Power Quality in Metering

Ming T. Cheng

Directory of Asian Operations

10737 Lexington Drive
Knoxville, TN 37932

Phone: (865) 218.5885

PQsynergy2012

www.powermetrix.com

Focus of this Presentation

- How power quality events affect metering
- What we will cover
  - Basic PQ terminology and events
  - Effects on metering and meter accuracy
- Harmonic Issues
- Infrastructural consequences

POWERMETRIX

What is Power Quality?

- Deviation from a pure sinusoidal voltage supply at a frequency of 50 Hz (60 Hz for US).
  - Sags, dips, swells
  - Transient voltages
  - Harmonics
  - Voltage Regulation
  - Frequency Variations

POWERMETRIX

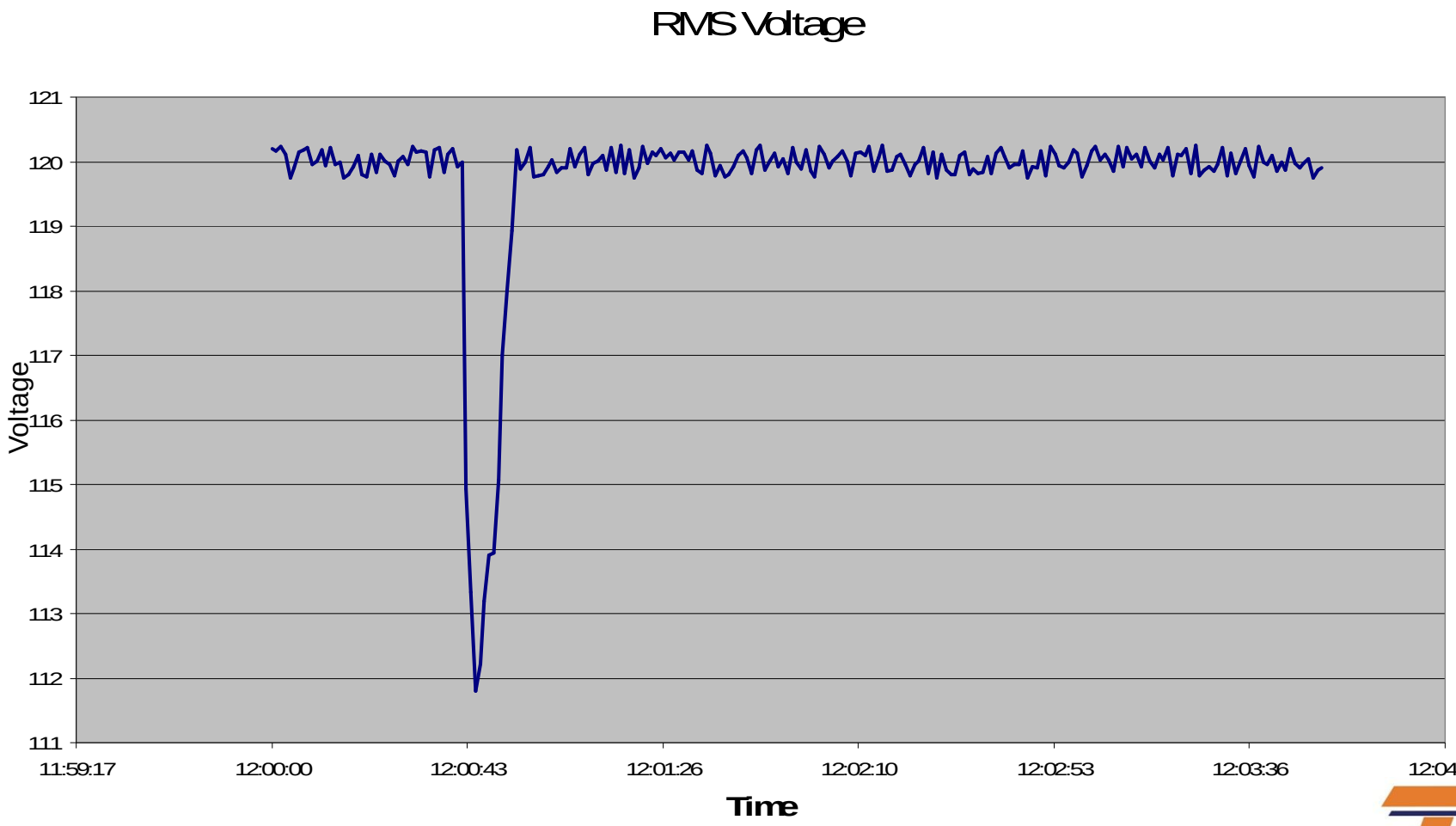
Power Quality Issues

- Sags and swells
  - Deviations from normal RMS voltage which last from 0.5 cycle to several seconds
  - Most common power quality issues caused by load transition
  - Very noticeable to customers
  - Often an infrastructure sizing vs. load issue
  - Generally not an issue from a **metering accuracy** point of view

