IPC Lab
Pressure Control Trainer Experiment

Aim :

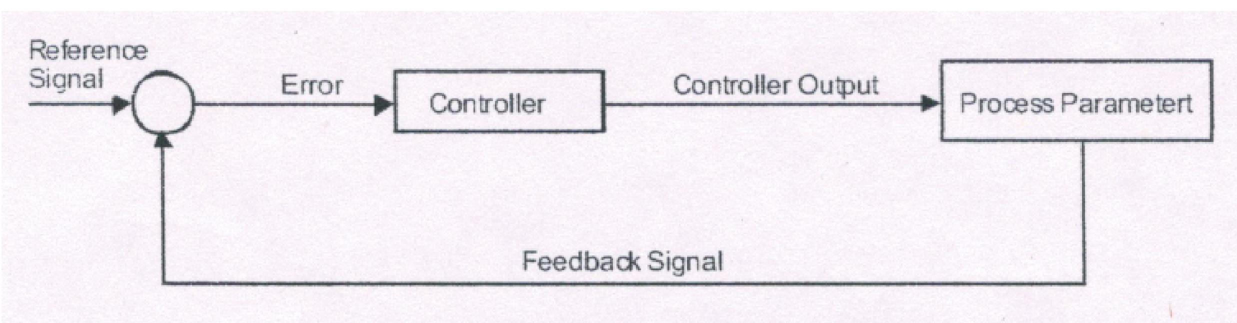
1. To find the parameters of the controller in the Pressure Trainer

Overview:
A pressure control trainer is an experiment designed for understanding the basic pressure control principles. The pressure transmitter senses the pressure inside the pressure tank and transmits the signals to the interfacing unit/control module. The output of the interfacing unit/control module is connected to I/P converter. A pneumatic control valve adjusts compressed airflow from the tank outlet. The process parameter (pressure) is controlled through a computer.

Theory

Process Controller

In an automatically controlled process, the parameter to be controlled is measured and compared with the setpoint by the process controller. The difference between the measured signal and the setpoint is an error. The controller performs online calculations based on error and other setting parameters and generates an output signal. The output signal drives the final control elements like a control valve or a damper to control the process to the set point.



Block Digaram of Typical Controller

On/Off Controllers

A special case of proportional control is On-Off control. If the proportional band of the controller is made very low (=0) the controller out put will move from one extreme position to other for slight deviation of process value from the set point. This very sensitive action is called On-Off control because final control element is either open

(On) or close (Off) i.e. operates like a switch. These are the simplest controllers. These controllers incorporate a dead band to keep the output from cycling rapidly between on and off. The controller will not turn on or off until the error signal moves out of the dead band. The process variable controlled by an on/off controller always cycles back and forth about the set point as shown in the fig. Dark line and dotted line shows process parameter and reference values respectively. Hysteresis is a value set in the vicinity of on-off operating point. Upper hysteresis is value or band in which process value is allowed to operate above the set point and lower hysteresis is value or band in which process value is allowed to operate below the set point.

Proportional (P) Controllers

In proportional controller the control algorithm generates a linear control output proportional to deviation. In proportional action the amount of change in the measured value (or deviation) is expressed' in percent of span that is required to cause the control output to change from 0 to 100 14, is called the proportional band. The controller output is given by:

$$OP = b + \frac{100}{PB} \cdot e$$

Where, OP is the output, PB is proportional band in %, b is the bias value, and e is the error signal. If there is no biasing, output OP will become zero when error is zero. Hence bias value decides the value of output when error is zero. The proportional controllers usually show some difference between the set point and process variable called offset. The offset can be reduced by decreasing proportional band or by readjusting the bias. With decrease in proportional band the process becomes oscillatory. There are two types of controller actions:

1) Increase-increase in which output increases as measurement increases. (error e = measurement - set point)
2) Increase-decrease in which output decreases as measurement increases. (error e = set point -measurement)

Proportional-Integral Calculator

The offset in proportional controller can be overcome by adding integral action. The control algorithm that applies changes in output as long as deviation exits, so as to bring the deviation to zero, is called integral action. Output of proportional-Integral controllers is given by:

$$OP = b + \frac{100}{PB} \times \left(e + \frac{1}{Ti} \int e \cdot dt \right)$$

Where OP is the output, b is the bias, PB is the proportional band in %, e is the error signal, Ti is integral time; this is the time required to repeat proportional action.

