CASCADE AND RATIO CONTROL
FINAL PROJECT REPORT

Prepared for
Mr. T. TenHave
Confederation College
Field Instrumentation IT 446

Neep Patel
&
Arulkumaran

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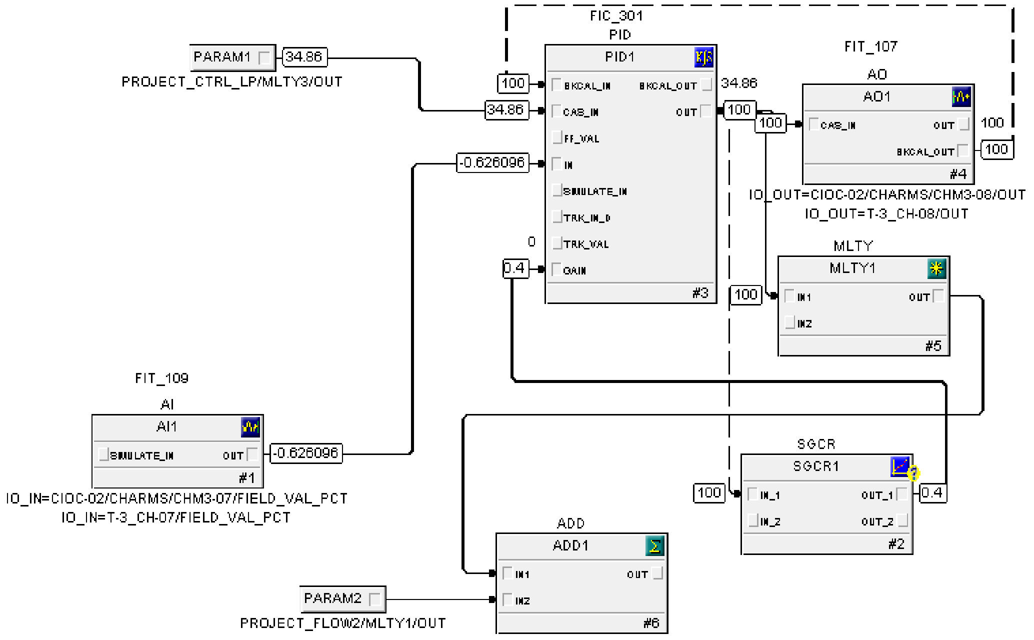
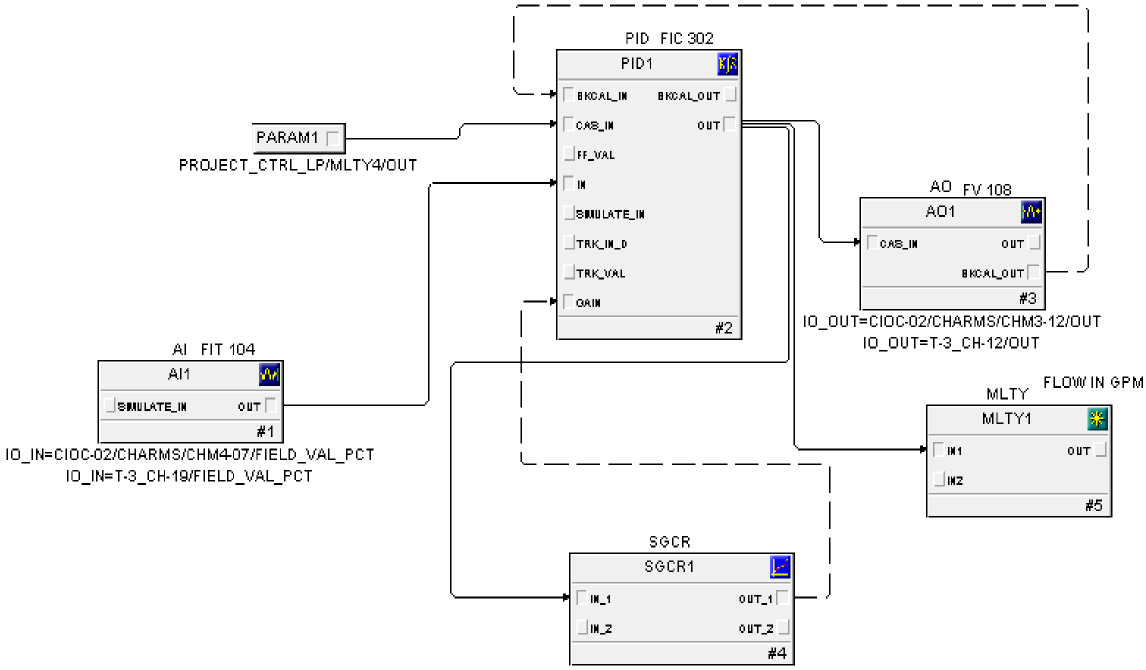
Abstract

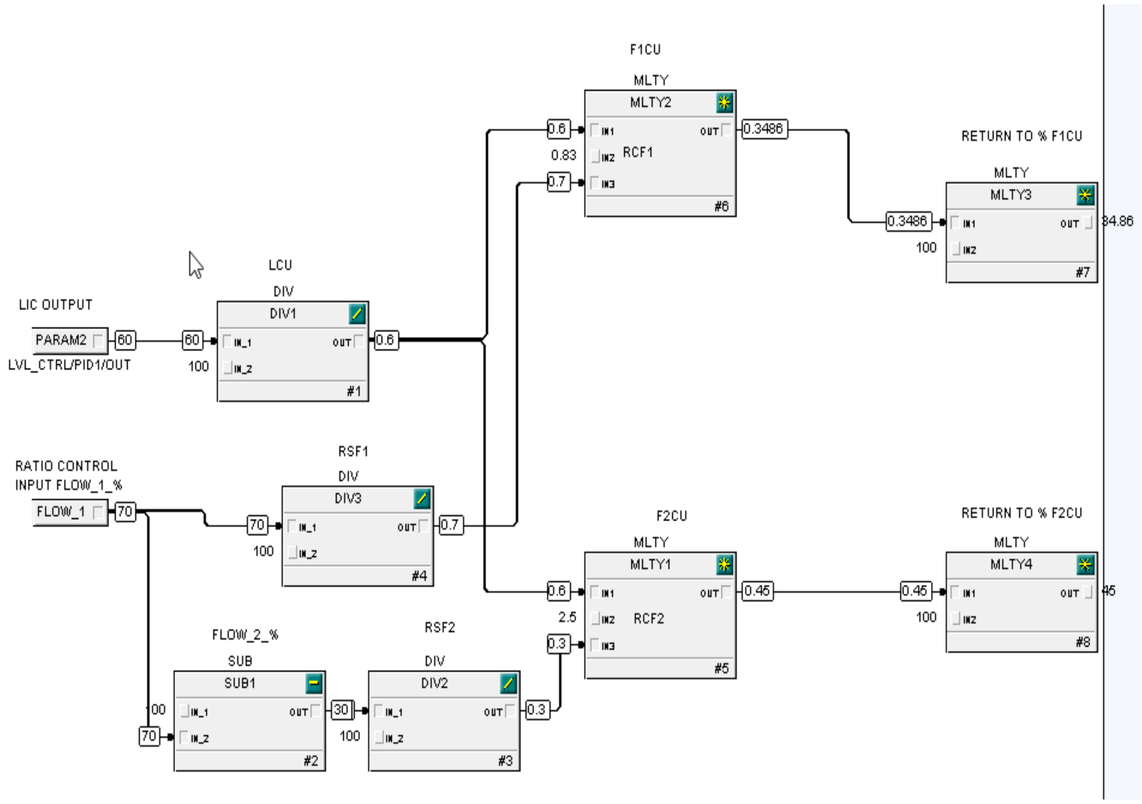
Automation control systems are used in a wide range of industries, including manufacturing, energy, transportation, and telecommunications. These systems can help increase efficiency, reduce costs, improve safety, and enhance quality by automating repetitive tasks, eliminating errors, and optimizing processes.

This report contains information of a process which is controlling a tank level by controlling two different flows. Also, for tunning how adaptive gain can be more efficient than simple lambda tunning. Moreover, this report will indicate the areas where errors can occur.

