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TITLE: Design of discrete control system with a DC motor. Motor shaft position control.

PROJECT PERIOD:
10.11.2020 ÷ 26.01.2021

COURSEWORK:
Rapid Prototyping of
Energy-Efficient Driving Systems

PROJECT GROUP:
2nd sem. S2 of AiR

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17

ABSTRACT:

The project involved designing and prototyping the motor shaft position control system. At the beginning it was necessary to identify the object and simulate the created model. Then, using QDR methods, various input signals and the SisoTool package, the best controller for the real object was selected. The last stage of the work was the use of positional and incremental algorithms in S-Function.

1. Recalculate output

The object's output had to be recalculated to obtain the motor shaft position in radians.

For this, an Fcn block has been added in Simulink.

2. Static characteristic

The static characteristics of the object were obtained.

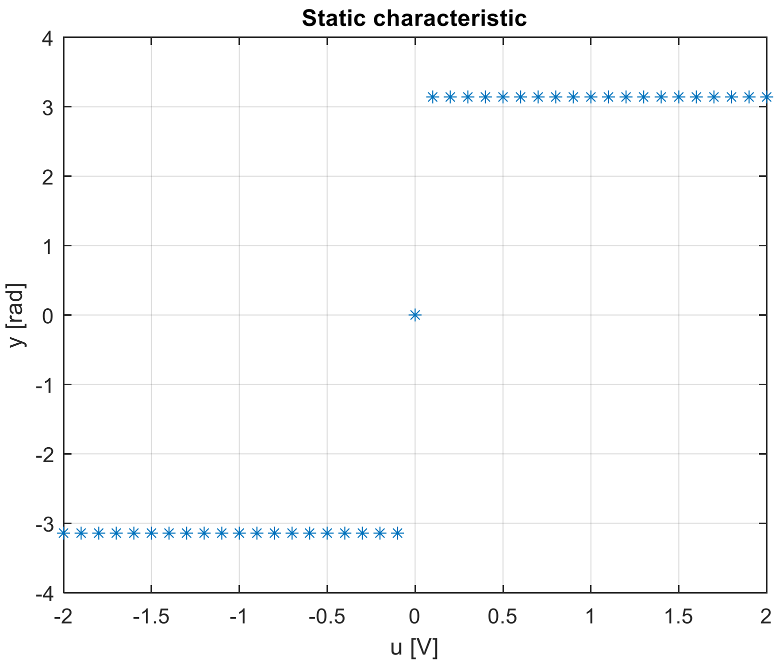


Figure 1 Static characteristic

The static characteristic cannot be determined because the system always reaches 180 degrees.

3. Identify the model

Performed an open-loop step response of the given plant using as a step value a 50% of control signal value. On this basis, the dynamic properties of the control object were analyzed.

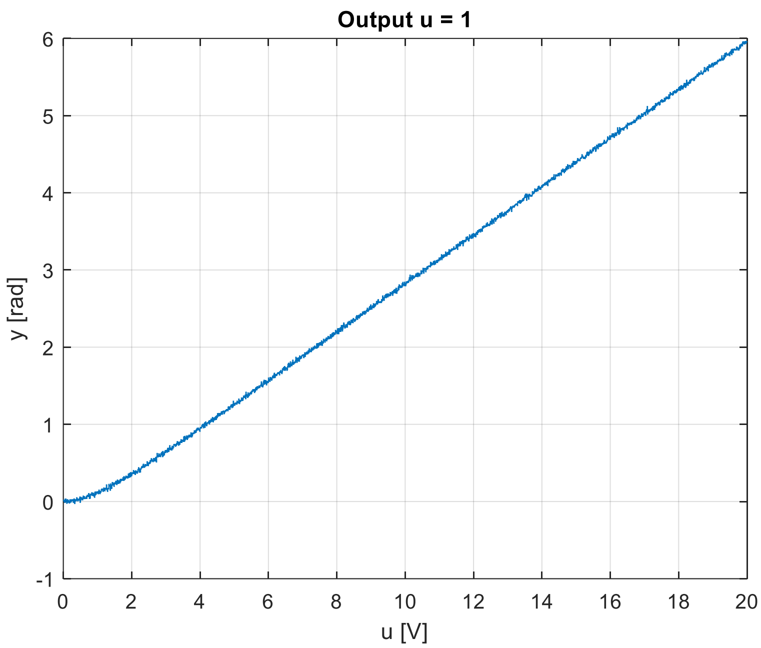


Figure 2 Plant output

The object's response to the input indicates that the object is an first order inertia combine with integral.

A mathematical model was identified using the computer-aided identification methods - toolbox IDENT.

$$K = \frac{0.3147}{s^2 + 1.003s + 1.017e^{-12}}$$

This can be written as:

$$K = \frac{0.3147}{s^2 + 1.003s}$$

Compare:

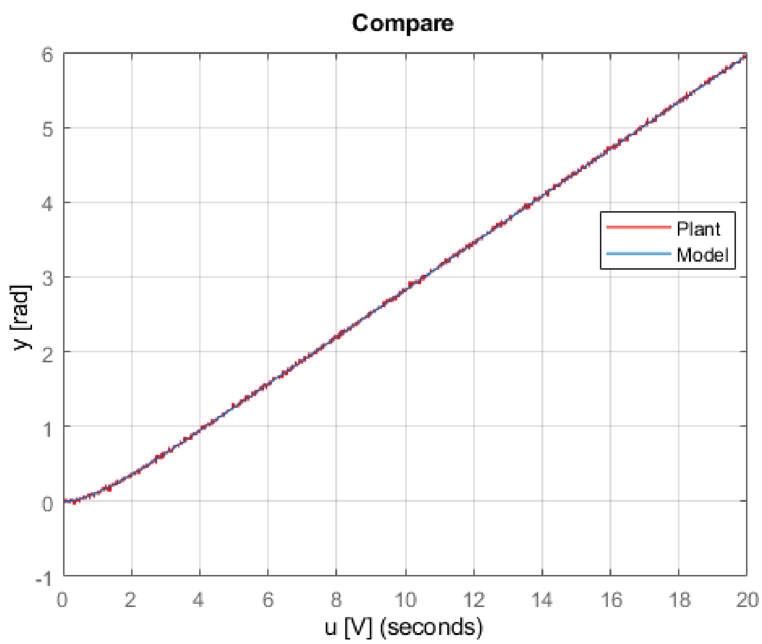


Figure 3 Compare plant output with the model output.