Proportional-Derivative (PD) controller

This mode of control is described by the relationship

$$OP = b + \frac{100}{PB} \left(e + Td \cdot \frac{de}{dt} \right)$$

Where OP is the output, b is the bias, PB is the proportional band in %, e is the error signal, Td is derivative time. Larger the derivative time larger is the action. Smaller is the proportional band the larger is the derivative action. In order to achieve faster response and more stable operation in slow processes derivative action is added to apply an output component proportional to the rate of change of input (error). Derivative action is used with P action or PI action.

Proportional—Integral—Derivative (PID) controllers

PID controllers are used for controlling almost all process variables like temperature, flow, level, pressure etc. in a continuous or batch process.

The output of a PID controller is given by:

$$OP = b + \frac{100}{PB} \left(e + \frac{1}{Ti} \int e \cdot dt + Td \cdot \frac{de}{dt} \right)$$

Where OP is the output, b is the bias, PB is the proportional band in %, e is the error signal, Ti is the integral time and Td is derivative time, Selection of proportional band, integral time and derivative time to achieve desired process response to load changes is called tuning of controller.

1. **To study the open loop response of a pressure control trainer:**

   Procedure:
   - The mains supply was switched on.
   - The compressor was switched on and the air was adjusted to flow at a constant rate.
   - The digital calibrator was kept at manual mode.
   - The controller output was changed in steps of 10% from 100-0%.
   - The process value was noted for each step change.

2. **To study the On/Off Controller:**

   Procedure:
   - The digital calibrator was kept at auto mode.
   - The software was opened in the computer and the controller was chosen as On/Off.
   - The upper and lower hysteresis values were set.
   - The set point value was changed twice during the run cycle.
   - The cycle was repeated thrice with different controller parameters

3. **To study the P-only Controller:**

   Procedure:
   - The digital calibrator was kept at auto model.
   - The software was opened in the computer and the controller was chosen as P.
   - The P bandwidth value was set.
   - The set point value was changed twice during the run cycle.
   - The cycle was repeated thrice with different controller parameters.

4. **To study the PD Controller:**

   Procedure:
   - The digital calibrator was kept at auto mode.
   - The software was opened in the computer and the controller was chosen as PD.
   - The P bandwidth and derivative time constant value were set.
   - The set point value was changed twice during the run cycle.
   - The cycle was repeated thrice with different controller parameters.

5. **To study the PID Controller:**

Procedure:

- The digital calibrator was kept at auto model.
- The software was opened in the computer and the controller was chosen as PID.
- The P bandwidth, integral time constant and derivative time constant value were set.
- The set point value was changed twice during the run cycle.
- The cycle was repeated thrice with different controller parameters.

