Grid2030: Intelligence through SCADA

National Instruments

Agenda

- Smart Grid
- Power Quality Analyzer
- Asset Monitoring

SmartGrid

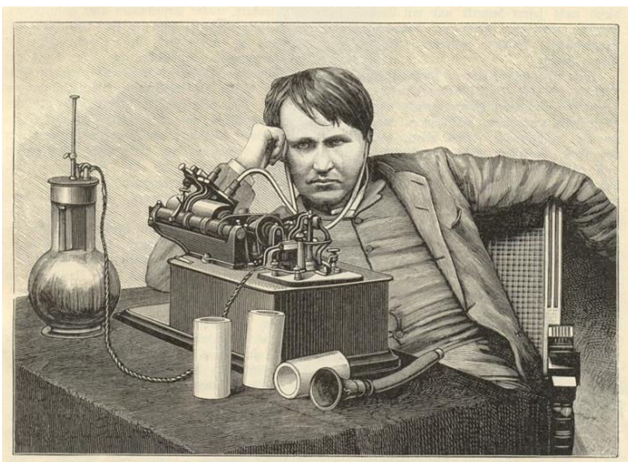
National Instruments

Grid – Current Model

Today

- Partial Control
- Poor Integration
- Not Optimized
- Reactive Maintenance
- Utility Focus
- Grids are Fragile

How did we get here?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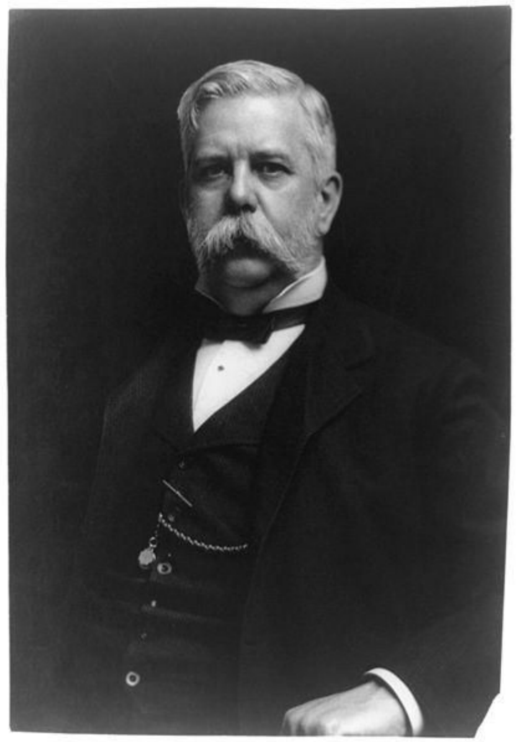
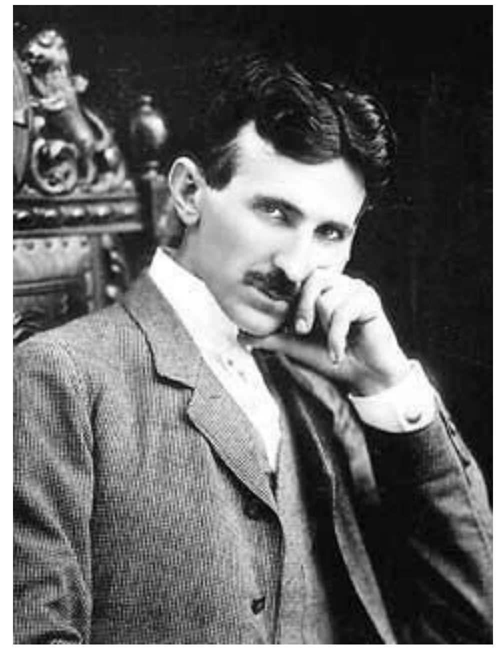




Framework for the Future

“ *The U.S. power supply network is the largest, most complex machine ever created and engages the most complex enterprise. It involves some 5,000 corporate entities, 100 million customers, 4 distinct forms of ownership and multiple levels of regulatory oversight. This must function at all times in absolute balance in it supply and demand while trying to satisfy conflicting economic, social, political and environmental objectives.* ”

EPRI – Electric Power Research Institute

ENERGY INDEPENDENCE AND SECURITY ACT OF 2007

TITLE XIII – SMART GRID

SEC. 1301. STATEMENT OF POLICY ON MODERNIZATION OF ELECTRICITY GRID

It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and achieve each of the following, which together characterize a Smart Grid:

(1) Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.

(2) Dynamic optimization of grid operations and resources, with full cyber-security.

(3) Deployment and integration of distributed resources and generation, including renewable resources.

(4) Development and incorporation of demand response, demand-side resources, and energy-efficiency resources.

(5) Deployment of ''smart'' technologies (real-time, automated, interactive technologies that optimize the physical operation of appliances and consumer devices) for metering, communications concerning grid operations and status, and distribution automation.

(6) Integration of ''smart'' appliances and consumer devices.

(7) Deployment and integration of advanced electricity storage and peak-shaving technologies, including plug-in electric and hybrid electric vehicles, and thermal-storage air conditioning.

(8) Provision to consumers of timely information and control options.

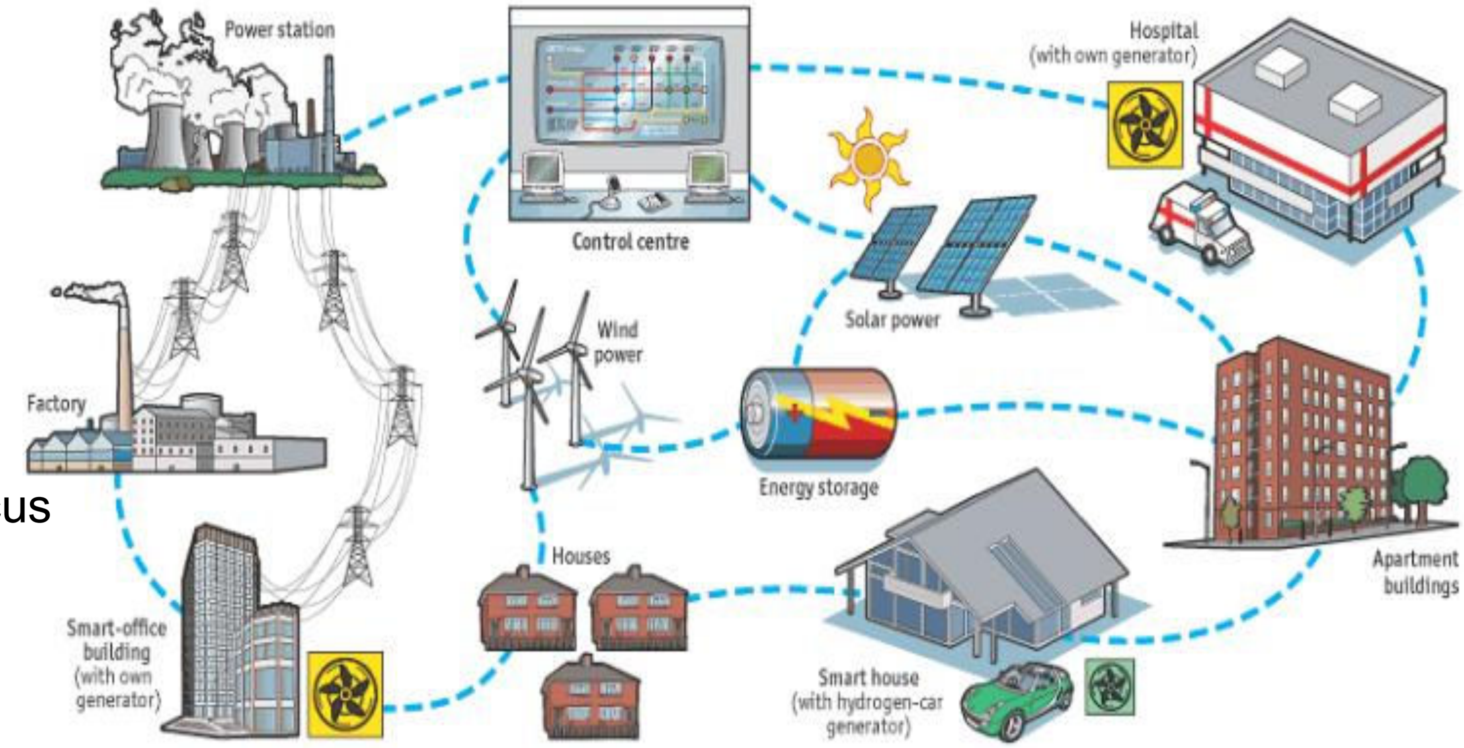
(9) Development of standards for communication and interoperability of appliances and equipment connected to the electric grid, including the infrastructure serving the grid.

(10) Identification and lowering of unreasonable or unnecessary barriers to adoption of smart grid technologies, practices, and services.

Smart Grid - Future

Future

- More Secure
- Total Control
- Integrated
- Optimized
- Interactive
- Self-Healing
- Customer Focus



Source: The Economist

Smart Grid - Future

"If you cannot measure it, you cannot improve it". -Lord Kelvin

Technology Challenges

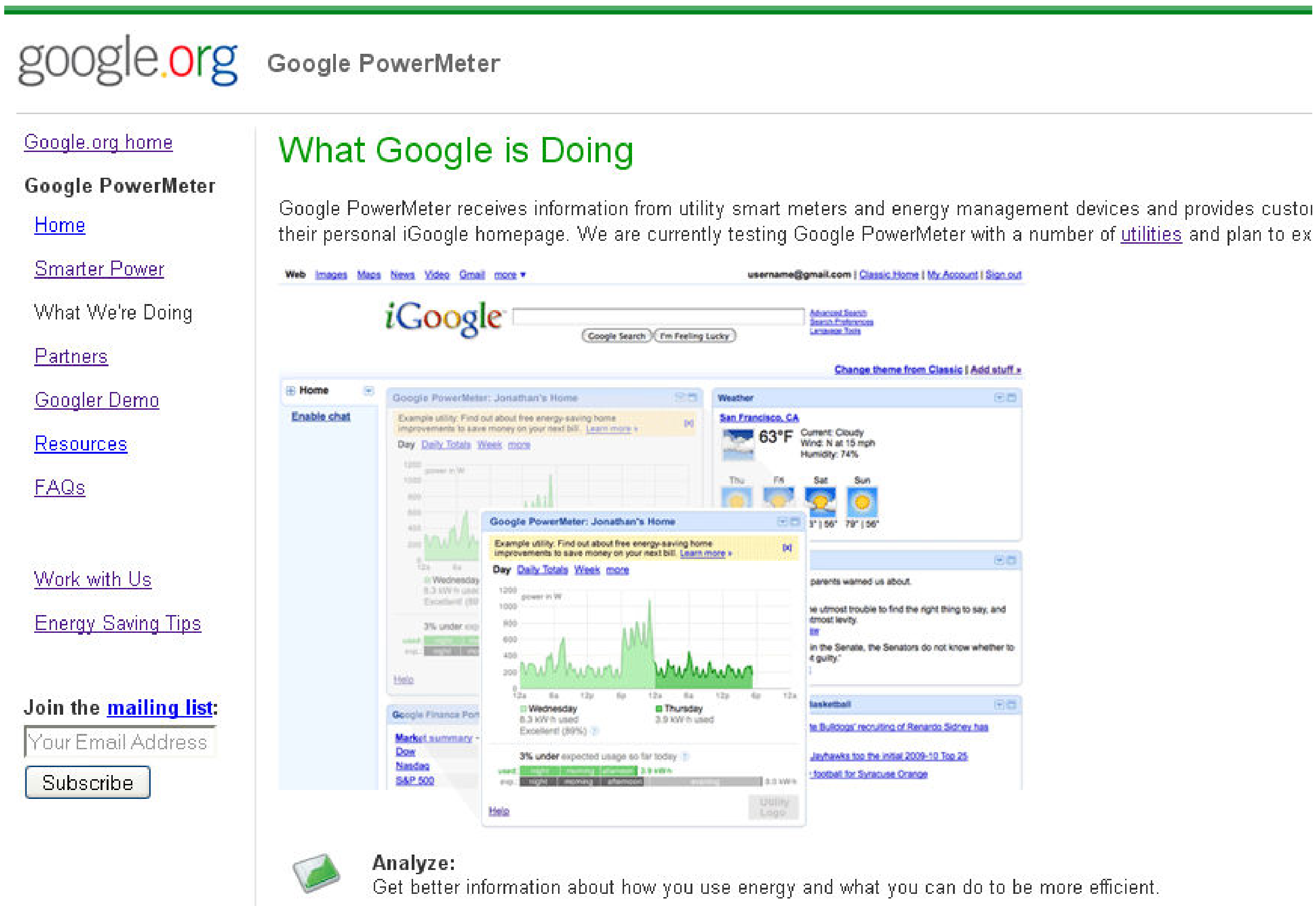
- Connect the power companies to power line hardware, industrial machinery, commercial and home appliances, communication network, and support system integration.

- Implement a responsive and intelligent layer of power systems capable of monitoring, distributed signal processing, control, and automation.

