Energy Savings with Plant Air Compressor Control Systems

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Energy Control Technologies,
West Des Moines, IA
Agenda

• Energy Control Technologies (ECT) overview
• Compressed air system - problems and opportunities
• Solution
• Advanced supervisory Plant Air control system using the Rockwell Automation PlantPAx™ Process Automation System
• Energy savings and economic benefits
• Case study review
• Conclusions
Energy Control Technologies Overview

• We specialize in the design and manufacture of advanced control systems for rotating machinery and energy system assets
  – Compressors
    • Screw compressors
    • Reciprocating compressors
    • Centrifugal compressors
    • Axial compressors
  – Turbines
    • Steam turbines
    • Gas turbines
  – Chillers
• Standardized on the Rockwell Automation ControlLogix™ platform
• Rockwell Automation partner
Our Markets

Oil & Gas

Biofuels

Industrial/Manufacturing
Our Mission

Delivering value through customer driven control solutions for processes and machinery to maximize:

- Production
- Energy efficiency

West Des Moines, Iowa
ECT Product Family

- TurboPAC™
  - SurgePAC™
  - PerformancePAC™
  - SpeedPAC™
  - FuelPAC™
- CentrifugePAC™
- AirPAC™
- PACView™
- ChillerPAC™
- SimPAC™
- VibrationPAC™
Studies show 79% of compressed air system costs are for energy. Therefore, it makes sense to pay special attention to the proper use of compressed air.

Machine Design April 2007
Air Compressor Control Technology Gaps

Deficiencies with many control systems:

• Cannot handle mix of positive displacement and dynamic (centrifugal) air compressors for efficient control

• Challenged with integration of different brands of compressors
  – Do not have the technology to directly control the capacity valves
  – Different types of capacity controls
  – Old and new units

• Provide basic sequencer function without
  – Advanced algorithms: feed forward or model predictive control algorithms
  – No matching of optimum mix of compressors to plant demand

• Remote monitoring and energy reporting capabilities

• Compressor performance monitoring
Challenges with Centrifugal Compressor Control

• Surge protection of compressor
• Efficient distribution of flow among parallel operating compressors
  – Especially for mix of screw and centrifugal compressor combination
• Unnecessary blow-off of compressed air to atmosphere at lower plant demands
Consequences and Problems

• Multiple partially loaded compressors controlled independently
  – Efficiency drops off significantly for Screw compressors at part load operation

• Multiple idling compressors on standby wasting energy
  – Regular operator intervention to line up compressors

• Compressor loading is staggered using cascaded set points
  – Control action is not coordinated among the compressors

• Large pressure swings when demand changes
  – Short cycling issues
  – Shift changes
  – Large machinery unit comes on line

• Stuck inlet valve, blow down valve actuation problems
Poor Header Pressure Control

- Pressure Set Point with Poor Control
- Pressure Set Point with Improved Control
Opportunities

• Manufacturing plants invariably run their plant air systems at a higher pressure than necessary
  – Running more number of compressors
  – Higher motor power
  – Higher air leaks
  – Oil leaks
  – Oil consumption for lubrication
  – Increase in run time for compressor – maintenance costs
  – Increase in wear and tear of valves
Find out the pressure they are currently operating at and what the lowest critical pressure is

- For every 2 psi decrease in discharge pressure, 1.6% in energy can be saved
- One year paybacks can be expected on systems with 800 hp running (@ $0.05 / KWhr)
- Contact ECT (@ www.energycontroltechnologies.com) for an audit of your air compressor system and calculating energy savings using our Plant Air Energy calculator spreadsheet
Tools - Energy Savings Calculator

• Annual Electricity Costs = (motor full-load horsepower) x (no of machines) x (0.746kW/hp) x (1/0.9) x (annual hours of operation) x (electricity cost in $/kwh)

Example

• Annual Electricity Costs = (5 machines) x (200 horsepower/ machine) x (0.746kW/hp) x (1/0.9) x (8760 hours/year) x ($0.05/kWh) = $363,053.33/year

• Energy Savings = Annual Electricity Costs x (Reduction in Set Point in psi) x (1.6%/2 psi reduction)
  Energy Savings = $363,053.33 x (15 psi) x (1.6%/2psi) = $43,466.