POWERMETRIX

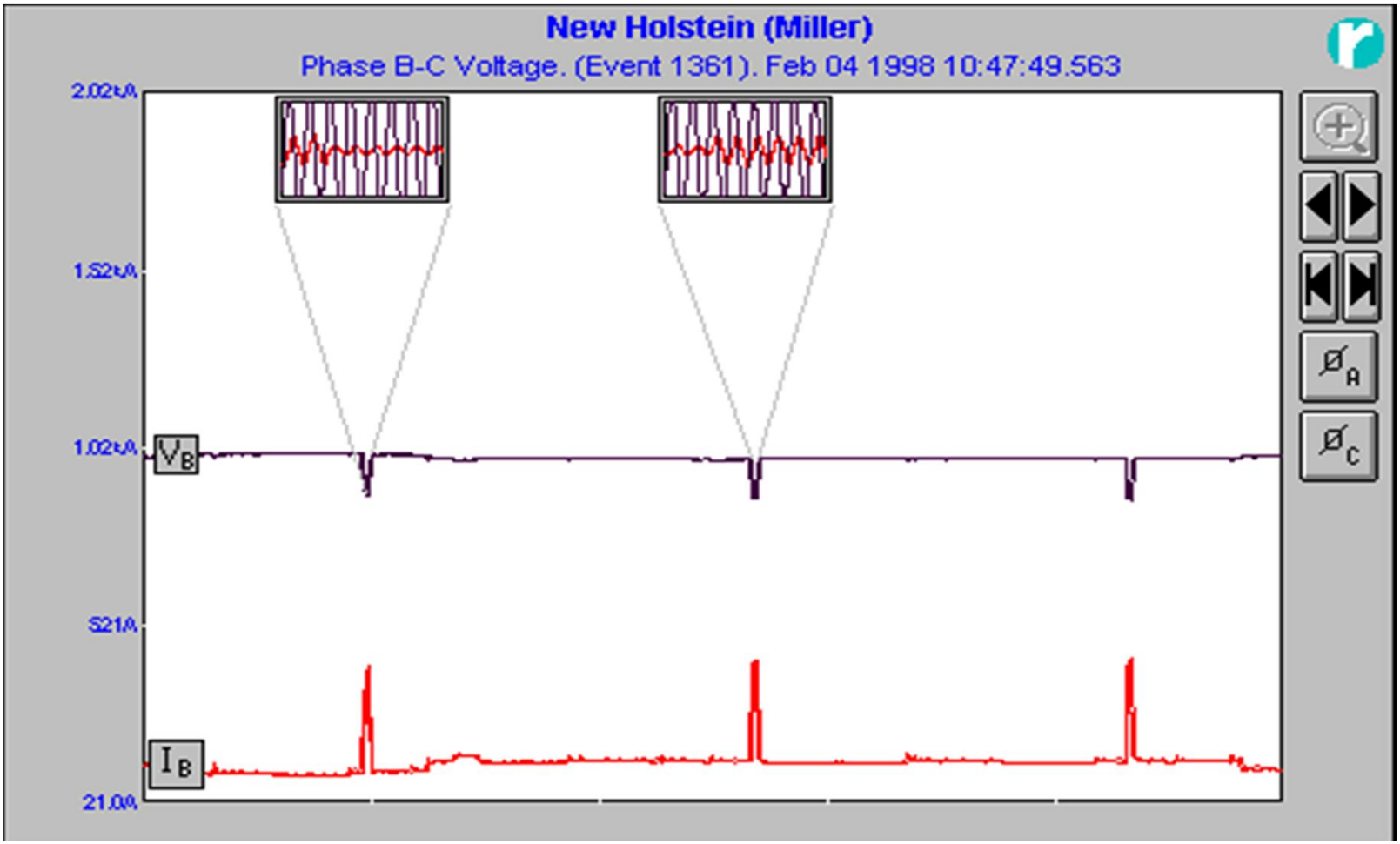
Power Quality Issues

Sag



POWERMETRIX

Power Quality Issues



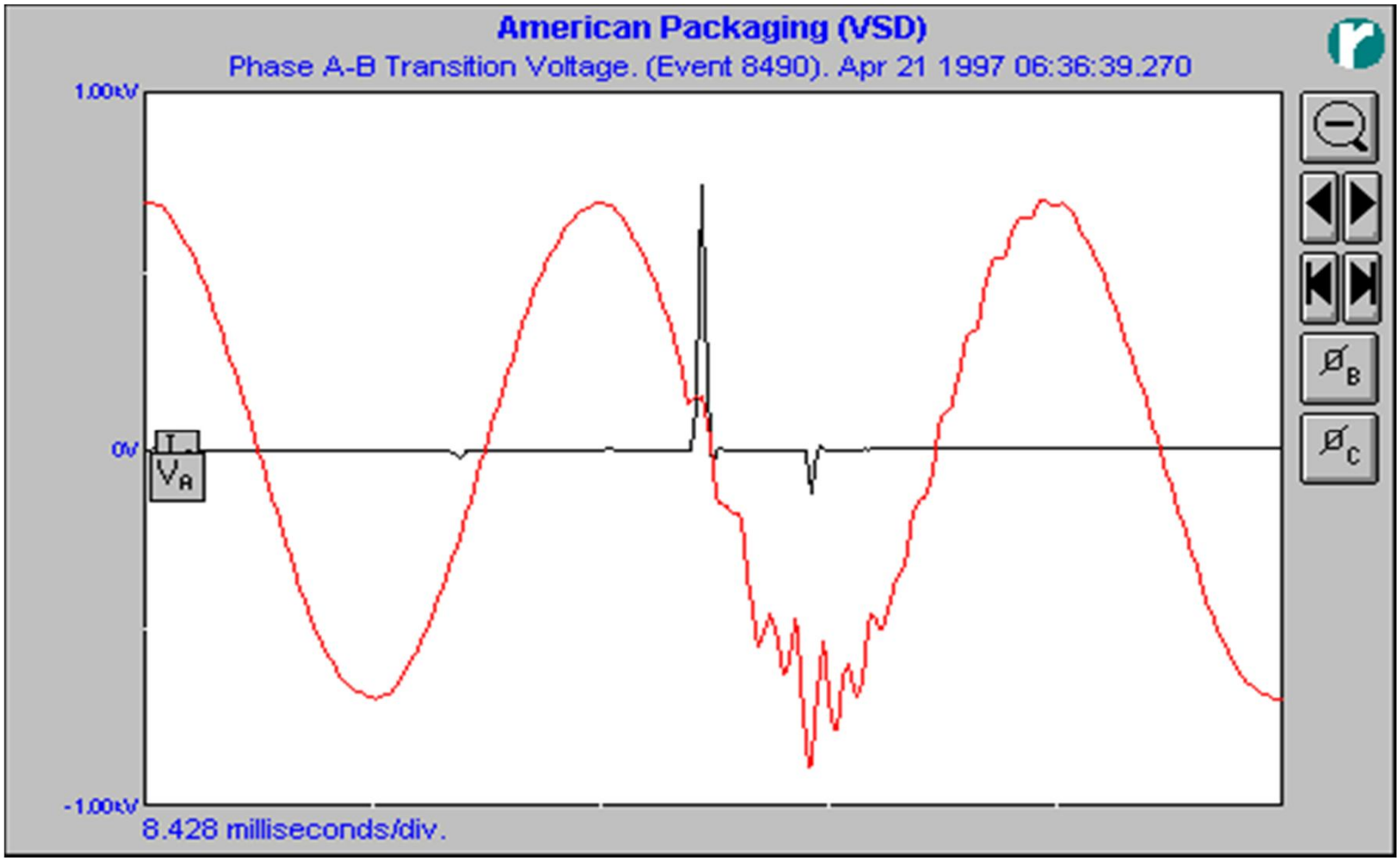
POWERMETRIX

Power Quality Issues

- Transient Voltages
  - Very short deviations from the normal sinusoidal voltage – “spikes”
  - Sources – capacitive switching, lightning
  - Can cause equipment failures both for utility and for customers
  - Other than potential meter damage, doesn’t usually cause **metering** problems

