Industrial View of Process Control

Dave Hokanson

Outline

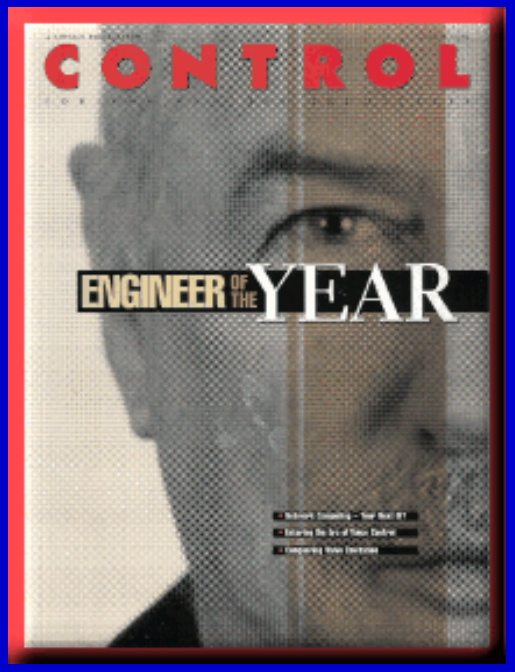
- **Who am I? What Do I Do?**
- **Intro to Industrial Control Engineering**
  - Control centers & personnel
  - Distributed Control Systems
  - What control engineers do
- **Models**
- **An extreme industrial control perspective**
  - Why it is wrong
  - Modern uses of
    - LaPlace Transforms
    - Z-Transforms
    - Frequency Analysis
- **If we have time...**
  - An short 1960s film from IBM film “Computer Control of a Catalytic Cracking Unit”

Who am I? What do I do?

- **"I'm Dave Hokanson, and I'm a process control engineer".**
  - Rice BSChE / MChE
    - Taught sections of the process control course (and before that, the design course) dating back to 1984.
    - I'll be giving a series of 4 lectures on process control design and an intro to industrial multivariable control in November.
  - Joined Exxon Chem / ExxonMobil Chem at graduation (1978), first in process design, then with a "rotational assignment" in process control (1980).
  - Still with process control, but in much different form…
    - Had assignments at the Baytown Chem Plant (control engineer, then lead control engineer),
    - Central Engineering (first DMCs within Exxon)
    - Control supervisor / leader at Rotterdam and Singapore
    - Since 1997 back in Central engineering leading the DMC effort.

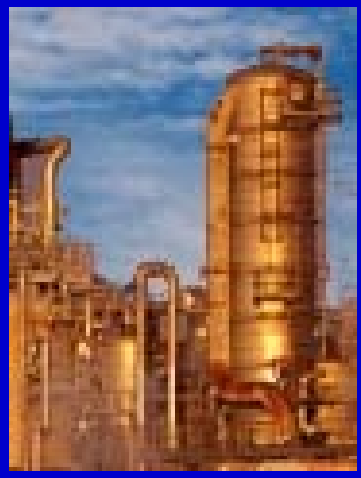
What is DMC?

- **Dynamic Matrix Control (DMC) – an industrial form of model-predictive, multi-variable control.**
- **Originally developed by Charlie Cutler**
  - Originally at Shell, formed DMC Corp in 1984
  - Sold to AspenTech in 1996
  - However, heeeee's back!!



Industrial Control

- **Refineries and most Chem plants are large and complex**
- **High revenue per employee (i.e., few people)**
- **Run 24 hours, sometimes 5-6 years between downtimes (called “Turn-Arounds”)**
- **Control centers are usually centralized and can be far away from the process equipment**
  - Run by “Console operators” – the man / woman who sits behind the computer screens, watching trends and monitoring the unit performance.
  - There are “outside operators” who do “rounds” – checking on the equipment, moving manually operated valves, starting / stopping pumps / fans/etc.



Modern Control Centers

What does a Control Engineer do?

