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# **Problem statement**

## **1.1 Problem at Hand**

The given system should have a constant flow of temperature and continuous flow rate, so the temperature in the reactor remains the same. We must design a mechanism that will fulfill all these tasks.

## **1.2 Requirement**

The parameter that we are going to control are as follow:

* Level
* Temperature
* Valve opening (F1)
* Steam valve

The control we are going to implement is **relaxed control**.

## **1.3 Economic and safety features**

### **1.3.1 Economic features**

#### **1.3.1.1 Venting**

It is possible to keep the exhaust from your water heater outside of your home if you properly vent it. A wide range of sizes and shapes are available for ventilation configurations, each designed to meet a particular requirement. Before the installation, you should have a qualified plumber inspect the ventilation system in your home. After the inspection, the plumber will make recommendations tailored to your requirements.

#### **1.3.1.2 Glass Lined tank**

Over eight decades ago, A. O. Smith was the first company to begin commercial production of glass-lined tanks for tank water heaters. These tanks were intended for use in tank water heaters. The interior of the tank has been lined with glass to prevent the exterior steel from rusting and becoming a safety hazard. It was done for obvious reasons. This action was taken to maintain the structure of the tank.

#### **1.3.1.3 Temperature and pressure relief valve**

The T&P valve may open and let out both the pressure and the hot water if the water temperature goes above the nominal temperature or if the pressure goes above the nominal pressure. Due to the water's expansion because of being heated, the pressure inside the tank increases when it is heated. We strongly suggest making use of an expansion tank to keep the pressure inside the tank at a healthy level. In the absence of an expansion tank, the surplus of water will be unable to find a place to go, which will lead to an increase in pressure throughout the system. If the T&P valve springs a leak, this may suggest that the temperature or pressure settings are not accurate. If this takes place for you, you should not hesitate to get in touch with an experienced plumber.

### 1.3.2 Economic features

* It must be in an isolated location far from any populated areas.
* The disposal of its waste requires careful attention.
* Because of this, it should not have a negative impact on the environment.

# **Modelling and Block diagrams**

**Diagram

Description automatically generatedFigure 1** Open-loop block diagram

## **2.1 Mathematical modelling**

A mathematical model will typically describe a system by employing a group of variables and a group of equations that establish the relationships between those groups of variables. It is how mathematical models work. The values of variables can be of any data type, such as strings, Boolean values, real or integer numbers, etc. Variables represent different aspects of the system, such as the system's measured outputs, which are typically in the form of signals, as well as timing data, counters, and the occurrence of events. Variables can also be used to keep track of the number of times something has happened. The actual model is made up of a collection of functions, each of which explains one of how the variables are related to one another.

Diagram

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**Figure 2** Mathematical modelling block diagram

**2.1.1 First order transfer function**

The convenient representation of the linear dynamic system. The single-order transfer function represents the one-to-one relationship between an input and an output. The terminology described here will be used

* X in the input, which is here to cause
* Y is the output which is here to effect generally known as output response

Assume the constant liquid hold-up and flow rates are as follows

Suppose the process is initially at a steady-state condition, then

T (0) = , =

Q (0) =

Where steady-state value of T, etc. For steady-state conditions

0 =

By subtracting the following equations, we get

-

But here,

…………………… (5)

is constant, so we can substitute (4 into the 2nd equation) to get,

Here is the introduction of the single derivative variable, which is also known as the first derivative variable, which is also known as perturbation variables

…………… (7)

…………… (8)

…………… (9)

Taking the Laplace transformation on both sides of the equations, we get

……………… (10)

Now evaluating the time (t=0). We get

……………… (11)

But in the start, we assumed our starting initial condition was that process was initiated at a steady state, i.e., T (0) = which follows from equation number 9, which is

But here, the one more important thing is that the advantage of using deviation variables is that the initial condition term becomes zero.

