement* for harmonics, flicker, sags/swells...

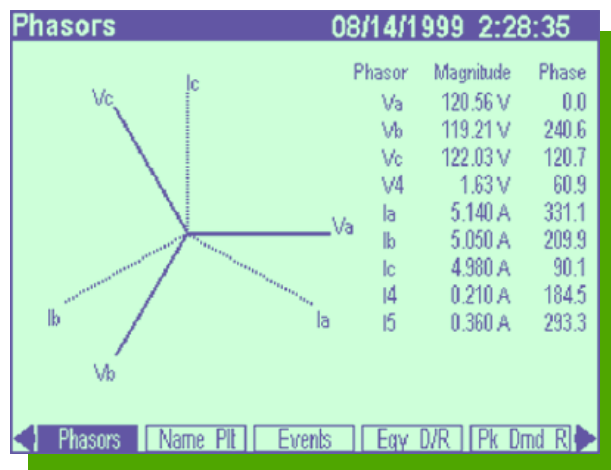


ITIC Compliance - Graphical



The Problem:

- None of the compliance standards define how to measure any parameter!
- Any compliance reporting or benchmarking is suspect at best
 - Reports to NERC may be inaccurate
- Any dispute between a utility and a customer has no path to resolution

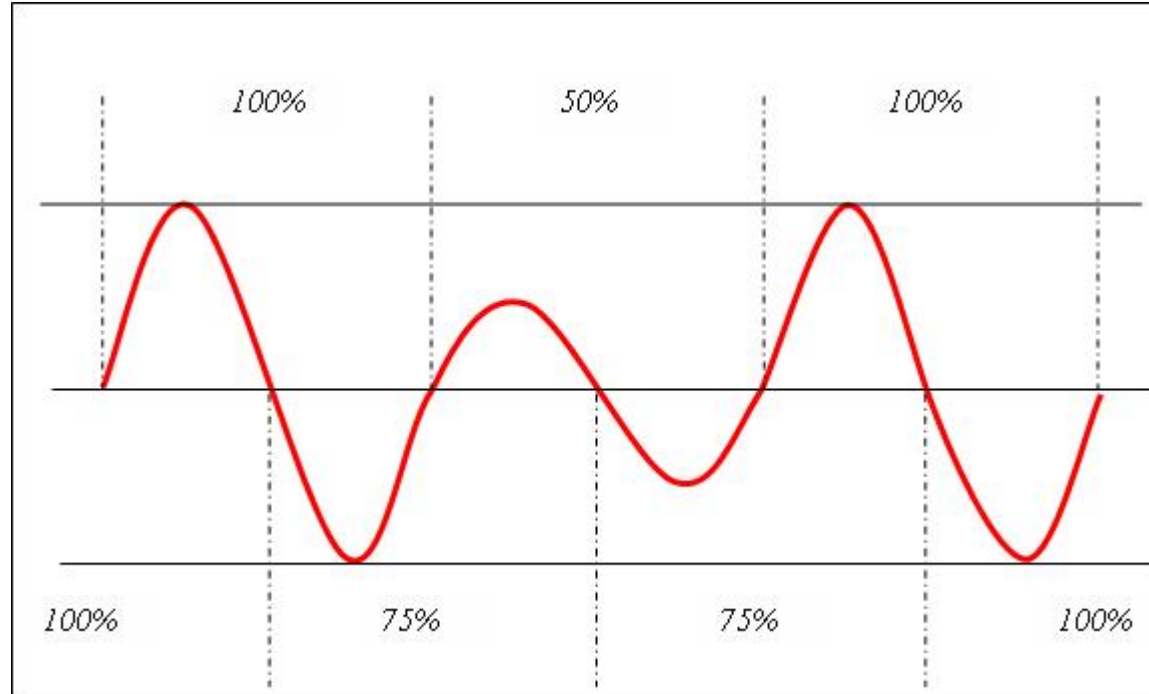


The Solution:

A comprehensive Power Quality
Measurement Standard

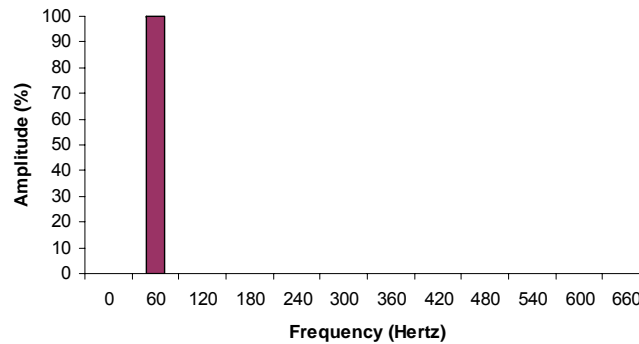
A Tale of Two Meters

- What is the SARFI 70?