Block Diagrams:



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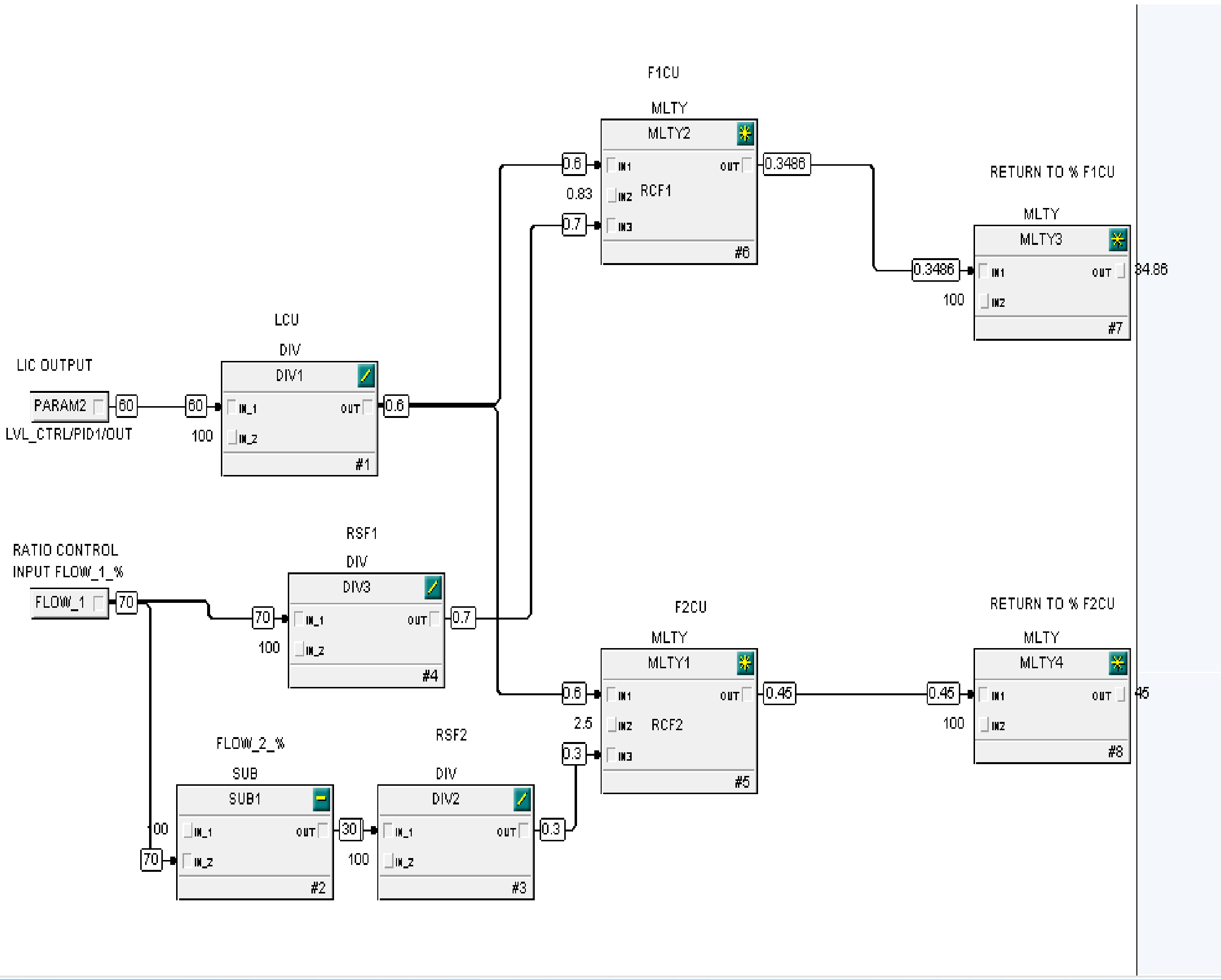
MLTY
MLTY2
RCF1
0.6
0.83
0.7
0.3486
#6
RETURN TO % F1CU
MLTY
MLTY3
0.3486
100
34.86
#7
LCU
DIV
DIV1
LIC OUTPUT
PARAM2
60
60
100
LVL_CTRL/PID1/OUT
0.6
#1
RSF1
DIV
DIV3
RATIO CONTROL
INPUT FLOW_1_%
FLOW_1
70
70
100
0.7
#4
F2CU
MLTY
MLTY1
RCF2
0.6
2.5
0.3
0.45
#5
RETURN TO % F2CU
MLTY
MLTY4
0.45
100
45
#8
FLOW_2_%
SUB
SUB1
100
70
30
#2
RSF2
DIV
DIV2
30
100
0.3
#3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RETURN TO % F2CU
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0.45
100
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#8
FLOW_2_%
SUB
SUB1
100
70
30
#2
RSF2
DIV
DIV2
30
100
0.3
#3

1. Process Description

The process and instrumentation diagram of technological process that fills the tank 2 is represented in Figure 1, pg. 5.

Control system of the process consist of three loops:

- First flow control loop;
- Second flow control loop;
- Level control loop.

First flow control loop includes uncontrolled Pump #1, Control Valve #1. The control of the flow rate is carried out in manual mode through the ABB DCS by the adjusting the Control Valve #1, according to the Flow Transmitter signal, that based on the orificeplate that is installed in the line before the valve. Second flow control loop includes uncontrolled Pump #2, Control Valve #2 (with pneumatic actuator) and Magnetic Flowmeter. The control of the second flow rate also is carried out in manual mode through the ABB DCS by the adjusting the Control Valve #2, according to the Magnetic Flowmeter signal.

Level control loop consists of Level Transmitter (D/P cell). The ABB DCS represents the level in the tank according to the Level Transmitter signals.

2. Process Control Requirements

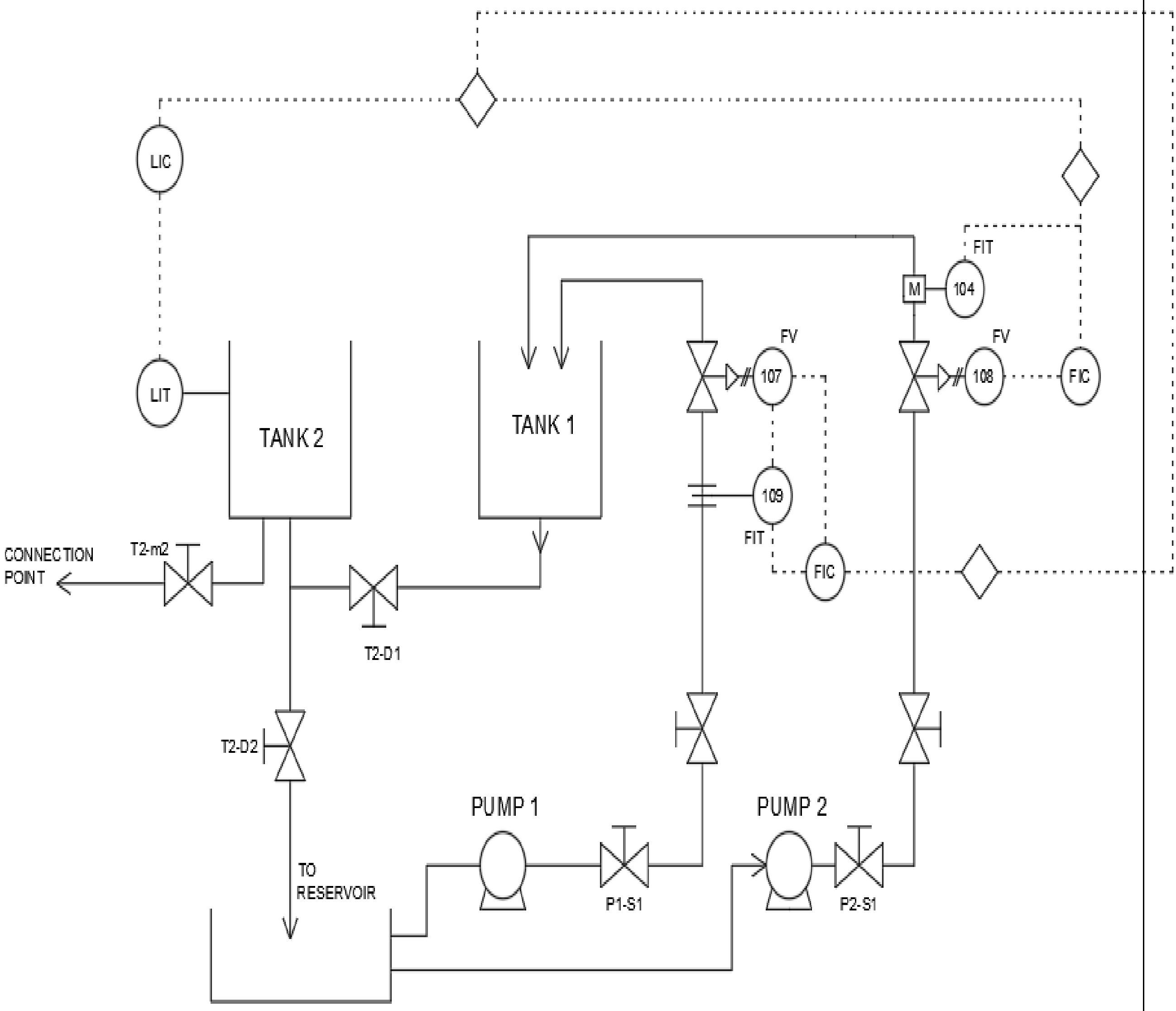
The ratio between flows must be adjusted by changing the percentage of each flow separately. The default settings for the flow loops should be 70% (First flow loop) and 30% (Second flow loop).

Each flow percentage should be represented on separate faceplates. Additional faceplate should represent combined percentages of both flows. Both control loops must be tuned to a Lambda of 8 seconds.

Both flow trends and remote set point of the level controller must be represented on one chart of digital recorder.

The main parameters of control loops are:

- Flow control loop one (secondary) 0 GPM to 15 GPM;
- Flow control loop two (secondary) 0 GPM to 5 GPM;
- Level control loop (primary) 0"H2O to 30"H2O



3. Methodology and Results

3.1 Implemented Methods Description

At first only lambda tunning was used for tunning the flow 1 and 2. But due to too many errors this was changed to finding the adaptive gain. The adaptive gain technique can be implemented using various algorithms, such as the least-mean-squares (LMS) algorithm or the recursive least-squares (RLS) algorithm. These algorithms use a feedback loop to adjust the gain of the system based on the difference between the desired output signal and the actual output signal.

