PROCESS CONTROL LOOPS
A Review Article

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ABSTRACT

Process control refers to the methods that are used to control process variables when manufacturing a product or controlling any parameter. In today's modern plants, to achieve control, several elements are coordinated together to achieve the control objective. Process control is an engineering discipline that deals with architectures, mechanisms and algorithms for controlling the output of a specific process within a desired range. In any instrumentation system, the control objective can be accomplished by designing proper control system for a specific purpose. Control can either be manual or automatic. Manual control involves the controlling process parameter to a specific value using human intervention. In automatic control, no human intervention is required rather sensors, controllers, actuators and other control elements are used to automatically control a system to maintain the system parameters to desired levels. This paper will explain the process control and different types of control loops.

Keyword: - *Process, Control loops, Basic control loops, Advance control loops.*

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1. INTRODUCTION

The term control means methods or means used to maintain parameters in any system to have specific or desired values. Process control refers to the regulation of a process variable so as to maintain a desired output level. The aim of process control instrumentation is to measure, indicate, and or control a process. For thousands of years, processes were controlled manually by humans with the necessary skills or expertise. A person or group of persons observed the process; determined the control actions required, and manipulated the variable or variables necessary to achieve satisfactory product. Due to the subjective nature of this control mechanism, the product quality varied widely and overall efficiency was often poor. Modern production systems use automatic control systems where control is carried out with minimal or without human intervention. Control processes use basic elements that include a sensor (primary element), controller, transmitter, and a final element. Product quality is high and consistent and the overall process efficiency is often near optimum. The role of a process technician in industrial production today is mainly to monitor and maintain automated processes. Simply stated, the term control means methods to force parameters in the environment to have specific values. [1]

2. IMPORTANCE OF PROCESS CONTROL

Process control engineering is an important tool for the operation and monitoring of an automated complex process. This technology is the tool that enables manufacturers to keep their operations running within specified limits and to set more precise limits to maximize profitability, ensure quality and safety. Here process parameters are measured, monitor and control using various control schemes as explained in the later sections.

2.1 Process

Usually Process means a system that is under observation, in which one or more parameters are maintain to the desired value known as process variables. Process as used in the terms process control and process industry, refers to the methods of changing or refining raw materials to create end products as shown in the Fig-1. Process industries include the chemical industry, sugar industry, the oil and gas industry, the food and beverage industry, the pharmaceutical industry, the water treatment industry, and the power generation industry. [1,2,5]

