T105 - Leverage Process & Motor Control Technology to Monitor & Extend Mechanical Equipment Life
What is Being Asked of You?

Manufacturers are being asked to “Do More with Less”

- Reduce Operating Costs
- Improve Productivity
- Reduce Risk

At the same time........

**Assets are Aging & Obsolescence Risk is GROWING**

- Nearly 3/4 of U.S. plants are more than 20 yrs old (source: Industry Week/MPI)
- The installed base of Legacy Automation Systems reaching the end of their useful life is equivalent to over $65 B (source: ARC Advisory Group)
What is Being Asked of You?

Our World Has Changed

- 10 > 5 - only 5 people will replace every 10 that retire
- 10xT - 10 times more technical material to understand
- $20B - cost of unscheduled down time
What is Being Asked of You?  
Our Technologies Have Changed

**Past**
- Basic Communication
- Mobile Phone (bag)
- Permanent install in cars
- Analog
- Expensive
- Clumsy
- Heavy

**Present**
- Improved Communications
- Smaller
- Less Expensive
- Digital
- Multiple Ringtones
- Games

**Performance**
- Various communications capabilities
- Small and Light
- Digital-Global Solution
- **PDA with multiple capabilities** - Camera - Text Messages - Web Enabled - Performance Enhancing!

*Cell phone technology has evolved from a pure focus on communications to an integral tool for improving business and personnel performance.*
Traditional Maintenance-Is Too Costly

In North America:
- 65% of Maintenance Performed is Reactive
- 30% of Maintenance is Preventive
  - Of which 60% is unnecessary
- 5% is Predictive Maintenance

Typical Causes of Motor Failures
Monitoring power, current and, if possible, voltage can detect 81% to 90% of motor failures, plus some pump failures.
Intelligent Pump/Motor Control Solutions For Process Applications

- Industry-wide estimates show that 48 percent of unplanned downtime occurs due to equipment failure.

- With the inclusion of the computing capability in the PAC, you can now manage both process equipment health and energy consumption.

- Cost-effective technologies are available for today’s pump control system that can insure enhanced operational performance and reduced annual operating expenses.

Presentation Goal: Highlight the latest pump/motor control technology that leverages your process automation system investment.
Process Control Technology - then Vs Integrated Pump Control-today

Past

Typical Process Control System
- Multiple control platforms
- Hardwired analog/digital connections
- Individual wire for each point to control/monitor
- Multiple software programs
- O&M’s never readily available

Performance

- Lower Total Installed Cost
- Monitors multiple technologies - Vibration, Temp, Pressure, Power
- Integrated Process and HMI control system
- Full visibility down to instruments
- Full transparent Ovation integration
- Whole process diagnostics
- Scalable capabilities
  - Built-in detailed diagnostics
  - Built-in security and disaster recovery
  - O&M manuals as PDFs on HMI

Process control technology has evolved to an integral tool for monitoring and control of the plant-wide process system
Compromising Pump Performance

**EXCESSIVE VIBRATION**
- Cause: Mechanical or hydraulic issues

**CAVITATION**
- Cause: Fluid/vapor pressure variance

**PRESSURE**
- Cause: Inadequate control & pump starts/stops

**TEMPERATURE FLUCTUATIONS**
- Cause: Changes in ambient temperature

**CURRENT FLUCTUATIONS**
- Cause: Current overload demands or locked rotor conditions

WARNING!
Compromising Pump Performance

Smart Monitoring + Scalable Control = Integrated Pump Control
Integrated Pump Control
- Embedded Diagnostics
- Condition Monitoring
- Energy Monitoring
- Model Predictive Control
- Troubleshooting Wizards
- Automatic Device Configuration
- Remote Monitoring
Typical VFD motor/pump control and protection system connection drawing

PLC Hardwired VFD Connections:
Approx 20 Control wires
Digital inputs:
  • Start/Stop Push Buttons
  • VFD interlock
  • Run/Ready/Fault Lights
Digital Outputs
  • Start
  • Stop
  • Alarm interlock
Analog Input
  • VFD Speed
Analog Output
  • VFD Speed Feedback

Motor Protection
Hardwired Connections:
  • Motor RTDs:
  • Analog Motor/Pump Vibration signal
  • VFD Interlock
  • PLC Alarm Interlock
Typical Motor Protection Control: System with Vibration Switches

- Single Alarm contact
- Analog Vibration sensors
- RTD Sensors
Traditional Critical Asset Motor Protection
Integrated Pump Monitoring
What does that mean?

