LY-PY-FY-TY Calculators

Example 1: Distillation Column Bottom Control System

Distillation tower bottom could be controlled via single-element or three-element. We use single element during start-ups since it is simpler while use three-element during normal operation. Notice that during start-ups the system is controlled manually rather than in auto-mode. Auto-mode is activated when the system is approximately stable.

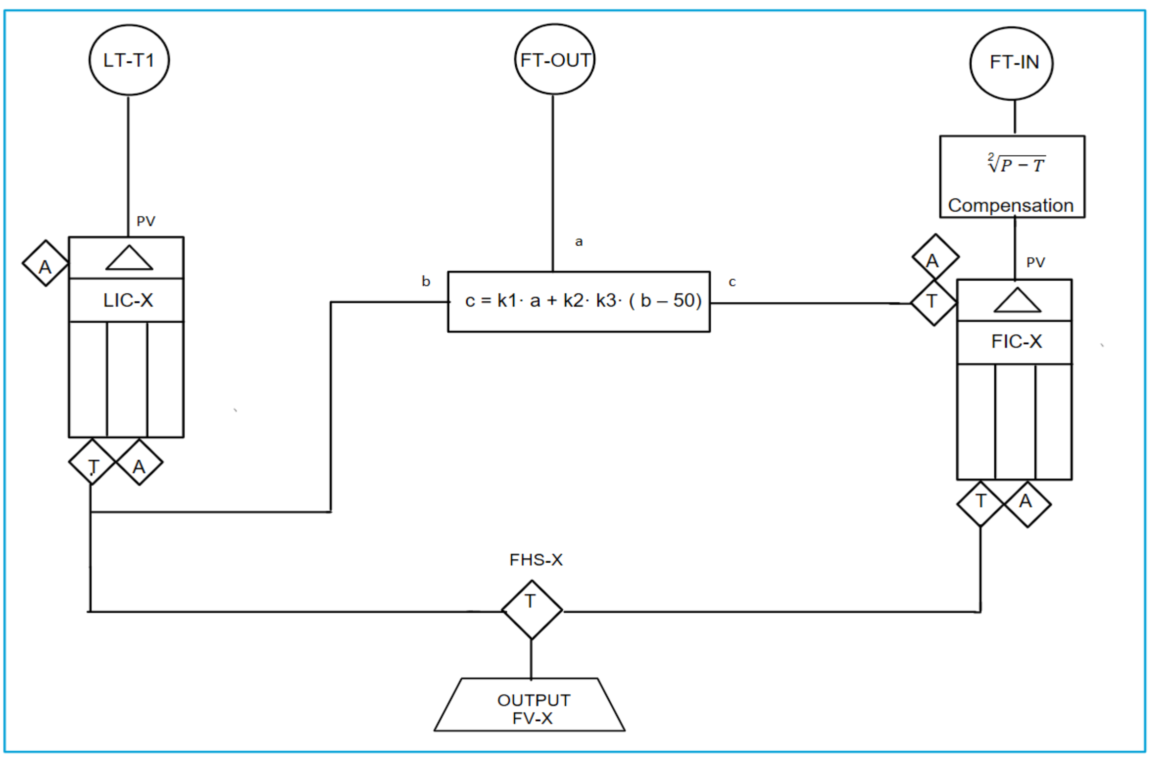
Note that we just stated that during start-ups single-element is selected while during normal operation three element is selected. How can we select them? Hand-Switch.

In single element level controller controls the feed to the tower while in three-element, feed controller controls the feed to the tower but receives its setpoint from LY calculator. LY is a simple calculation block.

