Process Control Project Guidelines

The simulation lab is a comprehensive application of the process control principles that are covered in the course. Below are some guidelines for items that should be included in the project.

1. Objective

The project should begin with a project objective. What are the control objectives, the manipulated variables (MVs), the controlled variables (CVs), the disturbances (DVs) and the expected or desired outcome? It is easy to lose focus on the objective when working through the individual parts of the project. It is important to continually visit this objective statement.

2. Prior Work

It is important to understand what work has already been completed. Below are some resources in searching for relevant literature.

- Google or other search engines
- Science Direct: http://www.sciencedirect.com
- Scopus: http://www-scopus-com.erl.lib.byu.edu
- HBLL Databases: http://lib.byu.edu/databases

In doing a literature search, it is important to cover a broad range (10-20 relevant articles) that can be skimmed (read the abstract, look at the figures and captions, and main results). Of those, 1-2 will typically be key articles that should be explored in-depth. What are the gaps in the prior work (what hasn't been done) and how does the project objective help to fill a gap?

3. Dynamic Response (Open-loop)

The following should be included when detailing an application:

- Diagram with key variables
- Assumptions relevant to the process simulation or control system
- Equations that describe the input to output relationship between the MVs and CVs
- Simplifications (linearization, transformations, etc.)
- Model parameter adjustments to fit data or make the model more realistic

Open-loop step tests of the model are often needed to show the dynamic and steady state response of the model to each of the MVs. Is the model response intuitive? For batch or semi-continuous systems, a step test may not be possible. A significant portion of the class is dedicated to understanding the transient behavior of systems that are not under control. This project reinforces simple mathematical models to describe such systems based on fundamental material and energy balances or other dynamic systems. With such a model, the transient relationship between input and output variables is determined. The relationships can be expressed in a variety of forms including:

- Transfer functions (Laplace domain)
- State space form (Time domain)
- Nonlinear differential and algebraic equations (Time domain)

It is important to have a thorough understanding of how to derive a model from either first-principles or from empirical methods. These models may be used to fit a set of transient data. Empirical methods include both graphical methods and numerical fitting techniques. It is important to understand what an open-loop step test is and why it is used and to have a qualitative feel for advantages and disadvantages of step vs. pulse testing. Many systems can be simplified to first (FOPDT) and second order systems.

4. Controller Design and Analysis (Closed-Loop)

Several types of controllers can be developed or compared for the application, depending on the complexity, nonlinearity, or other factors. It is best to use the simplest controller that will meet the project objectives. Several types of controllers include a Proportional Integral Derivative (PID), linear Model Predictive Control (MPC), Nonlinear Model Predictive Control (NMPC), or Dynamic Optimization (http://apmonitor.com/do). There may be cascade controls, feedforward controls, measured disturbances, or unmeasured disturbances.

5. Discussion and Conclusions

This project reinforces the basic concepts behind control systems. It is important to know the difference between feedback and feedforward control and know how each of these might be used. To test the controller, set point or disturbance changes can be simulated to validate the control response. What is a range of controller tuning that keeps the system stable? What is the trade-off between aggressive tuning to quickly reach a set point versus avoiding overshoot? What is the “best” tuning and why?

Conclusions should include the main results of the study, recommendations, and any future work that could be pursued. The conclusion should address the objective.

Sample Schedule

Week 1

- Brainstorm ideas, identifying 2-3 that are relevant to engineering, interesting, and useful
- Literature search – what has been done? Find 10-20 articles.
- What hasn’t been done and what are the gaps in the prior work? Identify 1-2 key articles.
- Draw a diagram with key variables such as MVs, CVs, and DVs. List assumptions.
- Develop a final report outline with objective statement and literature review.

Week 2

- Write governing equations that relate inputs (MVs and DVs) to the outputs (CVs)
- Simulate the equations with step tests. Change each MV and DV with a step or doublet test to verify both dynamic response and steady state behavior in open-loop.
- Refine model to either match data or make the model response more intuitive.
- Write the report section that describes the model, equations, and open-loop response graphs.

Week 3

- Develop a control system that may include feedback or feedforward control.
- Test the stability limits of the controller tuning.
- Refine the controller tuning with several scenarios such as disturbance or set point changes.
- Write the report section that describes the controller, stability, and best tuning.

Week 4

- It is a good idea to write the report during the project instead of at the end. Write the conclusion.
- Refine the report and revisit sections. For example, is there additional literature discussion or has the model been changed or expanded.
- Prepare slides or video for the final presentation (5 min max).
- Condense the report to 2 pages, for the executive summary overview.