Temperature control using a PID controller of Home Appliance (Cloth Iron)

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Abstract

Temperature Control Systems are a major part of Home Automation and are widely used across various industries. Here we model a system that maintains the temperature of the home appliance (Cloth Iron) at a desired level.

I. INTRODUCTION

In this paper we present the mathematical modelling of a system that controls the temperature of the cloth iron**.** Clothing Irons are used in almost every household.

The paper is divided into ***XIV*** sections (including this one). In this section we have introduced the basic structure of our system. The transfer function of the Home Appliance is calculated in section II.

The input of the system is the desired reference we want and the output is the controlled output.

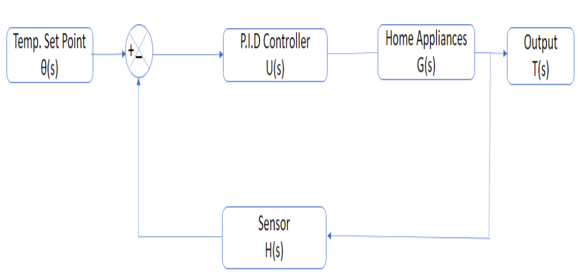

Fig 1. PLANT BLOCK DIAGRAM

Derivation of Appliance Transfer Function

The heat we input is used up in the following two forms,

1) Part of it is used in the transfer from the coil to the plate of the Cloth Iron
2) Part of it is lost to the atmosphere.

Heat can be transferred via 03 ways, i.e., conduction, convection and radiation. Ignoring the effect of radiation for simplicity, Heat transfer by conduction and convection is given by,

$$\Theta = \alpha \Delta T \qquad \textbf{(1)}$$

Where, Θ is the rate of heat flow with unit joule/sec.

ΔT is the Temperature difference, and

α is a constant

Thermal Resistance is defined as,

$$R = \frac{\Delta T}{\theta}$$

Thermal Capacitance is given as,

$$\theta = \frac{C \times (d(\Delta T))}{dt} \qquad \textbf{(2)}$$

Comparing these relationships with Analog Electronics, we can notice that thermal resistance is the analogous to V-I characteristics of a Resistor and the same can be said about the thermal capacitance and a Capacitor.

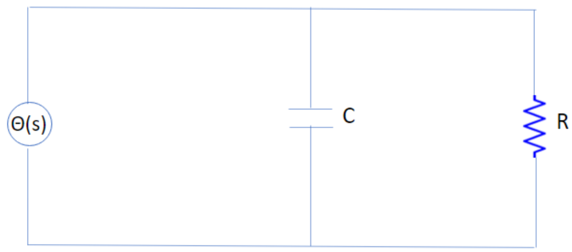

FIG 2. ANALOGOUS CIRCUIT

By applying law of conservation of energy,
Heat in = Heat stored + Heat lost

We get,

$$\theta(T) = C\times\frac{d(T)}{dt} + \frac{T-T_{ROOM}}{R}$$

Where,
θ Is the rate of heat flow,
C is the thermal capacitance,
R is the thermal resistance,
T is the output Temperature,
T_{ROOM} is the room temperature.

Taking Laplace Transform we get with initial zero conditions,

$$\frac{T(s)}{\theta(s)} = \frac{R}{1+sRC}$$

II. PID Controller

The Proportional-Integral-Derivative Controller is the most widely used controller. These 3 parameters minimize the error which is the difference between the desired value and the process value.

The mathematical form of the PID Controller is given below,

$$u(t) = K_p e(t) + K_i \int_0^t e(t')dt' + K_d \frac{de(t)}{dt}$$

Where K_p, K_i and K_d are all non-negative coefficients.

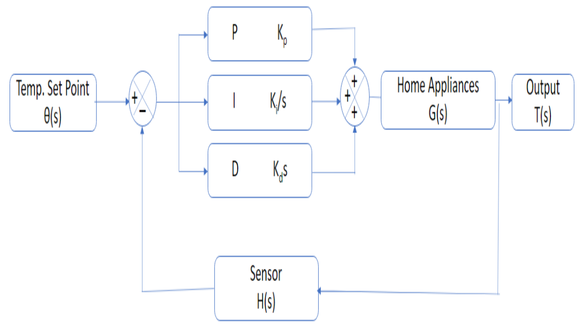

FIG. 3 PID BLOCK DIAGRAM

Transfer Function of PID controller

$$U(s) = K_p + \frac{K_i}{s} + K_d s$$

The values of the parameters in our system are as follows:

1) K_p = 500
2) K_s = 0
3) K_I = 0

III. OVERALL CLOSED LOOP TRANSFER FUNCTION

The overall closed loop transfer function of our plant is given by **eq^n (X).**

$$\frac{T(s)}{\theta(s)} = \frac{U(S)G(s)}{1+H(s)U(s)G(s)}$$

Where,
U(s) = Controller Transfer Function
G(s) = Plant Transfer Function
H(s) = Feedback

A. TIME DOMAIN ANALYSIS

IV. Open Loop Transfer Function

For the sake of simplicity we have just considered the Proportional Part (P) of the PID controller.

Open loop Transfer Function

The step response of the open loop system is calculated in MATLAB to analyze the need of a PID controller.

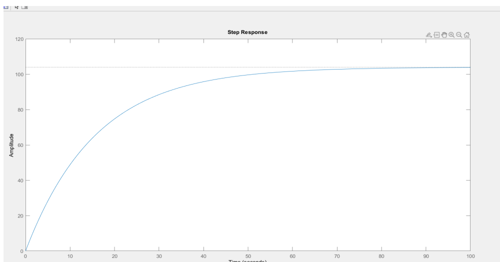

FIG. 4 STEP RESPONSE OF OPEN LOOP SYSTEM

The performance specifications are analyzed. We can see that the *Rise Time* and the *Settling Time* are very high for a system of clothing iron. Due to this fact we need the presence of a PID controller in our plant.

PERFORMANCE SPECIFICATIONS

Rise Time	34.6688 s
Settling Time	61.7325 s
Peak	103.9973 ^{0}C
Peak Time	166.4134 s
Overshoot	0
Undershoot	0
Settling Min	94.0681 ^{0}C
Settling Max	103.9973 ^{0}C

V. DESIGN OBJECTIVES

We have to keep in mind the design objectives before tuning the PID controller parameter. Design objectives values one define beforehand so as to achieve desirable output.

In our system, we have assumed the design objective as follows:

Design Objectives

Overshoot	<=2%
Rise Time	<=1.5 s
Peak Time	<=10 s

VI. CLOSED LOOP TRANSFER FUNCTION

Rise Time	0.7162
Settling Time	1.2753
Peak	99.9973
Peak Time	3.4379
Overshoot	0
Undershoot	0
Settling Min	90.4500
Settling Max	99.9973

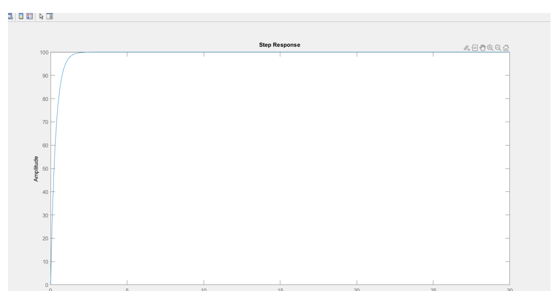

FIG. 5 STEP RESPONSE OF CLOSED LOOP SYSTEM

VII. ROUTH-HURWITZ

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Given polynomial coefficients roots :

sysRoots =

  -3.0675
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Routh-Hurwitz Table:

rhTable =

      733500
     2250000

~~~~~> it is a stable system! <~~~~~

Number of right hand side poles = 0
```

We can see in the above table that the sign in the first column is not changing and hence the number of roots on the right hand side of the s-plane, according to Rout-Hurwitz Criterion, is 0, and hence the system is stable.