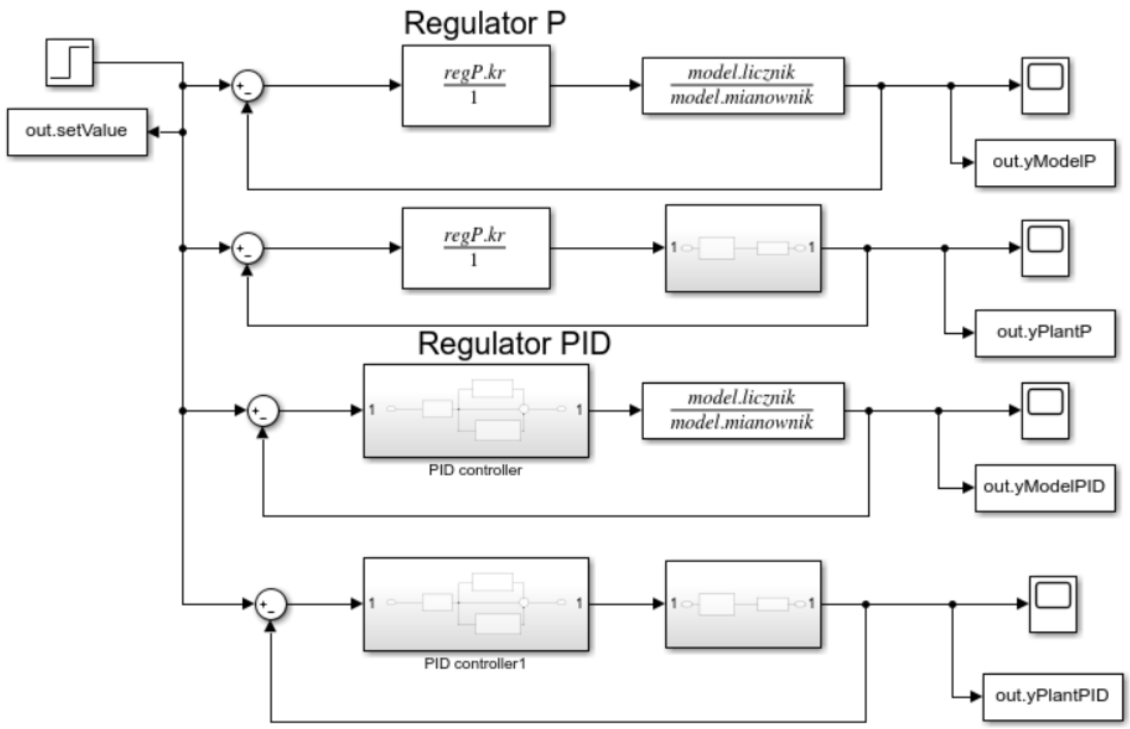
The mathematical model was well chosen, which can be seen in the comparison of the model with the plant.

4. Regulators' proposal

Based on the step response, two types of regulators have been proposed. It was decided to use the PID and P. The most important controller we wanted to check is the P controller, because the I element is actually in the plant. So the P regulator should work very well.
The values of the discrete controller parameters were determined using the QDR method. Four responses were used to average the results. The step time response was used for values between 0.3% and 0.7% of the maximum value.

The following results were obtained for the P controller:
kr = 0.96835
The following results were obtained for the PID controller:
kr = 1.162 Ti = 5.578 Td = 1.3945

A control system with previously designed controller has been created in the Simulink software.



Both controllers were tested with a set value of 1.

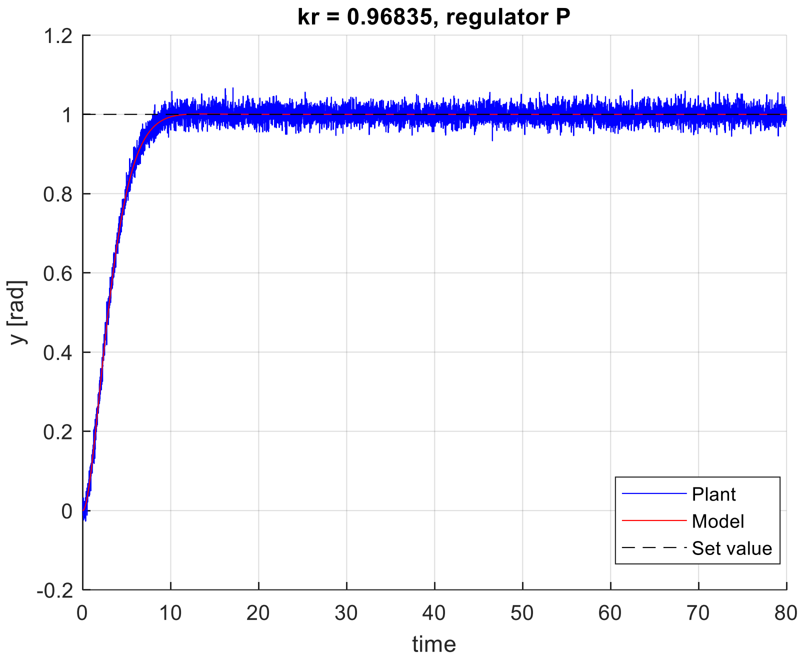


Figure 4 Control system output with controller P

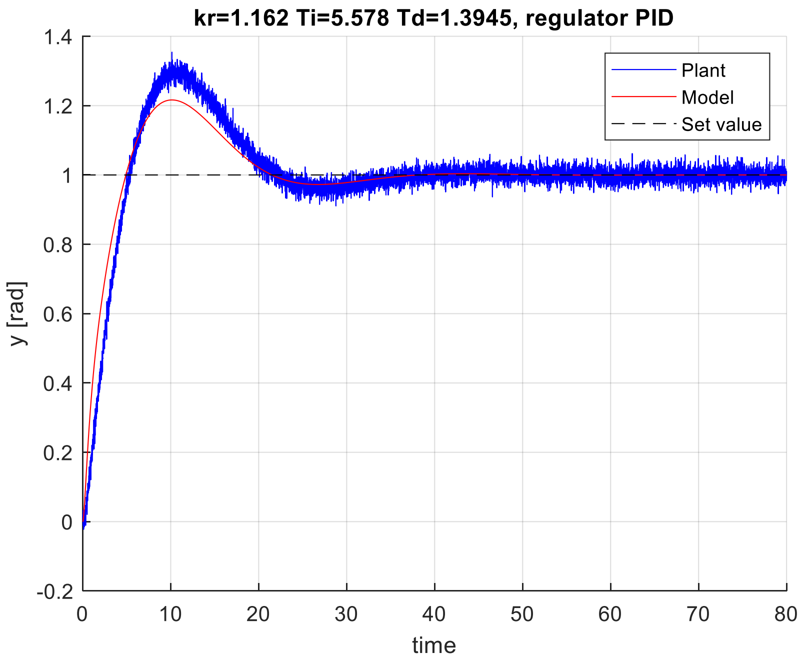


Figure 5 Control system output with controller PID

The simulation was performed for the control signal -1, 1, π.