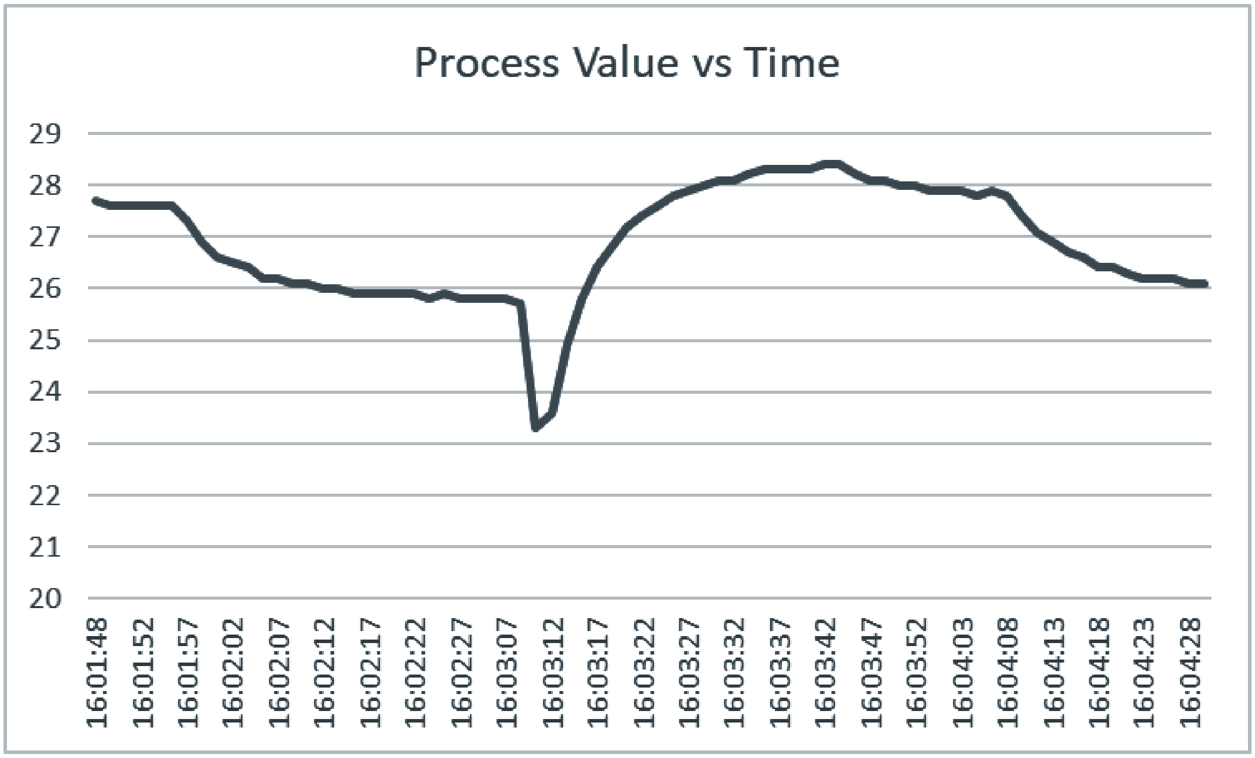
6. **Tuning of controller (Open loop method)**

