Faculty of Enigeering

Cairo University

PID Single Loop Control

PROCESS DYNAMIC CHARACTERISTICS

Presented for ELC 4046 Lab 1

Presented to:

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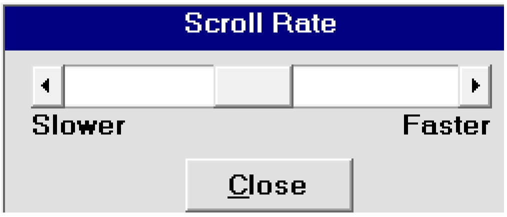
LABORATORY EXERCISE 1
(PROCESS DYNAMIC CHARACTERISTICS)

OBJECTIVE: To become familiar with various forms of process dynamic characteristics, and to learn a method of constructing a simple process model from step test data.
Optional: To become familiar with obtaining data from frequency response tests.

1. RUNNING THE PROGRAM

Run **PC – ControLAB.**

Slow down the simulation speed via **View | Scroll Rate** and select a mid-value, to have more practical experience.



2. FIRST ORDER LAG PLUS DEAD TIME PROCESS

- Click on **Process | Select Model**.
- Highlight "Folpdt.mdl" (First Order Lag Plus Dead Time) and press **Open**.
- Press **Zoom** and change the PV scale range to 50-75. (Note that the PV scale has already been converted to 0 – 100% of measurement span.)
- With the controller in MAN, press **Out**. Note the initial values:

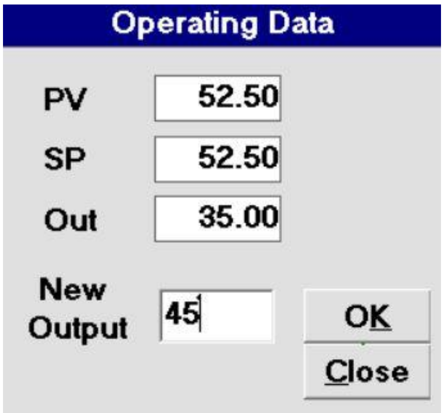


Figure 1 : Before changing controller output

Q1: Present (PV) value?

- ➢ 52.5 %

Q2: Present Controller Output (Out)?

- ➢ 35 %

- Key in a new output value of 45.0.
- (Hint: After the numerical value is keyed in, wait until a vertical green line on the grid is just crossing the grid boundary before pressing ENTER. This will make it easier to estimate subsequent times.)
- After the PV has stabilized at a new value, press **PAUSE**.

Q3: Final value of PV ?

- 67.49 % (as shown in fig.2)

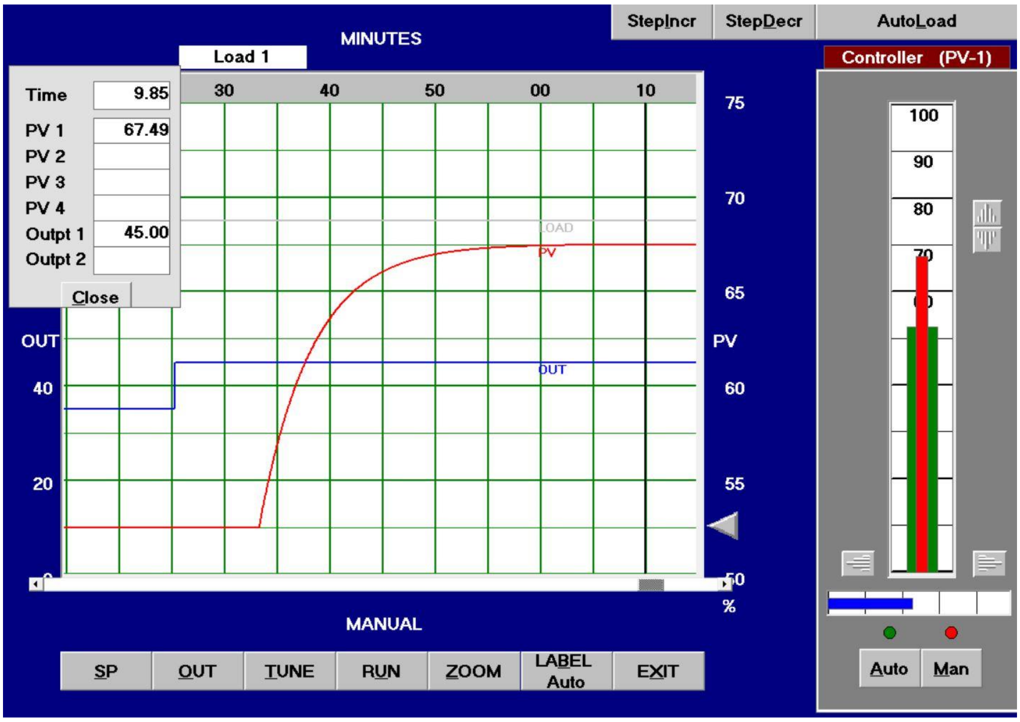


Figure 2 : After changing controller output

Q4: What type of process response does this appear to be?

- **Self-Regulating** Process because the PV settles at a certain value after a while (will seek its own equilibrium)

Q5: How much did the PV change?

- PV change = new value (after changing controller out in fig.2) - old value (before changing controller out in fig.1) = 67.49 - 52.5 = 14.99.

Q6: How much did you change the controller output?

- MV Change Controller Output = 45 (in fig.2) - 35 (in fig.1)= 10.

Q7: Process Gain?

- $K_p = \frac{\Delta\, PV}{\Delta\, MV}$ (**without** scale normalization) $= \frac{14.99}{10} = 1.499$.

- $K_p = \frac{\Delta\, PV\, /\, (PV\ range)}{\Delta\, MV\, /\, (MV\ range)}$ (**with** scale normalization) $= \frac{14.99\, /\, (100-0)}{10\, /\, (100-0)} = 1.499.$

Q8: How long after the controller's output changes before the PV starts changing?

Dead Time (θ)?