Now rearranging the equation number 8 to solve for the T' (s)

T' (s)=…………… (12)

Now here, two new symbols are defined

and ………… (13)

So, the first-order transfer function will have occurred when supposing the is constant at a steady-state value. Thus, (t) = (t) = 0 = 0. Then we can substitute into the equation number 12 and rearrange it to get the desired transfer function which is

**………… (14)**

(t)= T (t-)

Taking the Laplace

T(s)=

(s)=

Taking the Laplace inverse

Deadbeat =

### **2.1.2 Energy balance**

## **2.2 State space**

Since both states are known and put the values from the question into the equations as mentioned earlier

## **2.3 Laplace Domain model**

For process 1

For process 2

# **Control strategies**

In the case of an impact system, the presence of a particular mathematical relationship between the system's input and output defines the system's nature. The term "linear proportionality" refers to the mathematical representation of the relationship between the inputs and outputs of a linear system. It is said that a system is nonlinear when the relationship between the input and the output cannot be described using a single linear proportionality—this points to the fact that there is a nonlinear relationship between the input and the output.

**3.1 Types of control systems**

There are different types of control systems, but they are all designed to keep costs under control. A system manages position, speed, acceleration, temperature, pressure, voltage, current, etc. An example of an operating system. To clarify the concept, let's take an example of a simple room thermostat. Imagine a specific heating element that can only generate heat when it is physically connected to a power source. When the power switch on the heater is turned on, the temperature in the room rises briefly before returning to the level that was previously set. If the desired temperature is always maintained inside, the heater will need to be manually turned on whenever the temperature outside drops. You can make manual adjustments to the room's temperature using this feature. One example of something that needs to be operated manually is presented here. If this system had a power timer that activated and deactivated the heating element at predetermined intervals, its performance would be significantly improved. It would make it much simpler to maintain the appropriate temperature throughout the space. Another cutting-edge method for regulating the temperature is applicable in any setting. The difference between the actual temperature and the desired temperature can be determined with the help of a sensor. If there is a temperature difference, the heater will work to bring it down until it reaches a set point, at which point it will turn off. If there is no difference in temperature, the heater will not work. Both systems are entirely computerized and managed by automated software and hardware. What goes into the system does not affect what comes out of it. The room temperature (or the plug, depending on where you are) will increase when the power is turned on. When the switch is turned to the "on" position, the heater radiates heat throughout the space.

On the other hand, the absolute temperature has no bearing on the amount of power delivered to the system. An open-loop system is the name of this computer operating system. In the second scenario, the heating element of the system operates based on the difference between the actual temperature and the temperature desired for the system. A "system failure" is what statisticians refer to when they see a difference of this nature. The system that oversees the input control is the one that detects and interprets this error signal. This variety of operating systems is known by its technical name, a closed-loop system. The reason for this is that the error feedback from the input paths and the output paths together form a closed loop.

## **3.2 Cascade control:**

When there are multiple measurements but just one control variable, cascade control is used. The variable controlling the process output temperature is the steam flow rate, not the valve opening. Because both valve opening and steam pressure determine the steam flow rate, a flow controller is utilized to maintain the steam flow rate despite variations in steam pressure. In a cascade, the flow controller gets its setpoint from the temperature controller [2].

Cascade control is often used to control slow operations governed by fast processes. Cascade control works best when a process interruption is detected. As a result, cascade control improves the ability to handle changes in steam pressure without affecting feed rate or temperature. The complexity of cascading control is also a disadvantage of additional measuring instruments and controllers. Good performance justifies investing when the internal cycle is more than three times faster than the external cycle. When it comes to how it is assembled, cascade control technology is distinct from other forms of control in several important respects. The first stage of the process is the vapour pressure stage, also called the "decomposition" stage. It can be used quickly and provides accurate measurements with little effort. When using the cascade control method, the output of the first controller communicates with the second controller, which has a feedback loop and tells it where to begin. As a result of the development of this technology, power outages can now be resolved in a shorter amount of time. In a system that only has one point of control, the level sensor is what provides the user with access to that control point. It allows the individual to control how quickly or slowly they pour liquid into the container. Because of how large the middle is, it takes significantly longer to bring the ship to a level position. The course of events could also shift dramatically in a short amount of time. Therefore, if something were to change the flow rate into the system, it might take a very long time for the level to change sufficiently to start making the necessary corrections. It is the case because the level is determined by the volume of water that is being introduced. The level sensor in a cascade system that regulates the flow of fluid provides feedback to the outer loop controller, which in turn serves as a reference input for the second controller. Because there is only one control system, flow level circuits can react quickly to changes in flow. Because of this, the differences between the levels are significantly reduced in magnitude.

