EE-401 LAB

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TOPIC: Temperature Regulation Process

SHORT DESCRIPTION:

Temperature regulation process maintains a device or a place at a constant temperature. This is used in almost each and every field of application such as household, industrial, research and other such applications. We also use temperature regulation systems in Air Conditioners, Refrigerators, geysers, etc. where the temperature is automatically adjusted as per the input settings. The overall workflow of these systems is, given a desired temperature we find the error signal by using current temperature measurement from the sensors and use a control algorithm to obtain the actuating signal which is sent to the heat source. Our aim is to use PID control as control algorithm.

PAPERS:

1) Temperature Control System and its Control using PID Controller
2) PID Control Design for a Temperature Control System
3) Real Time Temperature Control of Oven Using MATLAB-SIMULINK

PAPER-1 SUMMARY:

The aim of this paper is to design a temperature control system and its control using PID controller for an oven. The paper starts with introducing the basics of heat transfer and develops a mathematical model of the oven. And then it explains basics of PID controller and how it becomes a part of overall regulation process. Then it obtains a transfer function model of the entire system using the experimental data that authors obtained from laboratory. And then it presents a Ziegler–Nicholas tuning method to tune the parameters of PID controller. And finally, in conclusion the authors provide their observations and results.

PAPER-2 SUMMARY:

The aim of this paper is to design a PID controller for the Temperature Control System. The paper starts with explaining P (proportional) controller, PI (proportional integral) controller, PID (proportional integral derivative) controller in detail. Then it explains the tuning of each of the controller mentioned using Ziegler- Nicholas tuning method. And finally, the authors provide their observation and results along with comparison between the P, PI, PID controllers.

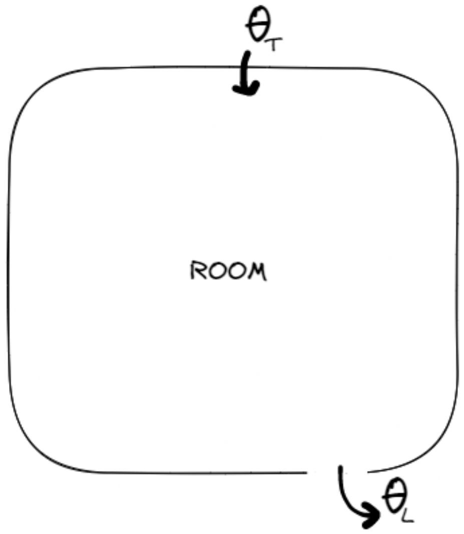
PAPER-3 SUMMARY:

The aim of this paper is to design a MATLAB-Simulink model to control the real-time temperature of an oven using a PID controller. The paper starts with explaining the reliability and performance of the PID controller and then introduces the auto tuning methods for PID controller in detail namely Ziegler-Nichols Step Response Method, Relay Tuning Method and Integral Square Time Error (ISTE) Tuning Method. The PID parameters obtained by the above-mentioned methods are used to control the temperature of the oven. The real-time temperature of oven is obtained in MATLAB-Simulink using a hardware. And finally, the authors provide their observation and results along with comparison between the three tuning methods.

PROBLEM STATEMENT:

We need to develop a mathematical model of a room and design a control system to regulate temperature in that room using PID control algorithm.

MATHEMATICAL MODELLING:



Consider a room whose temperature needs to be regulated. θ_T is the rate of total rate of heat flow which is controlled. θ_L is the rate of heat flow moving out of room considered as loss. So, (θ_T - θ_L) is used to decrease or increase the temperature in the room.