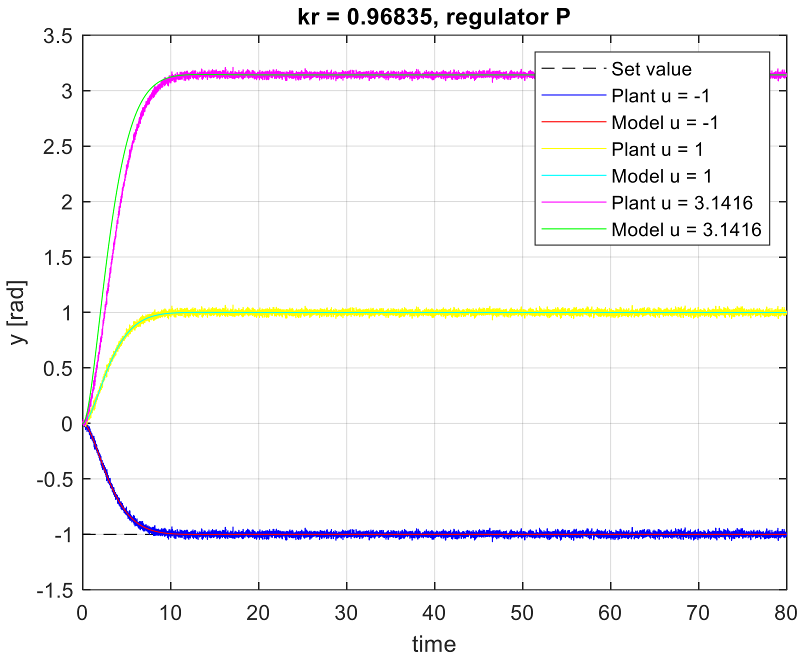


Figure 6 Control system output with controller PID, for different input signals

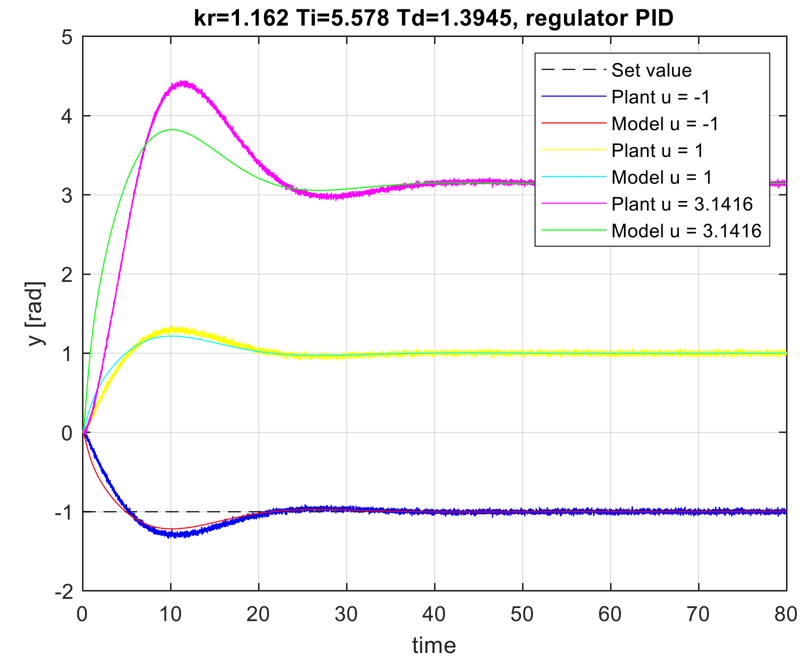


Figure 7 Control system output with controller PID, for different input signals

The P controller works very well, the control system reaches a steady state, no overshoots and no difference between the set value and the output value. The PID controller works worse than the P controller, there are overshoots, no difference between the set value and the output value. It takes longer to reach steady state.

5. Various input signals

We checked whether the quality of control could be improved by changing the driver settings. For the assumed operating point, a square wave was introduced as a set value. The results of the program operation for different values of the controller parameters were observed.

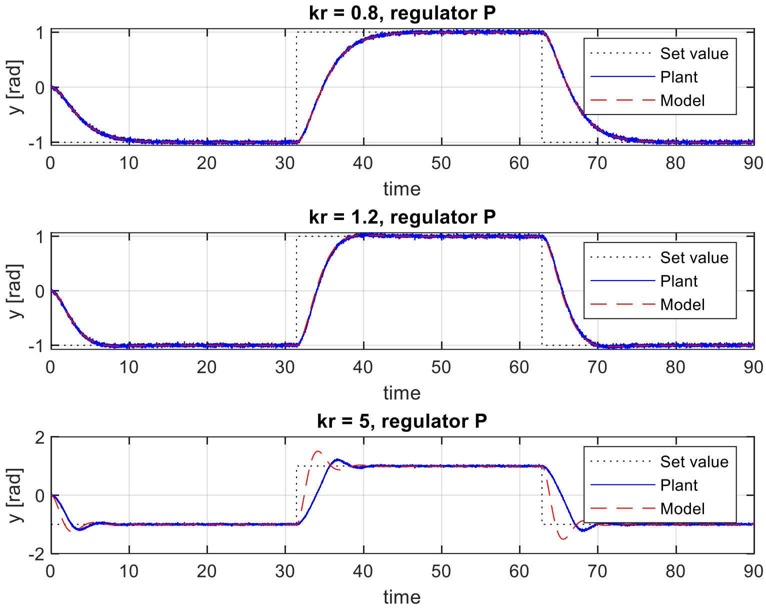


Figure 8 The results for the square wave for the P controller

The best result for the P-type controller was obtained for the gain equal to 1.2. For greater amplification, there was an overshoot. For a lower gain, the regulated signal reached the expected value in a longer time.

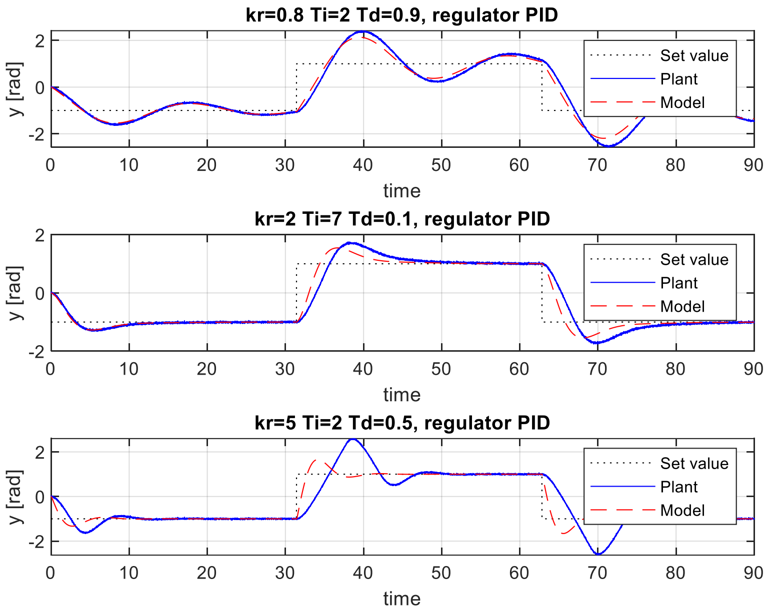


Figure 9 The results for the square wave for the PID controller

The best results for the PID controller were obtained for the gain of 2, integration time of 7 and derivative time of 0.1. With lower values of the parameters kr and Ti, the controlled value had large overshoots and reached the set value for a long time. For high gain, the controlled signal reached the steady state at a similar time as the middle plot, but had a much greater overshoot.

Then the set value was changed to a sine wave. The operation of the control system was tested with selected parameters of the regulator for different sine wave frequencies.