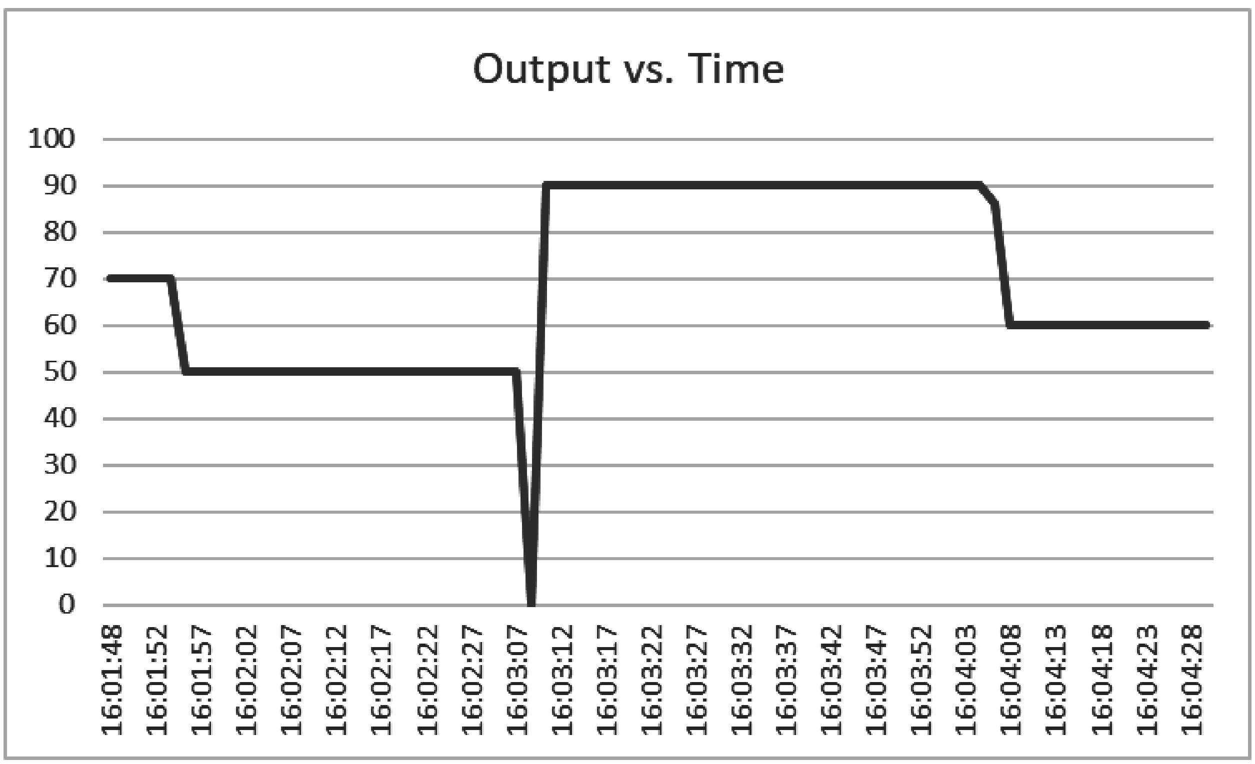
Procedure

1. Start up the set up and select Open loop option for control.
2. Adjust controller output, so that the process value is maintained at 50%.
3. Start data logging.
4. Apply a 20 - 30 % change to controller output. (Open the control valve) Record the step response. Wait for the steady state.
5. Stop data logging.
6. Plot the step response (Process reaction curve) from stored data. Find out the value of slope at the point of inflection and time lag.
7. Calculate P I D settings for different modes.
8. Select close loop, switch auto manual key to auto mode and then select controller to study. Set the PID values obtained from the calculations. Apply the step change & observe the response of the system. Allow the system to reach steady state. ObserVations (Refer theory for formulae.)
9. Step change to the system AP = Initial output - Final output of the controller.
10. Plot the graph of process value Vs Time on a graph paper. From process reaction curve:
    a. Slope of the process reaction curve R =
    b. Time lag L=
11. Calculate P, PI, PID setting from above values.
12. Observe response of the system for different PID settings.

