Computational Intelligence - Project 1

DC Motor Fuzzy Controller

Nikolaos Konstas

Department of Electrical & Computer Engineering
Aristotle University of Thessaloniki

February 2024

Contents

1 Classic Controller

We first simulate the closed-loop system with a classical PI controller to find the values of K_P and K_I for which the specifications are satisfied and then use them for the initial values of the Fuzzy PI controller. The closed loop system is shown in the figure below and can be found in the Classic_Control.slx file.

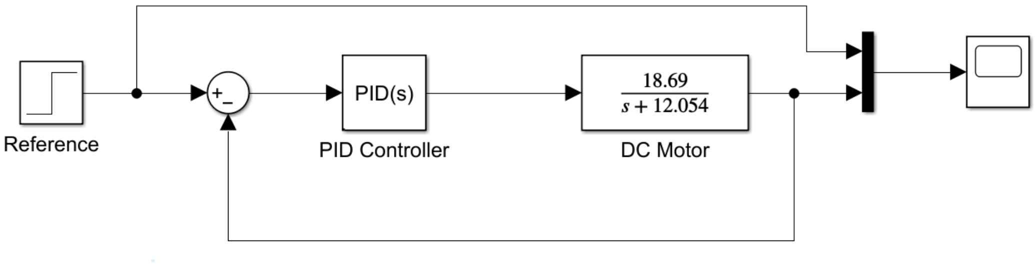

Figure 1: Classic Control

With the help of PID Tuner App we arrive at the values $K_P = 2$ and $K_I = 12$ for which we have a rise time of $112.938ms$ and an elevation of 0.505%, so the specifications are met. The system response for step input is shown in the figure below.

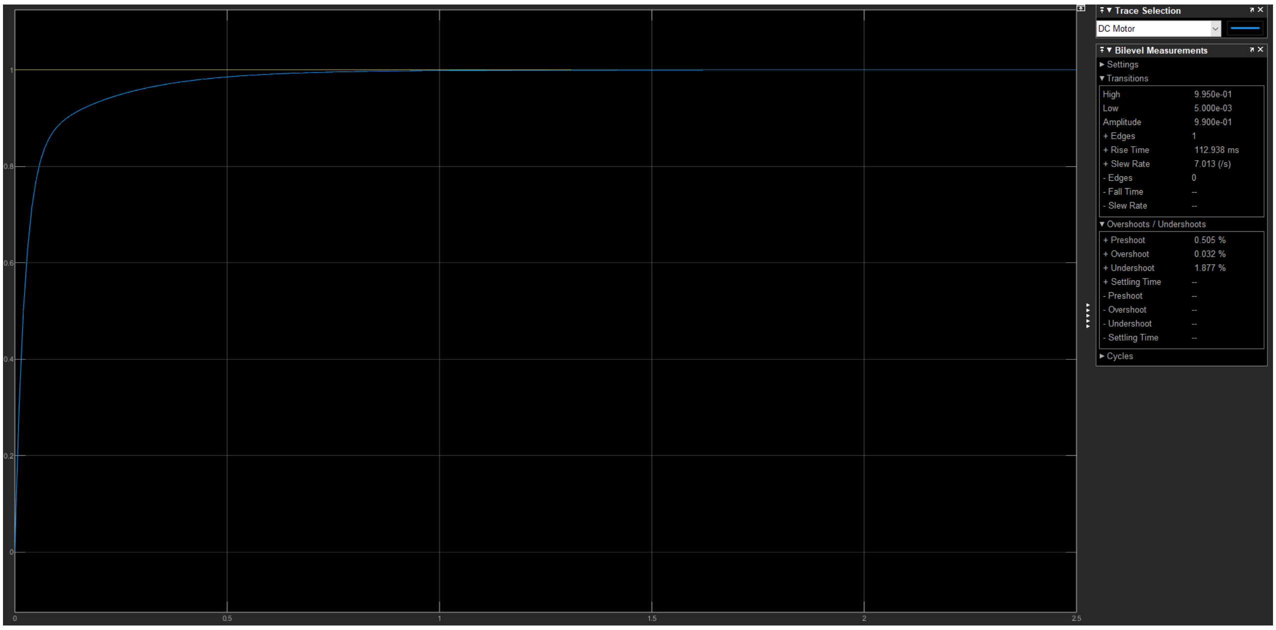

Figure 2: Response for step input

2 Fuzzy Controller

We begin by designing the fuzzy system and rule base of the control law. This is done in the create_fis.m file, initializing the system, input/output variables, and participation functions, and then creating the rule base with the help of the fuzzyLogicDesigner GUI. Based on the pronunciation instructions, the rules are derived:

dE/E	NV	NL	NM	NS	ZR	PS	PM	PL	PV
PL	NS	ZR	PS	PM	PL	PV	PV	PV	PV
PM	NM	NS	ZR	PS	PM	PL	PV	PV	PV
PS	NL	NM	NS	ZR	PS	PM	PL	PV	PV
ZR	NV	NL	NM	NS	ZR	PS	PM	PL	PV
NS	NV	NV	NL	NM	NS	ZR	PS	PM	PL
NM	NV	NV	NV	NL	NM	NS	ZR	PS	PM
NL	NV	NV	NV	NV	NL	NM	NS	ZR	PS

Next we design in Simulink the Fuzzy PI controller:

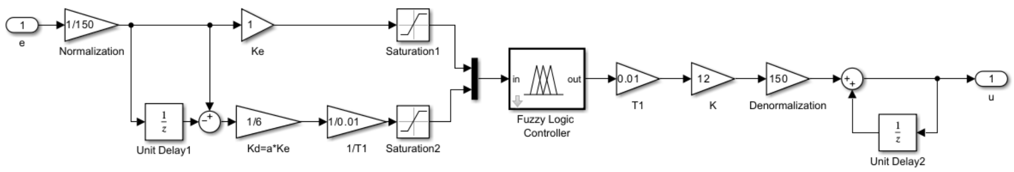

Figure 3: Fuzzy PI controller

And the closed loop system:

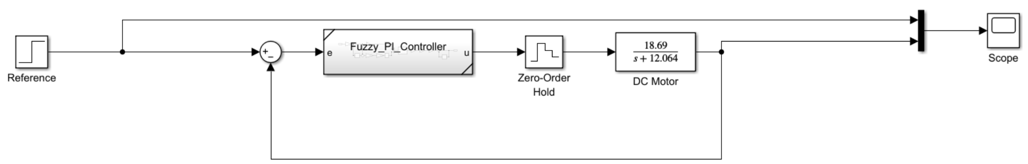

Figure 4: Closed loop system

First, based on the above values of K_P, K_I and equations (9-74) of the course notes, we calculate the initial values of K_e, α, K:

- $K_e = 1$
- $a = T_i = \dfrac{K_P}{K_I} = \dfrac{1}{6}$
- $K = \dfrac{K_P}{F\{\alpha K_e\}} = \dfrac{2}{F\{1/6 \cdot 1\}} = \dfrac{2}{1/6 \cdot F\{1\}}$ =12

With these initial values, the specifications are met, having a rise time of $146.091ms$ and an overshoot of 0.376%, with a response as shown in the figure below:

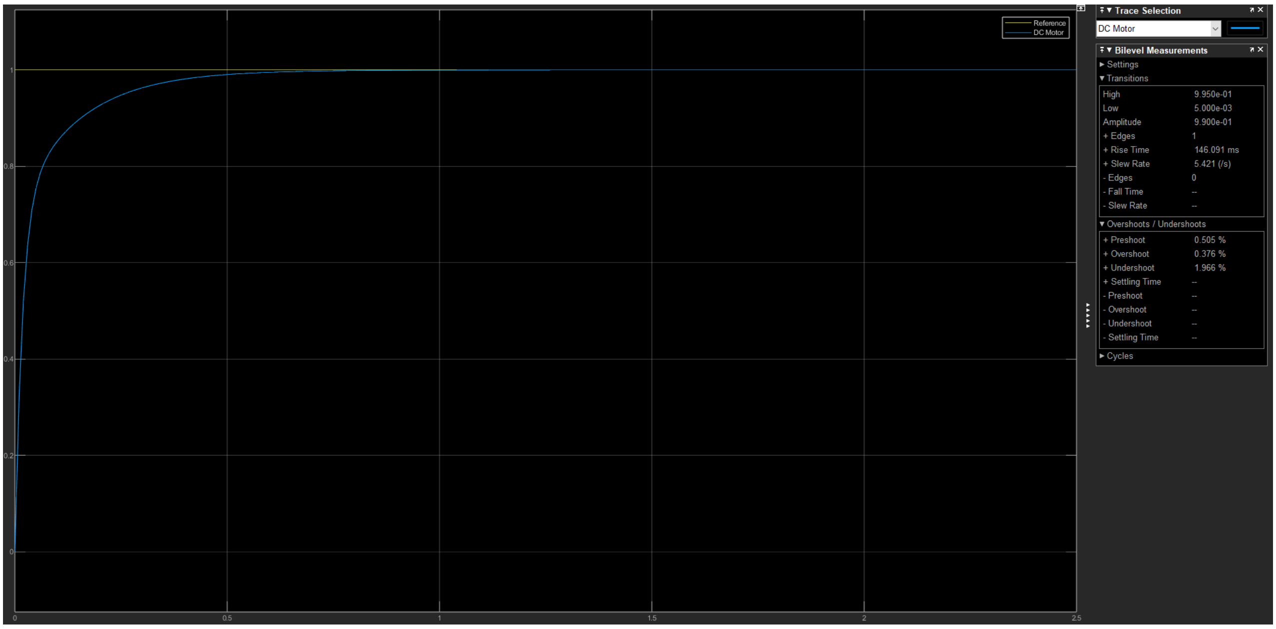

Figure 5: Response for step input

Although the specifications are met, we proceed to tuning of the controller and with trial and error we arrive at the values $K_e = 1.5, \alpha = 0.1, K = 15$ for which we have $49.221ms$ and an elevation of 0.083%. The step responses of classic, initial fuzzy and final fuzzy are shown in the figure below:

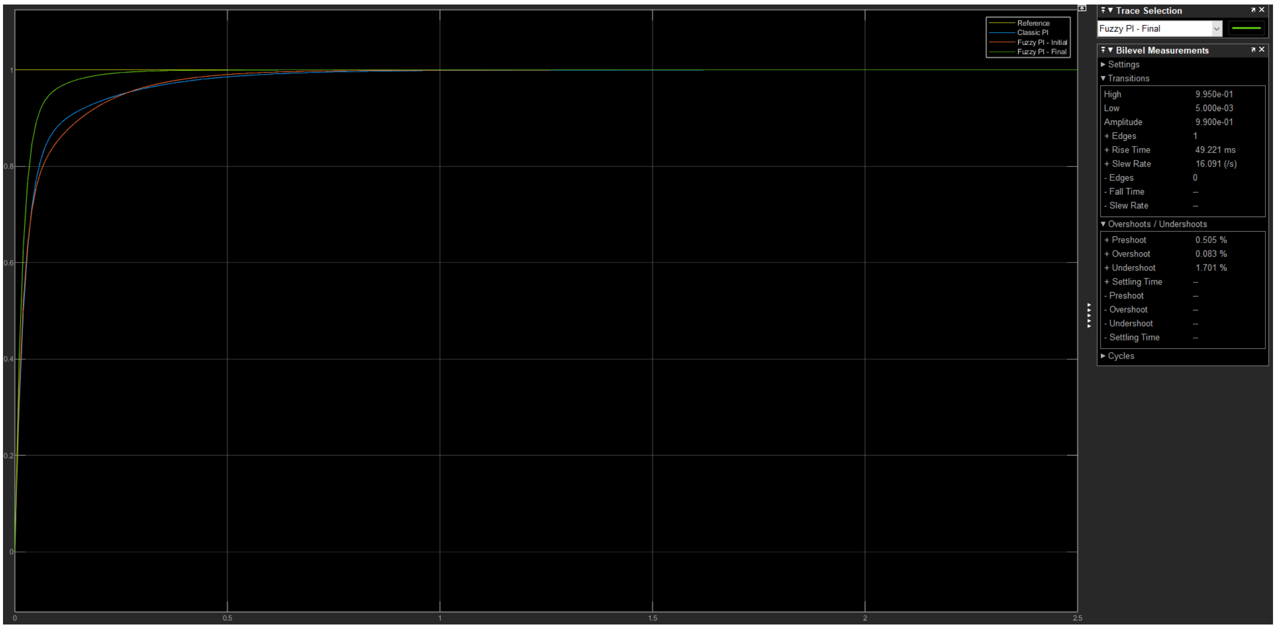

Figure 6: Response for step input

2.1 Scenario 1

We proceed to simulate the system with input the reference signal given in Figure 3 of the utterance (Scenario1.slx). The following figure shows the response of the system:

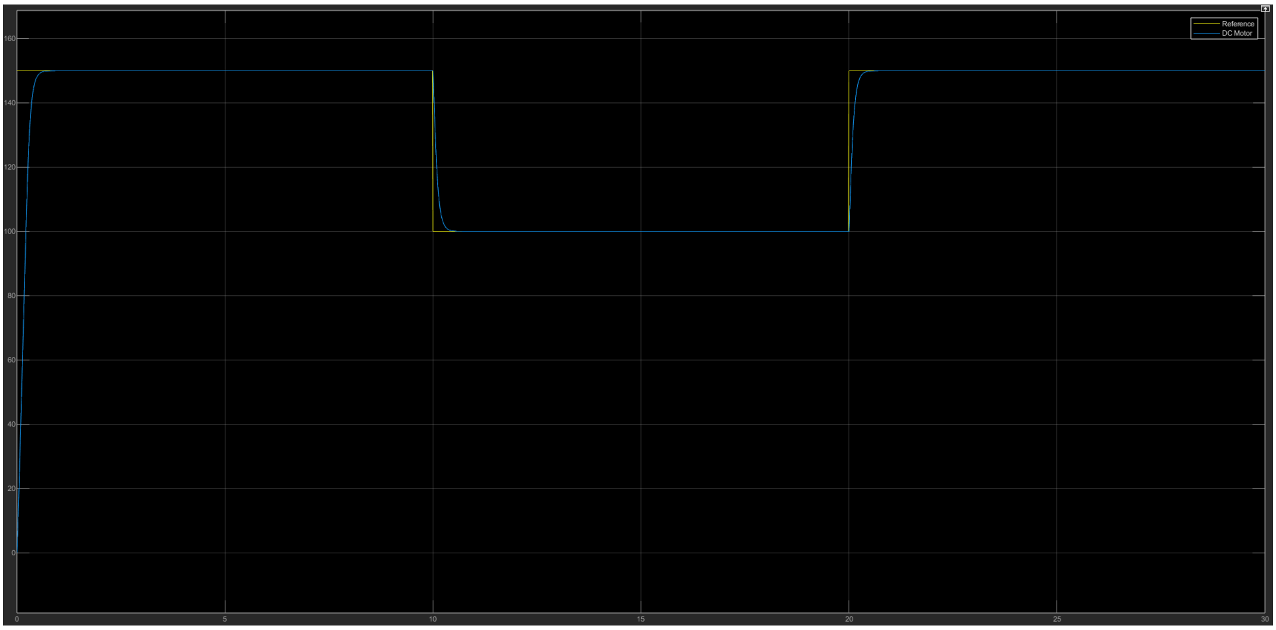

Figure 7: Response - Scenario 1

As is evident, the system follows the reference signal at high speed, while the negligible elevation is not visible to the naked eye.

For the requested example we give the values $e = 0.25(PS)$, $\Delta e = -0.67(NM)$ and thus rule (41) is activated **IF e is PS AND $\boldsymbol{\Delta}$e is NM THEN $\boldsymbol{\Delta}$u is NS**, as shown below:

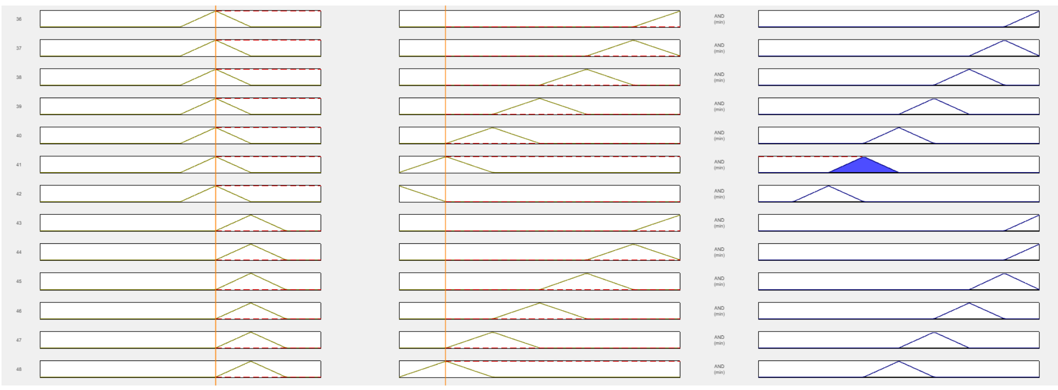

Figure 8: Rule Stimulation

Finally, the requested surface of the fuzzy controller output is shown:

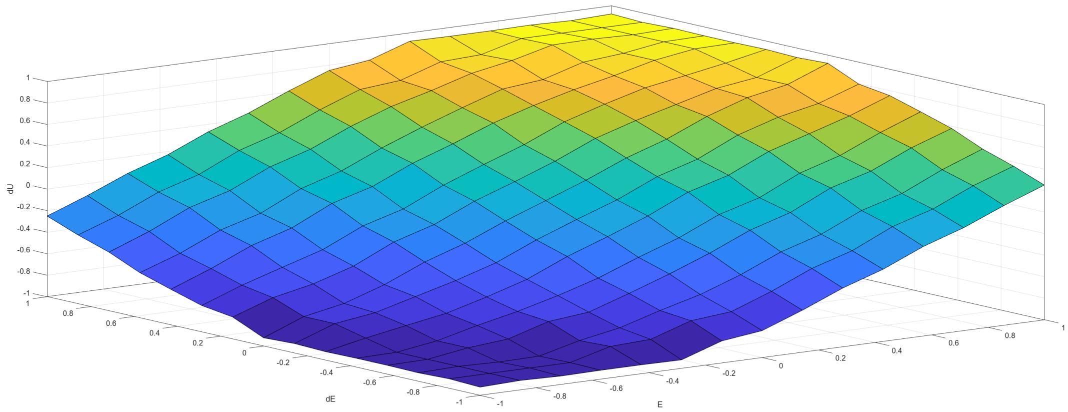

Figure 9: 3D output surface

2.2 Scenario 2

Initially regarding the requirement for almost zero overshoot no additional adjustment of the gains needs to be made, since the overshoot of 0.083% is practically zero as we noticed above. Also, the steady state error is also zero.

So we proceed to simulate the system with the reference signal of Figure 4 of the utterance (Scenario2.slx) and get the following response:

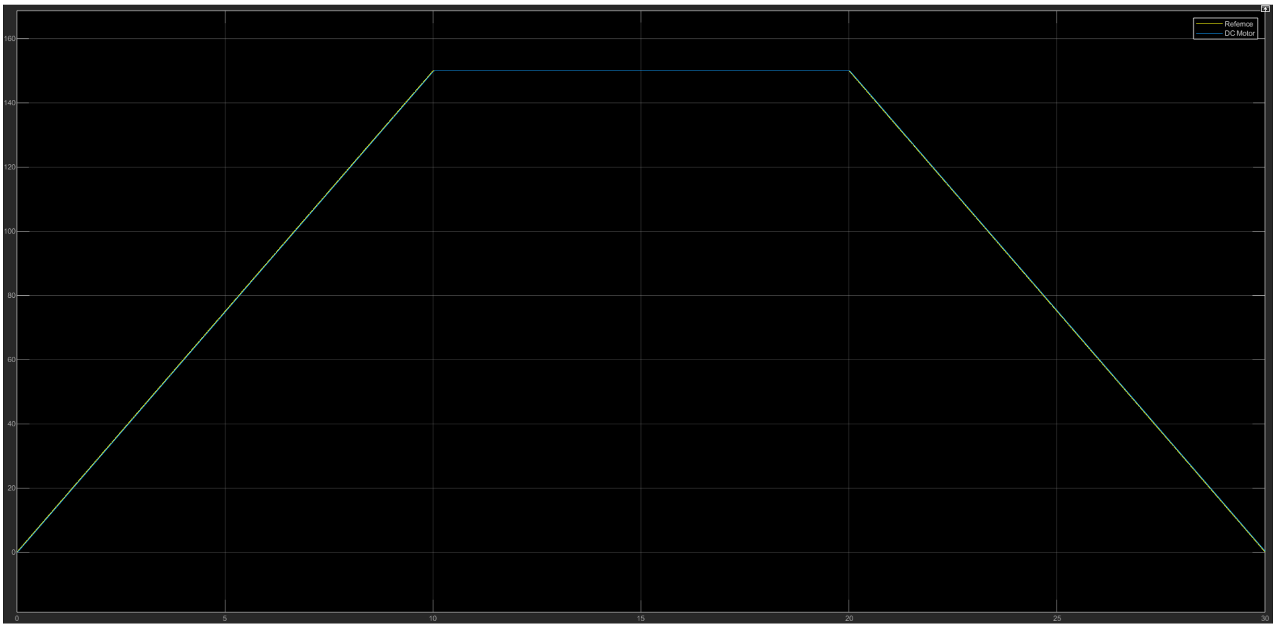

Figure 10: Response - Scenario 2

As we can see the system tracks the reference input perfectly with the two curves practically matching.