3.2 Cascade and Ratio Control Implementation

The desired structure for this process must combine all control loops (two flow control loops and a level control loop) in one process control loop. The changing of the level in the tank will cause the level controller to generate an output signal that will be used by the flow controllers to adjust the overall flow going in the tank. Therefore, level control becomes a primary loop, which provides the remote set point to secondary flow loops.

Flow 1: 0-15 gpm

Flow 2: 0-5 gpm

Maximum combined flow: 12gpm

Level range: 0-30”in H20

RCF1: $\frac{MCF}{\text{URV of F1}} = \frac{12}{15} = 0.8$

RCF2: $\frac{MCF}{\text{URV of F2}} = \frac{12}{5} = 2.4$

Lets take 70% of max combined flow from F1 and 30% from the F2.

RSF1 = 70/100 = 0.7

RSF2 = 30/100 = 0.3

To find the lower setting of flow 1 and flow 2

MCF – (%F1)MCF < 5gpm

12*(1 – F1%) < 5gpm

F1 < $1 - \frac{5}{12}$

F1 < 58.4 %

So lowest setting for 12gpm of combined flow can be said as 58% of MCF from F1 and and 41.6 % from F2.

For 70%:30%, F1:F2

LCU = 0.5

F1CU = RCF2 * RSF2 * LCU

= 0.7 * 0.8 * 0.5

= 0.28 = 28%

F2CU = RCF2 * RSF2 * LCU

= 0.3 * 2.4 * 0.5

= 0.36 = 36%

3.3 Lambda tuning

The Flow #1 and the Flow #2 are processes with the first-order dynamics, therefore the first-order dynamics Lambda tuning was used to determine controllers' settings for 8 seconds (λ=8[s]) loops response time.

First-order dynamics Lambda tuning for flow (non-integrating process)

$\mathrm{Ks} = \Delta\mathrm{PV}/\Delta\mathrm{OP}$

$\tau = 63.2\%\ of\ \Delta PV$

Kc = $\frac{\tau}{Ks*(\lambda + \mathrm{TD})}$

FIC-301: ADAPTIVE GAIN CALCULATION

1:

60- 70:

KS = 1.8

TD=2 sec

τ=3 sec

8 sec = λ

KC= 0.17

Ti = 3sec

2:

70 -80:

KS = 0.76

τ= 3 sec

TD= 2 sec

Λ= 8 sec

KC= 0.3

Ti = 3 sec

3:

80 – 90:

KS = 0.53

TD=2 sec

τ= 3 sec

Λ= 8 sec

KC= 0.47

Ti = 3 sec

FIC-302: ADAPTIVE GAIN CALCULATION

1: 10- 20:

KS = 1.807

TD=2 sec

τ= 8 sec

8 sec = λ

KC= .152

Ti = 8 sec

2: 30 -40:

KS = 0.573

TD=1 sec

τ= 7 sec

TD= 2 sec

Λ= 7 sec

KC= 0.205

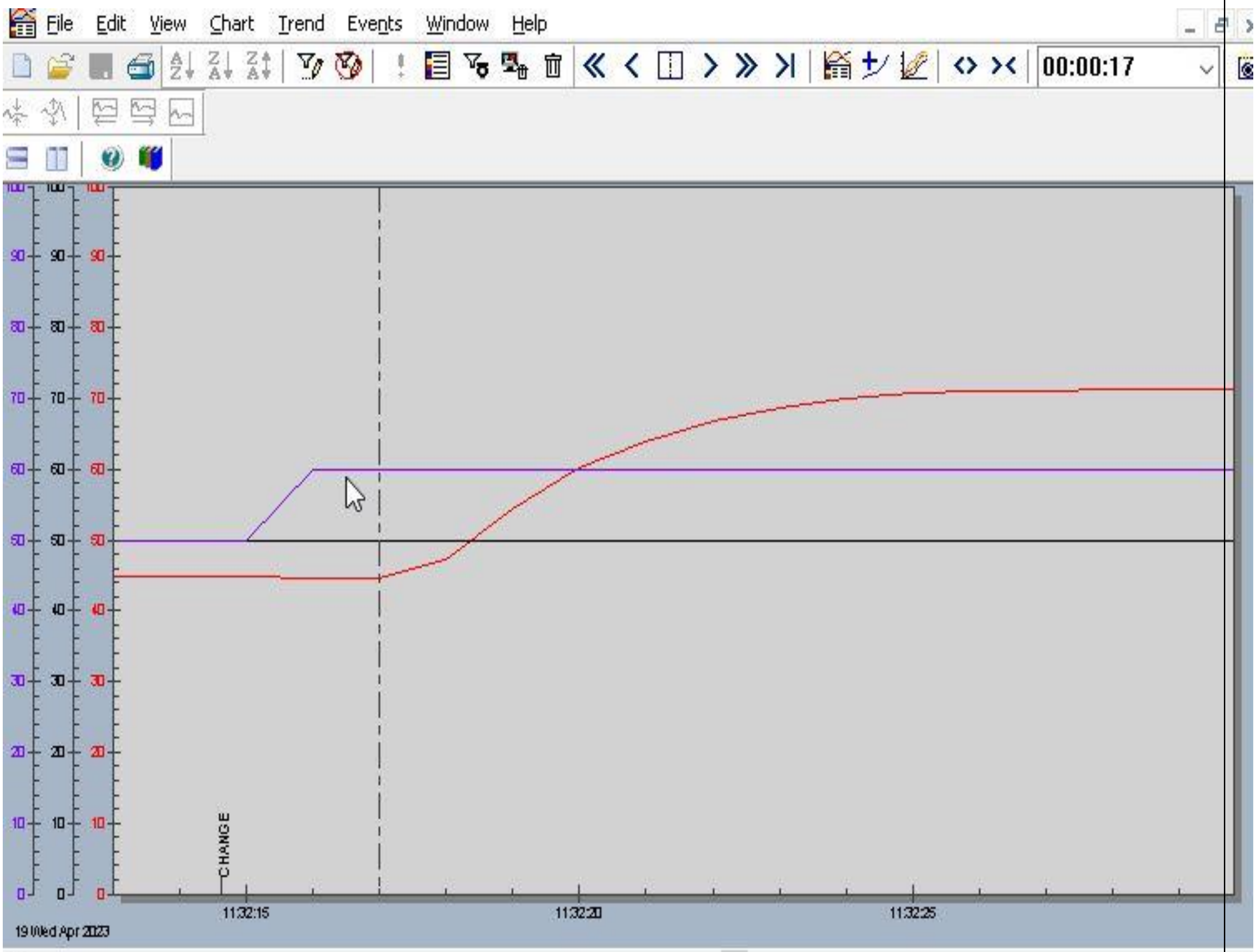
Ti = 8 sec

1. Flow #1 tuning parameters

As per the graphs shown below the chart for flow 1 given the dead time of constant 2s for all the bumps.

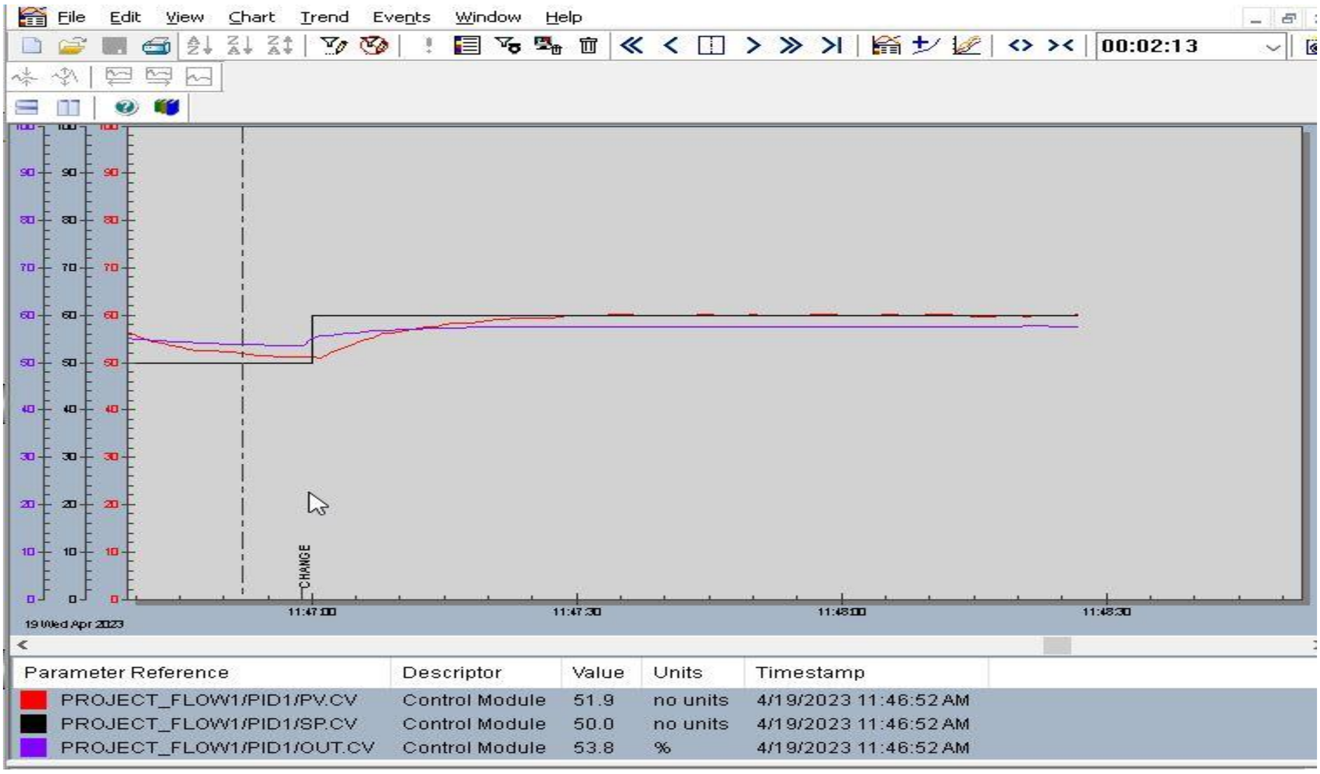
If it is different the overall average is to be taken.