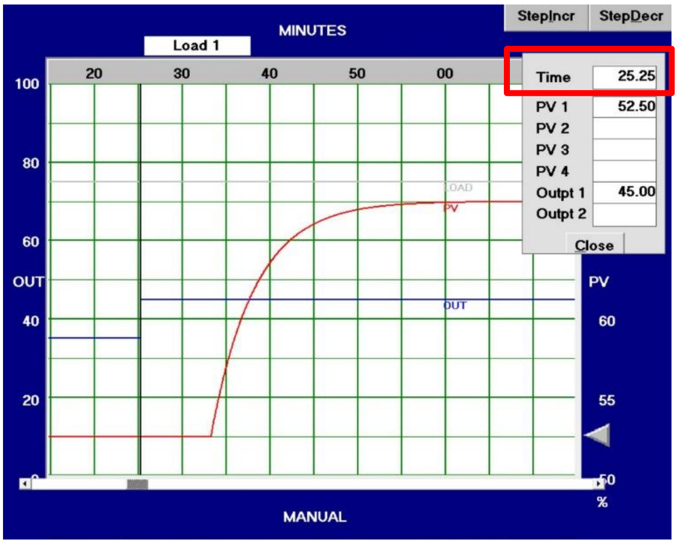


Figure 3 : Start time of MV (Controller OUT) change

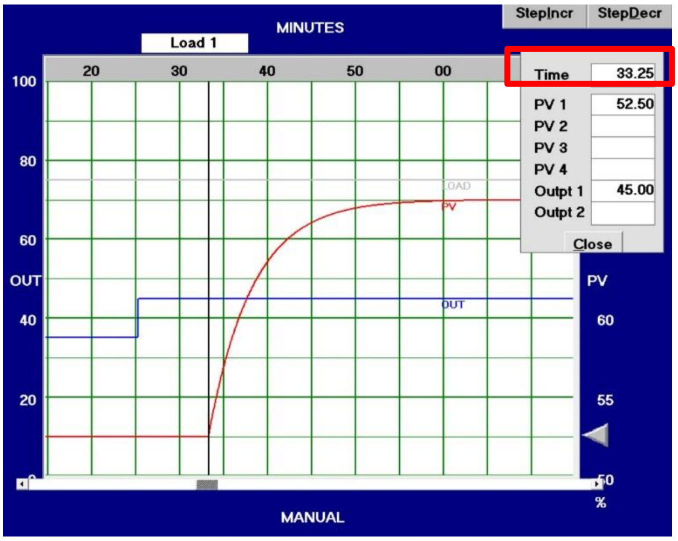


Figure 4: Start time of PV change

- Dead Time = 33.25 (time in fig.4) - 25.25 (time in fig.3) = 8 minute.

Q9: Calculate 63.2% of PV change (Theoretical)?

- = 63.2% x PV change = 63.2/100 x 14.99 = 9.47368.

Q10: Actual value of PV at 63.2% of change?

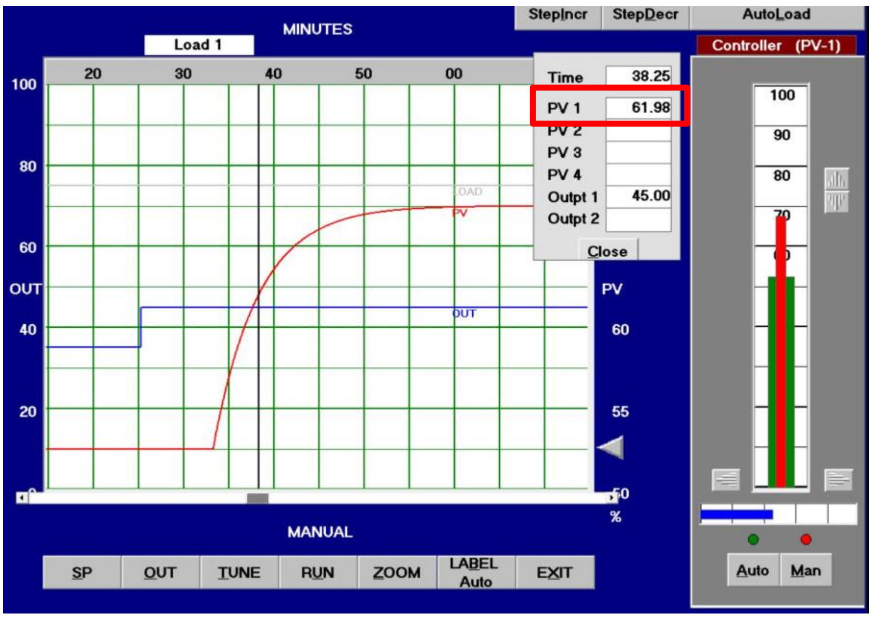


Figure 5 : PV reaches 63.2% of the change

- = initial value of PV (before changing controller out in fig.1) + 63.2% of PV change

  = 52.5 + 9.47368 = 61.97368.

Q11: How long after the PV started changing (i.e, at the end of the dead time) before the PV crossed the 63.2% point? Time Constant (τ)?

- = (time @ which PV reaches 63.2% of the change in fig.5) – (time @ which PV starts to change in fig.4) = 38.25 - 33.25 = 5 minute.
- **Hint:** not subtract dead time from 38.25.

- Select **Process** | **Change Parameters**. Observe the values listed for Dead Time and Time Constant.

Q12: Do these parameter values agree with what you observed?

- Yes, they agree (in Q7.8.11).

- Select **Process** | **Initialize**.
- Select **Process** | **Change Parameters**.
- Select "Dead Time" and change its value to 2.0 (minutes).
- Select "Process Gain" and change its value to 1.0.
- Select "Time Constant" and change its value to 3.0 (minutes).
- Press **CLOSE**.
- Change the controller output from 35.0 to 45.0. Observe the response.

