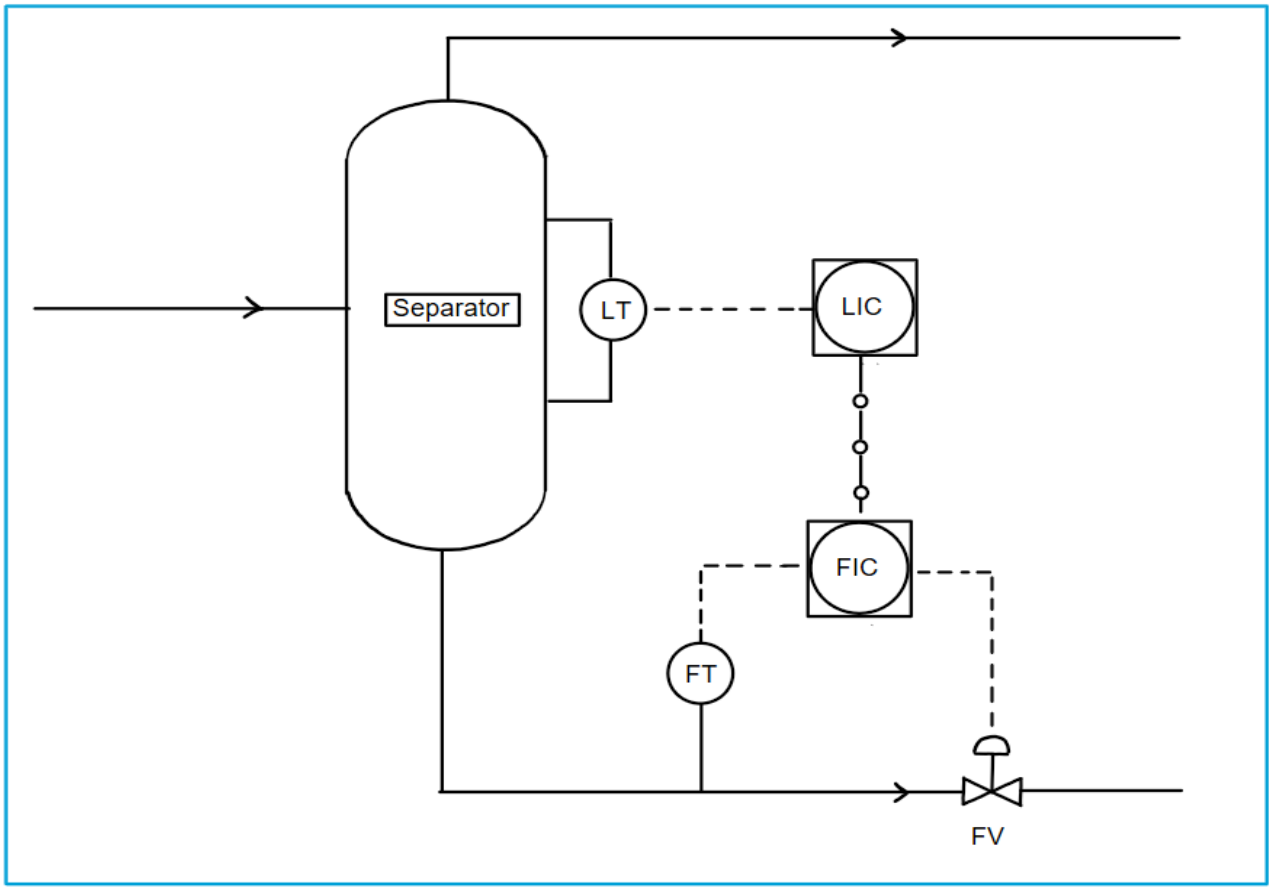
Advanced Control

Cascade Control

Cascade control:

What is a cascade control?
In single-loop control, the controller's set point is set by an operator, and its output drives a final control element. For example: a level controller driving a control valve to keep the level at its set point. In a cascade control arrangement, there are two (or more) controllers of which one controller's output drives the set point of another controller. For example: a level controller driving the set point of a flow controller to keep the level at its set point. The flow controller, in turn, drives a control valve to match the flow with the set point the level controller is requesting.