As we are using the range of Flow 1 from 58.4 50 100, so bumping will start from 50.



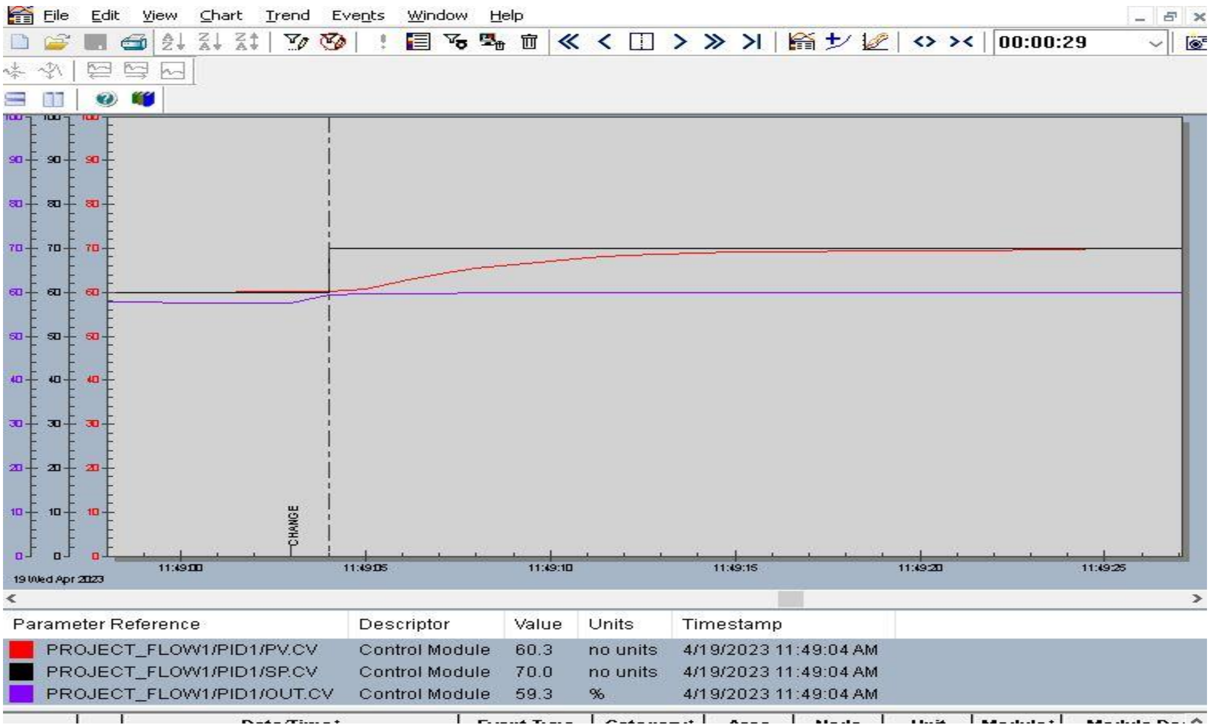
Parameter Reference	Descriptor	Value	Units	Timestamp
PROJECT_FLOW1/PID1/PV.CV	Control Module	44.6	no units	4/19/2023 11:32:17 AM
PROJECT_FLOW1/PID1/SP.CV	Control Module	50.0	no units	4/19/2023 11:32:17 AM
PROJECT_FLOW1/PID1/OUT.CV	Control Module	60.0	%	4/19/2023 11:32:17 AM

Fig bumping in man from 50 to 60



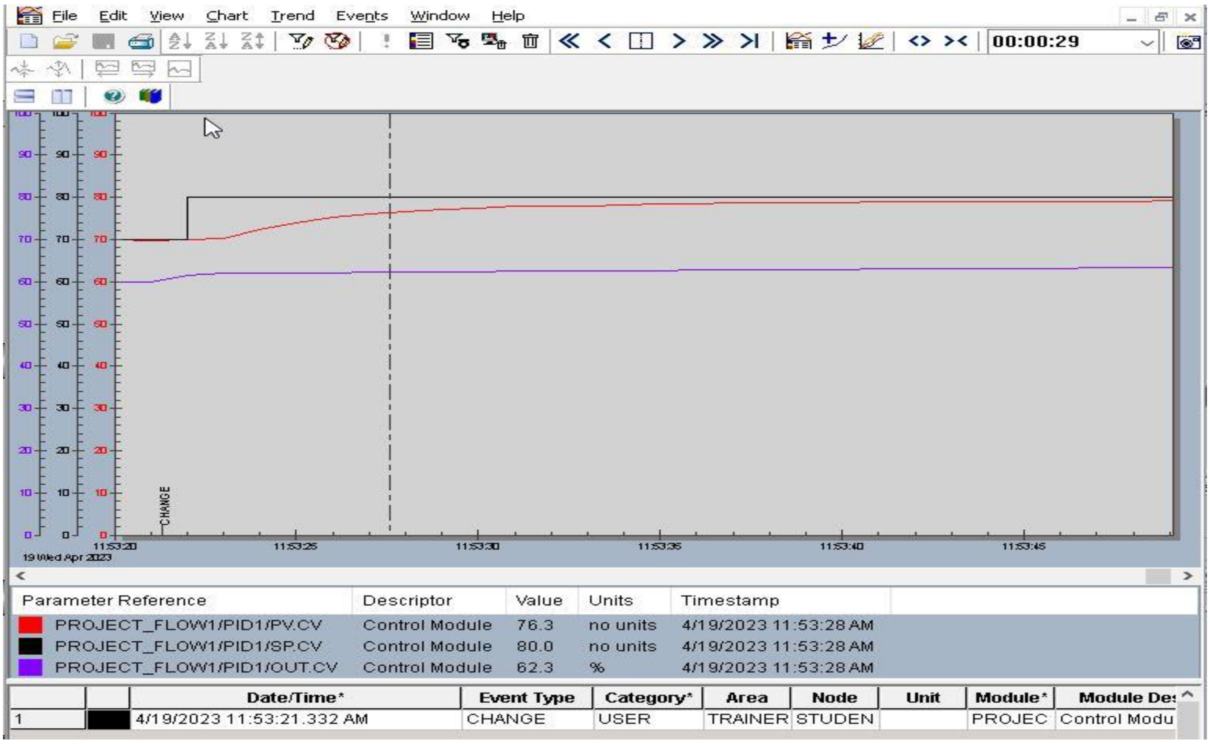
Auto from 60-70

At every bump the dead time, time constant and system gain is taken and from that the controller gain is obtained.

