Cost Savings and Efficiency through Power Quality Monitoring

National Instruments

Measure It. Fix It.

"Once you start **monitoring** something…you know you can **fix** things"

-Dave Brandt
Electrical Engineer NUCOR Steel
NI Customer

Measure Energy. Reduce Cost.

TechWeek europe

Energy Now Fastest Rising Cost For Data Centres

Energy related costs now make up 12 percent of data centre expenditure, Gartner has found, and things will get worse

On September 29, 2010 by Tom Jowitt 0

SPIEGEL ONLINE

Merkel's Switch to Renewables

Rising Energy Prices Endanger German Industry

By Frank Dohmen and Alexander Neubacher

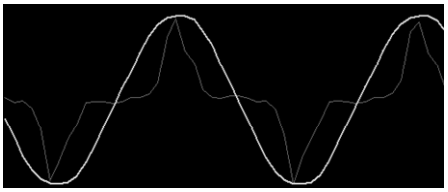
Bloomberg

Consumer Rates Climb After Deregulation Goldman Sachs Funded

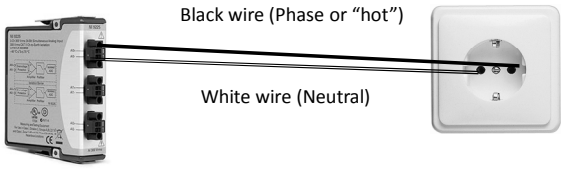
By Darrell Preston - Feb 23, 2012 4:57 PM CT

Power Measurements

- Measure two waveforms with respect to time
  - Voltage
  - Current
- Calculate
  - RMS
  - Frequency
  - Power
  - Energy
  - …



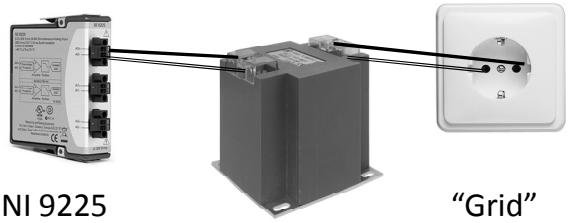
Voltage Measurement



NI 9225 “Grid”

Up to 300 V_{RMS}

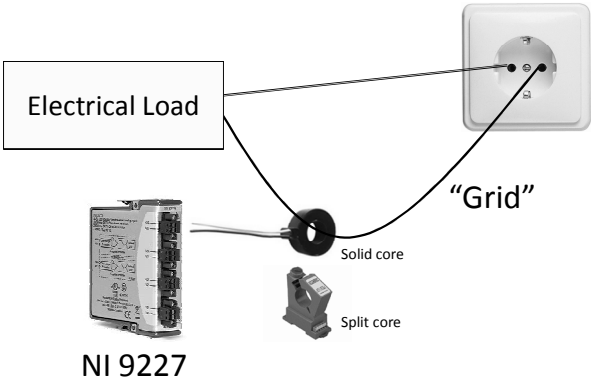
Voltage Measurement



NI 9225 “Grid”

Use a potential transformer (PT) for higher voltages
Sold by ratio (2:1, 4:1, 5:1, etc) where output “1” = 230 V

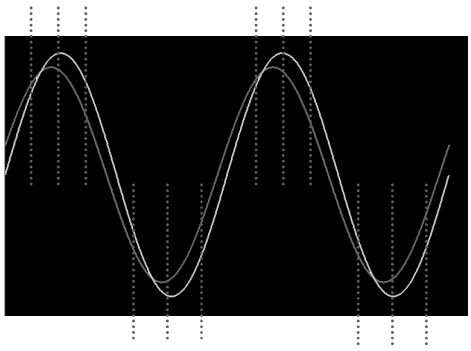
Current Measurement



Current Transformers are almost always needed
Sold by ratios and output either 1A or 5A