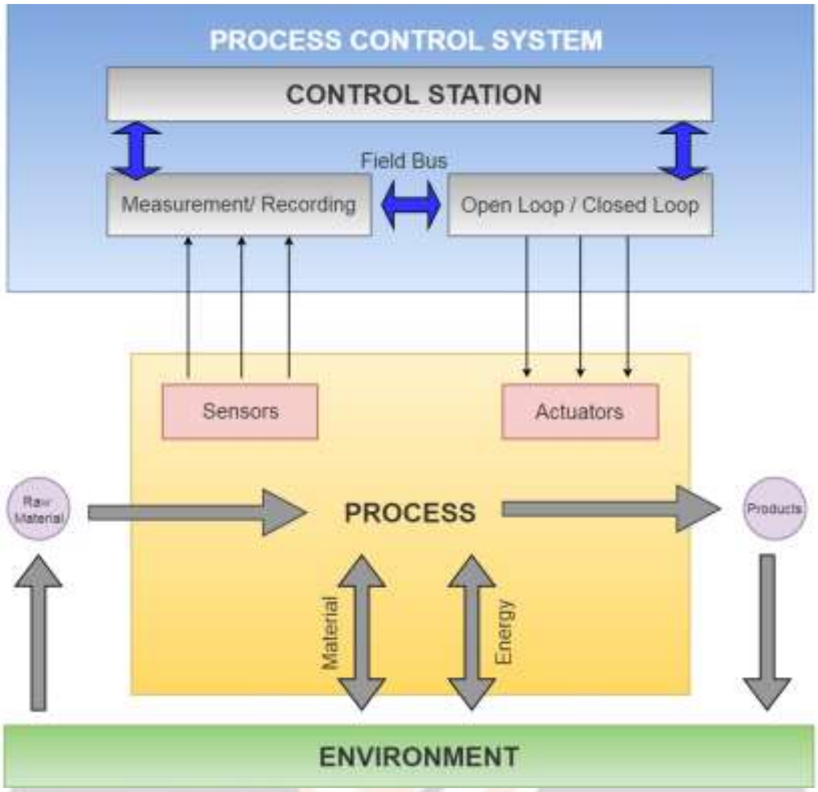

Fig -1: Block diagram of Process control

2.2 Process Control

Process control refers to the methods that are used to control process variables when manufacturing or processing a product. For example, factors such as the proportion of ingredients, temperature of the materials, and the pressure under which the materials are held are some of the critical factors those are having significant impact on the quality of an end product. There are three important reasons for which manufacturers control the production process:

a. Reduce variability: Process control can reduce variability and non-uniformity in the end product, which ensures a consistently high-quality product. This also helps in meeting required product specifications. With accurate and precise process control, the set point (desired or optimal point) can be moved closer to the actual product specification and thus save the manufacturer money.

b. Increase efficiency: In some processes, few parameters are quite critical for maintaining the end product at the desired specifications. For example, a control point might be the temperature at which a chemical reaction takes place. Accurate control of temperature ensures process efficiency.

c. Ensure safety: Precise process control may also be required to ensure safety for run-away processes, such as an out-of-control nuclear or chemical reaction. The consequences of a run-away process can be catastrophic. For example, maintaining proper boiler pressure by controlling the inflow of air used in combustion and the outflow of exhaust gases is crucial in preventing boiler implosions that can clearly threaten the safety of workers.

2.3 Process Variable

A process variable is a condition of the process fluid (a liquid or gas) that can change the manufacturing process in some way. In the example of you sitting by the fire, the process variable was temperature. The process variable is a dynamic feature of the process which may change rapidly. Accurate measurement of process variables is important for the maintenance of accuracy in a process. There are four commonly measured variables which affect chemical and physical process: pressure, temperature, level and flow. [5]

3. TYPES OF CONTROL LOOPS

Generally control processes use basic elements which include a primary sensing element, controller, transmitter, and an actuator or a final control element. In process control, the basic objective is to regulate or control the value of some quantity. To regulate means to maintain that quantity at some desired value regardless of external disturbances. The desired value is called the reference value or set-point. There are two basic types of control loops, namely open-loop and closed-loop systems, which are explained below. [1]

3.1 Open-Loop Control System

Fig. 1 shows an open-loop control system. This system incorporates two control elements consisting of controller and a regulator or actuator. The regulator is used in a generic sense, being able to alter the input variable in response to the signal from the controller. Regulator does not mean a specific type of actuator or control valve. An open loop system has no feedback or feed-forward mechanism, so the input and output signals are not directly related. Timed controllers can operate the regulator in an open control system. Such system are simply influenced by the input, an open loop control system is shown in the below figure, the process is controlled by providing the input to the control of the open loop system to keep the output at a desired level. The set point of the open loop system is also called “Command input”. Since there is only one command input as set-point, so it is important to operate this system at the optimal level. The open loop control system are cheaper and less complex then the closed loop control system, while the controlling efficiency of this system is nearly zero but at the same time open loop systems are more stable than the closed loop system. An open control loop exists where the process variable is not compared, and action is taken not in response to feedback on the condition of the process variable, but is instead taken without regard to process variable conditions.

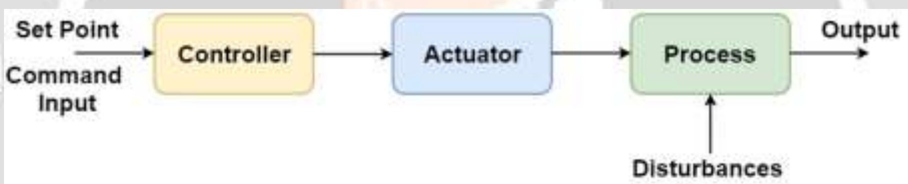

Fig -2: Open Loop Control System

3.2 Closed-Loop Control System

Fig. 2 shows a closed-loop control system. As the diagram shows this system includes all the basic control elements of the primary sensing element, transmitter, controller and the final control element (actuator) or regulator. The sensor is used to capture the current value of a process variable. This value is then compared with the set-point and the corresponding error will be generated. The controller then communicates to the actuator what action is needed to ensure that the output variable value is matching the desired value or the set-point. A closed-loop control system has the ability to automatically drive the system so as to eliminate a difference between an output level and the desired level. Therefore there is a high degree of assurance that the output variable can be maintained at the desired level.