Areas to Develop and Integrate

- Substation Monitoring and Automation
- Transformer Load Management
- Real Time Grid Condition Monitoring
- Automated Grid Switching
- Fault Location and Characterization
- Home meters to perform as a sensor

Consumer based solutions



Current Vendor Defined Technology

AFD –	Arc Flash Detector
DDR –	Dynamic Disturbance Recorder
DFR –	Digital Fault Recorder
ENV –	Environmental data
HIZ –	High Impedance Fault Detector
HMI –	Human Machine Interface
HST –	Historian
LGC –	Scheme logic
MET –	Substation Metering
PDC –	Phasor Data Concentrator
PMU –	Phasor Measurement Unit
PQM –	Power Quality Monitor
RIO –	Remote Input/Output Device
RTU –	Remote Terminal Unit / Data Concentrator
SER –	Sequence of Events Recorder
TCM –	Trip Circuit Monitor

Lack of: interoperability, Flexibility, Expandability, Upgradability, etc

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Technology and Design Gaps for one single platform

- Downloadable Firmware Technology
- Seamless integration with current assets
- Flexible to be used in varying systems
- Record and Analyze data in distributed architecture and with reconfigurable data granularity
- Scalable and upgradeable to add memory, resolution, functionality and applications
- Communication: multi platform and scalability
- Multi data format compatibility
- Distributed data processing for decision making

What is necessary to implement the Smart Grid Intelligent Layer

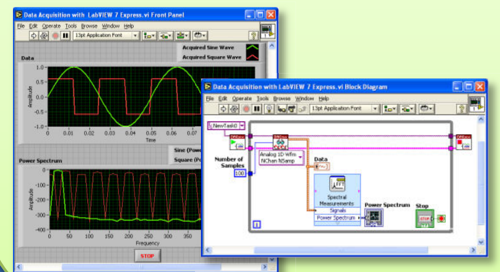
- Preventative Element
  - Identify and Repair Problems / Minimize Outages
- Real Time Sensing and Control
  - Quick Response to Disturbances
- Permanent Monitoring
  - Dynamically Optimize the Performance of Systems

- What will make the Grid smart?
  - The ability to transform data into information and make decisions

Introducing National Instruments: What We Do

Modular Measurement and Control Hardware

Productive Software Development Tools



Highly Integrated System Platforms

Used By Engineers and Scientists for Test, Design and Control

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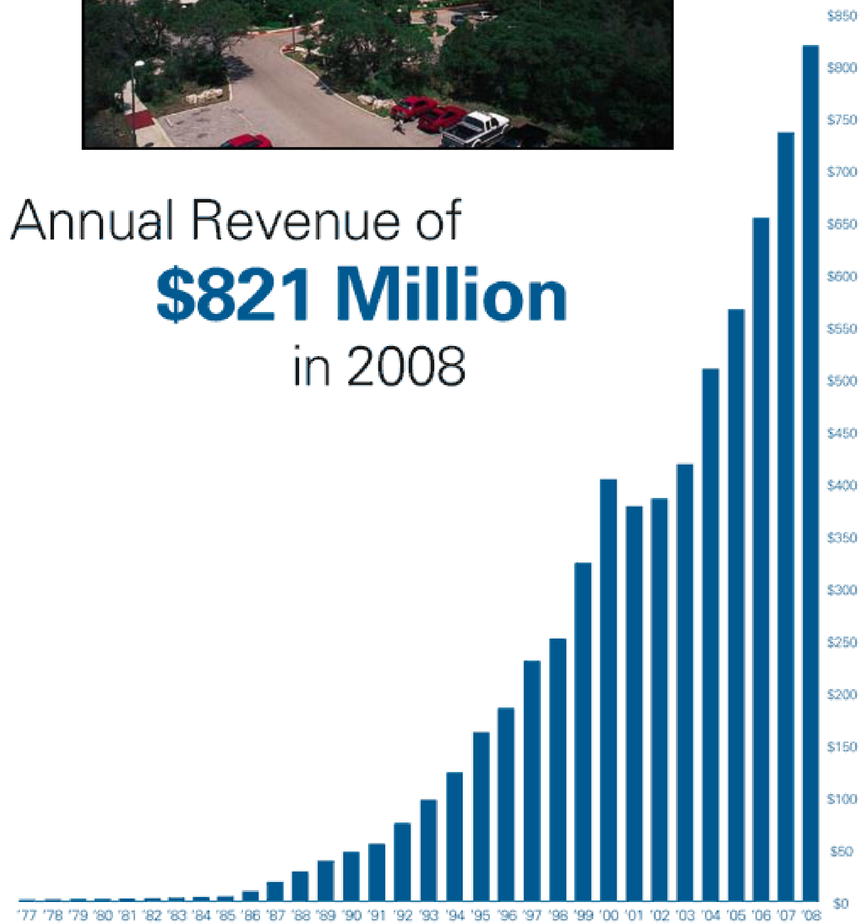
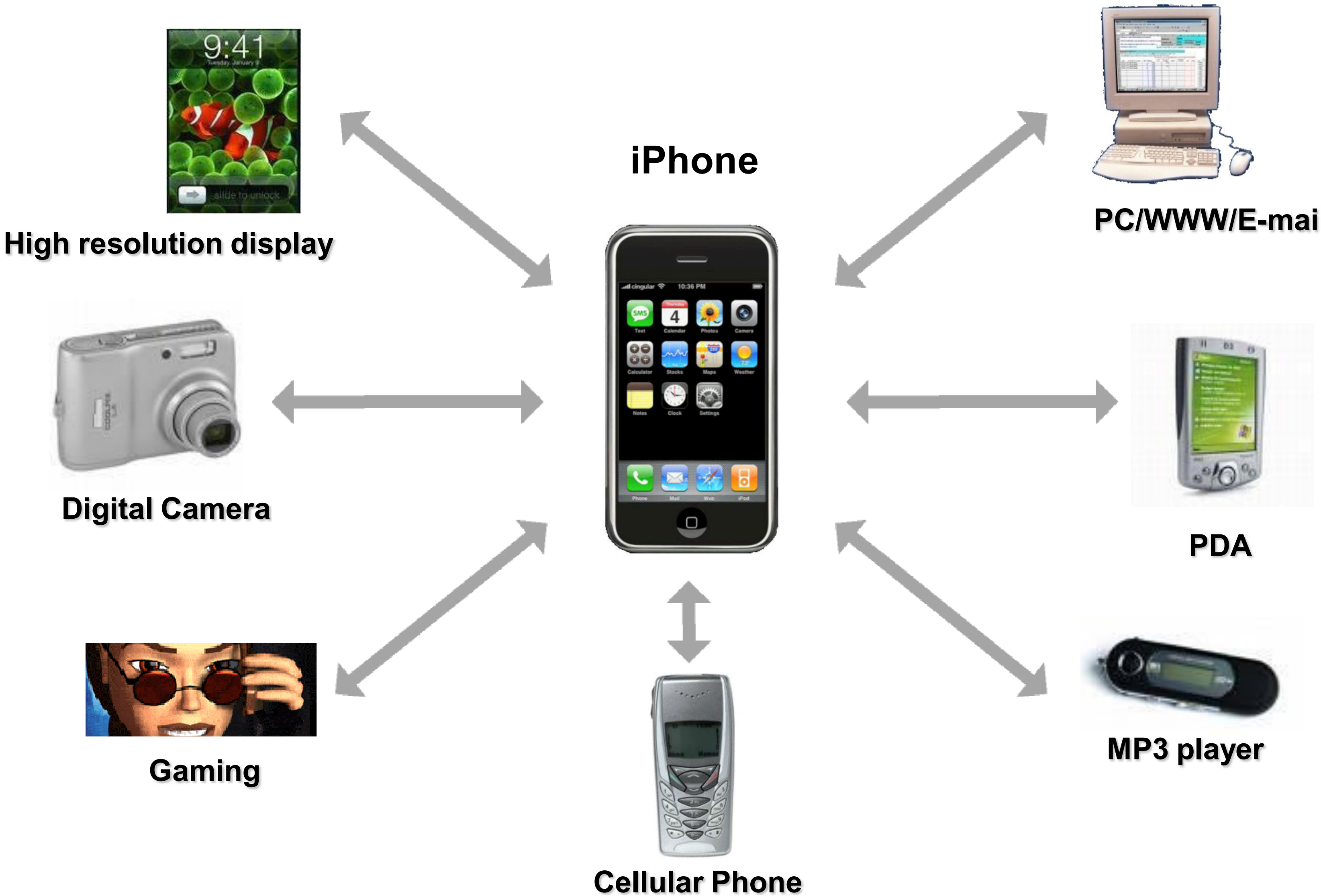
National Instruments

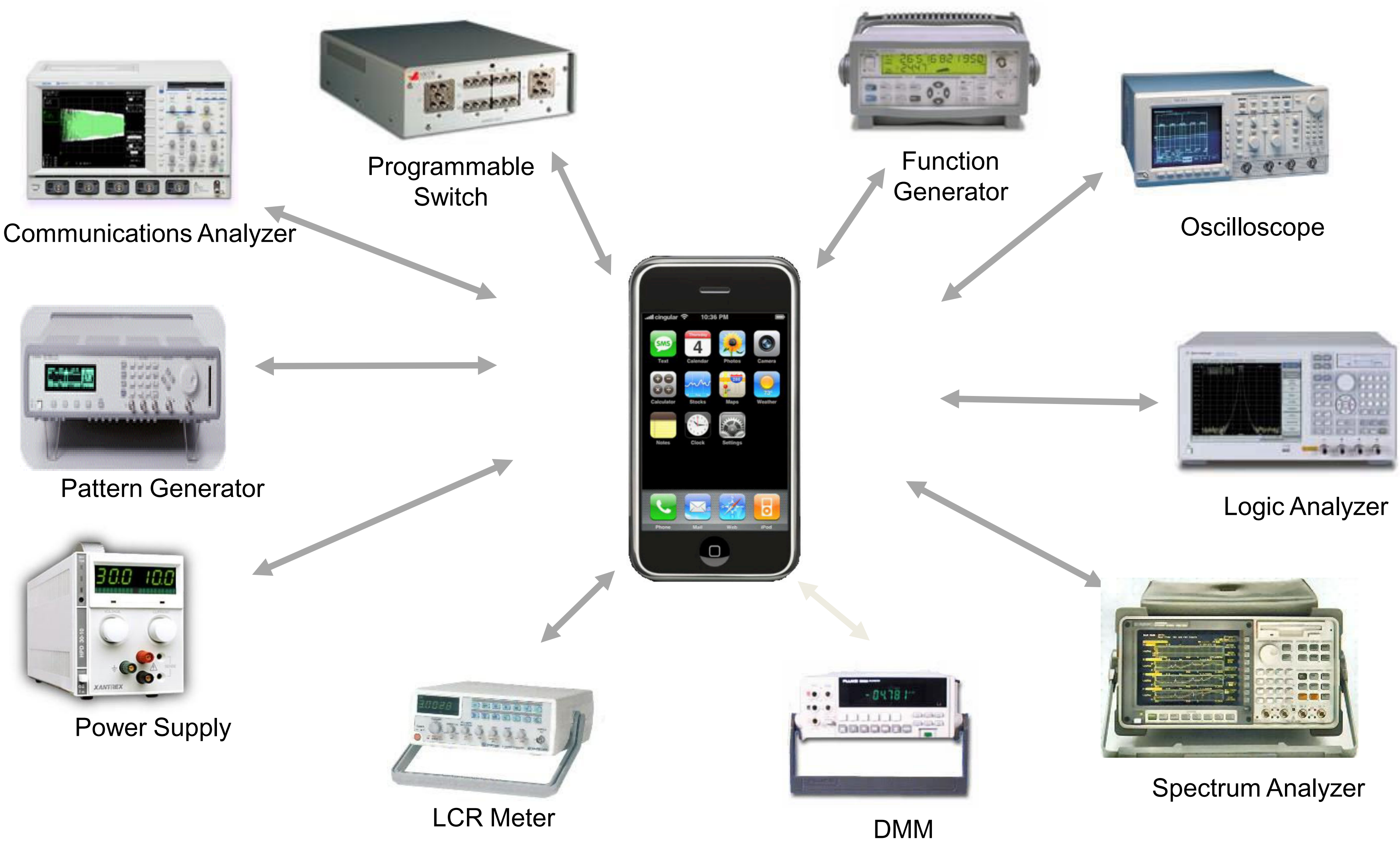
- Leaders in Computer-Based Measurement and Automation
- Long-term Track Record of Growth and Profitability
- More than 5,157 employees
- Operations in 40+ countries
- Fortune’s 100 Best Companies to work For Tenth Consecutive Year