The controller driving the set point (the level controller in the example above) is called the primary, outer, or master controller. The controller receiving the set point (flow controller in the example) is called the secondary, inner or slave controller.

Why should it be used?

- Isolation of load disturbances,
- Improved speed of response,
- Precise manipulation of mass or energy
- Compensation for nonlinearities

When Should Cascade Control be Used?

Cascade control should always be used if you have a process with relatively slow dynamics (like level, temperature, composition, humidity) and a liquid or gas flow, or some other relatively-fast process, has to be manipulated to control the slow process.

There is general comparison between fast-acting of each controller:

FIC > PIC > LIC >= TIC

So, for cascade control the following configurations are recommended:

- TIC-FIC, TIC-PIC, TIC-TIC
- LIC-FIC
- PIC-FIC

Example 1: Distillation column reflux

We have already talked about a control part of columns in split-range part. Do you remember that? In that example we talked about the pressure control of reflux drums. For now, let's focus on the level of the reflux drum. The P&ID like-sketch is shown on next page.

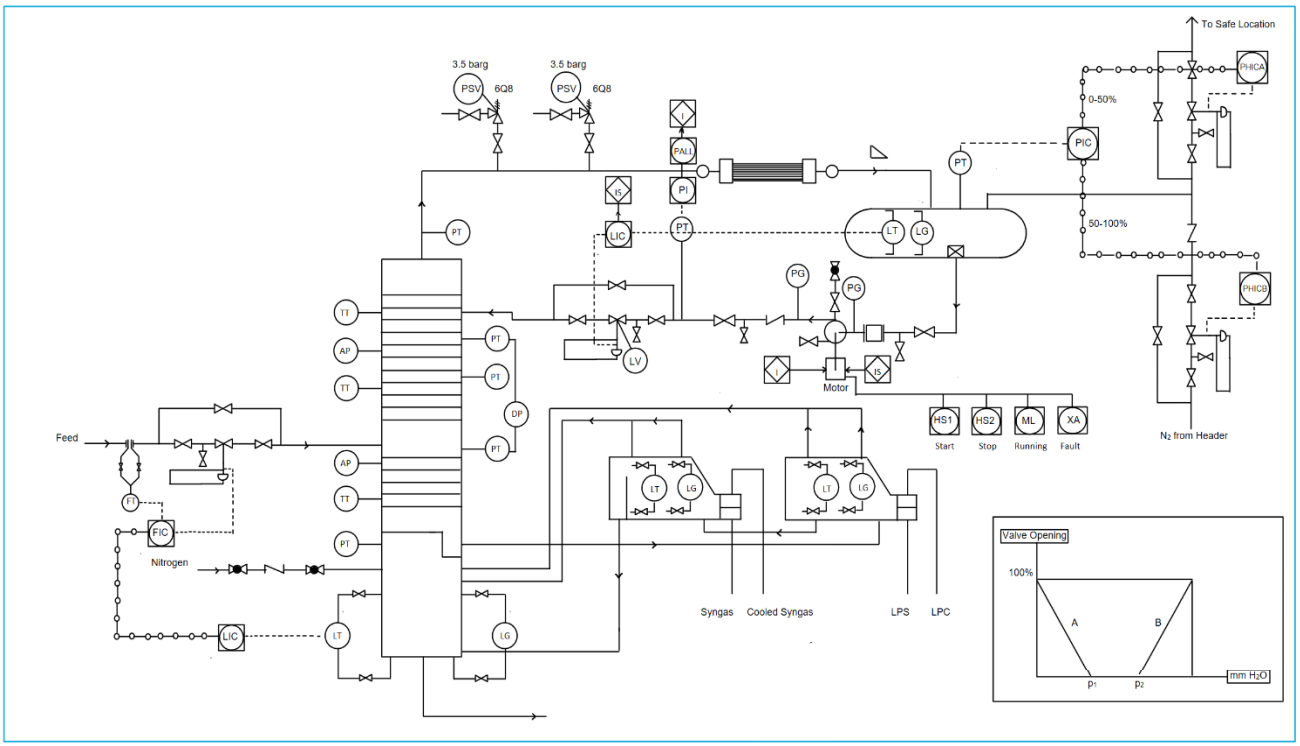
Let's start with simple level control. Yes, it can control reflux drum level in a very very good way! But it does not mean we are done with it because if we behave like this, it means we really know nothing about distillation columns separation, how it functions, and why we need it.