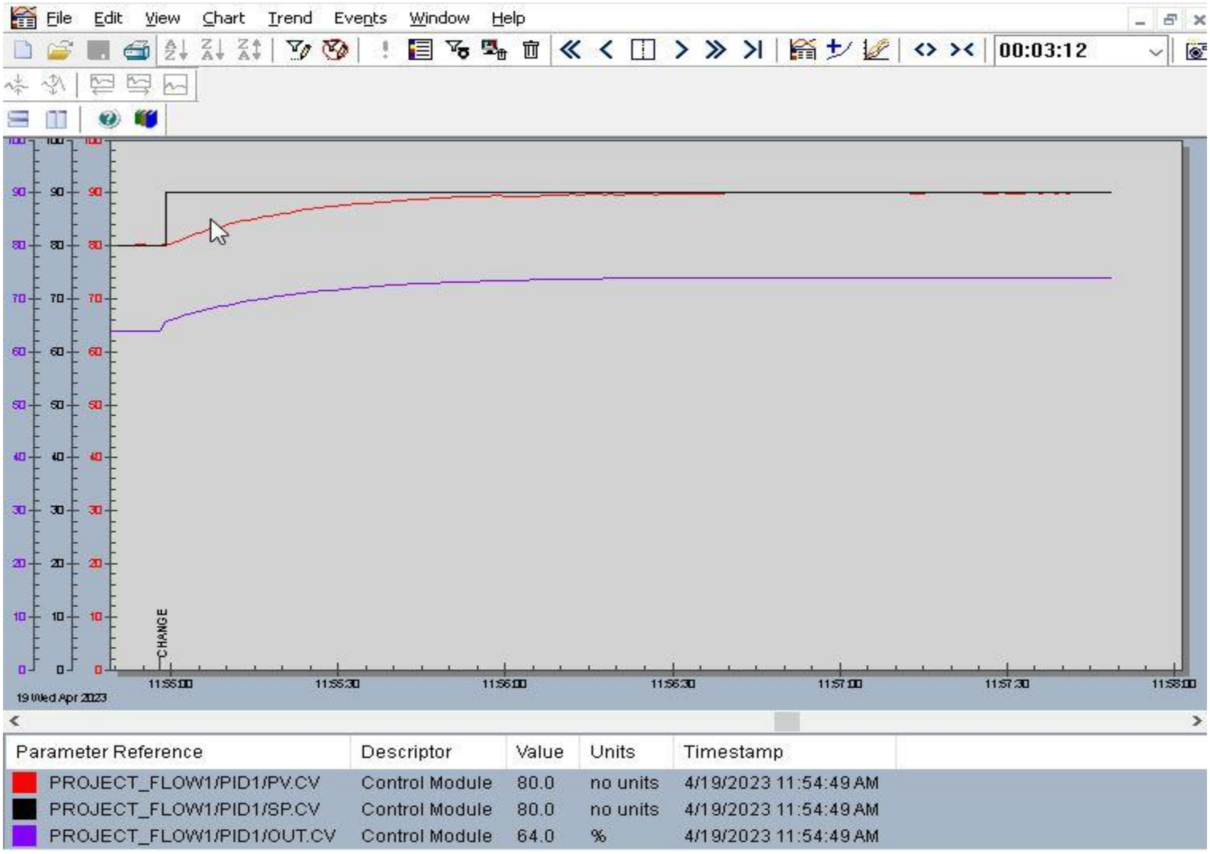


From 60 - 70

From 70-80



From 80 -90



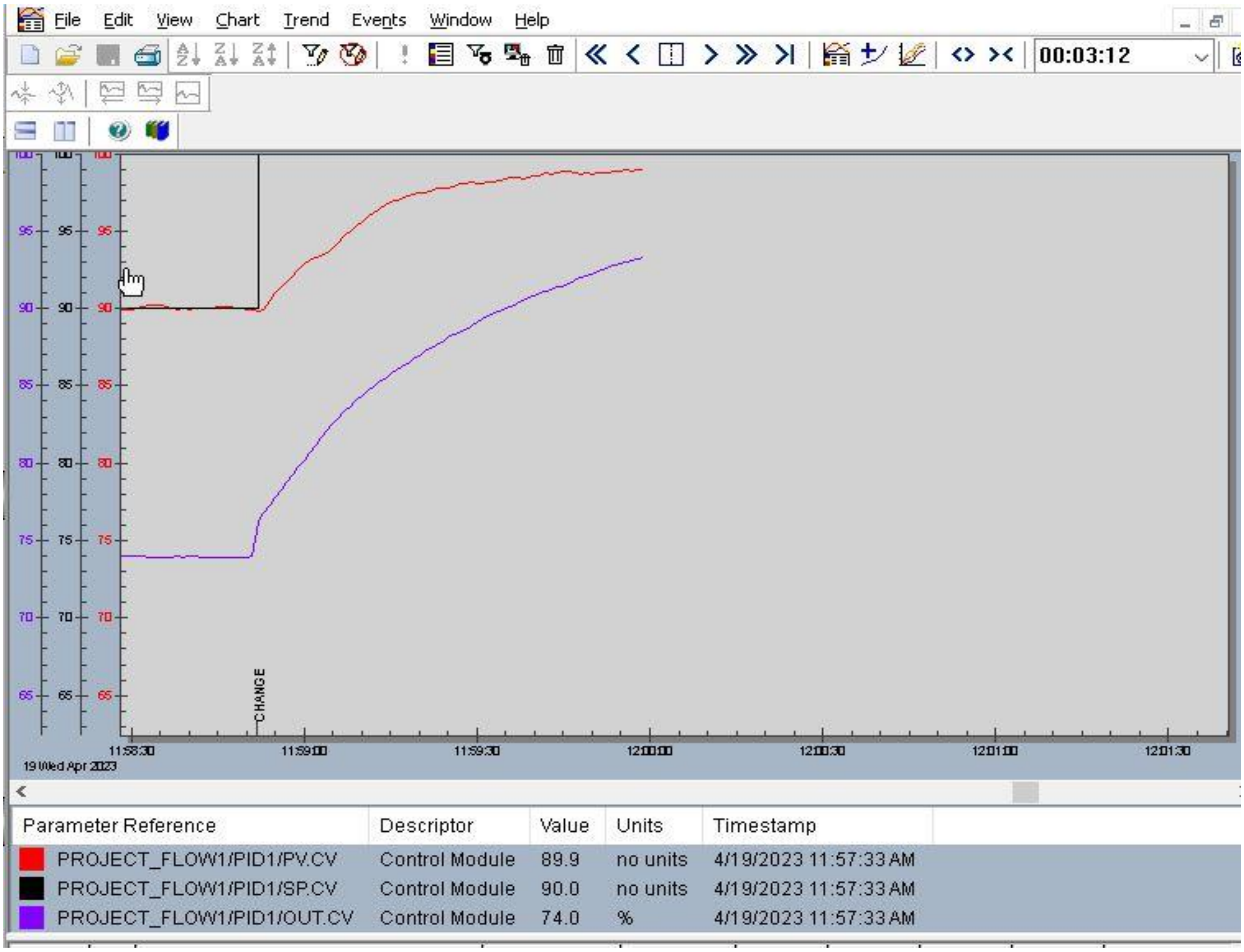


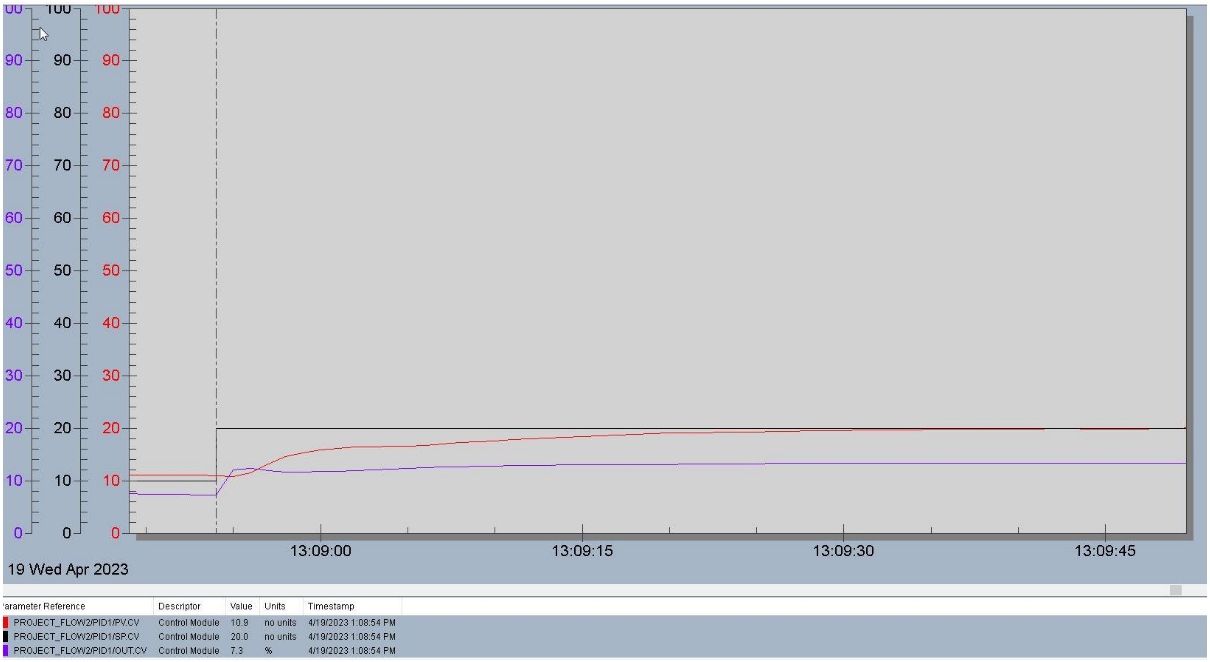
Table for Adaptive gain for Flow 1: $\tau = 3s$, Td = 2s

X- Axis	Y-Axis
60	0.17
70	0.17
80	0.3
90	0.47
100	0.4

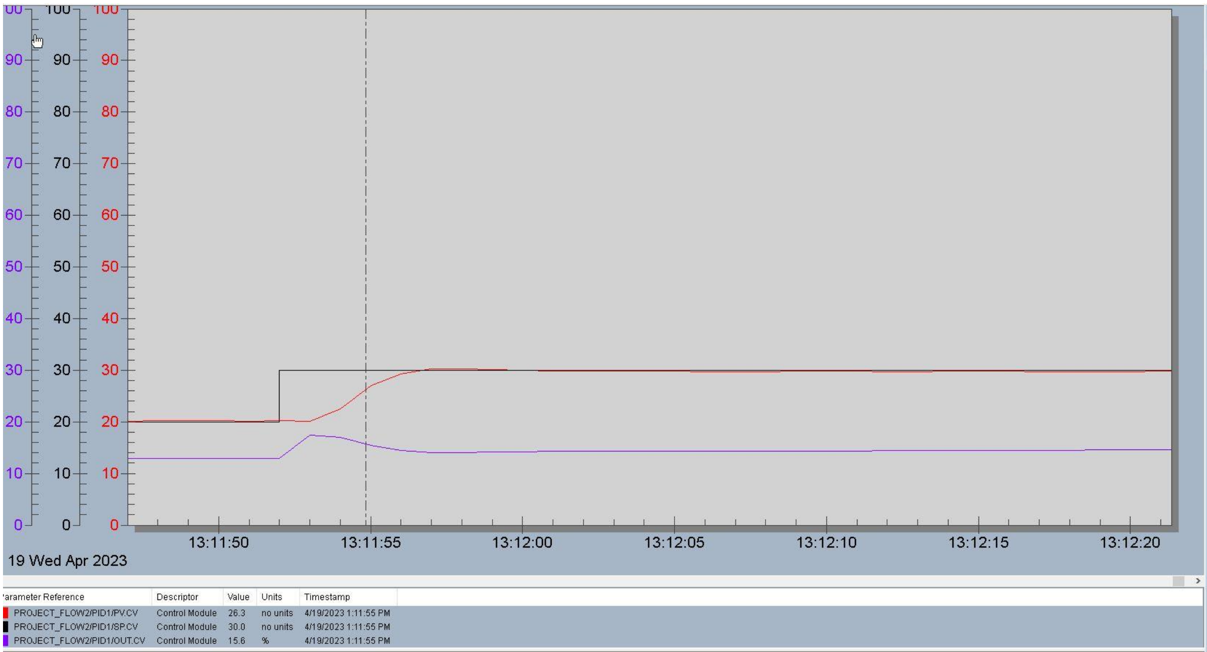
2. Flow #2 Tunning Parameter:

Flow controlled from 0 to 5 gpm.