• Additional 25-50% savings due to eliminating unnecessary idling machines
### Input Data

<table>
<thead>
<tr>
<th>Compressor</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated power (hp)</td>
<td>300</td>
</tr>
<tr>
<td>Nominal motor efficiency</td>
<td>0.9</td>
</tr>
<tr>
<td>Voltage (V)</td>
<td>480</td>
</tr>
</tbody>
</table>

| Max output (scfm/hp) | 4.2 |
| Nominal power factor | 0.85 |
| Volume storage (gal) | 2600 |

<table>
<thead>
<tr>
<th>Controls</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Type</td>
<td>Load/Unload</td>
</tr>
<tr>
<td>Automatic shutoff</td>
<td>Enabled</td>
</tr>
<tr>
<td>Minimum pressure (psig)</td>
<td>100</td>
</tr>
<tr>
<td>Maximum pressure (psig)</td>
<td>110</td>
</tr>
<tr>
<td>Fraction broke power at no output</td>
<td>0.70</td>
</tr>
<tr>
<td>Fraction rated power at max output</td>
<td>1.95</td>
</tr>
</tbody>
</table>

### Plant Air Demand

| Constant plant air demand (scfm) | 600 |

| Simulation interval (minutes) | 3 |

<table>
<thead>
<tr>
<th>Percent Simulation Interval</th>
<th>Plant air demand (scfm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>From 0% to 25%</td>
<td>100</td>
</tr>
<tr>
<td>From 25% to 50%</td>
<td>50</td>
</tr>
<tr>
<td>From 50% to 75%</td>
<td>100</td>
</tr>
<tr>
<td>From 75% to 100%</td>
<td>50</td>
</tr>
</tbody>
</table>

| Average air demand (scfm) | 600 |
| Total storage (gal) | 287 (193) |
| Average current (A) | 36.67 |
| Average power (kW) | 211.2 |

### Graph

- **Pressure (psig)**
- **Power (kW)**

- **Time (minutes)**

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ECT Air Compressor Supervisory Control System - AirPAC™ *

- ECT Control system developed using Rockwell Automation PlantPAx process control system has proven to:
  - Lower the operating pressure
  - Eliminate unnecessary idling machines
  - Eliminate unnecessary blow-off to atmosphere
  - Match horsepower to the load
    - Parallel load-distribution
    - Control supply air flow to meet user flow demand
    - Constantly evaluate and select the best combination of compressors to meet the demand
  - Eliminate multiple throttled compressors
  - Eliminate pressure dips below critical level
    - Model predictive and feed forward control algorithms

* Control algorithms of ECT AirPAC control system are patent pending
### ECT AirPAC control system vs. Competitor Air Compressor control system

<table>
<thead>
<tr>
<th>ECT AirPAC control system</th>
<th>Competitor Air Compressor control system</th>
</tr>
</thead>
<tbody>
<tr>
<td>Direct valve modulation control strategy to regulate the supply air flow to meet demand</td>
<td>Employ flow-pressure regulators downstream of compressors to maintain the system pressure</td>
</tr>
<tr>
<td>PLC based hardware-software control system with basic mechanical elements</td>
<td>Mechanical centric strategy with minimum electronic control elements</td>
</tr>
<tr>
<td>Adopt static and dynamic simulation techniques to determine optimum storage volume</td>
<td>Control strategy depends on excessive storage receivers to over pressurize the tanks and buffer the demand fluctuations</td>
</tr>
<tr>
<td>Model based algorithms minimizes short cycling issues</td>
<td>Prone to short cycling issues and hence need more storage volume</td>
</tr>
<tr>
<td>Selects the best combination of compressors to meet fluctuating demands</td>
<td>Operators manually match the compressors to meet fluctuating demands</td>
</tr>
<tr>
<td>Advanced control system with supervisory controls and feed forward algorithms</td>
<td>Basic sequencer logic function is provided to start/stop the compressors</td>
</tr>
<tr>
<td>Minimizes pressure drops as the compressors are directly controlled to meet the demand</td>
<td>Supply and demand are isolated using receivers. More pressure losses due to pressure regulators</td>
</tr>
<tr>
<td>Best ROI to end user</td>
<td>Lower ROI to end user</td>
</tr>
</tbody>
</table>
Competitor Solution = Storage Tanks + Pressure/Flow Regulators + Sequencer
Why Rockwell Automation?