- Historical Trip Data and Trip Snapshots

**Mechanical Attributes**
- Overall Vibration
- Speed / Cavitation
- Looseness / Vane Pass
- Cracked Rotor
- Turbulent Flow

**Electrical Attributes**
- Voltage / Current
- Ground Faults
- Over/Under/In Range Limits
- Temperature
- Energy Consumption

- Real Alarm Information & Descriptions
- Real time Trending & Documentation
- Historical Trip Data and Trip Snapshots

Providing the Real-time and Historical Detailed Health Data of Critical Equipment

Not LEDs and Cryptic Codes
Not “Where is the Manual?”
Not Clipboard Data
Integrated Pump Monitoring
Power- Energy- Temperature….the E300

Electrical Attributes
E300

- Voltage, Current and Energy
- Trip / Warning Histories
- % Thermal Capacity Utilization
- Time to Trip
- Time to Reset
- Operational Hours
- Number of Starts
- Snapshot Log

Expansion I/O

- Device Level Ring (DLR) or DeviceNet
- Native I/O
- Device Logix enabled
- Integrated into Logix
- Pre-programmed Operating modes and Trip/Warning histories
- Web browser

Digital I/O

- 4 inputs/ 2 outputs
  - 24V DC
  - 120V AC
  - 240V AC

Analog I/O

- 3 universal inputs/1 output
  - 4–20 mA
  - 0 – 10V
  - RTD
  - NTC

Expansion Operator Station

- Diagnostic station
- Control station
Integrated Pump Monitoring

Vibration-cavitation-mechanical: The Dynamix™ 1444

- Forces manifest as vibration at specific frequencies...

Vibrations at these frequencies indicate the presence of a specific condition (or fault) (or one of several that may be indicated by vibration at the same frequency)
The magnitude of the vibration is an indication of the severity of the condition (fault)
Integrated Pump Monitoring…
What Vibration Can Tell Us – Repetitive (Cyclic)

- **Vibration as a core of condition monitoring is based on three principles:**
  - All rotating equipment vibrates
  - Vibration increases/changes as equipment condition deteriorates
  - Vibration can be accurately measured and interpreted

- **Causes of vibration:**
  - Forces that change in direction with time (e.g., Rotating Unbalance)
  - Forces that change in amplitude or intensity with time (e.g., Motor Problems)
  - Frictional Forces (e.g., Rotor Rub)
  - Forces that cause impacts (e.g., bearing anomalies)
  - Randomly generated forces (e.g., Turbulence)
The pressure output to the volute will vary as the vanes pass depending on how exactly the vanes align with the outlet at any given moment.

So with any centrifugal pump there will be a pulsation (pressure pulse) that occurs at a frequency equal to the number of vanes times the speed of the pump.

**Vane Pass** frequency is equal to the number of vanes times the speed of the pump.

In this case, if 1000 rpm and a 5 ‘Vane” pump:

\[
\frac{1000 \times 5}{60} = 83.33 \text{ hz expected vibration frequency}
\]
Integrated Pump Monitoring…

Capabilities- Gear Mesh Frequency

Drive 54T  Driven 27T

Gear mesh frequency

\[
\frac{54 \text{ t} \times 1000 \text{ rpm}}{60 \text{ s}} \quad \frac{27 \text{ t} \times 2000 \text{ rpm}}{60 \text{ s}} = 900 \text{ hz}
\]

Input =1000 RPM
Output =2000 RPM
Gear mesh=54000 CPM

Also:
Lg Gear bearing elements = 20
\[
(1000 \text{ rpm} \times 20) / 60 = 333 \text{ hz}
\]
Sm Gear bearing elements = 36
\[
(2000 \text{ rpm} \times 36) / 60 = 1.2 \text{ kHz}
\]
Integrated Pump Monitoring…
What Vibration Tells Us – Frequency & Amplitude

A Fast Fourier Transform Algorithm converts the time domain to a frequency domain.
That creates a (FFT) Spectra Plot that depicts all frequencies and amplitudes.
Integrated Pump Monitoring…
What Vibration Tells Us – Frequency & Amplitude

All mechanical or electrical anomalies impart forces on the machine that can be detected by changes in vibration.

The math can tell us what fault is causing what vibration. The magnitude can tell us what the severity is. The trend can tell us how fast the fault is propagating.