2.3 Scenario 3

Based on Example 9.9.1 the system in the presence of disturbances becomes the following, which can be found in the file Scenario3.slx:

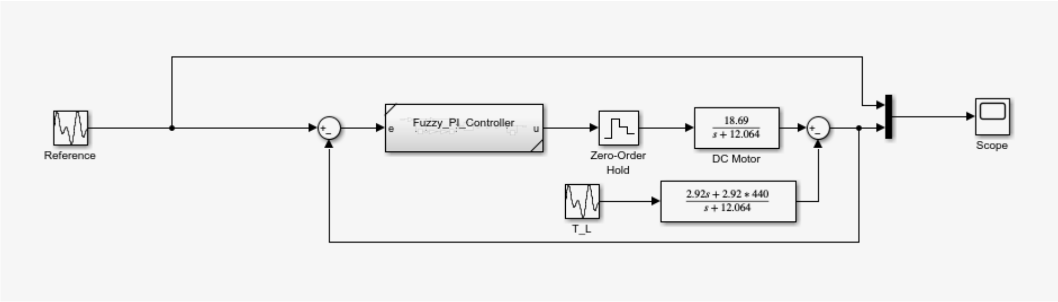

Figure 11: Closed loop system

Below is the system response for the reference input and the perturbation given in Figure 5 of the utterance:

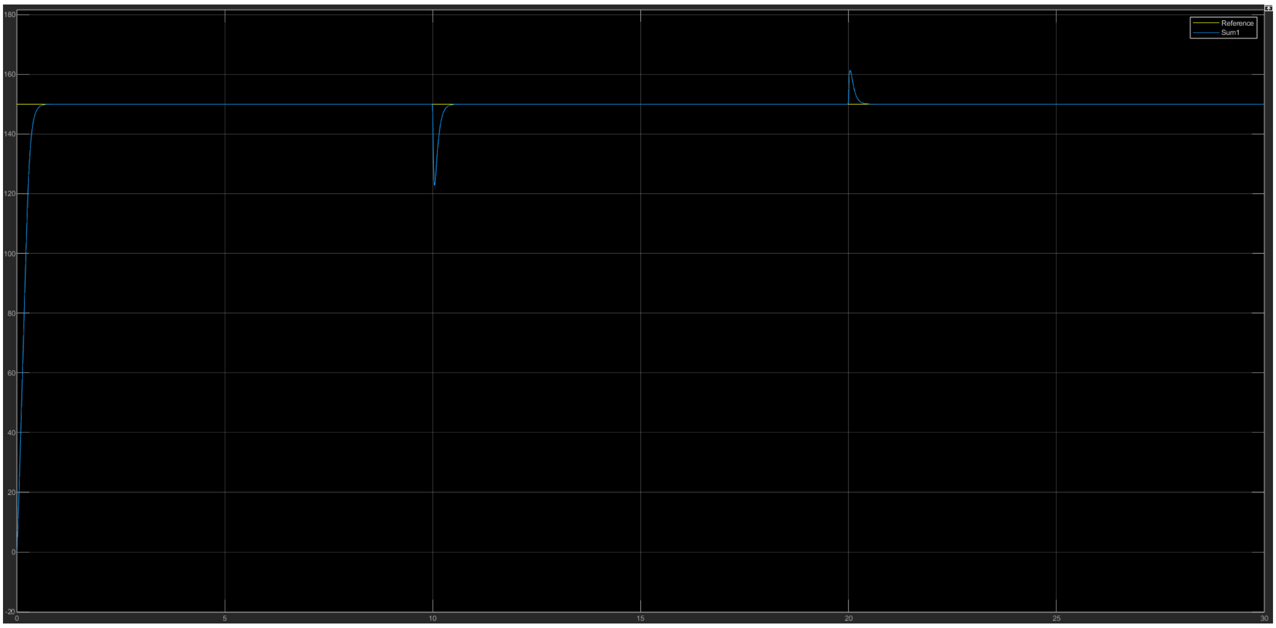

Figure 12: Response - Scenario 3

Indeed, at the initial appearance of the disturbance the engine speed shows a dip, but very quickly recovers to the reference value. Then, when the disturbance subsides, the RPMs show a momentary increase, but again quickly return to the desired value.