POWERMETRIX

Power Quality Issues



Transient Caused by Capacitor Bank Switching

POWERMETRIX

Power Quality Issues

- Voltage Regulation
  - Long term variations in voltage
  - ANSI C84.1 defines two **service** ranges
    - Range A Normal conditions
      < 600 VAC ±5.0% at service entrance
      > 600 VAC -2.5% +5.0%
    - Range B Short durations or unusual conditions
      -8.3% +5.8%
  - Not a metering accuracy issue

POWERMETRIX

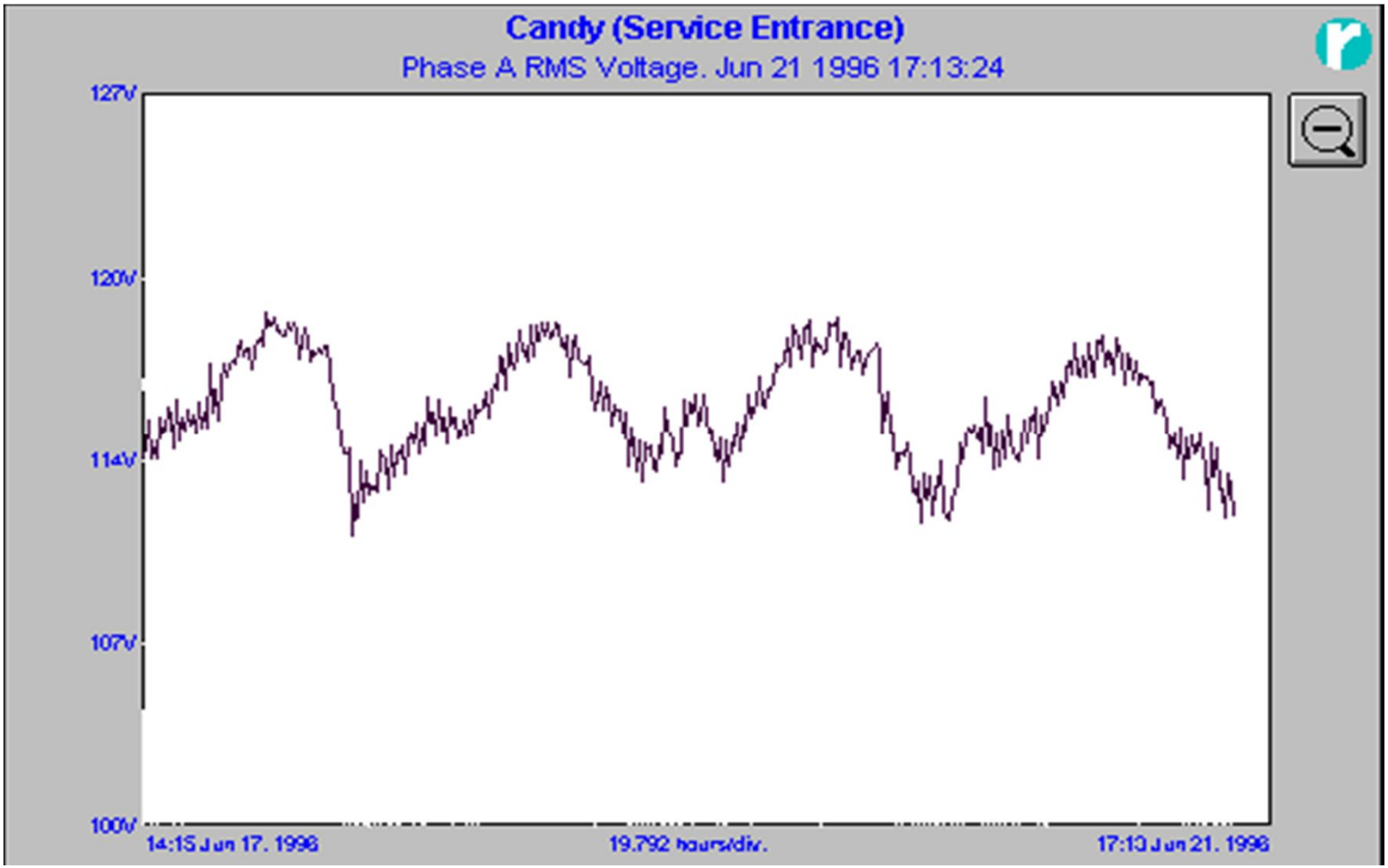
Power Quality Issues

- Voltage Regulation
  - Long term variations in voltage
  - ANSI C84.1 defines two **utilization** ranges
    - Range A Normal conditions
      < 600 VAC -8.3% +5.0%
      > 600 VAC -10% +5.0%
    - Range B Short durations or unusual conditions
      -12% +5.8%
  - Not a metering accuracy issue

If we provide service that meets the SERVICE range requirement the customer utilization range requirement should be met.

POWERMETRIX

Power Quality Issues



Voltage regulation issue created by overloaded circuit.

POWERMETRIX

Power Quality Issues

- Frequency Stability
  - Fluctuations are generally small and slowly varying averaging to zero
  - Western Grid Data
    - Normal: ±0.015 Hz
    - Sudden Changes: ±0.100 Hz (several times a month)
    - Major Breakup: ±0.750 Hz (once every few years)
  - Can potentially cause metering issues in measuring VAR, VA and PF, especially for VAR measurement