Closed-loop control system can be a feedback or a feed forward system. Fig. 2 is a feedback closed-loop system, feed-forward will be explain later. A closed control loop exists where a process variable is measured, compared to a set-point, and action is taken to correct any deviation from set-point.

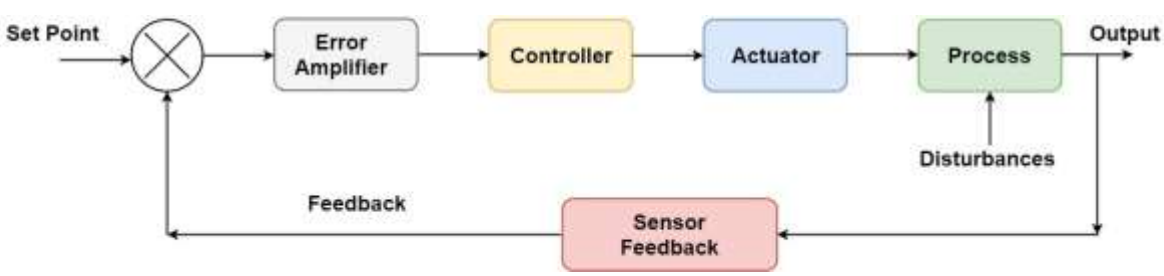

Fig -3: Closed Loop Control System

4. BASIC CONTROL LOOPS

Basic control loops are control loops for the single common process variables like temperature, pressure, flow, level, and analysis. The main difference in basic control loops is the sensor. This is determined by the variable being measured. Consequently, temperature element (TE), pressure element (PE), temperature element (TE), level element (LE), and analysis element (AE) are specific to process variables of interest. [1, 2]

4.1 Temperature Control Loop

Fig-4 shows a single variable temperature control loop. Temperature measurements are taken in furnaces, reactors, boilers, heat exchangers, etc. or from the exiting charge from the equipment. Thermocouples and RTDs are the common temperature sensors (TEs). The TEs are linked to Temperature transmitters (TTs) that send signals to the other instruments. [1, 2]

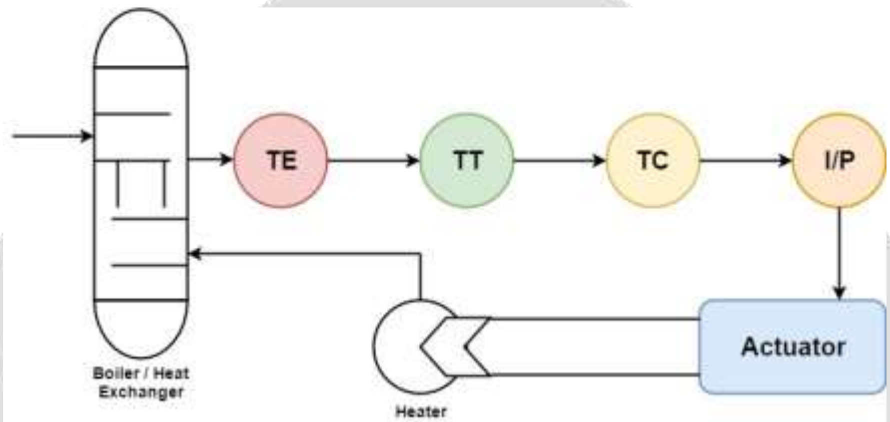

Fig -4: Temperature Control Loop

4.2 Pressure Control Loop

Fig-5 shows a single variable pressure control loop. Pressure measurements are taken in pumps, compressors, furnaces, reactors, boilers, heat exchangers, etc. or from the connecting piping to or from the equipment. Pressure sensors (PEs) are typically expansion-type pressure gauges such as the bourdon tube gauge. The PEs are linked to Pressure transmitters (PTs) that send signals to the other instruments. [1, 2]