Today’s Demand: Converging Complexity

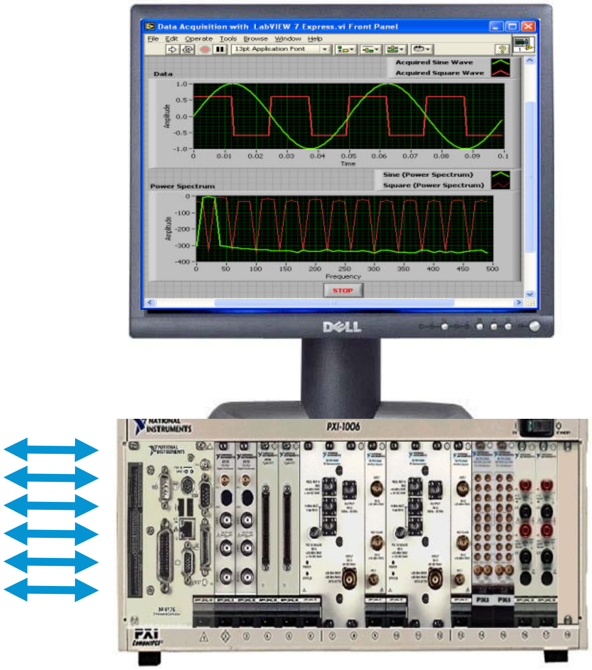


Today’s Challenges: The Traditional Approach



NI’s Value Proposition

- Lower cost
- Higher performance
- Smaller size
- Flexible
- Easily upgraded
- User-defined



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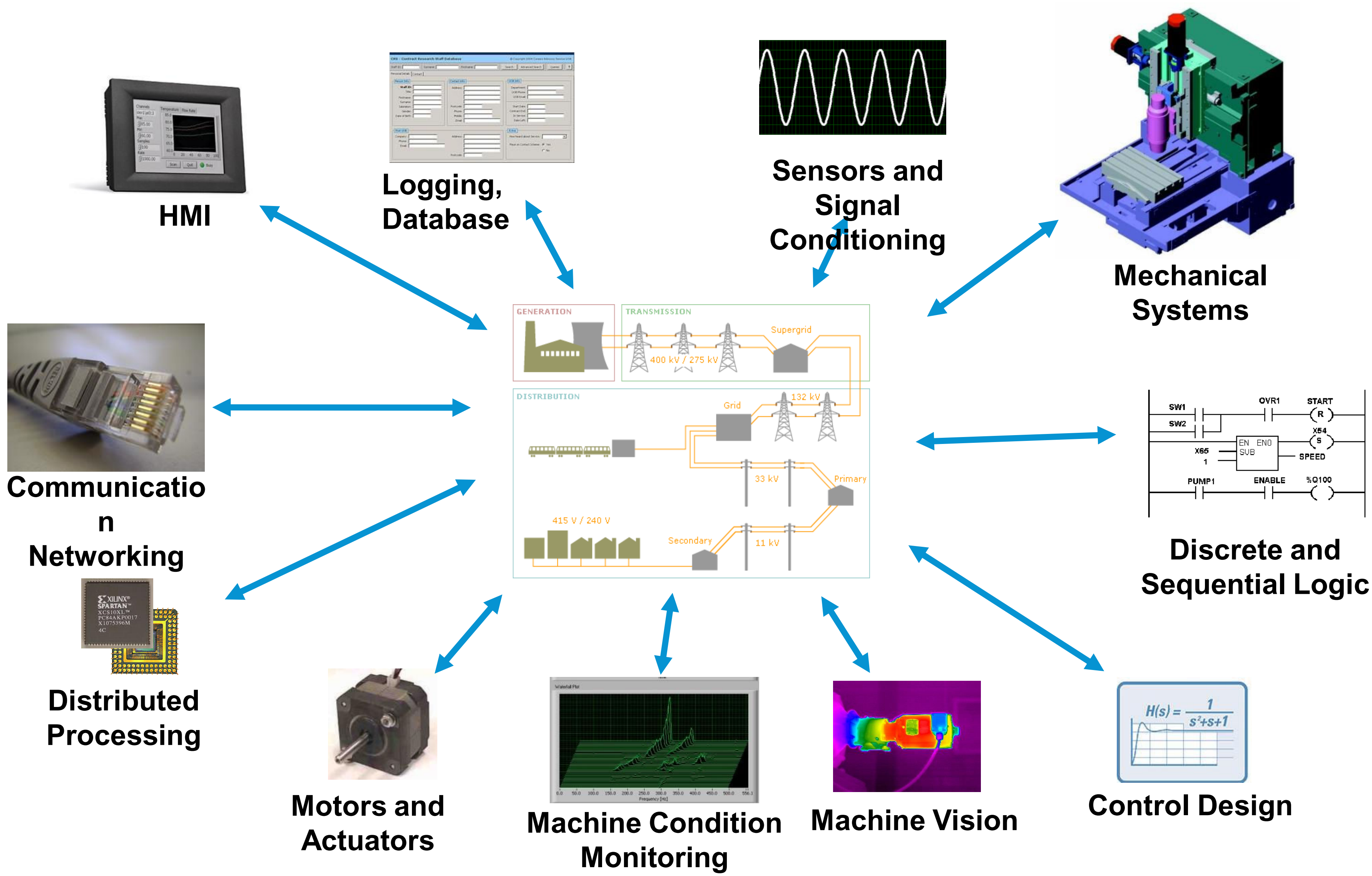
Smart Grid Technology Complexity



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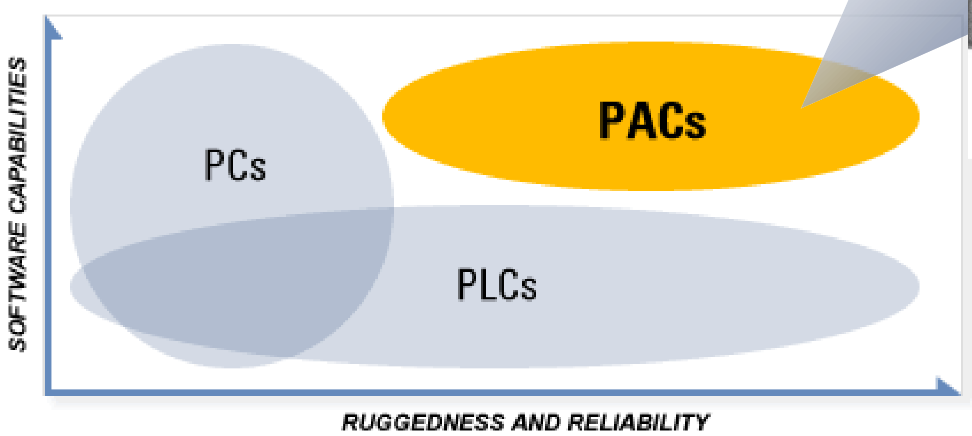
Introduction to CompactRIO

Programmable Automation Controller (PAC)

- Open Embedded System
- Reconfigurable FPGA
- Extreme Ruggedness
- Expandable
- Multi Protocol



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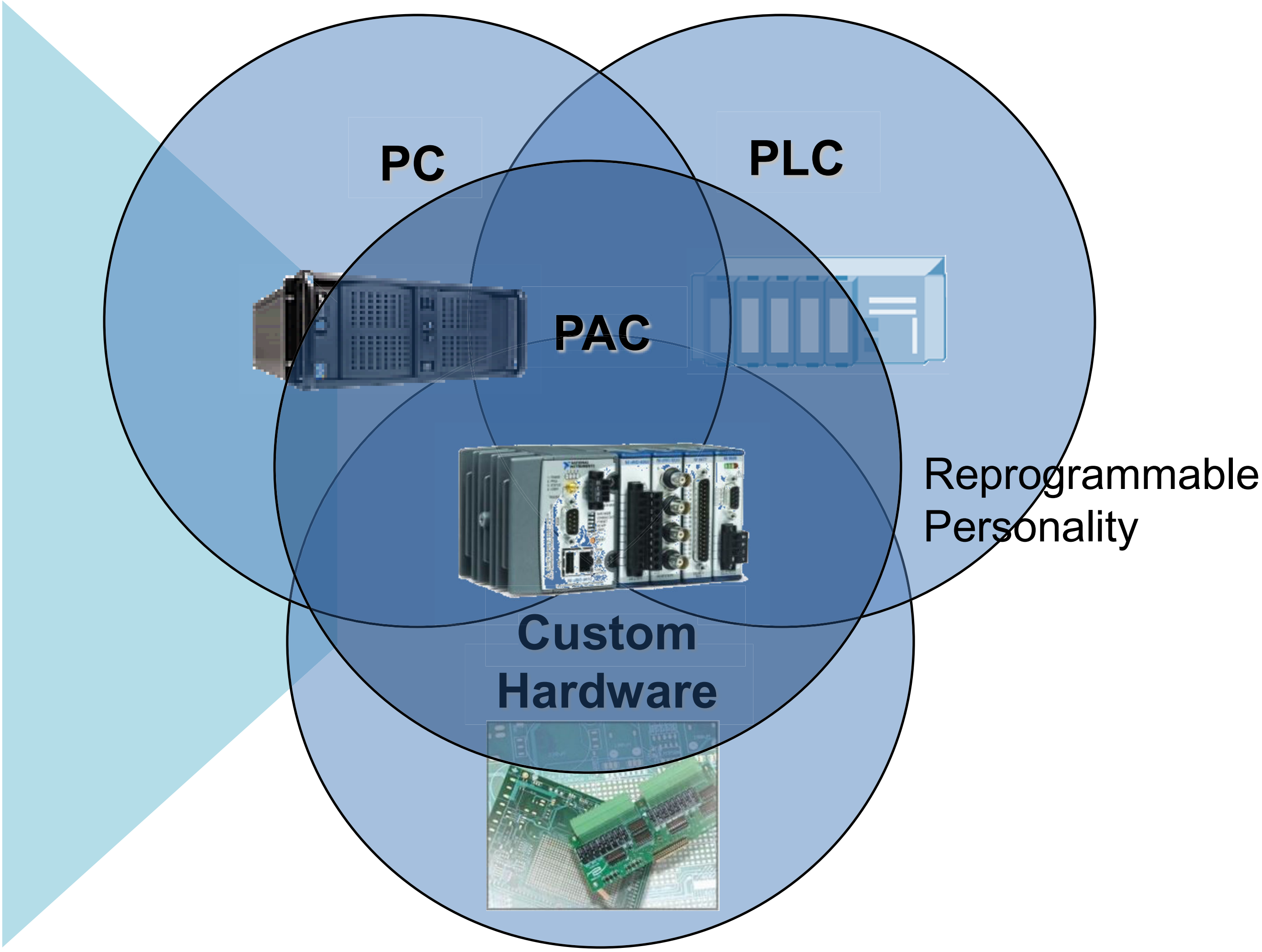
The Design Platform to address Convergence of Technology