- **Design control strategies at process design phase**
  - We'll be looking at this later
  - Specify measurements and final elements, along with basic regulatory control structure (i.e., control a level in a vessel)
- **Design control strategies after unit is running**
  - Basic regulatory
    - PID
    - Single-Input / Single-Output (SISO)
  - Advanced regulatory
    - Cascade & feed-forward control
    - Multiple Input / Single Output (MISO)
  - Advanced Control / multi-variable, model-based control
    - DMC
    - MIMO
  - Real-Time Optimization
    - First Principal, steady-state models reconciled with the plant
- **What are the tools:**
  - Distributed Control System (DCS) – links measurements with final control elements
  - Advanced computing platforms
  - Software packages

DCS – Engineer's Work Station

Models

- **"All models are wrong; some are useful"**
- **If you can model the process, you can control it!!**
  - The world does not live in steady-state!!
  - Hence, many dynamic models are "useful".
- **Some industrial process control uses of models:**
  - PID tuning & simple model-based control
    - 1st order plus deadtime
  - DMC and similar model-based control
    - Unit step responses (in vector arrays) – derived using various model ID packages (FIR, ARIMA, SubSpace)
  - State-Space Controllers
    - State Space Models (can be derived by "SubSpace" model ID packages)
  - Non-Linear Model-based control
    - Neural Nets or 1st principal dynamic models
  - Dynamic Simulations (for process analysis or operator training)
    - 1st principal dynamic models.
  - Real-Time Optimization
    - 1st principal, steady-state models

An Extreme Control Perspective

- **Robert V. Bartman**
  - ProControl, Inc.
  - Process Control Education and Technology
- **A good friend / former mentor at Exxon**
  - We did a lot of joint development together on Exxon's first multi-variable, model-based control
  - Bob charges a lot of money - $12k for 96 hour course
    - Elapsed-time, not credit hours!
    - Makes Rice look very cheap!
  - "Money-back guarantee if we mention such stalwarts as LaPlace transforms, or z-transforms, or Nyquist diagrams, or Bode plots, or Ziegler-Nichols tuning, in other than critically-humorous terms."
- **While he's an excellent teacher and a very humorous guy, he's wrong if you want to understand the basics process control, particularly as our field continues to develop**

LaPlace Transforms

- **Recently had to look at the tuning on a Foxboro control system.**
  - Their PID algorithm is a bit different, and I went to the book to understand what it was doing:

- Proportional and integral (PI):

$$m_b = \frac{100}{P}\left(\left(\frac{1}{Is} + A\right)r - \left(\frac{1}{Is} + 1\right)c_f\right)f_r + b$$

$$\tau = 0$$

- Proportional, integral and derivative (PID):

$$m_b = \frac{100}{P}\left(\left(\frac{1}{Is} + A\right)r - \left(\frac{1}{Is} + 1\right)(1 + Ds)c_f\right)f_r + b$$

$$\frac{1}{\tau} = \left(\frac{1}{I} + \frac{1}{D}\right)K_D$$

- Non-interacting PID (NIPID):

$$m_b = \frac{100}{P}\left(\left(\frac{1}{Is} + A\right)r - \left(\frac{1}{Is} + 1 + Ds\right)c_f\right)f_r + b$$

$$\tau = \frac{D}{K_D}$$

More on LaPlace Transforms

- **But there's more...**
  - This PID has a built in filter for the Derivative Term
    - Good idea
    - What type??

♦ In the above expressions of measurement filter:

$$c_f = \frac{c}{1 + \tau s + 0.5(\tau s)^2}$$

- **Bottom line: An industrial process control engineer needs to be able to speak this language.**

Z-Transforms

- **Used frequently in "the days of old" for coding control algorithms (filters, PID controls, etc)**
  - Also used to understand "aliasing" – loss of data in a sampled data system – due mostly to slow sampling
- **Now used for mostly in various forms of ARX modeling**
  - Here's a formula directly from a fundamental paper on ARX modeling by Yucai Zhu of Tai Ji Control