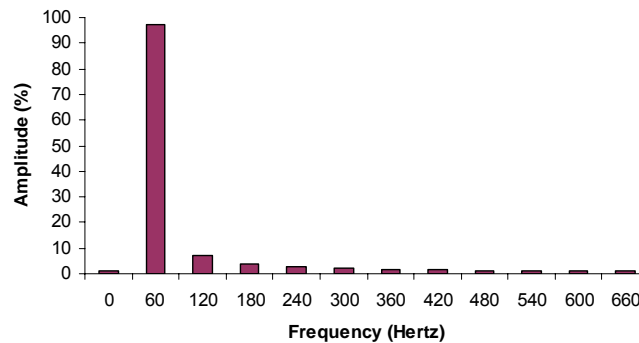
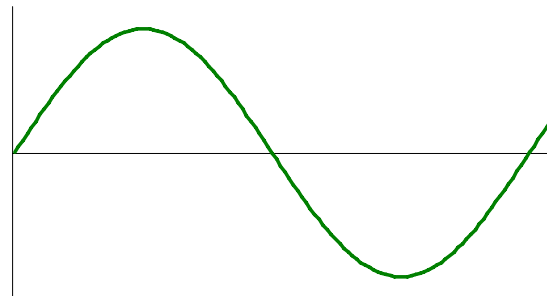
- *“...the value of r.m.s. voltage measured over 1 cycle, commencing at a fundamental zero-crossing, and refreshed every half cycle”*

A Tale of Two Meters, Part Two



Class A meter adjusts sampling rate based on frequency of signal

“Synchronous Sampling”



Class B meter does not (assumes frequency is always exactly nominal)

Power Quality *Measurement* Standards



- Harmonics

- IEC 61000-4-7

- Flicker

- IEC 61000-4-15

- IEC 61000-4-30 Class A

- Clearly defines method of measurement

- Defines:

- Power frequency
- Flicker
- Voltage interruptions
- Supply voltage unbalance
- Voltage interharmonics
- Rapid voltage changes

Voltage magnitude
Voltage sags/swells
Transient voltages
Voltage harmonics
Mains signalling
Over/Underdeviation

- IEEE 1159 will use same measurement methods as 4-30



Benefits of 4-30 Class A Monitoring

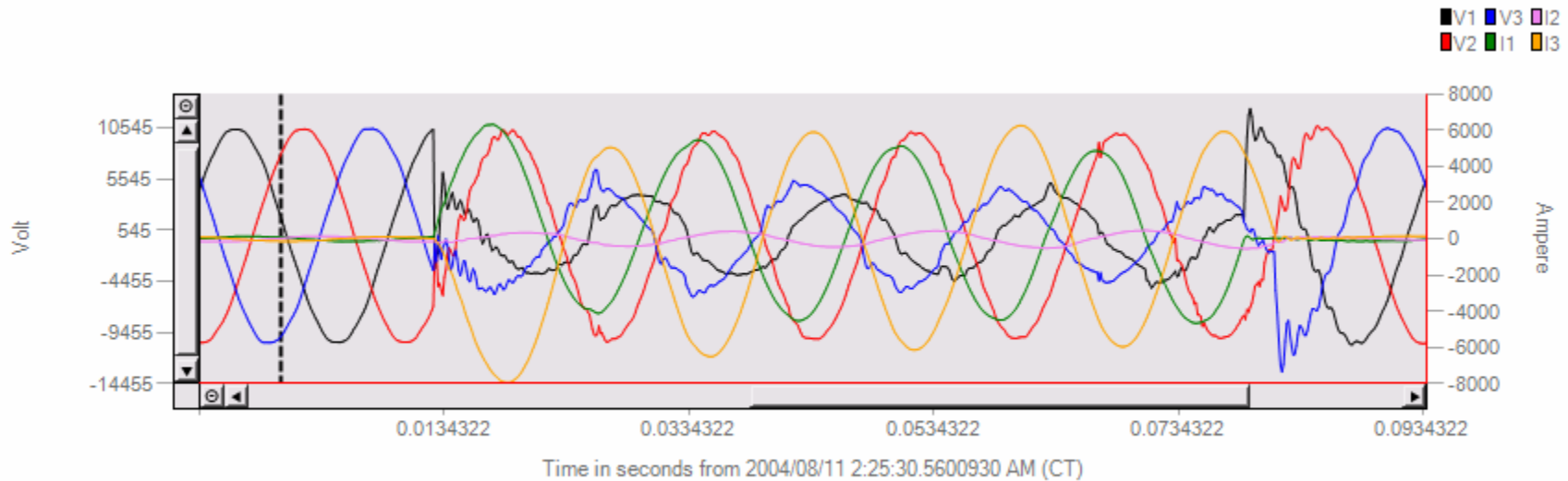
- Class A devices produce the same results when exposed to the same signal
- For regulators: this means benchmarking is valid between different utilities and different countries
- For utilities: this means end-users and utilities will agree on the level of power quality provided



Without Class A there is no guarantee that results will match!