AFD
CLK
DDR
DFR
ENV
HIZ
HMI
HST
LGC
PDC
PMU
PQM
RIO
RTU
SER
TCM



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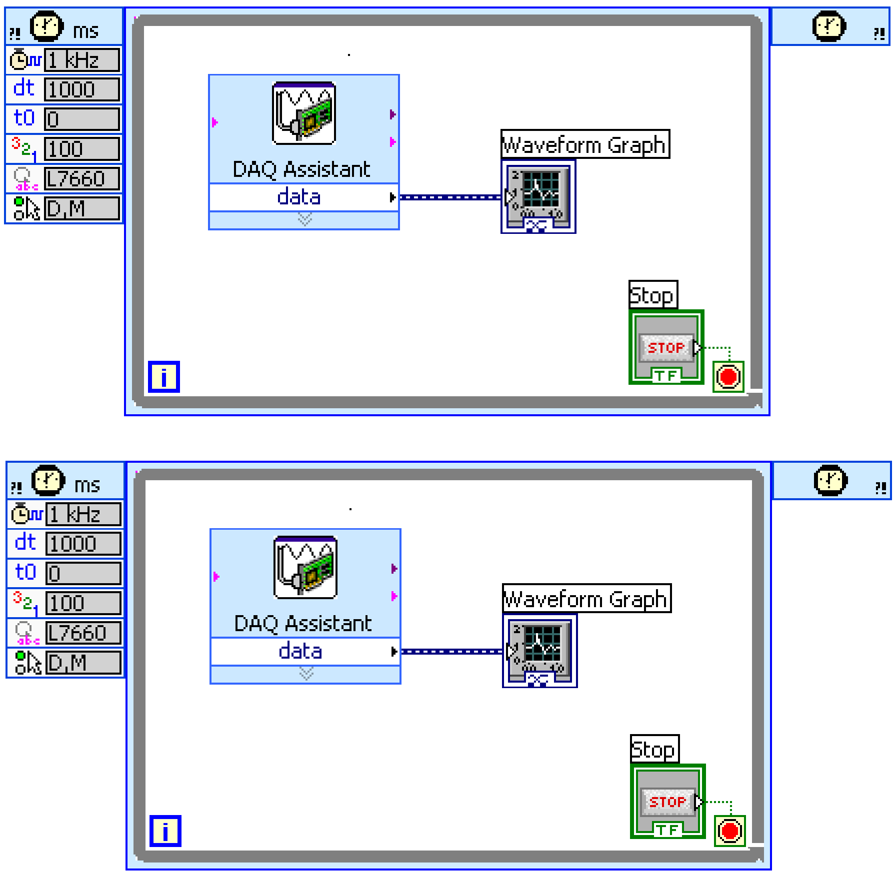
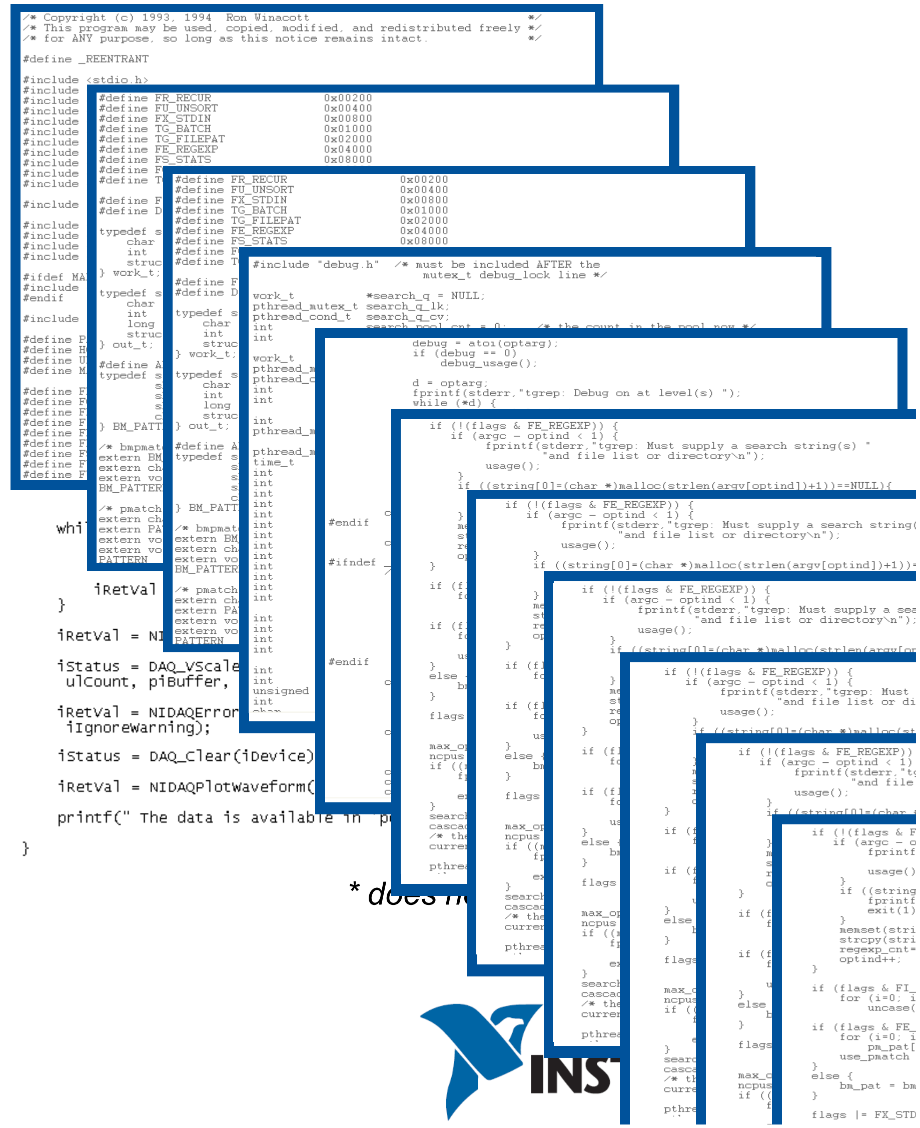
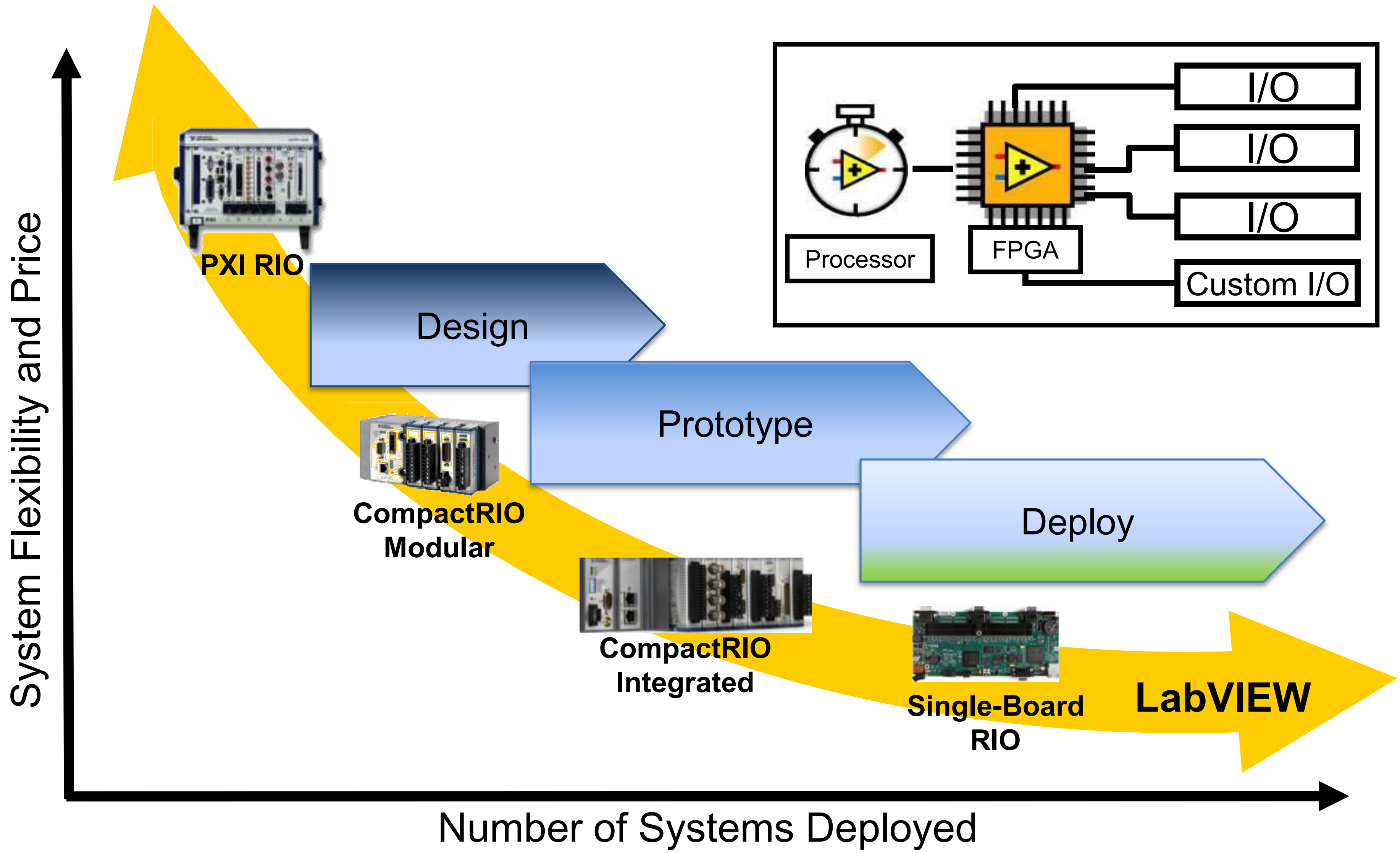
Software Abstracts System Complexity

LabVIEW	C*





PAC Technology Deployment Curve



Current Projects

- NI / Universities / Utilities Joint collaboration
  - Power Quality Monitoring
  - Distributed Fault Anticipation
  - Remote Terminal Unit
  - High Impedance Fault Detector
  - Phasor Measurement Unit
  - Transformer Monitoring
- Motivation and Objectives
  - Transform Data into Information
  - Support System Management
  - Allow Decision Making Processes
  - Enhance Reliability and Availability
  - Ensure Power Quality Monitoring
  - Integration System

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Power Quality Analyzer

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What is Power Quality

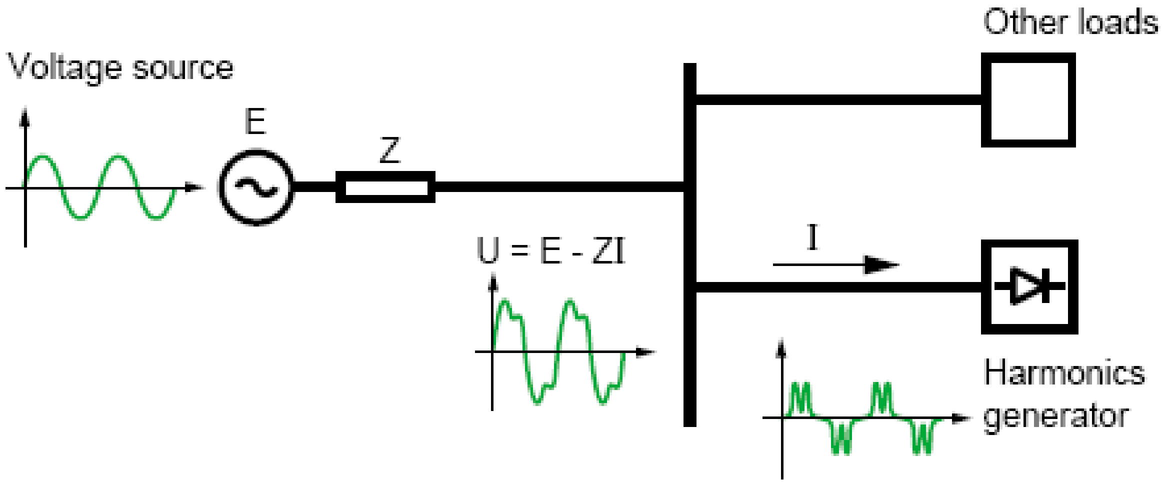
Any Power problem manifested in voltage, current, or frequency deviations that results in failure or misoperation of customer equipment.

Why is Power Quality Important?

- Electricity is a product, like any other
- Customer loads are more sensitive to transients and short variations in the voltage supply
- Corrective action must be taken if the supply is not sufficiently ensured!
- Utilities, appliance manufacturers, and residential customers need information about residential power quality
- Electrical power has to comply with specific quality requirements:
  - Voltage level 110 V (or different)
  - Sinusoidal shaped AC voltage signal
  - Fundamental frequency 60 Hz
  - 3 phases voltage
  - Availability

Sources of Power Pollution

- Today electric power consumption is often controlled by switching electronics.
- Loads have non-linear U/I characteristic and this cause non-sinusoidal current
- Non-sinusoidal current causes distortion of supply voltage because of power grid impedance



Short term impact on PQ: HEV recharging

Power Quality Problems

- Whether or not the customer is likely to suffer from power quality problems depends on:
  - The quality of voltage supplied by electricity supplier
  - The types of loads in customer's installation
  - The sensitivity of customers equipment to various kind of disturbances
- <u>There is not single</u>, generic solution of PQ problems.

Power Quality Phenomenas

electromagnetic reactions

- telegrams
- flicker
- voltage fluctuations
- swells
- harmonics
- voltage drops
- Inter-harmonics
- transients
- unsymmetrical voltage
- frequency fluctuations
- rapid voltage changes
- over-voltages

PQ Events as categorized by IEEE

Other Standards:

IEC 61000-4-7

Harmonics and Interharmonics Measurements

IEC 61000-4-15

Flickermeter – Functional and design specifications

IEC 61000-4-30

Measurement methods for power quality instruments

phenomena defined in IEEE 1159:1995

Categories	Typical spectral content	Typical duration	Typical voltage magnitude
1. Transients			
1.1. Impulsive			
1.1.1. Nanosecond	5 ns rise	<50 ns	
1.1.2. Microsecond	1 µs rise	50 ns–1 ms	
1.1.3. Millisecond	0.1 ms rise	>1 ms	
1.2. Oscillatory			
1.2.1. Low frequency	<5 kHz	0.3–50 ms	0–4 p.u.
1.2.2. Medium frequency	5–500 kHz	20 µs	0–8 p.u.
1.2.3. High frequency	0.5–5 MHz	5 µs	0–4 p.u.
2. Short-duration variations			
2.1. Instantaneous			
2.1.1. Sag		0.5–30 cycles	0.1–0.9 p.u.
2.1.2. Swell		0.5–30 cycles	1.1–1.8 p.u.
2.2. Momentary			
2.2.1. Interruption		0.5 cycles–3 s	<0.1 p.u.
2.2.2. Sag		30 cycles–3 s	0.1–0.9 p.u.
2.2.3. Swell		30 cycles–3 s	1.1–1.4 p.u.
2.3. Temporary			
2.3.1. Interruption		3 s–1 min	<0.1 p.u.
2.3.2. Sag		3 s–1 min	0.1–0.9 p.u.
2.3.3. Swell		3 s–1 min	1.1–1.2 p.u.
3. Long-duration variations			
3.1. Interruption, sustained		>1 min	0.0 p.u.
3.2. Undervoltages		>1 min	0.8–0.9 p.u.
3.3. Overvoltages		>1 min	1.1–1.2 p.u.
4. Voltage imbalance		Steady state	0.5%–2%
5. Waveform distortion			
5.1. d.c. offset		Steady state	0%–0.1%
5.2. Harmonics	0–100th H	Steady state	0%–20%
5.3. Interharmonics	0–6 kHz	Steady state	0%–2%
5.4. Notching		Steady state	
5.5. Noise	Broad-band	Steady state	0%–1%
6. Voltage fluctuation	<25 Hz	Intermittent	0.1%–7%
7. Power frequency variations		<10 s	