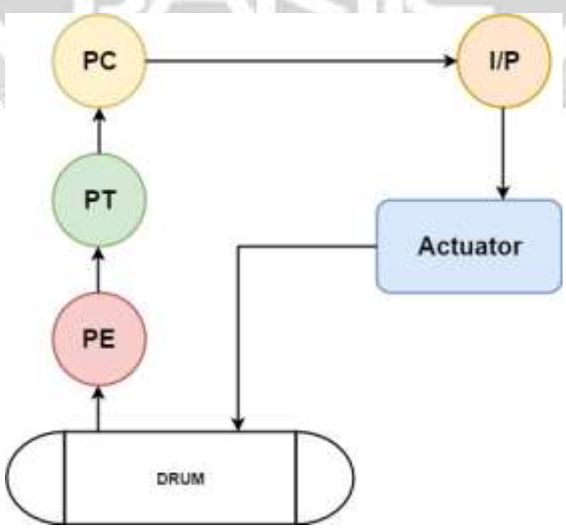

Fig -5: Pressure Control Loop

4.3 Flow Control Loop

Fig-6 shows a single variable flow control loop. Flow control loops start at the flow element (FE), which can create differential pressure. This may be an orifice, venturi, etc. meter. This differential pressure then could be measure by using differential pressure transmitter (DPT / FT). The FEs are linked to Flow transmitters (FTs) that send signals to the other instruments. [1, 2]

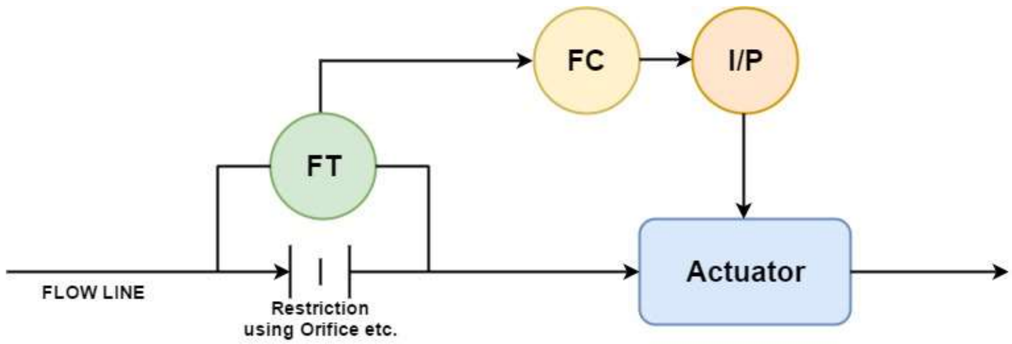

Fig -6: Flow Control Loop

4.4 Level Control Loop

Fig-7 shows a single variable level control loop. Level control loops start at the level element (LE). This may be a DP transmitter or other level sensor. LEs are linked to level transmitters (LTs) that send signals to the other instruments. [1, 2]

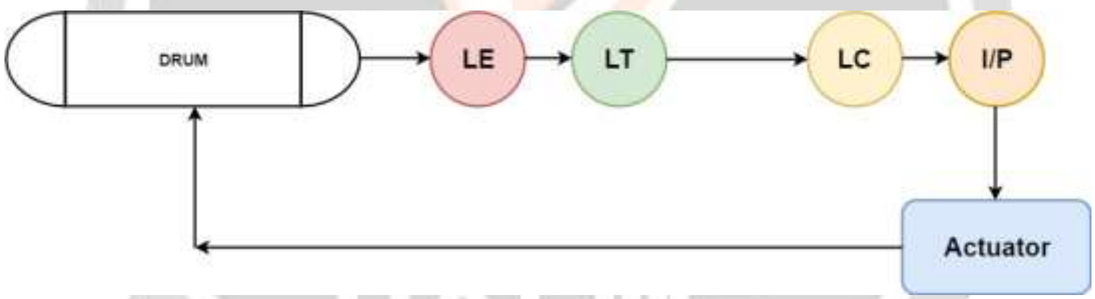

Fig -7: Level Control Loop

5. MULTI-VARIABLE / ADVANCED CONTROL LOOPS

Multivariable loops are control loops in which a primary controller controls one process variable by sending signals to a controller of a different loop that impacts the process variable of the primary loop. When tuning a control loop, it is important to take into account the presence of multivariable loops. The standard procedure is to tune the secondary loop before tuning the primary loop because adjustments to the secondary loop impact the primary loop. Tuning the primary loop will not impact the secondary loop tuning. [1, 3]