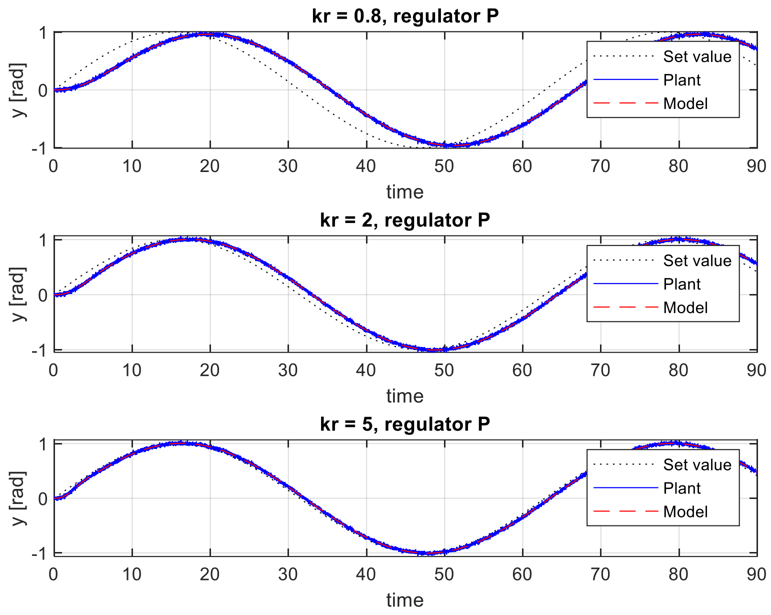


Figure 10 The results for the sine wave for the P controller, f = 0.1

When forced to a sinusoidal signal, the greater the gain, the better the controlled value follows the input signal.

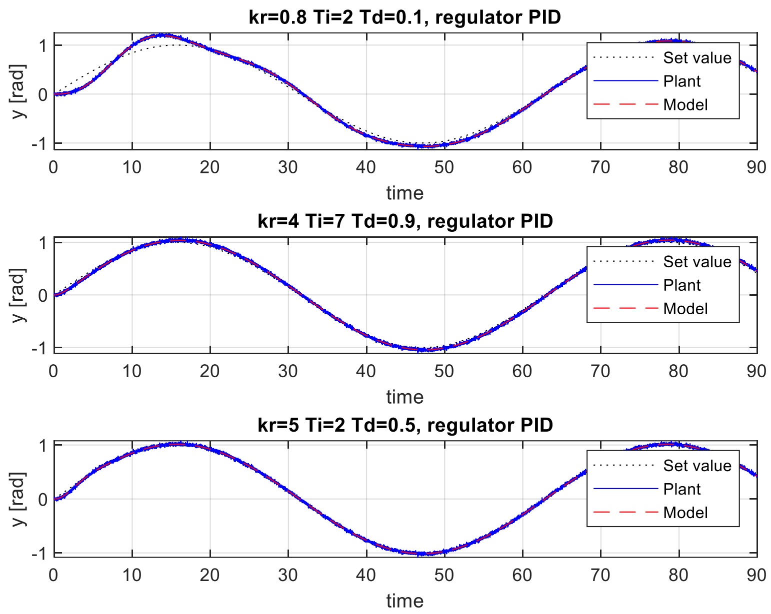


Figure 11 The results for the sine wave for the PID controller, f = 0.1

The best results were obtained for the middle plot, for kr = 4, Ti = 7, Td = 0.9.

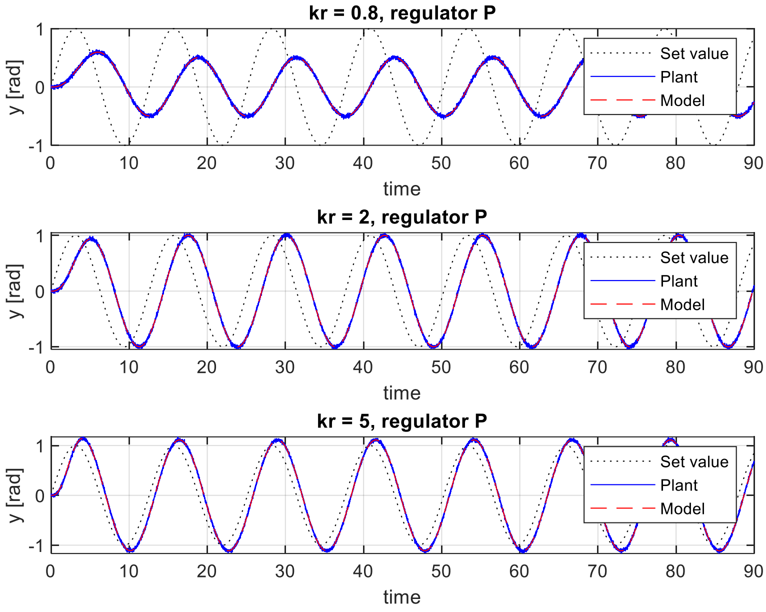


Figure 12 The results for the sine wave for the P controller, f = 0.5

Similarly to the lower frequency, also in this case the regulated value follows better with higher gain values.

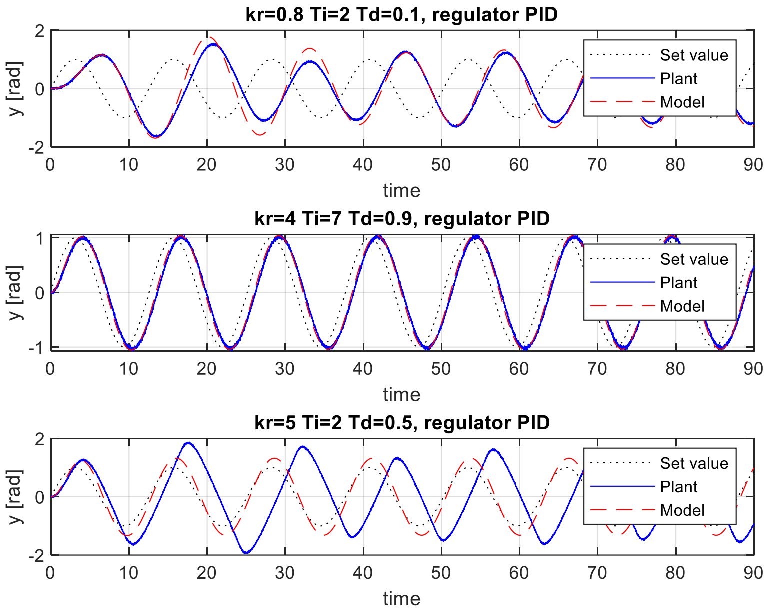


Figure 13 The results for the sine wave for the PID controller, f = 0.5

In this case, the advantage of the parameters from the second graph is clearly visible (kr = 4, Ti = 7, Td = 0.9). In other cases, the regulated value does not follow the sinusoidal signal.

Using the Chirp Signal block in Simulink, a sine wave input was set up with a frequency varying with time.

