FAKULTÄT FÜR ELEKTROTECHNIK UND INFORMATIONSTECHNIK

Institute for Automation Engineering
Chair for Automation/Modeling

AUTOMATION LAB-25/26

TEMPERATURE CONTROL LAB 1

REPORT TCL1

DATE: 23-11-2025

GROUP 16

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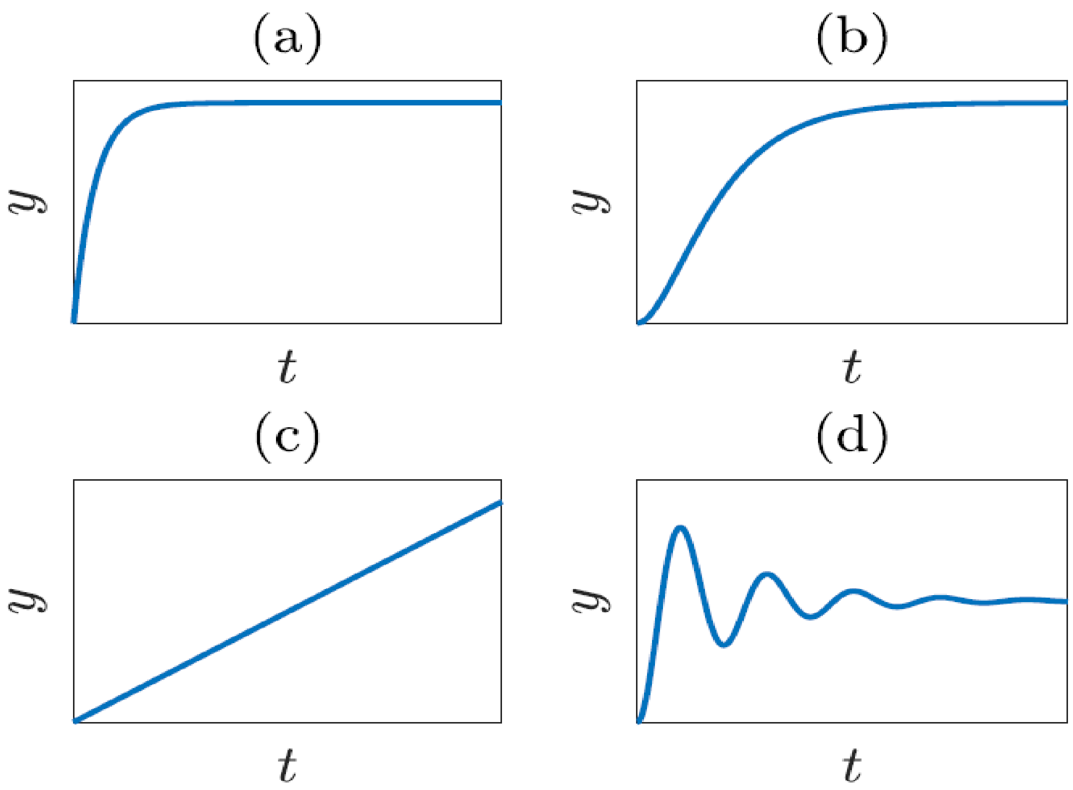
CONTENTS

2 Model identication with aperiodic test signals

2.1 Preparation

2.1.1 Identification of system behavior



[1]Figure 2.1: Step responses of four basic dynamical systems.

- Figure 2.1(a): The response has flat rise, no overshoot and it also approaches the steady value asymptotically. Thus it is the response of a **PT1 system**(First order-lag).
- Figure 2.1(b): The response has curved s shape with slower rise and no overshoot. Thus, it the response of a **PT2 system without oscillation**(Second order, overdamped system).
- Figure 2.1(c): The response increase linearly with time. Thus, it is an **I system**(Integrator)
- Figure 2.1(d): The response has clear oscillations that decay over time. Thus, it is the response of a **PT2 system with oscillation**(Second-order, underdamped).

2.1.2 Identification Methods:

The three identification methods used for the dynamical systems are:
1.Least squares method
2.Schwarze method
3.Tangent method

Tangent Method:

(a)Requirements of applicability.

