Otto-von-Guericke-University Magdeburg
Faculty of Electrical Engineering and Information Technology
Institute for Automation Engineering

Automation Lab

Temperature Control Lab 1 (TCL1)

Report

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1 Preparation

Acquiring knowledge about parameter estimation methods for linear systems.

1.1 Task 1

Identify qualitatively the associated system behaviour (PT1, PT2 with oscillation, PT2 without oscillation, I) of each step response in Figure 1.1.1.

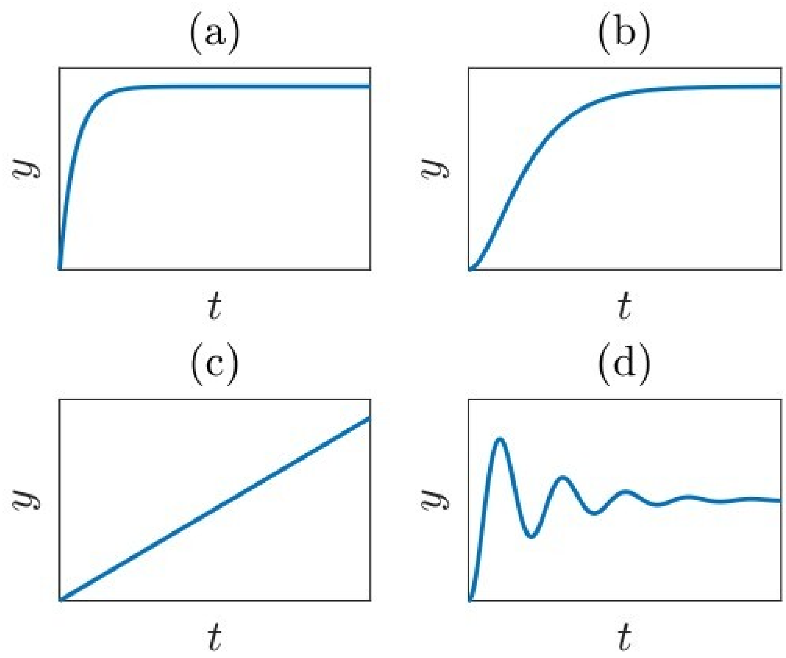

Figure 1.1.1: Step responses of four basic dynamical systems.

(a) PT1

(b) PT2 without oscillation

(c) Integrator

(d) PT2 with oscillation

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1.2 Task 2

Using literature such as [1, 2], acquire knowledge about identification methods used for dynamical systems mentioned above. State three typical methods and explain two of them in detail by answering the following questions.
Below mentioned are some of the identification methods used for dynamical systems :

- Point of Inflection or Tangent Method
- Method of Schwarze
- Sundaresan & Krishnaswamy Method
- Least Square Method
- Relay Feedback Method

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1.2.1 What are the requirements for the applicability of the identification method?

- Process model structure and its Step Response. (1)

Step response must be stable

1.2.2 What kind of input signal is required?

- Step Input
- The same input is required for all the methods.