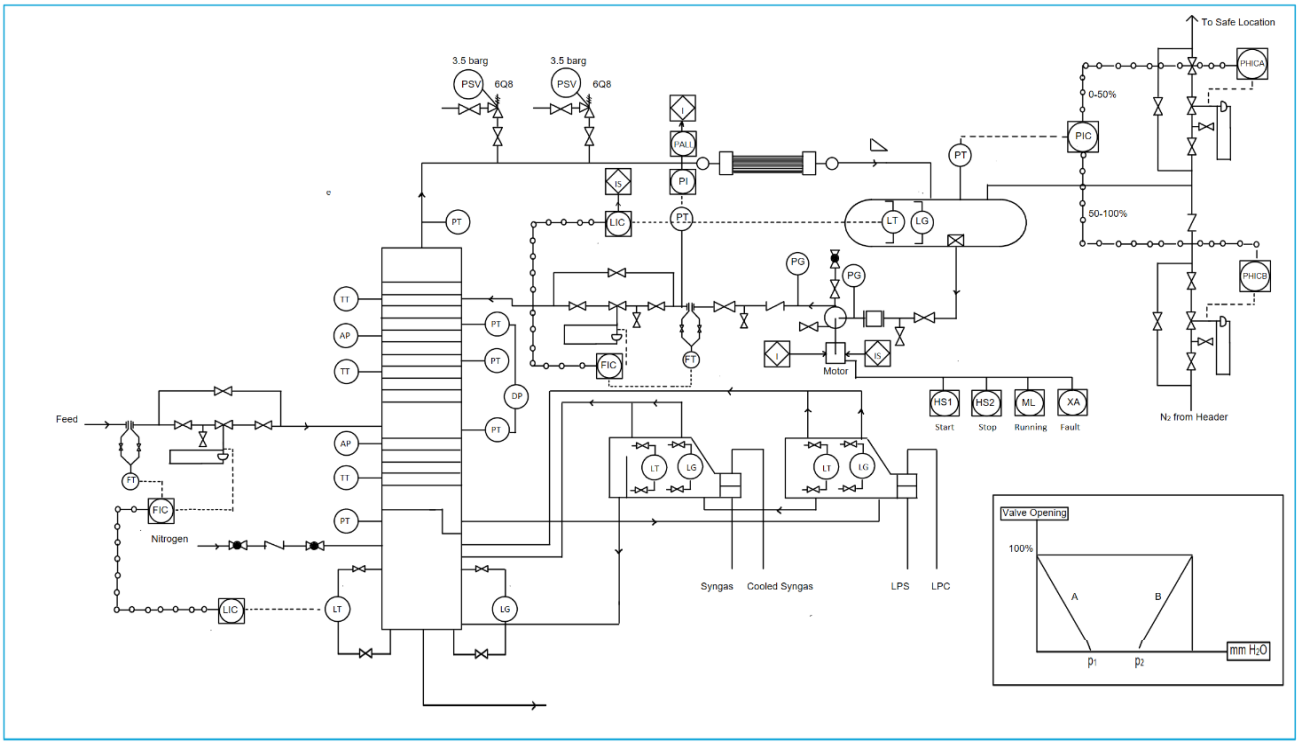
We need distillation columns to purify un-purified products or get a desired component out of two-component or three-component mixtures. The simple way we can detect that the tower is not working properly is the purity of the product. In this regard, the reflux flow is one of important parameters which can impact the purity and separation greatly. So, the change in flowrate should be performed with meticulous care.