- The system must be stable and the step response must be monotonic(no oscillation).
- Mainly applicable for PT1 and over-damped PT2 system.
- Curve must be smooth enough to draw a clear tangent at the inflection point.
- Requires measurable delay and rise time.
- Step response must reach a steady final value.

(b)Required Input Signal.

- A step input signal is required.

(c)How parameters are obtained from its response to the input signal.

- Locate the inflection point on the step response on the step response and draw the tangent.
- Read the characteristic times,delay time(Tu) and rise time(Ta).
- Use the time ratio Ta/Tu with reference tables to identify the system order and also to obtain normalized parameters.
- Determine the steady state gain Ks by the following equation,where Δy the change in output and Δu the applied input step amplitude.

$$Ks=\Delta y/\Delta u.$$

- For PT2 systems use the looked up factors(from the same table) to convert Tu and Ta into the PT2 parameters:damping ratio(ζ),natural frequency w_n or the two time constants T1,T2.

Schwarze Method:

(a)Requirements of applicability.

- The system must be linear and time invariant and the step-response must be smooth and sufficiently noise free.
- The system must reach a steady state after applying the step input.

- Suitable primarily for PT2 systems where damping and natural frequency are unknown.

(b)Required input signal.

- A step input signal is required. The amplitude of the step should be known to compute steady state gain.

(c)How parameters are obtained from its response to the input signal.

- Calculate system gain (*KS*)as in the Tangent Method.
- Measure three characteristic time points on the step response corresponding to 10%, 50%, and 90% of the final value.
- Use the ratio $\mu = t_{90}/t_{10}$ to identify system order (n)from a reference table.
- Determine time factors (τ_{10},τ_{50}, τ_{90}) from parameter tables.
- Compute system time constant(*T*) using: $T = \frac{1}{3}\left(\frac{t10}{\tau 10} + \frac{t50}{\tau 50} + \frac{t90}{\tau 90}\right)$.

2.2 Practical Part.

2.2.1 Temperature profile obtained with Sensor 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.

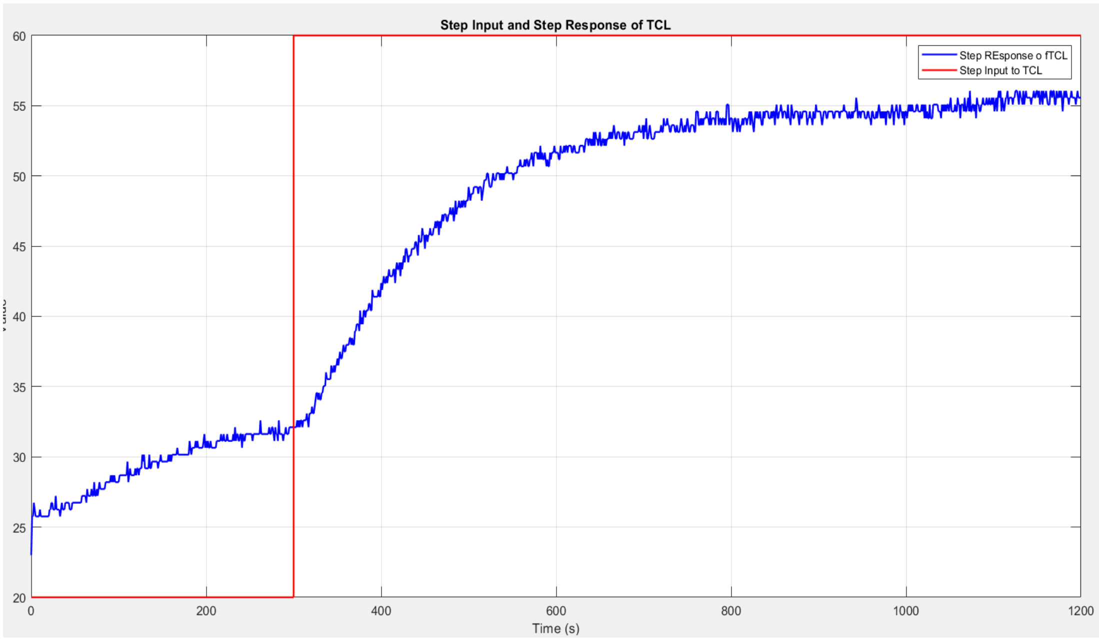


Fig2.2 Input and step response of TCL

The analysis of the step response of the Temperature Control Lab (TCL) indicates that the Heater-Sensor System exhibits the characteristics of a second-order system without oscillatory behavior, commonly referred to as a PT2 system.