Diagram

Description automatically generated

**Figure 3** Cascade Control

## **3.3 Single loop control**

Single loop controllers are devices that control a single temperature or process variable. These controllers are relatively inexpensive and simple to operate. Single loop controllers come in various forms, ranging from straightforward virtual instruments to complex variants that include a plethora of additional features. These controllers can be utilized to exert fine-grained control over various software programs. Single loop controllers are typically located on the front of the panel most of the time. A good number of our controllers come equipped with simple displays to read, allowing you to discern critical pieces of process information and warning signals immediately. Controlling process variables in a wide variety of applications is possible with the help of a single loop controller. Some examples of these applications include industrial and laboratory ovens, sealers, kilns, food processing, extruder barrel heating, and heat presses [3].

What takes place in a control system with a closed loop is dependent not only on the output variables but also on the input variables. By incorporating feedback into an open-loop control system, it is possible to transform it into a closed-loop control system.

By causing a change in the output, feedback can prevent interference from occurring from the outside world. As a result, the term "closed control system" is frequently used to refer to an automatic control system. The following diagram illustrates a closed eastward feedback system that receives and transmits feedback in the eastward direction.

Diagram

Description automatically generated

**Figure 4** Single loop control

### **3.3.1 Advantages of single-loop control system**

* Closed control systems offer a higher degree of precision, but their operation is not linear
* It has a very high degree of accuracy because if it makes a mistake, a feedback signal will correct it
* Added more bandwidth
* The process of automating things has become less complicated thanks to recent changes
* The level of sensitivity of the system can be dialled down, which will result in the system becoming more stable
* The volume level of this system is likely to be lower.

### **3.3.2 Disadvantages of single-loop control system**

* It is more expensive
* It is more difficult to design
* It requires more upkeep
* It causes responses to go back and forth
* It reduces gross profit.

## **3.4 Feedforward control:**

A part or path that transmits a controlling signal from an external source to an external load is a feedforward component of a control system. This component may also be spelt feedforward. It is also possible to refer to the signal that controls the machine as the feedforward signal. It is an order that usually comes from the outside world.

A feedback system, as opposed to a feedforward system, modifies the input to consider how the load is affected by the input and how the load may change in unexpected ways. It is generally agreed that the load belongs to the system's external environment. [1].

The task itself is a component of the system's external environment, and the feedback system modifies the input to observe its effect on the task. In addition to this, the task may develop in ways that were not anticipated. On the other hand, forwarding systems adjust their revenue to consider how much load they carry. It is never acceptable to use errors to alter the functioning of a delivery system. Process data, such as a mathematical model of the process and a way to find or measure process failures, are required for it to function correctly and are necessary for it to work at all.

Even if it does not include a feedback control system, a net forward strategy still needs specific characteristics to succeed. An external command or control signal and the appropriate amount of time must be transmitted from the outside to determine how the system's output affects the load (typically, the expected load needs to remain constant). The term "ballistic" refers to the inability to make any adjustments once a control signal has been transmitted in a system that uses forward control without feedback. The most recent control signal must be utilized before making any system adjustments. On the other hand, cruise control uses a feedback system to adjust the cost per the number of passengers in the vehicle.

Diagram

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**Figure 5** Feedforward control

# **Features of control**

The recommended control is PI control

## **4.1 PI control**

In the PI controller, the actuating signal is directly proportional to the error signal added with the integral of the error signal. It also reduces steady-state error without affecting of stability of the system, especially since Kp is large.

**Diagram, schematic

Description automatically generatedFigure 6** Proportional Integral Controller

## **4.2 Proportional controller**

The signal that tells the system to do something equals the error signal in a proportional controller. It ensures that the system always responds appropriately. The error signal, transmitted via feedback, is the difference between the signals at the input and the signals at the output.

**A picture containing text, clock

Description automatically generatedFigure 7** Proportional controller block diagram

## **4.3 PID controller**

The signal that tells the system to do something is directly related to the error signal plus its integration and derivative in a PID controller. This signal tells the system to do something. Controlling a system's stability and the error at a steady state within a predetermined ratio range requires using a PID controller.

s

**Diagram, schematic

Description automatically generatedFigure 8** Proportional integral derivative controller

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