1.2.3 How are the specific parameters of the dynamical system obtained from its response to the input signal?

- **Point of Inflection or Tangent Method**

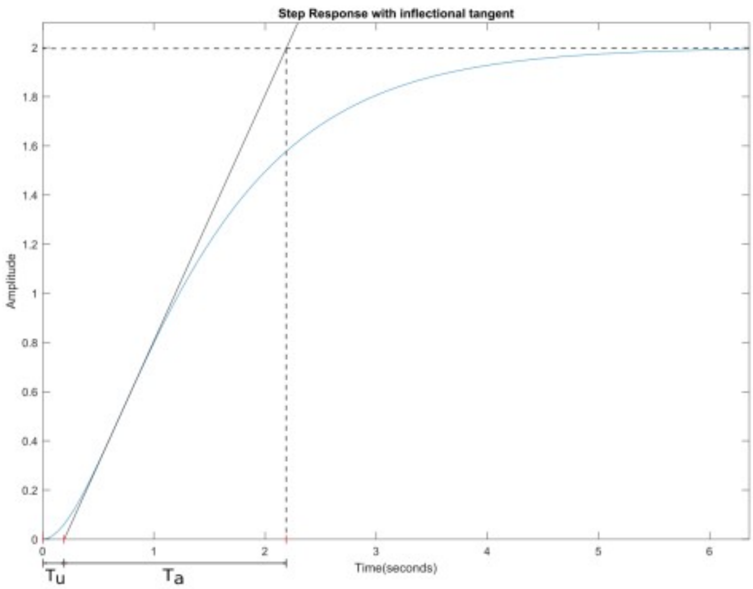

Figure 1.2.1: Step response of a PT2-System with inflectional tangent

Parameters of the transfer function are n, K_s, T_1 and T_2 ; where n is the order of the system which decides the transfer function of the system.

$$G(s) = \frac{K_s}{(1 + T_1 s)(1 + T_2 s)}$$

n, T_1 and T_2 are determined by the values of delay time T_u and rise time T_a.

n	T_a/T_u
2	9.65
3	4.59
4	3.13

Table 1.2.1: System order identification

T_2/T_1	T_a/T_1	T_a/T_u
2.0	4.00	10.35
3.0	5.20	11.50
4.0	6.35	12.73
5.0	7.48	13.97
6.0	8.59	15.22
7.0	9.68	16.45
8.0	10.77	17.67
9.0	11.84	18.88

Table 1.2.2: Relation between the factors.

Process gain K_s is calculated by

$$K_s = \frac{\Delta y(t)}{\Delta u(t)}$$

- **Method of Schwarze**

  Parameters of the transfer function are n, K_s and T of the transfer function

  $$G(s) = \frac{K_s}{(1 + Ts)^n}$$

  Process gain K_s is calculated by,

  $$K_s = \frac{\Delta y(t)}{\Delta u(t)}$$

  To calculate system order n and time factor T the time instance at 10%, 50% and 90% of amplitude is required as shown in the figure 1.2.2.
  n is identified by using ratio μ from table 1.2.3 :

  $$\mu = \frac{t_{10}}{t_{90}}$$

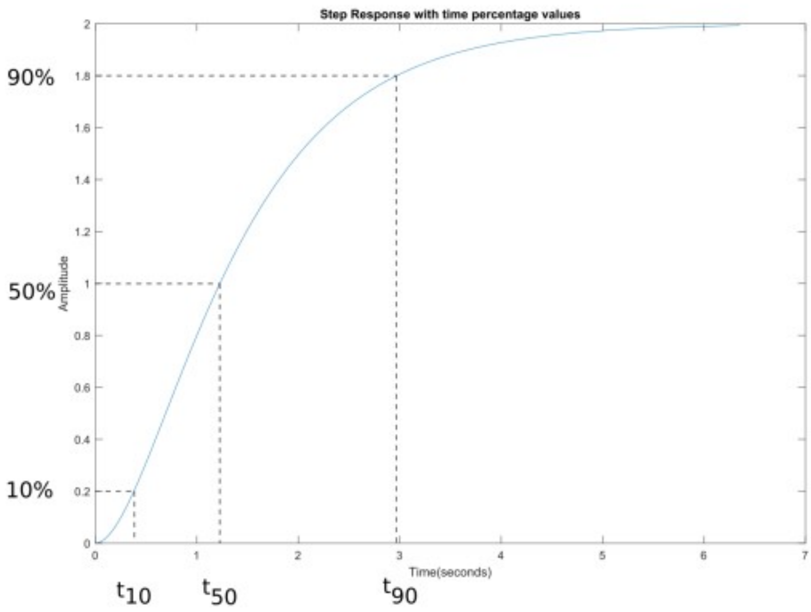

Figure 1.2.2: : Step response of a PT2-System with time percentage values

n	μ
2	0.137
3	0.207
4	0.261

Table 1.2.3: System order identification

Identify percentage-based parameters, τ_{10}, τ_{50} and τ_{90} with the order n from the table 1.2.4

n	10	50	90
1	0.105	0.693	2.303
2	0.532	1.678	3.890
3	1.102	2.674	5.322
4	1.745	3.672	6.681

Table 1.2.4: Percentage-based parameter identification.