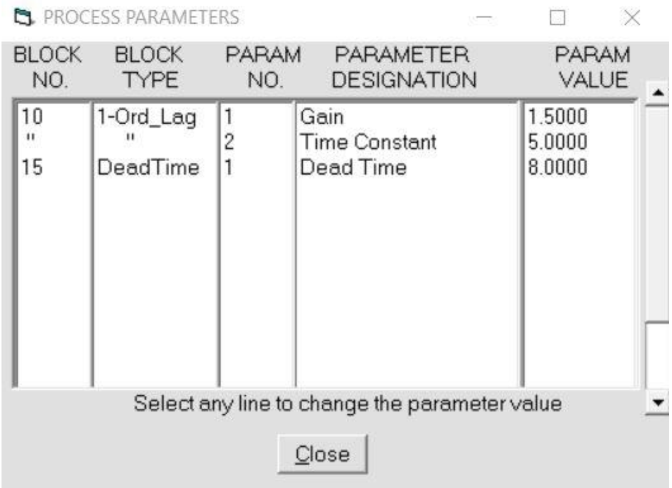


Figure 7 : Old Process Parameters

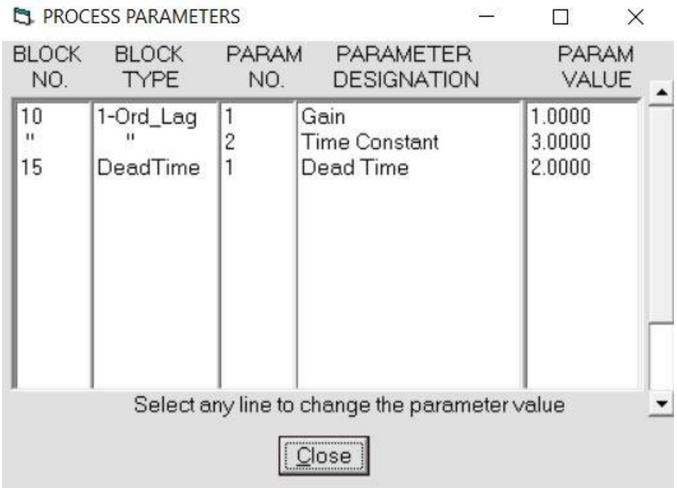


Figure 6 : New Process Parameters

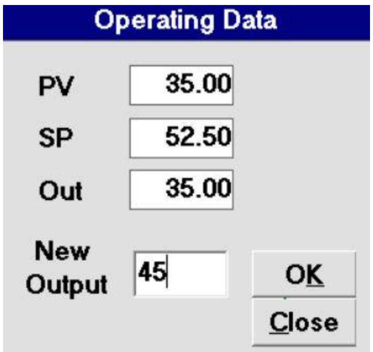


Figure 8 : New Controller Output

Q13: Is this that you would expect?

- Yes, since the process gain = 1 the PV final value will be the same as MV final value (change in PV = change in MV).
- Also, it's expected that the PV will respond faster to the change in the MV, as the dead time decrease from 8 min >> 2 min.
- Also, since the time constant decreases the PV reaches 63.2% of the change faster than the old case.
- <u>1) With respect to dead time:</u>

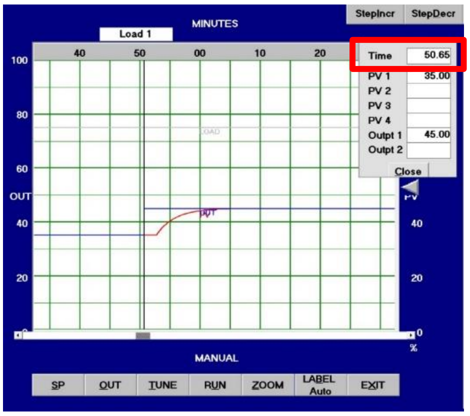


Figure 9: Start time of MV (Controller OUT) change

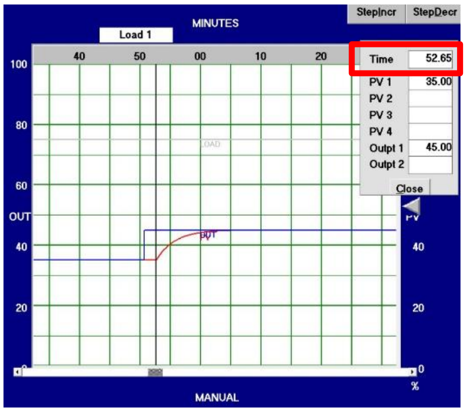


Figure 10: Start time of PV change

- Dead Time = 52.65 (time in fig.10) - 50.65 (time in fig.2) = 2 minute as expected in new process parameters in fig.7.

- <u>2) With respect to Process gain:</u>

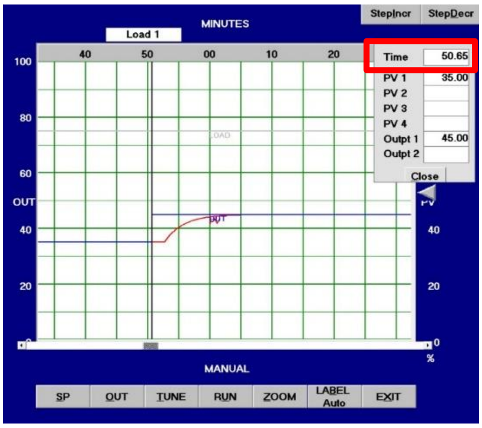


Figure 11: Start time of MV change

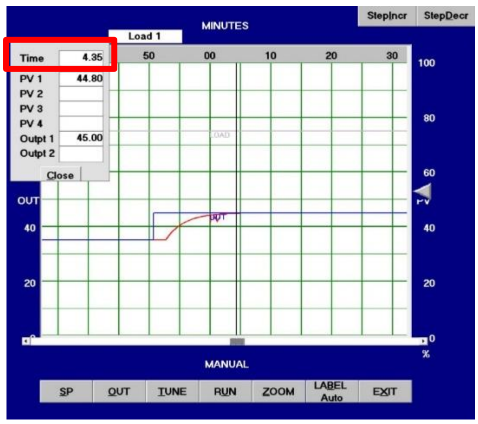


Figure 12: Final Value of PV change

- Process gain $(K_p) = \frac{\Delta\, PV}{\Delta\, MV} = \frac{44.80 - 35 \text{ (in fig.12)}}{45 - 35 \text{ (in fig.11)}} = 0.98$, approx. = 1 as expected in new process parameters in fig.7.