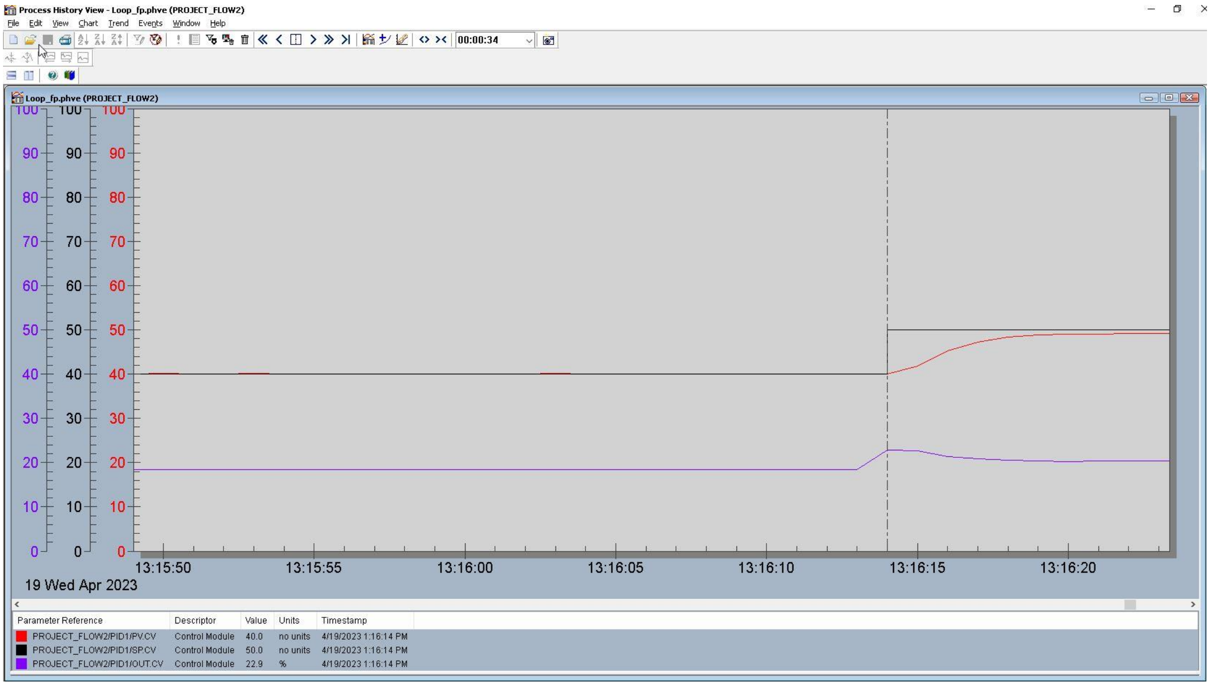
We can use whole range of Flow 2 for controlling the level with max combined flow 12gpm.



