Making Effective Decisions about Energy Efficiency Improvements

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ISC Background

Industrial Systems and Control Ltd.
- Founded 1987, University spin out
- Control Engineering Consultancy and Training
- Initially marine & metals Industries
- Now process, power, utilities and automotive

Applied Control Technology Consortium
- Started in 1990 with (3 yrs.) DTI funding
- Large end-users of control – BP, Shell, RWE, British Energy, Scottish Power, BAE Systems
Overview

- Consider only energy savings from process / operations
  - From simple operational changes to full optimisation
  - New equipment selection
  - "Moving" energy consumption

- How to decide what to do:
  - Top-level audits / energy mapping
  - Detailed analysis of process energy usage

Energy Audits

- Top-level Surveys
  - Identify energy usage – incl. buildings / people
  - Identify "quick wins"
  - Assessment of process itself maybe too complex
  - Can be free of charge !! e.g. Carbon Trust

- Routine Inspections:
  - Period inspection of air / steam leaks, lagging
  - Fix anything broken
Audit of Energy Users: Example

- Compile list of energy consumers in process - mainly motors driving pumps and blowers
  - fixed or variable speed
  - on-off control or throttled flow
  - Rate by kW, duty, run-time
  - Calcs give crude estimate of energy savings (e.g. fixed speed to VSD)

- Can then prioritise energy users by potential savings

The “Affinity” Law

Savings Example: On-Off to VSD

- VSD runs at same average speed, but much lower average power
  - power \( \propto (\text{speed})^3 \)
  - on-off ave speed = 66%
  - on-off ave power = 0.66 * f.s. power
  - VSD ave power = (0.66)^3 * f.s. power
  = 29% of f.s. power

Energy Saving: 56%
Throttled Flow Energy Losses

Savings Example: Throttled Flow to VSD

- Consider pressure drops
- Estimated from pipe-work dimensions
- VSD can only save ‘Valve Power Loss’

Saving can be calculated as:
\[
\text{valve loss kW} = \text{valve } \Delta \text{press.} \times \text{flow} \times 10^{-3}
\]
\[
= (12.7 \times 10^{-3} \times 9.81) \times 0.31 \times 10^{-3}
\]
\[
= 38.62 \text{ kW}
\]

Energy Saving: 28%

Effect of Operating Point on Energy

Note that as flow decreases, Valve Power Loss typically increases, which means Energy Savings potential increases.
Energy Efficiency Audit Tools

- ISC developed a spreadsheet for audits:

Detailed Analysis of Energy Use

- Often need more detailed analysis:
  - For more accurate estimates of energy savings
  - When process is more complex – as usually is
  - Exploration of alternative scenarios

- Often simpler to use high-fidelity dynamic models
  - Use of static models (as simple audits) becomes cumbersome
  - Can identify new, optimal ways to operate
    - operations, control settings / strategies, new equipment
Simple Dual Pump Example

Elevated Discharge

Manifold

Inflow from Filter beds

Sump

Twin Pumps (Duty + Assist)

Mathematical Model
Model Validation

Model Tank Level Trend

Actual Tank Level Trend

Study and Practical Results

<table>
<thead>
<tr>
<th>Level Control Strategy</th>
<th>Model Prediction</th>
<th>Pumping Station Results</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>kWh</td>
<td>kWh</td>
</tr>
<tr>
<td></td>
<td>(1 hour)</td>
<td>(1 hour)</td>
</tr>
<tr>
<td>Energy Savings</td>
<td>(%)</td>
<td>Energy Savings (%)</td>
</tr>
<tr>
<td>On-Off control</td>
<td>39.39 kWh</td>
<td>70 kWh</td>
</tr>
<tr>
<td>Single pump VSD</td>
<td>29.2 kWh</td>
<td>25.6%</td>
</tr>
<tr>
<td>Dual pump VSD</td>
<td>13.99 kWh</td>
<td>64.5%</td>
</tr>
</tbody>
</table>

- Can explore additional “no cost” options:
  - Tighter level control – can raise average level – and so reduced lift
Detailed Energy Analysis

- Advantages of using high-fidelity dynamic model:
  - Can look at any scenario
    - e.g. varying demands, varying tariffs
  - Look for other energy saving opportunities
    - e.g. effect of raising level SP in previous example
  - Can extend to much more complex processes
  - Can be used for any process, not just pumping

Example: Multiple Pumping
“What if?” Scenario Results

<table>
<thead>
<tr>
<th>Scenario</th>
<th>24 hr period Total Pump Energy (kWh)</th>
<th>Overall Energy Saving %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current validation model</td>
<td>2786</td>
<td>-</td>
</tr>
<tr>
<td>Test #1 (BHP on/off, HLP PID)</td>
<td>2799</td>
<td>0.47% (higher)</td>
</tr>
<tr>
<td>Test #2 (all PID)</td>
<td>1905</td>
<td>32% (lower)</td>
</tr>
<tr>
<td>Test #3 (Asw &amp; HLP PID, Swa off)</td>
<td>1883</td>
<td>32% (lower)</td>
</tr>
<tr>
<td>Test #5 (Swa &amp; HLP PID, Asw off)</td>
<td>2197</td>
<td>21% (lower)</td>
</tr>
<tr>
<td>Test #6 (Swa &amp; HLP PID, Asw on/off)</td>
<td>2551</td>
<td>8.4% (lower)</td>
</tr>
<tr>
<td>Test #7 (Asw &amp; HLP PID, Swa on/off)</td>
<td>2328</td>
<td>16% (lower)</td>
</tr>
<tr>
<td>Test #8 (Asw &amp; HLP on/off, Swa off)</td>
<td>2783</td>
<td>0.11% (lower)</td>
</tr>
<tr>
<td>Test #9 (BHP PID, HLP on/off)</td>
<td>2049</td>
<td>26% (lower)</td>
</tr>
<tr>
<td>Test #4 (bypass GAC plant)</td>
<td>2798</td>
<td>0.97% (lower)</td>
</tr>
</tbody>
</table>

Overall Energy Saving

- 24 hr period
- Total Pump Energy (kWh)
- Scenario

Pumpsim Modelling Toolbox
Other Energy Investigations

- **WWTP**
  - Investigate DO control strategies - 5-7% energy saving predicted (simple control changes), 20-30% if use MPC

- **Steel Reheat Furnace**
  - Trade-off between fuel-gas usage and production rates
  - Formal optimisation (using nonlinear MPC) estimated savings

- **Coal-Fired Power Station**
  - Benefits study of advanced control to give tighter temperature control
  - Allowing increase in superheater temp, increasing overall efficiency

Moving Energy Consumption

- **Energy prices not constant:**
  - If vary wrt time – move peak energy consumption to cheaper periods
  - If vary wrt consumption – use inventory in process to smooth demand

- **Process needs to have predictable energy consumption**
Concluding Message:

- If energy savings are obvious:
  - Implement them!!

- Sometimes ROI / benefits are not clear:
  - Spend a bit of time considering options
  - Simple analysis can be useful

- Occasionally a detailed study needed:
  - e.g. when need more confidence or if complicated by other factors
  - call in outside help
  - factor in study cost into possible ROI

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