If we want the simple loop controller to control the level of reflux drum, it just thinks about the level and open the LV whenever it wants and whatever it wants. The opening of LV changes the reflux flowrate, which leads to changes to purity as a result. Another scenario is that due its being low-acting compared to other controllers, it might want to open the LV for a while with high openings, which finally causes a great load on upper trays and damage them mechanically.

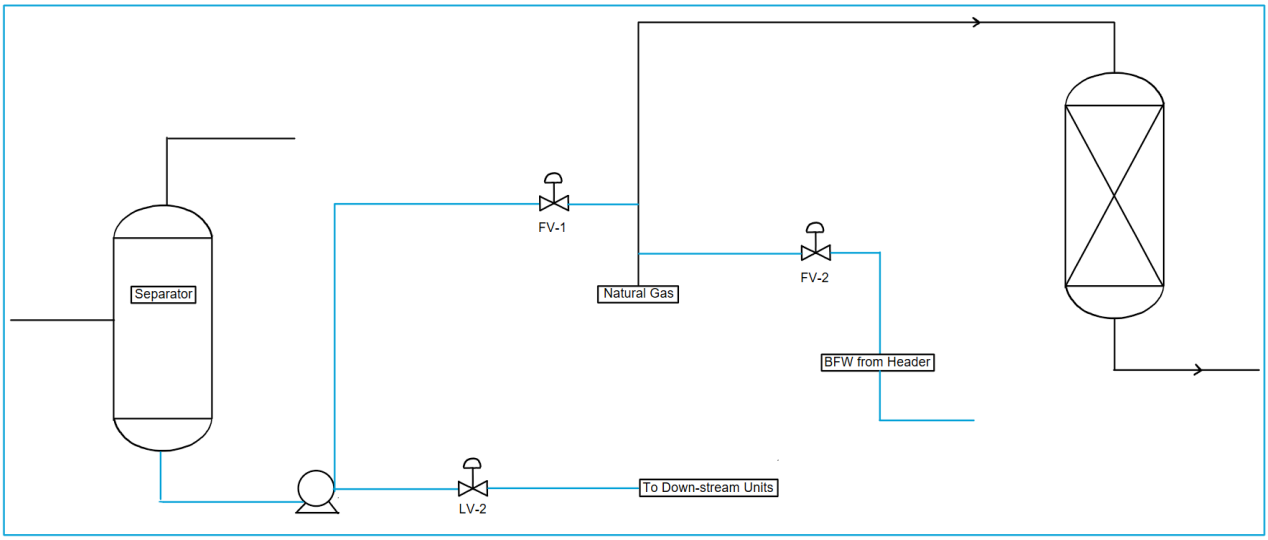
Now let's change it to cascade control to see the advantages:

- Isolation of load disturbances, which means the disturbance in process is controlled.
- Improved speed of response, which prevents excessive load on trays.
- Precise manipulation of mass or energy, which really matters for control room operators.


To Safe Location
3.5 barg
PSV
6Q8
3.5 barg
PSV
6Q8
PHICA
0-50%
PIC
PT
50-100%
PHICB
PALL
PI
LIC
LT
LG
PG
LV
Motor
HS1
Start
HS2
Stop
ML
Running
XA
Fault
N2 from Header
TT
AP
PT
DP
Feed
FT
FIC
Nitrogen
LIC
Syngas
Cooled Syngas
LPS
LPC
Valve Opening
100%
A
B
p1
p2
mm H2O


To Safe Location
3.5 barg
PSV
6Q8
3.5 barg
PSV
6Q8
PHICA
0-50%
PIC
PT
50-100%
PHICB
PALL
PI
LIC
LT
LG
PG
FIC
FT
Motor
HS1
Start
HS2
Stop
ML
Running
XA
Fault
N2 from Header
TT
AP
PT
DP
Feed
FT
FIC
Nitrogen
LIC
Syngas
Cooled Syngas
LPS
LPC
Valve Opening
100%
A
B
p1
p2
mm H2O