2.2.2 (a)Tangent method to determine the system behaviour.

The Tangent Method uses the delay time(Tu) and the rise time(Ta) as fundamental parameters for deriving a system's transfer function. The figure below demonstrates how the Tangent Method is applied to the original step response, showing how these time constants characterize the system's dynamic behavior and enable the determination of its transfer function.

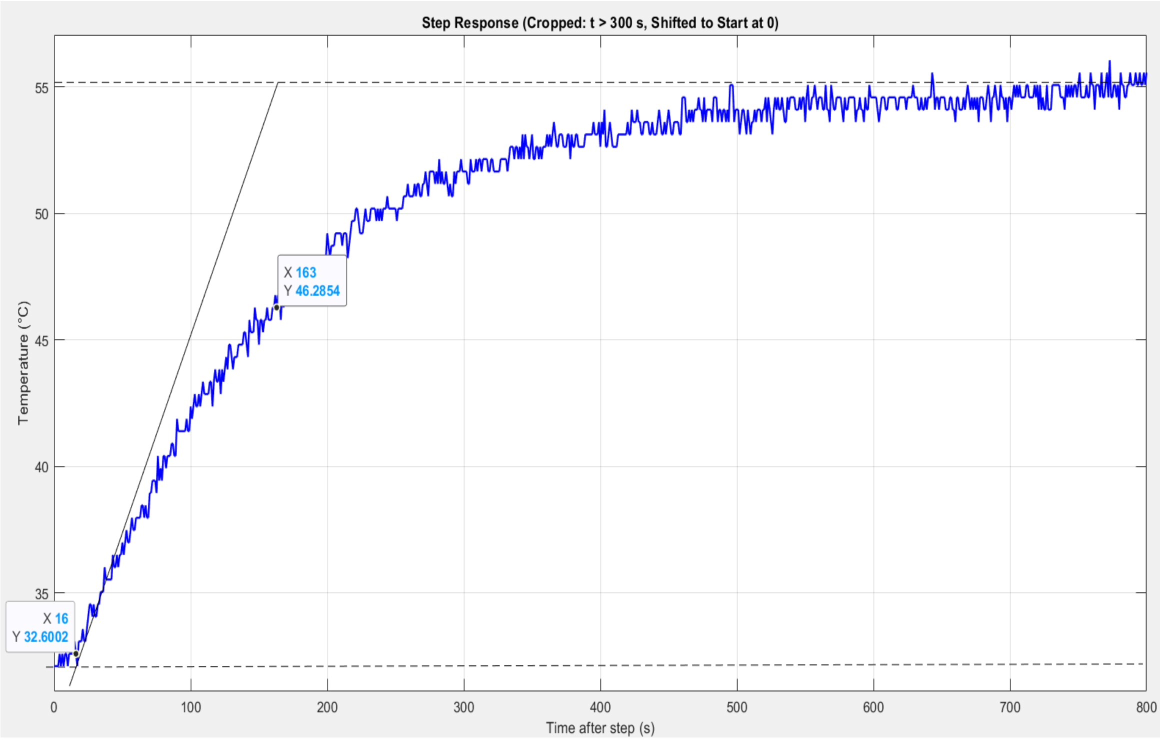


Fig2.3 Step response of sensor with inflection point

The system order n can be determine using the ratio $\frac{Ta}{Tu}$. By reading the values from the graph using MATLAB.

$$\frac{Ta}{Tu} \approx 9.18, \text{Tu} = 16, \text{Ta} = 147$$

By comparing this ratio with the entries in the table 1 of Handout[2]. From the comparison, it is verified that the system is of order n = 2.