3. UNKNOWN PROCESS

- Click on Process | Select Model. Highlight “Generic” and press Open.
- Notice that the PV scale is now in Engineering Units, rather than in percent.

Q14: Upper end of scale (corresponds to high end of transmitter range)?

➢ 500 DegF

Q15: Low end of scale (corresponds to low end of transmitter range)?

➢ 0 DegF

Q16: Span of PV = range of PV?

➢ 500

Q17: Initial value of PV (in engineering units)?

➢ 275 DegF

Q18: Initial value of PV (in percent of span)?

➢ $= \frac{275}{PV_{range}} = \frac{275}{500} \times 100\% = 55\%$

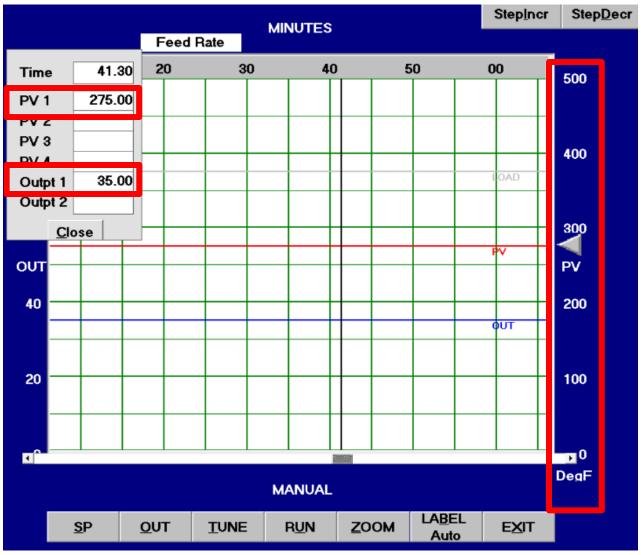


Figure 13: Output, PV, Range Start Values

- Change the controller output from 35.0 to 45.0.

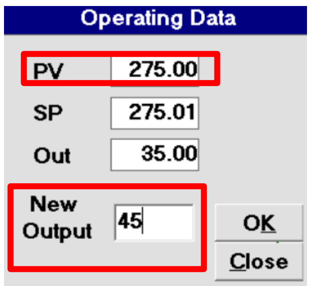


Figure 14: New Output

Q19: When the PV reaches (apparent) equilibrium, press Pause.

After that we change the controller output from 35% to 45%

The PV reach apparent equilibrium state after approximately 35 minutes as shown in fig (15).

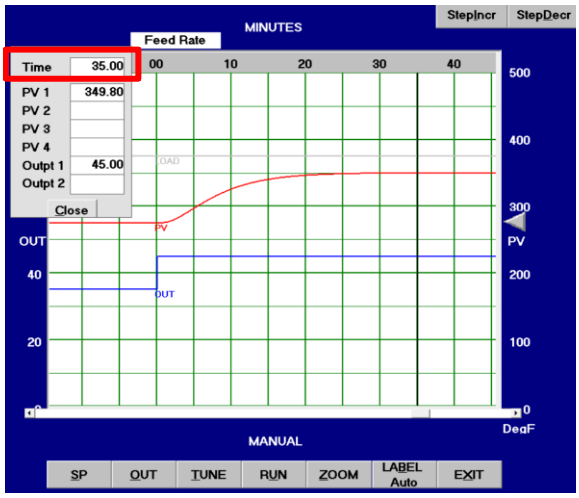


Figure 15: Settling time of PV to reach an equilibrium state

Q20: Does this look like a true first order lag plus the dead time process?

- NO

Q21: Does it look "approximately" like a first order lag plus dead time process?

- YES, as shown in fig.16.

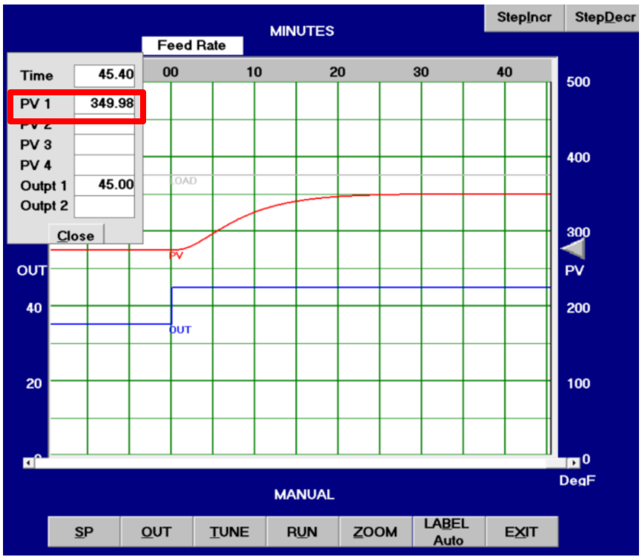


Figure 16: Final PV Value

Q22: What is the final value of the PV (to the nearest whole number)?

- 350 DegF.

Q23: How much did the PV change (in engineering units)?

- $\Delta\text{PV} = \text{PV value in Fig.}(16) - \text{PV value in Fig.}(14) = 350 - 275 = 75 \text{ DegF.}$

Q24: How much did the PV change (in percent of span)?

- $= \dfrac{\Delta PV}{PV_{range}} = \dfrac{75}{500} \times 100\ \% = 15\ \%$

Q25: Estimated process gain K_p ?

- $\text{K}_\text{p} = \dfrac{\Delta\ PV\ /\ (PV\ range)}{\Delta\ OUT\ /\ (OUT\ range)} = \dfrac{75\ /\ 500}{10\ /\ 100} = 1.5$

- To estimate the dead time, draw (or visualize) a tangent to the PV curve, drawn at the point of steepest rise. From the time of controller output change to the intersection of this tangent with the initial steady state value is the apparent dead time.