5.1 Feed-forward Control

As its name depicts, a feed-forward control is a control system that anticipates load disturbances and controls them before they can impact the process variable. For feed-forward control to work, the user must have an understanding regarding the algorithm of how the manipulated variables will impact the process variable. Fig-8 shows the block diagram for any feed-forward control. In this system disturbances are felt/measured in advance. So that the corrective measures can be done and hence minimizing the error due to the known disturbances. [1, 3]

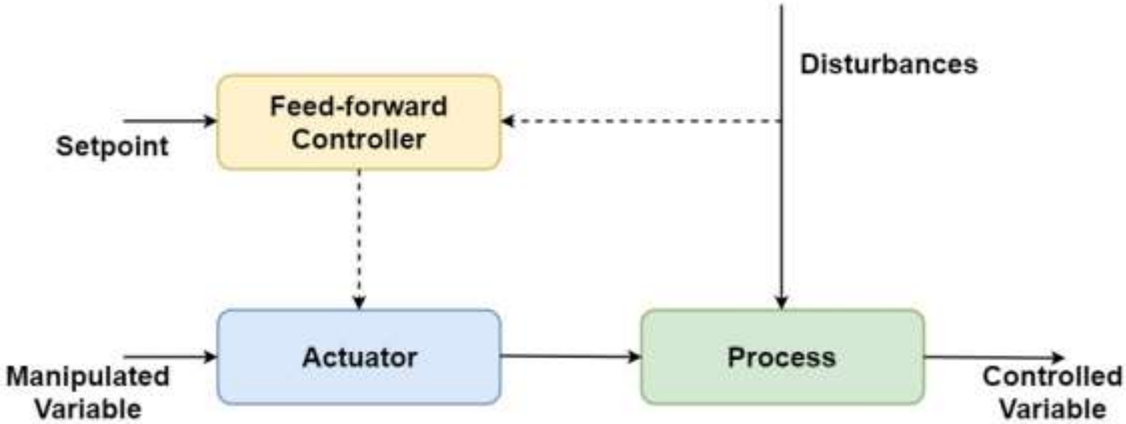

Fig -8: Feed-forward Control System

One of the primary advantage of feed-forward control is that error is prevented, rather than corrected. However, it is difficult to account for all possible load disturbances in a system through feed-forward control. Factors such as outside temperature, buildup in pipes, consistency of raw materials, humidity, and moisture content can all become load disturbances and cannot always be effectively accounted for in a feed-forward system. Due to complexity and costing feed-forward control may not be efficient for small systems, where high degree of accuracy is not important.

5.2 Cascade Control

Cascade control is a control system in which a secondary (outer) control loop is set up to control a variable that is a major source of load disturbance for another primary (inner) control loop. The controller of the outer loop determines the set-point for the inner loop as shown in the Fig-9.

