The goal is to design a control system for the process in figure 1. You can find this model in the ASE370L web site.

1. If we use a proportional controller \( K_c \), what is the range of values that can be programmed in the controller that guarantees the stability of the control system?

2. Get the values of \( K_c \) for the following cases: 25%, 50%, 75% and 125% of the range. For example, if the range is \( K_c = (1, 4) \) then \( K_{25\%} = 1.75 \), \( K_{50\%} = 2.5 \), ...

3. In figure 2 you can find the Simulink diagram that can be used to simulate the control system. Use the diagram to simulate the control system with the four controllers calculated before. In all the cases consider that the reference changes from \( 0^\circ \) to \( 15^\circ \) when \( t = 3s \) and the wind speed is 0. Take the measurements that you consider to fill out the following table:

![Figure 1: Aileron/wind-bank angle model.](image)
Take into account that although the process model works with radians all the results must be in degrees.

4. Get the $E_{ss}$, $MV_{ss}$ and $Ad_{ss}$ theoretically and compare these results with the ones obtained during the simulations (the ones in the table). If the results are different explain why.

5. Perform the same kind of simulations when the reference is 0 and the wind speed changes from 0 to 10 m/s in $t = 3s$. Fill out the following table:

<table>
<thead>
<tr>
<th></th>
<th>$K_{25%}$</th>
<th>$K_{50%}$</th>
<th>$K_{75%}$</th>
<th>$K_{125%}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady-state error</td>
<td>$E_{ss}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Settling time (98%)</td>
<td>St</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overshoot (%)</td>
<td>$\delta$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control action in steady-state</td>
<td>$MV_{ss}$</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Aileron deflection in steady-state</td>
<td>$Ad_{ss}$</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

6. Get the $E_{ss}$, $MV_{ss}$ and $Ad_{ss}$ theoretically and compare these results with the ones obtained during the simulations (the ones in the table). If the results are different explain why.

7. In order to have a more realistic simulation include one block to take into account the saturation on the control action. The range of the possible control actions is $MV(t) = [-5V, 5V]$.

8. Perform one simulation to show how the above saturation can affect to the control system. Will this saturation modify the results obtained in the previous sections? Will this saturation affect the stability of the system?

You can perform several simulations to answer these questions and compare the results with the ones in the tables. Change the amplitude of the reference so that you can see the effects of the saturation.
9. If the wind speed is can be modelled as $w_1(t) = 4\sin(10t)$ (case 1) and $w_2(t) = 4\sin(100t)$ (case 2) simulate the the control system for both cases (the reference must be zero) and obtain:

- The steady state frequency of the manipulated and controlled variable. Justify using the linear systems theory the results obtained.
- The amplitude of the controlled variable in steady state in both cases. Explain in detail the results obtained.

Hint: for both exercises you will need the frequency response of a linear system.

\textit{use the Sine Wave block from Simulink to generate this kind of inputs.}

10. What is the maximum speed of the wind that cannot be compensated by the actuator? Hint: this value does not depend on the controller that we are using.

11. Add one \textbf{Random Number} block to simulate the sensor noise. The mean must be 0 and the variance must be: $1.9039e^{-5}$. If this block is generating noise in normal distribution, what is the range of error of the sensor in degrees?
Figure 2: Block diagram of the control system for Simulink.