Power Measurement

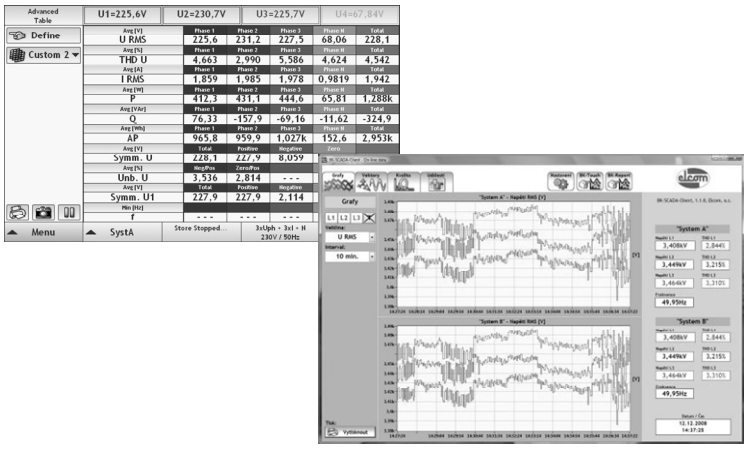
$$Power_{AVG} = \frac{Voltage_{Inst} \times Current_{Inst}}{Samples}$$



DEMO

Model	Purpose	Specifications
NI cRIO-9024	RT Processing and Control	800 MHz, 512 MB RAM, 4 GB Storage
NI 9225	Voltage Measurement	24-bit, 300 V_{RMS} , 50 kS/s/ch
NI 9227	Current Measurement	24-bit, 5 A_{RMS} , 50 kS/s/ch

PQ Software Created in LabVIEW



Why Measure Power

Measurement	Action	Cost Savings Through
Total energy consumption	Verify with bill from utility	Overpayment elimination
Sub-metering of energy	Assign to cost center	Focus on largest energy consumers

Sub Metering

Use multiple CTs to subdivide energy measurement

By building

By floor

By wing

Lighting

HVAC

Sub Metering

Metered Component	Example Result
Organizational Cost Centers (by building, floor etc.)	R&D department starts turning off computers at night because it is now part of their budget

Case Study: Energy Monitoring

- 15% Energy Reduction
  - Paid for cost of system in 6 months
- Sub-meters total facility energy
- Real time data access to
  - Electric grid
  - Diesel generators (energy/fuel)
  - HVAC
  - Lighting
  - and more…

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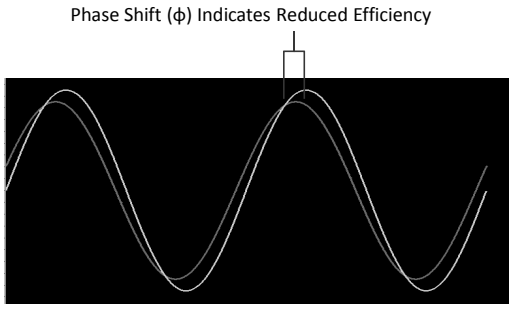
Demand prediction	Run machines in shifts or alter process control algorithm	Avoid peak usage fees
Power factor	Run machines in shifts or alter process control algorithm	Avoiding fines from utility

Avoid Excess Fees and Fines

- Max energy consumption limits (Energy Demand)
- Time of Use Billing
- Power Factor limits

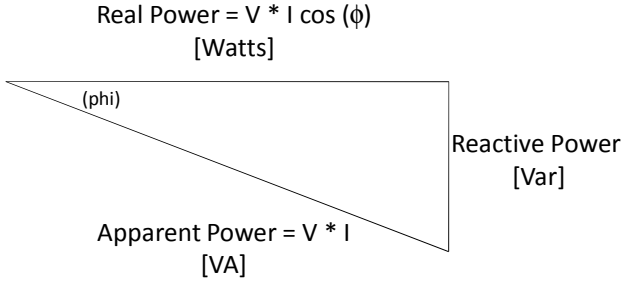
Power Factor (PF)

$$Power_{AVG} = V_{RMS} \times I_{RMS} \times \cos\phi$$
$$PF = \cos\phi$$



The Power Triangle

Mathematical Analogy



How Loads Affect Power Factor

Inductive	Resistive	Capacitive
		
Lagging Phase	In Phase	Leading Phase

Power Factor Correction

Inductive		Capacitive
	Lagging and leading phases combined will cancel out 	
Lagging Phase		Leading Phase

Power Factor Correction

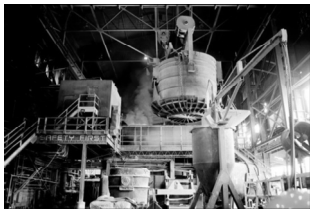
Adding Capacitive Loads to Inductive Grid

