Essential Technologies for Energy Efficiency and Management

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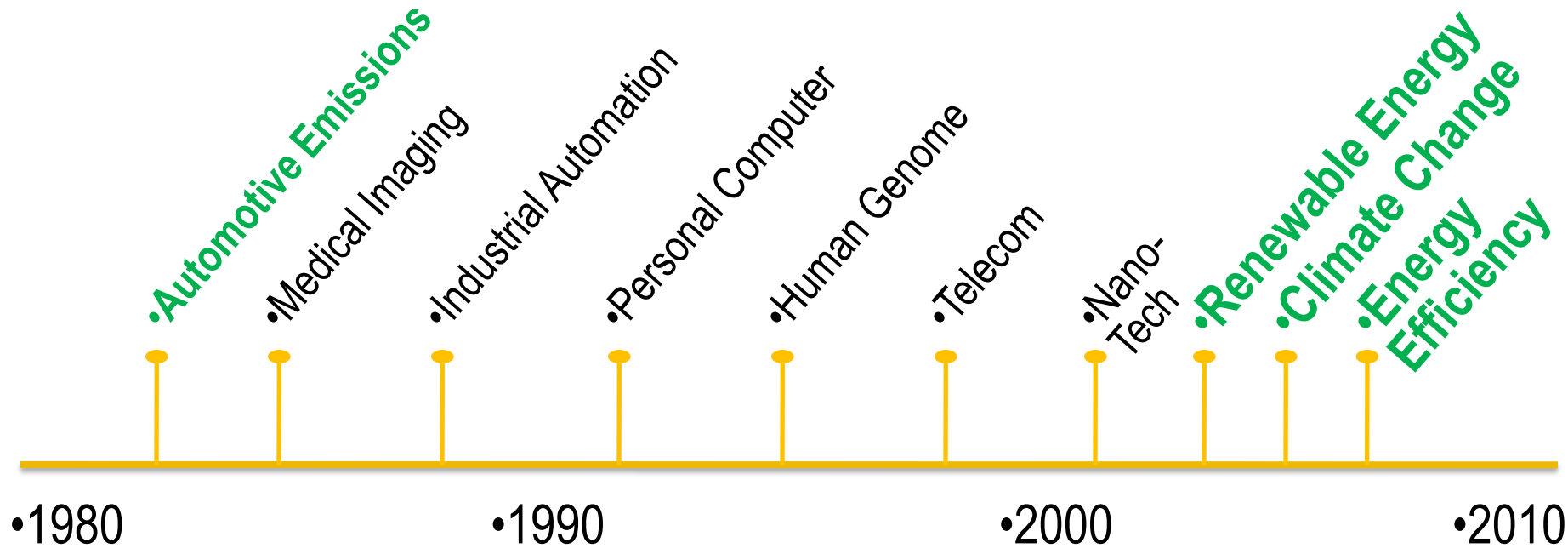
30 Years of Engineering Trends, Challenges, and Milestones



Why more efficiency?

- Soaring E
  - Strengt
    - Oil ha
- New ene
- Concerns
- Increasing
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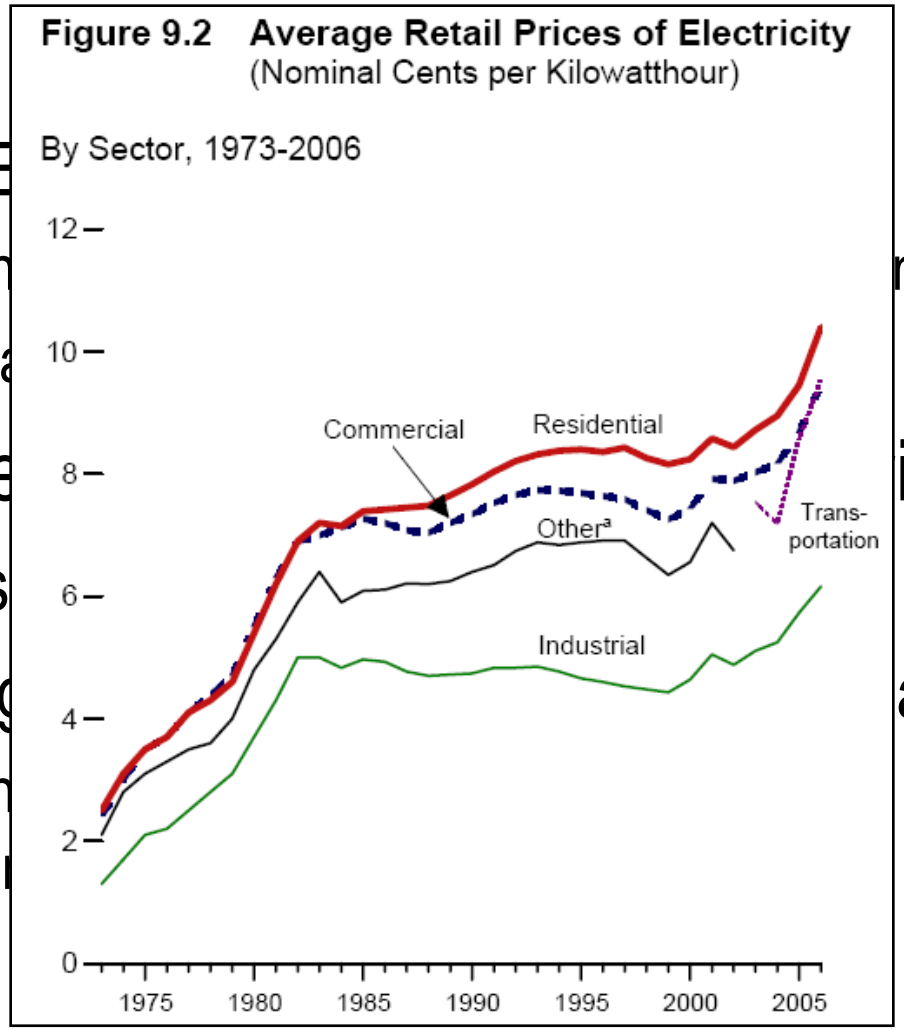
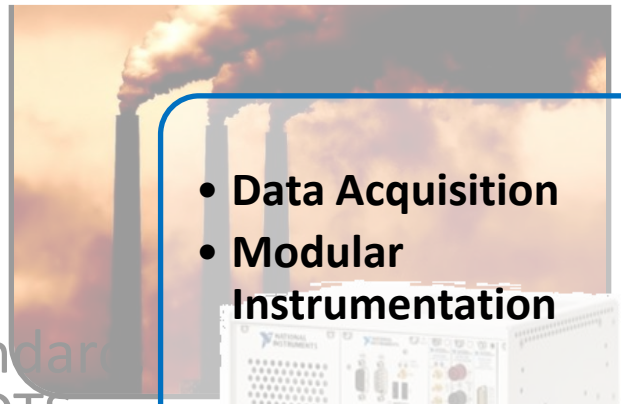


Measure It

The Engineering Innovation Process

Graphical System Design Platform



- **Data Acquisition**
- **Modular Instrumentation**

Measurements

"Fix it" Designs

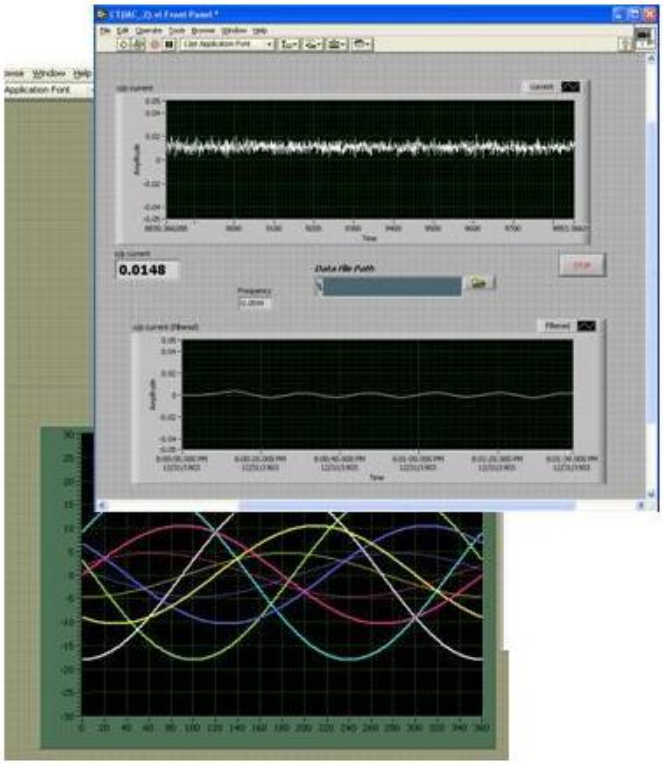
- **Control Design**
- **Simulation**
- **Analysis**

- Standard COTS Hardware
- **Measure** W Architectures
- **Measure** S
- **Measure** Energy Consumption
- Single, Consistent ine Controllers Graphical Software
- **Fix:** Predictive Maintainence
- **Fix:** Demand/Response

Energy Consumption Measurement System

- **Challenge:** Developing an integrated, simple data acquisition system for different energy consumption measurement applications,

- **Products:** LabVIEW, DAQ

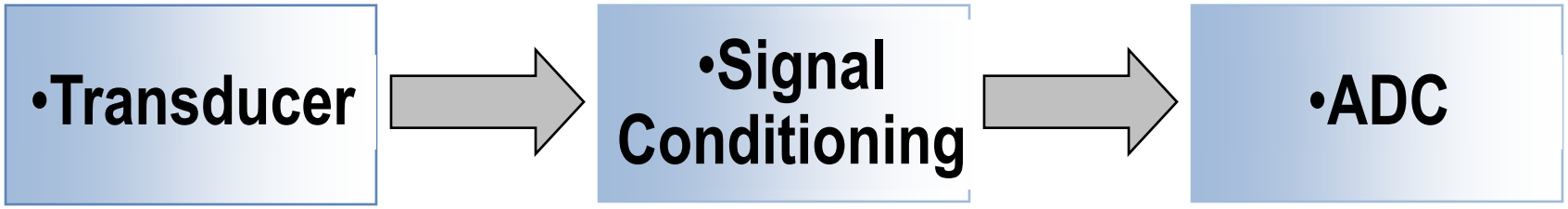


- "With simple components, we now can monitor, measure, and control the energy for any system while saving money and data-logging time."