Q26: Apparent dead time (θ)?

➢ $\theta = 1.25\ Minutes$, as shown in Fig (17) & (18).

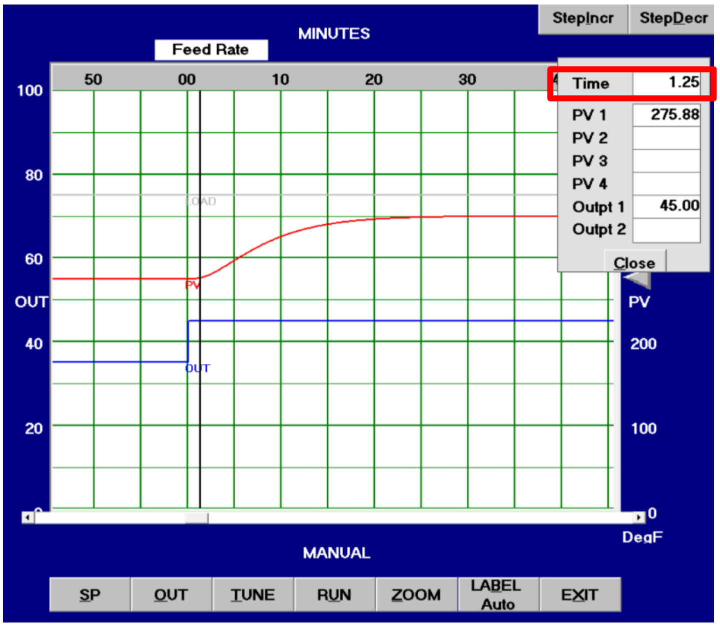


Figure 17: Dead Time from graph

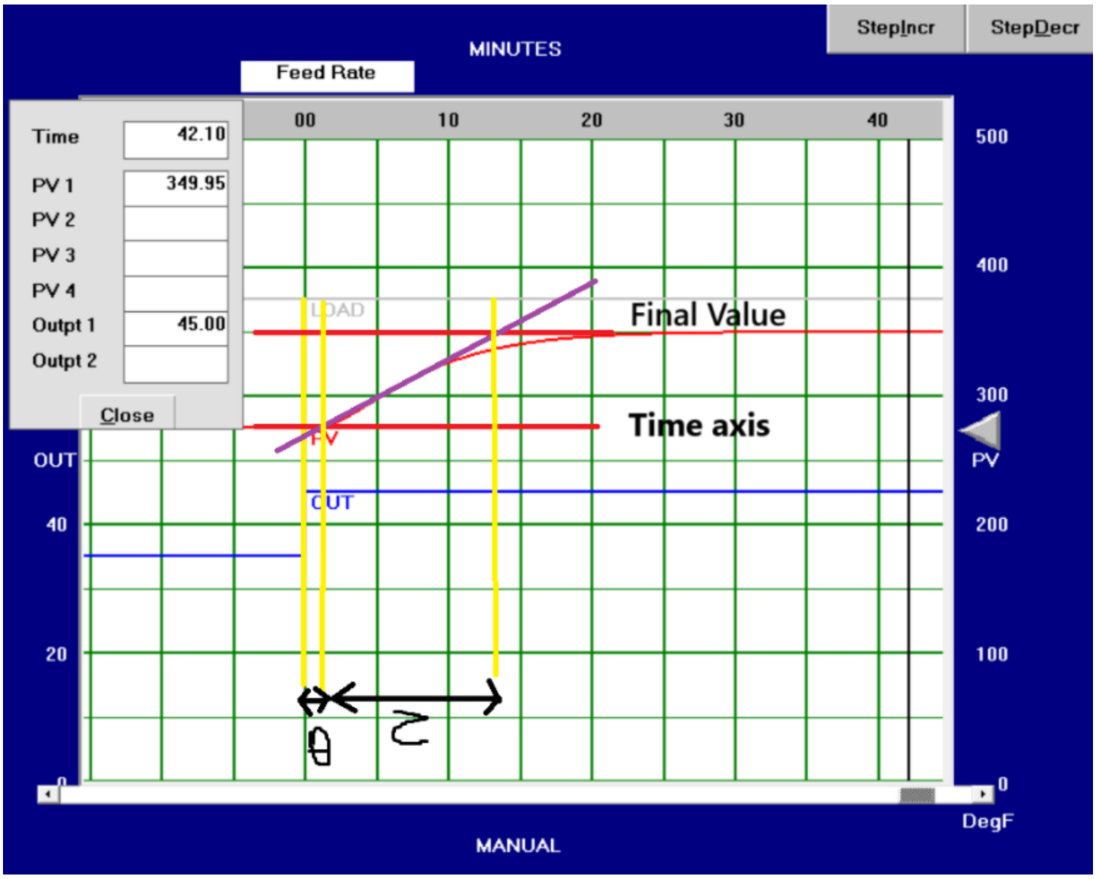


Figure 18: Dead time and constant time using Ziegler-Nicholas tangent Method

- The apparent time constant is the time from the end of the dead time to 63.2% of the process rise

Q27: Apparent time constant?

