MCE441: Intr. Linear Control Systems

Lecture 17: Implementation Issues

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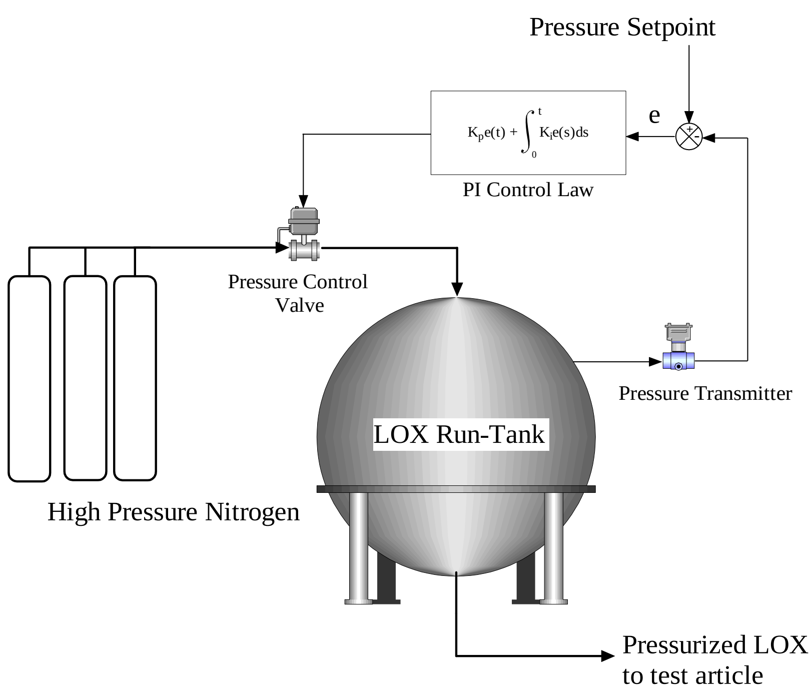
Recognizing a Dynamics/Ctrl Problem



Constructing a Mathematical Model

- Simplifying assumptions (basis of physical modeling)...
- Neglecting nonlinearity...
- Evaluating uncertainty (structural and parametric)...
- Validating the model...

Analyzing Open-Loop Behavior

- Stability/Instability
- Poor Performance
- Controllability (mathematical definition available)
- Availability of real-time measurements
- Influence of noise and disturbances
- Weigh-in the benefits / cost of feedback

Choosing a Control Strategy and Design Approach

- Control Strategy: Architecture of the closed-loop block diagram. We've studied only one.
- Control Strategy: Fixing the structure of the compensator (PID, lead-lag, p-z cancellation...)
- Design Approach: How to choose controller parameters: tuning. (loop-shaping, root locus, optimization...)
- Result of the design process: a compensator TF.
- Simulation is usually required to validate assumptions.

Analog Implementation

- 60 years ago only analog implementation was possible.
- Find a mechanical, electrical, pneumatic contraption that materializes the control TF.
- A PID controller can be built approximately with resistors, capacitors, amplifiers.
- Complicated nonlinear functions are difficult to obtain with physical components.

Digital Implementation

- Present-day controllers are usually implemented in a digital processor.
- DSP (digital signal processors) are typically used for consumer products and pre-packaged industry solutions.
- Examples: cruise control chips, hard-disk controllers, biomedical devices.
- Industrial PCs and PLCs (programmable logic controllers) are used as flexible control hosts for industrial applications.
- Examples: Manufacturing robots, chemical processes.
- Specialized controllers are also built: aerospace, defense.

DSP Chips

Industrial PCs

Industrial PCs

Tuboly AG www.tuboly.ch

Christoph Müller, manager of electrics and software at Tuboly, operates a transformer winding machine. Operation is largely automated.

Key data of winding machines

Wire speed	600 meters/minute
Foil speed	250 meters/minute
Weight of transformer coil	1 kilogram ... 20 tons
Number of controlled axes	2 ... 12
Cycle time	1 ms
Real-time load	approx. 40 %
Industrial PC processor	Pentium III, 850 MHz
Main memory (RAM)	256 MB
Operating system	Windows NT/2000/XP

Issues with Digital Implementation

- Dynamic evolution of control values is discrete in nature.
- Sample-and-hold devices maintain the control input constant during a sampling cycle.
- If the sample rate is too low, performance (even stability) is compromised. Compensator design must be done in discrete domain (a whole course).
- Data converters (Analog-to-Digital and Digital-to-Analog) are required. Significant errors and spurious cycling at low resolutions.
- When the sample rate is high enough, *emulation* design is usually satisfactory.

Other Significant Issues

- Actuator Saturation: Our compensators must either produce control signals within physical limits (voltage, piston travel, pressure, etc.) or be specifically designed to guarantee stability and performance under saturation.
- State Saturation: States may represent physical variables and must therefore remain under allowable limits. Our designs must not reach state saturation limits.
- Finite-Precision Implementation: DSPs and industrial PCs have a finite number of bits. Round-off and truncation processes result in errors and spurious cycling and noise.
- Robustness: Our designs must not break down when assumptions don't hold or when there is uncertainty in the plant model.