University of Miami

Measurement System Components

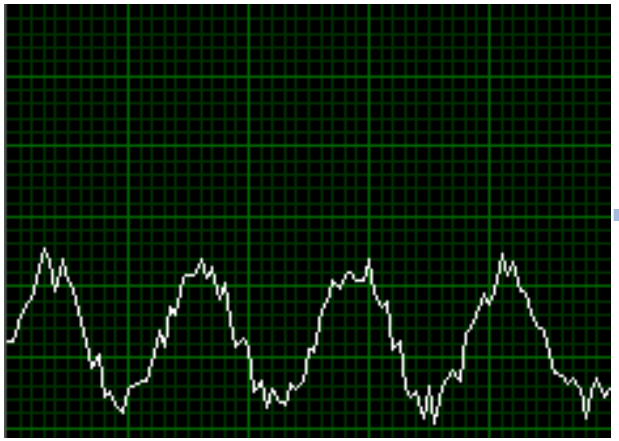
- *All monitoring systems have these components in common:*



Transducers and Signal Conditioning

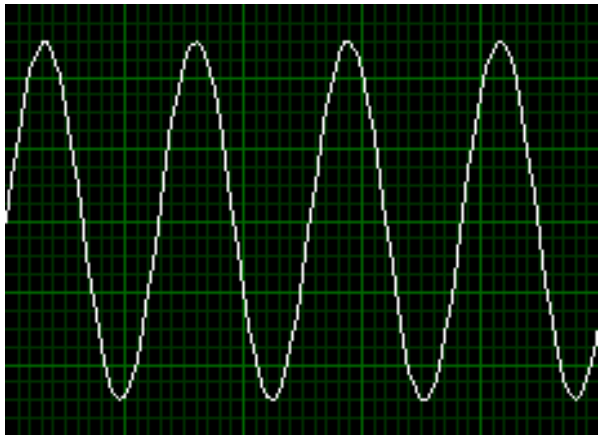
Phenomena	Transducer	Signal Conditioning
Temperature	Thermocouples Resistive Temperature Devices (RTDs) Thermistors	Amplification, Linearization, Cold-Junction Compensation, Current Excitation
Proximity	Limit Switches Proximity Switches	Power
Vibration	Accelerometers Proximity Probes	Current Excitation, AC-Coupling, Eddy Current Power
Force and Pressure	Strain gages Load Cells	Voltage Excitation, Bridge Completion, Linearization
Position and Displacement	Potentiometers Linear voltage differential transformer (LVDTs) Tachometers	RMS Voltage Excitation
Fluid Flow	Rotational Flowmeters	Excitation, Filtering

Why Use Signal Conditioning?



•Noisy, Low-Level Signal

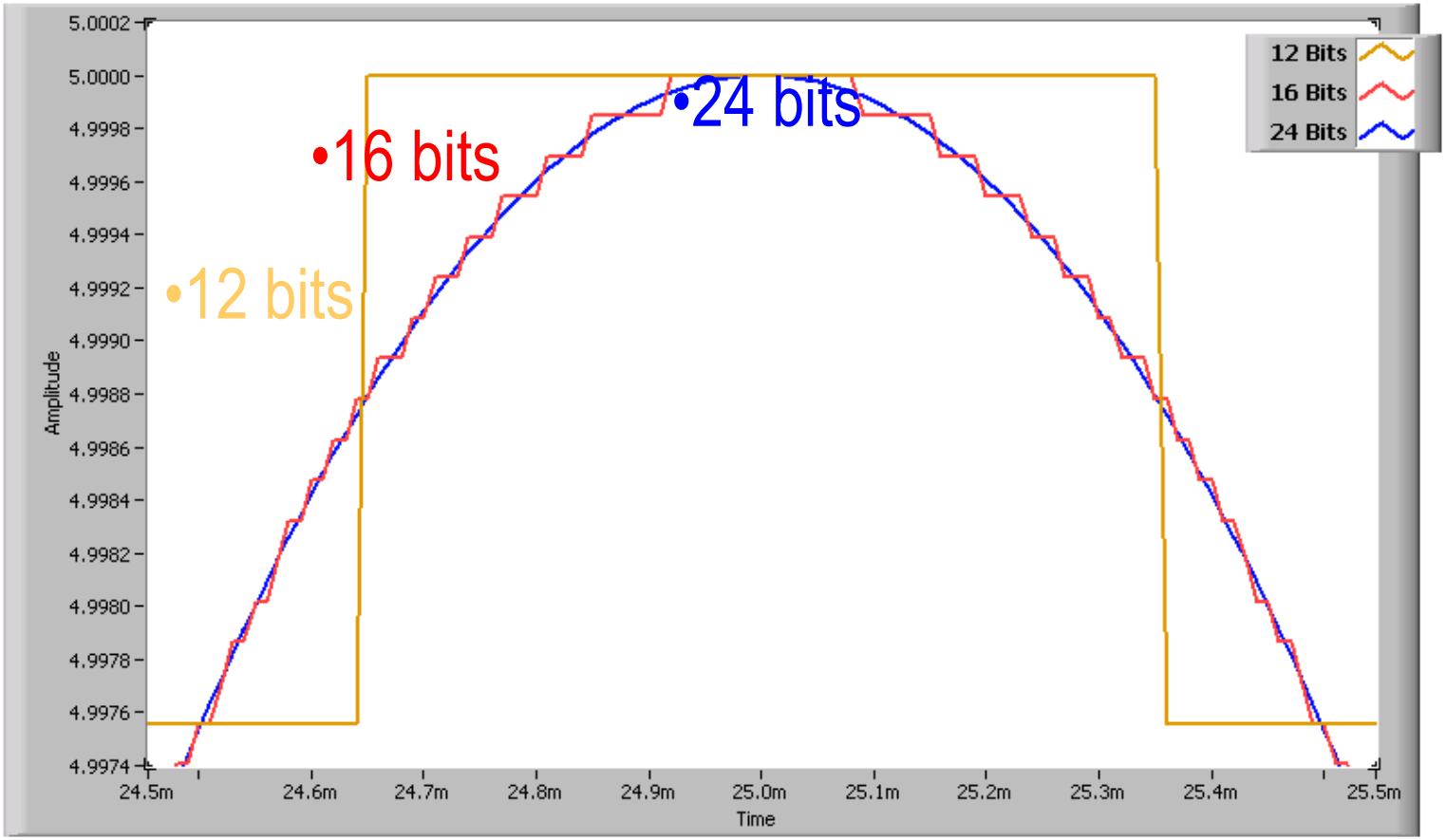
•Signal Conditioning



•Filtered, Amplified Signal

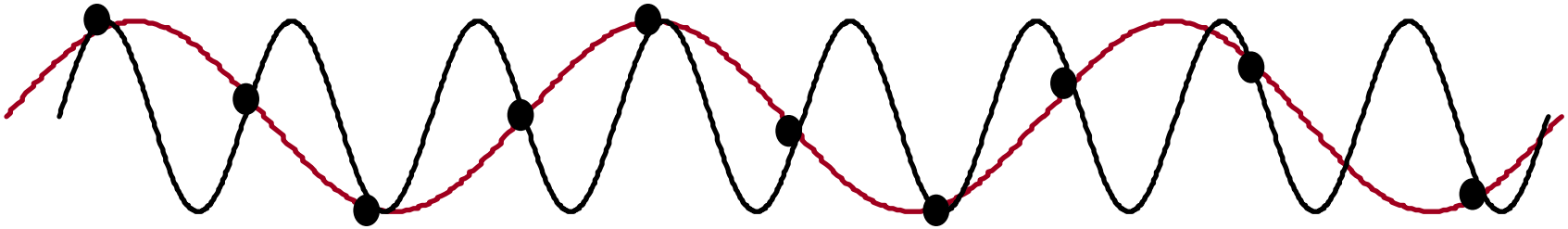
- Improve signals for better measurement quality
- Power or excite sensors
- Read sensor information – TEDS
- User and system safety

12-bit, 16-bit, and 24-bit ADCs



•Demo 2

ADC Sampling Rates



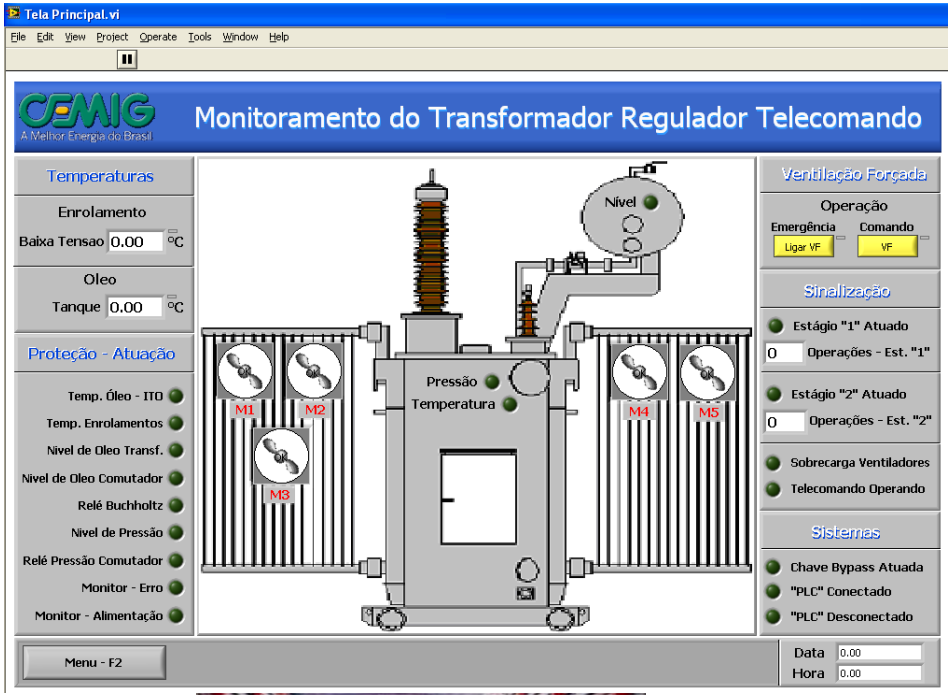
- Black wave = signal
- Green wave = sampled signal

Why is sample rate important?

- Sample too slowly = incorrect data (invalid test)
- Always sample at least 2x the frequency of your measured signal (Nyquist Frequency)
  - 5-10 x for more accurate time waveform representation is recommended

Substation Monitoring

- Transformer Monitoring
- Environment Monitoring
- Fan Control
- Switches Monitoring
- Circuit Breaker Monitoring
- Remote access and alarming
- Off the shelf solution >$1Mi
- NI solution based on FP LV-DSC plus development costs <$200k



GE trafo

Elcom – Power Quality Monitoring

Characteristics of ENA450

Model **ENA450** is based on compact case with integrated computer and signal conditioning for 3 voltages and 4 currents. ENA450 mounts directly on a 35mm DIN rail.