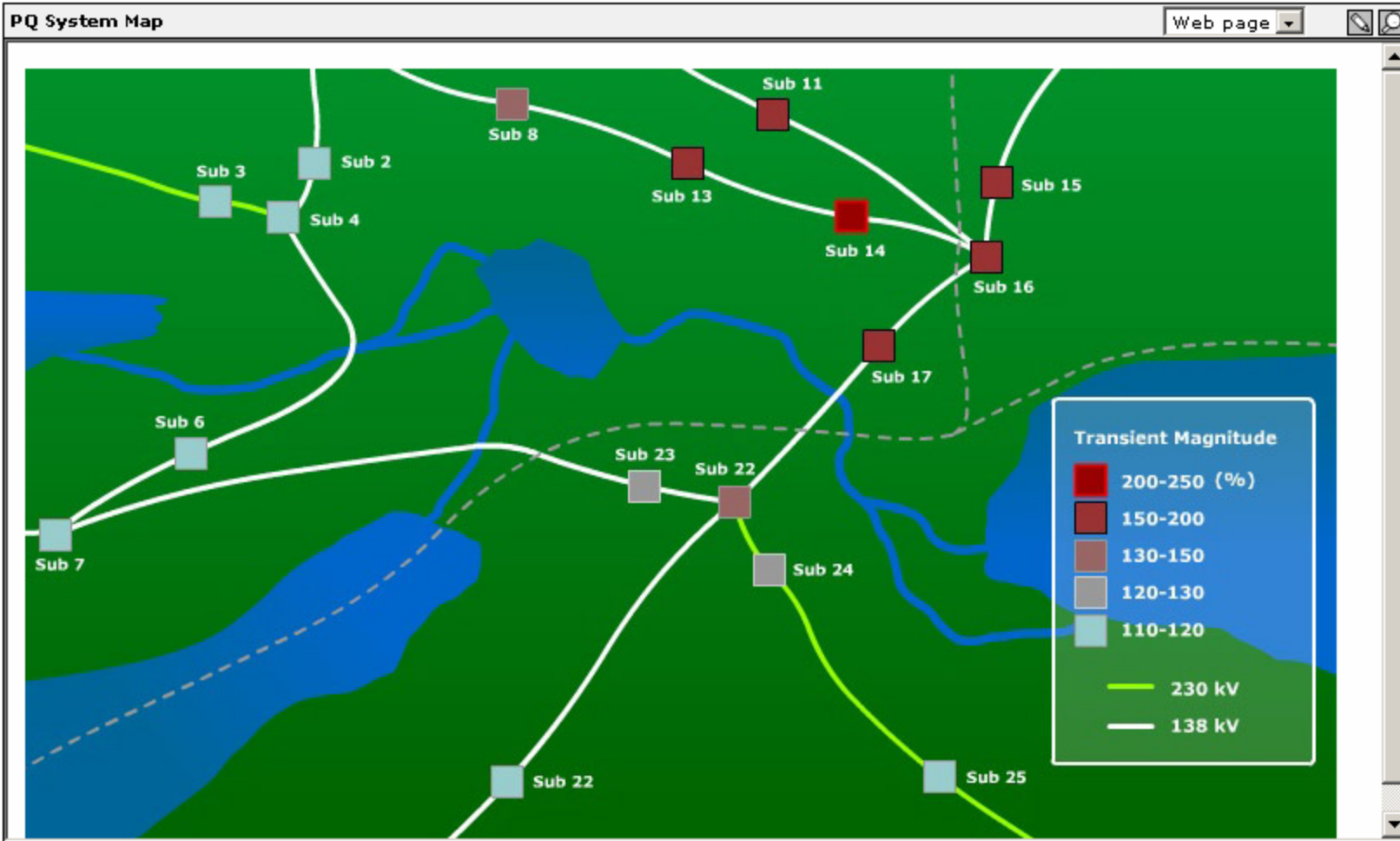
Longer-term Trends

- Improved Distance and Direction to Fault algorithms
- New protocols
 - IEC 61850 with PQ model?
 - COMTRADE in XML?
- Automatic Fault Analysis and *Anticipation*
 - Algorithms to predict faults based on waveform capture



- es
- Transient Map
- Aggregation
- Identify source
- Observe trends
- Analysis ITI
- Analysis SEMI
- Identify cause
- Class. & phase
- Class. & workwk
- Event table
- FD histogram
- RFI report
- 450160 report
- Network report

System map shows the flow of a transient and lets you drill-down to details

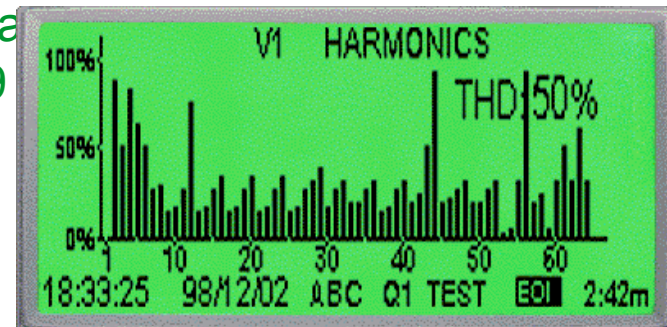


Questions?

