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Overview of different control strategies for a typical cryogenic warm compressor stations.

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Aknowledegments: the cryo operator team

Agenda

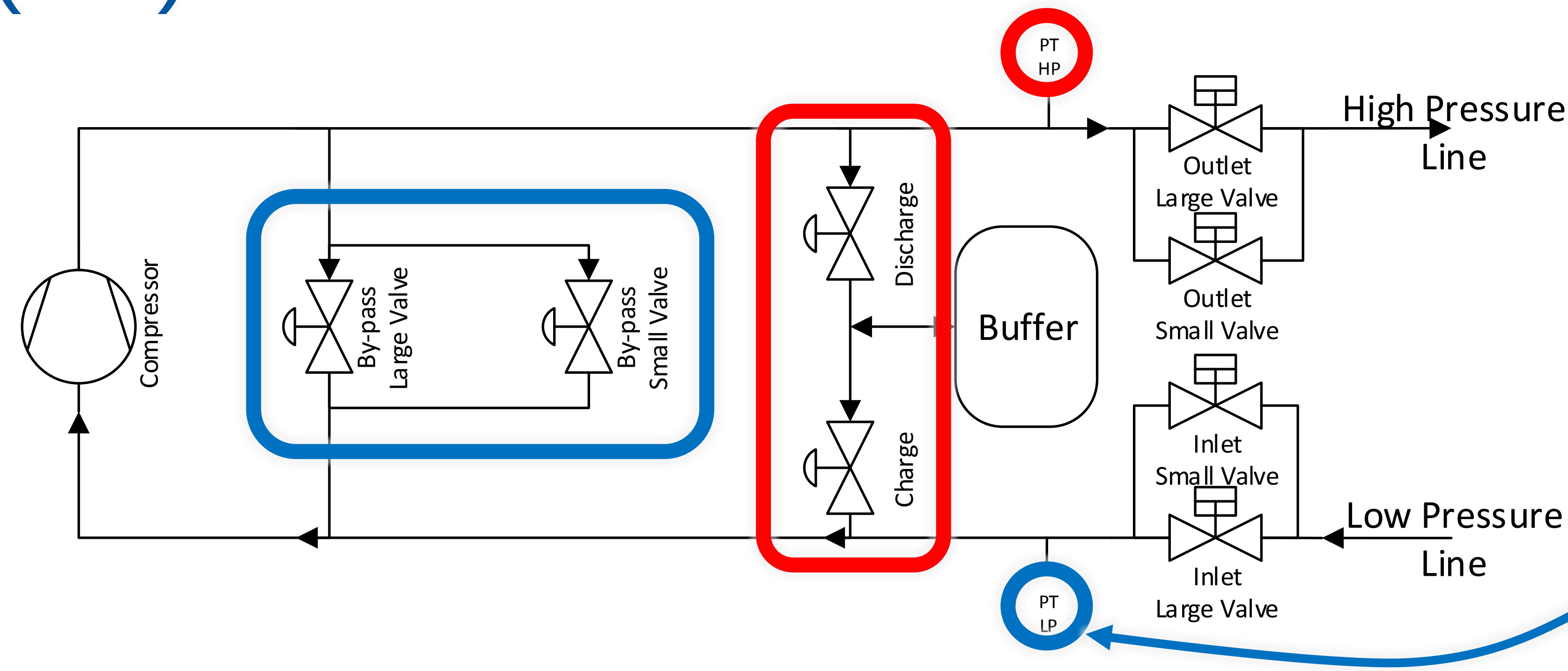
- Introduction
- The compression station
- The control methods
  1. (4+1) PI
  2. Fuzzy Control PI/PD-Like
  3. Internal Model Control
- Methods Comparison
  - Test protocol
  - Simulation Results
- Conclusion

Introduction

- This presentation aims to show an overview of the studies that are being made about the best methods to control the **by-pass** and the **charge-discharge** systems in a compressor station.
- Work based on generic compression station configuration, not in any specific installation.
- The simulations are made in EcosimPro 5.4.19 using the CERN/CryoLib library.