The Cost of Poor Power Quality

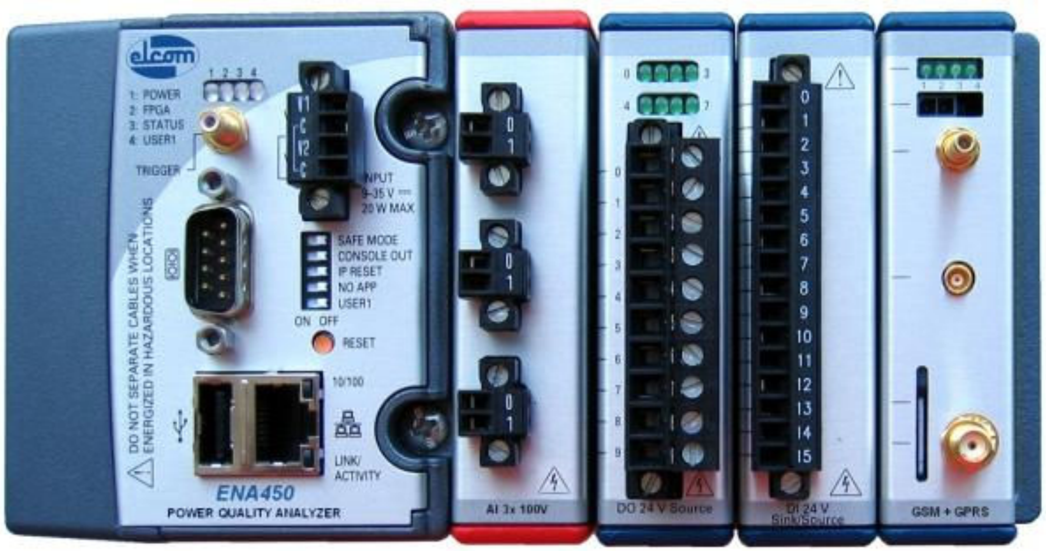
- It is estimated that power quality problems costs industry and commerce **about $80 billion per year** [Berkeley Lab Study] while expenditure on preventative measures is less than **5 %** of this.
- Problems must be identified first:
  - industry needs PQ monitoring tools
- By monitoring PQ it is possible to identify potential problems before they are big enough to make damages.

What is needed to recognize PQ problem

- International Standards
- Measurement Instrument
- SW Tool for Analysis and Presentation

User Solution:

ELCOM Power Quality Analyzer ENA450

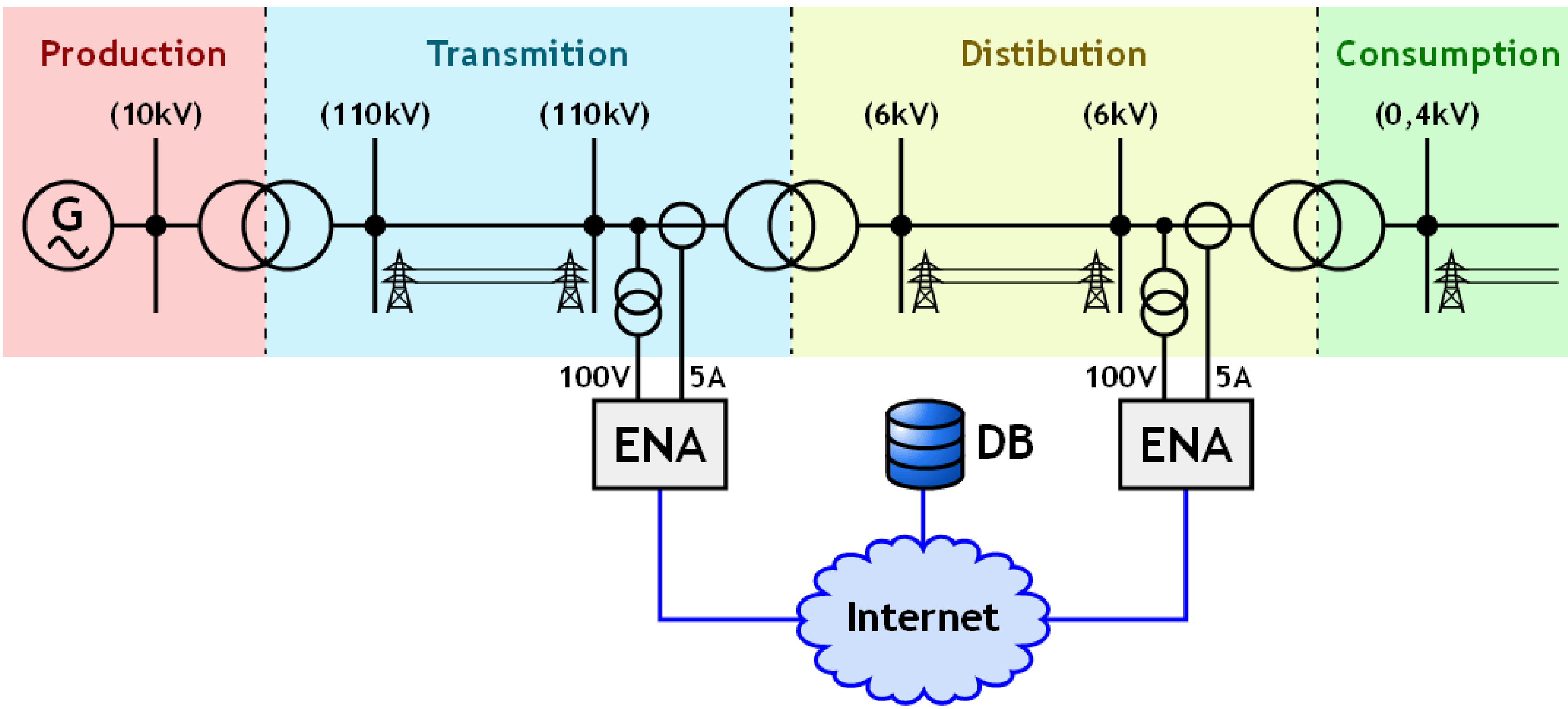


National Instruments Content:

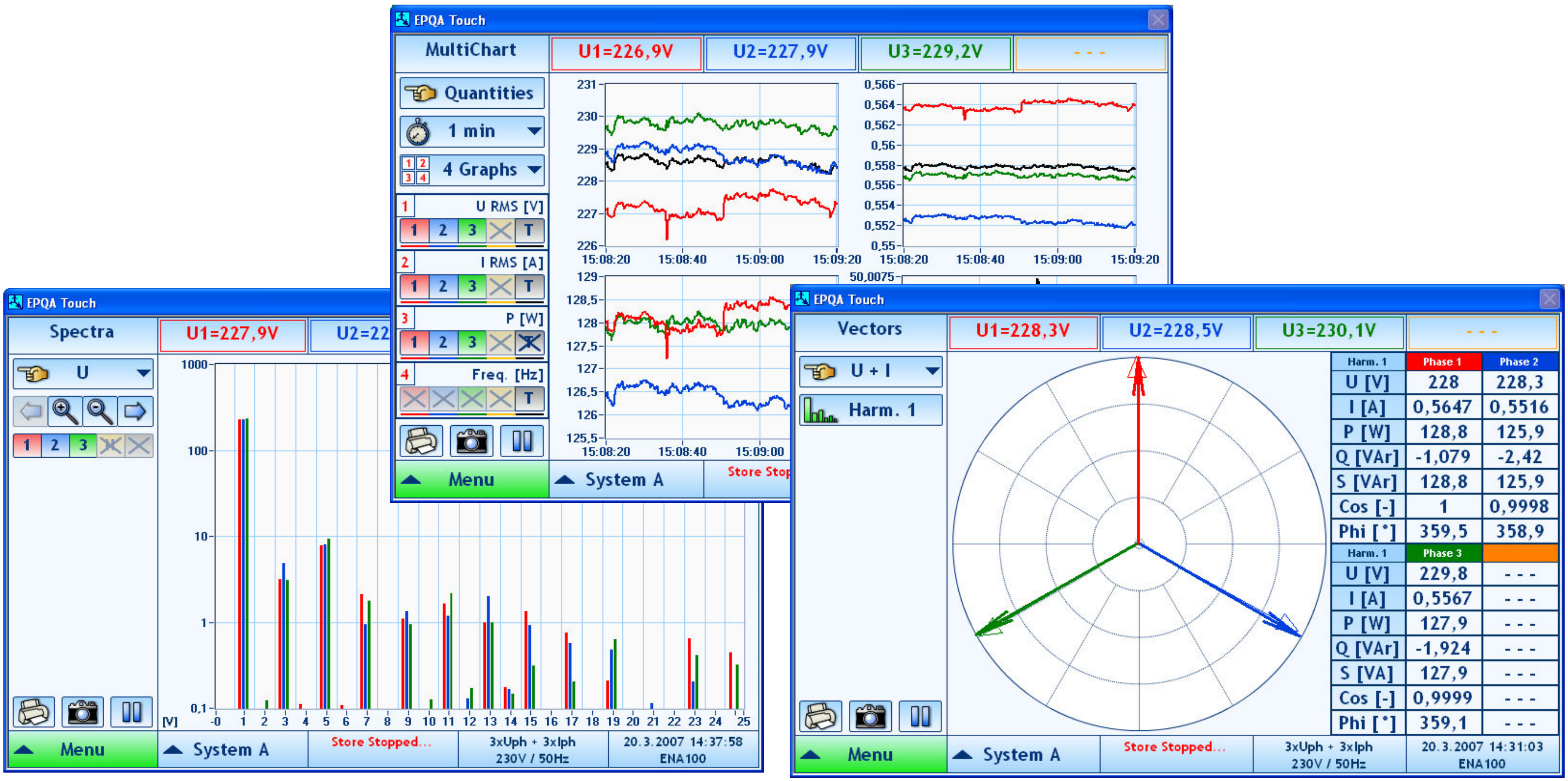
- NI cRIO 9014
- NI cRIO 9103
- NI 9225
- NI 9239
- NI 9422
- Optional GPS and GPRS

- 3x direct voltage inputs 300V RMS
- 4x indirect currents inputs by **current clamps**
- IEC 61000-4-30 class A PQA

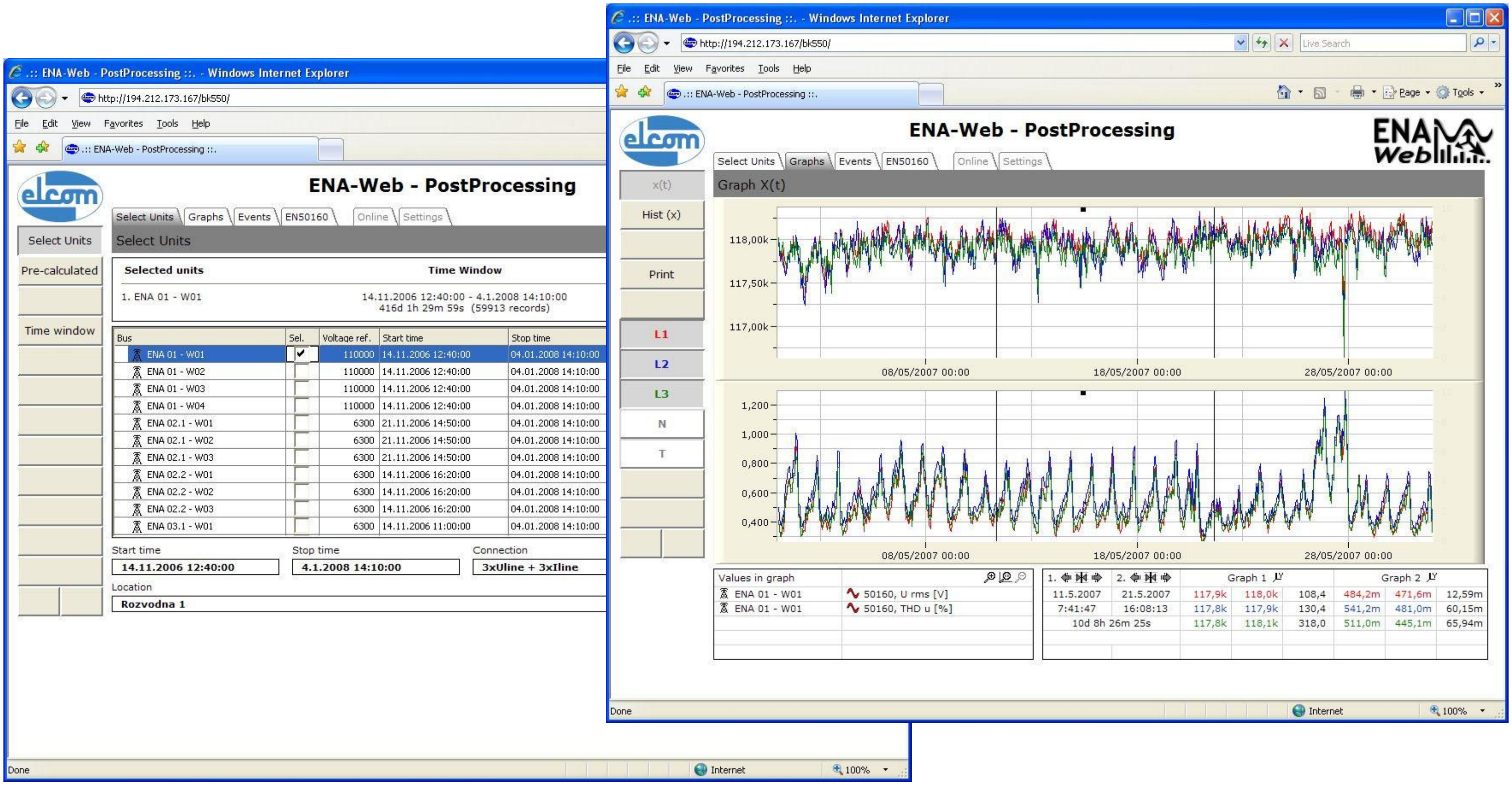
Electrical Energy Transmission with PQ Monitoring