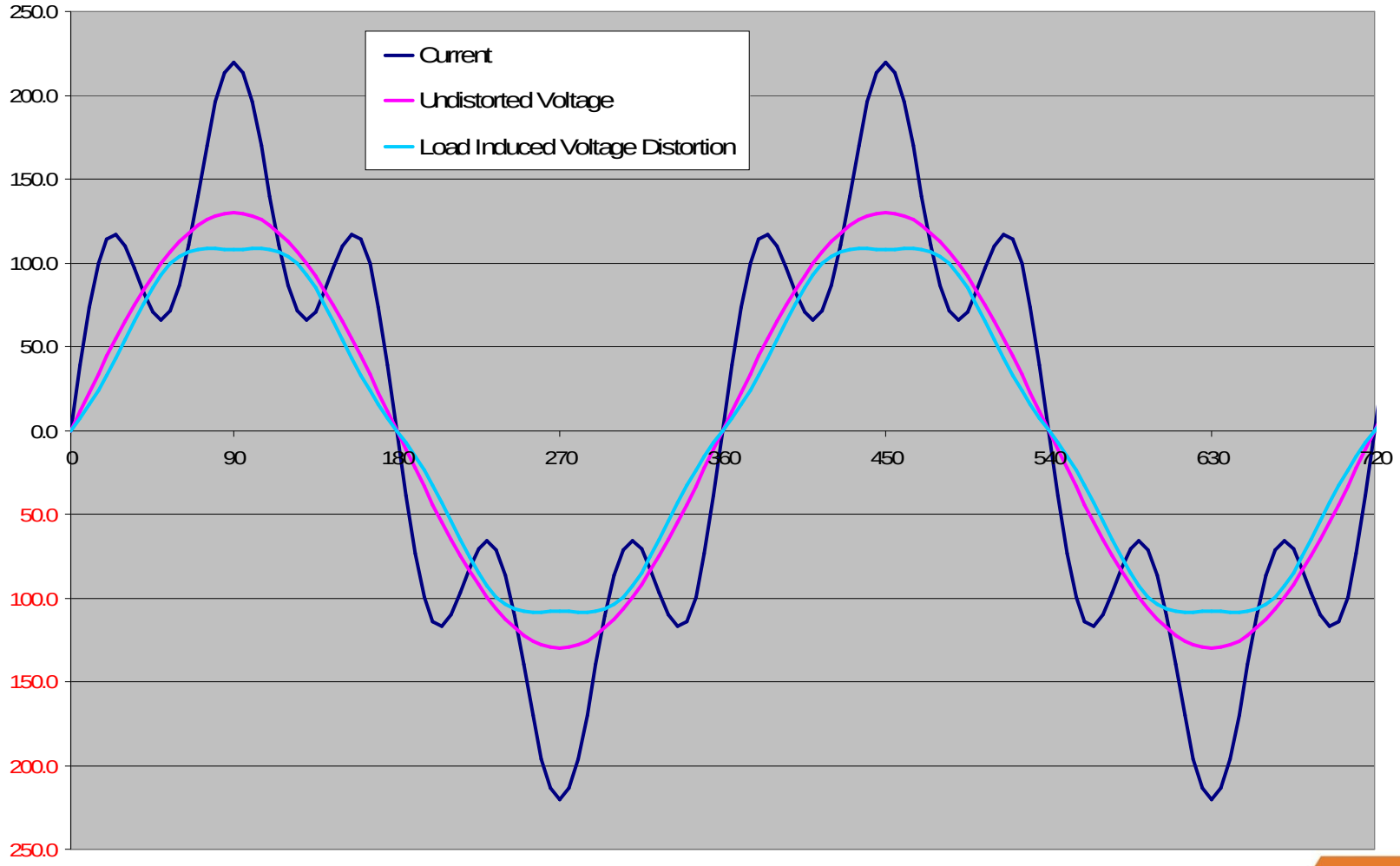
POWERMETRIX

Power Quality Issues

- Harmonics
  - Repetitive contamination of the voltage or current waveform
  - Generated by non-linear loads. Voltage harmonics are a reflection of the non-linear load on a distribution system with finite impedance
  - Produce a variety of infrastructural problems
  - Generate system losses
  - Can result in metering errors and disputes in measuring Power (P)

POWERMETRIX

Power Quality Issues



POWERMETRIX

Focus on Harmonics

- Where do harmonics come from?
  - Non-linear loads at the customer's site
  - Coupling from loads at other sites sharing the distribution system
    - One customer's harmonic current load is converted into voltage harmonics at other customer's sites by the impedance of the system

POWERMETRIX

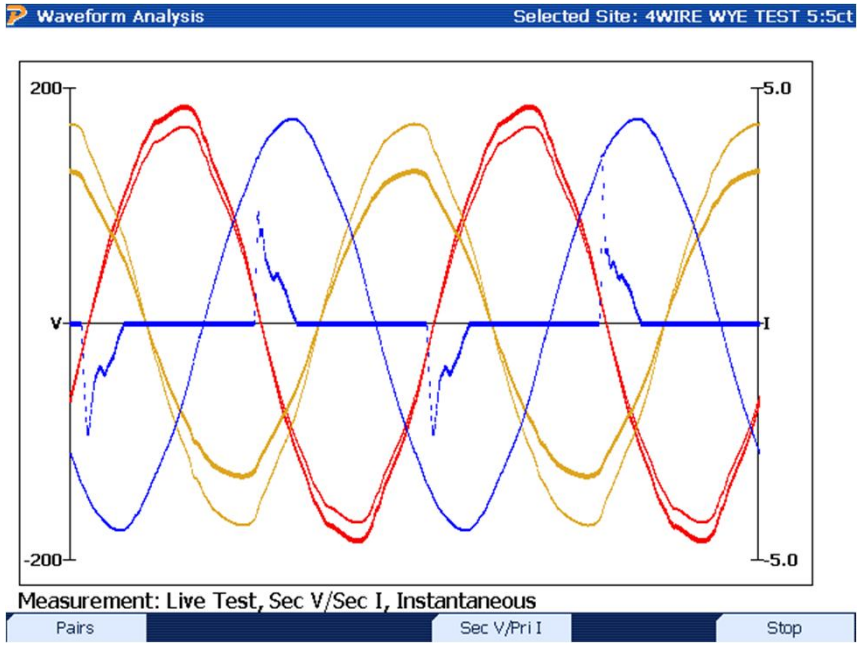
Traditional Harmonic Sources

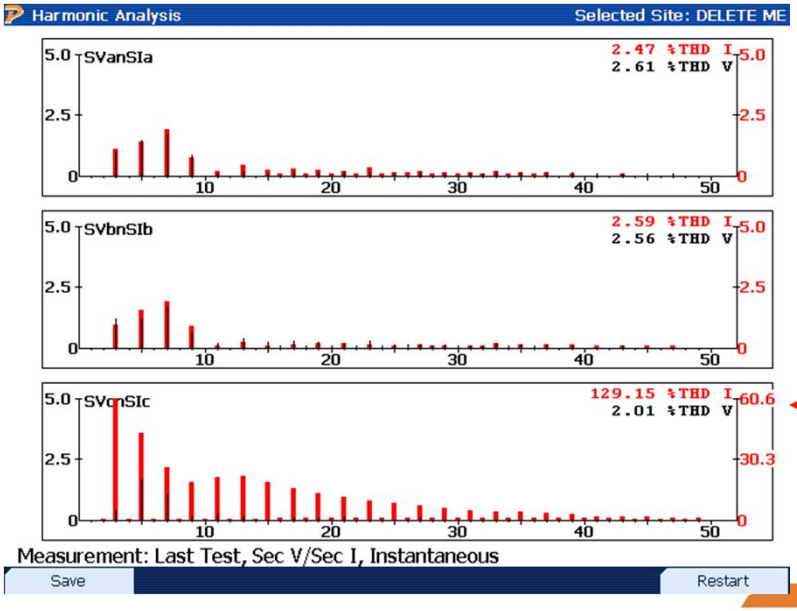
SOURCE	TYPE	LEVEL
Transformer ▪ Saturation ▪ Energization	**Current Harmonics** **3,5,7… & 2,4…**	**1 to 85%**
Arc Furnace Welders	**Voltage Harmonics** **5 & 7**	**2.5 to 8%**
Line Commuted Converters	**Volt. & Cur. Harmonics** **H = np ± 1**	**10 to 30%**
Static VAR Compensators	**Current Harmonics** **H = np ± 1**	**2 to 4%**
Saturable Reactors	**Current Harmonics** **3,5,7…**	**1 to 8%**