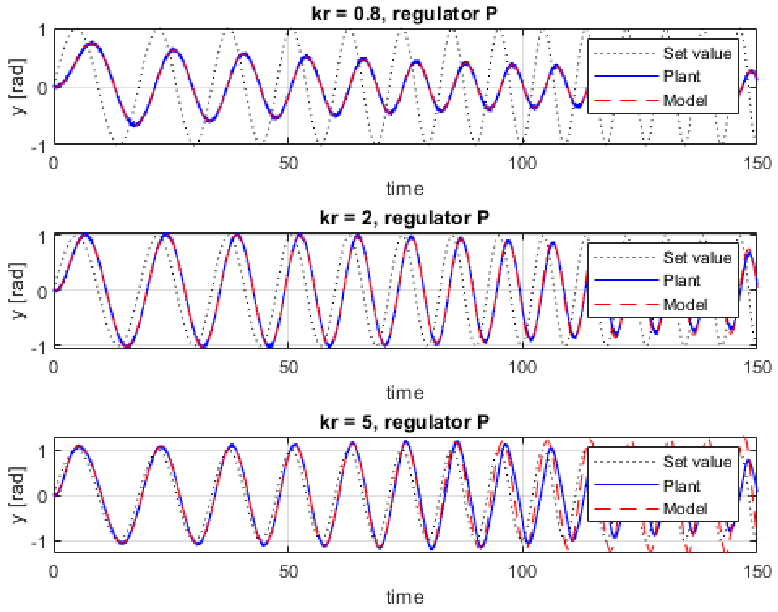


Figure 14 The results for the sine wave with frequency varying for the P controller

The best results for the P-type controller were obtained for the gain equal to 2.

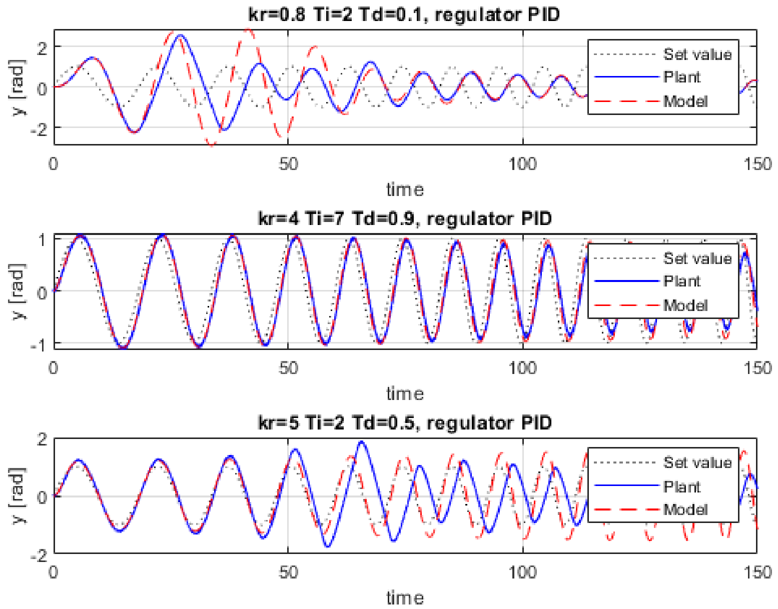


Figure 15 The results for the sine wave with frequency varying for the PID controller

The best results for the PID controller were obtained for the values of kr = 4, Ti = 7, Td = 0.9.

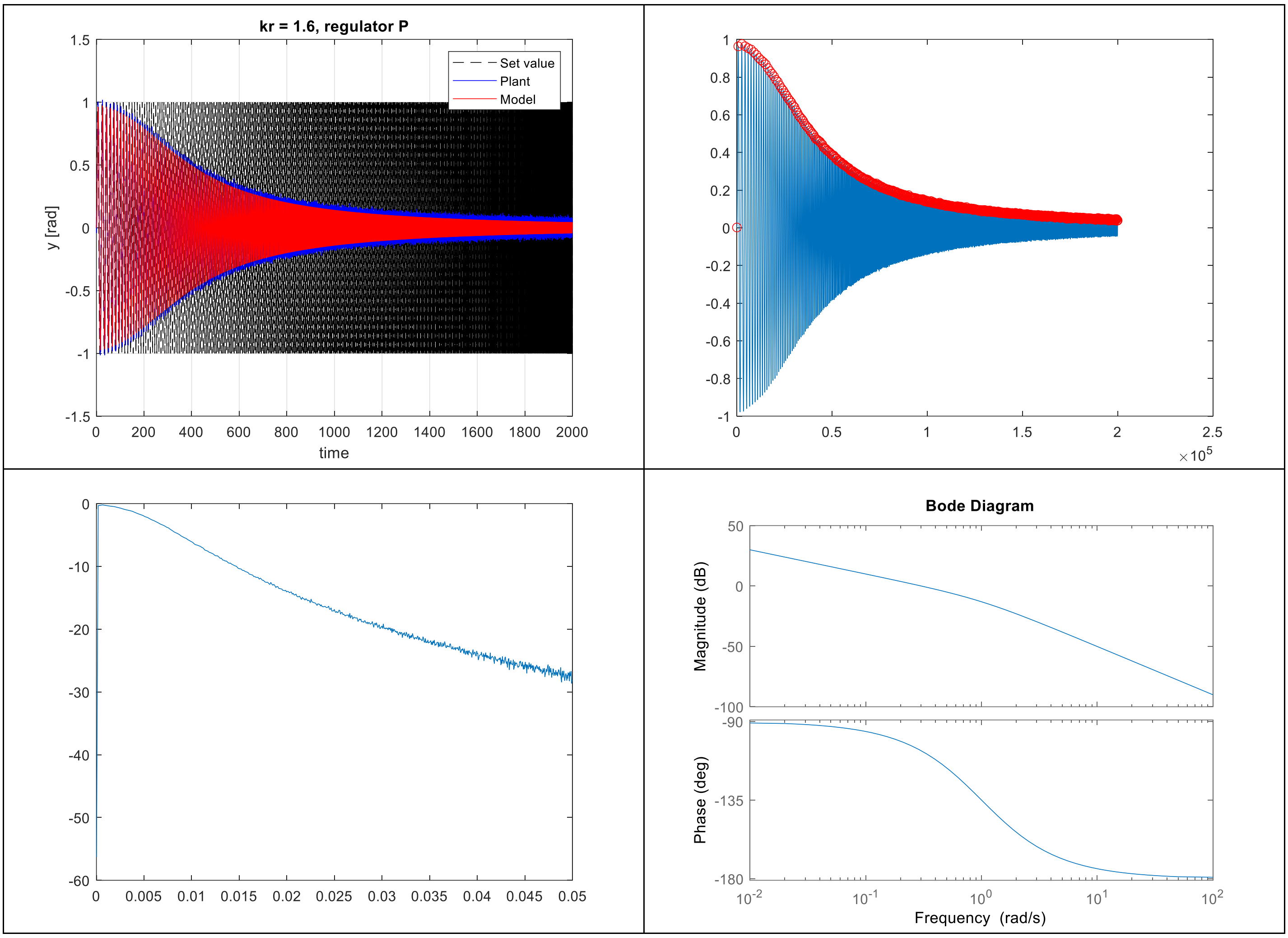


Figure 16 Characteristics of Bode

The results for the best parameters were averaged.