Calculate time Factor T by using

$$T = \frac{1}{3}\left[\frac{t_{10}}{\tau_{10}} + \frac{t_{50}}{\tau_{50}} + \frac{t_{90}}{\tau_{90}}\right]$$

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2 Practical part

Gaining practical experience by applying model identification methods to independently obtained real world data.

2.1 Task 1

After a pre-heating phase of 5 min using 20% of the maximal power output regarding Heater 1, apply a step input to Heater 1 from 20% to 60% of the maximal power output and save the temperature profile obtained with Sensor 1.

- Input : Heater 1 (%)
- Output : Temperature 1 (°C)

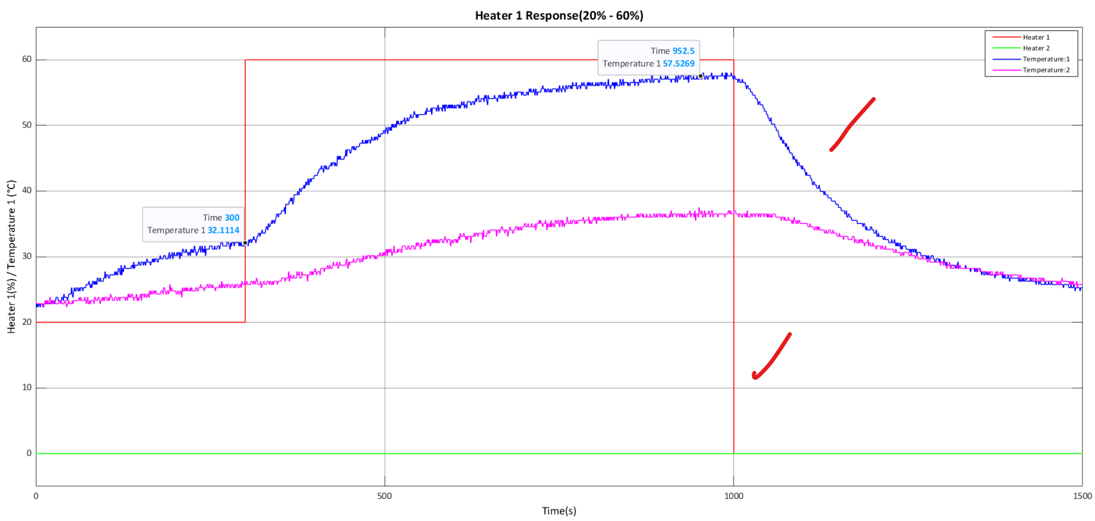

Figure 2.1.1: Heater 1 Step Response (20% - 60%)

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2.2 Task 2

Identify the system behavior of the Heater-Sensor-System. Use the tangent method [3] as well as the method of Schwarze [3] to determine the transfer function of the Heater-Sensor-System.

2.2.1 Tangent Method

In order to calculate the transfer function using the tangent method, an inflectional tangent of the step response is drawn as shown in Figure 2.2.1