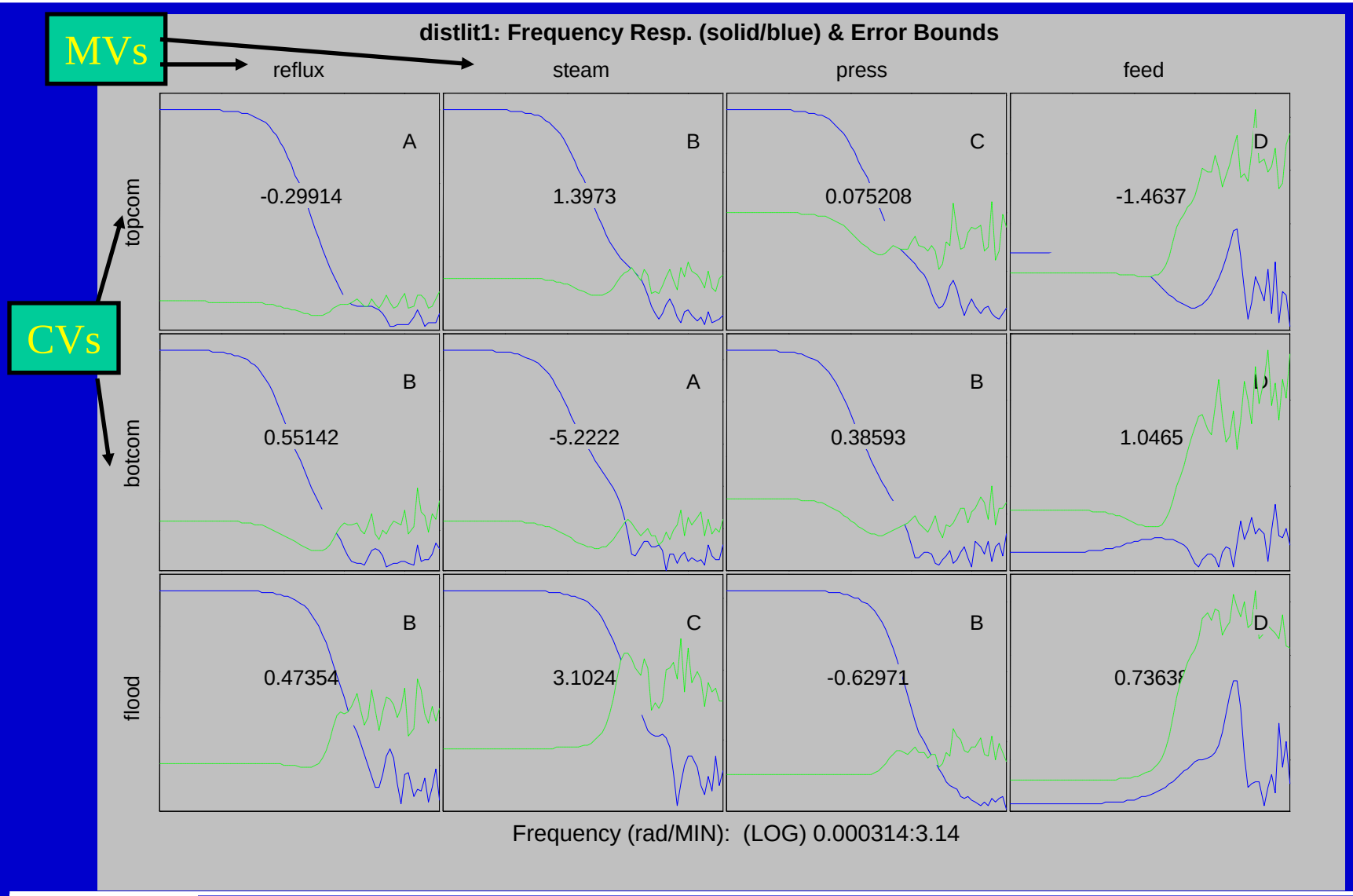
$$y(t) = G(z^{-1})u(t) + H(z^{-1})e(t)$$

