Open-loop PID tuning methods

Aim of the work

On the data obtained from the tests of open control system (Lab. No. 1 Control objects), PID parameters can be set. Work purpose is tuning of the controller and system performance verification.

1 Equipment

Controller E5EN

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

Controller with relay output provides pulse signal $u(t)$ which value is $\{ON, OFF\}$, with a period CP and changeable parameter$t_i = 0 \dots \text{CP}$. Output is characterized by the value $u(\%) \approx \frac{t_i}{\text{CP}} \cdot 100\%$ which is in range $0\% \dots 100\%$.

If actuator input is $u(t) = ON$ then it provides RMS voltage U, otherwise $u(t) = OFF \rightarrow U = 0$.

Controller parameters can be observed and set using settings menu.

Power supply and Object

The output signal of the AC power supply (actuator) has 50 Hz frequency and U_{RMS} value, voltage can be changed between $0 \dots 250\ V$.

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 $°C$. Actuator voltage is 180 V.

Work flow

2 Assembling

NB! Connect controllers output and actuator input (power supply) only with protected wires.

✓ Check if power supply is turned 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 object (input of the controller) with oscilloscope CH1 via amplifier.

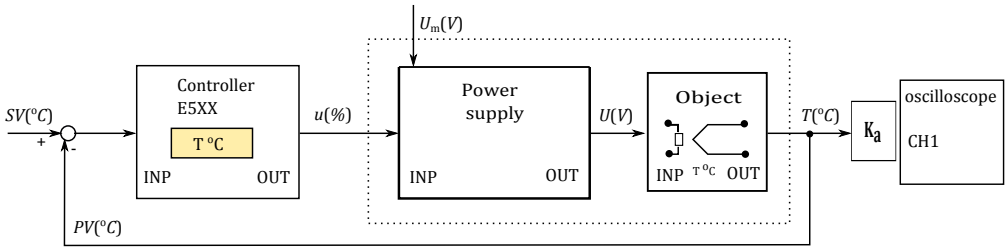

Figure 1: Assembling diagram: PID Control

3 Calculation of the controller's parameters

Use the obtained thermal object data (steady-state characteristic, time constant, delay).

✓ Choose Control Period CP as $CP < \frac{\tau_p}{20}$ of object Time Constant. Set that parameter to the controller in **Initial Setting Level**.

✓ Calculate

1. steady-state gain parameter for the block: "actuator + object" $K_p = \frac{\mathrm{d}T}{\mathrm{d}u\ [\%]}$ (see Lab. No. 4);
2. and dynamic parameters:
   - Time Constant τ (see Lab. No. 1),
   - Delay θ (see Lab. No. 1).

✓ Choose a controller type (PI or PID) and one of the tuning methods suitable for the current process according to the control criteria (see Lecture 8, sections 3.2-3.4).

✓ Calculate the controller parameters $K_c, T_i, \ldots$ using K_p, τ and θ.

4 Control system performance

✓ Set set-point value SV and open-loop tuning parameters K_c, T_i, T_d.

✓ Set digital oscilloscope parameters in **Transient Recorder** mode $0,2\ V/div,\ 50\ s/div$.

✓ Check if amplifier signal offset equals to zero (the leftmost position).

- Turn off CH2 (it is not in use).
- Shift initial level of the channel CH1 to the bottom using "Position" slider.

✓ Turn ON actuator ($U_m = 180V$), observe the signal.

✓ In case of overshoot write maximal temperature value T_{max}, does overshoot exceed $\sigma > 5\%$.

✓ Wait for the steady-state (PV $\approx$ SV).

✓ To observe signal more precisely at the temperature 180 $^\circ C$ neighborhood:

- Change the sensitivity of oscilloscope 20 mV/div - signal will increase;
- Shift the signal level to the second division (from the bottom) on the screen $\approx$ 6 divisions of Output Offset $\curvearrowright$.

4.1 Make the next tests:

1. Change actuator's voltage $\Delta U_m = +40\ V$ and $\Delta U_m = -40\ V$ - reaction on disturbances;
2. Change SV value 180 $^\circ C \rightleftarrows$ 200 $^\circ C$ - step response test;
3. 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.

5 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 (1-3) from subsection 4.1.

5.1 Completion of the work

Set source voltage $U_{in} = 0\ V$. (**Caution!** $U_m = 0 \ldots 250\ V$!)

✓ Disconnect the object, power source and controller.

✓ Disconnect the amplifier from PC USB port.

6 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.