The gain KS is calculated using the following formula:

$$\text{Ks} = \frac{xa}{xe} \approx 0.58, \ x_a = 23.5 \ , x_e = 40$$

Time constants T1 and T2, and from the ratio $\frac{Ta}{Tu}$(We choose first row of the table 2 of Handout[2] having value near to the ratio value).

From the table $\frac{Ta}{T1} = 4$, So $T_1 = \frac{Ta}{T4} = 36.75$.

$\frac{T2}{T1} = 2$, $T_2 = 2T_1 = 73.5$.

There for the transfer function by Tangent Method according to the Handout[2] of the Heater-Sensor System is:

$$G(s) = \frac{KS}{(1+T1s)(1+T2s)}$$

$$G(s) = \frac{0.58}{(1+36.75s)(1+73.5s)}$$

2.2.2 (b)Schwarze method to determine the system behavior.

Inorder 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 below.

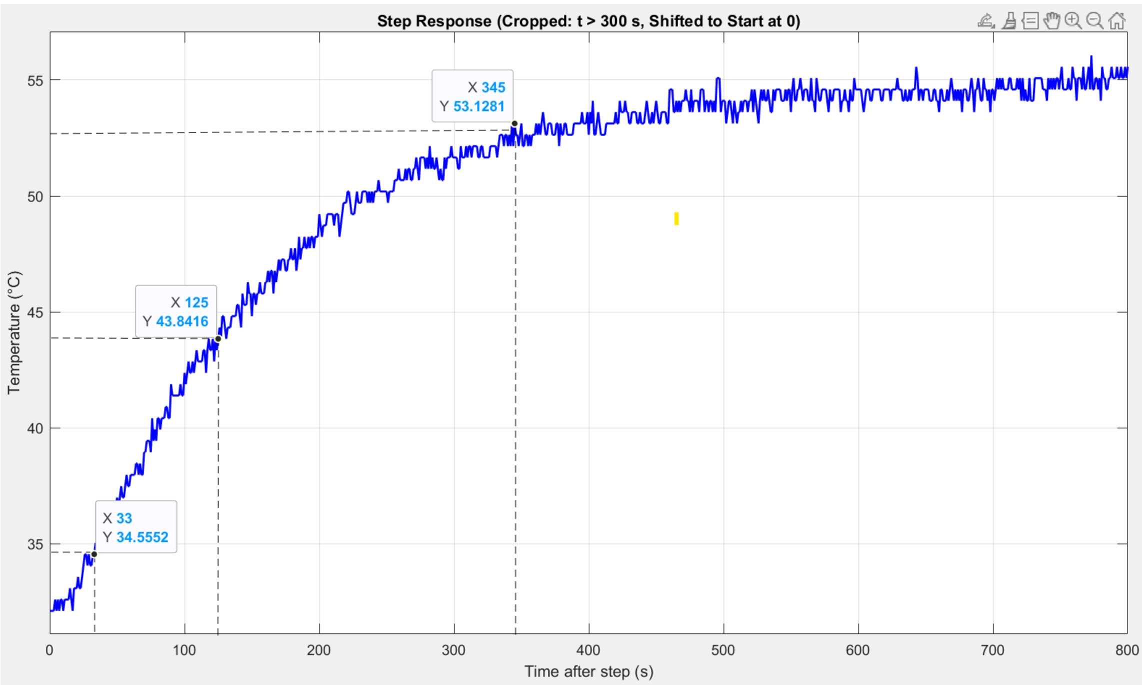


Fig2.4 Step response of a system with time percentage value

- The transfer function of the system is: $G(s) = \frac{Ks}{(1+Ts)^n}$

- From the figure, we determined the corresponding time which amplitudes are 10%, 50% and 90% of steady state value which are:

$$t_{10} = 33s \text{ , } t_{50} = 125s, t_{90} = 345s$$

- Order n of the system is determined using the ratio from table 3 in Handout[2] $\mu = \frac{t10}{t90} \approx 0.09$,Hence the system order is n = 2.
- The gain Ks = 0.58 as same as the Tangent Method
- With the data from the step response and table 4 from the Handout [2], for n = 2, the parameters are: $\tau_{10} = 0.532$; $\tau_{50} = 1.678$; $\tau_{90} = 3.890$.
- The time constant T should be calculated as $T = \frac{1}{3}(\frac{t10}{\tau 10} + \frac{t50}{\tau 50} + \frac{t90}{\tau 90})$

$$T = \frac{1}{3}(\frac{33}{.532} + \frac{125}{1.678} + \frac{345}{3.890}) = 75.07 \approx 75$$

$$G(s) = \frac{Ks}{(1+Ts)^n} = \frac{.58}{(1+75s)^2} = \frac{.58}{(5625s^2+150s+1)}$$

3 Simulink Model.

Validated the identified transfer function in SIMULINK by replacing the corresponding TCL-block with the respective transfer function of both tangent and shwarze method and simulated the temperature response of the Heater-Sensor-System using the same step input.

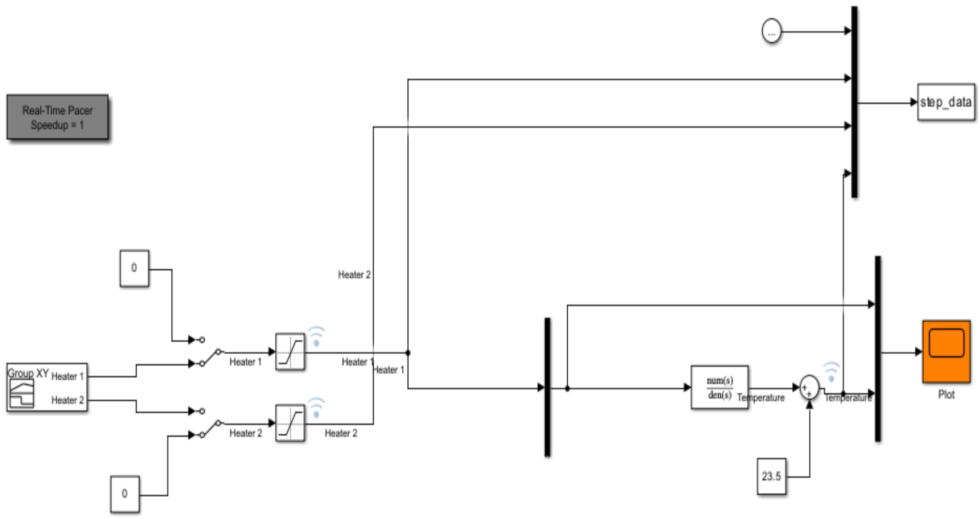


Fig 2.5: Transfer Function Simulation.

Note:The contstant was added for the convenience for the comparision plot of 3 simulations for individual step response(where TCL block was replaced with transfer function), 23.5 was reduced to tally the constant block added to the simulation block diagram to show the orginal step response.

3.1(a) Tangent Method.

The measured response starts at 23.5 °C because it shows the real ambient temperature,while the TCL block starts at 0 since the model is expressed in deviation form and only represents the change from the initial value.