Thank you for your time!

8 of 12: Harmonics

- Harmonics: voltage or current occurring at multiples of system frequency. 3rd harmonic is $3 \times 60 \text{ Hz} = 180 \text{ Hz}$. <see demo>
- Two views commonly used
 - Bar graph showing individual components
 - THD (Total Harmonic Distortion) represents the sum of all individual components expressed as a percentage of the fundamental (60 Hz) value.
- IEEE 61000-4-7 defines in detail and interharmonics. IEEE 519 provides information on harmonics.



Compliance Reporting

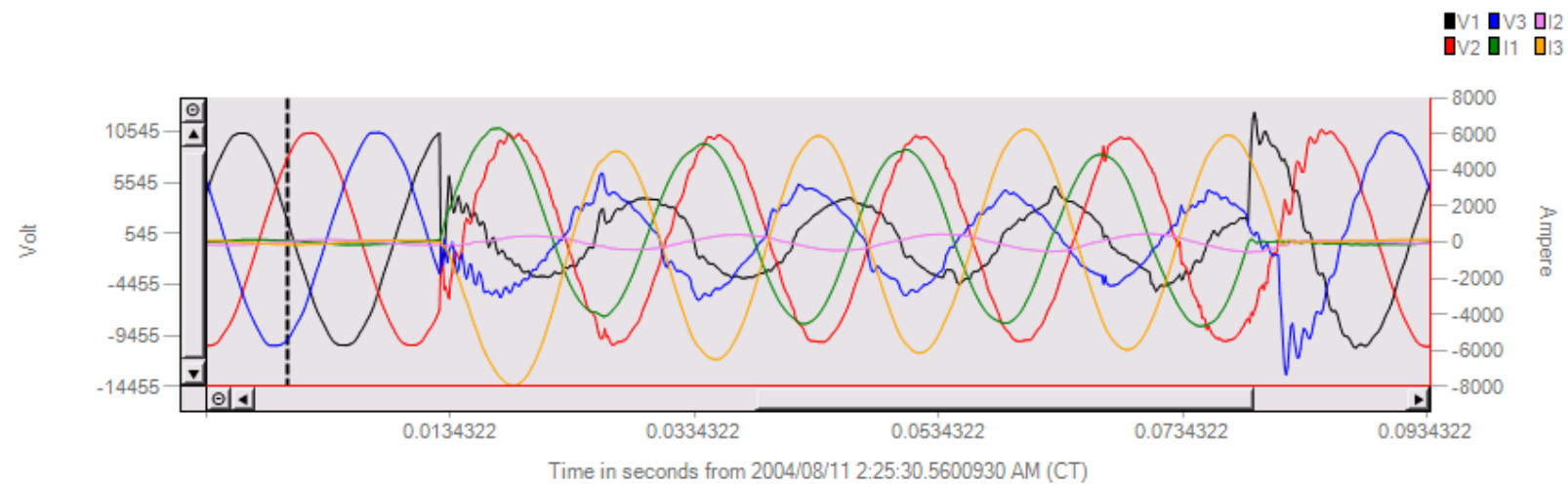
PMI - Network Summary Report

Jan 01, 2004 - Jan 01, 2005

Node	Frequency Mean (Hz)		V Unbal Mean (%)	Voltage Deviation (%)		Voltage HD 95th Percentile (%)						Voltage Dips		SARFI						EN50160	Mon Points
	Max	Min		Max	Min	3	5	7	9	TEHD	THD	TOHD	Agg	Raw	35	50	70	90	110		
Campus1	50.16	49.87		4.42	99.90	0.63	0.70	0.26	0.02	0.07	2.11	2.11	43	59	13	24	29	43	16	FAIL	5
Center1_11kV	50.16	49.87		99.90	99.90								12	15	3	7	8	12	0	PASS	1
Center2_11kV				99.90	99.90								0	0	0	0	0	0	0	PASS	1
Center3_11kV	50.13	49.87		99.90	99.90								9	9	3	5	6	9	0	PASS	1
PowerQuality_Feeder1	50.14	49.87		4.26	1.72					0.00	2.11	2.11	12	15	3	7	8	12	0	FAIL	1
RTU_11KV_Campus1	50.14	49.89		4.42	1.73	0.63	0.70	0.26	0.02	0.07	0.86	0.85	10	20	4	5	7	10	16	PASS	1
