Control Engineering Laboratory.

Experiment No. 5

Control System Design for a SISO system

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Control System Design for a MIMO system

Aim: To analyse and develop a control system for a MIMO system.

Theory and Analysis:

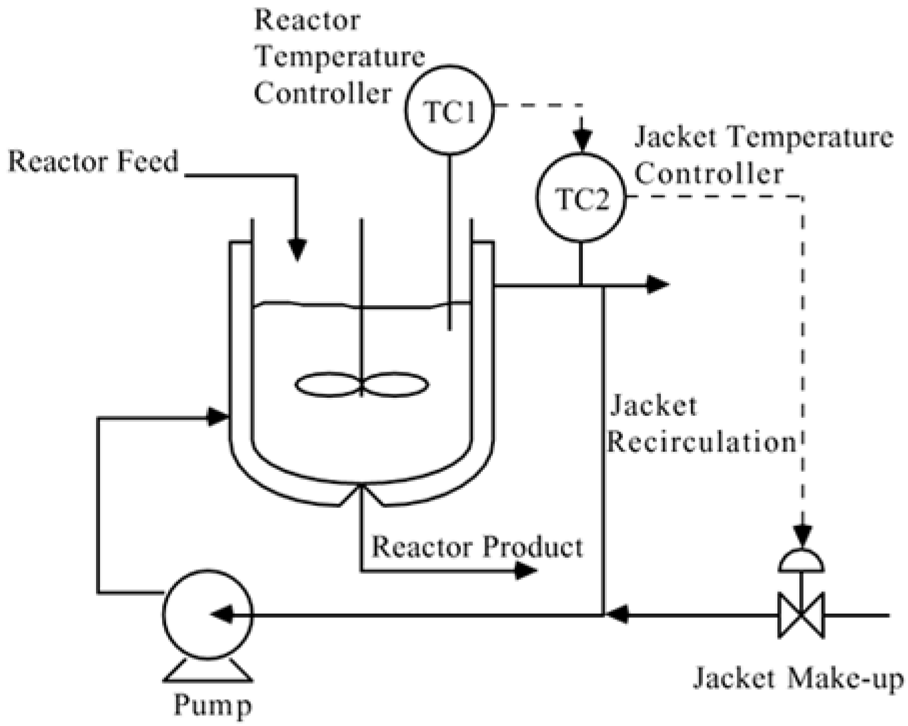

Fig1: Cascade control, with jacket outlet temperature as the secondary control variable

Change in temperature:

$$\frac{dT}{dt} = \frac{F}{V}(T_i - T) + \frac{U.A}{C_P.V.\rho}(T_j - T) \quad ---\rightarrow (1)$$

$$\frac{dT_j}{dt} = \frac{F_j}{V_j}(T_{jin} - T_j) + \frac{U.A}{C_{Pj}.V_j.\rho_j}(T_j - T) \quad ---\rightarrow (2)$$

$$A_{11} = \frac{\partial \dot{T}}{\partial (T - T_S)} = \frac{\partial \dot{T}}{\partial T} = -\frac{F_S}{V} - \frac{U.A}{C_P.V.\rho}$$

$$A_{12} = \frac{\partial \dot{T}}{\partial (T_j - T_{jS})} = \frac{\partial \dot{T}}{\partial T} = \frac{U.A}{C_P.V.\rho}$$

$$A_{21} = \frac{\partial \dot{T}_{JS}}{\partial (T - T_S)} = \frac{\partial \dot{T}_J}{\partial T} = -\frac{U.A}{C_{Pj}.V_j.\rho_j}$$

$$A_{22} = \frac{\partial \dot{T}}{\partial (T_j - T_{jS})} = \frac{\partial \dot{T}_J}{\partial T_J} = -\frac{F_{jS}}{V_j} - \frac{U.A}{C_{Pj}.V_j.\rho_j}$$

Given,

U.A = 183.9 units

V = 10

V_J = 1

$\rho_J.C_{PJ}$ = 61.3

$\rho.C_P$ = 61.3

F_{JS} = 1.5

F_S = 1

T_{IS} = 50

T_{JINS} = 200

T_S = 125

T_{JS} = 150

Putting the values,

$$A = \begin{bmatrix} -2/5 & 3/10 \\ 3 & -9/2 \end{bmatrix}$$

$$B = \begin{bmatrix} \dfrac{\partial \dot{T}}{\partial F_j} & \dfrac{\partial \dot{T}}{\partial F} & \dfrac{\partial \dot{T}}{\partial T_i} & \dfrac{\partial \dot{T}}{\partial T_{Jm}} \\ \dfrac{\partial \dot{T}_J}{\partial F_j} & \dfrac{\partial \dot{T}_J}{\partial F} & \dfrac{\partial \dot{T}_J}{\partial T_i} & \dfrac{\partial \dot{T}_J}{\partial T_{Jm}} \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & \dfrac{T_{is} - T_s}{V} & \dfrac{F_s}{V} & 0 \\ \dfrac{T_{Jins} - T_{Js}}{V_j} & 0 & 0 & \dfrac{F_{js}}{V_j} \end{bmatrix}$$

$$B = \begin{bmatrix} 0 & \dfrac{-15}{2} & \dfrac{1}{10} & 0 \\ \dfrac{50}{1} & 0 & 0 & \dfrac{3}{2} \end{bmatrix}$$