Compression station set-up

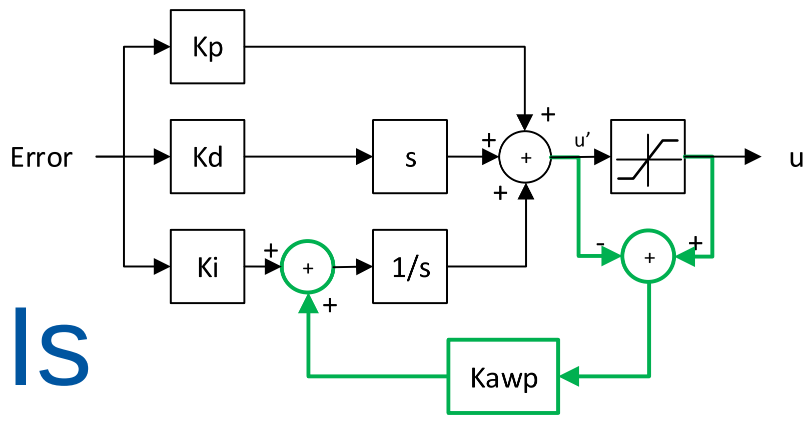
- The general idea is to control the charge and discharge with the pressure in the high pressure line (HP)



The input of the volumetric compressor cannot deal with big variations in the LP

- And the by-pass with the pressure in the low pressure line (LP)

The control methods



Hypothesis:

- Anti Wind-Up is implied in the PIs
- Valves Behaviour
  - Do not move for too small changes in the control signal (*u(t)*)
- PI are well tuned (Parameters calculated through the Åström-Hägglund method).

Performance and Robustness

LP regulation:

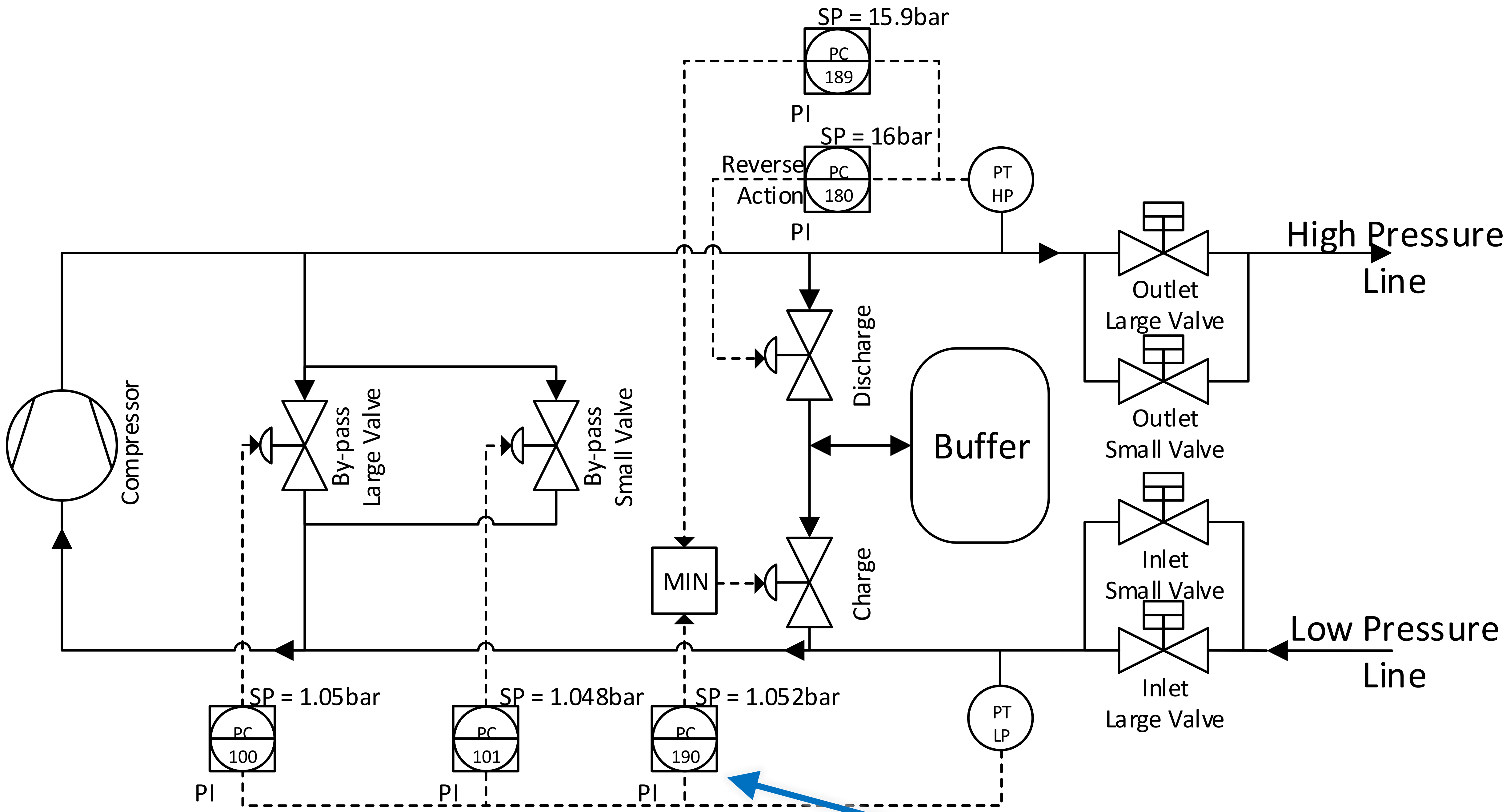
- Main goal → Resist to disturbances
- Prevent from reaching high values → 0.2bar over the operational set-point may stops the volumetric compressor
- Faster and more precise than the HP regulation