POWERMETRIX

New Harmonic Sources

SOURCE	TYPE	LEVEL
Fluorescent Lighting	Current Harmonics 3,5,7… up to > 49	> 400%
Electronic Power Supplies Especially Computers	Current Harmonics 3,5,7… up to > 25	>100%

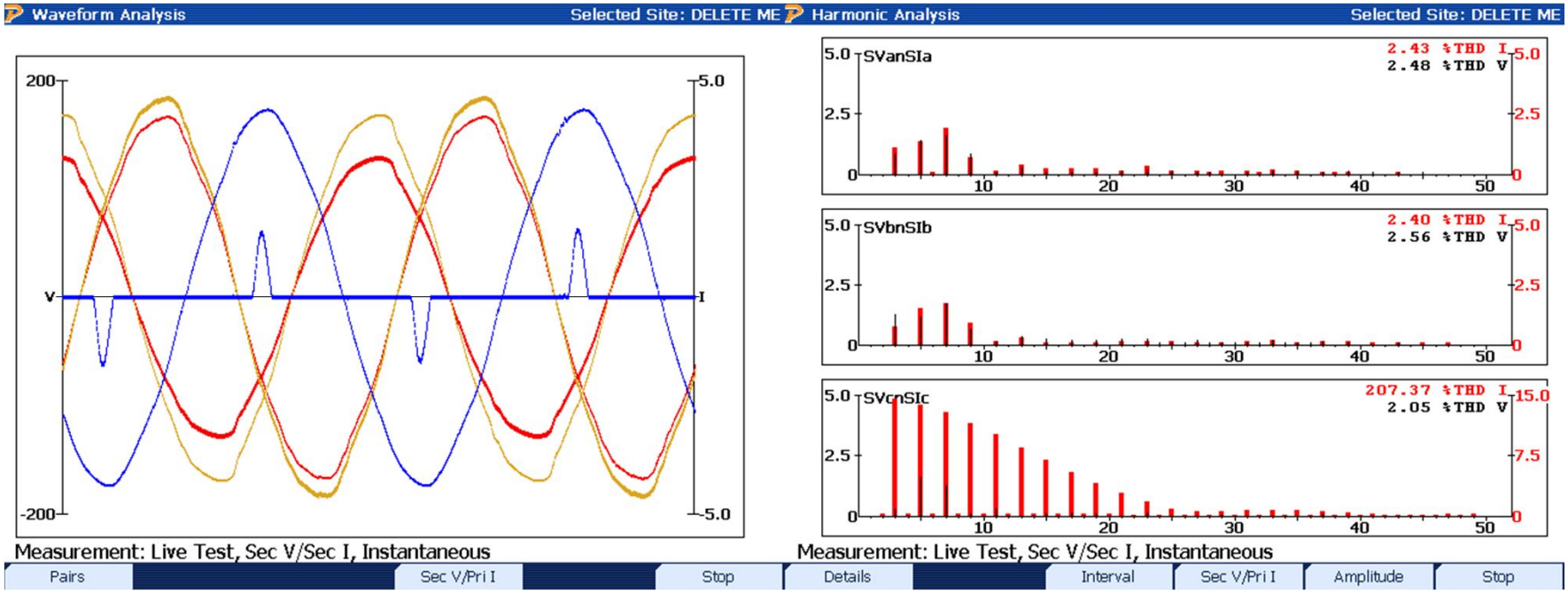




Current waveform for compact fluorescent light.

POWERMETRIX

New Harmonic Sources



Current waveform for laptop computer.

POWERMETRIX

Focus on Harmonics

- Common harmonic generating loads
  - Variable speed motors
  - Electronic equipment of all types
    - Especially computers
  - Fluorescent lights
- In today's world there are very few loads that do not generate harmonics.
- Many meters make mistakes under these conditions