P controller: kr = 1.6;
PID controller: kr = 3, Ti = 7, Td = 0.5.

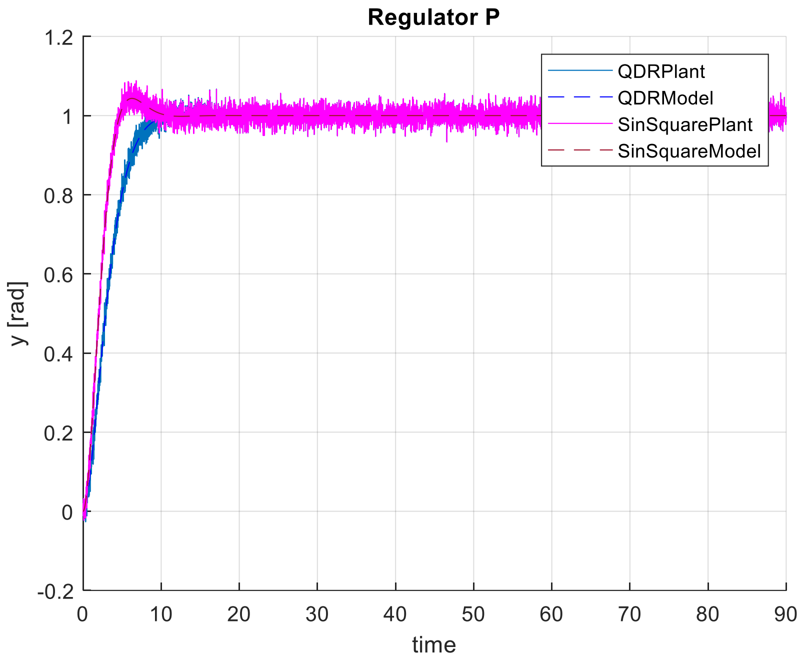


Figure 17 Average parameter values for P controller

In the P controller, the QDR method resulted in less overshoot, but the signal to the set value is slower.

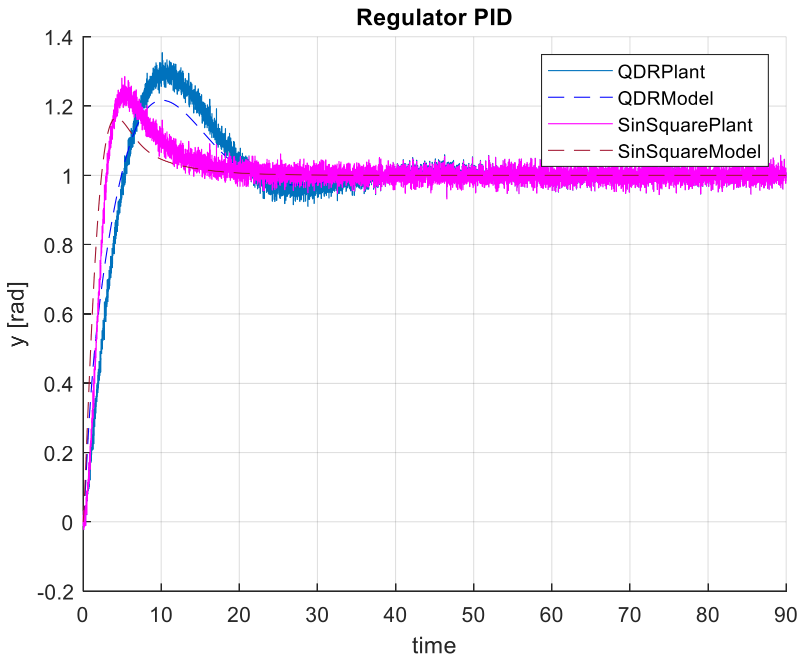


Figure 18 Average parameter values for PID controller

The P-type and PID-type controller work well, quickly reach the set point and there are no major overshoots. P-type regulator works best.

6. Tuning SisoTool

In the next part of the project, the tuning of the regulators using SisoTool was repeated.

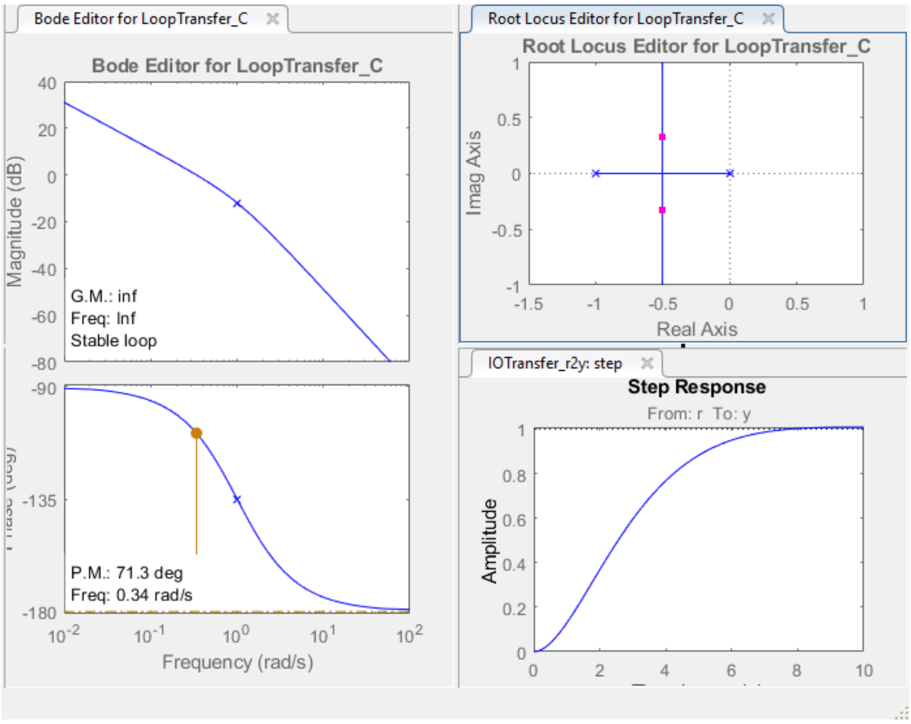


Figure 19 SisoTool

The regulators were tuned using many different methods available in SisoTool. The possibility of manually shifting zeros and poles was also used.