- Since PV change = 75 DegF >> $\therefore 63.2\ of\ change = 0.632 * 75 = 47.4\ \text{DegF}$
- Therefore, the value of PV @ $63.2\ of\ change = 275\ (initial) + 47.4 = 322.4\ \text{DegF}$
- $\therefore\ \tau = 9.10\ (\text{time @ PV reaches 63.2\% of change}) - 1.25(\text{dead time}) = 7.85\ min$

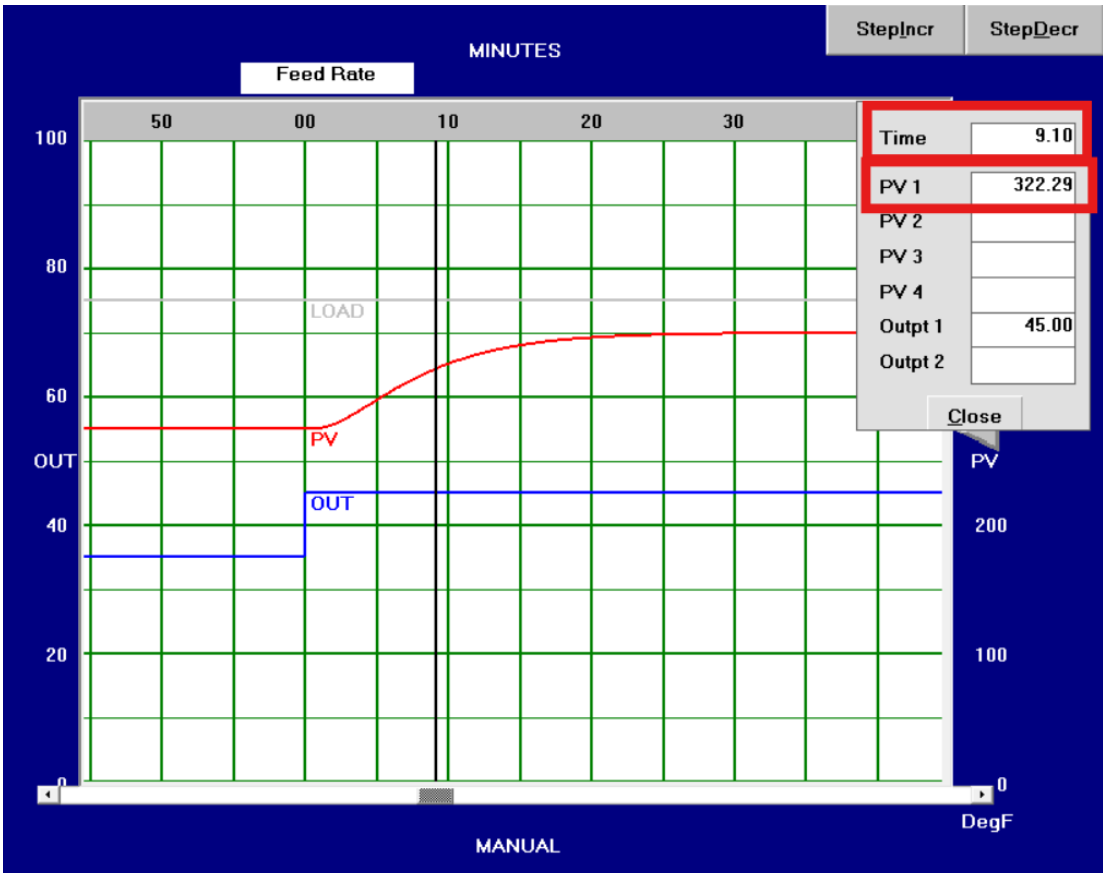


Figure 19: Time @ which PV reaches 63.2% of the change

4.0 OTHER FORMS OF STEP RESPONSE

4.1 Negative Process Gain

- Select **Process** | **Select Model**. Highlight “generic3.mdl" and press **Open**.
- Record the initial values:

Q28: PV initial value?

- $= 46\ \text{DegF}, = \frac{46}{100} * 100 = 46\ \%$ (as shown in fig.20)

Q29: Controller output initial value?

- $= 70\ \text{DegF}, = \frac{70}{100} * 100 = 70\ \%$ (as shown in fig.20)

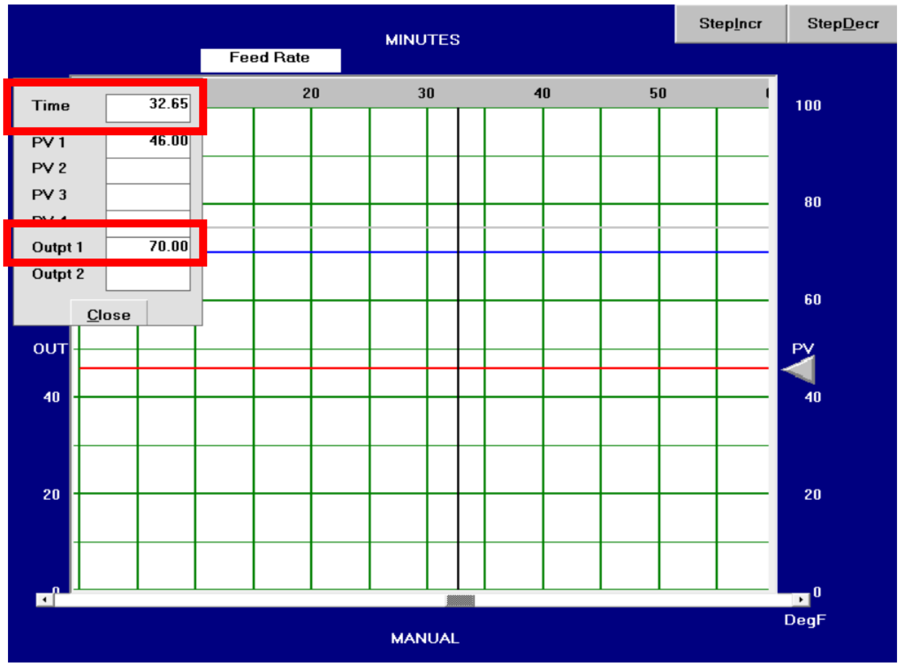


Figure 20: Initial values of PV and out of generic3 Process

- Increase the controller output by 10%. When the PV reaches equilibrium

Q30: Final value of PV?

➢ $= 40.24\ \text{DegF}\ , = \frac{40.24}{100} * 100 = 40.24\ \%$ (as shown in fig. 21)

Q31: Final value of controller output?

➢ 10 % of controller output = 0.1 * 100 = 10, therefore new out = 70 + 10 = 80 %

Q32: Process Gain?