VIII. ROOT LOCUS

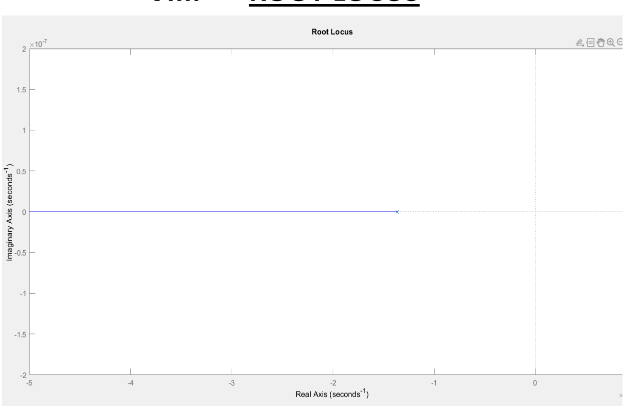

FIG. 7 Root Locus

B. FREQUENCY DOMAIN ANALYSIS

IX. BODE PLOT

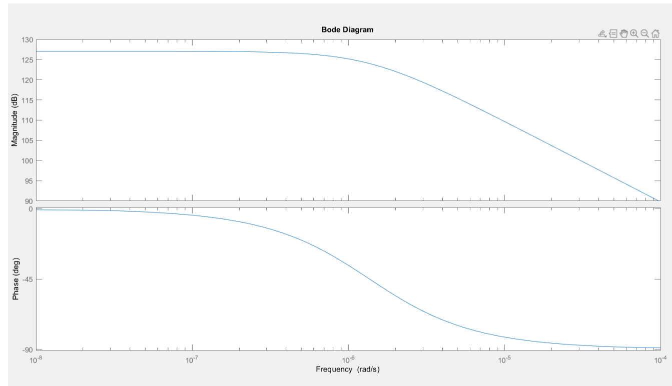

FIG. 6 BODE PLOT

X. Stability using Gain and Phase Margin

The gain margin (GM) of the system is INFINITY, i.e. the system is stable if we increase or decrease the gain by any value.

The phase margin (PM) is the amount of phase which can be increased or decreased without making the system unstable. In our case, the PM is 90 degrees.

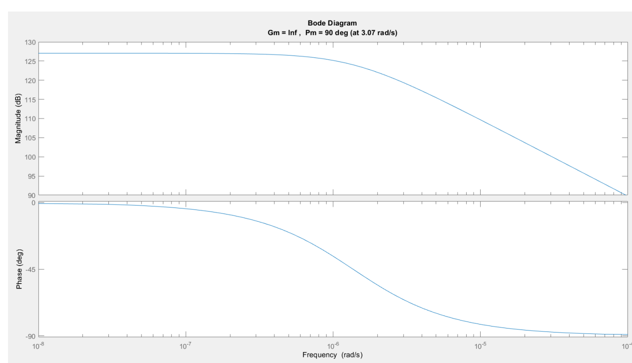

FIG.8 GM and FM from BODE PLOT

XI. POLAR PLOT

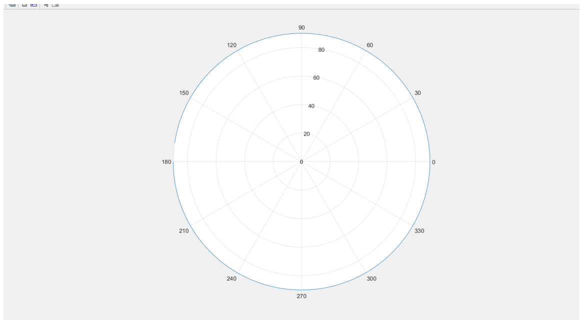

FIG.9 POLAR PLOT

XII. Nyquist Plot

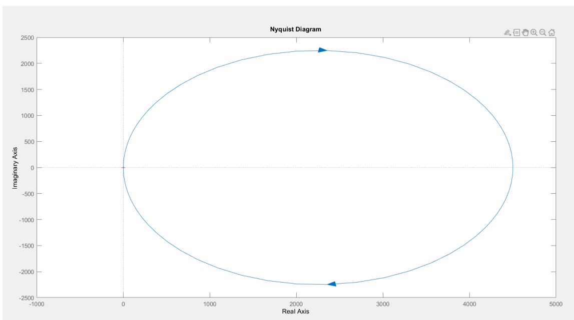

FIG.10 NYQUIST PLOT

We can see that N (Number of encirclements about the critical point (-1+0j) = 0 and P (OLTF poles on the right hand side of the s-plane) =0
Hence according to the Nyquist Criterion, Z = 0. This means that our system is stable.

XIII. CONCLUSION

In this paper we have designed a Temperature control system for Home Appliance (Iron Cloth). We can observe from the simulations that only P controller is sufficient to match our required design objectives.

For future scope, we can enhance this model with the addition of the Internet of Things. We can create a "Smart Cloth Iron" that maintains the temperature and will alert if the clothing iron is ON and not in use.

XIV. REFERENCES

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