LabVIEW User Interface



Web Enabled Tools



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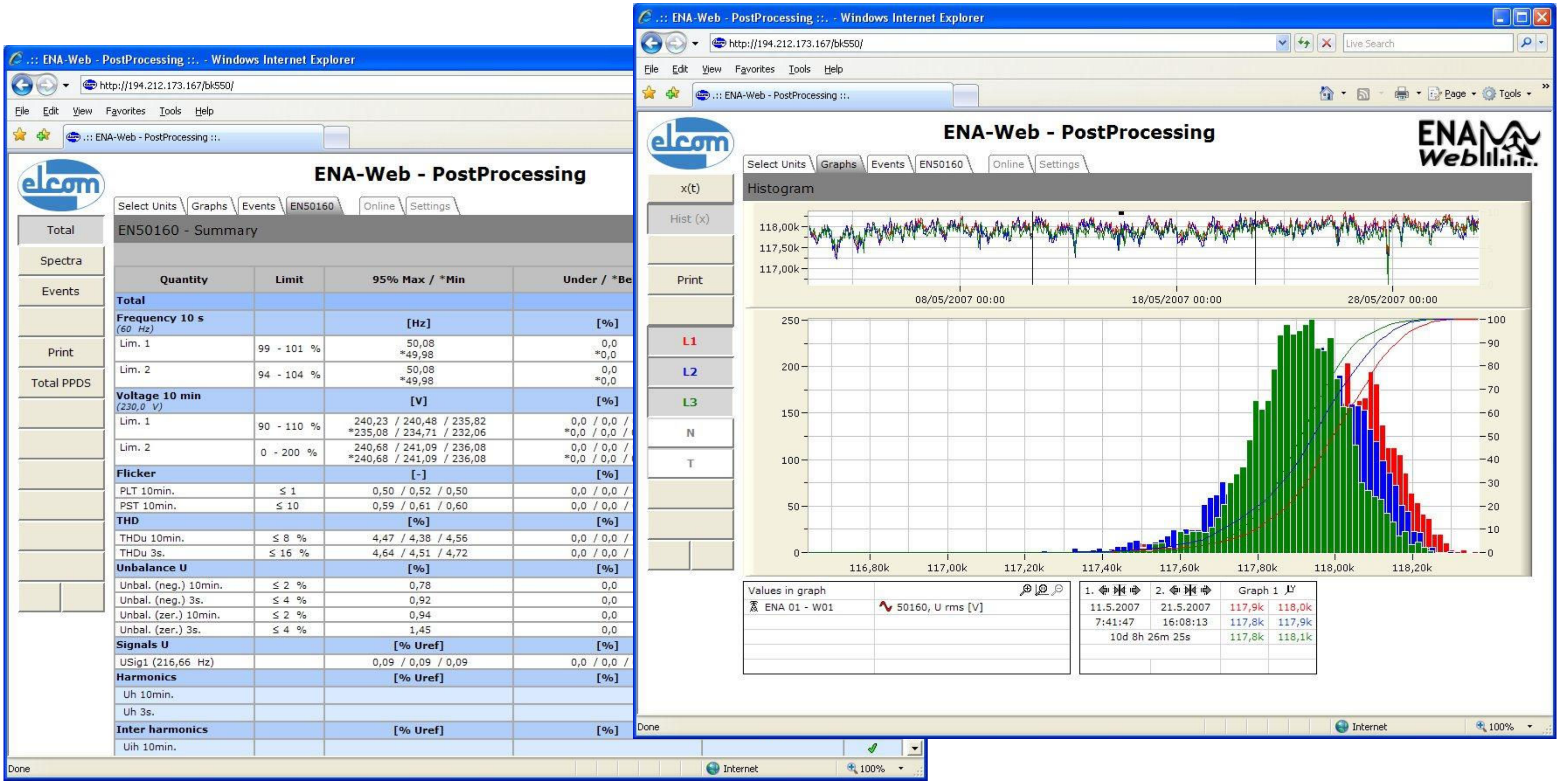
Web Enabled Tools



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Additional Case Studies

- Power Quality Monitoring and Power Metering Tutorial
  - http://zone.ni.com/devzone/cda/tut/p/id/4714
- Real-Time Monitoring and Analysis System for Power Quality
  - http://sine.ni.com/csol/cds/item/vw/p/id/134/nid/124400
- Internet-Ready Power Network Analyzer for Power Quality Measurements and Monitoring
  - http://sine.ni.com/csol/cds/item/vw/p/id/387/nid/124400
- Creating Power Acquisition Network (PAQ Net) with NI LabVIEW
  - Http://sine.ni.com/csol/cds/item/vw/p/id/363/nid/124400

- For more details visit www.ni.com/info and type “Power”

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PQ ENA450 Summary

- cRIO-based Power Quality Analyzer ENA450 is ready to use solution for distributed fixed installation
- Comprehensive suite of SW components allows building distributed monitoring systems with central database
- LabVIEW flexibility allows fast modification of PQA to add and modify functionality as needed

Asset Monitoring

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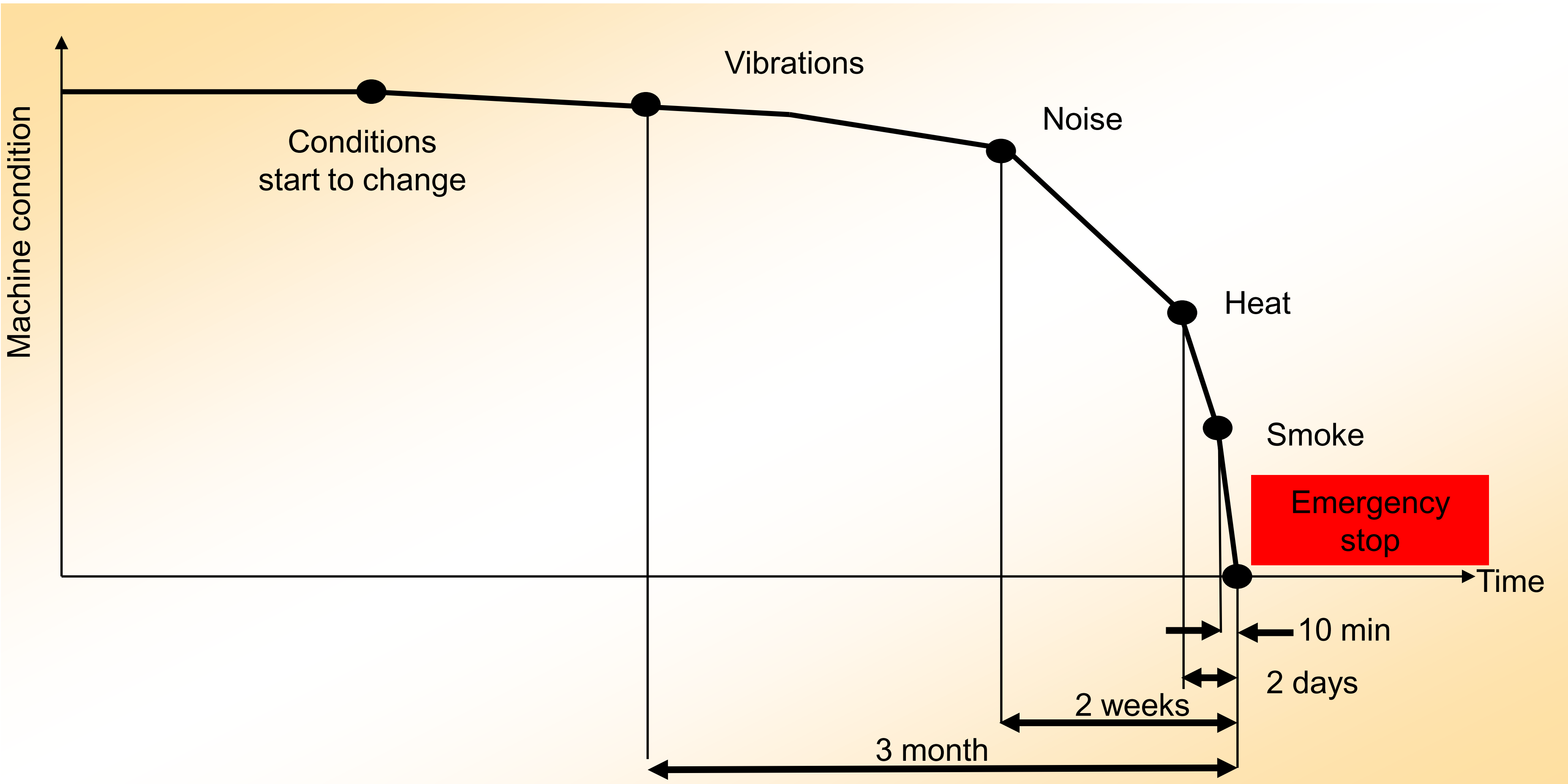
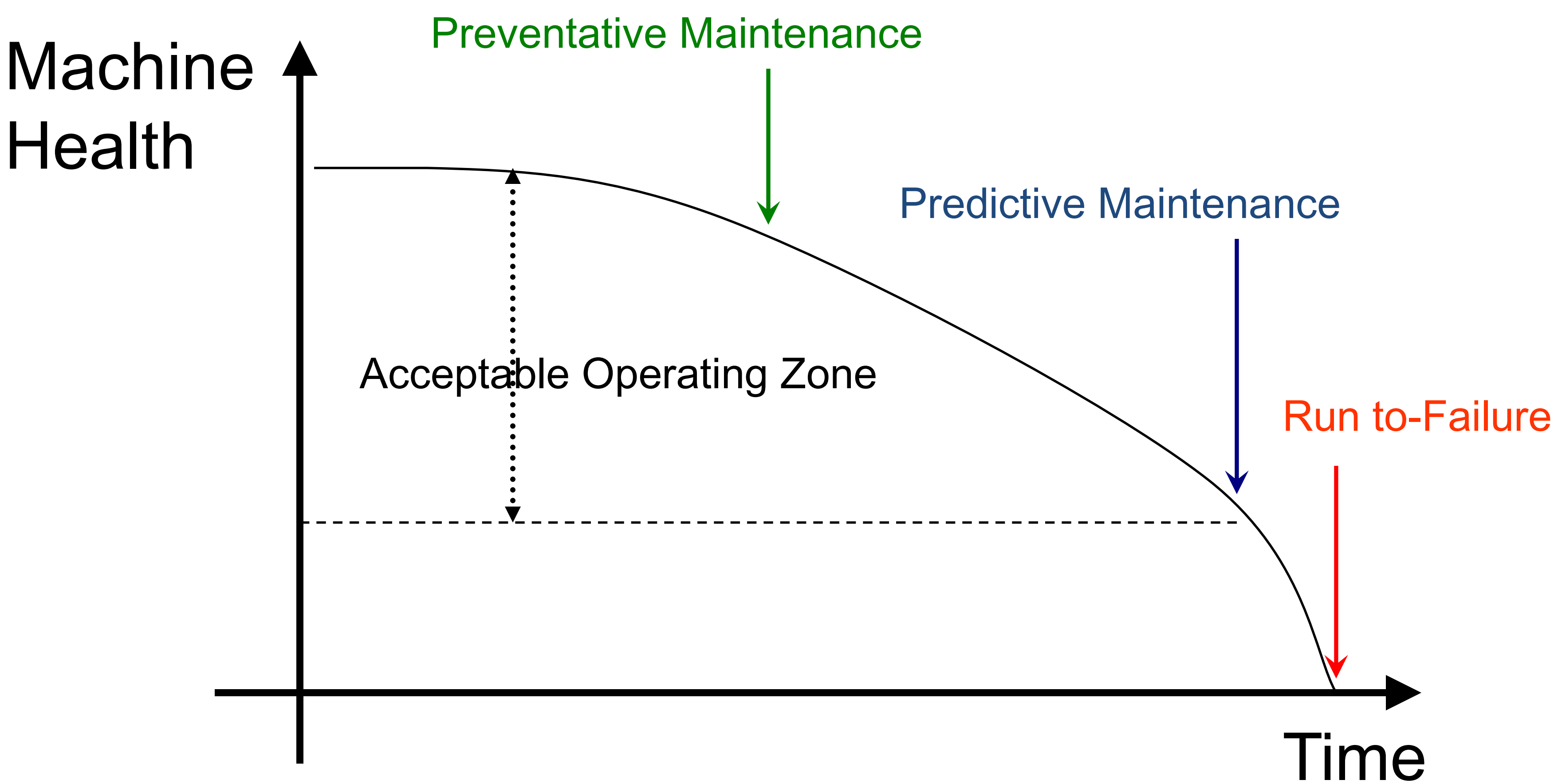
Predictive Maintenance Means Savings