Hence,

$$\theta_T = mc\frac{\Delta T}{\Delta t} + \theta_L$$

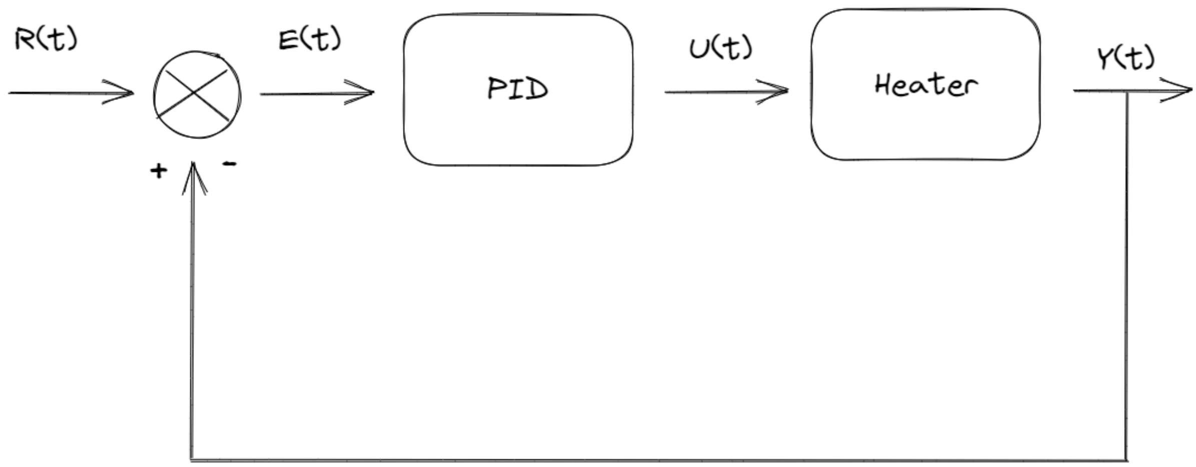
where,

m is mass of the air in the room (which is around 80 kg)

c is the specific heat of air at constant volume (which is 0.718 kJ / kg K) and

$$\theta_L = \frac{(T_{room} - T_{out})}{R_{eq}}$$

CONTROL DESIGN:



$$U(t) = K_p E(t) + K_i \int_0^t E(\tau) d\tau + K_d \frac{dE(t)}{dt}$$

Here, R(t) is the constant setpoint, E(t) is the error signal which is the difference between setpoint and measured temperature in the room. And U(t) is θ_T. And Y(t) is the measured temperature.

PID TUNING:

Tuning the PID controller involved determination of K_p, K_i, K_d that best suit our needs. We started with Zeigler-Nichols method. First, we set K_i and K_d to 0. Using the proportional control action only, we increase K_p from 0 to critical value K_{cr} at which the output exhibits sustained oscillations. Thus, the critical gain K_{cr} and the corresponding period P_{cr} are experimentally determined. Ziegler and Nicholas suggested that we set the values of the parameters K_p, K_i, K_d according to the formula shown below:

$$K_p = 0.6\, K_{cr}$$

$$K_i = 1.2\, \frac{K_{cr}}{P_{cr}}$$

$$K_d = 0.075\, K_{cr}\, P_{cr}$$

But we found these values are overshooting and causing the measured temperature to diverge. So, we used the formulas from No Overshooting method.

$$K_p = 0.2\, K_{cr}$$

$$K_i = 0.4\, \frac{K_{cr}}{P_{cr}}$$

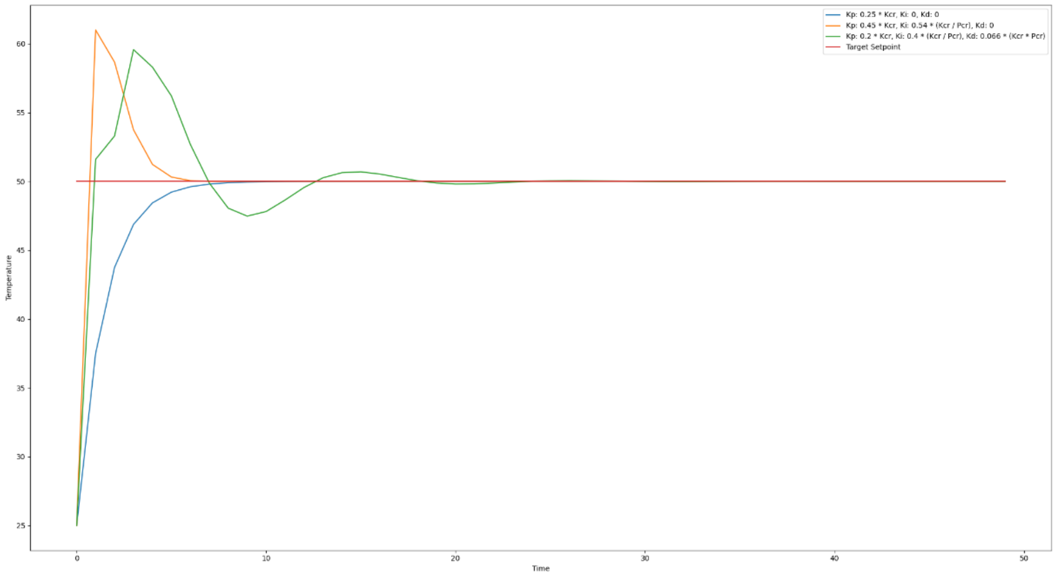
$$K_d = 0.0\overline{6}\, K_{cr}\, P_{cr}$$