Key features:

- 3 galvanic isolated voltage inputs with antialiasing filters
- 4 indirect current inputs (using current clamps) with antialiasing filters
- Adaptive sampling frequency
- Dimensions: 88 x 180 x 90mm (H x W x D)
- A/D converter with 24-bit resolution for high precision
- Galvanic isolated digital inputs (8x)
- Consumption less than 10VA
- For high reliability has ENA450 no rotating parts
- ENA450 uses operating system VxWorks

ENA450

ENA-Node firmware of Elcom Network Analyzers

Some ENA power quality analyzer features like number of voltage and current inputs, voltage and current ranges, power supply level, etc. are defined by ENA analyzer hardware model.

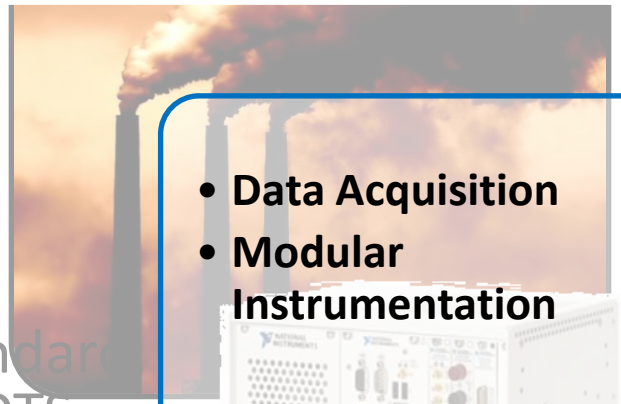
Other ENA power quality analyzer features like evaluated quantities, stored data type and communication protocols are defined by instrument firmware. All models of ENA family use inified data format and have identical user interfaces. ENA analyzers firmware called ENA-Node fully complies with actual international standards defining power quality measurement methods and other national-specific documents:

- IEC 61000-4-30 "Power quality measurement methods", class A
- IEC EN 61000-4-7 "Guide on harmonics measurements"
- IEC EN 61000-4-15 "Flickermeter"
- EN 50160 "Voltage characteristics of electricity supplied by public distribution systems"

Analyse It

The Engineering Innovation Process

Graphical System Design Platform



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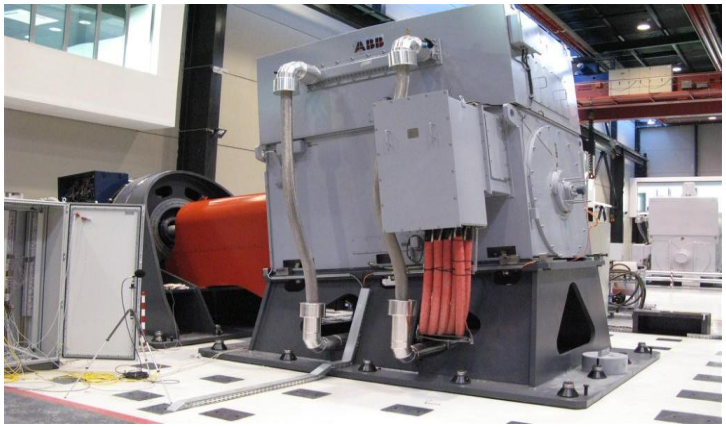
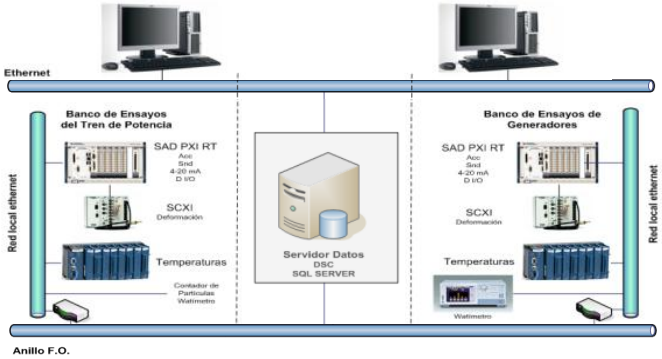
Case Study: GES Siemsa

- Laboratory validation and manufacturing certification test system for wind turbines
- Mechanical systems capabilities: power train and generator
- **Green Benefit**
  - One of only a few systems in the world that can fully simulate the wind, with all the reactions that occur at the hub



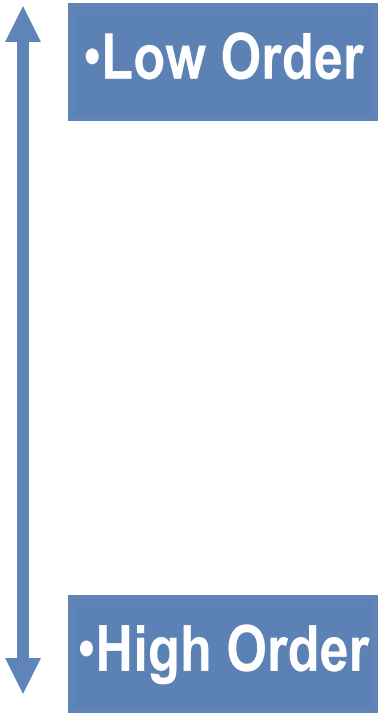
GES Siemsa System

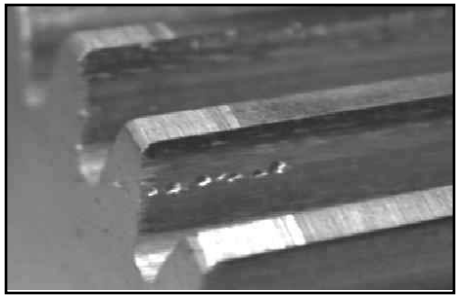


- 32 channels of high-speed, dynamic sound and vibration data are acquired with PXI
- An SCXI system measures strain and deflection from 32 channels
- Additional measurement inputs are used for temperature, displacement, and pressure
- LabVIEW analyzes data and communicates results to an database with an SQL server

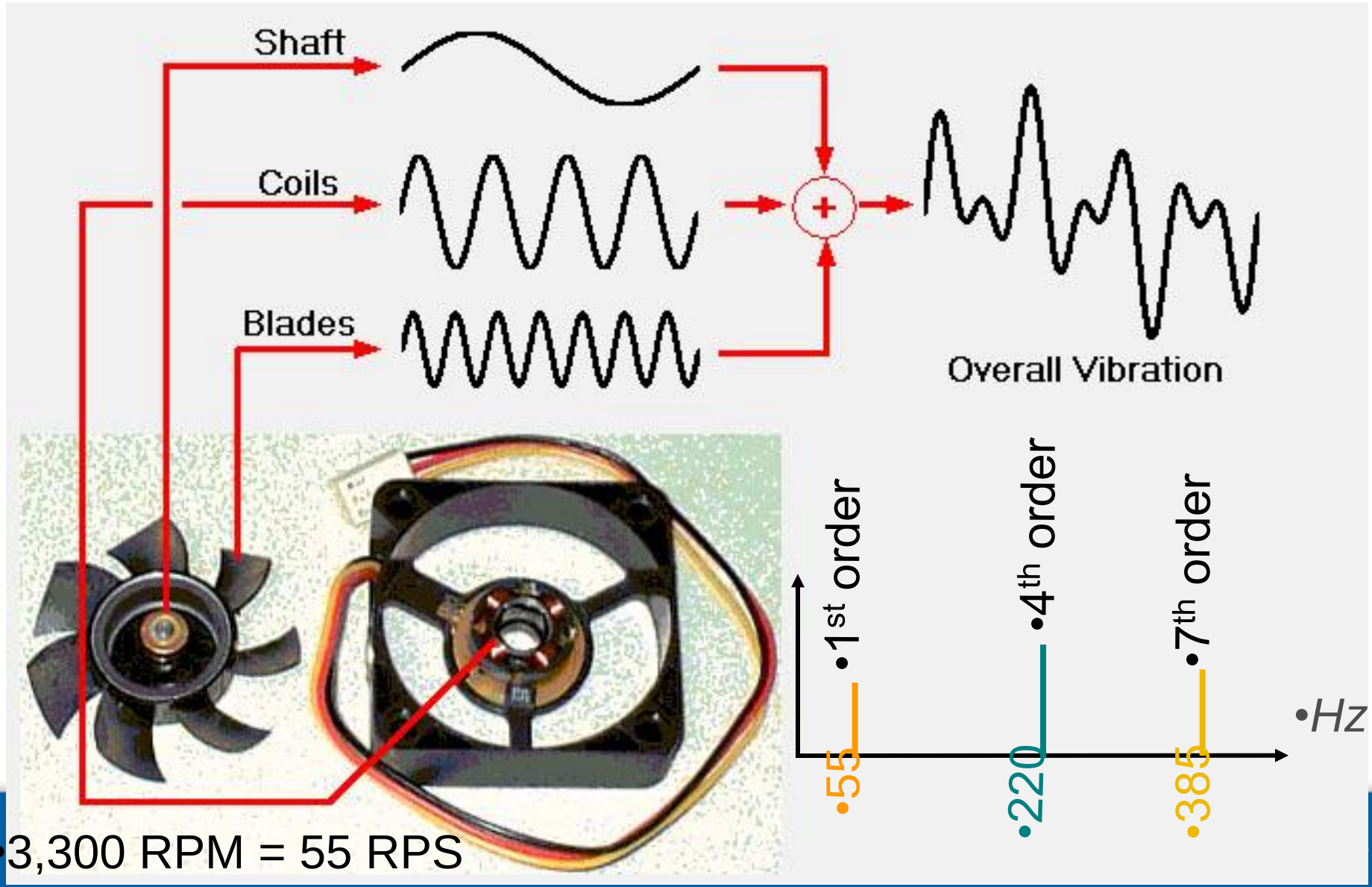
Relationship of Orders and Faults

- We can diagnose machine faults by knowing the order:
  - Imbalance
  - Misalignment
  - Loose Coupling
  - Valve Noise
  - Bearing Defects / Wear
  - Blade Pass Frequency
  - Gear Mesh