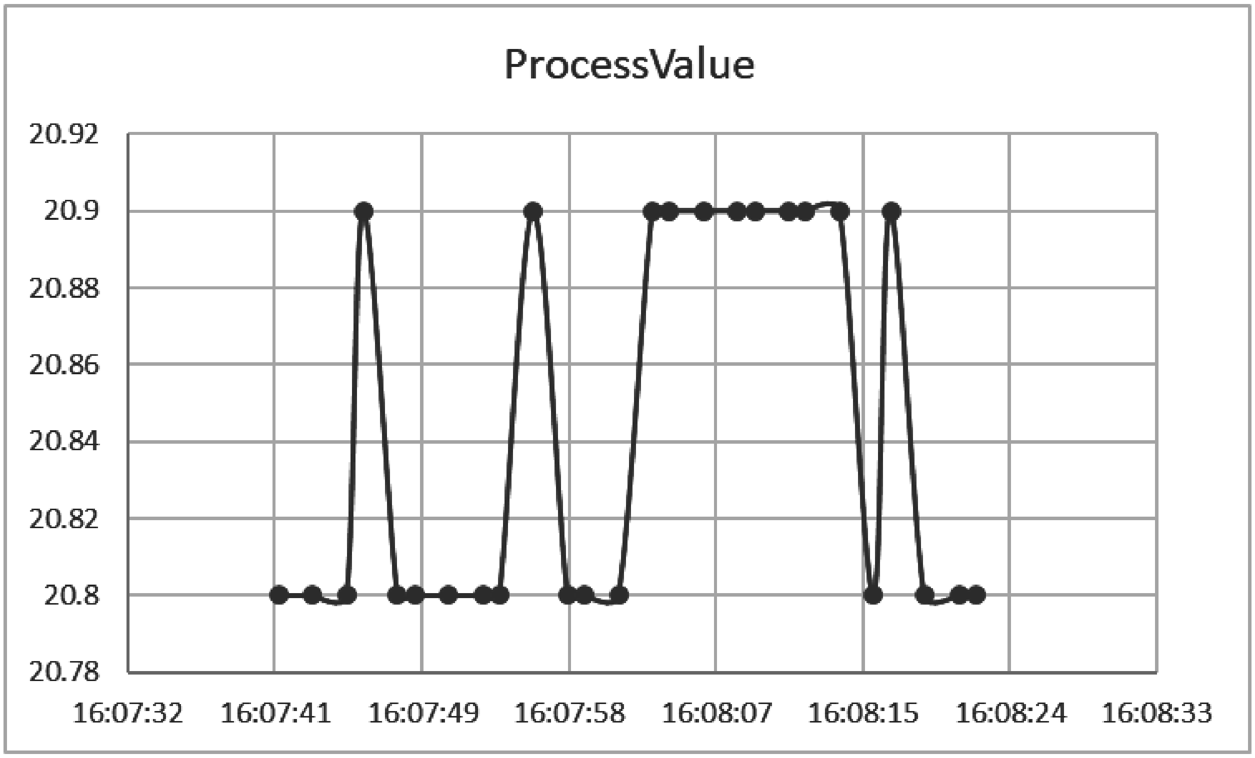
Plots

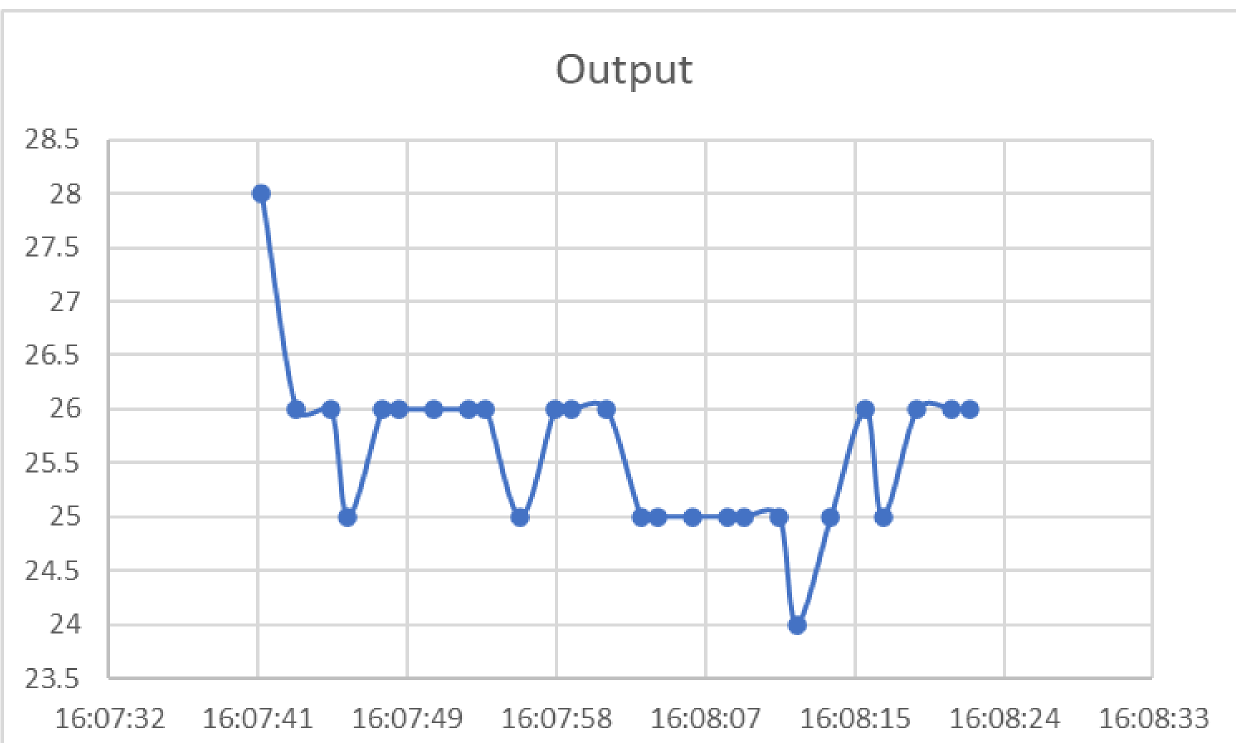
Proportional Controller

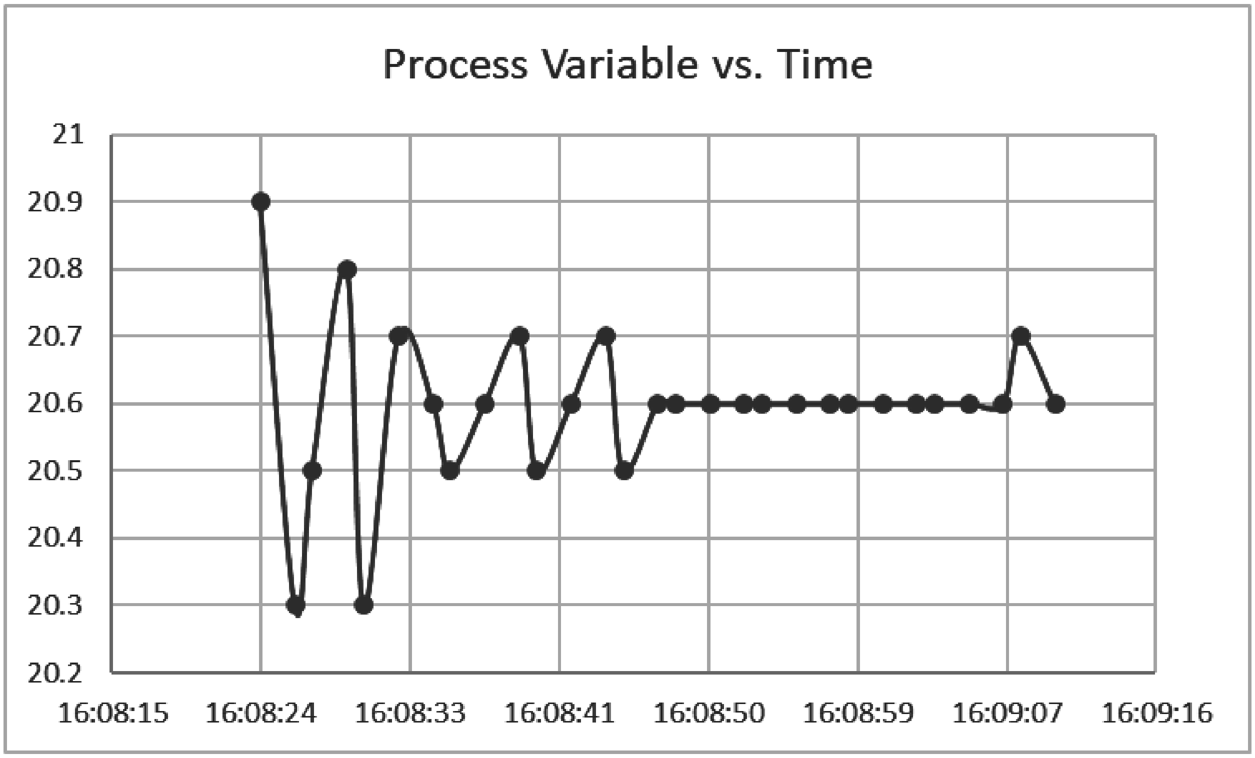


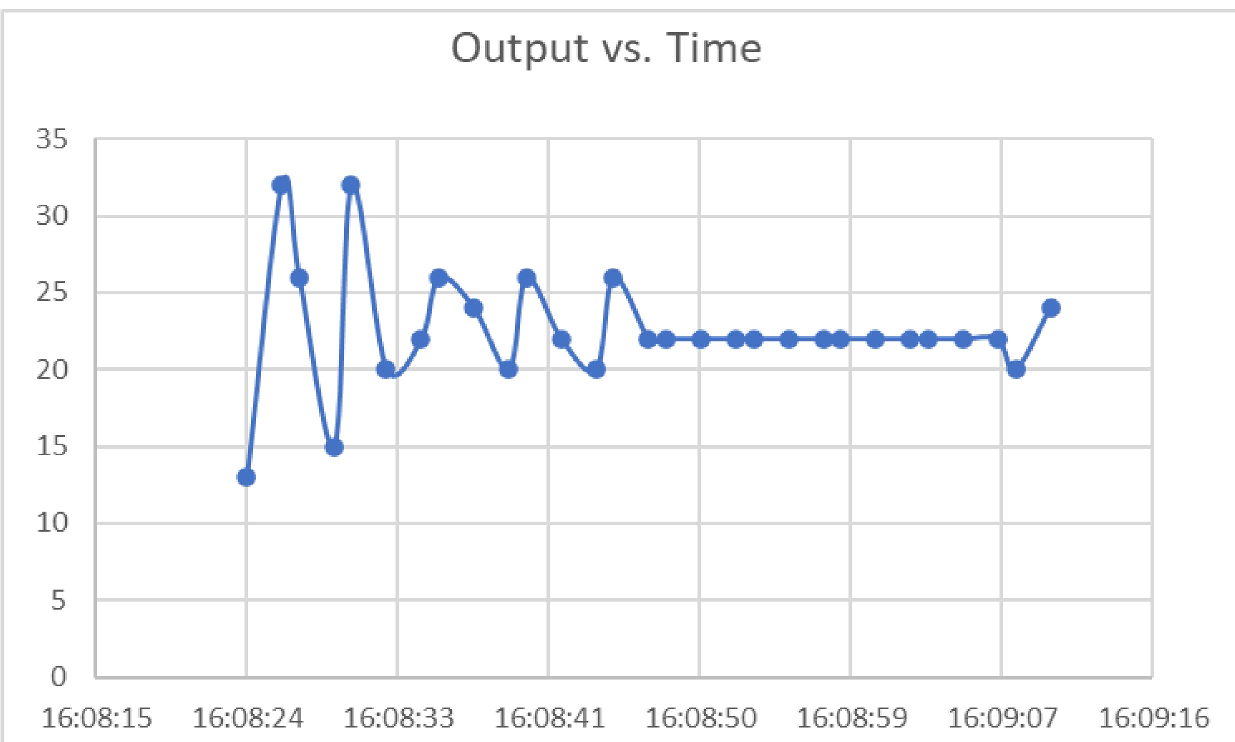


Proportional Integral Controller

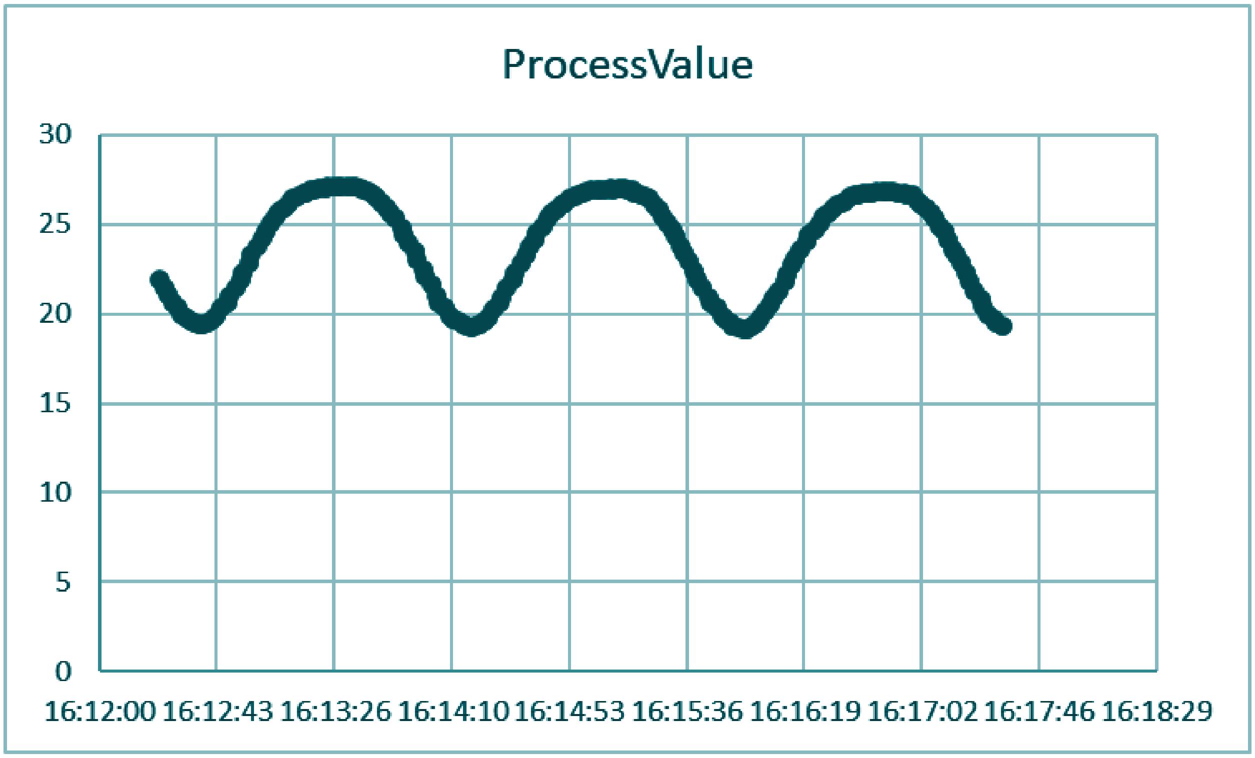


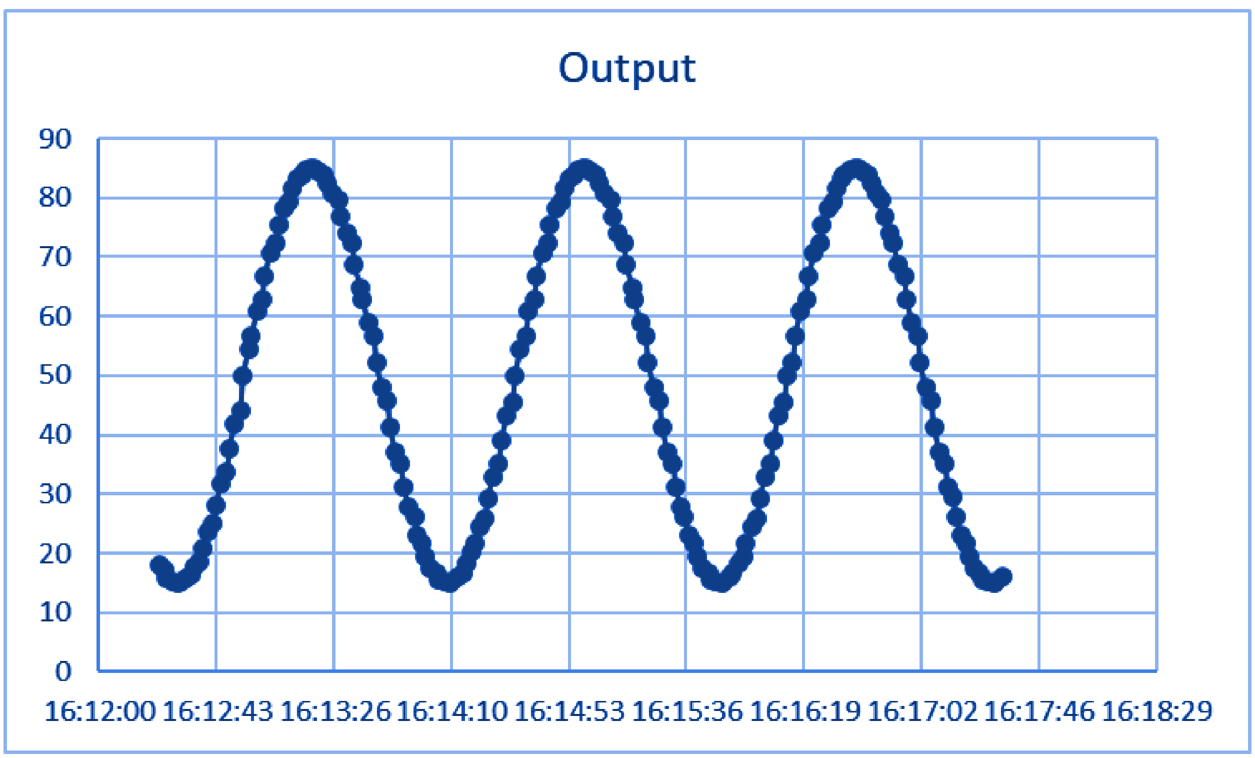



Process Variable vs. Time
21
20.9
20.8
20.7
20.6
20.5
20.4
20.3
20.2
16:08:15
16:08:24
16:08:33
16:08:41
16:08:50
16:08:59
16:09:07
16:09:16


Output vs. Time
35
30
25
20
15
10
5
0
16:08:15
16:08:24
16:08:33
16:08:41
16:08:50
16:08:59
16:09:07
16:09:16

For Ultimate Proportional Band (PBu)





Conclusion and Discussions

For calculating the offset values we need to wait for steady state to be attained.The graph patterns and offsets show that the parameters are very important for optimum offset and fast action.The addition of derivative action added to the speed of the control action, but the process value was seen to execute an oscillatory motion.The addition of integral action is used to eliminate the offset when there are step changes, but this slows down the process.The offset values do not exactly have any pattern for parameter changes at different set points. But different optimizing techniques can lead to exact ranges for these values and then the experiment can be carried out to see which values give best results.The output and process variable are oscillatory when the proportional band reaches the ultimate proportional band.