Closed-loop PID tuning methods

Aim of the work

Using the data obtained from the tests of the closed-loop control system (Åström-Hägglund method), PID parameters can be set. Work purpose is tuning of the controller and system performance verification.

1 Equipment

Controller E5CN or E5CN-H

- Controller type: PID;
- Sensor: temperature (thermocouple type K voltage $0 \ldots 50\ mV\ DC$);
- Output signals: reverse characteristics (for heating).

Process

Thermal object static characteristics are known. Dynamics of the process is unknown, due to the fact that system is "object + thyristor".

Thyristor Y13 with an input signal $i = 4 \ldots 20\ mA$ and output signal $U_{RMS} = 0 \ldots 230\ V$.

Signals recording

- Software oscilloscope Velleman PCSU1000 (PCLab2000) and the amplifier.

TASK

1. **Control criteria**: Step response of the system should be fast and with a small overshoot σ (not greater than 5%).
2. Tune a controller for the object with known parameters.
   (a) Object desired temperature is 180 $°C$.
   (b) Use thyristor as actuator.

Work flow

2 Assembling

✓ Check if Thyristor is turned off (Power OFF).

✓ Assemble the test process (see Fig. 1): controller, actuator and the same thermal object you used in Lab. No. 1.

- Connect output of the controller with input of the thyristor using **Current to Voltage Converter** black and red input jacks.
- Connect output of the controller with the CH2 of the Digital Oscilloscope using **Current to Voltage Converter** black and yellow input jacks.

✓ As the load for the actuator plug the lamp.

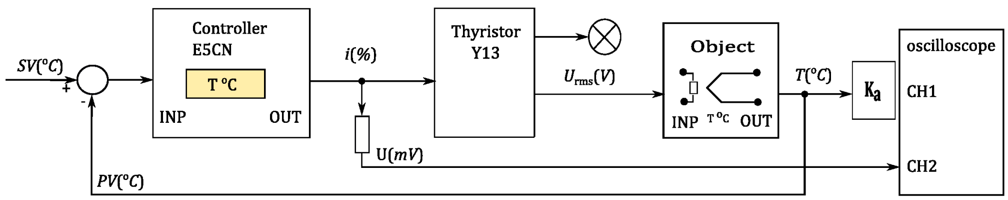

Figure 1: Assembling diagram: PID Control

3 Choice of the operation point

✓ Find out static characteristic $T[°C] = F(i[\%])$ of the block ("thyristor + object"). Use data obtained in Lab. No 1 and Lab. No 3.

Our system is linear, thus it can be tested with any operating point. Lets limit the controller's output i symmetrically in the neighborhood of the operating point $i = i_0 \pm i_m$. If controller's output signal changes inside the whole range $0\% \ldots 100\%$ or $50\% \pm 50\%$, then operating point is $i_0 = 50\%$ and output signal amplitude is $i_m = 50\%$.

✓ Calculate your object temperature T which corresponds to the signal $i_0 = 50\%$.

✓ Set that value as the SV to the controller in **Operation Level**.

4 Tests

✓ Change the controller's type: two-position (ON/OFF) controller in **Initial Settings Level**.

✓ Set minimal possible hysteresis H value in **Adjustment Level**.

✓ Check the applicability of other parameters such as thermocouple: type K, characteristic: reverse.

✓ **Transient Recorder** Mode of the Digital Oscilloscope set the next parameters for signal registration

- CH1 is 0.2 V/div via amplifier (offset = 0-leftmost position) ;
- CH2 is 0.2 V/div output of the controller $i(t)$ through resistor $R = 47.5\Omega$;
- Shift signal CH1 level to the bottom of the screen and CH2 level to the middle of the screen.
- Registration speed is 20 s/div.

✓ Plug in cooler and turn on the actuator.

✓ Observe signal with minimum hysteresis value min H:

1. Wait until process steady-state, read $T_{\max}$ and $T_{\min}$ from the controller's display
2. Record oscillations, study signal more precisely (5 s/div), save figure. Do NOT close the graph!

5 Calculation of the controller's parameters

✓ Determine from the obtained test data next parameters:

1. Process input amplitude i_m [%] (output of the controller);
2. Process output amplitude T_m [$°C$];
3. Period of oscillations P_u

✓ Calculate ultimate gain is $K_u = \dfrac{T_m \cdot \pi}{4 \cdot i_m}$.

✓ Calculate the controller parameters $K_c(\Rightarrow \text{Pb}), T_i, T_d$ (see Lecture 8, Section 4.2).

6 Control system performance

✓ Set the SV = 180 $°C$ in **Operation Level.**

✓ Change the controller's type - PID in **Initial Settings Level**.

✓ Set all PID tuning parameters in **Adjustment Level**.

✓ To observe signal more precisely at the temperature 180 $°C$ neighborhood

1. Change the oscilloscope CH1 range to 20 mV/div;
2. Shift the signal level to the second division (from the bottom) on the screen ≈ 6 divisions of Output Offset $\curvearrowright$.

6.1 Make the next tests:

1. Change SV value 180 $^\circ C \rightleftarrows 200\ ^\circ C$ - step response test;

   (a) Observe overshoot σ [%],

   (b) Settling time T_s.

2. Switch off/on the cooler - reaction on disturbances.

If reaction is unsatisfactory (does not satisfy control criteria) change the PID tuning parameters and repeat the tests.

7 Auto-tuning

✓ Wait for the steady-state.

✓ Turn on the auto-tuning "At: At-2" in **Adjustment Level**. Do nothing until "At" indicator in Adjustment Level or "SV" value in Operation Level stops to flash.

✓ When tuning process is stopped check the new controllers parameters. Write those down.

✓ Make the tests (1-2) from subsection 6.1.

7.1 Completion of the work

✓ Turn of the thyristor (Power OFF).

✓ Disassemble the object input, output.

8 Calculations

1. Provide calculations of the controllers parameters and the results of the tests.

2. **Evaluate** controller performance: what are the overshoot and the settling time values.