➢ $K_p = \frac{\Delta\, PV\ /\ (PV\ range)}{\Delta\, OUT\ /\ (OUT\ range)} = \frac{(40.24 - 46\ )/\ 100}{(80-70)/\ 100} = -0.576$

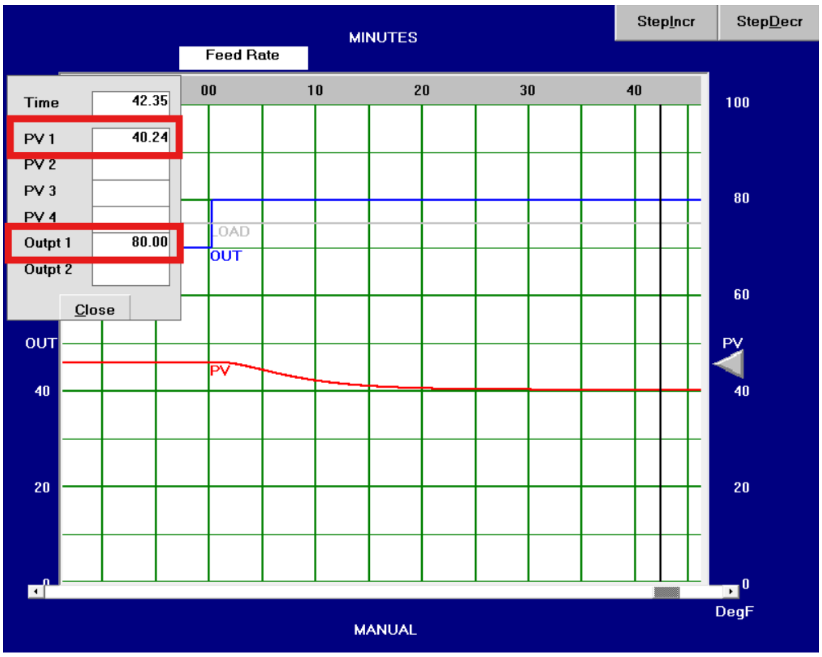


Figure 21: PV Final value after changing the controller output

4.2 Integrating Process

- Select **Process** | **Select Model**. Highlight “level2.mdl” and press **Open**.
- This process model simulates a level control application in which the tank outflow is an independent process disturbance (load), and the controller controls a valve in the inflow line.
- Select **Process** | Change Parameters.
- Highlight the parameter labeled **"Valve Pos: 0 = No; 1 =Yes.”** Change this parameter value to **1**.
- Select the parameter labeled **“Levl Noise: 0=No; I =Yes”.** (Use the scroll bar at the left-hand side of the parameter list, if this parameter is not visible initially.) Change this parameter value to **0**.

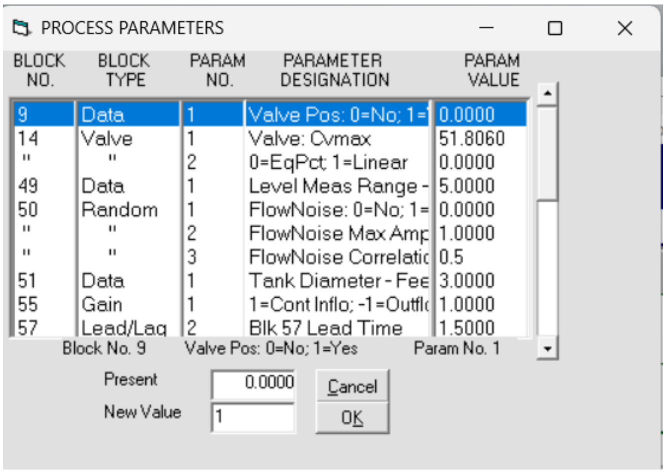


Figure 22: Changing "Valve Pos: 0 = No; 1 =Yes.”

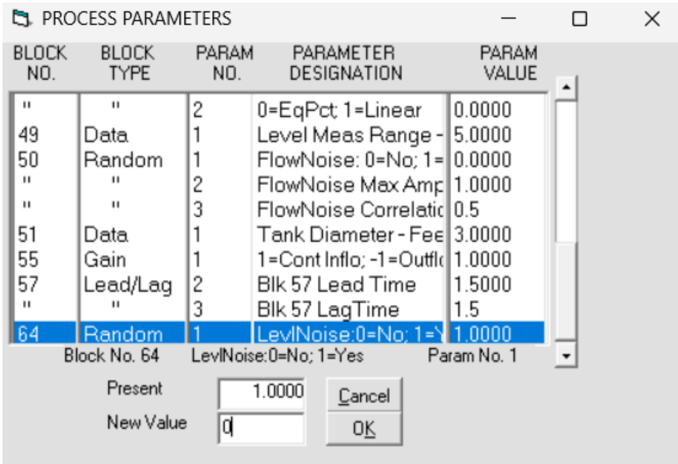
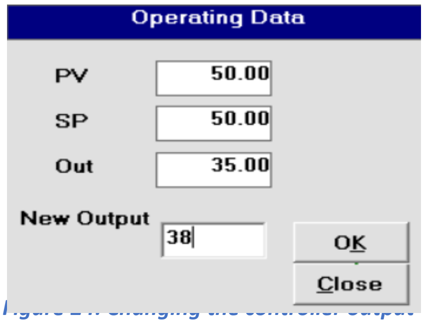


Figure 23: Changing “Levl Noise: 0=No; I =Yes”.



- Change the controller output from 35.0 to 38.0. This simulates an **increase in inflow to the tank**.

Q33: What does the PV (tank level) do?

- ➢ PV will increase in an accumulative way until saturated at 100% of its scale.

Q34: Does it appear that the PV is going to reach an equilibrium?

- ➢ No, it will not reach an equilibrium state.