Campus2	50.16	45.00		4.52	100.00	0.62	1.02	1.11	0.10	0.10	1.45	1.45	83	115	1	19	30	83	2	PASS	12
CenterA_11kV	50.00	50.00		100.00	100.00								0	0	0	0	0	0	0	PASS	1
CenterB_11kV	50.16	49.90		99.90	99.90								7	11	0	2	3	7	0	PASS	1
CenterC_11kV				100.00	100.00								0	0	0	0	0	0	0	PASS	1
CenterD_11kV	50.16	49.87		99.89	99.90								8	10	0	2	4	8	0	PASS	1
CenterE_11kV				99.90	99.90								0	0	0	0	0	0	0	PASS	1
CenterF_11kV	50.13	49.87		99.90	99.90								6	7	0	2	3	6	0	PASS	1
PowerQuality_FeederA	50.13	49.87		4.03	1.17				0.00	0.00	1.45	1.45	10	14	0	3	4	10	0	PASS	1
PowerQuality_FeederB	50.13	49.87		3.96	1.23					0.00	1.42	1.42	11	15	1	3	5	11	0	PASS	1
PowerQuality_FeederC	50.13	49.88		3.46	0.79					0.00	1.12	1.12	9	14	0	2	3	9	0	PASS	1
PowerQuality_FeederD						0.49	1.02	1.11	0.00	0.00	1.31	1.31	7	11	0	2	3	7	1	PASS	1
PowerQuality_FeederE	50.13	49.88		3.44	0.87		1.00	0.62	0.00	0.00	1.14	1.14	19	23	0	2	2	19	0	PASS	1
RTU_11KV_Campus2	50.16	45.00		4.52	1.53	0.62	0.55	0.98	0.10	0.10	1.10	1.10	6	10	0	1	3	6	1	PASS	1

Waveform Viewer: Detail Mode

Johnson City 2004/08/11 2:25:30.5600930 AM (CT)



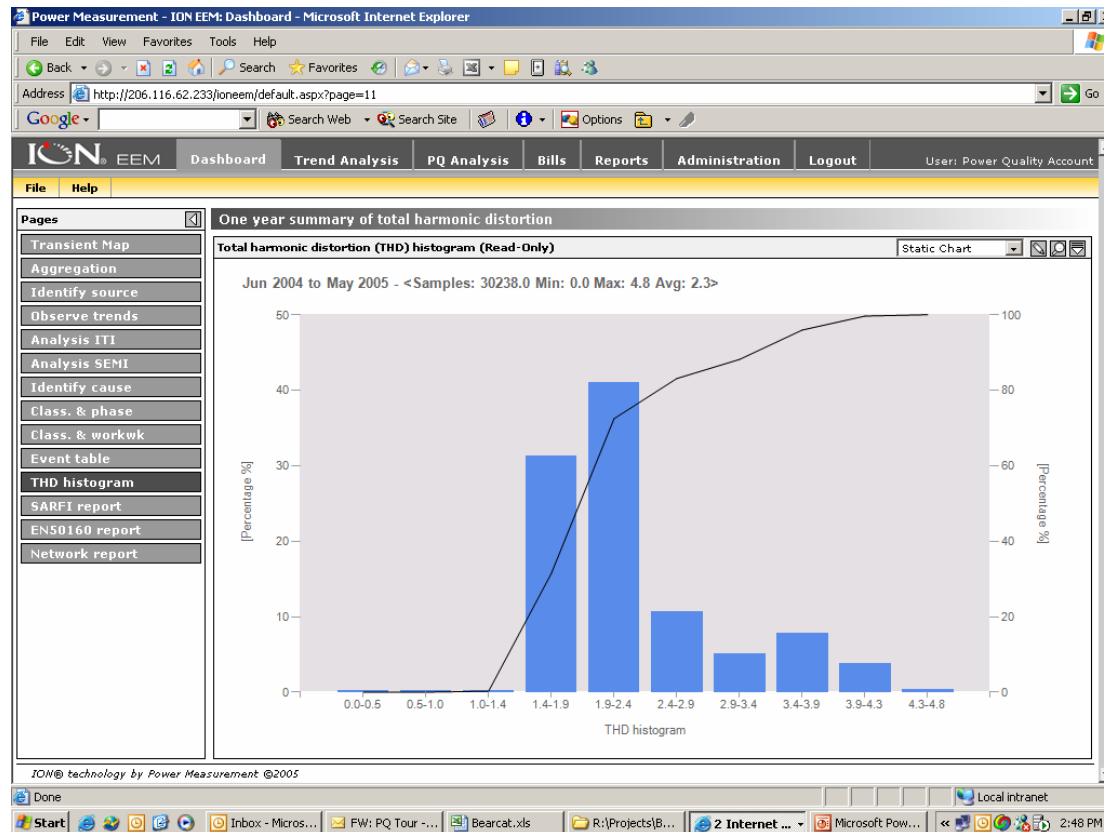
Update Chart Return to Waveform List

Related Event Summary:
Start: 2004/08/11 2:25:30.5600930 AM (CT)
End: 2004/08/11 2:25:30.6350510 AM (CT)
Type: Instantaneous Sag