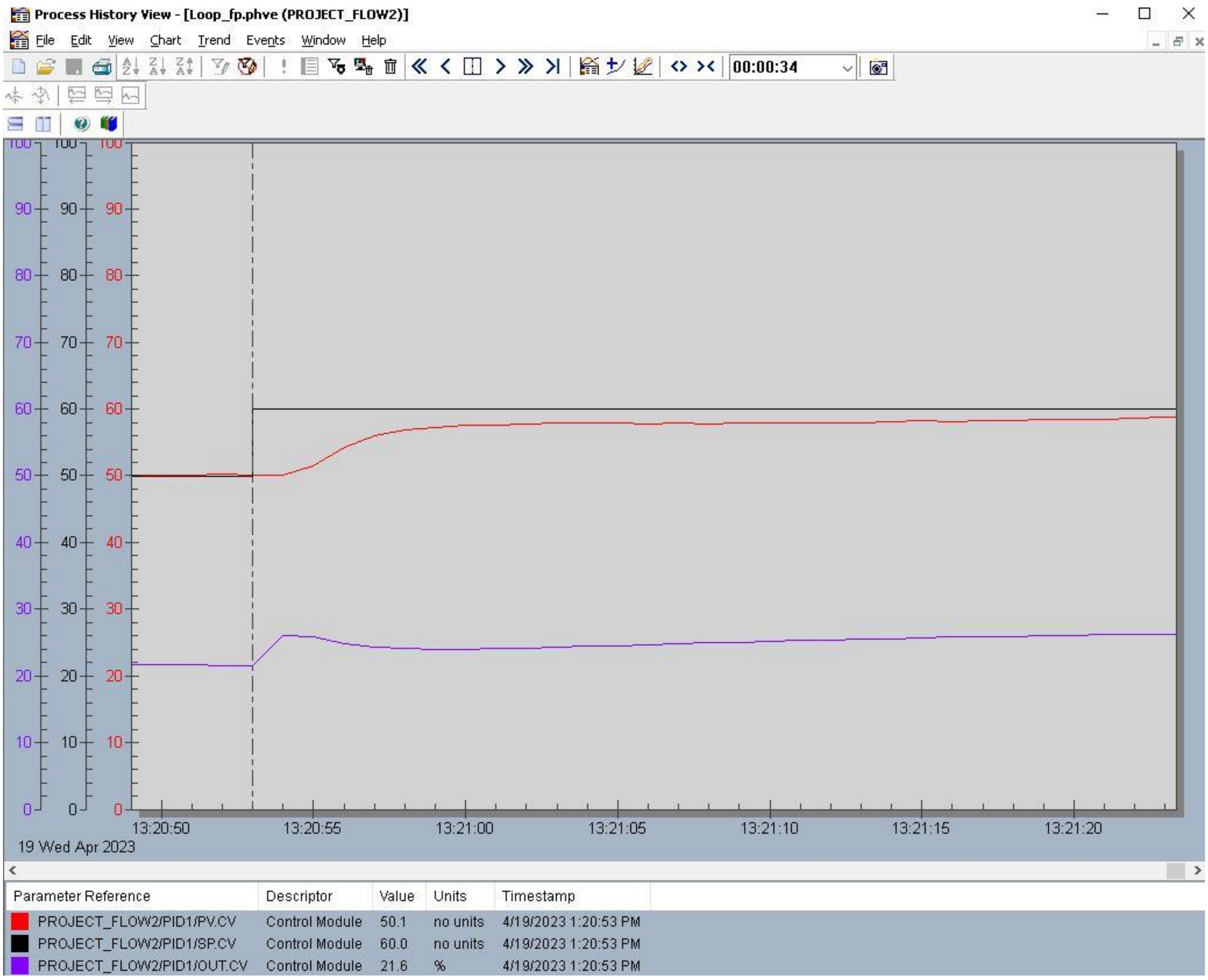
Bumping 10 to 20



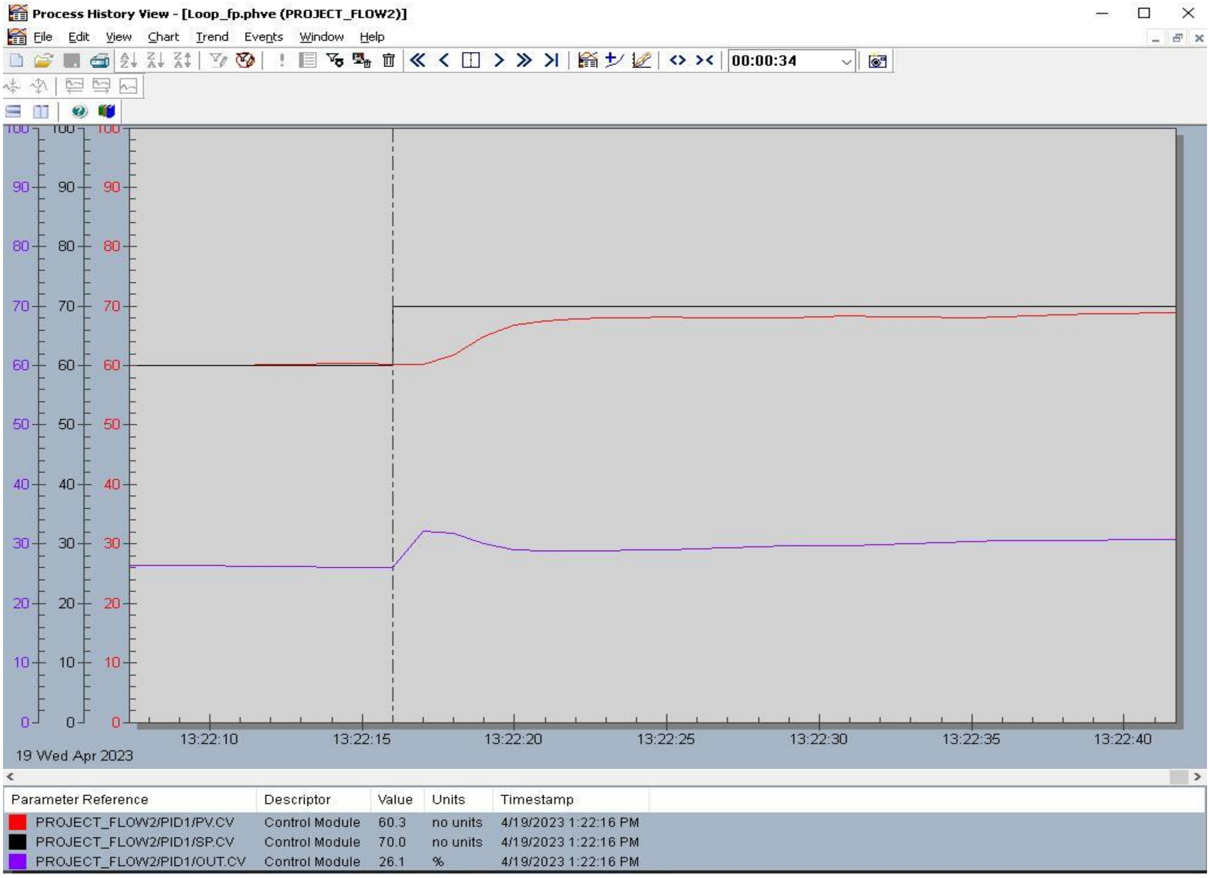
Bumping 20 to 30



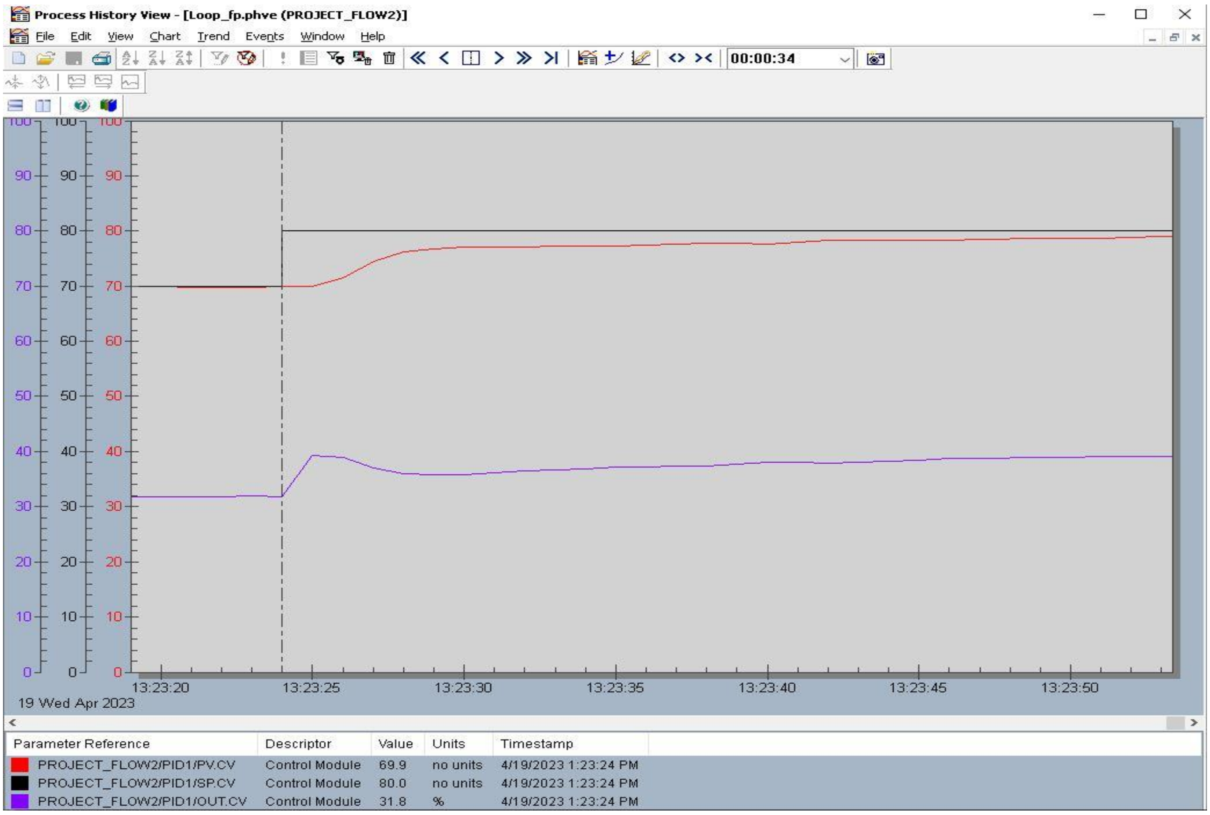
40 to 50



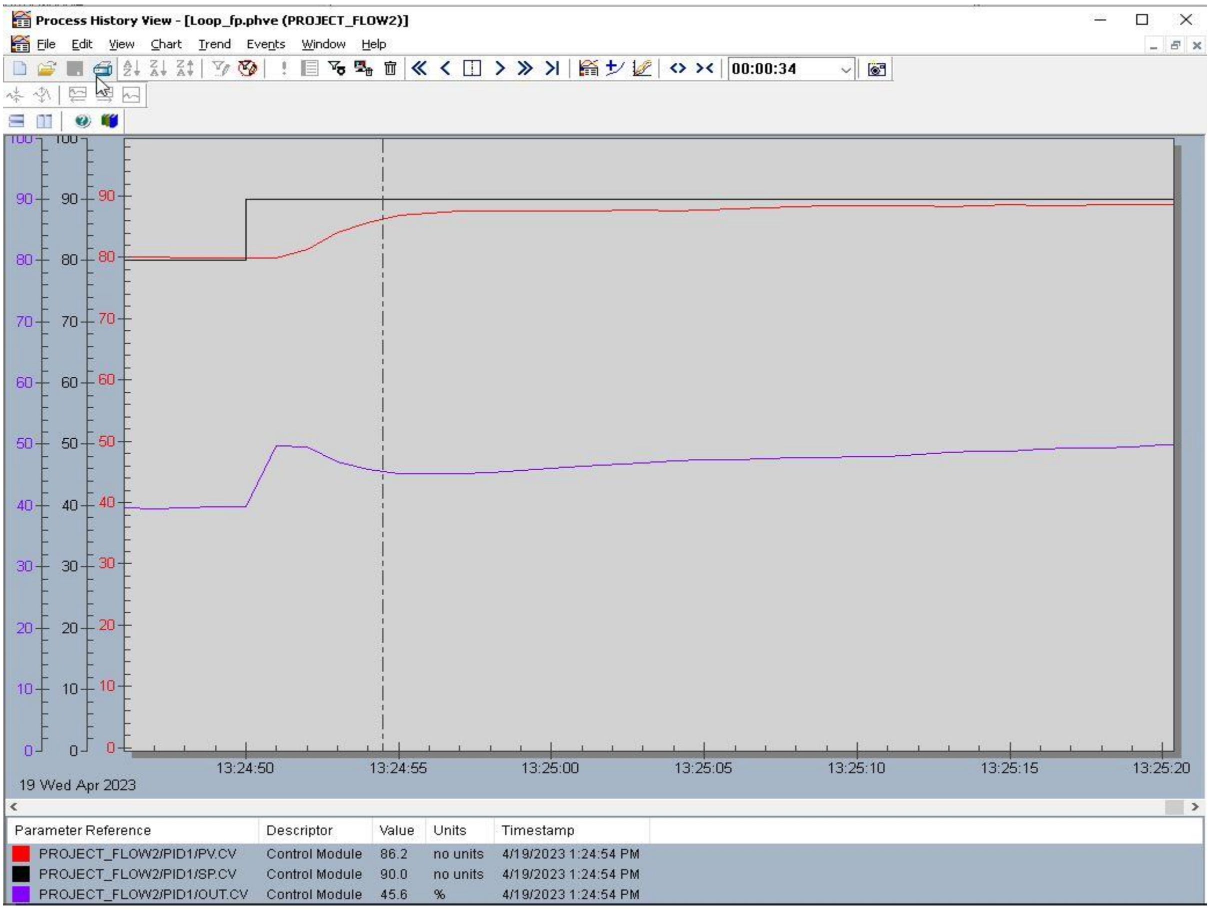
From 50 to 60



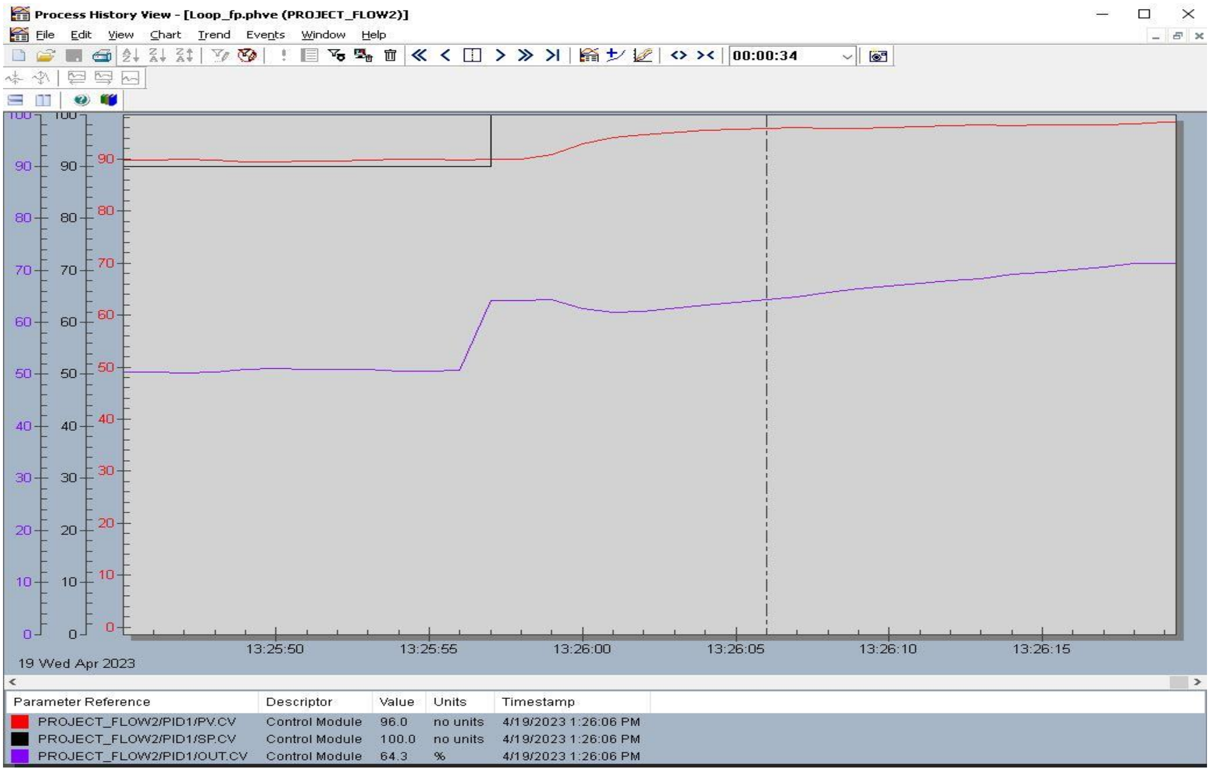
From 60 to 70



From 70 to 80



From 80 to 90



From 90 to 100

Table for Adaptive gain for Flow 2: $\tau = 9s$, Td = 2s

X - Axis	Y – Axis
0	0.492
20	0.439
40	1.047
60	1.2
80	1.64
100	1.6

Level Tunning:

The level is the process that has the integrator dynamics, therefore the Lambda tuning for integrated process was used to determine controllers` settings.

The primary loop of the Cascade control should be at least 3 times slower than secondary loops, therefore λ for the level control loop should be, at least, equal to 24 seconds.

Integrator dynamics Lambda tuning

$K\mathrm{s} = \frac{slope\ 2 - slope\ 1}{\Delta output}$

$K\mathrm{C} = \frac{2\lambda + Td}{Ks * (\lambda + \mathrm{Td})^{\wedge}2}$

$T\mathrm{i} = 2\lambda + Td$

Level tuning parameters

To determine all necessary parameters for Level the manual change of the set point was used ($\Delta Output$ = 10%).

HMI:

In industrial automation, HMI is used to monitor and control machines and processes. It provides an interface for operators to interact with the machines and displays information such as process variables, alarms, and other important information.

It includes:

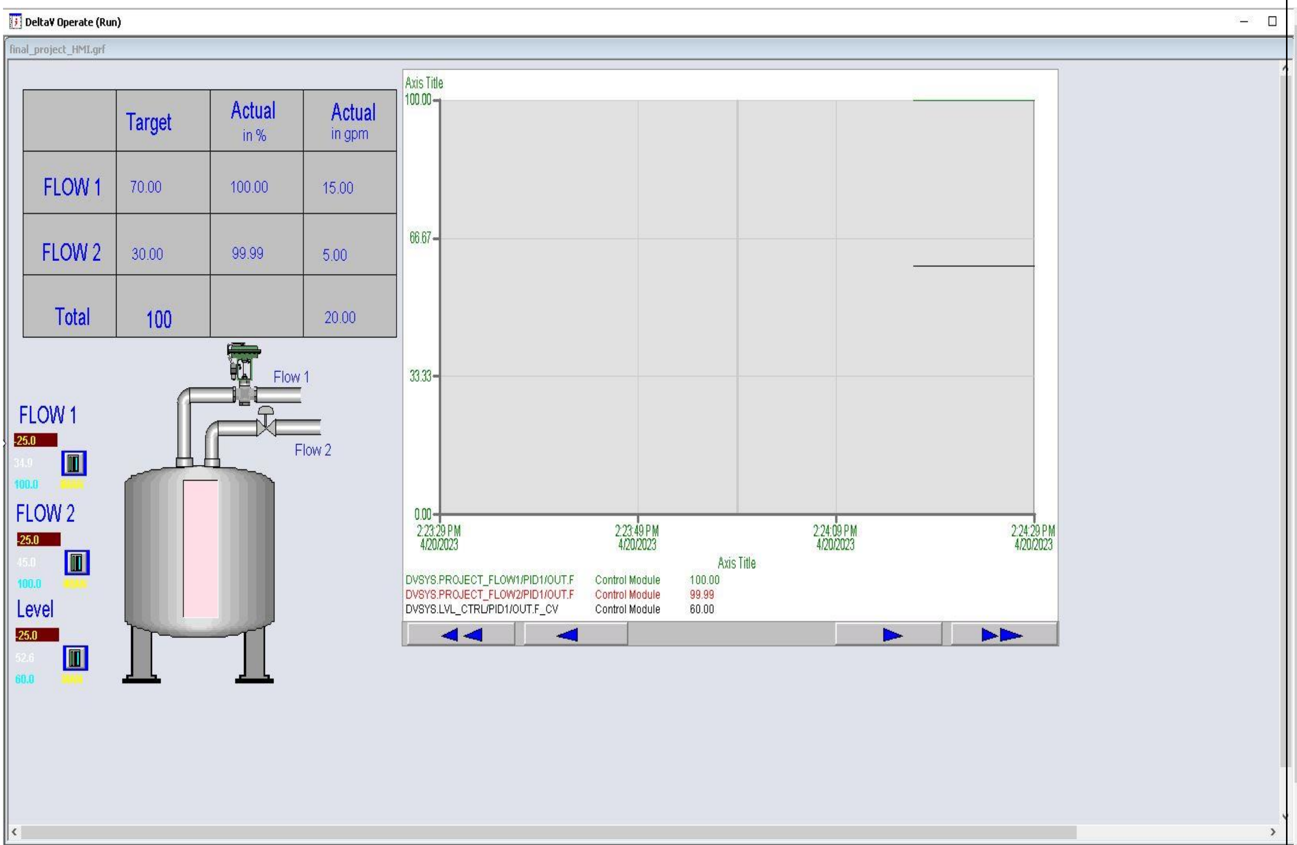
Faceplates:

- Flow 1
- Flow 2
- Level

Table for the value of Actual, Target and gpm value of Flow 1 and Flow 2.

A combined chart for all three loops.

Anime for Tank and level.



Errors:

For the flow there is a little deviation in value of response time. So, at the time of tunning that was same for all the step change. But in testing mode it was varying.

1. first reason can be because of valve position. For flow 2 we used i/p to control 108 which was showing different value for the same step change. The valve shows different value at both times, one value while incrementing the PV and another for decrementing the PV.

   To minimize this, we can take very small possible step change. Because for flow 2 for every little change in pressure increases flow by its square. Hence, it would be more accurate if we used smaller range.