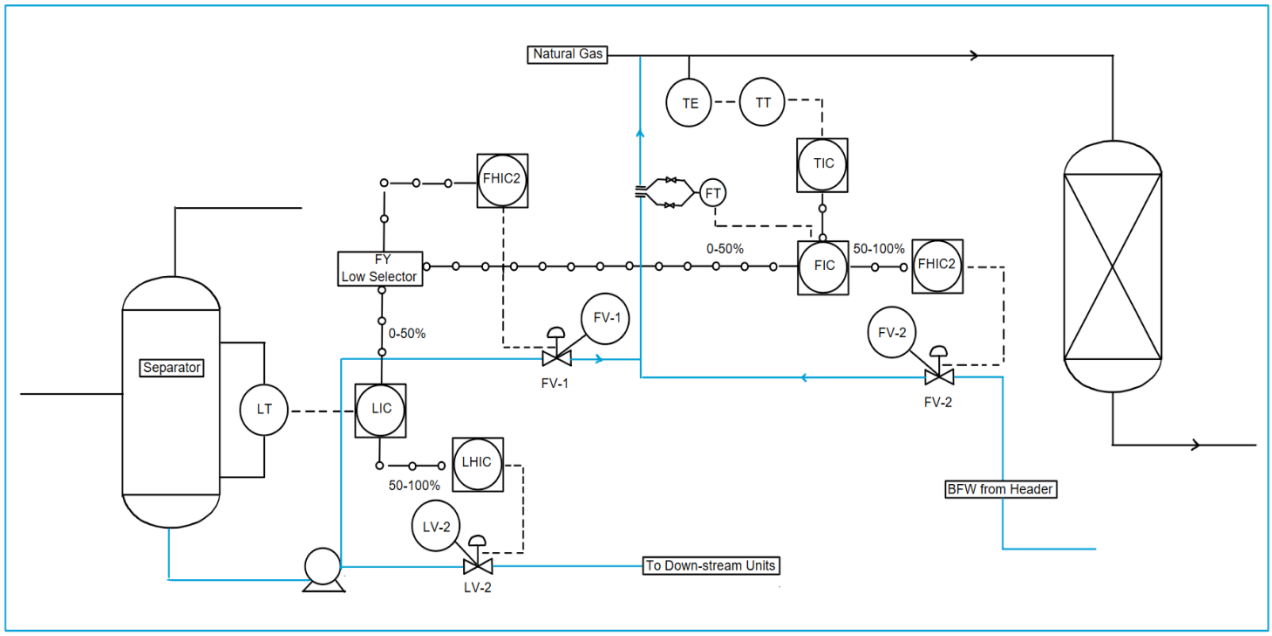
Example 2: Reactor inlet temperature control
In reforming section in hydrogen plant, there is a reactor which is sensitive to the inlet gas temperature. To control the temperature, BFW is added to the gas prior gas entrance to the reactor. Here is the PFD-like sketch.



As stated before, we want to reduce BFW consumption due to optimization and process constraints. To address the issue, we can use the process water outlet of one of the separators we talked about in previous session. Also, thanks to the fact flowrate of water outlet of the separator is high and we can't use completely to add it the NG, a part of the this should be sent to downstream units to be re-used.

So far you have learned about separator level control configuration and as a result we are not going to explain it.

Without a doubt, for the reactor inlet temperature control we should use a TIC. We can change the name of FV- and FV-2 to TV-1 and TV-2 and as a result they will get order from master TIC but for such important reactor which contains expensive catalysts, it is much better to use secondary controller to increase the speed of response. Finally, the control system for this would be like next page:


Natural Gas
TE
TT
TIC
FHIC2
FT
FY
Low Selector
0-50%
FIC
50-100%
FHIC2
FV-1
0-50%
FV-2
Separator
LT
LIC
FV-1
FV-2
LHIC
50-100%
BFW from Header
LV-2
To Down-stream Units
LV-2