CODE STRUCTURE:

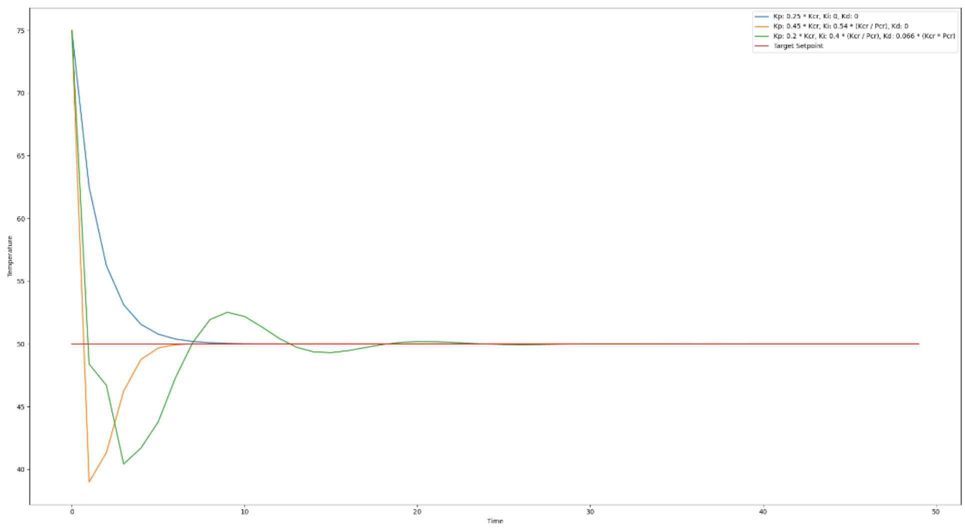
The code is available [here]

1. **room.py:** It implements a class, Room with init and step methods.
2. **pid.py:** It implements a class PID with init, step and reset methods.
3. **main.py:** It runs the simulation and contains the flow of the code. And plots the results of the simulation.

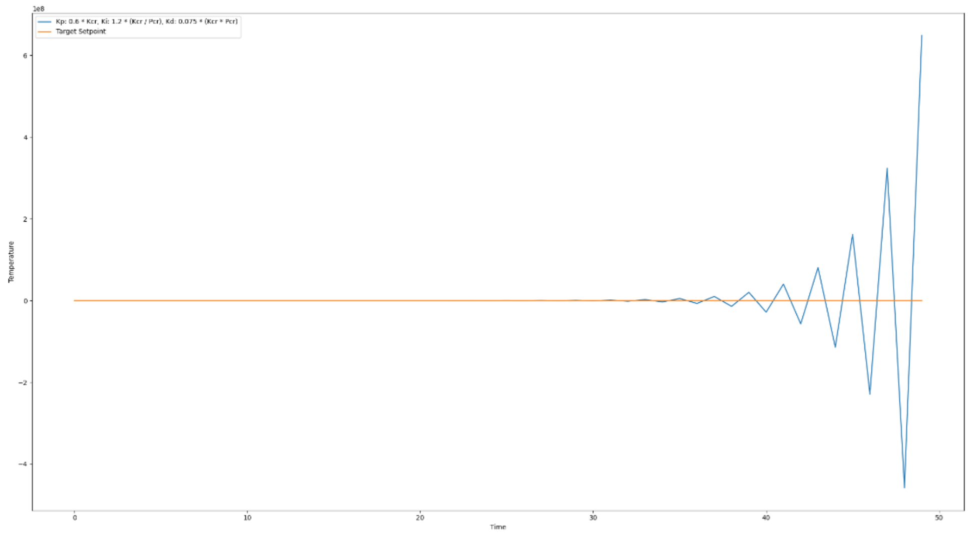
OUTPUTS AND SIMULATION:



Simulation with P, PI, PID controllers (with starting temperature of 25°C)



Simulation with P, PI, PID controllers (with starting temperature of 75°C)



Simulation of PID controller with parameters obtained from ZN method (Diverges)

CONCLUSION:

From the simulations and observations, we have seen that PID controller can be used to regulate temperature in different conditions. But PID tuning should be done carefully, because in our case on using the Ziegler-Nicholas second method parameters, we found that the response is diverging away from the setpoint.

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