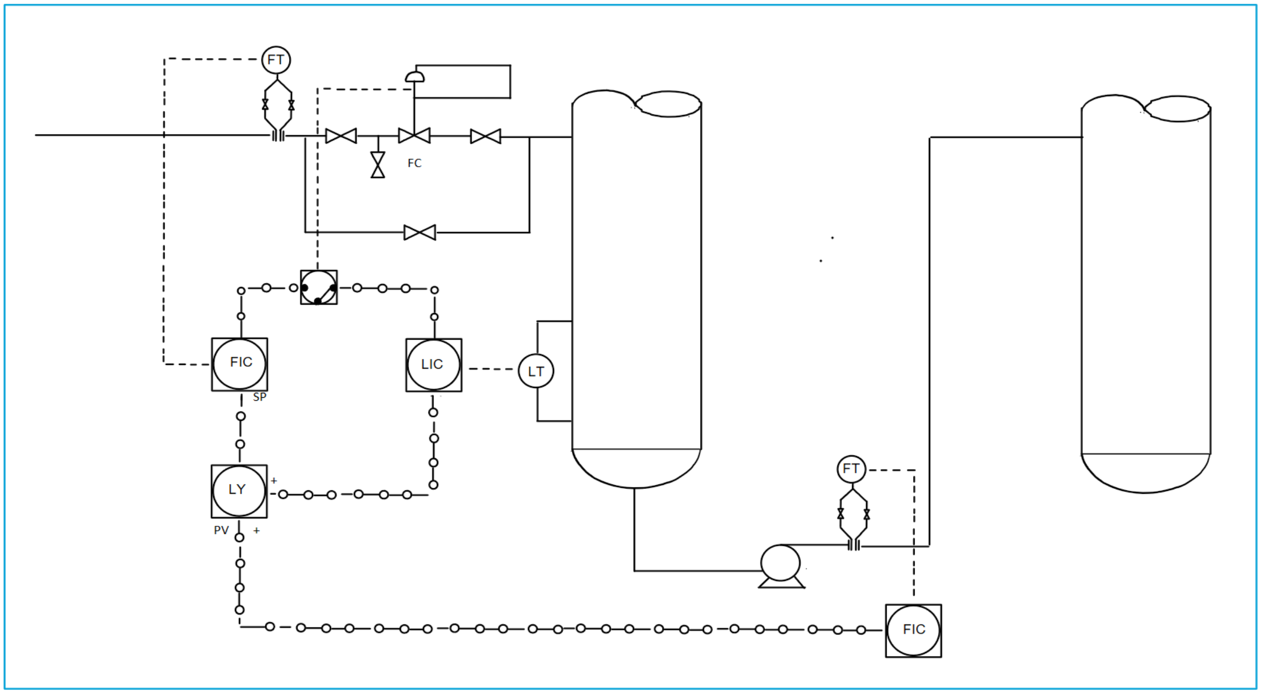
In single-element the calculation is based only on the changes in the level while in three-element the calculation is based on mass balances and level change, which is more accurate.

$$c = k_1 \cdot a + k_2 \cdot k_3 \cdot (b - 50)$$

where
c: Remote set point to Liquid Controller FIC [kg/h]
a: Liquid flow outlet column FI [kg/h]
b: Output from Level Controller LIC [%]
k_1: Tuneable constant (default value 1)
k_2: Tuneable constant (default value 0.1)
k_3: Conversion factor (default URL of Liquid flowmeter inlet column [kg/h] /50[%])



The above diagram is shown in complex loop documents while the below diagram is shown on P&IDs.



Example 2: Steam Drums

Steam drum level could be controlled via single-element or three-element. We use single element during start-ups since it is simpler while use three-element during normal operation. Notice that during start-ups the system is controlled manually rather than in auto-mode. Auto-mode is activated when the system is approximately stable.

Historically, three-element was developed to overcome swell and shrinkage effect in steam drums. When steam turbine is put in service, it takes a great deal of steam suddenly, which means the pressure inside the steam drum reduces and liquid droplets start bubbling, which increases the level of steam drum. Reverse phenomena happen when the turbine goes into tripped state.

In single-element approach, the feed to the drum is controlled based on level changes while in three-element the feed is controlled based on steam flow and level changes. Here is the relation between feed flow, steam flow and level changes:

$$c = k_1 \cdot a + k_2 \cdot k_3 \cdot (b - 50)$$

where
c: Remote set point to BFW Controller FIC [kg/h]
a: Steam Flow FI [kg/h]
b: Output from Level Controller LIC [%]
k_1: Tuneable constant (default value 1)
k_2: Tuneable constant (default value 0.1)
k_3: Conversion factor (default URL of BFW flowmeter [kg/h] /50[%])

Also notice that compensated steam flow is used in above equation. In order to compensate the flow, the following equation is used:

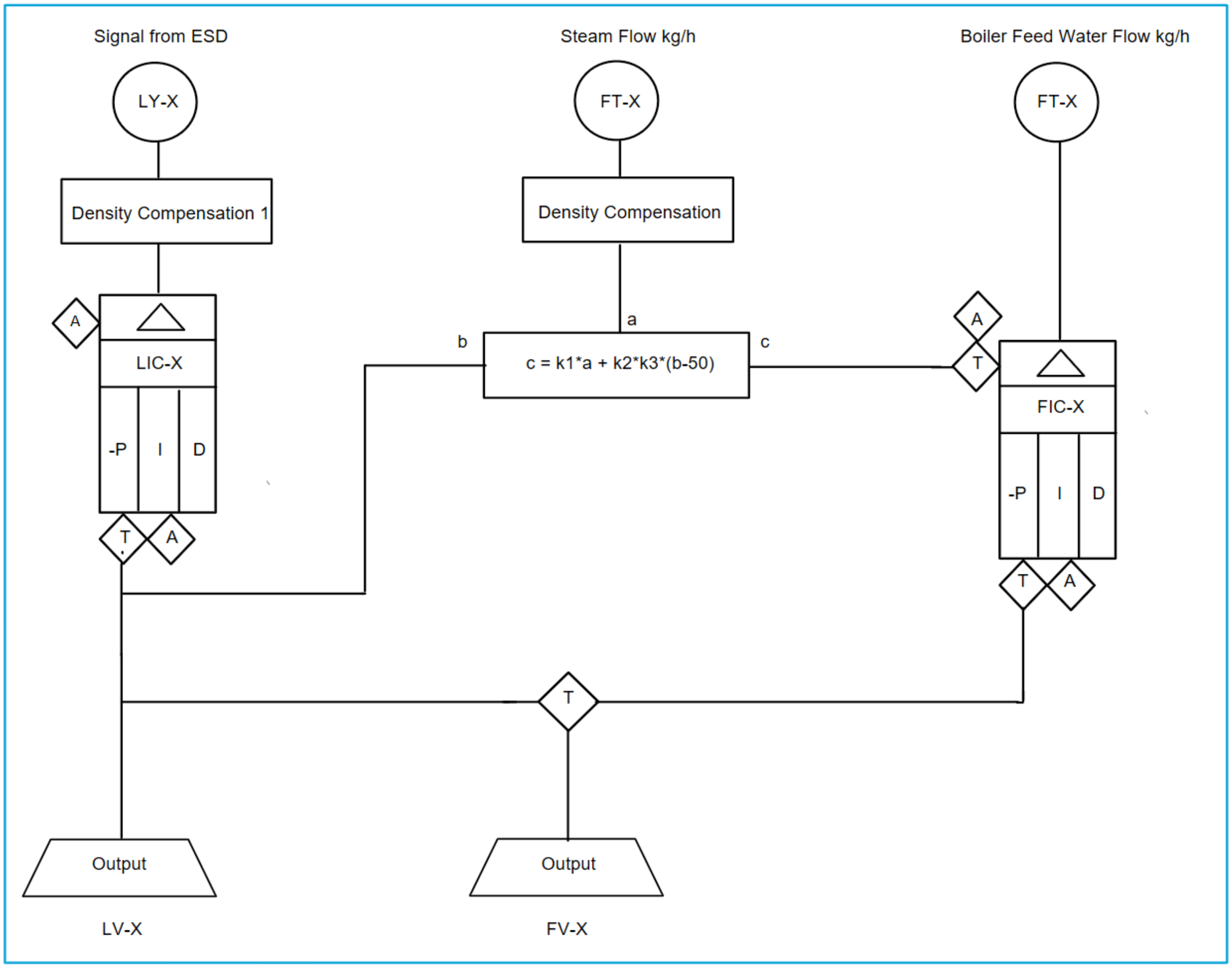
$$Q_{c\ Mass} = Q_{R\ Mass} \sqrt{\frac{Da}{Dd}}$$

$Q_{C\ Mass}$: Compensated flow [kg/h]
$Q_{R\ Mass}$: Uncompensated flow [kg/h]
P: Actual pressure [bar g]
D_a : Actual density [kg/m_3]
D_d : Sizing density [kg/m_3]

The actual saturated steam density D_a can be found from the pressure P by the following approximation:

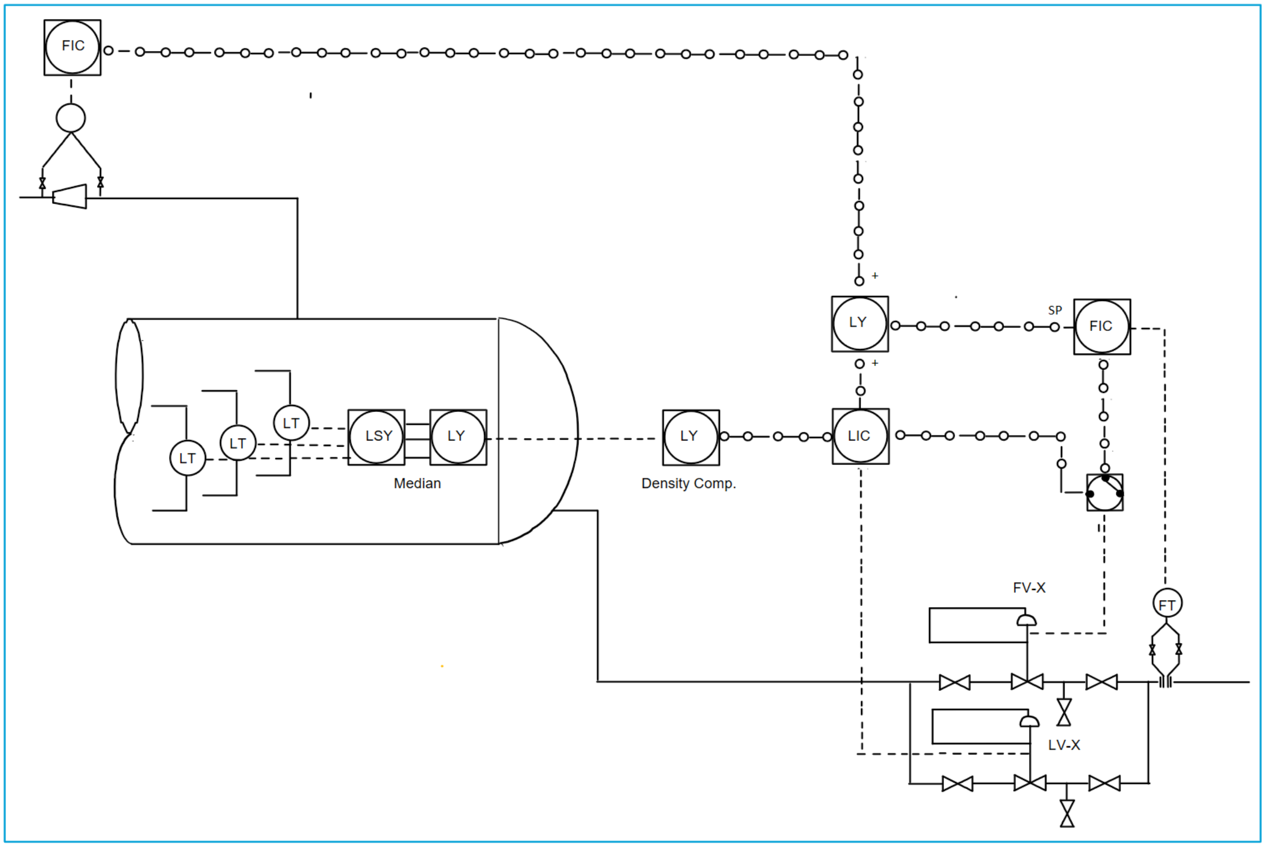
$D = 3.438 + 0.3631\ P + 0.001651\ P^2$ [kg/m3] (atm. press. 1.013 bar a)

Now if we want to show it in complex loop diagram, it would be like the diagram in following page:



Remember the density compensation 1 is different from density compensation for saturated steam flow.

Here is how we show it on P&IDs:


FIC
LY
SP
FIC
LT
LT
LT
LSY
LY
Median
LY
Density Comp.
LIC
FV-X
FT
LV-X

Example 3: Turbine Extraction Loop

This example should be learned after watching the video about steam headers from the course "Process Plant Design".

Imagine that everything is normal and the let-down between headers occurs automatically and the turbine extraction is discharged to HPS header. Suddenly because of the vibration alarm in steam turbine, the turbine goes into state of trip. Now here are the consequences:

1.HHPS becomes surplus because before that it was being consumed by the large turbine. So HHPS pressure goes up.

