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

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Aknowledgments: the cryo operator team
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)

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

The input of the volumetric compressor cannot deal with big variations in the 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 → 0.2 bar 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

Charge/ Discharge
By-Pass
Valves
Valves

SR_2
SR_1

Fuzzy Controller
Defuzzyfication
Fuzzification
Inference
Base of Rules

LP Error
HP Error

LP Error MF
HP Error MF

Bypass MF
Charge Discharge MF

μ (Bypass)
μ (ChadDis)

μ (E)
μ (D)

HP Deriv MF
LP Deriv MF

Bypass MF
Charge Discharge MF

NL
NS
Z
PS
PL
LOWLOW
LOW
NORMAL
HIGH
HIGHHIGH
FALLING
STEADY
RISING
Internal Model Control

Real Measure – Expected Measure

PID Anti Wind-up

Real Process

Mathematical models of the process

Real Measure

Expected Measure
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

LOW PRESSURE

- SP
- PID
- IMC
- FLC

Pressure (bar)

Pressure (bar)

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.