Consider a 2x2 distillation system, where $y_1$ and $y_2$ are process variables, $u_1$ and $u_2$ are manipulated variables, and $D$ is the disturbance variable.

\[
\begin{bmatrix}
Y_1(s) \\
Y_2(s)
\end{bmatrix} = \begin{bmatrix}
k_{11} e^{-\theta_{11}s} \\
6.7s + 1 \\
1.11 e^{-5.5s} \\
3.25s + 1
\end{bmatrix} \begin{bmatrix}
-0.61 e^{-2.5s} \\
8.64s + 1 \\
\theta_{22} e^{-\theta_{22}s} \\
5.0s + 1
\end{bmatrix} \begin{bmatrix}
U_1(s) \\
U_2(s)
\end{bmatrix} + \begin{bmatrix}
0.28 e^{-7s} \\
6.2s + 1 \\
1.06 e^{-5.5s} \\
6.9s + 1
\end{bmatrix} D(s)
\]

Different model parameters are assigned for each team as follows:

<table>
<thead>
<tr>
<th>Team No.</th>
<th>$k_{11}$</th>
<th>$k_{22}$</th>
<th>$\theta_{11}$</th>
<th>$\theta_{22}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.66</td>
<td>-2.16</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>0.80</td>
<td>-2.26</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
Final Workshop (Report)

(1) Based on the RGA, suggest how the variables should be paired in a multi-loop control structure.

(2) Design the following controllers for this 2x2 process:

(a) A simplified decoupling control system using dynamic decoupler and PID controller. What are the dynamic decoupler and PID parameters?

(b) An unconstrained MPC (DMC) with Δt = 0.5.
   Design parameters: N = 100, P = 10, M = 4, Q_{ii} = 1, R_{ii} = 0.1.
   What is the controller gain matrix K_{c1}?

(3) Simulate and compare the responses of controllers (2a) and (2b) under nominal condition and ±20% plant-model mismatch on steady-state gains.
(Compare both responses of y and u)

Consider the case:

y_1 set-point +1 step change at t = 0, y_2 set-point +1 step change at t = 100, and disturbance -1 step change at t = 200.

Make comments on your simulation results.