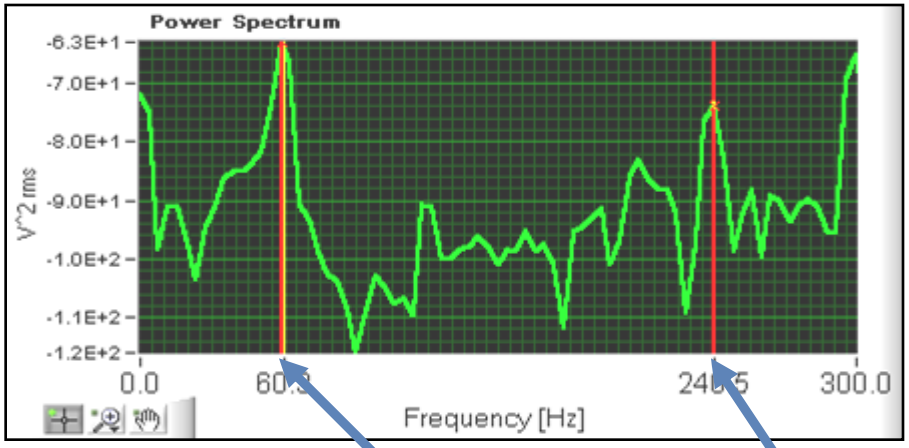
Using Order Analysis on Machinery



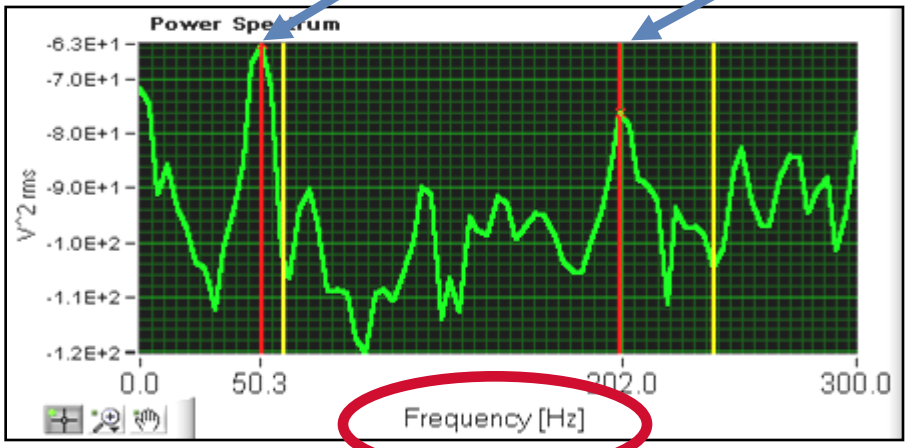
- 3,300 RPM = 55 RPS

Power Spectrum

•Rotating Speed:
•60 Hz
•(3600 RPM)



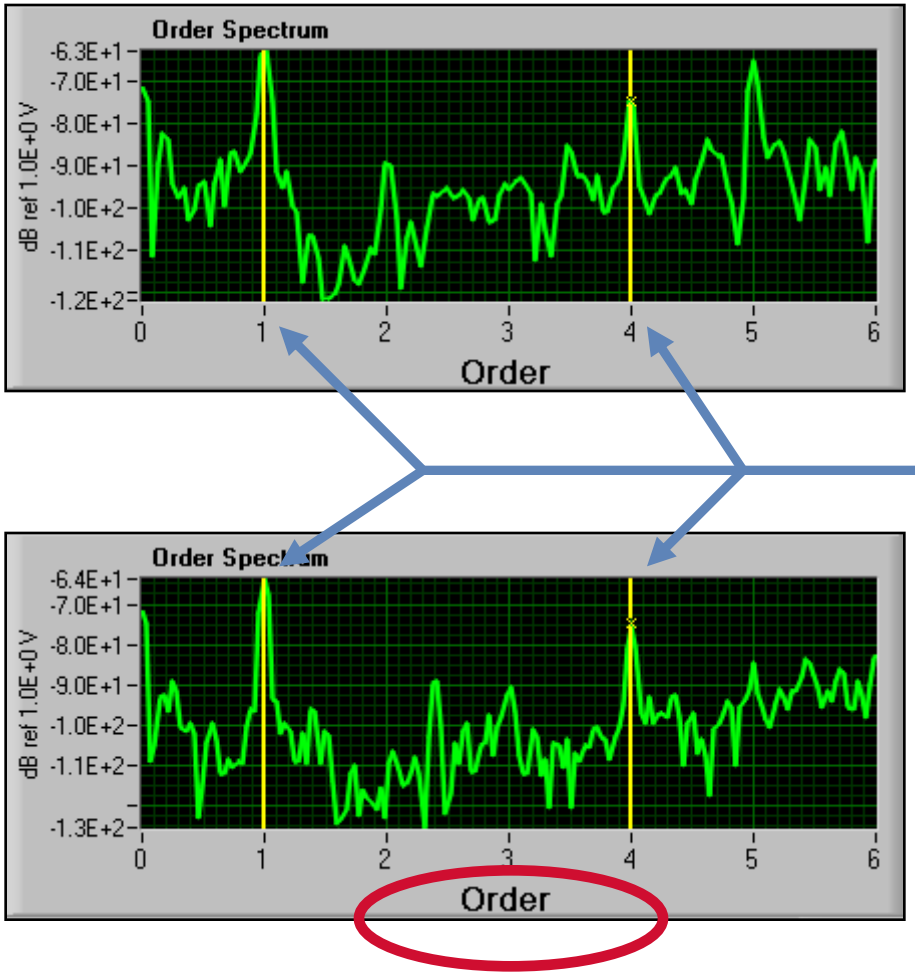
•Rotating Speed:
•50 Hz
•(3000 RPM)



•Frequency components shift with speed change

Order Spectrum

- Rotating Speed:
  - 60 Hz
  - (3600 RPM)



- Rotating Speed:
  - 50 Hz
  - (3000 RPM)

- Order components remain fixed with speed change

Hydro Generator Diagnostic

CEPEL
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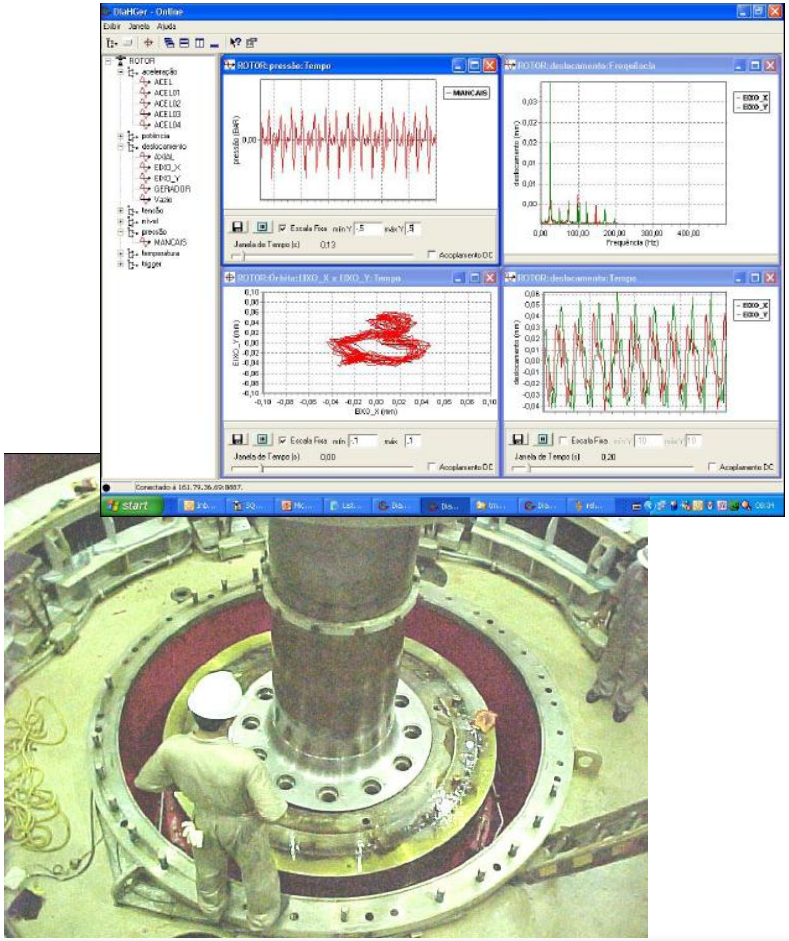
- Dynamic analysis of rotating machine
- Behavior monitoring
- Fault identification
- Root cause association based on computational intelligence
- Maintenance Web based Portal



Control It

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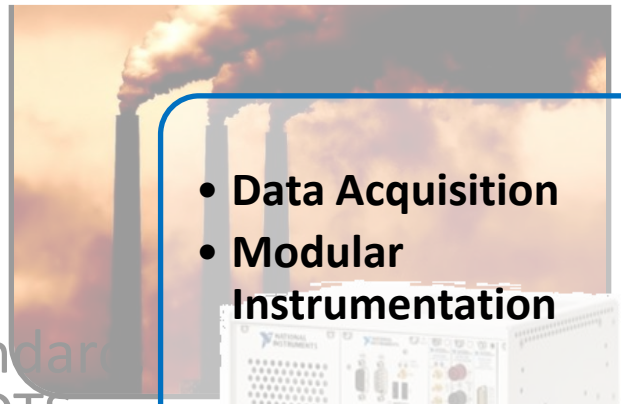

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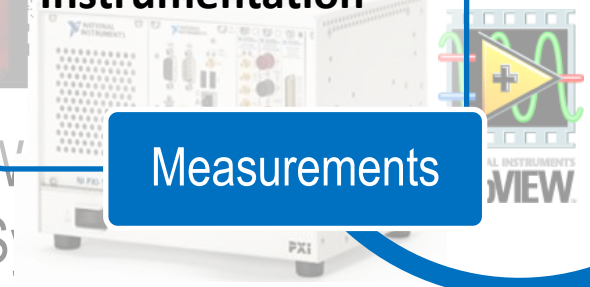

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- ine Controllers
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Chiller Energy Management System (CEMS)

- Malaysian based company retrofitting large-scale, commercial and industrial air-conditioning systems
- **Measuring** temperature, humidity,
- Performing calculations based on advanced control, thermodynamics,
- **Fixing** excessive electricity use by sending new and optimized operating instructions to the chillers
- **Efficiency**
  - Reduced chiller energy consumption by up to 30%
  - Industrial chillers use approximate 30% of all electrical power in Taiwan

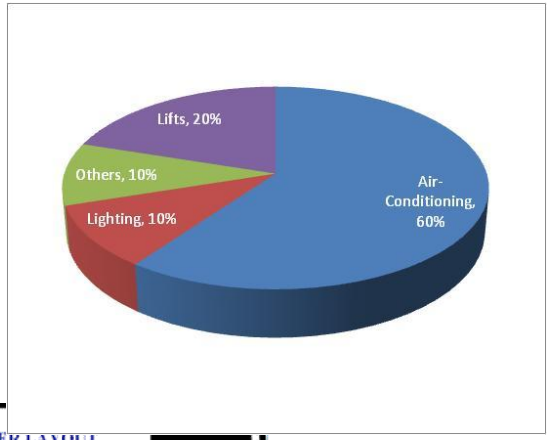
•**CEMS Reduces Energy Consumption by 30% using NI Graphical System Design**

