Control Loop Performance Assessment for Power Plants

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Abstract

Control loop performance benchmarking is starting to cross over from the process industries into power generation. The talk will review tools and methods for measuring closeness of the control to the control objectives. An example in power generation will be presented showing the improvements achieved after the root causes of control loop problems were identified and rectified.

About the Author

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Control Loop Performance Assessment for Power Plants

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Layout of the presentation

Control loop benchmarking
- Using measurements from routine operation
- Example from the process industries

Plant-wide disturbances
- Detection and characterization
- Isolation and diagnosis of the root cause

Application in a power plant
Control loop benchmarking

Using measurements from routine operation

- Desborough and Harris (1992) approach:
  - Controller should have no $d$-step ahead predictable component ($d$ is a prediction horizon)
  - Choose $d$ to reflect engineering criteria, or use time delay.

\[
\begin{align*}
 y &= \hat{y} + r \\
 \hat{y} &= \text{controller dependent term (predictable component)} \\
 r &= \text{residual (independent of controller)}
\end{align*}
\]
Control loop benchmarking

Examples from the process industries

\[ \eta = \frac{\text{mean of } (r^2)}{\text{mean of } (\text{controller error}^2)} \]

Commercial tools

- **ABB**: Optimize IT Loop Performance Manager and Plant Disturbance Analyser (PDA)
  
  http://www.abb.com/
  
  (search for Loop Performance Manager)

- **Aspentech**: Aspen Watch
  

- **ControlArts**: CAT I, III, and V
  
  http://www.controlartsinc.com/

- **Entech/Emerson Process Management**
  
  http://www.emersonprocess.com/entechcontrol/Services/
  
  http://www.emersonprocess.com/home/services/
Control loop benchmarking

Commercial tools, continued

- **ExperTune**: Plant Triage
  http://www.expertune.com/index.html

- **Honeywell**: Loop Scout

- **Matrikon**: ProcessDoctor
  http://www.matrikon.com/products/

- **PAS**: ControlWizard
  http://www.pas.com/controlwizard.aspx

Plant-wide disturbances
Plant-wide disturbances

Slowly developing
- Heat exchanger fouling,

Abrupt
- Compressor trip,

Persistent
- Valve limit cycle, hydrodynamic instability, tuning problems, controller interaction, recycles
- Signal analysis in time and frequency domain are used

This talk focuses on persistent disturbances

A wish list from:
- Facility-wide approaches, behaviour clustering;
- Detection of one or more oscillations;
- Detection of non-periodic disturbances;
- Determination of the locations and root causes;
- Non-invasive stick-slip detection in control valves;
- Automated model-free causal analysis;
- Incorporation of process knowledge.
Plant-wide disturbances

PLANT-WIDE DISTURBANCE DETECTION & CHARACTERIZATION

- oscillating
  - spectral methods
    - spectral similarity
    - Spectral envelope
  - time-domain methods
    - integrated error deviations
    - dynamics of linear model
- correlation methods
  - zero crossings
- non-oscillating
  - spectral methods
    - spectral similarity
    - Spectral envelope
- non-stationary
  - wavelet

For plant-wide analysis both detection and clustering are needed.
Plant-wide disturbances

Automated analysis

- Visualization of clusters with similar spectra.
- The vertical axis is a measure of how unalike they are;
Plant-wide disturbances

METHODS FOR ROOT CAUSE DIAGNOSIS

non-linear causes

- non-linear time series analysis
- bicoherence testing;
- Lyapunov exponent.

linear causes

- valve diagnosis methods
- intervention
- controller tuning
- SISO methods
- interaction/structural causality methods

Plant-wide diagnosis: (a) Find clusters; (b) Find the likely root cause.

Plant-wide disturbances

Non-linearity testing

- Faulty valves, hydrodynamic instability, slugging flow;
  (power plant examples ...)
- Non-linearity is most strong closest to the root cause;
- Two main branches:
  - bicoherence analysis and surrogates analysis
    (U of Alberta) (UCL)
- There have been several successful studies.
Plant-wide disturbances

Application in a power plant
Application in a power plant

Process schematic

1 week load signal

33 observed loops

Loop performance report

Poor: T-CoalMillAir 4, T-CoalMillAir 3, F-Primary Air M4

- Excellent
- Good
- Fair
- Poor

The IET Seminar on Power Generation and Control

November 28th 2006
**Application in a power plant**

**Loop auditing report of one week (Diagnosis part)**

<table>
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<th>Loop</th>
<th>Loop name</th>
<th>Setpoint</th>
<th>PV</th>
<th>SP</th>
<th>Control error</th>
<th>Action</th>
<th>Variance</th>
<th>Variance</th>
<th>Total variance</th>
<th>Total</th>
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</tbody>
</table>

T-CoalMillAir 1,...,3
T-CoalMillAir 4 permanently in saturation, therefore out of valuation (poor)

**Application in a power plant**

**Loop detail plot for one data set**

- Oscillation detected
- Bad control accuracy
- Set point moving more than controlled var.
Application in a power plant

power plant data

Application in a power plant

oscillating cluster

root cause not strong
3 loops
Next steps
- Investigate these three loops.
- Discuss with personnel if this cluster is explained by the process schematic.
- Automatic tools would be preferable!

Outcomes
- Cluster identified
- Many signals due to dense instrumentation (many sensors measure similar effects)
- Combine PDA with LPM results and investigate most likely causes from both analyses.
Conclusions

- Methods used for control loop diagnosis in the process industries have potential in power generation;

- Plant-wide disturbances affecting numerous measuring points can be identified and their root causes isolated;
END