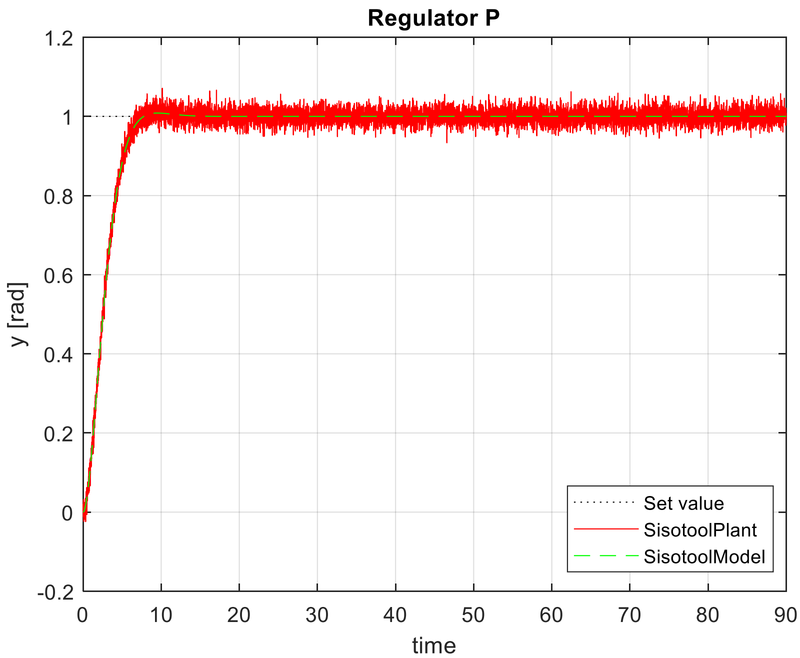


Figure 20 Settings obtained from SisoTool, P controller

The regulated value for the P controller has no overshoots and quickly reaches the set point.
Kr = 1.1437

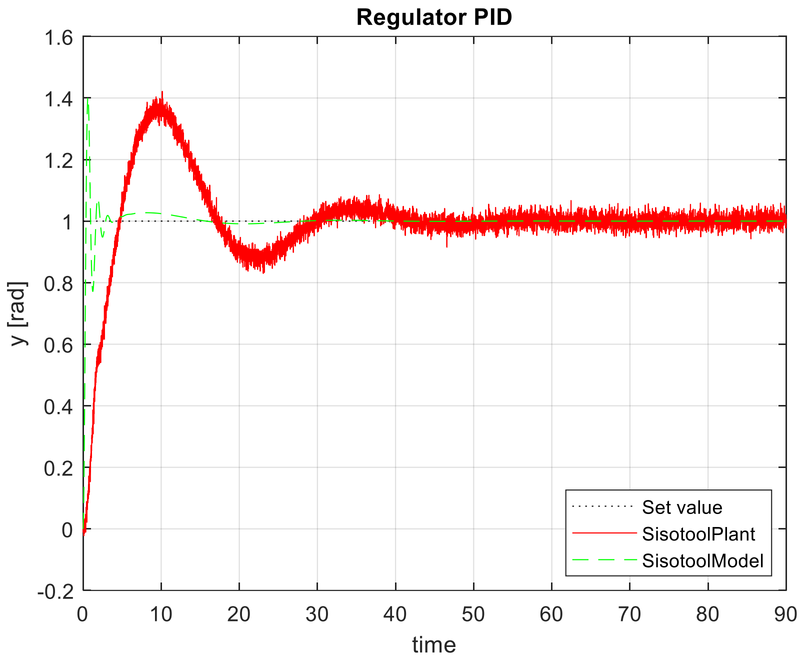


Figure 21 Settings obtained from SisoTool, PID controller

By using the SisoTool package, very good parameters of the regulators were obtained in a fairly quick and easy way.
Kr = 7.4055, Ti = 2.0207, TD = 6.0264.

7. Compare the results

The results obtained with the QDR method, sinusoidal and rectangular force and the settings from SisoTool were compared.

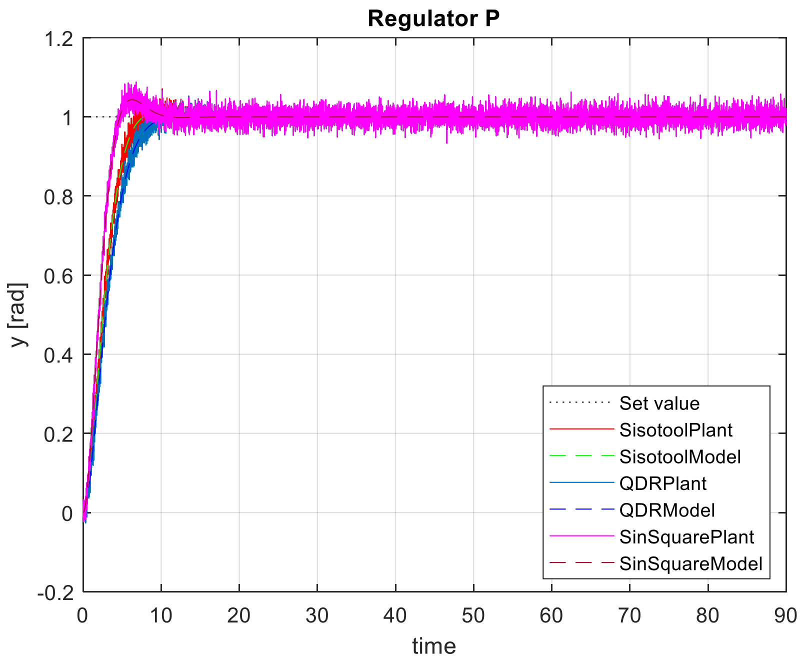


Figure 22 Comparison of the results for the P controller

The best results for the P controller were obtained with SisoTool. The controlled signal has no overshoot and quickly reaches the set value.

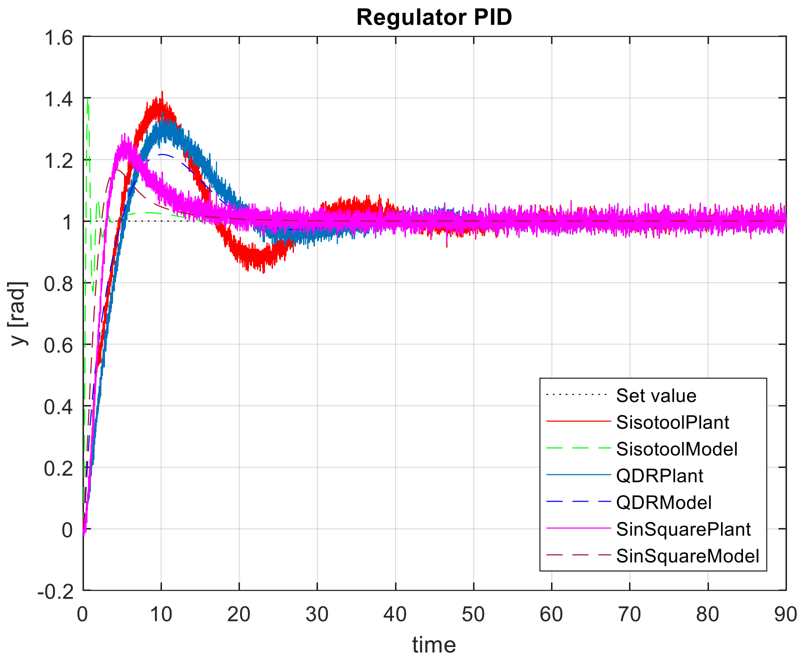


Figure 23 Comparison of the results for the PID controller

The best results for the PID controller were obtained from the average of the settings, with sinusoidal and rectangular force. The controlled signal has the smallest overshoot and reaches the steady state the fastest.