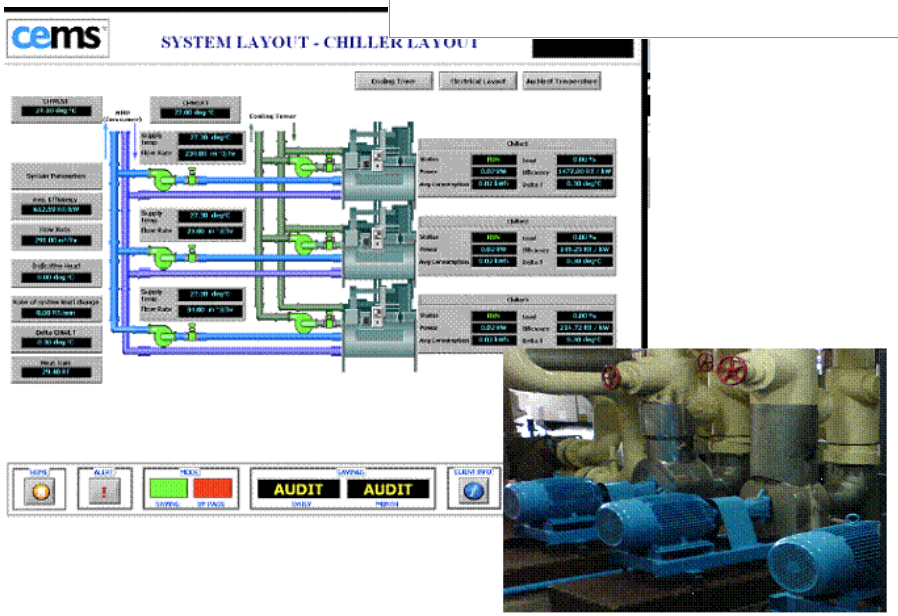
Chiller Energy Management System

- genetic algorithms with combination of heat transfer principles, thermodynamics, and advanced mathematical predictions

- inside, outside sensors

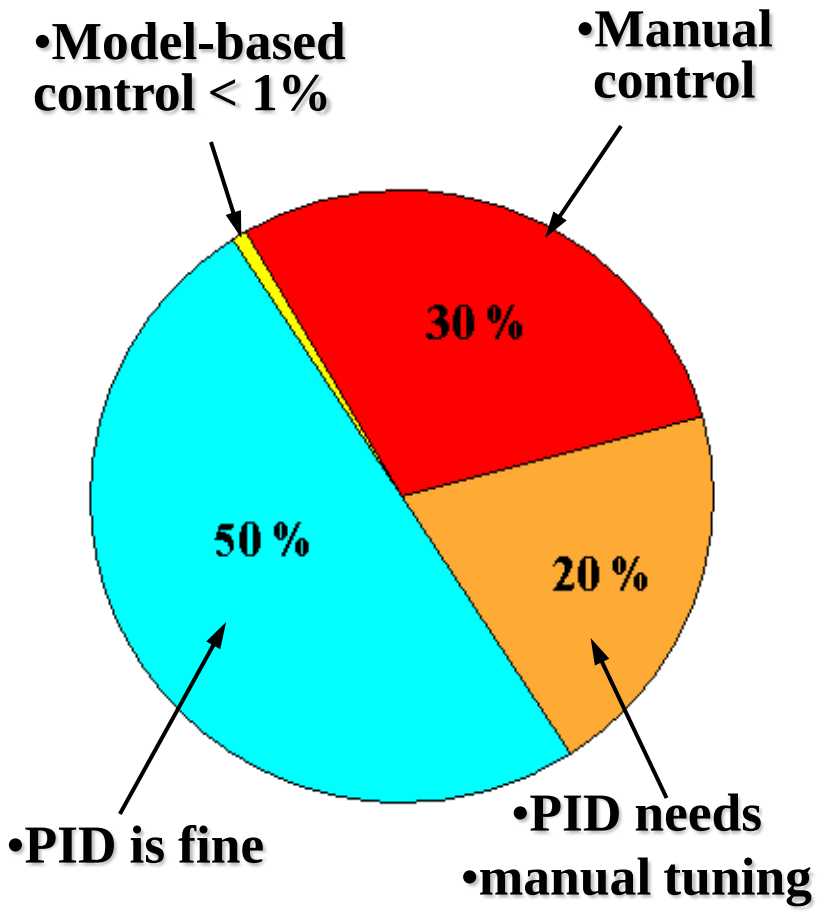
- include preventive maintenance





Benefits of Advanced Control and Tuning

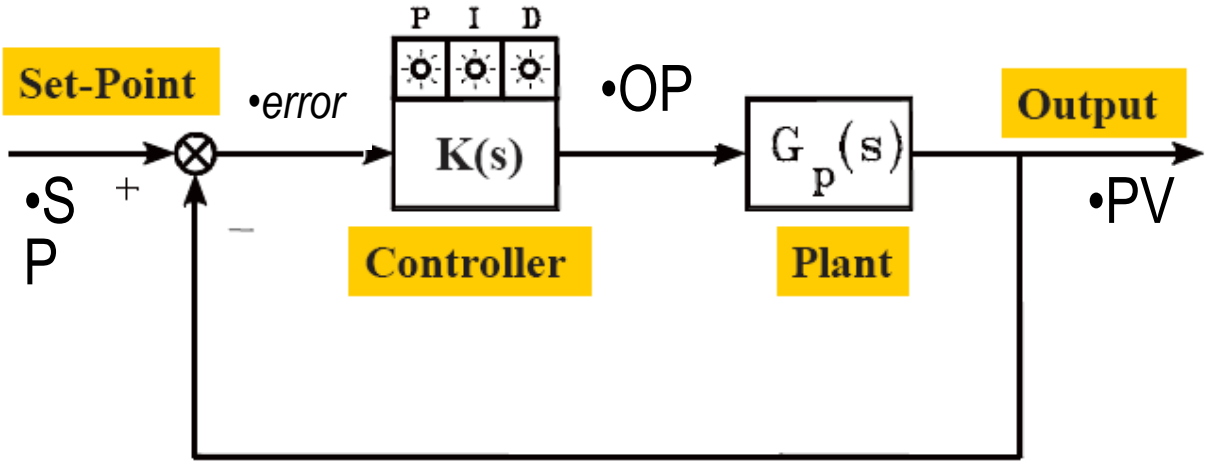
- A poorly tuned control valve costs additional $880/year*
- A bad pH loop incurred chemical waste of $50,000/month*
- A badly tuned temp loop cost $30,000/month*



•*Sources: Cybosoft and ExperTune

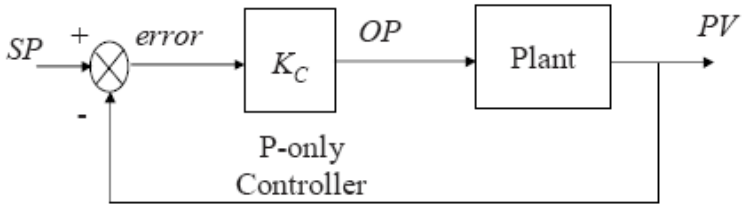
What is PID

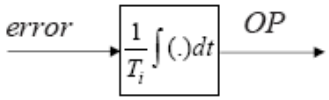
- Set Point (SP) – Desired control point
- Output (OP) – Controller output
- Process Variable (PV) – Plant/process output
- *Error* = SP - PV

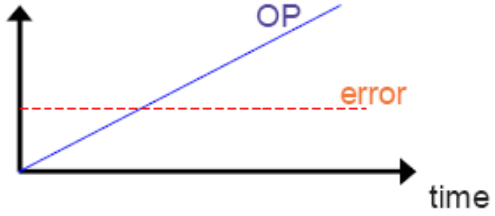


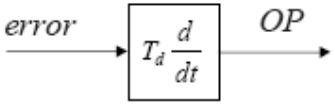
PID Parameters

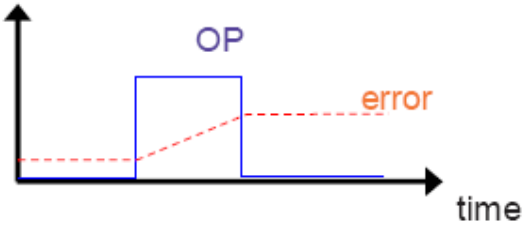
- **Proportional**
  - **Drive to setpoint**
  - *Error* → 0, OP → 0
  - "Steady-state error"
- **Integral**
  - Eliminate steady state error
  - OP **proportional to ∫ error**
- **Derivative**
  - Increase response rate
  - OP **proportional to rate of change of error**





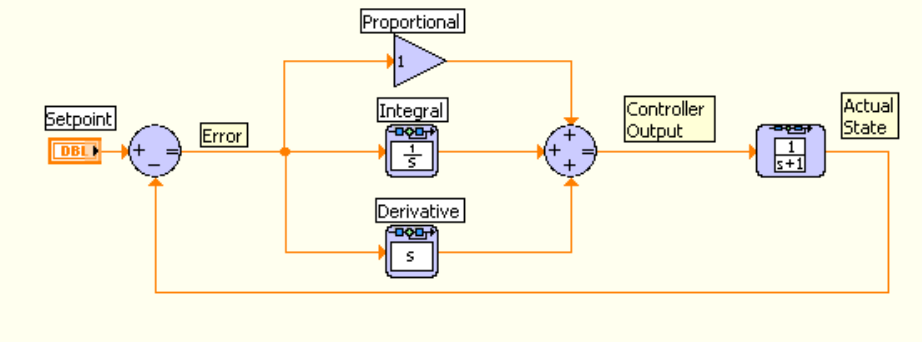






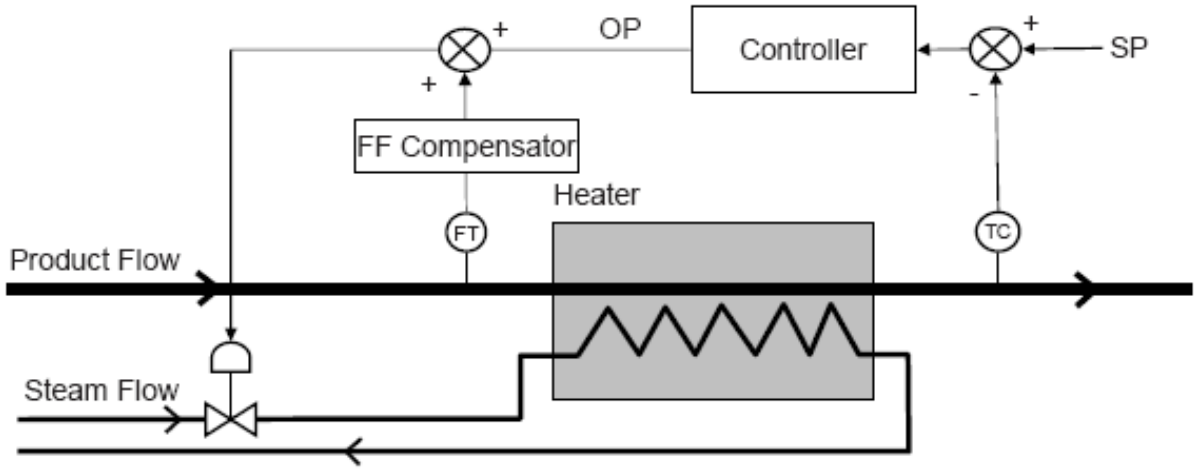
PID Control – Pros and Cons

- Advantages
  - Proven
  - Easy to implement
- Disadvantages
  - Not easy to tune
  - Not suitable for all systems
    - Backlash, friction, and so on