- **Another language that needs to be understood.**

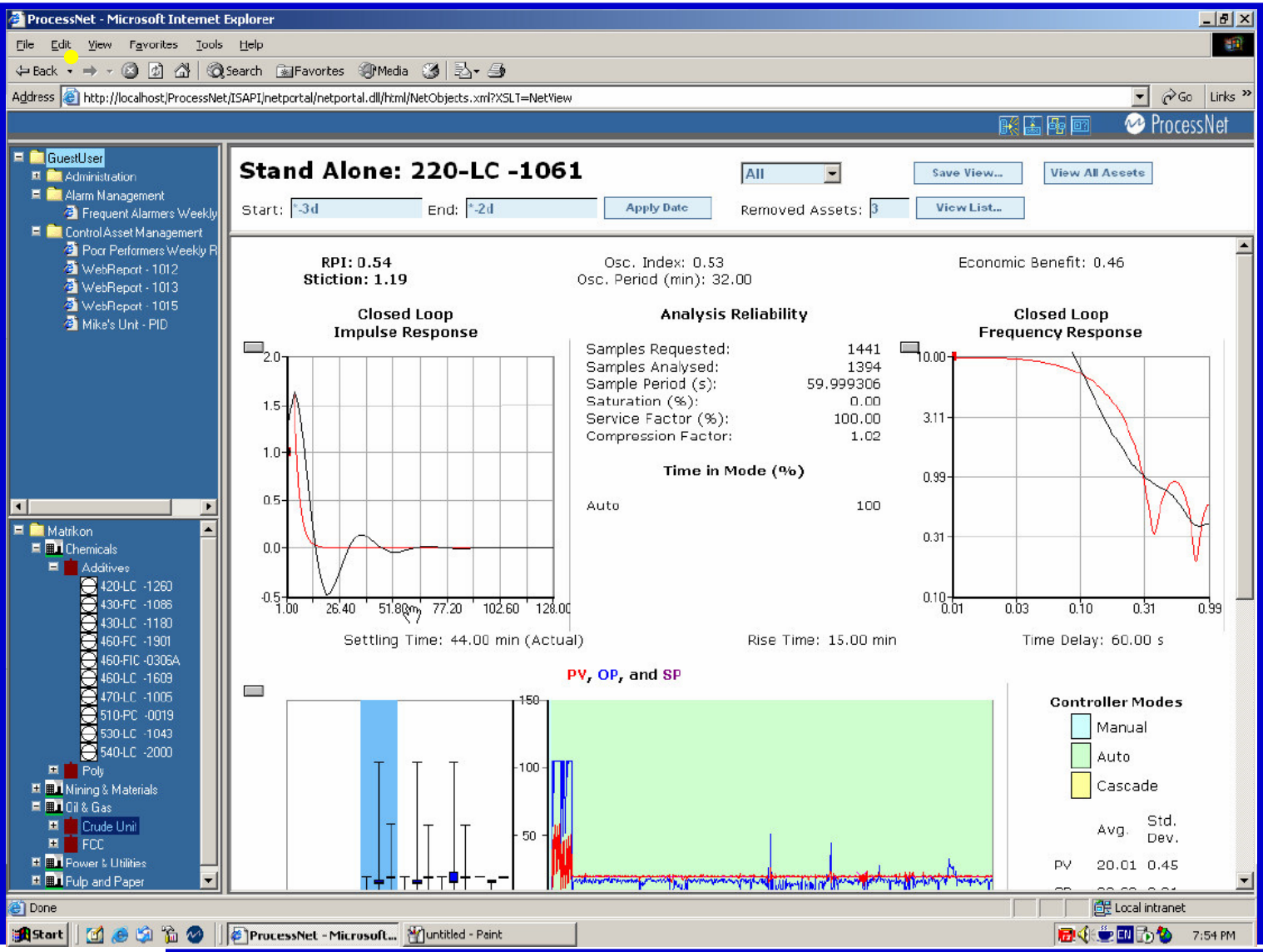
Bode Plots / Frequency Analysis

- **Up until about 6-8 years ago, I agreed with my old mentor Bob Bartman on the usefulness of frequency analysis**
- **Then the usefulness for this technique became once again useful in two areas**
  - Control Performance Monitoring
  - Model quality from a model identification software

Frequency Analysis of a 3x4 Model



Control Monitoring Tools



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To Summarize

- **Control Engineering can be a fun job**
  - It's a chance to make a direct impact on the plant operation
  - In our business "No money is made until a valve is moved"
    - We move valves!
- **Technology continues to evolve**
  - What we thought was useless is now useful!
- **Bottom line:**
  - Keep an open mind as you move from the world of Process Dynamics into the world of Control
  - I'll be back to cover process control design, feed forward, cascade, and an intro to multi-variable, model-based control (e.g., DMC)