2. Flow 1: which was quick opening so, for a small changes in input will give a higher opening of Valve.

   To minimize this also we can use Adaptive gain with smaller step change.

3. As signal Characterizing blow in control studio still uses averaging function for taking the value between the range.

   For example, if one gave 0.32 gain for 30 – 40 range. It will average and will find a gain at operating point (say at 35). So taking small changes will help to find accurate gain value for this point.

4. For the calculation and measuring parameters from graph is taken from the value which was showing only 1 decimal point. To solving for this system there should be more significant digit so it will be precise value.

Conclusion

Overall, creating an efficient and robust automated control system requires a thorough understanding of the requirements of the application, as well as expertise in selecting and integrating the appropriate instruments. Different tuning techniques were used to provide parameters for automated level control system.

Both cascade and ratio control are advanced control strategies that require careful design and tuning to ensure optimal performance. These control strategies can be particularly useful in complex process control applications where traditional proportional-integral-derivative (PID) control may not be sufficient to achieve the desired level of control.

The Lambda tuning method aims to determine the optimal values for the proportional, integral, and derivative gains of a PID controller to achieve a desired level of control performance. The method involves measuring the response of the controlled process to a step change in the setpoint or disturbance, and then using this information to calculate the optimal PID gains.

The several improvements to the tuning process can be done, to provide better ratio and level control.

There are some errors in both tunning for flow 1 & 2 and Level control. To minimize those error, we can use a smaller range for Adaptive gain. After finding adaptive gain for all step changes, we can put it in signal characteristic. Which can be used during the ongoing process.

The several improvements to the tuning process can be done, to provide better ratio and level control.