- Voltage
- | | | |
|--|----------------------------------|------------------------------|
| V1 <input checked="" type="checkbox"/> Raw | <input type="checkbox"/> Min/Max | <input type="checkbox"/> RMS |
| V2 <input checked="" type="checkbox"/> Raw | <input type="checkbox"/> Min/Max | <input type="checkbox"/> RMS |
| V3 <input checked="" type="checkbox"/> Raw | <input type="checkbox"/> Min/Max | <input type="checkbox"/> RMS |
- Current
- | | | |
|--|----------------------------------|------------------------------|
| I1 <input checked="" type="checkbox"/> Raw | <input type="checkbox"/> Min/Max | <input type="checkbox"/> RMS |
| I2 <input checked="" type="checkbox"/> Raw | <input type="checkbox"/> Min/Max | <input type="checkbox"/> RMS |
| I3 <input checked="" type="checkbox"/> Raw | <input type="checkbox"/> Min/Max | <input type="checkbox"/> RMS |

- # Histogram Views

Histograms and Cumulative Probability charts can be used to track values such as harmonic distortion or line loading



Technical Requirements for Class A Monitoring

- Time clock uncertainty must be <20 ms
 - GPS sources and/or temperature-compensated oscillators required

- All measurements must be synchronized to zero crossings



- Half-cycle floating-point measurements required for dips, swells and interruptions
 - Powerful DSP or ASIC needed



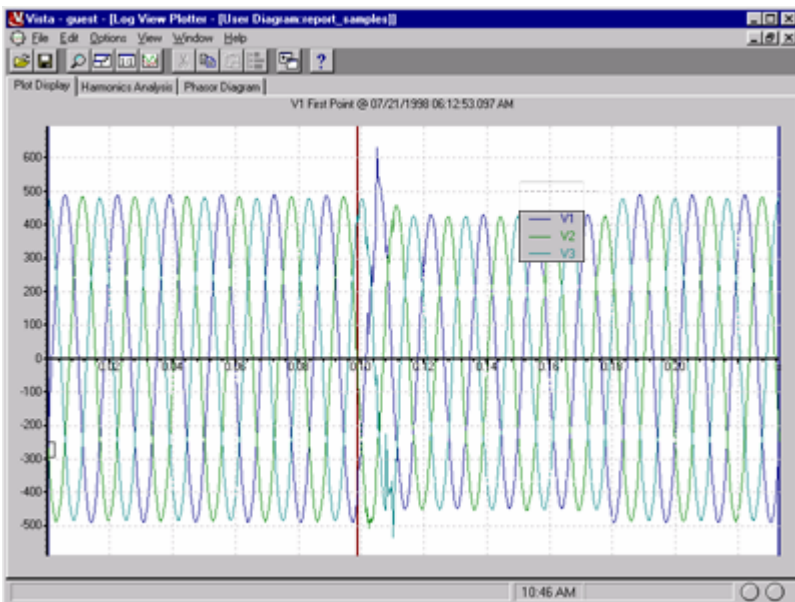
- Gapless, continuous measurements required
 - Never 'blind'
 - Continuous FFT calculations