• More customers are wanting open control system as opposed to a black box hardware provided by the OEMS
  – Expandability
  – Support issues
  – Obsolescence

• Standardized our products on Rockwell Automation ControlLogix platform
  – Meets or exceeds technical requirements
  – Technology bandwidth provides great flexibility
  – Time to market
    • AOI blocks for application software
    • Templates for HMI development, Logix ACD Projects
  – Excellent support
  – Documentation
  – Integration

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Case Study: Automotive Plant

- Energy audit of Centrifugal Air Compressor Control System
- An automotive plant was reviewing the performance of installed centrifugal air compressors at their facility
- RA Sales and SI team approached ECT to audit the compressed air system and provide recommendations
- ECT reviewed 1 week of data and conducted a site survey to calculate energy savings and efficiency improvements
- A proposal was submitted to replace the OEM control system with ECT AirPAC system based on PlantPAx
- Using ECT proposal, customer is in the final stages of getting the budget approved for the project
Air Compressor Configuration and Operation

- There are 4 plant air centrifugal compressors
- Compressor model: Atlas Copco ZH6000-6-115
- Operate 2 concurrently. One is lead, one is lag. Lead is always 3-4 psi higher than lag. Lead is usually 108 psig
- Can run header pressure down to 90 psig before problems are reported by production
- Compressors are manually started/stopped and rotated
- Energy cost assumption: $0.05/kWh
- No of days production/year : 250
- 1 Compressor is used for weekend operation
Problems and Opportunities

- Pressure band ~ 97 to 109 PSIG (12 psig)
  - Average 103.91; Max 108.89; Min 97.24 Psig
- Higher system pressure than necessary
  - Higher motor power requirement
  - Higher air flow leakage
- Multiple partially loaded compressors controlled independently (cascaded set point)
- Cannot go below pressure of ~ 90 psig
- ECT recommends to run @ 93 psig header pressure
Calculated Energy Savings

- Current pressure band ranges from 97 to 109 psig.
- Proposed Supervisory Network Control from ECT will reduce energy costs by 8.7%
  - Controlling the header pressure around 93 Psig set point within +/- 1 Psig
- Translates to annual savings of ~ $42,000 (@ 250 days of operation) from reduction in header pressure
- Elimination of Blow off using ECT system results in estimated savings of ~$30,500 (@250 days of operation)
- Total estimated savings from ECT Control System ~ $72,500
- Estimated payback < 2 years
Simulation Results - Current OEM system operation
Blow-off Elimination Using ECT AirPAC Control System

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Case Study: Allsteel Inc. (HNI Corporation)

- Manufacturer of office furniture
- Located in Muscatine, IA
- Actual savings from Compressed Air Control System
- Allsteel maintenance engineering team was tasked with reviewing the performance of installed air compressors at their facility
- Rockwell Automation Iowa distributor, Van Meter Industrial (VMI) approached ECT to audit the compressed air system
- ECT conducted a detailed site survey to calculate energy savings
- A proposal was submitted for installation of Compressed Air Management - ECT AirPAC system based on PlantPAx
- After a competitive bidding process, ECT was awarded the project to retrofit the 7 screw compressor control system
## Compressor details

<table>
<thead>
<tr>
<th>Unit #</th>
<th>Model</th>
<th>HP</th>
<th>Capacity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compressor #1</td>
<td>Gardner Denver SAV</td>
<td>200 HP</td>
<td>835 CFM</td>
</tr>
<tr>
<td>Compressor #2</td>
<td>Gardner Denver SAV</td>
<td>200 HP</td>
<td>835 CFM</td>
</tr>
<tr>
<td>Compressor #3</td>
<td>Gardner Denver SAV</td>
<td>200 HP</td>
<td>835 CFM</td>
</tr>
<tr>
<td>Compressor #4</td>
<td>Ingersoll Rand SSR</td>
<td>125 HP</td>
<td>520 CFM</td>
</tr>
<tr>
<td>Compressor #5</td>
<td>Ingersoll Rand SSR</td>
<td>125 HP</td>
<td>520 CFM</td>
</tr>
<tr>
<td>Compressor #6</td>
<td>Ingersoll Rand SSR</td>
<td>200 HP</td>
<td>835 CFM</td>
</tr>
<tr>
<td>Compressor #7</td>
<td>Quincy QSI</td>
<td>150 HP</td>
<td>600 CFM</td>
</tr>
</tbody>
</table>
Compressed Air System layout