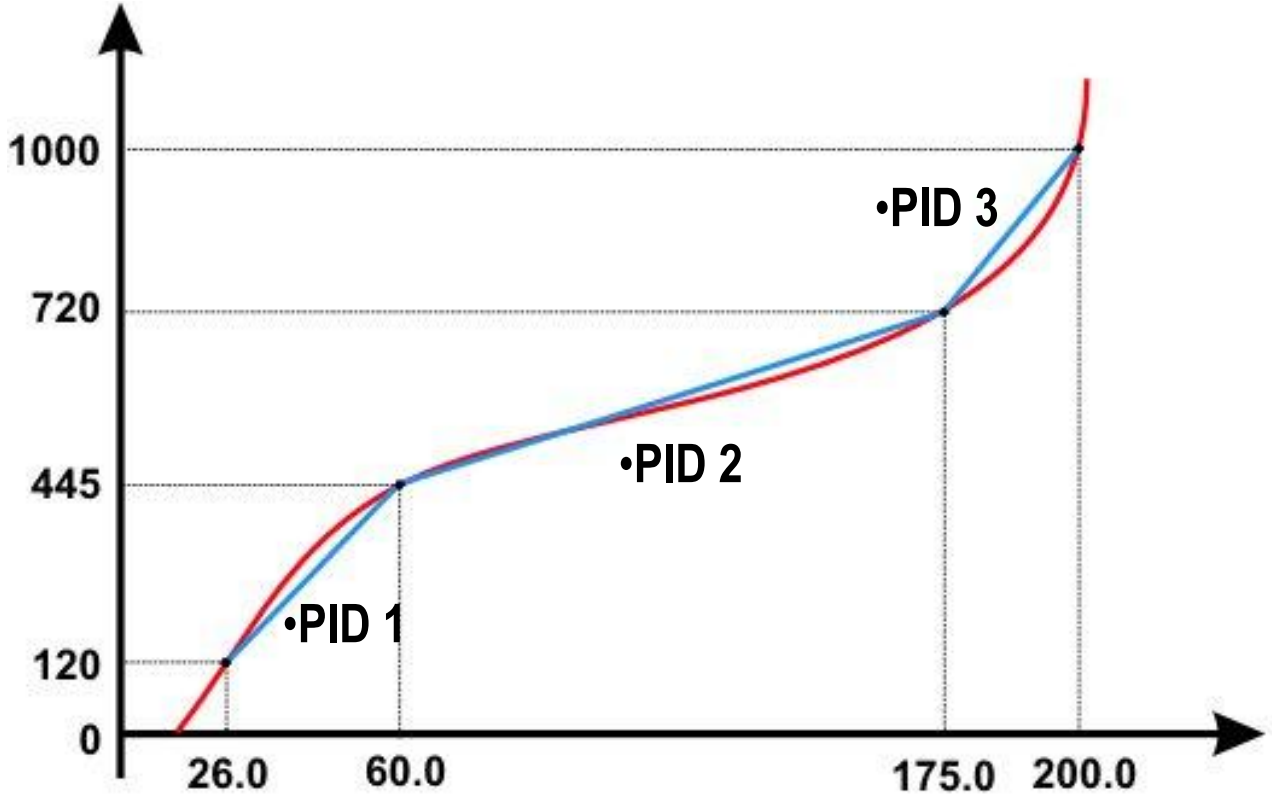


Feed-Forward

- Commonly used to compensate for a *measurable* external disturbance before it affects a controlled variable.
- e.g. product feed rate changes

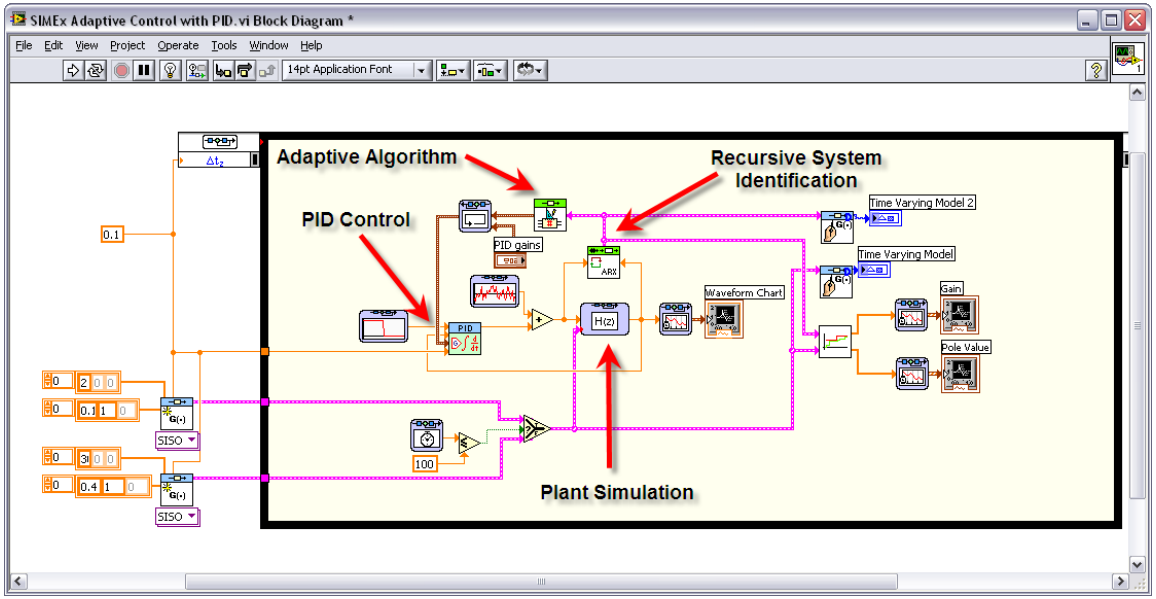


Gain Scheduling



Adaptive PID

- Mixed of On-Line system identification and common PID control.
- Can handle time-variant systems



Advanced Controllers

National Instruments

- Optimal Controllers (**LQR, LQG**)
- Model Predictive Control (**MPC**)
- Kalman Filters
- Fuzzy LogicNeural
- Networks (ni.com/labs)

Third Party Partners

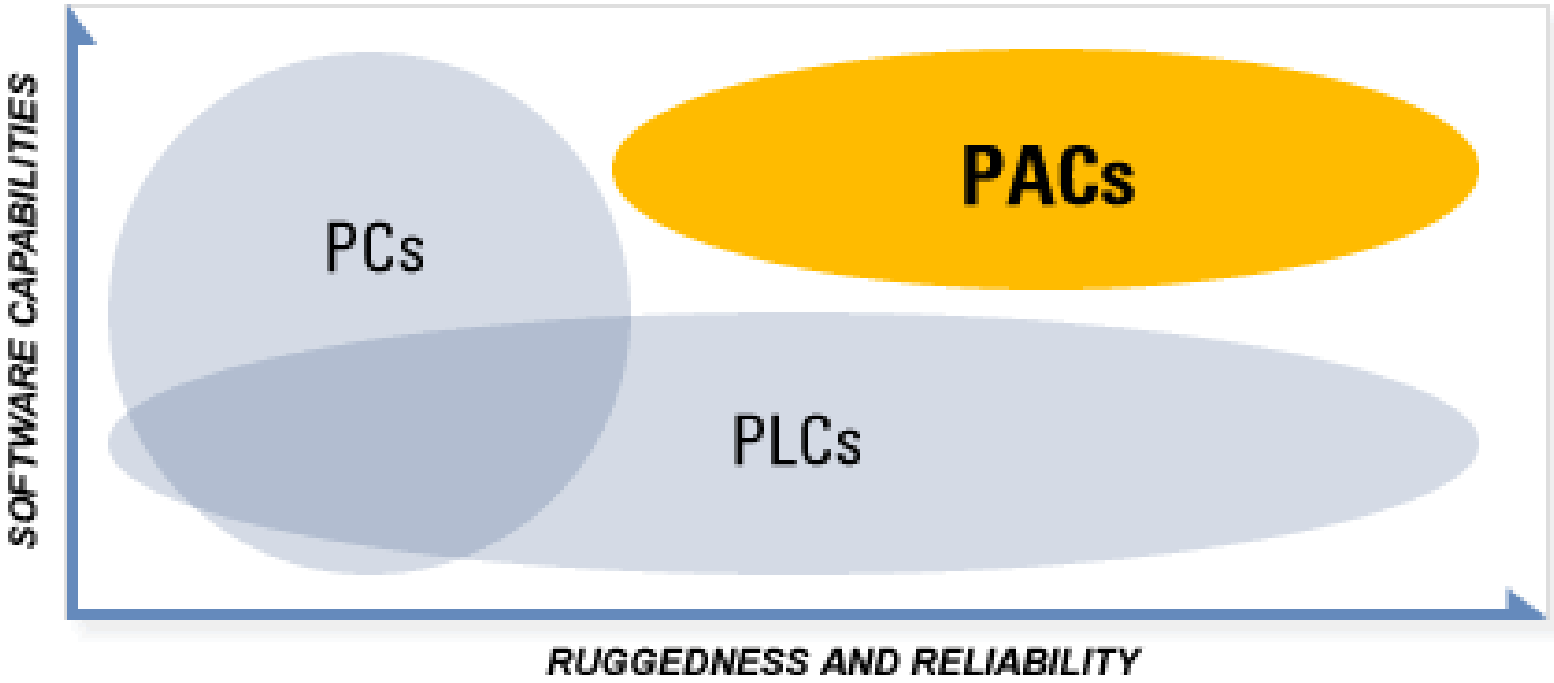
- Genetic Algorithms
- Model Free Adaptive

Others

- Matlab®/Simulink® Integration

Advanced Hardware Platforms:
Programmable Automation Controller (PAC)

- **Open Embedded System**
- **Combines Flexibility with Ruggedness**



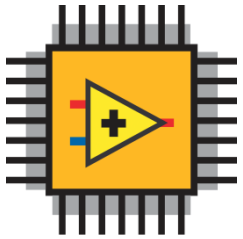
Optimizing Steel Melting Process

- **Application**
  - Large steel producer/recycler
  - Optimize metal melting process
  - Automate for safety and efficiency
- **Requirements**
  - Reduce electricity consumption
  - Limit grid power draw and avoid flicker
  - Real-time control protection of high-volt equipment