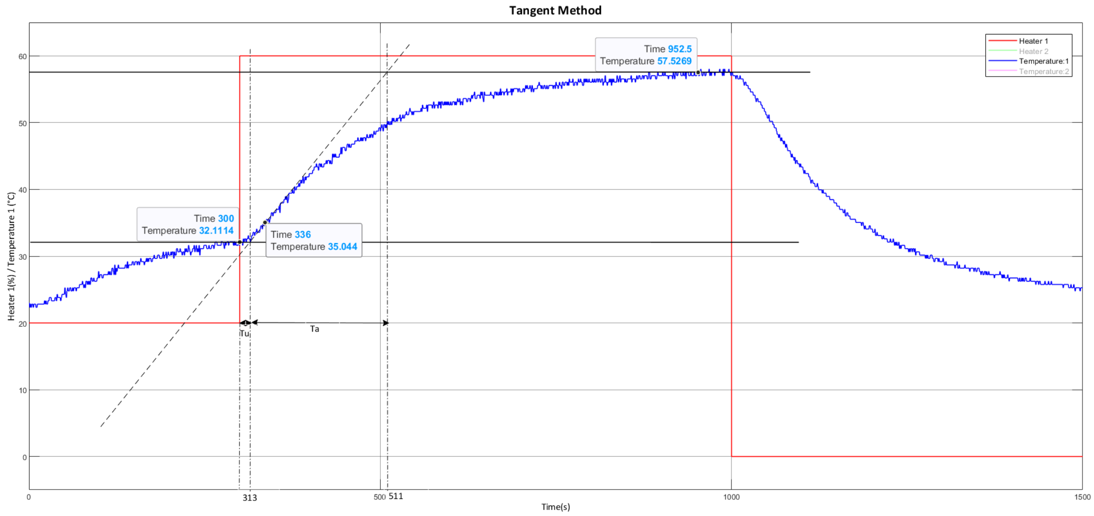

Figure 2.2.1: System Identification using Tangent Method

Y-axis	Heater 1(%) / Temperature 1(°C)
Inflection Point	t = 336s & Temp = 35.044°C
Delay Time(T_u)	13s (313 - 300)
Rise Time(T_a)	198s (511 - 313)
T_a/T_u	198/13 = 15.23
K_S=x_a/x_e	(57.5 - 32.1)°C/ (60 - 20)% = 0.635

Table 2.2.1: Data for calculating Transfer Function using Tangent Method

- Step response origin is considered at x = 300s; y = 32.1114°C / 20% maximum ouput power. Steady state value of the step response is 57.5°C.
- An inflectional tangent of the step response is drawn as shown in figure 2.2.1 with the inflection point as mentioned in table 2.2.1.
- As per the table 2.2.1 T_a/T_u is 15.2 and when compared with the data given in the handout [3] order of the system can be taken as n= 2. Therefore we take :

$$\frac{T_a}{T_1} = 8.59 \qquad \frac{T_2}{T_1} = 6.0$$

- Solving this equation gives $T_1 = 23.05$ and $T_2 = 138.3$. Hence Transfer Function G(s) can be written as :

$$G(s) = \frac{K_s}{(1 + T_1 s)(1 + T_2 s)}$$

$$G(s) = \frac{0.635}{(1 + 23.05s)(1 + 138.3s)} = \frac{0.635}{(3187.8s^2 + 161.35s + 1)}$$

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2.2.2 Method of Schwarze

In order to calculate the transfer function using the method of Schwarze, time percentage values are determined. These are obtained from the step response as shown in Figure 2.2.2