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

$$D = \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix}$$

$$\begin{bmatrix} \dot{T} \\ \dot{T}_J \end{bmatrix} = \begin{bmatrix} -\dfrac{2}{5} & \dfrac{3}{10} \\ 3 & -\dfrac{9}{2} \end{bmatrix} \cdot \begin{bmatrix} T \\ T_J \end{bmatrix} + \begin{bmatrix} 0 & \dfrac{T_{is} - T_s}{V} & \dfrac{F_s}{V} & 0 \\ \dfrac{T_{Jins} - T_{Js}}{V_j} & 0 & 0 & \dfrac{F_{js}}{V_j} \end{bmatrix} \cdot \begin{bmatrix} F_j \\ F \\ T_i \\ T_{Jin} \end{bmatrix}$$

$$\begin{bmatrix} T \\ T_J \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} T \\ T_J \end{bmatrix}$$

Simulation and Results:

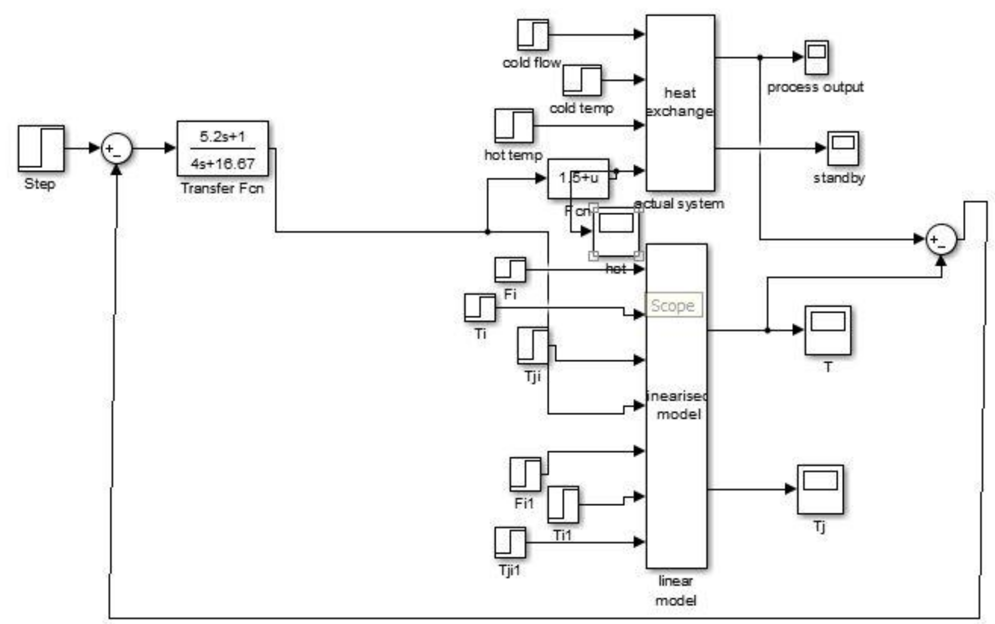

Fig 2) Block Diagram of a steering heater system

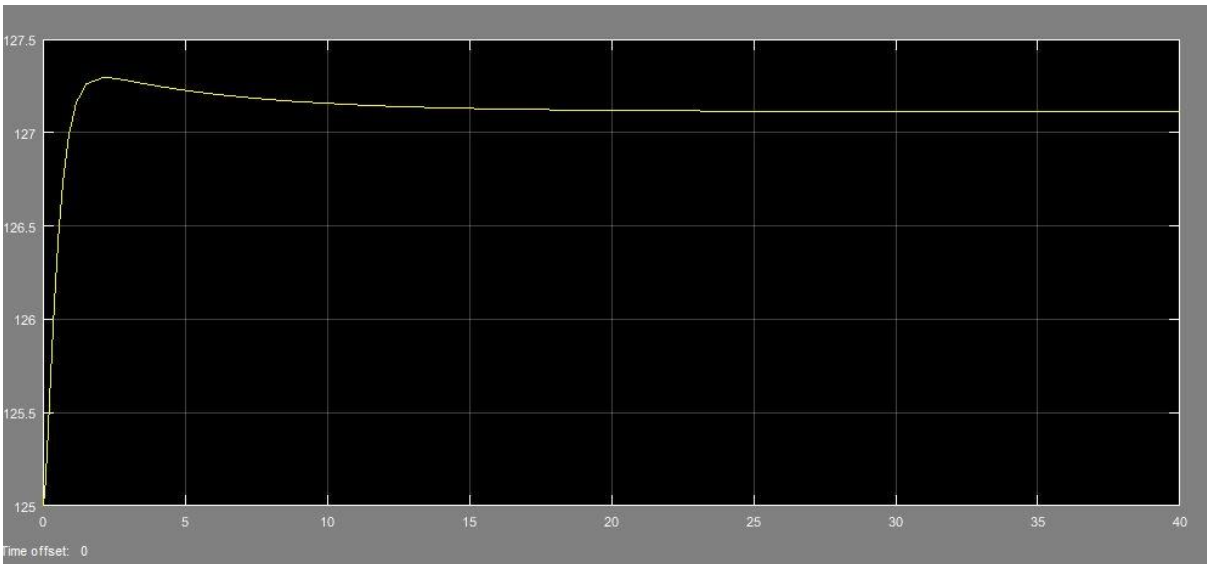

Fig. 3)Output of T scope

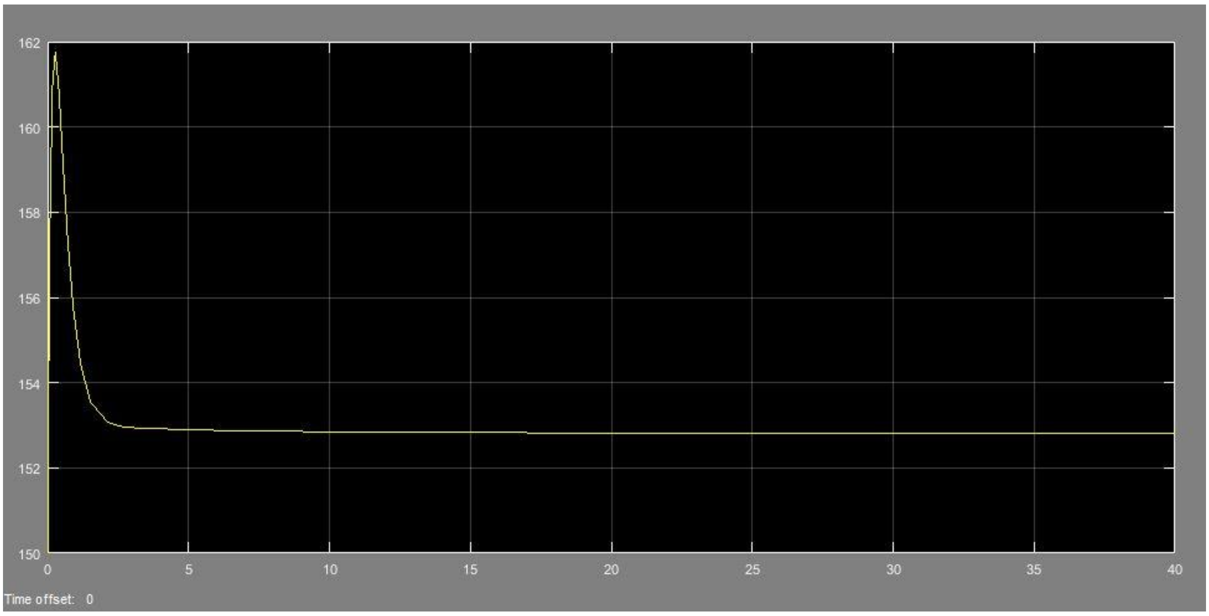

Fig.4) Output of T_J Scope

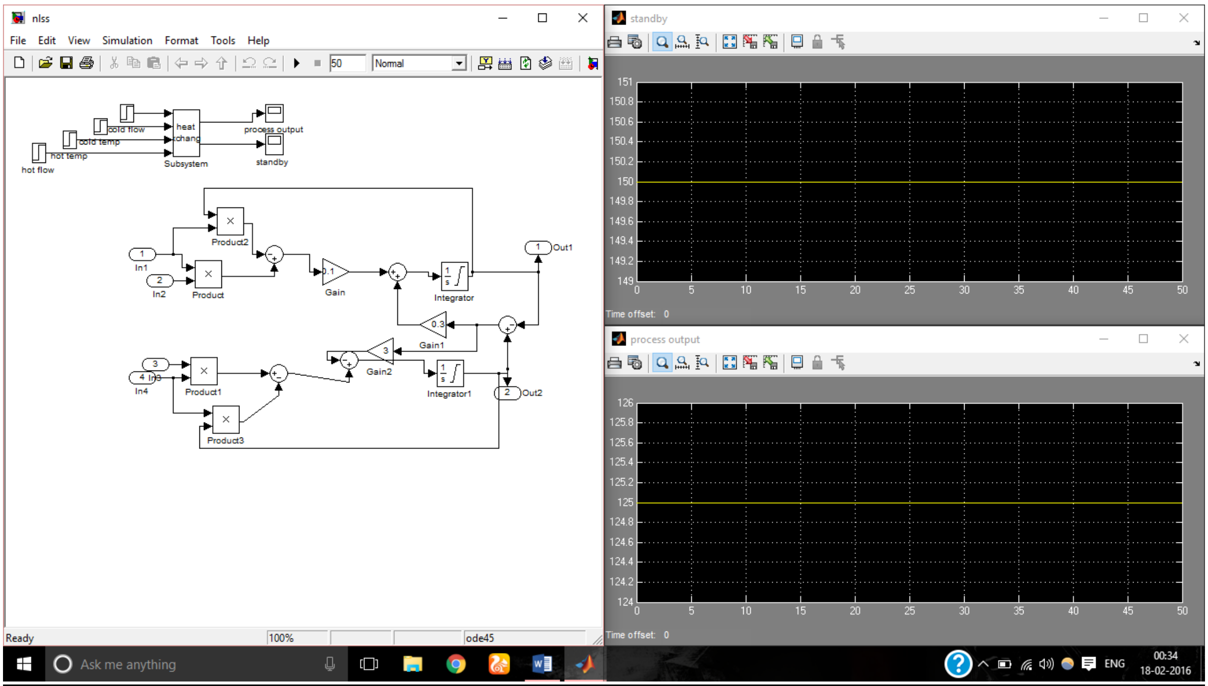

Fig.5) Constant Input Model

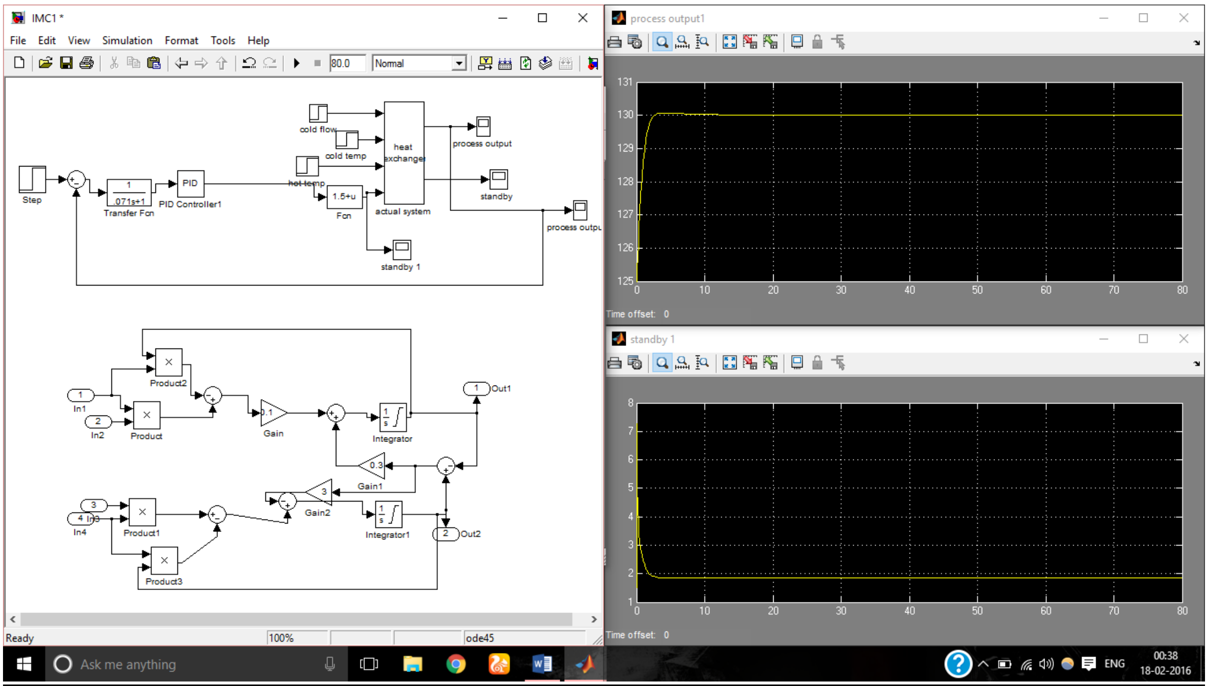

Fig.6) Heater Control with PID

Result:

Hence the MIMO steering heater system was analysed and simulated.

Conclusion:

1. The state space equation of the system explains that the system is of higher order which correctly explains the response of T and T_J.
2. This kind of controlled system is used in complex process control application such as in nuclear reactors, thermal power plants and boilers. There are two process variables and two manipulative variables in the system.