Building Installation

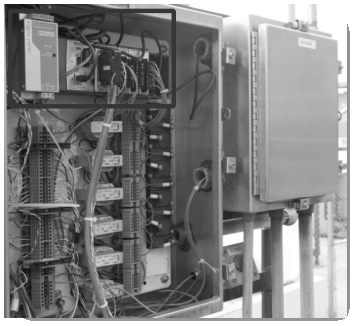
Substation Installation

Case Study: NUCOR Steel

- One of the largest steel producers in the US, and the largest recycler
- Implemented grid power monitoring
  - Acted on grid power information
    - Avoided fines
    - Improved power quality
  - Large cost savings
  - Lower environmental impact



NUCOR Power Monitoring Station



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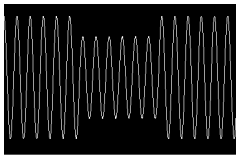
Unbalance, RMS trend/level, harmonics, SAG/SWELL	Machine health monitoring	Energy efficiency and predictive maintenance (machine life, minimize downtime)

Power Quality Events

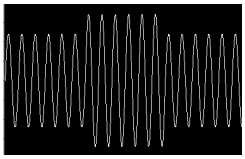
Sag



Voltage Level (% of nominal)
10%<sag<90%*

Duration
Instantaneous 0.5-30 Cycles
Momentary 30 Cycles – 3 seconds
Temporary 3 seconds – 1 minute

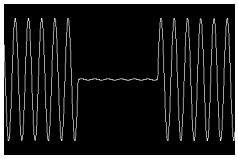
Swell



Voltage Level (% of nominal)
110%<sag<180%*

Duration
Instantaneous 0.5-30 Cycles
Momentary 30 Cycles – 3 seconds
Temporary 3 seconds – 1 minute

Interruption



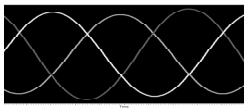
Voltage Level (% of nominal)
110%<sag<180%*

Duration
Momentary 30 Cycles – 3 seconds
Temporary 3 seconds – 1 minute

*Levels differ based on duration. Data pulled from IEEE 1159:1995 See standard for full data.

Voltage Unbalance

Phase 1≠ Phase 2≠ Phase 3



$$\% \text{ Unbalance} = \frac{100 \times \text{max phase voltage deviation from average}}{\text{average voltage}}$$

$$\text{Temp Rise (°C)} = 2 \times (\% \text{ Unbalance})^2$$

Machine Efficiency Cost

Example
1800-RPM, 100-hp motor (~74kW)
8,000 hours of operation per year
€ 0.07/kWh
75% load

Motor Efficiency* Under Conditions of Voltage Unbalance			
Motor Load % of Full	Motor Efficiency, %		
	Voltage Unbalance		
	Nominal	1%	2.5%
100	94.4	94.4	93.0
75	95.2	95.1	93.9
50	96.1	95.5	94.1

Table from U.S. DOE Energy Efficiency and Renewable Energy

Moving the voltage unbalance from 2.5% to 1% would save ~€ 564/year

Voltage Unbalance

Fix It.

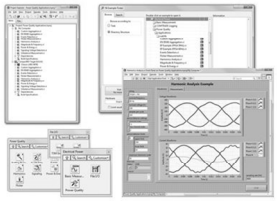
Potential Solutions

- Fix the phase voltages to match
  - Facility wide
    - Contact utility company
  - Within the facility
    - Run other motors/devices in shifts OR move other machines to balance the three phases
  - Within the motor
    - Repair/replace

NI Based Power Monitoring Systems

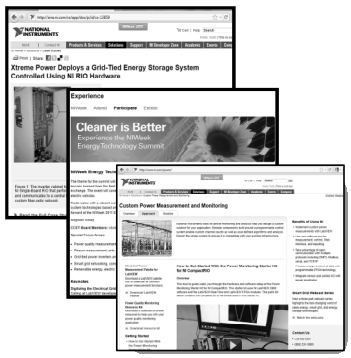
Advantages

- Access to high speed waveform data
  - Combine with LabVIEW power quality analysis functions
- Programmable Software
  - Custom diagnostics, analytics
  - User defined interface
- More than just power measurements
  - Temperature for HVAC
  - Flow and vibration for pumps
  - Torque and RPM for shaft monitoring



ni.com/power

- Demo code
- Tutorials
- White papers
- Case studies
- Sensor recommendations



Thank you for attending the
NI Embedded Control & Monitoring
Technology Day

For more information, please visit
www.ni.com/embeddedsystems

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