CL 686 : Advanced Process Control
Nonlinear System 1 (Group A): Computing Assignment 2

- **Measuremed Outputs:** X_2 (reactor fluid temperature) and X_3 (reactor cooling jacket fluid temperature), i.e.

$$\mathbf{C} = \begin{bmatrix} 0 & 1 & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

In pactice, measurements obtained from any device are corrupted with random errors generated as a part of signal conversion and transimssion process. Thus, to simulate realistic measurement scenario, simulate the measured outputs as follows

$$\mathbf{Y}(k) = \mathbf{C}\mathbf{X}(k) + \mathbf{v}(k) \tag{1}$$

$$\mathbf{v}(k) = \begin{bmatrix} v_1(k) \\ v_2(k) \end{bmatrix} \tag{2}$$

where $v_1(k)$ is a zero mean nomally distributed random number with $\sigma_{v_1} = 0.2$ and $v_2(k)$ is a zero mean nomally distributed random number with $\sigma_{v_1} = 0.25$.

- **Random noise in disturbance input D:** In practice, the unmeasured disturbance inputs are often corruped with ransome fluctuations. Thus, to simulate realistic unmeasured disturbance inputs, simulate disturbance by including random noise $w(k)$, where $w(k)$ is a zero mean nomally distributed random number with $\sigma_d = 0.015$.

- Simulate closed loop servo and regulatory control behavior for two multi-loop PI controllers.

Controller Pairing: $y_1 - u_1$ and $y_2 - u_2$

$$\text{PID 1 } (y_1 - u_1)\text{: } G_c(s) = 8.5396\left(1 + \frac{1}{0.7278\ s}\right)$$

$$\text{PID 2 } (y_2 - u_2)\text{: } G_c(s) = -1.5703\left(1 + \frac{1}{0.5286\ s}\right)$$

Simulation Time: $t_f = 10$, $T = 0.1$ and $N_s = 100$

Servo Control Problem:

$$\begin{aligned} \mathbf{r}(k) &= \begin{bmatrix} 0 & 0 \end{bmatrix}^T \text{ for } t < 0.5 \\ \mathbf{r}(k) &= \begin{bmatrix} -5 & 0 \end{bmatrix}^T \text{ for } t \geq 0.5 \\ d(k) &= dstep + w(k) \\ dstep &= 0 \quad \text{for all } t \end{aligned}$$

Regulatory Control Problem:

$$\begin{aligned} d(k) &= dstep + w(k) \\ dstep &= 0 \text{ for } t < 0.5 \\ dsetp &= 0.1 \text{ for } t \geq 0.5 \\ \mathbf{r}(k) &= \begin{bmatrix} 0 & 0 \end{bmatrix}^T \text{ for all } t \end{aligned}$$

Input Constraints

$$\mathbf{U}_L = \begin{bmatrix} 0 & 0 \end{bmatrix}^T \quad \text{and} \quad \mathbf{U}_H = \begin{bmatrix} 250 & 60 \end{bmatrix}^T$$

- Start the system at the equilibrium point as the initial condition in each case. Provide facility in your program to switch ON or OFF random disturbance input $w(k)$ and measurement noise $\mathbf{v}(k)$ as explained in the algorithm below.

Closed Loop Plant Dynamic Simulation Algorithm

- **Initialization**

  Load system parameters and $(\mathbf{X}s, \mathbf{U}_s, D_s)$ from data file

  Set $\mathbf{X}(0) = \mathbf{X}s, \quad \mathbf{U}(0) = \mathbf{U}_s, \quad D(0) = D_s; \quad \mathbf{Y}(0) = \mathbf{Y}s$

  Initialize PI controller related parameters and arrays for storing input, output and state variables

  Set $Noise\_ON = 1$ or 0 to switch ON or switch OFF noise

- **Dynamic Simulation**

  FOR k = 1 to Ns

  - Specify setpoint $\mathbf{r}(k)$ and $d(k)$
    Generate random input $w(k)$ and stecify $dstep$
    $D(k) = D_s + dstep + Noise\_ON * w(k)$
    Generate $\mathbf{U}(k)$ as using Discrete PI Controller
    $\mathbf{y}(k) = \mathbf{Y}(k) - Y_s$
    $\mathbf{e}(k) = \mathbf{r}(k) - \mathbf{y}(k)$
    $\boldsymbol{\eta}(k+1) = \boldsymbol{\eta}(k) + \mathbf{e}(k)$
    $\mathbf{u}(k) = C_{PI}\boldsymbol{\eta}(k) + D_{PI}\mathbf{e}(k)$
    $\mathbf{U}(k) = \mathbf{u}(k) + \mathbf{U}_s$
    $\mathbf{U}_L \leq \mathbf{U}(k) \leq \mathbf{U}_H$
    Solve for $\mathbf{X}(k+1) = F\left[\mathbf{X}(k), \mathbf{U}(k), D(k)\right]$
    Generate random noise $\mathbf{v}(k+1)$
    Find $\mathbf{Y}(k+1) = \mathbf{C}\mathbf{X}(k+1) + Noise\_ON * \mathbf{v}(k+1)$

  END FOR

- Display Simulation Results

  - Plot $X_i(k)$ v/s Time for $i = 1, 2, 3$
    Plot $Y_i(k)$ v/s Time and $R_i(k)$ v/s Time for $i = 1, 2$
    Plot $U_i(k)$ v/s Time for $i = 1, 2$
    Plot $D(k)$ v/s Time