Exercise 10 Tuning The Reactor Cooling Water Temperature Loop

I. OBJECTIVE

The objective of exercises 10 to 14 is to demonstrate how one can tune loops once a plantwide control architecture has been selected. The Tennessee Eastman simulation [1] is used and in exercise 14 several candidate architectures are evaluated. A challenging aspect of the loop tuning process for the Tennessee Eastman plant centers around the fact that the process is open loop unstable. As a result a traditional reaction curve approach does not work for most loops since the process does not come to steady state after a bump test. The cause of the instability is the reactor, and if the reactor coolant loop is closed then the instability is eliminated. This exercise deals with tuning the reactor coolant loop.

II. CONTROL TECHNOLOGY

a) OVERVIEW: The following nonlinear dynamic model is used to simulate the Tennessee Eastman process [1]:

$$\dot{x} = f(x,u) \tag{1}$$

$$y = g(x,u) \tag{2}$$

where x is the state vector, u is the vector of manipulated variables, and y is the vector of process measurements. The vector, y, contains all the available process measurements, including those for the 10 inner cascade loops. Several MATLAB m-files have been written to interface with the FORTRAN simulation of eqns. 1 and 2. These m-files allow one to carry out reaction curve tests on the process, and to simulate it with various loops closed. Once a plantwide control architecture is decided upon, its loops can be tuned by starting with the fastest loops and proceeding to the slowest loops. For the Tennessee Eastman process the fastest loops involve the inner cascade loops. Next the level loops should be closed, since the levels are integrating in nature and these variables increase without bound if they are not controlled. The next fastest loops involve the control of non-composition variables, such as reactor pressure, stripper temperature, etc. The slowest loops involve control of product and purge composition. All the controllers used in exercises 10 to 14 are PI controllers. They are implemented in velocity form as:

$$\Delta mv(t) = K_C(\varepsilon(t) - \varepsilon(t-1) + \varepsilon(t)\Delta t / T_R) \tag{3}$$

where Δmv is the change in manipulated variable, e(t) is the error at time t, K_C is the controller gain, and T_R is the reset time. The integration time step used in the simulation is 1 sec. Note that some of the routines ask for simulation times in seconds, and others in minutes. The first loop to be tuned is the reactor cooling water temperature loop. Since the reactor is open loop unstable, this loop in tuned in a closed loop manner. The m-file *reactorcw* is used for this purpose. This m-file asks for K_C and T_R for the reactor cooling water loop as well as the simulation time. If the simulation time is kept short, a few minutes or less, then one can observe the performance of the reactor cooling water loop essentially by itself. For longer simulation times the response of other variables, e.g. the integrating levels, becomes a factor. A 1 ^{O}C step change in the reactor cooling water temperature set point is introduced and plots of the cooling water temperature, and reactor temperature, pressure, and feed flow are displayed. The last three variables are plotted to illustrate that the process itself does not come to steady state after the bump test.

III. COMPUTER EXERCISE

Vary K_C and T_R by trial and error until a good transient response is obtained for the reactor cooling water temperature. Report the values of the tuning parameters found.

IV. RESULTS ANALYSIS

How fast can the reactor cooling water temperature be changed under feedback control? Why is a negative gain required for K_C?

V. REFERENCE

[1] Downs, J. and Vogel, E.,"A Plant-Wide Industrial Process Control Problem", Computers and Chemical Engineering, **17**, 245-255 (1993).