- High frequency resolution needed for interharmonics and mains signalling

Technical Requirements for Class A Monitoring - *Tomorrow*

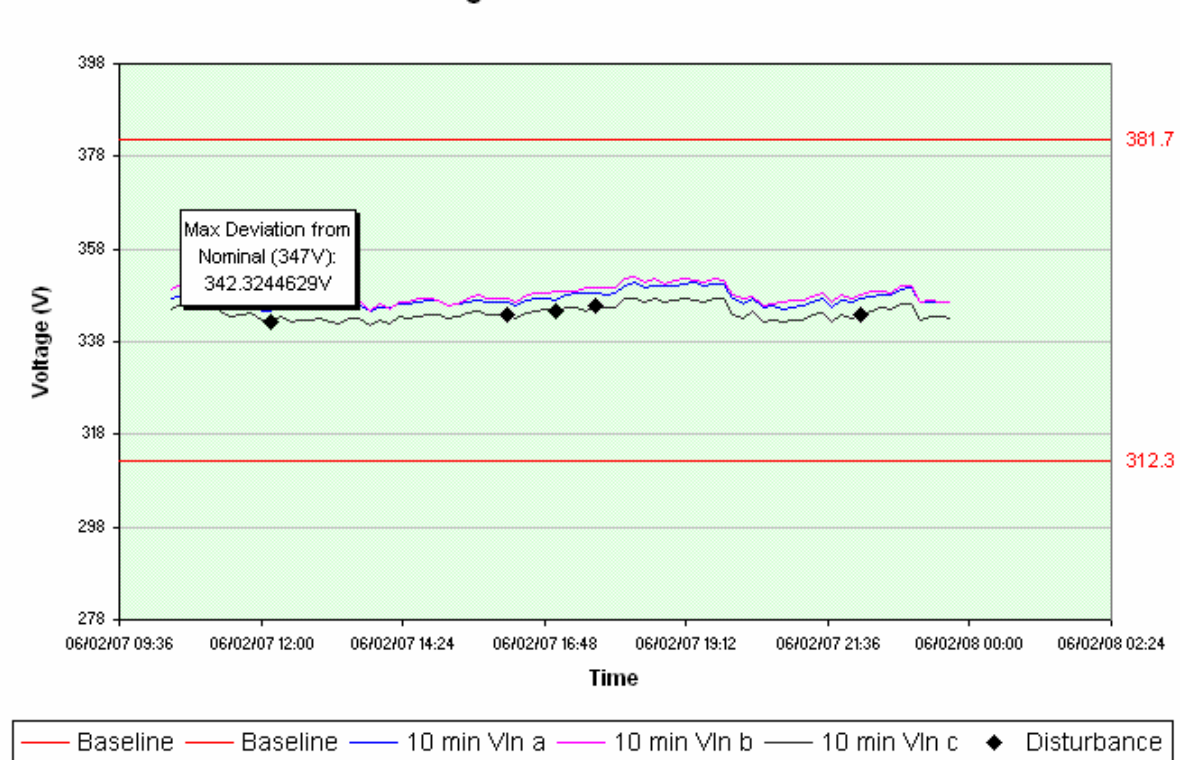
- Flexibility needed for Rapid Voltage changes
- Measurement of Voltage and Current
 - 5 current gain stages, simultaneous sampling for saturation
- Monitoring current harmonics useful for transformer maintenance and optimization
- Waveform capture of current useful to determine fault location through either waveshape analysis or phasor plots
- Transient capture required in future standard revision
 - 1024 samples/cycle gives 20 μ s capture



Steady-state measurements (Frequency, Voltage)

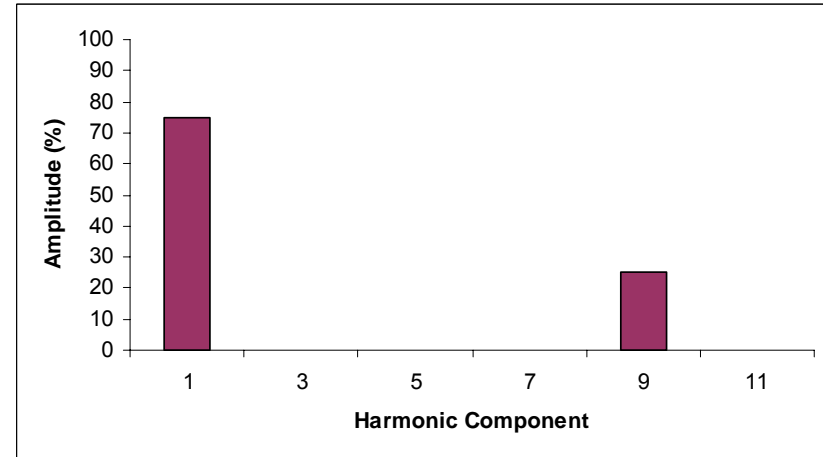
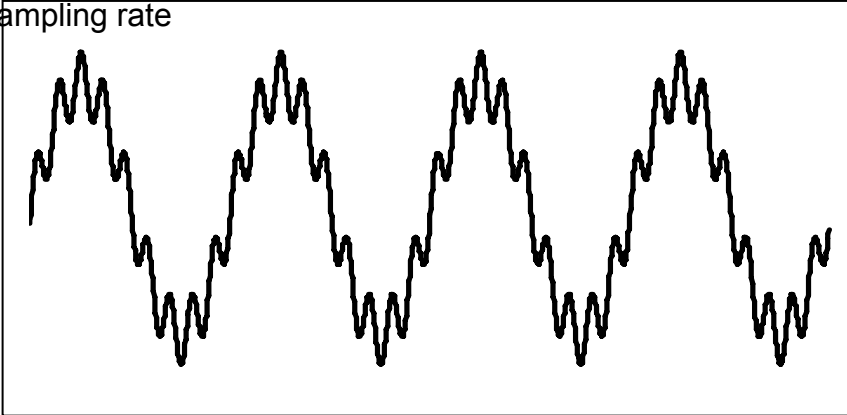
IEC 61000-4-30	
Voltage Profile for Test_Main_7600_10min	
Test Company Name	From: February 7, 2006 10:30:00
10 Minute Interval	To: February 7, 2006 23:40:00