HP regulation:

- Must perform well when facing changing on the set-point

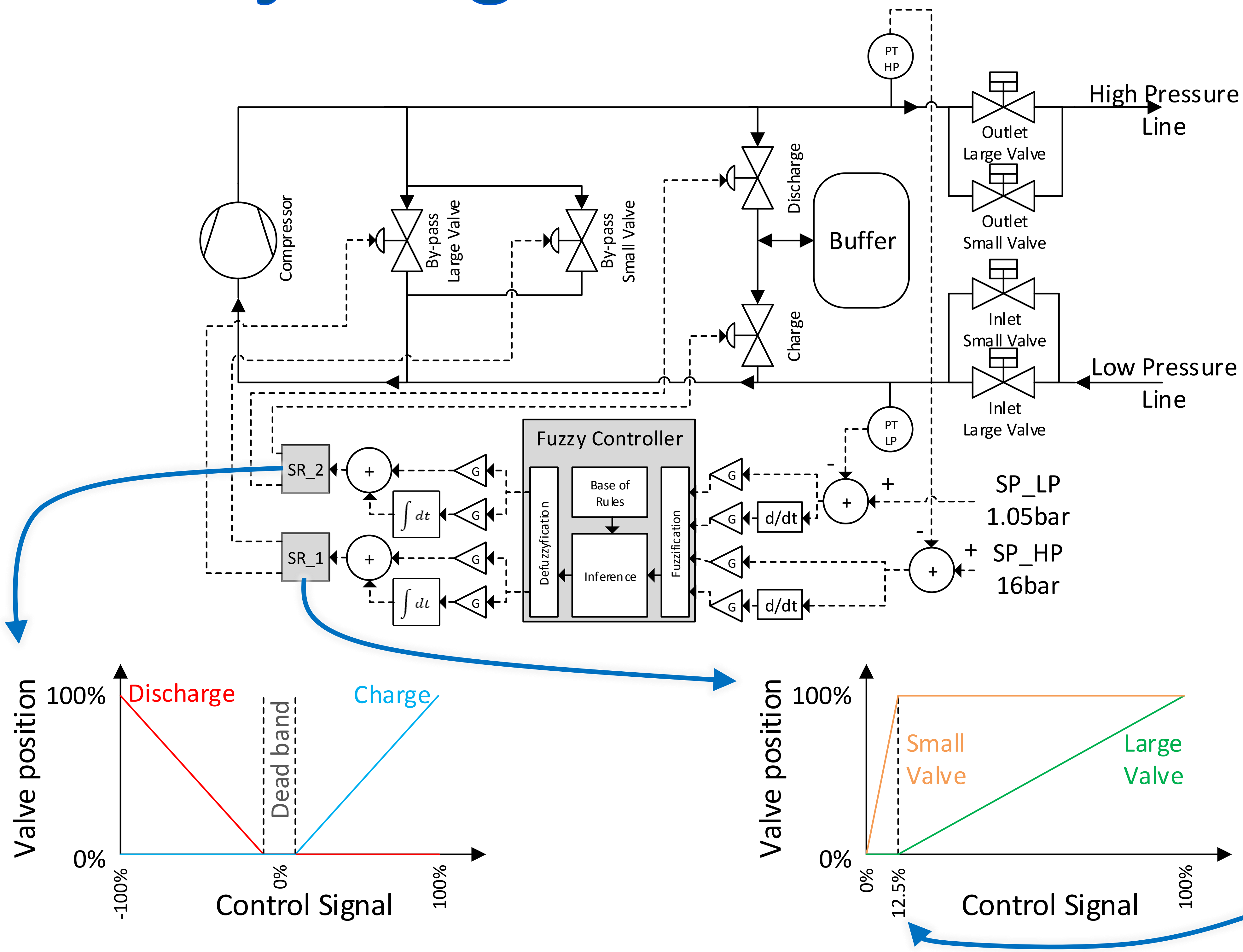