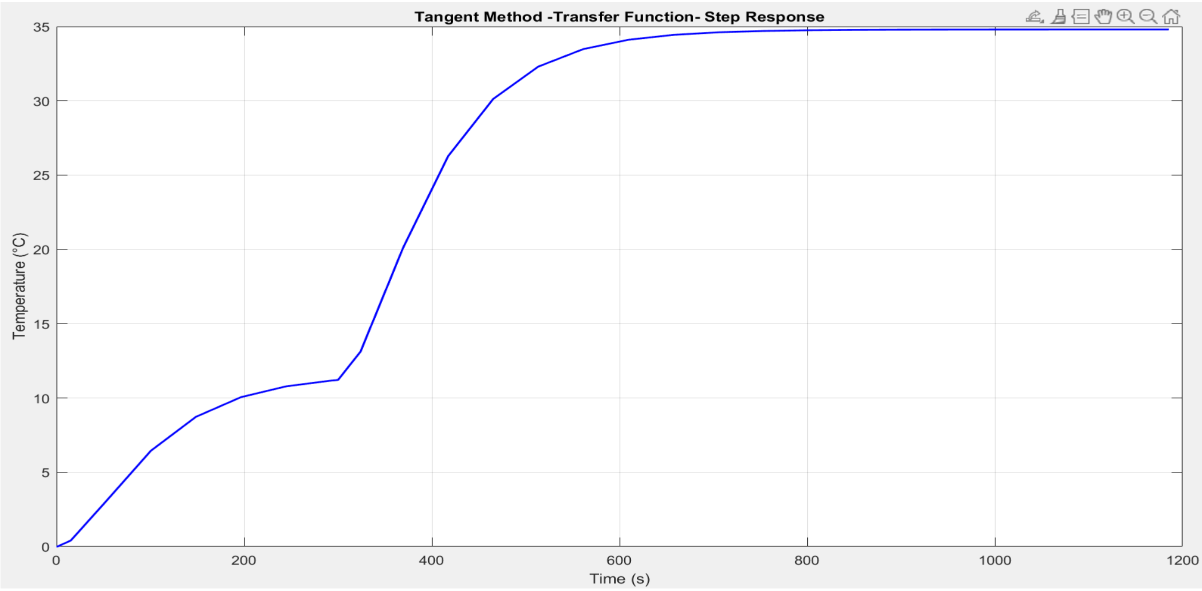


Fig 2.6 Transfer function simulation using tangent method

3.1(b) Schwarze method.

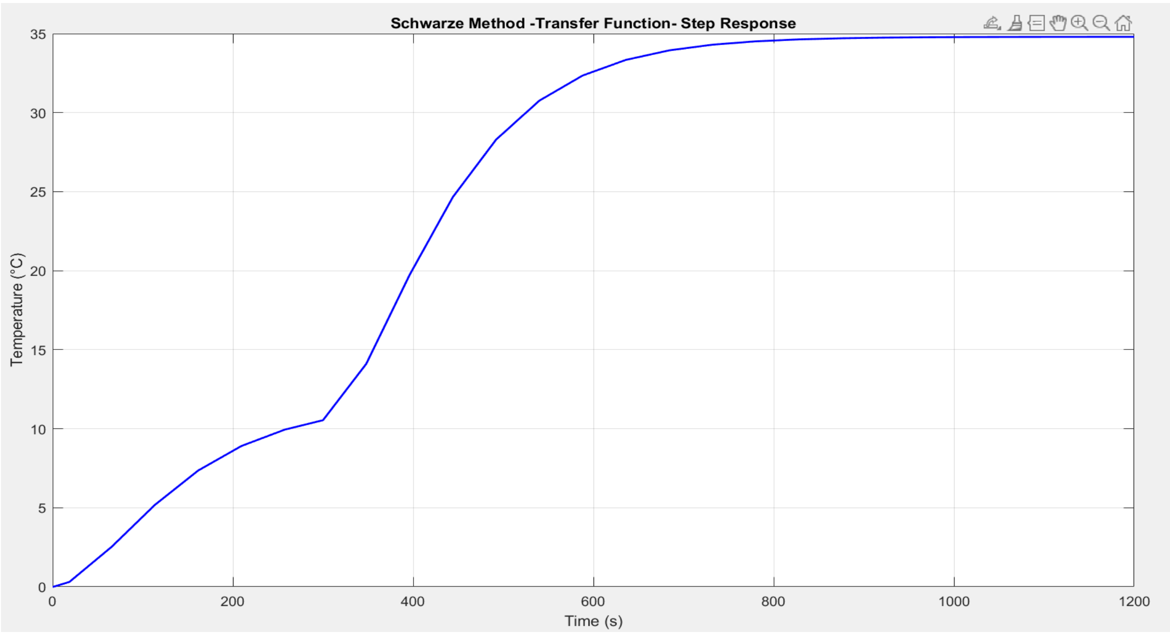


Fig 2.7 Transfer function simulation using schwarze method

For this system, the Schwarze and Tangential methods produce very similar transfer-function responses, and the difference between them remains small and limited to decimal-level variations.