- Asset Management
  - Improves reliability of machinery
  - Lowers energy cost of running machinery
  - Lowers resources necessary for maintenance
- Structural Health Monitoring
  - Builds a smarter infrastructure
  - Improves Safety
  - Lowers Cost of maintaining current infrastructure

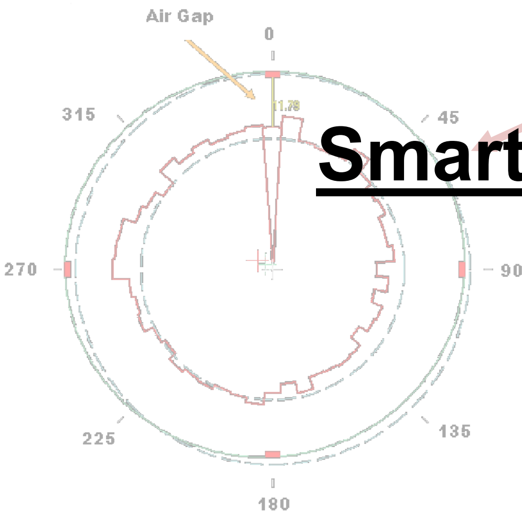
On-line Monitoring: Performance & Health

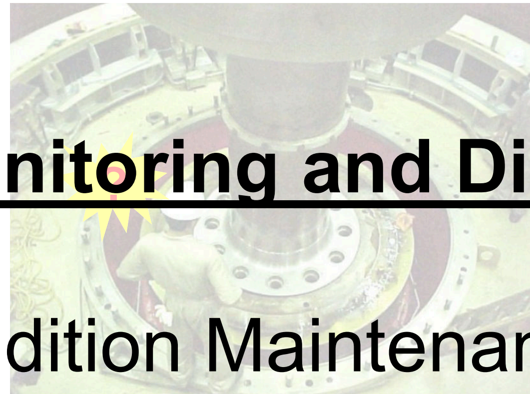


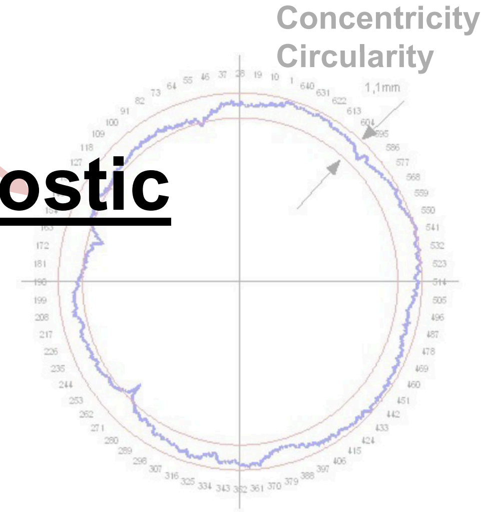
Increasing Availability



Trend and Real Time Analysis

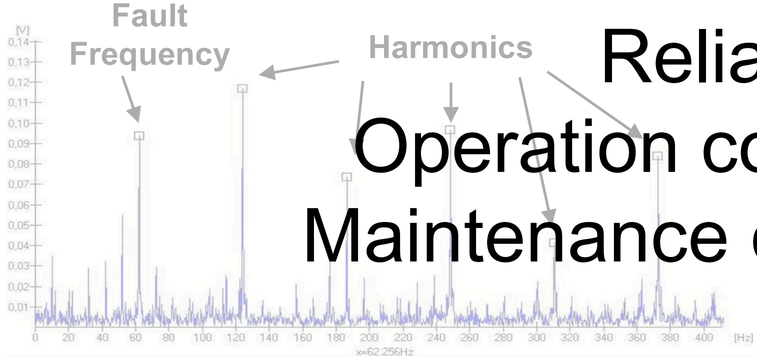


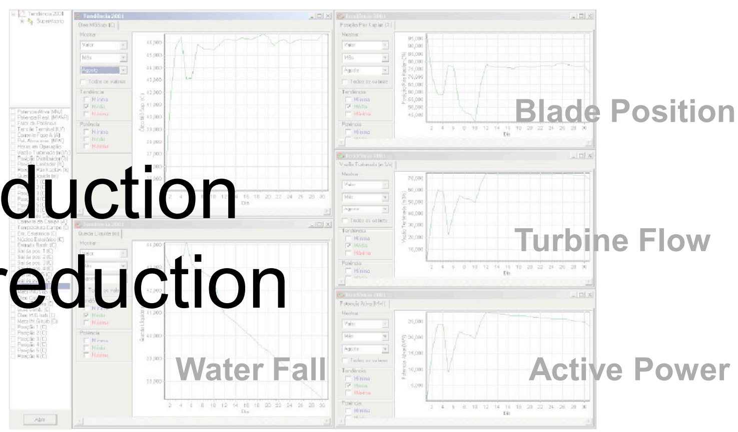




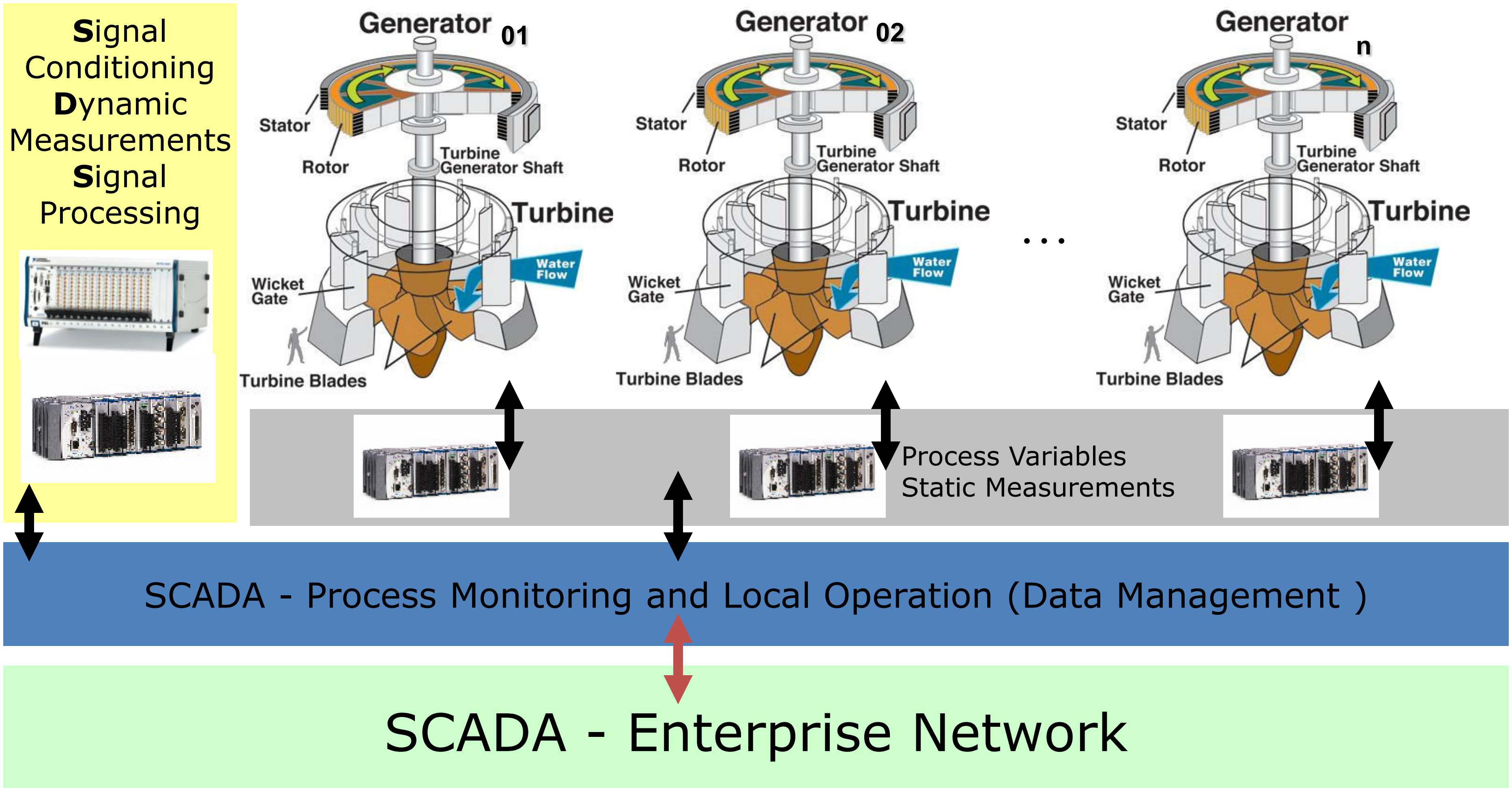
Smart Monitoring and Diagnostic

Condition Maintenance
Asset Management
Power Quality
Safety
Reliability
Operation cost reduction
Maintenance cost reduction





Hydro Plant: Overall architecture



Machine Monitoring Functional Capabilities

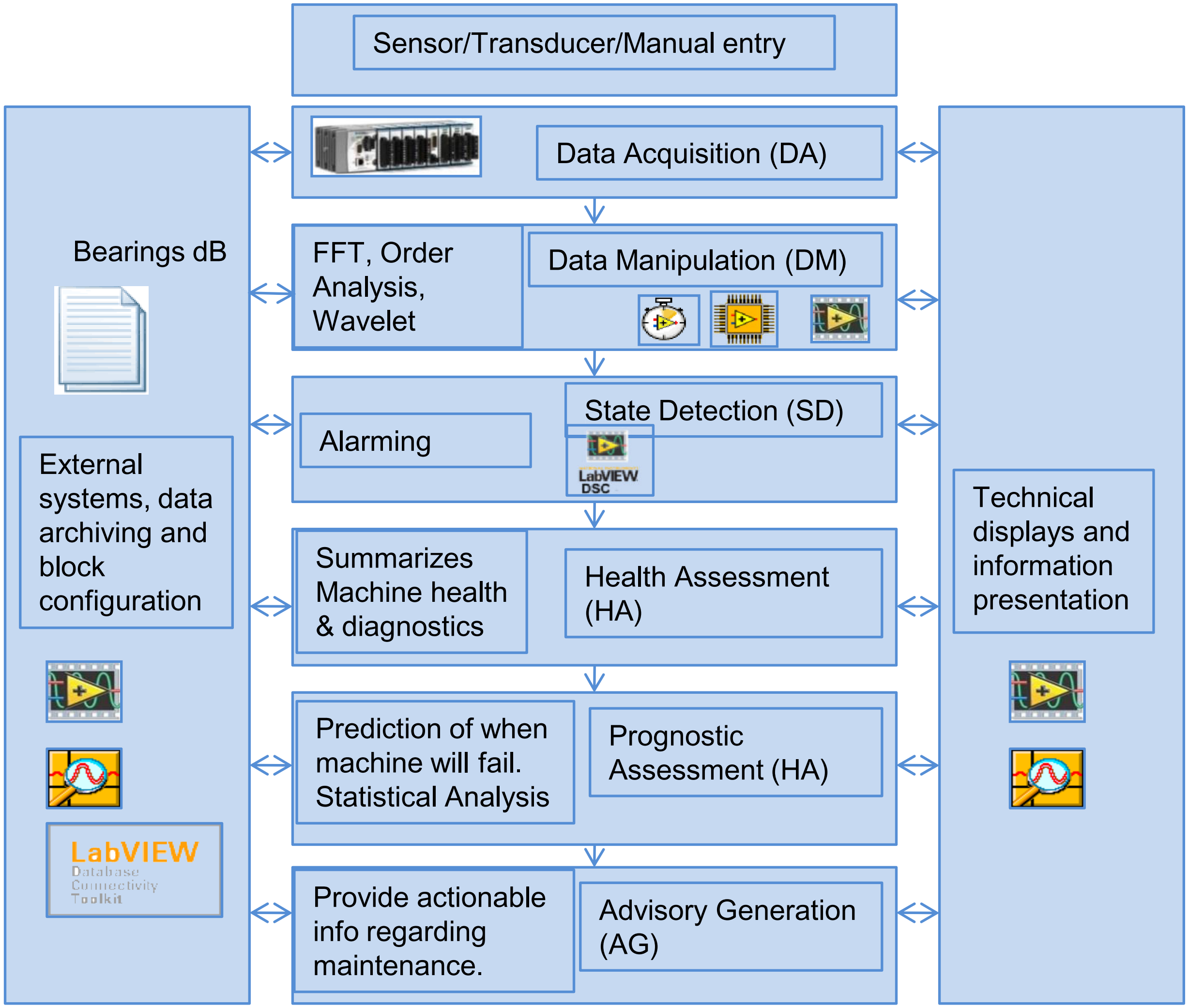


Diagram from ISO 13374-1 Condition and Diagnostics of machines

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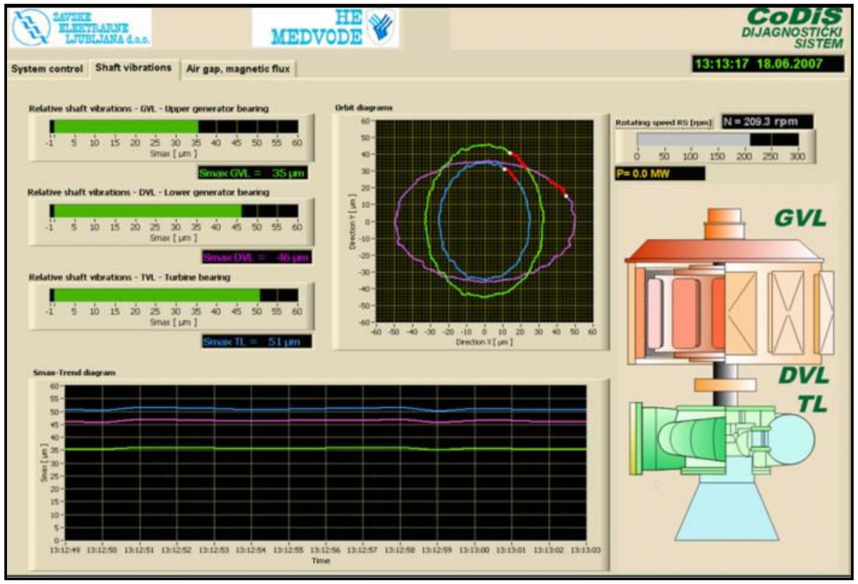
User Solution: Veski