Control Methods

(4+1) PI



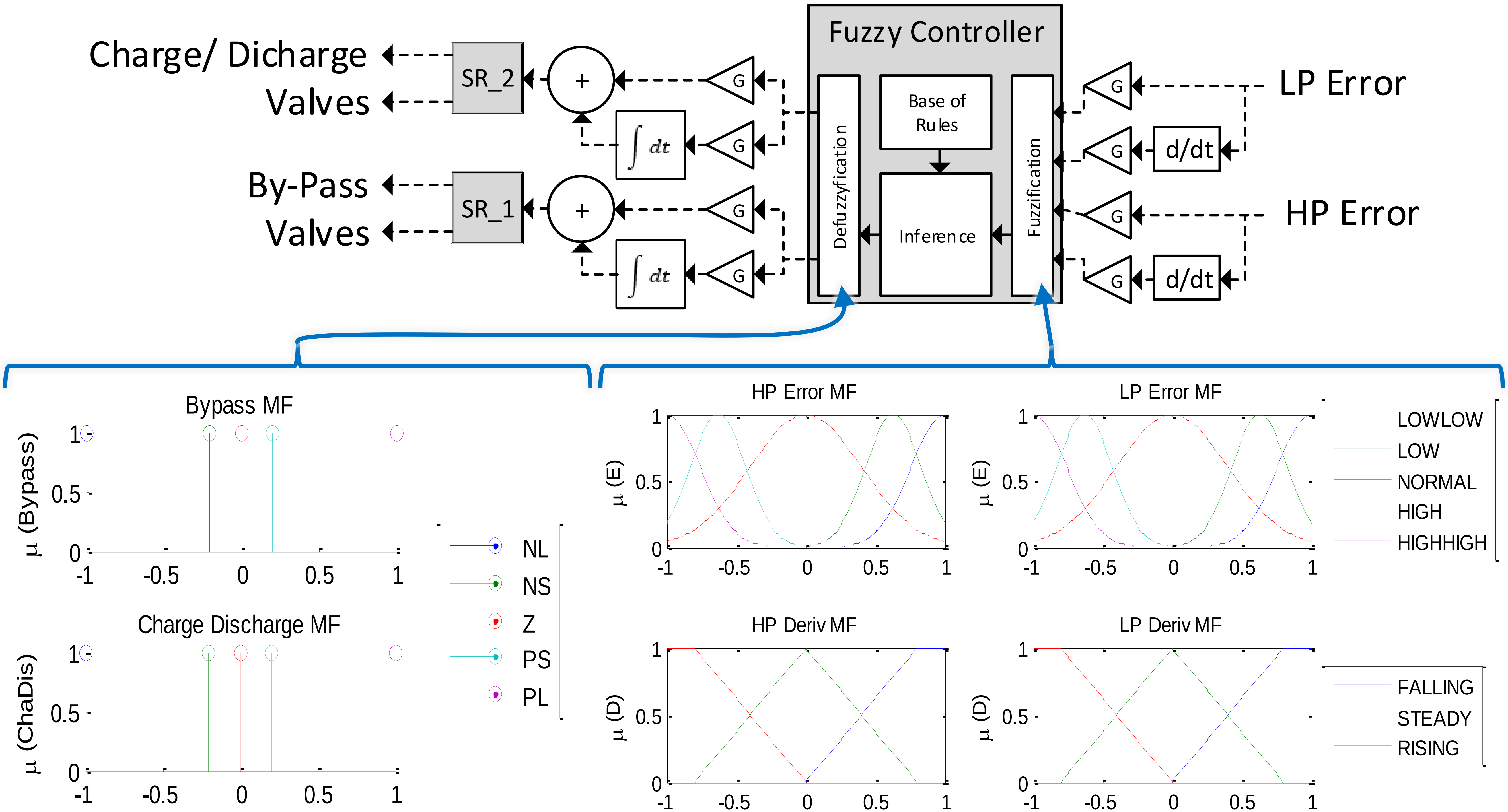
We shouldn't open the charge if the LP is already overloaded