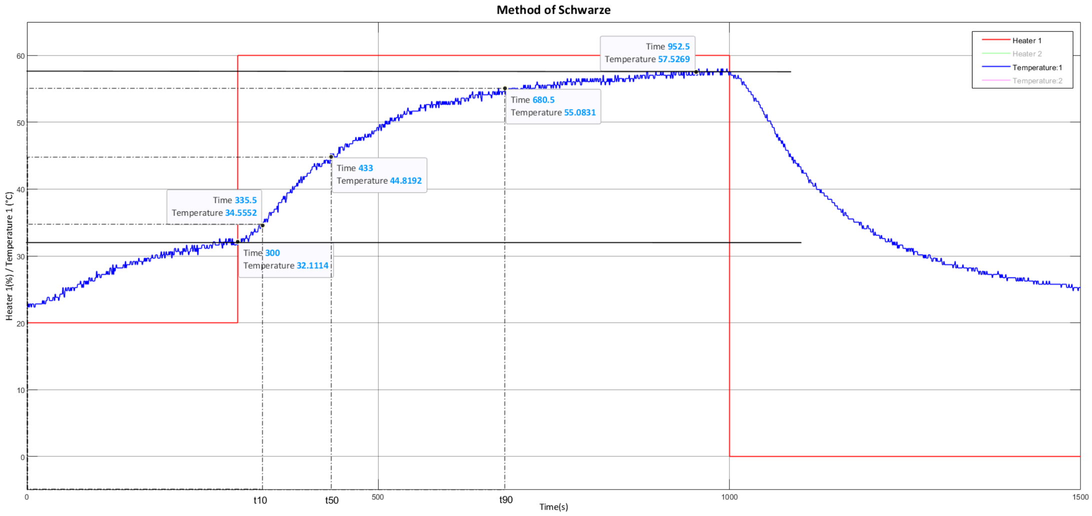

Figure 2.2.2: System Identification using Method of Schwarze

Y-axis	Heater 1(%) / Temperature 1(°C)
K_S=x_a/x_e	0.635(From Tangent Method)
t_{10}=10% → t(34.6°C)	335.5s(35.5s as 300s is Step signal input time)
t_{50}=50% → t(44.8°C)	433s (133s)
t_{90}=90% → t(57.96°C)	680.5s (380.5s)

Table 2.2.2: Data for calculating Transfer Function using Method of Schwarze

- Step response origin is considered at x = 300s; y = 32.1114°C / 20% maximum output power.The steady-state value of the step response is 57.5°C.
- The values of time corresponding to 10%,50%, and 90% of the steady state value of the system are identified in the figure 2.2.2.

$$\mu = \frac{t_{10}}{t_{90}} = \frac{35.5}{380.5} = 0.093$$

- Therefore based on the value of μ, n=2 . For n = 2, $\tau_{10} = 0.532, \tau_{50} = 1.678; \tau_{90} = 3.890$; is taken as given in the handout [3]

$$T = \frac{1}{3}\left[\frac{t_{10}}{\tau_{10}} + \frac{t_{50}}{\tau_{50}} + \frac{t_{90}}{\tau_{90}}\right] = 81.26$$

- Hence the transfer Function can be written as :

$$G(s) = \frac{K_s}{(1+Ts)^n}$$

$$G(s) = \frac{0.635}{(1+81.26s)^2} = \frac{0.635}{(6603.1s^2+162.52s+1)}$$

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2.3 Task 3

Validate the identified transfer function in Matlab/SIMULINK by replacing the corresponding TCL-block with this transfer function and simulate the temperature response of the Heater-Sensor-System using the same step input.

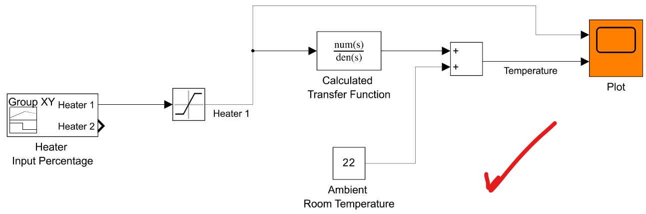

Figure 2.3.1: Simulink diagram corresponding to replacing the TCL Unit

- The above-given simulink diagram is used, due to the fact that the TCL block reads the real-time value from the system and hence the Transfer function will result in an error if the TCL block is removed. However, the figure 2.3.1 replicates the system behaviour with the same input as given to the TCL block.
- The simulation is performed for both method's transfer function.

2.4 Task 4

Compare the experimental step response with the simulated step response.

- The Tangent Method's transfer function led to reaching the steady-state value of 57.5°C compared to the Schwarze Method's transfer function. why?
- Practical Experiment: A disturbed step response(Temperature 1) is observed for step input(heater 1). Increase in Temperature 2 is seen even though the input of heater 2 is zero, due to conduction of heater 1.
- Simulation : A smooth step response is observed for a step input.

2.4.1 Tangent Method

Comparing Figure 2.2.1 and 2.4.1

- The Steady state value of Simulation is 59.7°C, where as in practical experiment it is 57.52°C

why?