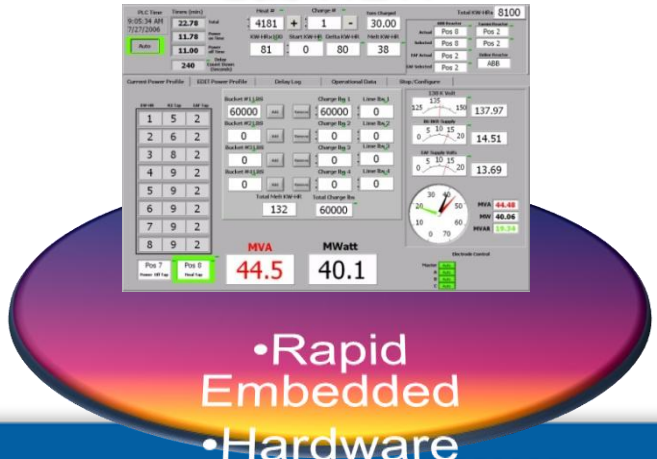
Optimizing Steel Melting Process

- **Technology**
  - CompactRIO
  - NI Compact FieldPoint
- **Software Access**
  - LabVIEW
  - LabVIEW FPGA
- **New Generation Solution**
  - Optimized metal processing
  - Monitor/control real-time grid power draw
  - 10X efficiency increase
  - Drastically reduced automation costs

•FPGA

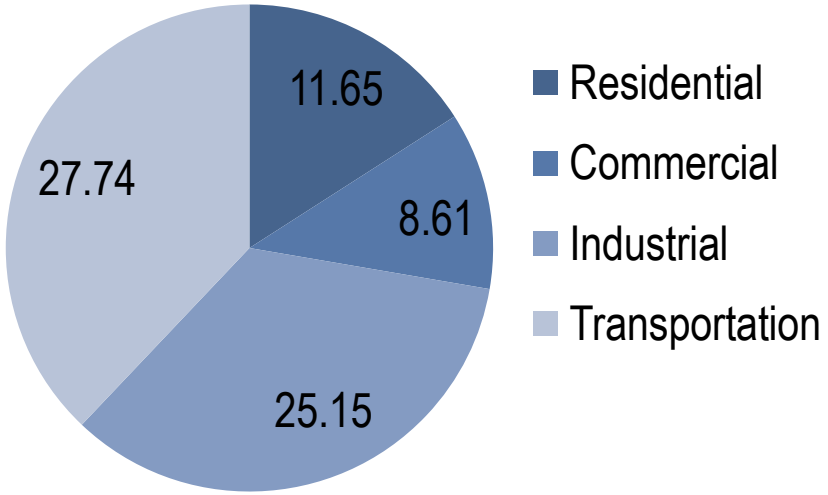


•LabVIEW



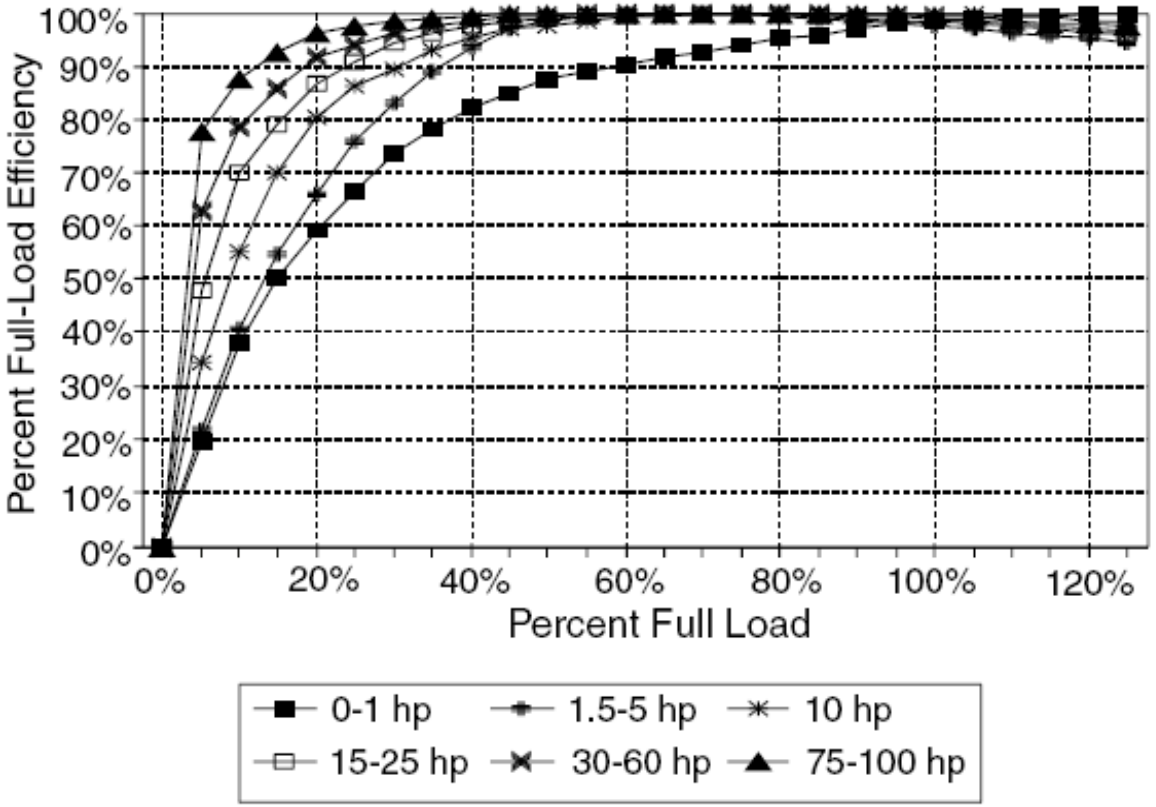
NATIONAL INSTRUMENTS

Impact of Motors



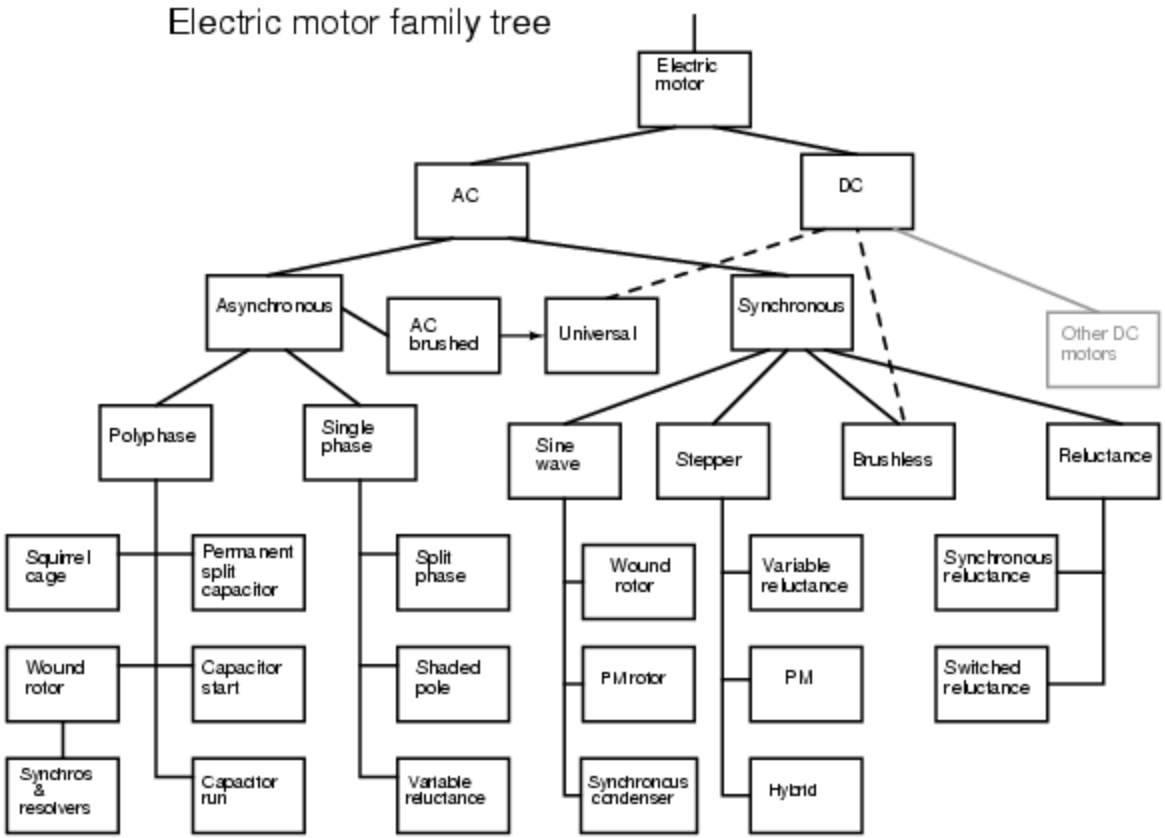
- 60% of WW Energy consumption is from Motors
- 80% of Motors are heavily over sized
- 96% of the total life cycle costs of a motor are energy costs
- Using more advanced Control Systems can pay back within two years