Fuzzy Logic Control PID-Like

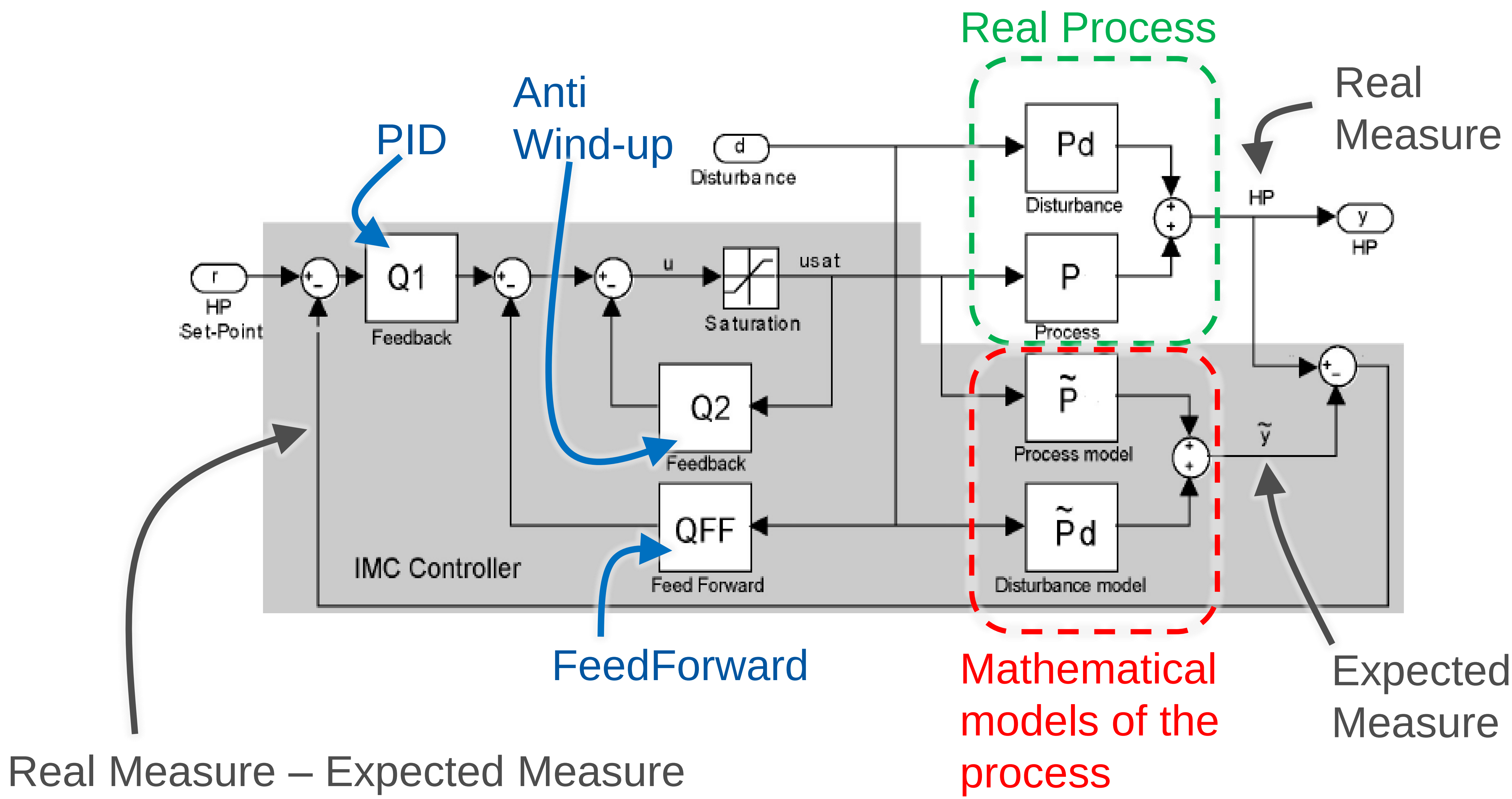


Proportional to the difference of size between the valves

Fuzzy Logic Control PID-Like

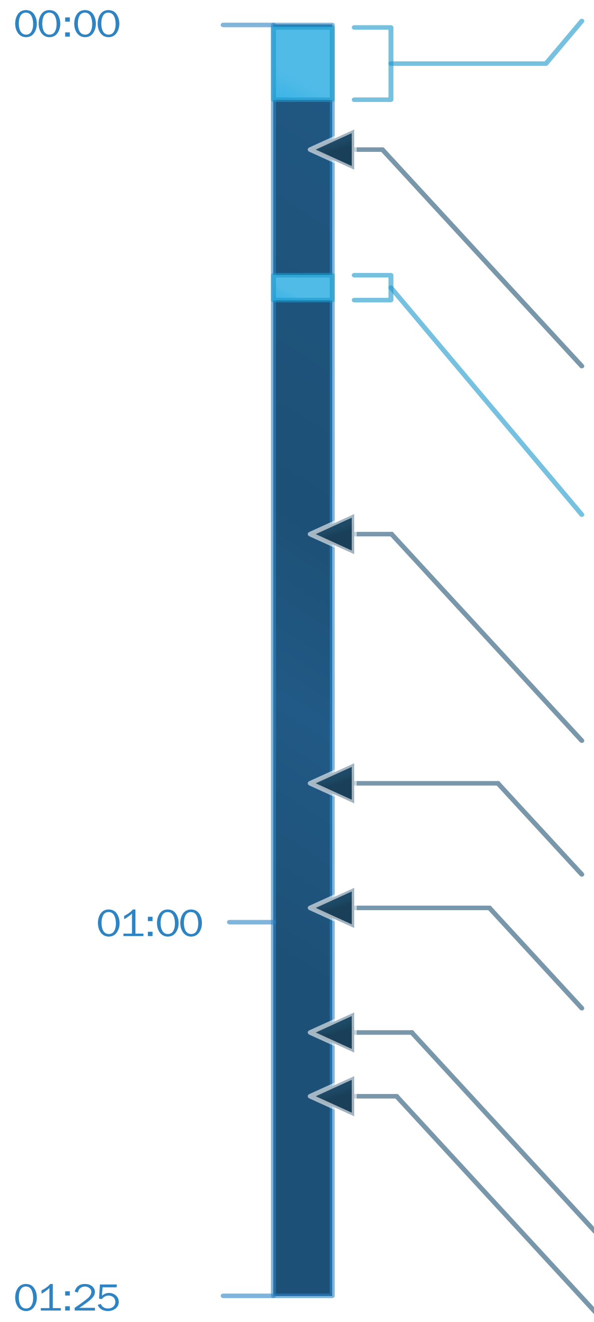


Internal Model Control



Methods Comparison

Ecosim test protocol timeline



Total simulation time: **5000s**

Normal starting:

- At 10s : Start the regulation of the LP
- At 100s : Compressor Start
- At 110s : Start the regulation of the HP
- At 300s : Compressor at full power

First operational Disturbance:

- At 500s : Step in the HP Set Point (14 to 17bar)

Second Operation Disturbance:

- At 1000s : Connection of the LP with Cold box
- At 1100s : Connection of the HP with Cold box

First external disturbance:

- At 2000s : Cold box's Turbines Start

Second external disturbance:

- At 3000s : Cold box's Turbines Stop

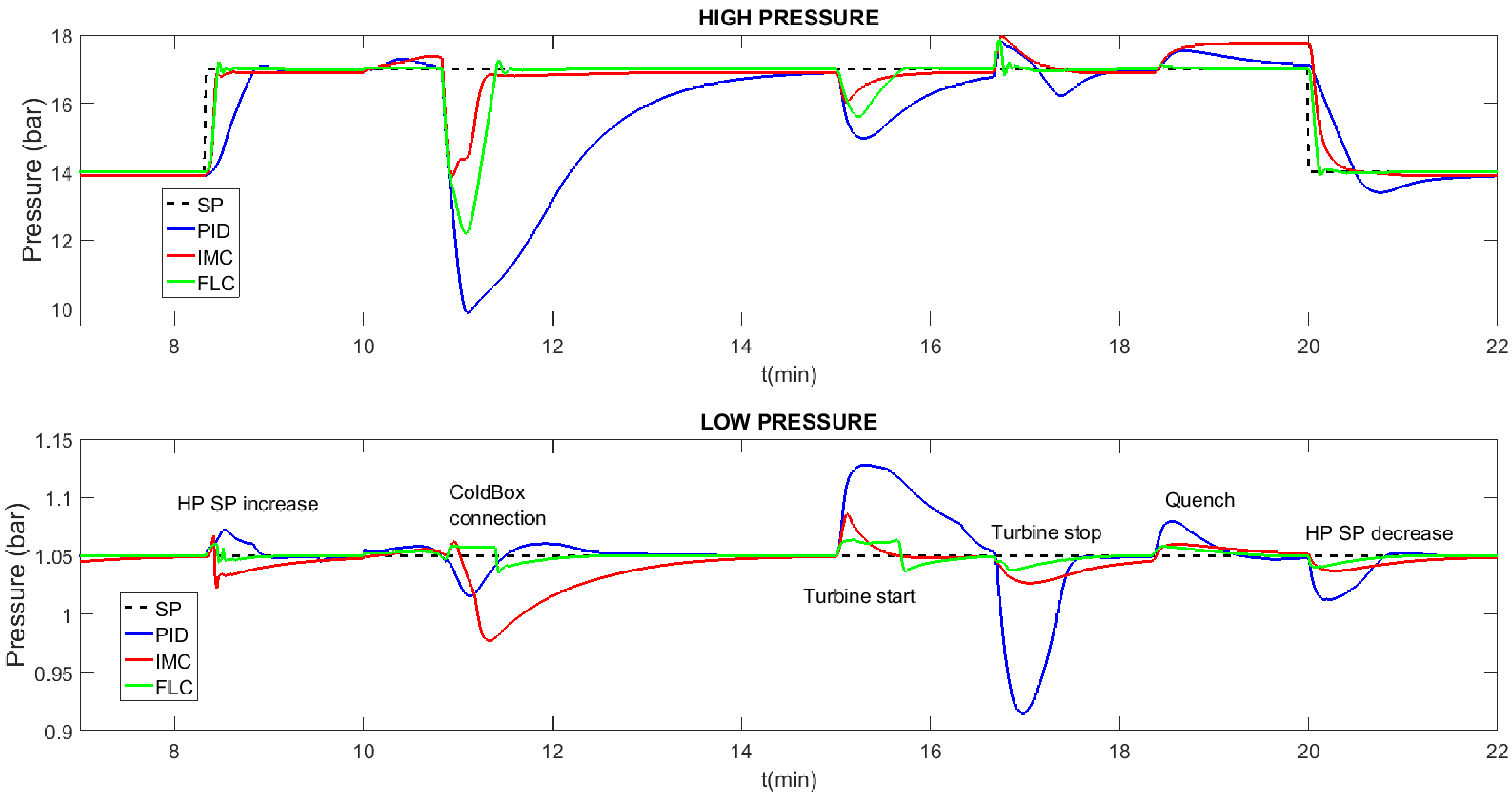
Third Operation Disturbance:

- At 3500s : Negative step in the HP Set Point (17 to 14bar)

Quench (Sudden input of gas from the Cold Box into the LP) :

- At 4000s : Starts
- At 4300s : Stops

Simulation



HIGH PRESSURE
Pressure (bar)
18
16
14
12
10
8
10
12
14
16
18
20
22
t(min)
SP
PID
IMC
FLC
LOW PRESSURE
Pressure (bar)
1.15
1.1
1.05
1
0.95
0.9
HP SP increase
ColdBox
connection
Turbine start
Turbine stop
Quench
HP SP decrease

Conclusion

- The PID solution still remains the best trade off between simplicity and operability.

- Both the IMC and the FLC methods improve control performances but their comprehension by operators remains an issue that could be handled using a good human machine interface (end-user oriented !!).

- This study allowed us to gather some knowledge that might be useful for more complex applications in the future and their impact on operators teams.