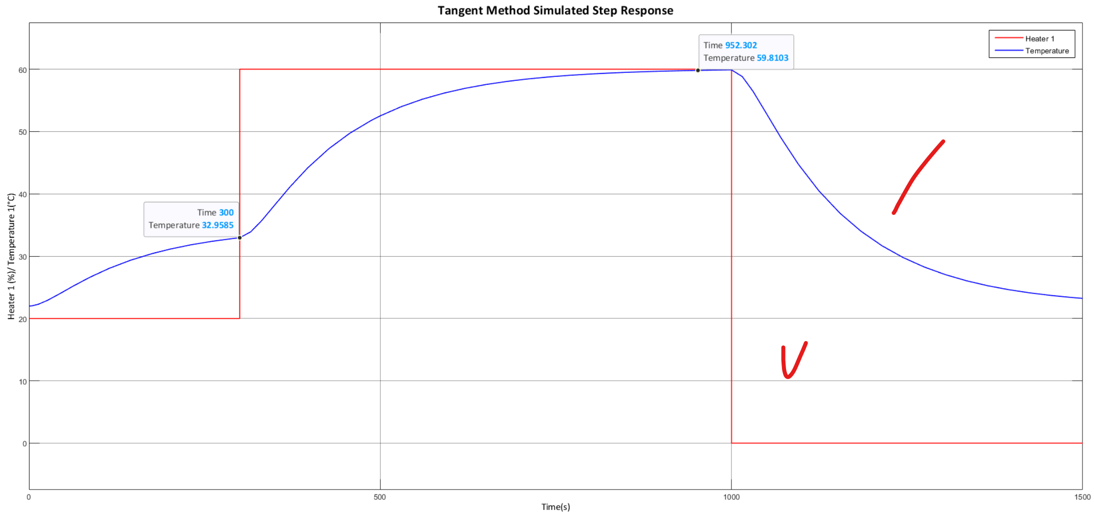

Figure 2.4.1: Step response of Transfer Function using Tangent Method

2.4.2 Method of Schwarze

Comparing Figure 2.2.2 and 2.4.2

- The Steady state value of Simulation is 60.0°C, where as in practical experiment it is 57.52°C

, why?

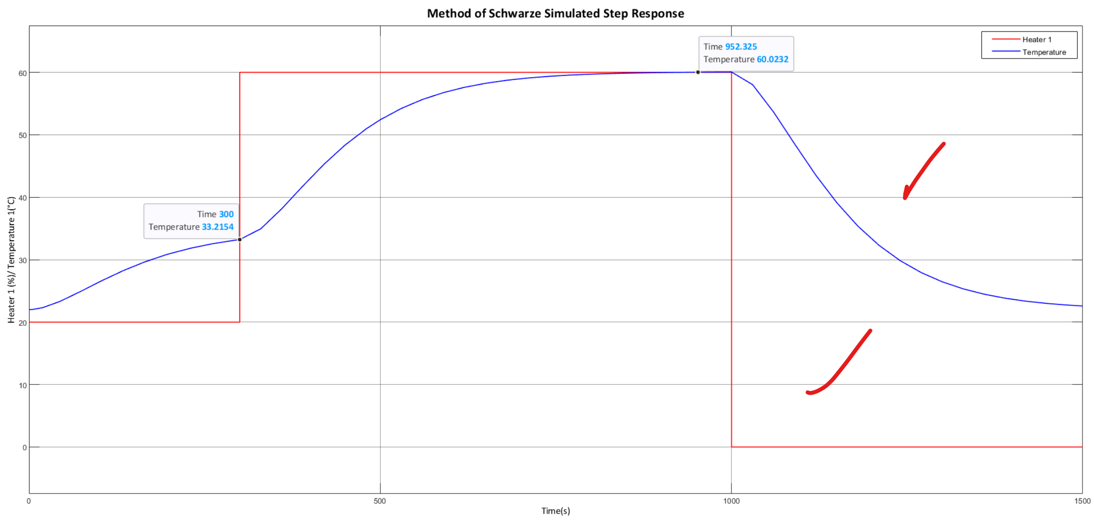

Figure 2.4.2: Step response of Transfer Function using Method of Schwarze

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Bibliography

[1] R. C. Panda and T. Thyagarajan, *An Introduction to Process Modelling Identification and Control for Engineers*, Alpha Science International, Hoboken, 2012.

[2] D. E. Seborg, *Process Dynamics and Control*, John Wiley and Sons, Oxford, 2017.

[3] Handout TCL 1.

Style: very nice but to many pages

captions ✓

resolution ✓

x-y label ✓

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