POWERMETRIX

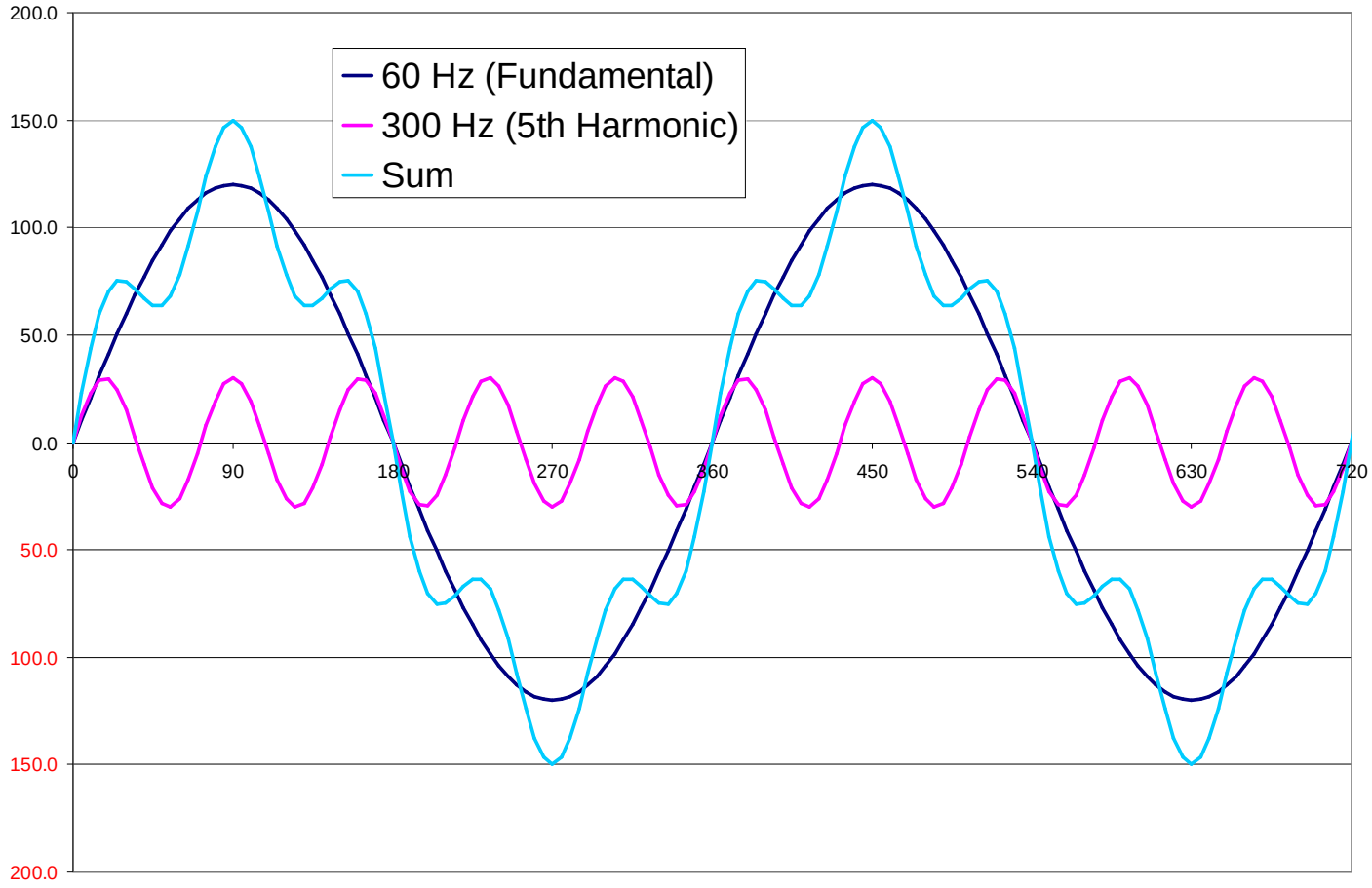
Harmonics Theory

- Basic Harmonic Theory
  - Harmonics describe disturbances which repeat every cycle for a significant number of cycles
- Engineers use Fourier notation to describe harmonic waveforms

$$V(t) = \sqrt{2}\sum_{n=1}^{\infty}\left(V_n Sin(n\omega_0 t - \alpha_n)\right)$$

POWERMETRIX

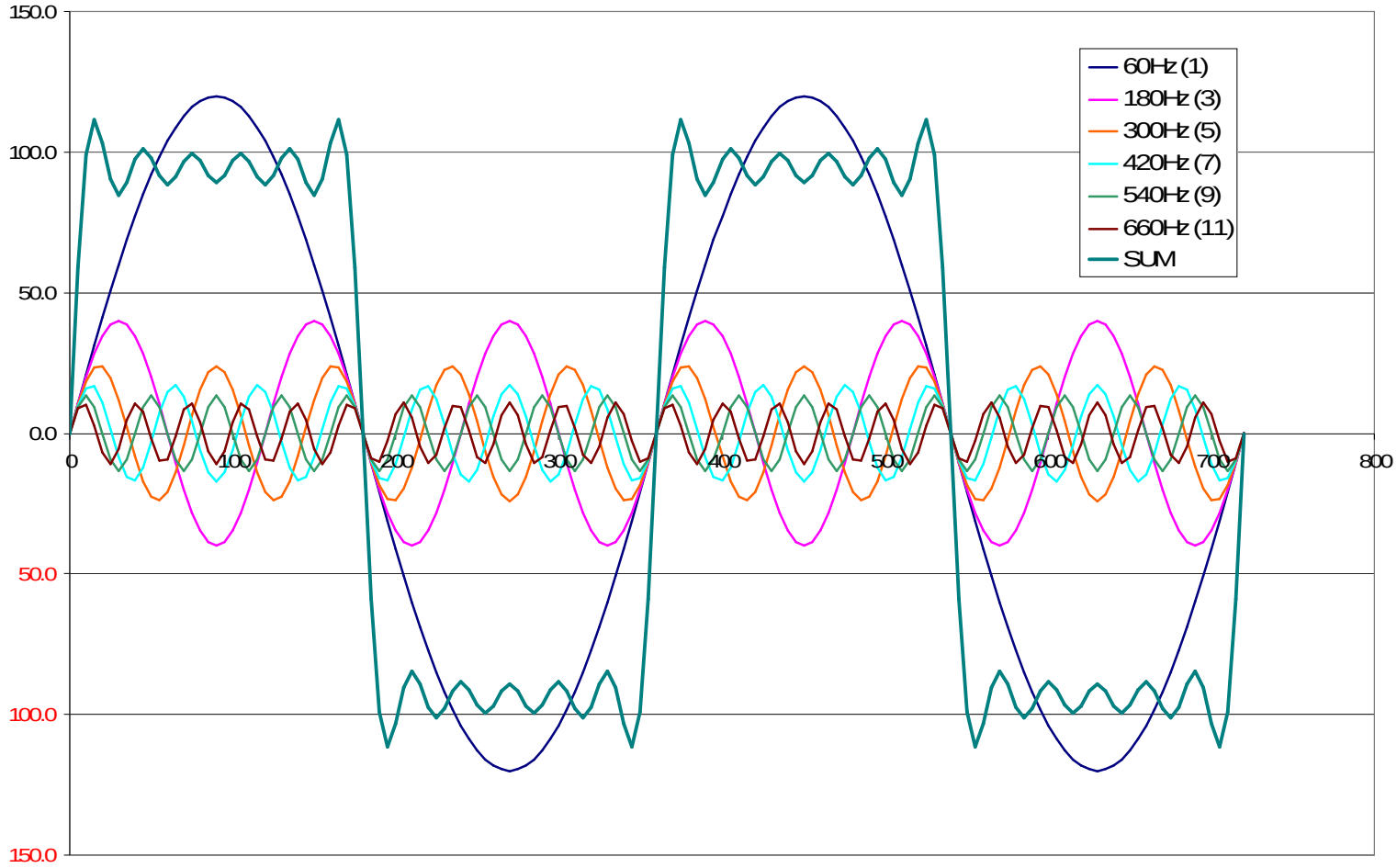
Harmonics Theory



$$V(t) = \sqrt{2}\sum_{n=1}^{\infty}\left(V_n Sin(n\omega_0 t - \alpha_n)\right)$$

POWERMETRIX

Harmonics Theory



Even a square wave can be represented as a series of harmonics.

POWERMETRIX

Harmonic Theory
An Alternate Approach

- Harmonics can be grouped into “sequences” which help us understand their effects.