4-30 Voltage Profile - 10 Minute Interval

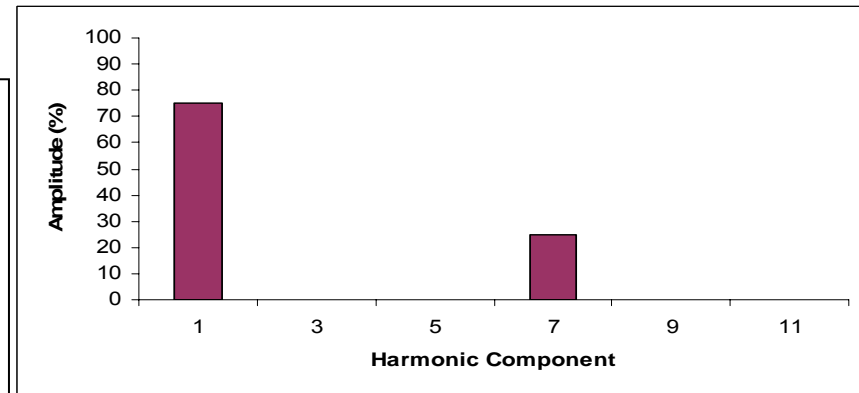
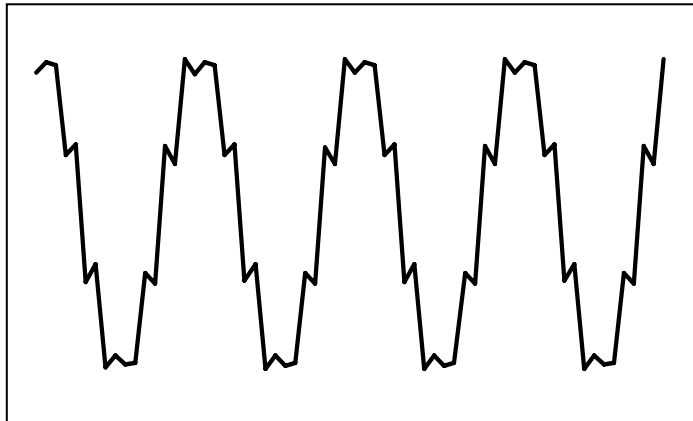


Aliasing Effect Example

@ 512 samples/cycle
sampling rate



@ 16 samples/cycle
sampling rate



'All In One' View

PMI - Network Summary Report

Jan 01, 2004 - Jan 01, 2005

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Center2_11kV				99.90	99.90								0	0	0	0	0	0	0	PASS	1
Center3_11kV	50.13	49.87		99.90	99.90								9	9	3	5	6	9	0	PASS	1
PowerQuality_Feeder1	50.14	49.87		4.26	1.72					0.00	2.11	2.11	12	15	3	7	8	12	0	FAIL	1
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CenterA_11kV	50.00	50.00		100.00	100.00								0	0	0	0	0	0	0	PASS	1
CenterB_11kV	50.16	49.90		99.90	99.90								7	11	0	2	3	7	0	PASS	1
CenterC_11kV				100.00	100.00								0	0	0	0	0	0	0	PASS	1
CenterD_11kV	50.16	49.87		99.89	99.90								8	10	0	2	4	8	0	PASS	1
CenterE_11kV				99.90	99.90								0	0	0	0	0	0	0	PASS	1
CenterF_11kV	50.13	49.87		99.90	99.90								6	7	0	2	3	6	0	PASS	1
PowerQuality_FeederA	50.13	49.87		4.03	1.17				0.00	0.00	1.45	1.45	10	14	0	3	4	10	0	PASS	1
PowerQuality_FeederB	50.13	49.87		3.96	1.23					0.00	1.42	1.42	11	15	1	3	5	11	0	PASS	1
PowerQuality_FeederC	50.13	49.88		3.46	0.79					0.00	1.12	1.12	9	14	0	2	3	9	0	PASS	1
PowerQuality_FeederD						0.49	1.02	1.11	0.00	0.00	1.31	1.31	7	11	0	2	3	7	1	PASS	1
PowerQuality_FeederE	50.13	49.88		3.44	0.87		1.00	0.62	0.00	0.00	1.14	1.14	19	23	0	2	2	19	0	PASS	1
RTU_11KV_Campus2	50.16	45.00		4.52	1.53	0.62	0.55	0.98	0.10	0.10	1.10	1.10	6	10	0	1	3	6	1	PASS	1

Comparison of Harmonic Compliance Levels