4.Comparision of step responses.

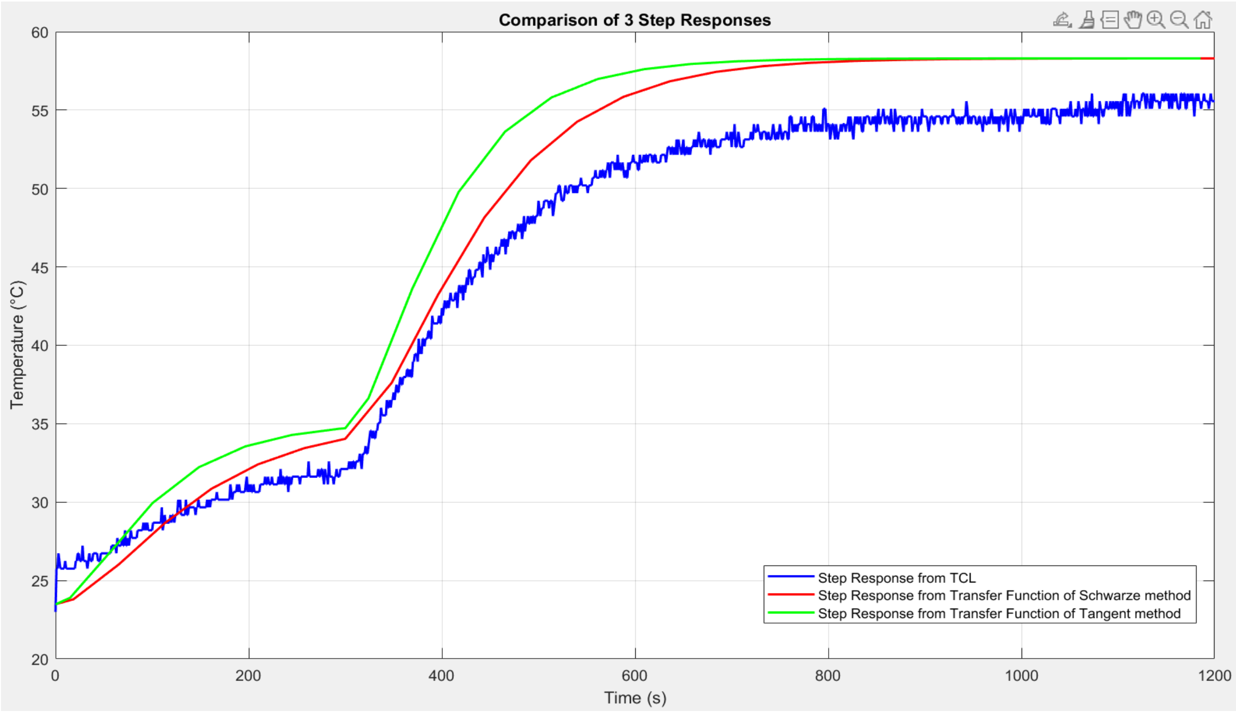


Fig 2.8 Comparision of step responses

5.Conclusion.

Based on the comparison of the three step responses,the response using schwarze method provides a more acurate representation of the Heater-sensor system's dynamic behavior than tangent method from the data derived from the TCL. Overall the task demonstrated both the theoretical identification of system parameters and their practical validation in Simulink. Both methods show similar overall behaviour, but the schwarze Method matches the real system more accurately**.**

6.References:

1. Material TCL 1, 2024. Course: [Automation Lab], University: [Institute for Automation Engineering OVGU].
2. Handout TCL 1, 2024. Course: [Automation Lab], University: [Institute for Automation Engineering OVGU].
3. R. C. Panda and T. Thyagarajan, An Introduction to Process Modelling Identi cation and Control for Engineers, Alpha Science International, Hoboken, 2012.