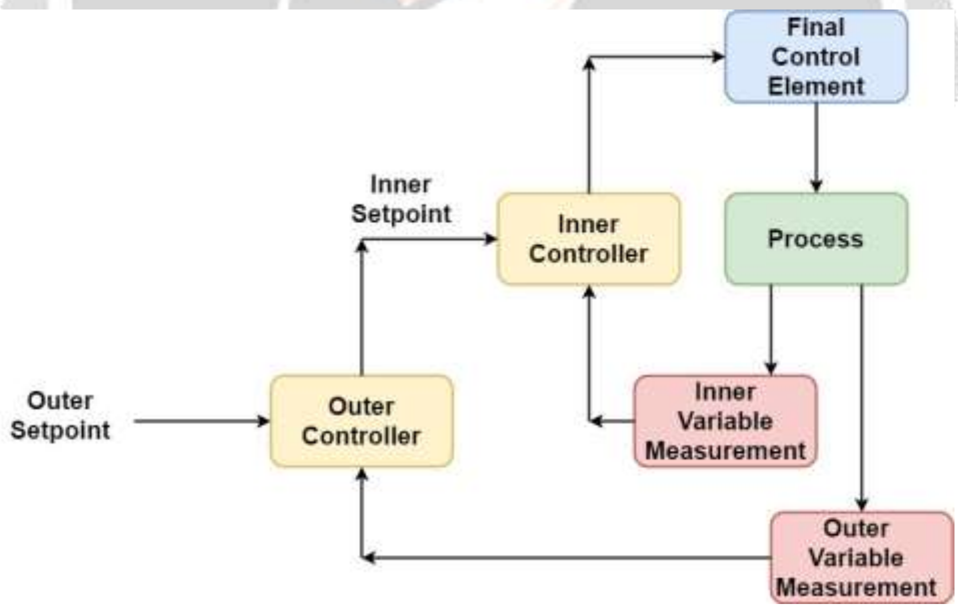

Fig -9: Cascade Control System

Generally for better overall control inherent interaction that occurs between two control systems is quite crucial for some applications. One method of accomplishing this is for the set-point in one control loop to be determined by the measurement of a different variable for which the interaction exists. A block diagram of such a system is shown in Fig-9. Two measurements are taken from the system and each is used in its own control loop. In the outer loop, however, the controller output is the set-point of the inner loop. Thus, if the outer loop controlled variable changes, the error signal that is input to the controller effects a change in set-point of the inner loop. Even though the measured value of the inner loop has not changed, the inner loop experiences an error signal, and thus new output by virtue of the set-point change. Cascade control generally provides better control of the outer loop variable than is accomplished through a single variable system. [1]

5.3 Ratio Control

Ratio control is used in many applications and involves a controller that receives input from a flow measurement device on the unregulated (wild) flow. The controller performs a ratio calculation and signals the appropriate set-point to another controller that sets the flow of the second fluid so that the proper proportion of the second fluid can be added. Ratio control might be used where a continuous process is going on and an additive is being put into the flow. [1-3]

The conceptual diagram below shows that there are two types of flow, one is wild flow which is unregulated or uncontrolled and the other is the controlled flow. In ratio control systems, we control only one flow based on the calculations of the wild flow. As the Fig-10 shows, a final control element (FCE) or actuator in the controlled feed stream receives and reacts to the controller output signal, COc, from the ratio control architecture. Here both the flow rates are measured but only one is to be controlled. Ratio relay will provide the set-point for the flow controller (FC), through which ratio of the mix will be maintained by regulating the controlled flow. [5]

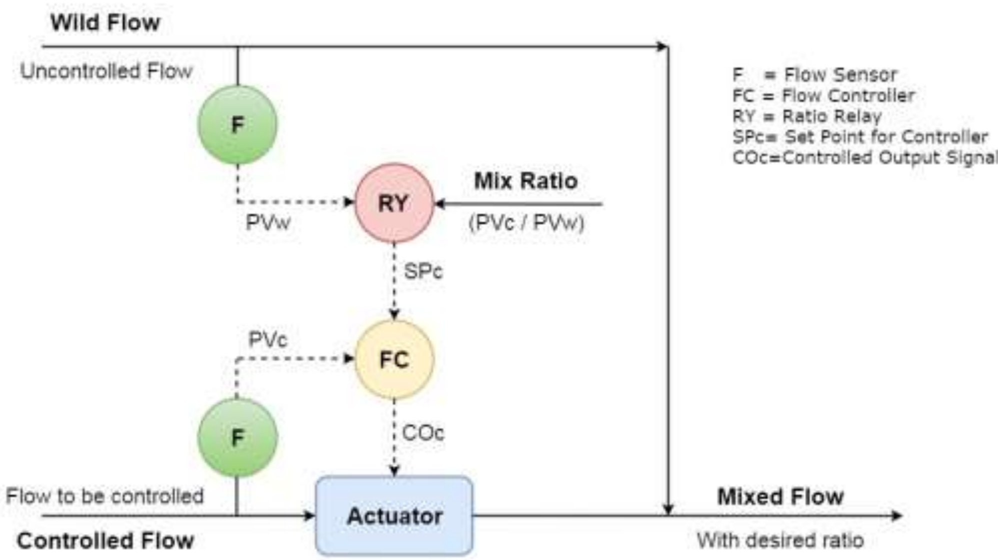

Fig -10: Ratio Control System

6. CONCLUSIONS

In this paper we have discussed various types of process control loops in detail. The study initially explains the basic concepts of a process and process control. A brief overview for different types of process control loops, their operation and advantages or disadvantages are described. This study could be further expanded to the various types of controller based on control algorithm discrete, multistep or continuous and process loop tuning using, P, PI and PID types.

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