"The continuous monitoring of vibrations and other signals is critical to predicting mechanical behavior and efficiency and usually requires continuous data acquisition and online database analysis. VESKI, a Croatian-based consulting firm that specializes in vibration analysis and diagnostics, relies on NI LabVIEW and NI CompactRIO at the core of its CoDiS monitoring software. "

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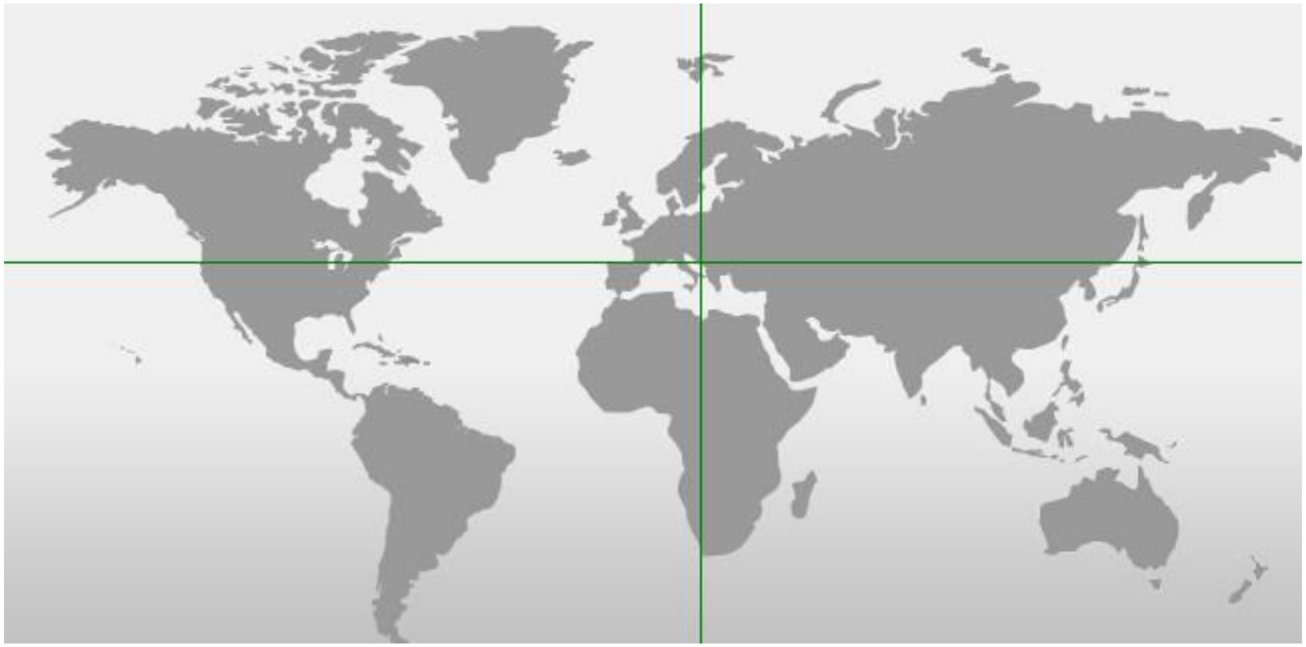
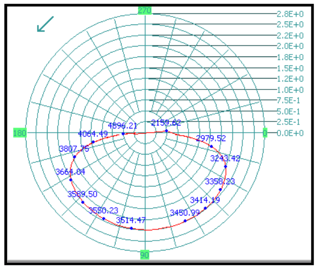
User Solution: Veski



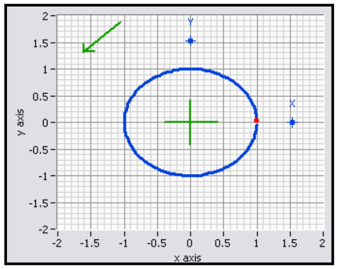
(Just in case you're not sure where Croatia is)

NI: an Asset Health Monitoring Supplier

- Machine Condition Monitoring has its own business segment
- Specific hardware and software products
- Leveraging over 15 years in Sound and Vibration applications
- Leveraging over 20 years in instrumentation control software
- Leveraging over 30 years in computer based instrumentation
- Domain expertise employees and partners



Polar Plot



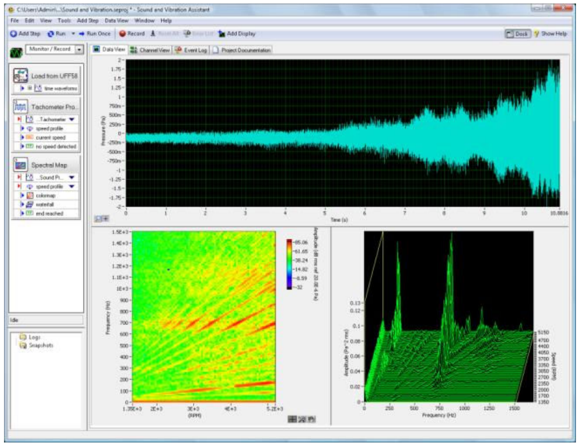
Orbit Plot

Magnitude and Phase Information

	Magnitude (g rms)	Phase (deg)
1x	0.202320	155.5
2x	0.007514	55.2
3x	0.001528	136.4
5x	0.001212	242.0
10x	0.001461	169.1

Tabular List

Run-Up

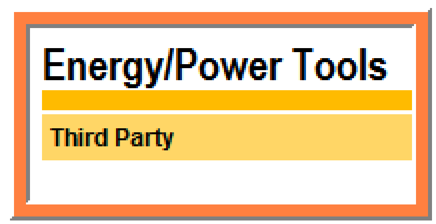


Cascade Plot Waterfall Plot

Additional Resources

- www.ni.com
  - search Power Quality Monitoring
  - search MCM

  - search Energy
  - ni.com/trylabview



Summary and NI's Role

Supply the tools for Design, Prototype and Deploy

- To Modernize the Electric Grid
- To empower the R&D in Science and Education
- Qualify and Develop Workforce

Enable

- Development of Smart Grid and Self Healing Capabilities
- Innovative Power Quality Solutions – T&D management
- Asset Health Monitoring – Improve Performance and Lifecycle

Support the Cultural Transformation

- Efficiency
- Resource Reuse

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Smart Grid - Future

"You CAN measure it, you CAN improve it".

–National Instruments

Case Studies

Internet-Ready Power Network Analyzer for Power Quality Measurements & Monitoring

- Challenge
  - Designing a PC-based power quality analyzer and running all instruments in parallel
- NI Tools
  - LabVIEW, Dynamic Signal Analyzers
- Results
  - Distributed system of 8 instruments, data processing and storage were done in parallel
  - Open framework that can implement future modules
  - Powerful & user-friendly power quality analyzer

"We continue to use the power and performance of the PC technology and NI products to implement more time-demanding advanced signal processing algorithms."

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Performing Advanced Nuclear Plant Research

- Challenge
  - Certifying next generation nuclear reactors
- NI Tools
  - DIAdem
  - LabVIEW Datalogging and Supervisory Control Module
- Results
  - Reduced validation time
  - Integrated solution with third party designs and tools

“Working as a team, OSU research and NI technology created a capable and validated data acquisition, storage, and retrieval system.”

NATIONAL INSTRUMENTS™

Testing High-Voltage Surge Arrestors

- Challenge
  - Characterizing the performance of metal-oxide varistors for overhead power distribution systems
- NI Tools
  - PXI
  - LabVIEW
- Results
  - Improved safety
  - Increased measurement accuracy to better understand performance
  - Improved data throughput speed

"By switching our test system to use LabVIEW and the PXI digitizer, we improved our measurement results while also increasing the safety of our test program,"
ABB Switzerland

Real-Time Monitoring & Analysis System for Power Quality

- Challenge
  - Certifying next generation nuclear reactors
- NI Tools
  - DIAdem
  - LabVIEW Datalogging and Supervisory Control Module
- Results
  - Reduced validation time
  - Integrated solution with third party designs and tools

"Because of the powerful analysis tools of LabVIEW combined with a high-performance embedded controller, live monitoring of frequency deviations, detection of deformations, and spikes is possible ." *Ngee Ann Polytechnic*

NGEE ANN POLYTECHNIC

NATIONAL INSTRUMENTS™

Creating Power Acquisition Network

- Challenge
  - Developing an independent network of power quality analyzers and a network server configuration tool that can provide data to other interfaces and store to a database.

ELCOM, a.s.

- Results
  - Power quality monitor with many different distribution points
  - Real-time operating system
  - Scalable, remote controlled based power analyzer

"Using National Instruments RT Series DAQ and PXI devices compatible with the LabVIEW graphical development environment enables us to run the PAQ Nod ELCOM on independent hardware using a real-time operating system."

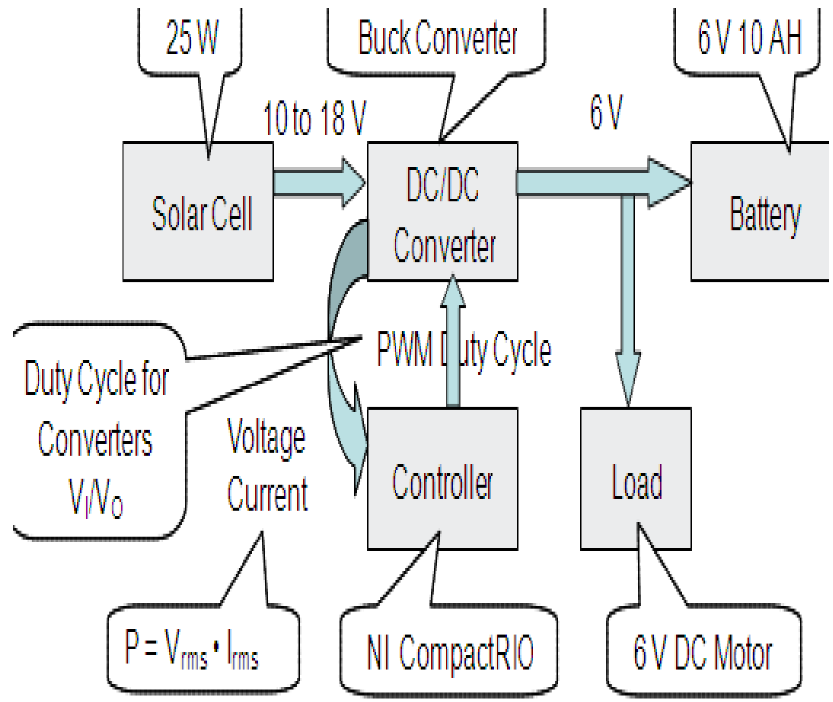
NATIONAL INSTRUMENTS™

Using NI CompactRIO to Design a Maximum Power Point Tracking Controller for Solar Energy Applications

Application: A system for real-time solar cell calculation to ensure that the maximum power output is achieved in a variety of environmental conditions.

Challenge: Identifying an efficiency point that achieves maximum solar cell power in varying environmental conditions.

Products: Legacy Devices, Real-Time Module, LabVIEW, cRIO-9101, FPGA Module



Key Benefit: CompactRIO increased time efficiency and simplified many complicated steps in the development process.

"After we completed our application, we continued to receive service from NI applications engineers. We approached them with our maintenance and technical problems, and the annual forums and cost-free tuition were helpful." Ru-Min Chao – Electromechanical Research Institute

Using NI CompactRIO to Design a Maximum Power Point Tracking Controller for Solar Energy Aapplications