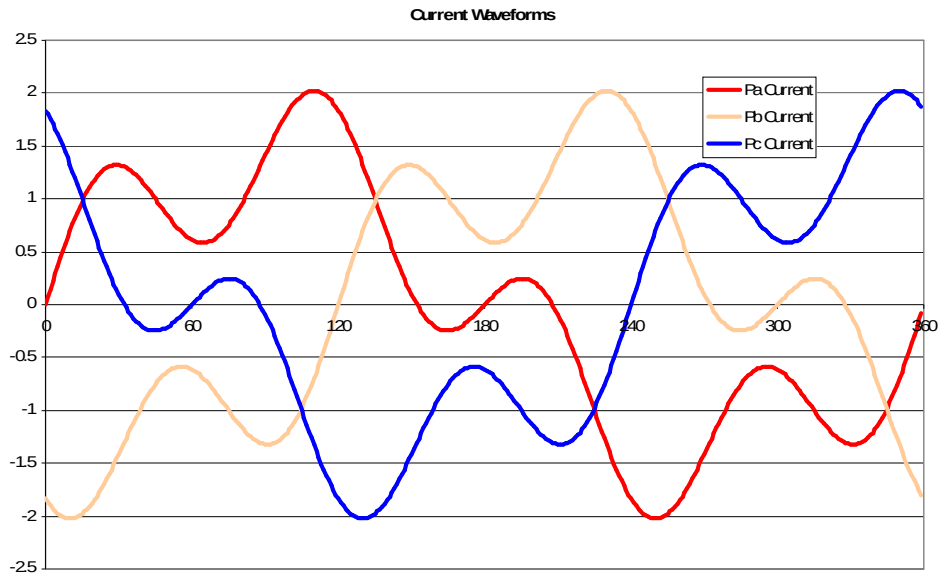
Name	F	2nd	3rd	4th	5th	6th	7th	8th	9th
Freq	60	120	180	240	300	360	420	480	540
Seq	+	-	0	+	-	0	+	-	0

POWERMETRIX

Harmonic Theory

An Alternate Approach

Name	F	2nd	3rd	4th	5th	6th	7th	8th	9th
Freq	60	120	180	240	300	360	420	480	540
Seq	+	-	0	+	-	0	+	-	0



Positive (+)

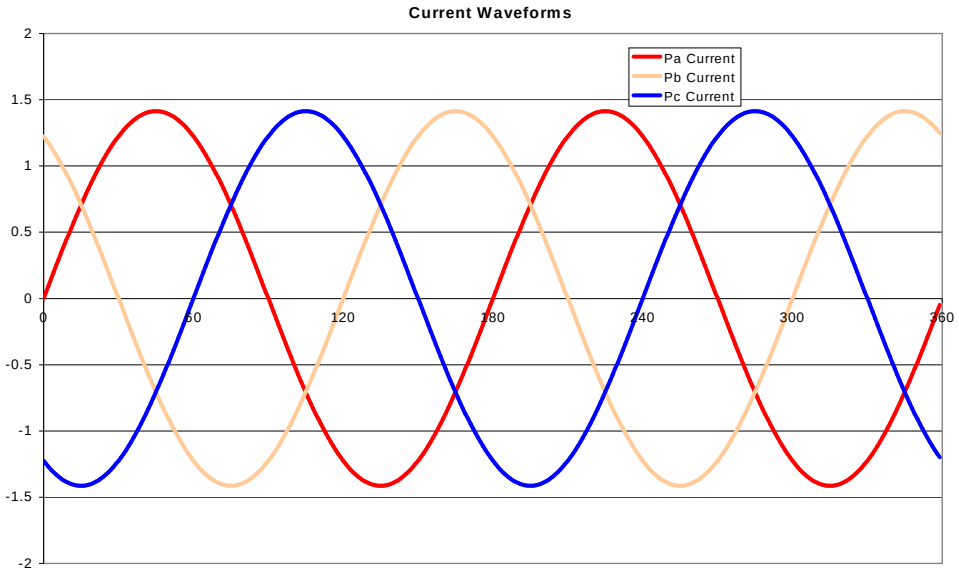
- If fundamental rotation is ABC then positive (+) sequence harmonics have ABC rotation

POWERMETRIX

Harmonic Theory

An Alternate Approach

Name	F	2nd	3rd	4th	5th	6th	7th	8th	9th
Freq	60	120	180	240	300	360	420	480	540
Seq	+	-	0	+	-	0	+	-	0



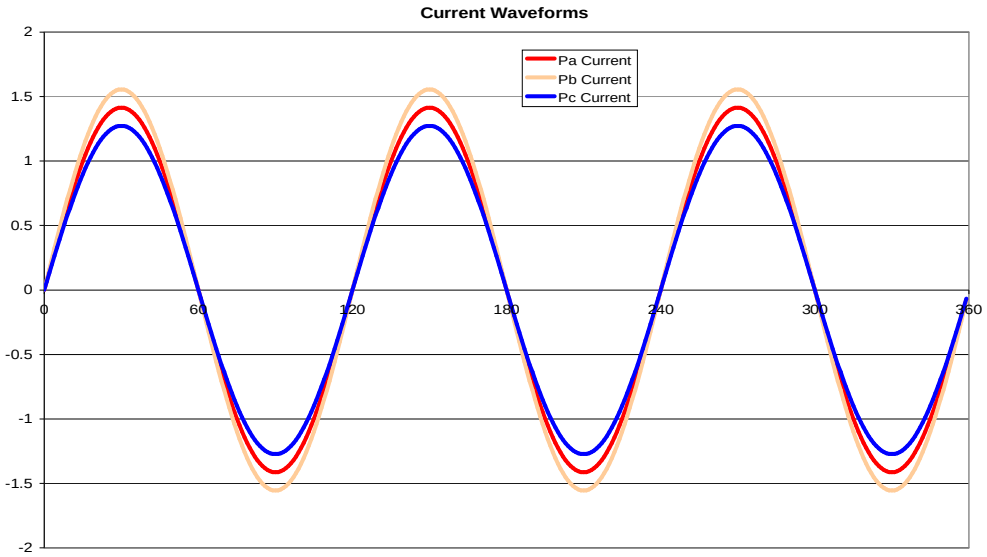
Negative (-)

- If fundamental rotation is ABC then negative (-) sequence harmonics have CBA rotation

POWERMETRIX

Harmonic Theory
An Alternate Approach

Name	F	2nd	3rd	4th	5th	6th	7th	8th	9th
Freq	60	120	180	240	300	360	420	480	540
Seq	+	-	0	+	-	0	+	-	0



ZERO (0)

- If fundamental rotation is ABC then zero (0) sequence harmonics have NO rotation

POWERMETRIX

Harmonic Theory
An Alternate Approach

- Positive (+)
  - Heating of conductors and transformers
- Negative (-)
  - Heating of conductors and transformers
  - Tries to make motors run backwards
- Zero (0)
  - Results in neutral currents which can be larger than phase currents