8. S-function

Incremental algorithm and positional algorithm and rectangular integration by the backward difference method are implemented for P controller.

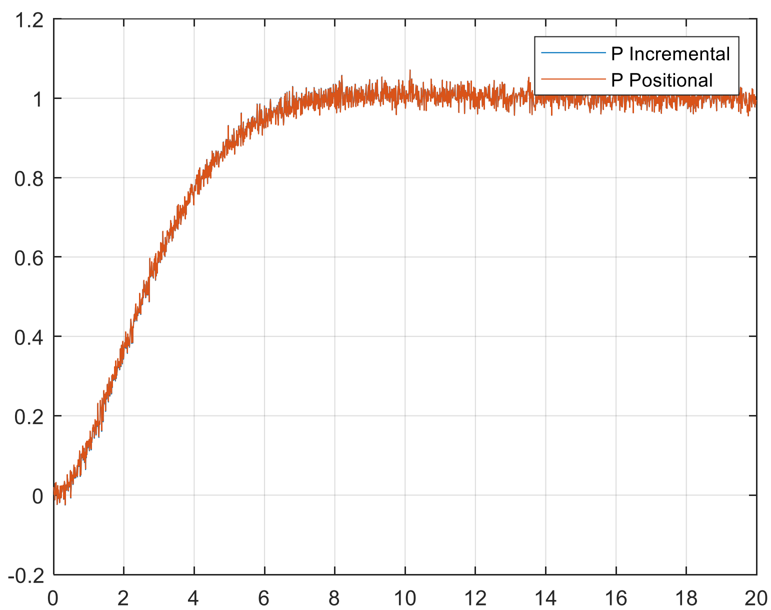
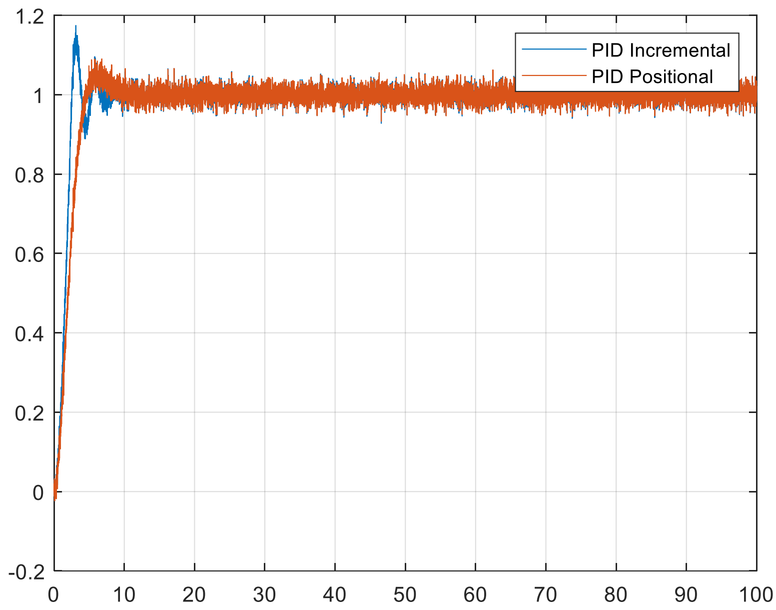


Figure 24 Comparison of P regulators



Rysunek 1 Comparison of PID regulators

9. Summary

The P regulator turned out to be the best type of regulator for our plant. The best parameters of the P controller were obtained using SisoTool.

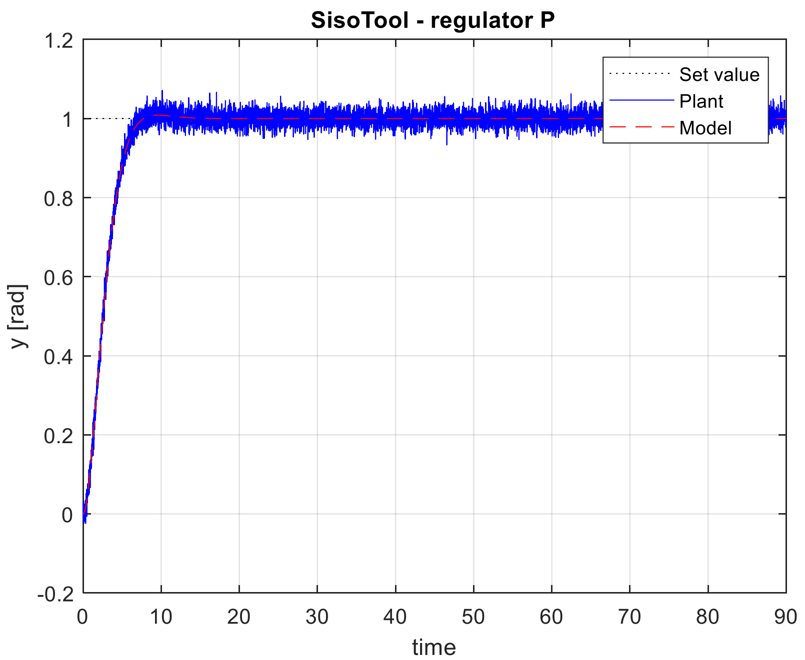


Figure 25 The best P controller settings

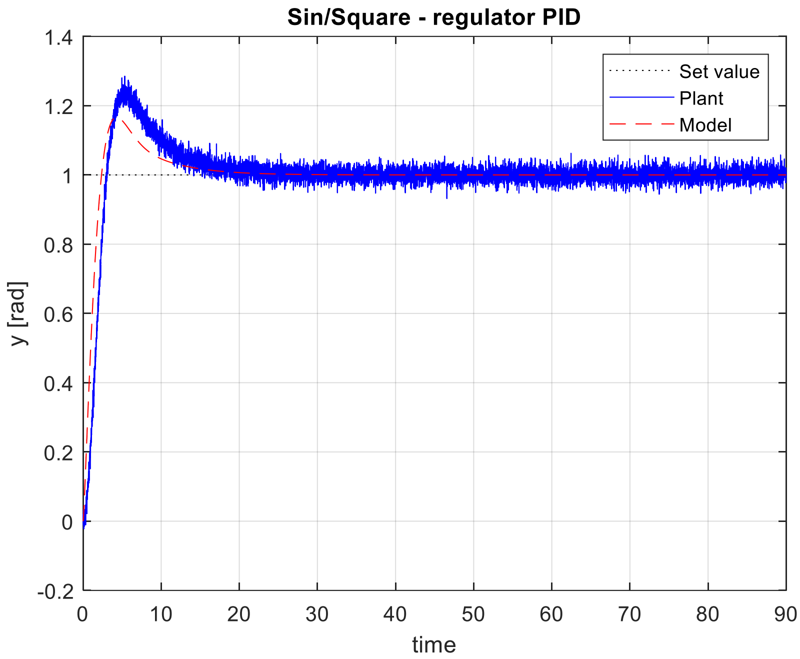


Figure 26 The best PID controller settings

The best parameters of the PID controller were obtained from averaging the parameters obtained when stimulating the system with sinusoidal and rectangular signals.