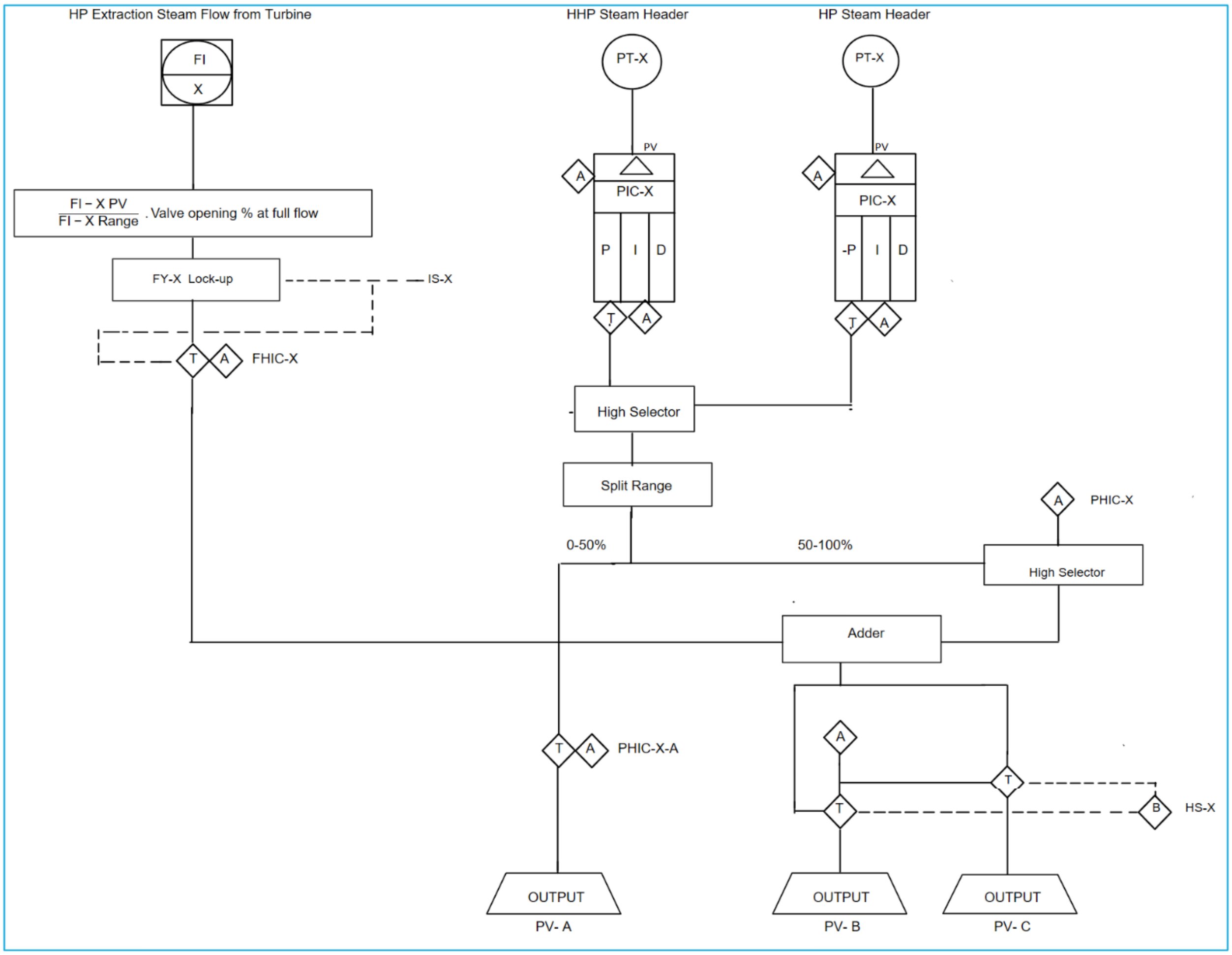
2.Before the trip of turbine, the extraction was feeding HPS header but now HPS header goes into state of deficit.

Solution: We add an online calculation block which calculates continuously the extra opening of let-down valve between these two headers. To better understand what it means, imagine before the trip the let-down valve opening was 65%. The calculation block continuously calculates 20% extra opening when turbine gets tripped but the calculation is not effective before the trip. The moment the turbine trips, the valve opening becomes 65% + 20% = 85%; in doing so, HHPS which is now surplus is more let-downed and HPS header does not go into state of deficit.

Note 1: Calculation to transform the flow signal to a valve opening which will give an additional opening of the steam conversion valve corresponding to this flow. For a linear valve (FI-X PV)/(FI-X range)*(valve opening % at full flow) Valid if valve characteristic is linear.

$$\text{Opening\%} = \frac{\text{FI}-\text{X PV}}{\text{FI}-\text{X range}} \times 75\%$$

Note 2: IS- locks and holds value from FY-X. & shifts FHIC-X to remote setpoint mode.



HP Extraction Steam Flow from Turbine
FI
X
FI – X PV
FI – X Range
. Valve opening % at full flow
FY-X Lock-up
IS-X
T
A
FHIC-X
HHP Steam Header
PT-X
PV
A
PIC-X
P
I
D
T
A
HP Steam Header
PT-X
PV
A
PIC-X
-P
I
D
T
A
High Selector
Split Range
0-50%
50-100%
A
PHIC-X
High Selector
Adder
T
A
PHIC-X-A
A
T
T
B
HS-X
OUTPUT
PV- A
OUTPUT
PV- B
OUTPUT
PV- C