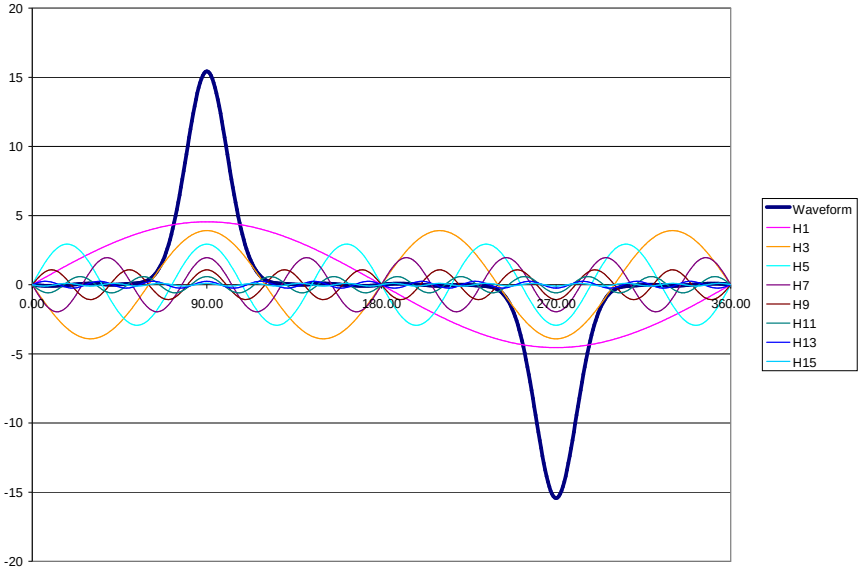
POWERMETRIX

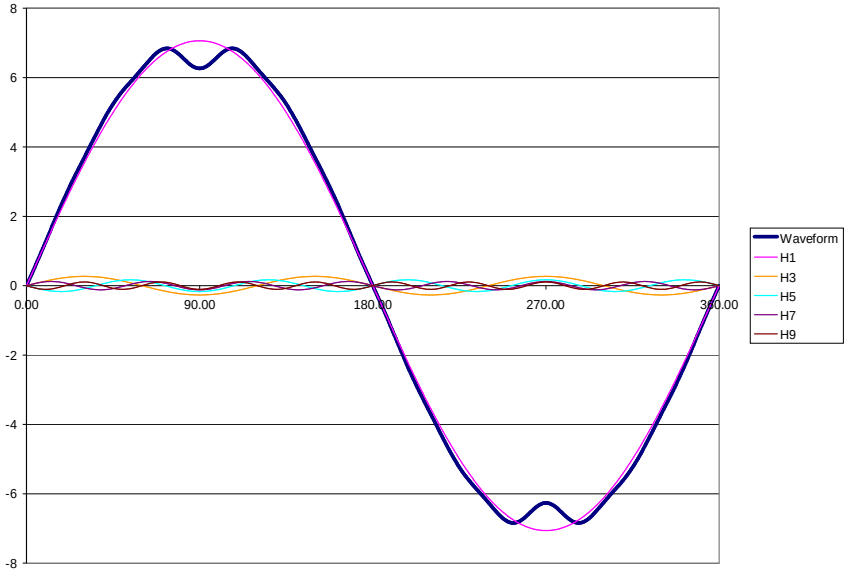
Harmonics & Metering Accuracy

- Today ANSI C12 Standard does not require meters to be tested under harmonic conditions
  - Harmonics Working Group formed to address the issue
  - First step to establish testing for harmonic influence on Watt hour measurements.
  - Preliminary testing of proposed waveforms show most meters do well, but a few do very poorly.

POWERMETRIX

Harmonics & Metering Accuracy





Harmonic	Current Amplitude	Phase	Voltage Amplitude	Phase	Power
1	100	90	100	90	10000
3	80	270	3.8	90	-304
5	60	90	2.4	270	-144
7	40	270	1.7	90	-68
9	22	90	1.5	270	-33
11	12	270	1.1	90	-13.2
13	5	90	0.8	270	-4
15	2	270			0
17	1	90			0
19	0.5	270			0
					9,433.80

POWERMETRIX

Harmonics & Metering Accuracy

- Primarily affect the calculation of VA, VAR and Power Factor
  - No ANSI standard for these calculations at this time
  - Different manufacturers use different methods and definitions.
  - Most manufacturers allow the user to make several choices for each
  - Differences of over 50 percent in answers can occur in high harmonic situations

POWERMETRIX

Other Power Quality Issues On Metering

- Sub Harmonics (Freq < Fundamental)
  - Generated by electronics
  - Not addressed in any standard
  - Not measured by FFT based approaches
- Non-Harmonic High Frequency Disturbances
  - Caused by PLC, Ethernet….
  - Not addressed in any standard
  - Not measured by FFT based approaches
- Sudden Load Changes
  - Large Load switched in and out instantaneously
  - Not addressed in any standard
  - Not measured by FFT based approaches

POWERMETRIX

References

IEEE Power Quality Standards

- SCC-22 Power Quality Standards Coordinating Committee
- 1159: Monitoring Electric Power Quality
  - 1159.1: Guide for Recorder and Data Acquisition Requirements
  - 1159.2: Power Quality Event Characterization
  - 1159.3: Data File Format for Power Quality Data Interchange
- P1564: Voltage Sag Indices
- 1346: Power System Compatibility with Process Equipment
- P1100: Power and Grounding Electronic Equipment
- 1433: Power Quality Definitions
- P1453: Voltage Flicker
- 519: Harmonic Control in Electrical Power Equipment
- P519A: Guide for Applying Harmonic Limits on Power Systems

POWERMETRIX

IEC Power Quality Standards

- 61000-1-X Definitions and methodology
- 61000-2-X Environment
- 61000-3-X Limits
- 61000-4-X Test and measurements
- 61000-5-X Installation and mitigation
- 61000-6-X Generic immunity and emissions standards
- Working Groups and Committees
  - SC77A Low Frequency EMC Phenomena
  - TC77/WG1 Terminology
  - SC77A/WG1 Harmonics and other low frequency disturbances
  - SC77A/WG6 Low frequency Immunity Tests
  - SC77A/WG2 Voltage fluctuations and other low frequency disturbances
  - SC77A/WG9 Power Quality measurement methods

POWERMETRIX

PowerMaster Family Of Products

POWERMETRIX

PowerMetrix Company Overview

PowerMetrix is best known throughout North America as the leading manufacturer of metering site field testing equipment and reference standards for Lab application for the electric utility industry. We are launching a very aggressive international expansion into major markets, such as, China, India, Japan…

Powermetrix serves three major markets:

- Electric utilities companies
- Energy meter manufacturers/energy meter test system manufacturers
- Governmental bureaus of energy measurement reference.

POWERMETRIX

PowerMaster®

POWERMETRIX