Compressor #7

Compressor #6

Compressor #5

Compressor #4

Compressor #3

Compressor #1

Compressor #2

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Problems and Opportunities

- Seven screw compressors distributed among four different areas
- Three OEM compressor brands with five types of unique compressor
- Compressors were operated to achieve header pressure of 115 ~ 120 psig to meet variable demand
- Each compressor was operated within its own control pressure band in an independent mode
- Large pressure swings: 100 to 120 psig
- Especially between 5-7 AM, pressure drops below 95 psig when a large machinery unit comes on line
- Compressors were idling for extended period of time in standby
- Operator’s manually start/stop and rotate compressors regularly
- Stuck inlet valve, blow down valve actuation problems
Large Pressure Swings
Energy Savings Estimated by ECT

- ECT conducted a detailed plant survey to understand the issues
- Plant header pressure averaged around ~ 120 psig
- The critical pressure in the plant was ~ 100 psig
- ECT proposed to lower the header pressure from 120 to 105 psig
- The Plant Air Compressor Supervisory Control system from ECT will maintain header pressure @105 psig within a +/- 2 psig band
- Reduces energy costs by 12%
- This translates to an annual savings of $25K
- Shutting down of excess idle compressors results in estimated savings of $40K
- Total estimated savings from ECT Control System ~ $65K per year
- Project payback estimated < 2 years

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• Provide a common adjustable system pressure set-point to control all the running compressors in a coordinated fashion
• Achieve tight header pressure control using:
  – Direct valve modulation control for 6 compressors
  – PowerFlex™ 700 VFD control for one IR compressor
• Feed forward control actions based on model based response
• Select the best mix of compressors to meet a given demand and optimize efficiency
  – Map out efficient distribution of flow among the running compressors
• Remote Start/Stop of available compressors
• Display of variables via PanelView Plus 1000 operator panel
• System parameters can be easily configured (timers, set points, sequence table) using the operator panel
• System redundancy
Energy Savings Estimated by OEM

• Proposed OEM solution
  – Add additional storage tanks
  – Install flow-pressure regulator
  – Install automatic sequencer

• Energy savings estimated by OEM ~ $32,000
• Estimated payback ~ 3 years
Summary of Results

• Header pressure was lowered from 120 psig to 105 psig without any issues
• Pressure was maintained within a +/- 1 psig band around the set point
• System was able to ride through shift changes and rapid load increase from large consumers coming on line
• Compressor performance monitoring
  – Efficiency of operation
  – Valve issues were flagged
• Fewer number of compressor on line
• Less oil consumption and leaks
• Easy to operate and maintain
Header Pressure Response - Before vs After
Customer Calculated Energy Savings

- Rockwell Automation Powermonitor 1000 was installed on all the compressors to record energy consumption
- Customer ran tests to capture energy consumption using ECT and OEM system over few months
- Customer calculated energy savings of ~ $260/day
- Translates to annual savings of $94,000 (@ 365 days operation)
- Calculated payback ~ 14 months
Benefits from ECT AirPAC and PlantPAx

- Operate at the lowest possible pressure
- Fewer number of compressors on line
- System redundancy
- Open system using Rockwell Automation Logix platform
  - AOI software blocks, templates for HMI and ACD Logix project
- Compressed Air Energy Management system
  - Power Flex 700 VFD
  - Power Monitor 1000
  - Endress and Hauser transmitters
  - Integration of dryers, coolers
  - FactoryTalk ViewPoint data monitoring
- Reduced operation costs
- Provides the highest ROI to customers
Thank you!

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