‘Earthquake Switch’ = 1 limit

Unbalance
1xRPM
Looseness
2xRPM
Shaft Bearing
Elements x RPM
VanePass / Cavitation

Time
Amplitude
Complex Waveform

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Integrated Pump Monitoring
Vibration Fault Indicators - they tell us “condition”

Fault Indicators
- are the magnitude, (and sometimes phase), values of specific frequencies of vibration that are caused by mechanical or electrical faults, or process conditions.

- Cracked rotor bar, loose laminations, eccentric air gap (1x & 2x Line Frequency)
- Rub (1/2x RPM)
- Unbalance (1x RPM)
- Turbulent Flow or Eccentric Impeller (nb x RPM)

Mechanical & electrical faults and many process conditions force vibrations at specific frequencies.
Integrated Pump Monitoring
Trend and Monitor the Fault Indicators

Mitigate Damage to…
- Protect Investments
- Protect Personnel
- Protect Environment

Assess condition to…
- Plan Maintenance
- Assure Production
- Assure Quality

Fault is present, severity is severe
Fault is present, severity is moderate
Fault is not present

Continued operation above “Alarm” may result in significant damage and possible failure. Generally maintenance performed before this point will be less expensive and require less time to perform.
Integrated Pump Monitoring

Objective: Implement Displays that Prompt Action

Review meaningful information like this Not this
Dynamix™ Condition Monitoring

SENSORS

PORTABLE DATA COLLECTORS

MONITORS 1444 Series
Dynamix 1444 Vibration Monitor Module
Typical Detectable Condition

- Pump Cavitation
- Pum/Blower Turbulence
- Unbalance
- Eccentric Rotor
- Bent or Bowed Shaft
- Coupling Misalignment
- Bearing Cocked on Shaft
- Machine Resonance
- Bent or Off-Plane Mounting

- Rolling Element Bearings
  - Race and Ball Problems
  - Spike Energy – gSE™
- Journal Bearings
  - Wear/Clearance Problems
  - Oil Film Problems
- Mechanical Looseness
  - Structural
  - Bearing Mounts
  - Between Component Parts

- Gearboxes
  - Tooth wear, Excess load, Misalignment, Damaged teeth, Excess backlash
- Motor Electrical Problems
  - Broken, cracked, or loose rotor bars, Loose laminations
- Belt Drive Problems
  - Misaligned or eccentric pulleys, Worn belts, Belt resonance
Dynamix 1444 Series

1 Main Module

Dynamic Measurement Module
(requires the 1444-TB-A terminal base)

- 4 Dynamic Inputs
- 2 Speed Inputs (TTL)
- 4 Buffered Outputs (BNC & Terminal Pins)
- 2 Digital Inputs
  - Function is user programmable
- 2 Digital Outputs
  - Function is user programmable
- 2 Ethernet ports
  - Single or Device Level Ring (DLR)
- 1 SPDT Relay

Overall Vibration

- Overall Vibration +
- 8 FFT Bands X 4 channels

Complex Waveform

- 36 Orders/Frequency Bands
- Plus Order MAG/Phase, Voted Alarming, etc.
Dynamix 1444 Series
1 Main Module, Tach Module, Relay Module, 4-20mA

Tachometer Signal Conditioner Expansion Module
(requires the 1444-TB-B terminal base)
- 2 Speed Inputs
  - any common speed sensors
- 2 Speed Outputs (TTL)
  - to Local Bus & Terminal Pins
- 2 Buffered Outputs (BNC)
- 6 Dynamic Measurement Modules
  - served per Tachometer Expansion Module
- 1 per Dynamic Measurement Module

Removable Plug Connectors
Spring or Screw Style
- Purchased separately for each module and each base

Dynamic Measurement Module
(requires the 1444-TB-A terminal base)
- 4 Dynamic Inputs
- 2 Speed Inputs (TTL)
- 4 Buffered Outputs (BNC & Terminal Pins)
- 2 Digital Inputs
  - Function is user programmable
- 2 Digital Outputs
  - Function is user programmable
- 2 Ethernet ports
  - Single or Device Level Ring (DLR)
- 1 SPDT Relay

4-20mA Output Expansion Module
(requires the 1444-TB-B terminal base)
- 4 Channels
  - Proportional to any measured value
- 1 per Dynamic Measurement Module

Relay Expansion Module
(requires the 1444-TB-B terminal base)
- 4 Single Pole Double Throw (SPDT) Relays
- 5 A, 250VAC/30VDC
- 3 per Dynamic Measurement Module

When (non TTL) speed signals must be monitored, a single Tachometer Signal Conditioner Expansion Module (TSCX) must be added. The TSCX is hosted by one Main Module but can serve its TTL output signals 6 Main Modules.
Dynamix 1444 Series—It is I/O to a PLC

Controller I/O: The Usual three Assemblies

Configuration Assembly

Large Configuration Assembly Requires Logix V20+

Assembly is fully exposed and programmatically accessible.