Energy efficiency and Motor Load



Typical Motor Types

- DC
  - Brushed
  - Stepper
  - Brushless
- AC
  - Single phase
  - Three phase

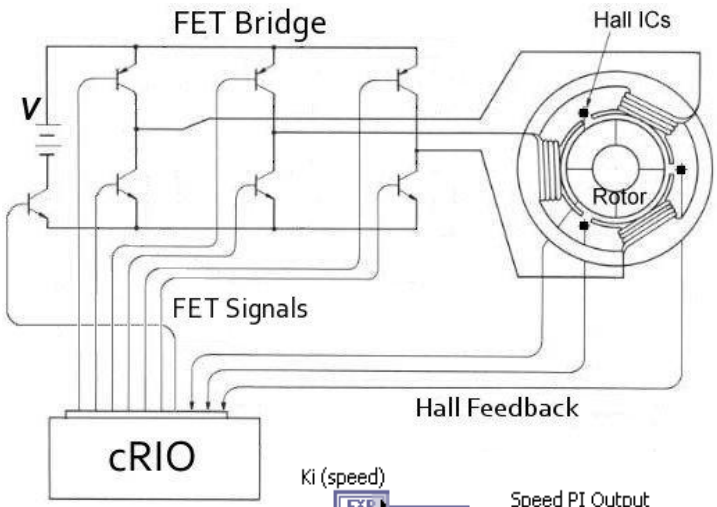


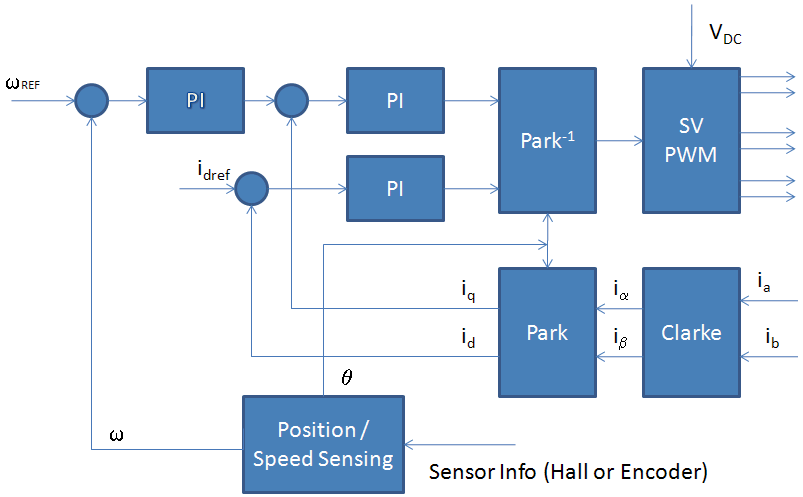
Why Use Brushless Motors

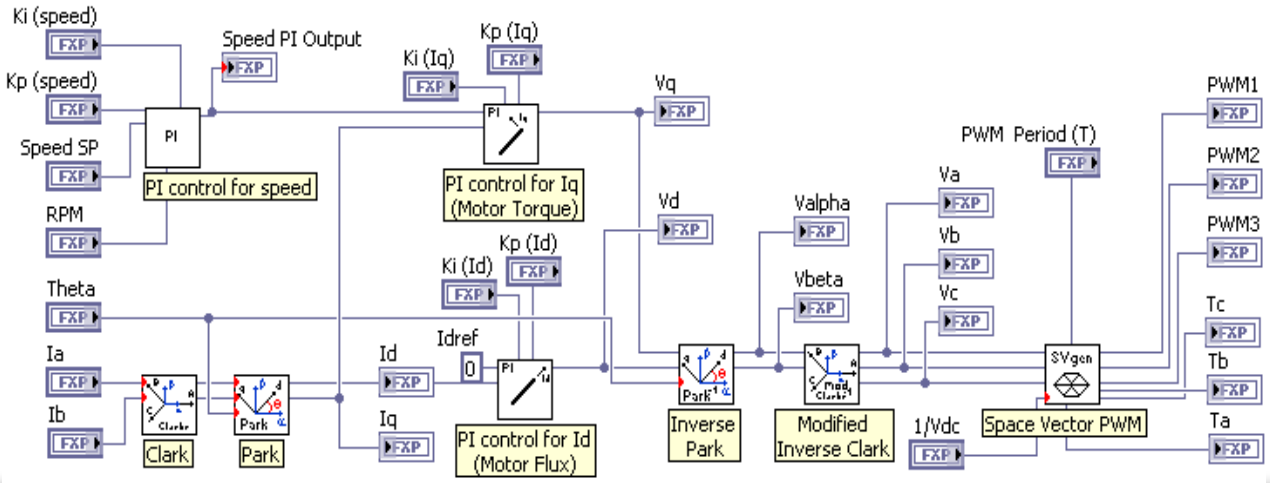
Brushless DC motors have…

- Longer lifetimes
- Higher efficiency
- Less induced electromagnetic interference
- Better heat dissipation
- Larger ranges of speed and torque
- Higher implementation costs

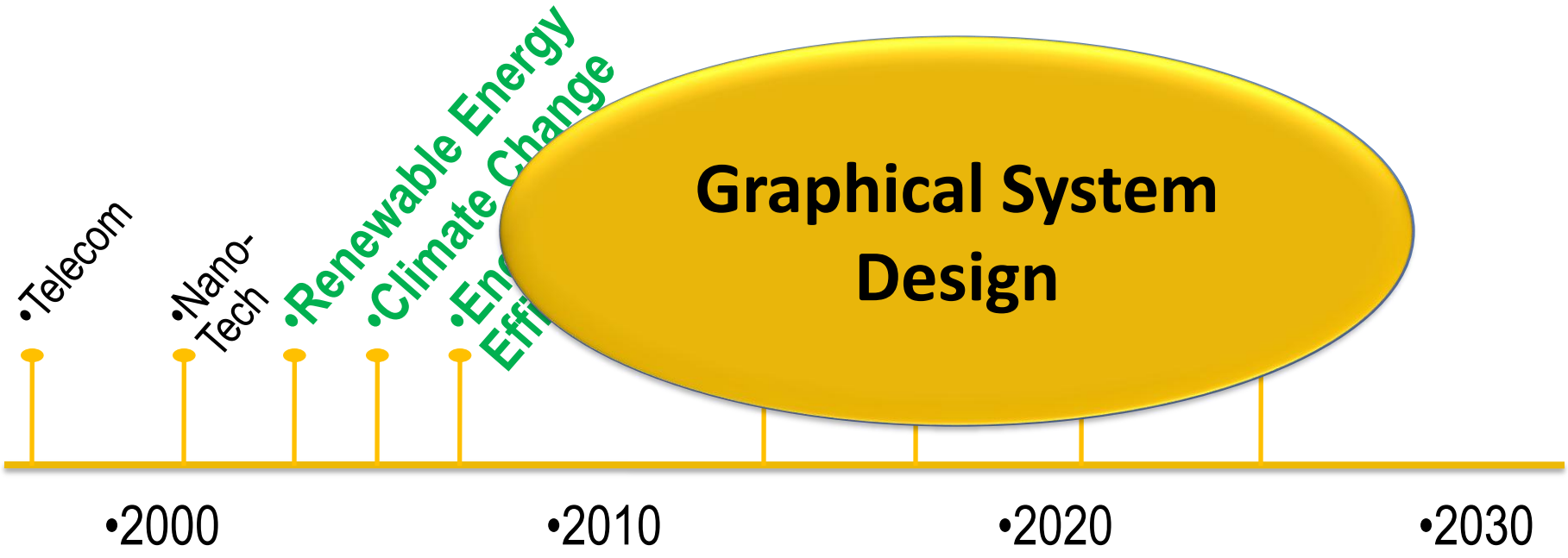
Field Oriented Motor Control (FOC)





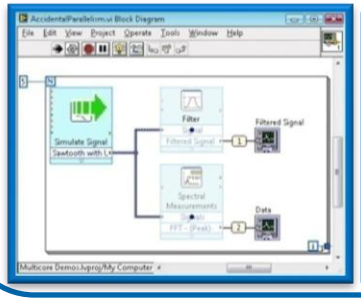


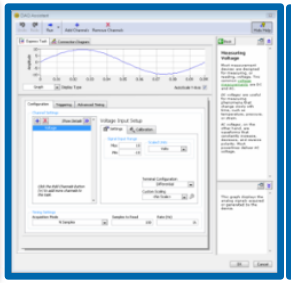
The Next 30 Years of Engineering Trends, Challenges, and Milestones



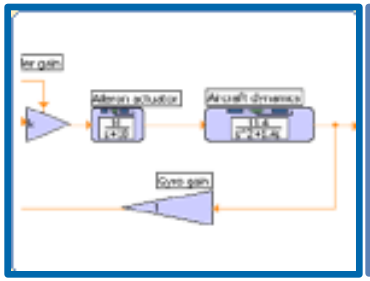
•High-Level Design Models

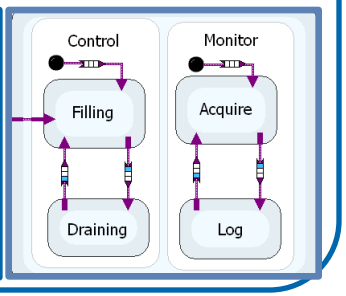
•Dataflow •Configuration •Textual Math •Control/Simulation •Statechart





```
1 c = 0.285 + 0.013i;
2 [X Y] = meshgrid(x, y);
3 z = X + i*Y;
4 for k=1:30
5     z = z.^2 + c;
6 end
```

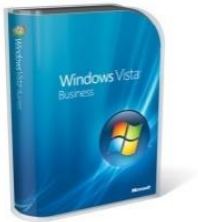




LabVIEW

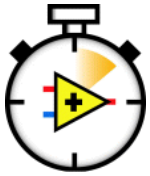
Graphical System Design

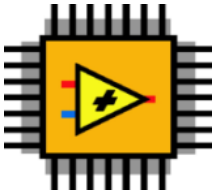
•Linux •Macintosh •Windows

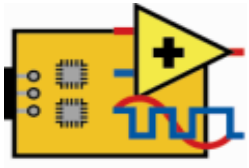


•Desktop Platform

•Real-Time •FPGA •MPU







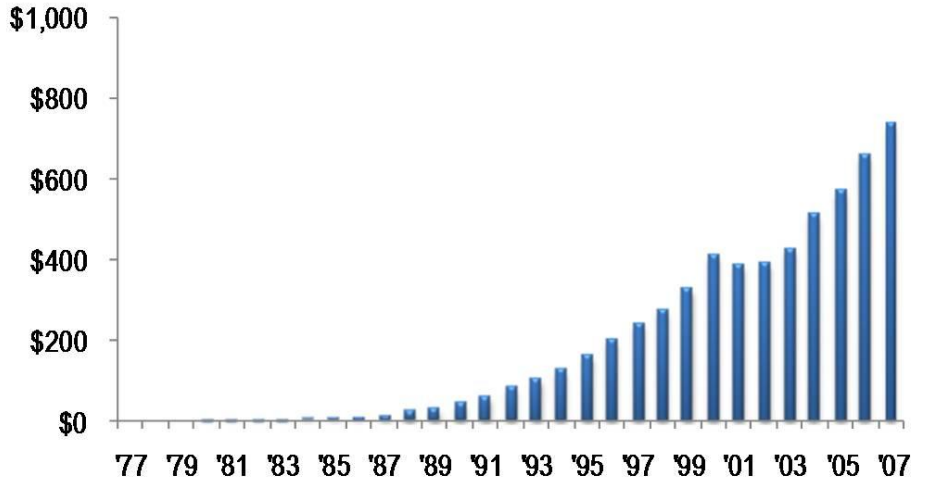
•Embedded Platform

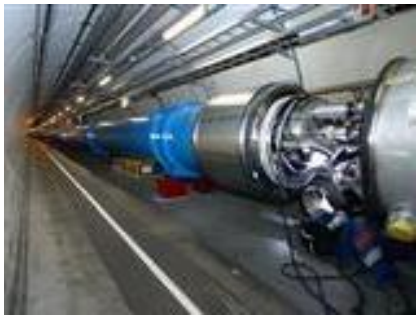
NATIONAL INSTRUMENTS

Profile

- *Leaders in Computer-Based Measurement and Automation*
- Long-term Track Record of Growth and Profitability
- $820M Revenue in 2008
- 16% for R&D
- More than 4,800 employees; operations in 40+ countries
- *Fortune's* 100 Best Companies to Work For Ninth Consecutive Year

•Record Revenue of $740 Million in 2007





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