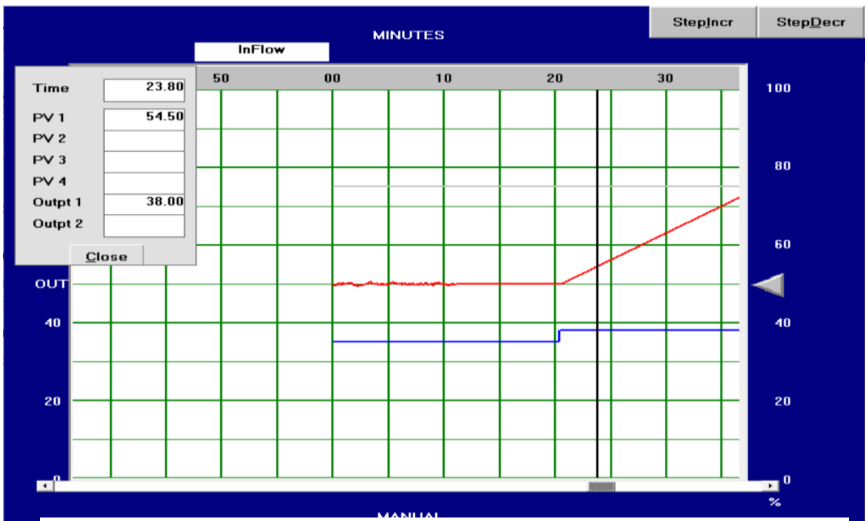


Figure 25: PV response after changing the controller output

- **Before** the PV reaches a limit (0 or 100), press the button **StepIncr** above the controller faceplate. This simulates an **increase in outflow from the tank**. Note the increase in the trace labeled 'LOAD'.

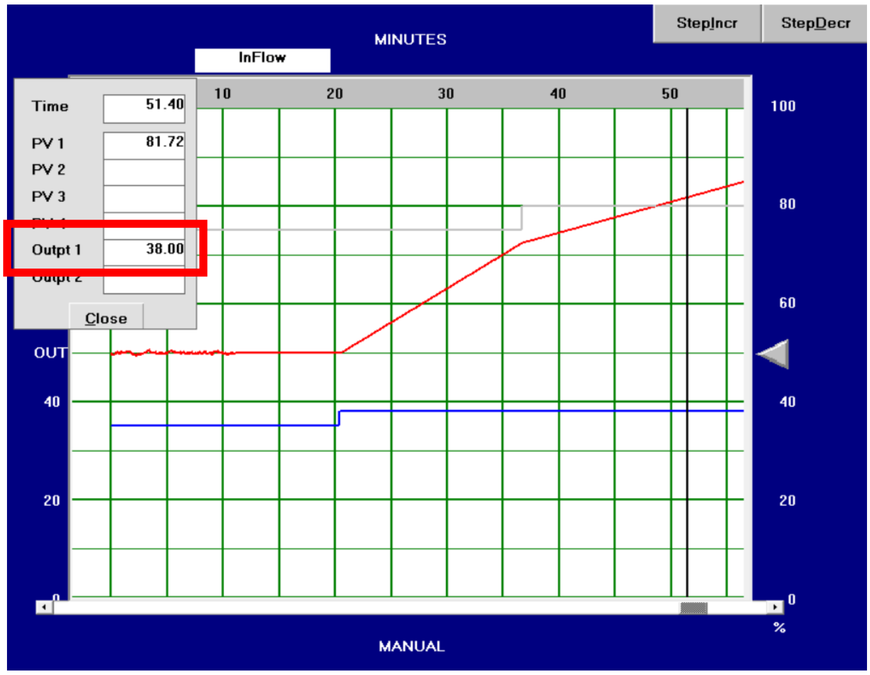


Figure 26: PV response after pressing the button StepIncr

- If the PV is now falling, then the rate of outflow must exceed the inflow. Slightly increase the controller output (to increase the tank inflow) to attempt to stabilize the level. If the PV is rising, decrease the controller output.

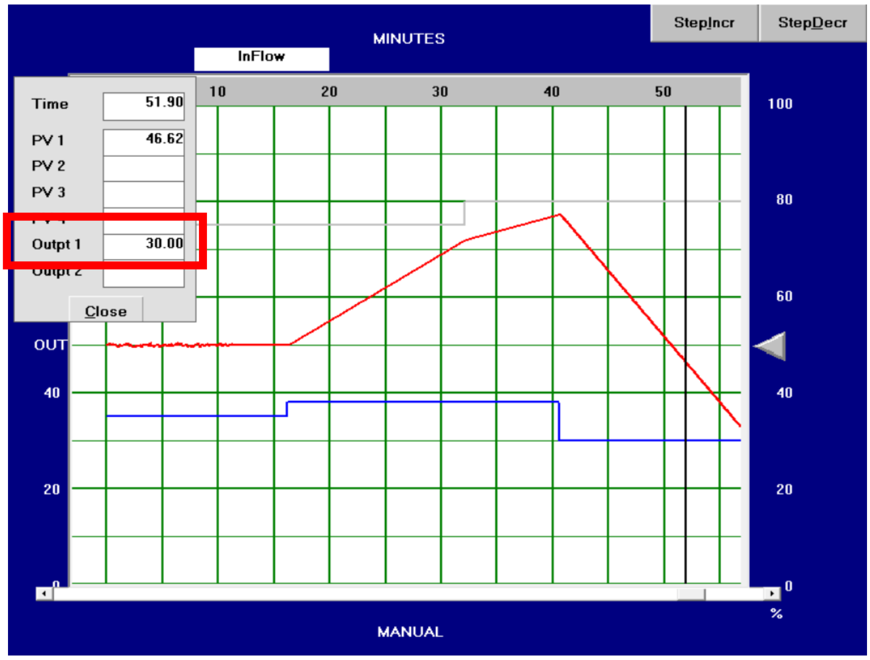


Figure 27: PV response after decreasing the controller output t0 30 %

Q35: ***Can you eventually (approximately) stabilize the level by manual control?***

- NO, Since the PV is still rising after pressing **StepIncr** (outflow), we will decrease the **controller output** or inflow to the tank (let say decrease it to 30%).

- So, the PV will decrease but **will not ever be stabilized by manual control** as the PV will decrease gradually till reaching 0% as shown in fig.27.