Controller Output

Control Bits
- Trip Inhibit
- Setpoint Multiply (2)
- Gate Controls (2)
- Alarm Reset
- Alarm Buffer Trigger
- Alarm Buffer Reset
- Transient Buffer Resets (4)

Data
- Speeds (2)
- Alarm Limits (16)

Controller Input

Input Assembly parameters selected in Module Definition.

I/O is provided and managed the same way as for any Integrated Architecture® product.
To keep equipment running…

Information is “power”

Call maintenance
To keep equipment running…

*Information is “power”*

- What’s the motor bearing temp?
- Was the pump cavitating?
- What’s was the description of the last fault?
- What was my motor voltage?
- What time did the pump kick out?
- AND WHERE ARE THE O&Ms?
Integrated Pump/Motor Management

Pump/Motor Diagnostic Information
- Pump/Motor vibration
- Sequence of events data
- Vibration waveform capture

Energy Monitoring/Power Metering
- RMS currents, voltage imbalance, frequency, power
- 3-Phase voltage, eliminate standalone metering

Logix/FactoryTalk® View Tightly Integrated
- EtherNet/IP standard
- No additional programming required
- Factory created AOIs and HMI Faceplates

Comprehensive Motor Protection
- Thermal overload, mechanical jam
- Unbalance
- Ground fault (CBCT)
- Under voltage,
- RTD (Optional)
- Vibration (Optional)

Advanced Automation
- Eliminate standalone dedicated motor protection packages
- Supports PlantPAx® Process Library including starter logic: FVNR, FVR, Two speed, wye-delta, inverter/soft-start?
- Start-up/Shut Down Sequence Control
- Process interlocks for starter supervision
- Multiple I/O options

No additional wiring required | Minimal additional Footprint required | Components available with optional Conformal Coated
Integrated Pump Control Solution - typical Configuration -

Pump Protection - **Current, Voltage, Temperature & Energy**

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**E-300 Provides Proactive Alerts for Motor:**

- Voltage, Current & Energy

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**Provides:**

- Free Preconfigured RSLogix AIO’s and PanelView Faceplates
- Extensive Diagnostics
- On-screen configuration and tuning
- On-Screen O&M’s and wiring diagrams

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Integrated Pump Control Solution - Typical Configuration - Pump Protection - Vibration

Provides:
- Free Preconfigured RSLogix AIO’s and PanelView Faceplates
- Extensive Diagnostics
- On-screen configuration and tuning
- On-Screen O&M’s and wiring diagrams
Solution Financial Benefits

- **Reduced engineering costs**
  - Offered as a Toolkit - Free Download
  - Zero cost for Processor Logic and PanelView™ HMI Screens
  - Use pre-engineered template with Logic and PanelView™ HMI displays
- **Reduced panel wiring and installation cost**
  - 50% fewer connections to wire
  - Less I/O to purchase
- **Reduced factory acceptance testing time**
  - Using Best in Class Factory created and supported Logic and PanelView HMI faceplates
- **Enhanced system diagnostics**
  - Reduced downtime
Most Robust VFD Visualization
for Enhanced Maintenance Efficiency

Cut downtime Costs with Local and SCADA HMI Information

- VFD Faceplates provide easy-to-understand diagnostic tools:
  1. VFD start up wizards, Simple Diagnostics, Energy Consumption (CIP Energy)
  2. Electronic, in panel As Built pump system control documentation:
     a) Display PDF wiring diagrams
     b) Spare Parts Lists
     c) Troubleshooting Manuals
        i. Bookmarked pages may be tied to specific alarms
        ii. Email alarms to remote maintenance locations
        iii. Manage high priority situations from a central location
Scalable Solution - IPM Bundled with Low Voltage & Medium Voltage Solutions

Can be supplied as turnkey system in:

- Medium Voltage PowerFlex® Drive
- Low Voltage MCC
- Low Voltage VFD or standalone Panel
Thank You!