Improve process stability by optimal tuning of PID control loops using Dynamic Simulation

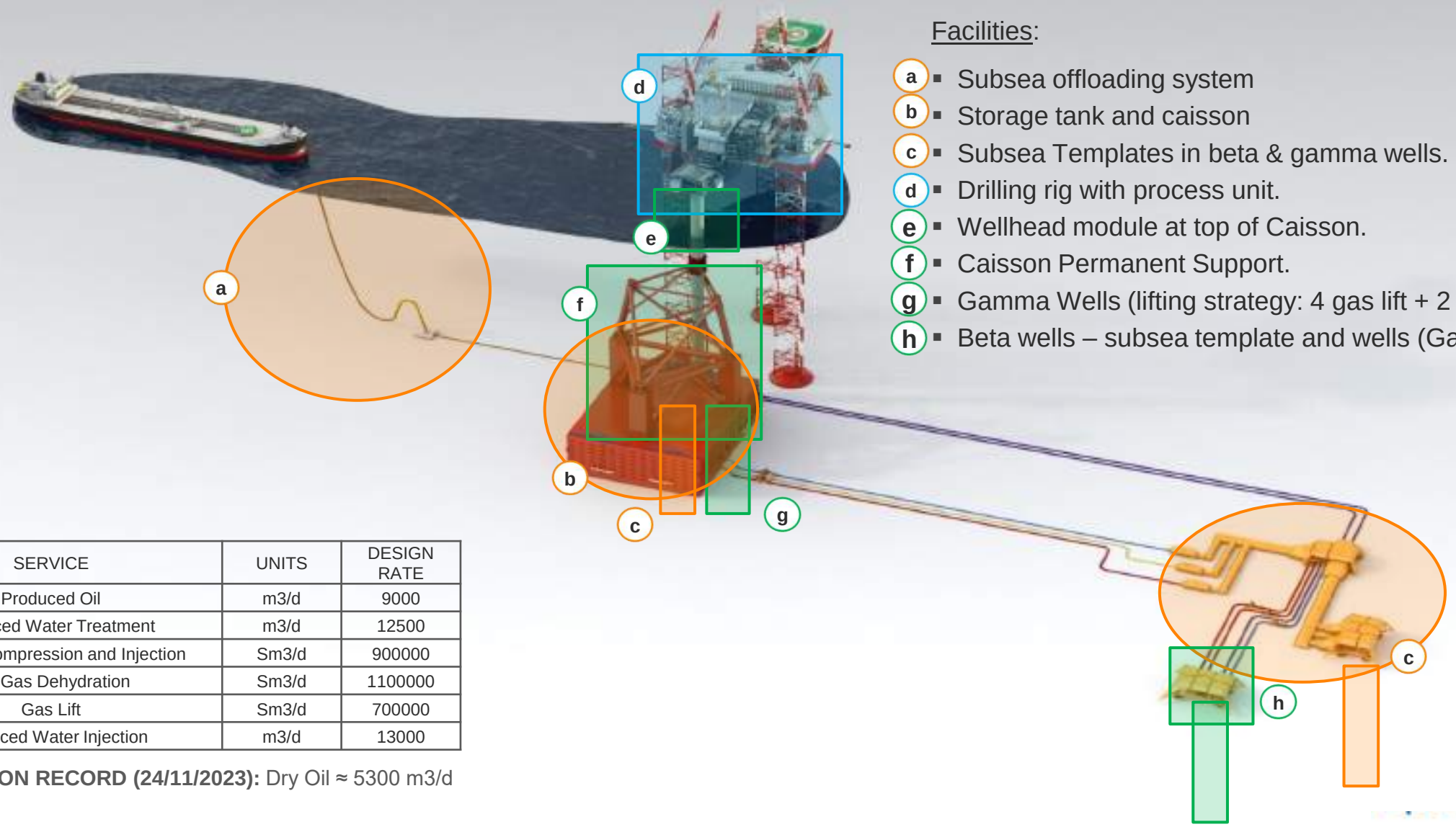
Jairo Segovia Reyes (Repsol)
Hanneliese Freites Kondratowitsch (Inprocess)
Paula Ventura, JoseMaría Ferrer (Inprocess)

Agenda

- Repsol YME overview
- Slugging: the challenges from the beginning
- Scope of work
- The role of the tuning
- Plant Result
- Takeaways and Conclusion

YME

Development concept: A mix of new and existing facilities



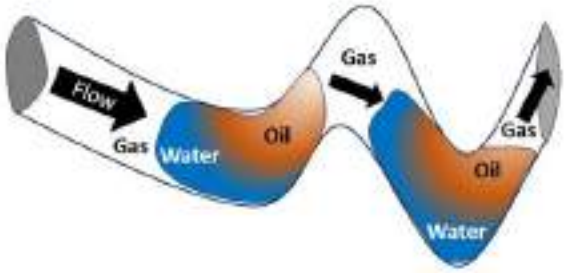
Facilities:

- a ▪ Subsea offloading system
- b ▪ Storage tank and caisson
- c ▪ Subsea Templates in beta & gamma wells.
- d ▪ Drilling rig with process unit.
- e ▪ Wellhead module at top of Caisson.
- f ▪ Caisson Permanent Support.
- g ▪ Gamma Wells (lifting strategy: 4 gas lift + 2 ESP)
- h ▪ Beta wells – subsea template and wells (Gas lift)

SERVICE	UNITS	DESIGN RATE
Produced Oil	m3/d	9000
Produced Water Treatment	m3/d	12500
HP Gas Compression and Injection	Sm3/d	900000
HP Gas Dehydration	Sm3/d	1100000
Gas Lift	Sm3/d	700000
Produced Water Injection	m3/d	13000

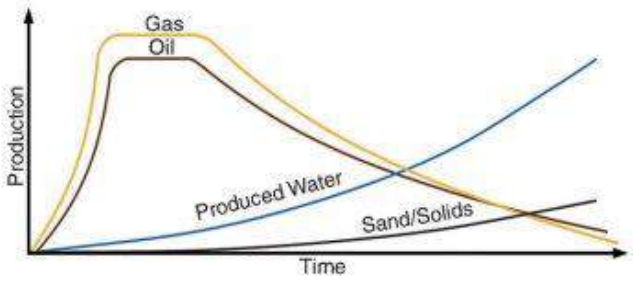
PRODUCTION RECORD (24/11/2023): Dry Oil ≈ 5300 m3/d

The challenges from the source



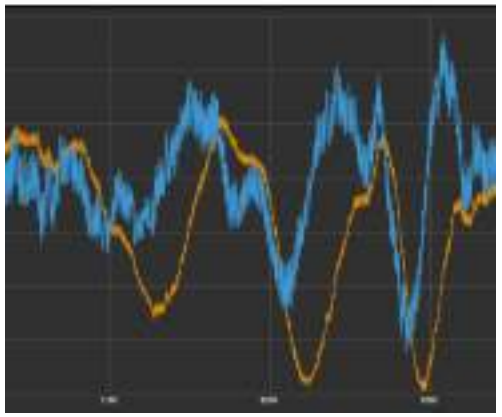
What is Slugging?

It is an erratic flow of a three-phase mixture caused by the alternating presence of liquid slugs and gas pockets



Mature Assets

They have depletion of oil production and increase of water cuts through time, promoting the slugging behavior



Plant Instability

It has been a real challenge from the startup of the facilities to avoid production deferment having choked wells, and in some cases with severe slugging resulting in partial and total Shutdowns.

A HYSYS dynamic model was created to study the loop tuning parameters

HYSYS Dynamic Model Scope

Fuel Gas

Dehydration

Compression train

Compression train

Re-injection

Production Manifold

High Pressure Separation

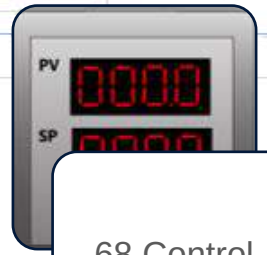
Low Pressure Separation

Produced Water

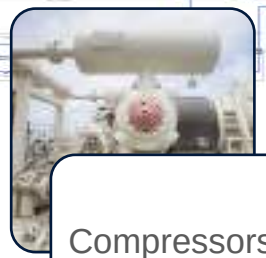
Gas Lift

Water Injection

Oil Production



68 Control Loops



Compressors

- 3 Trains Compressors

Three Phase Separation

- At low Pressure
- At high Pressure

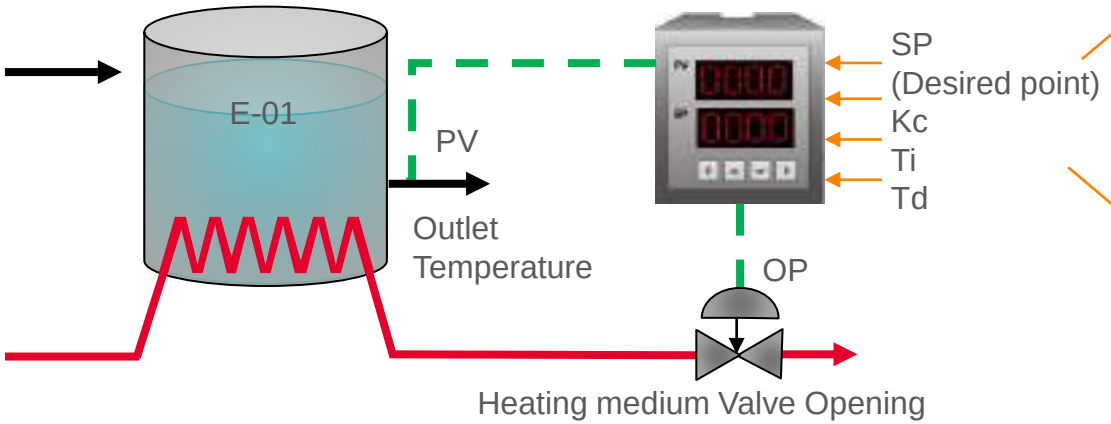
Heat Exchangers

- 8 Shell &Tube
- 7 Air Coolers

11 Pumps

Is the Tuning important?

Same Process,
Same Disturbance,
Different results…….

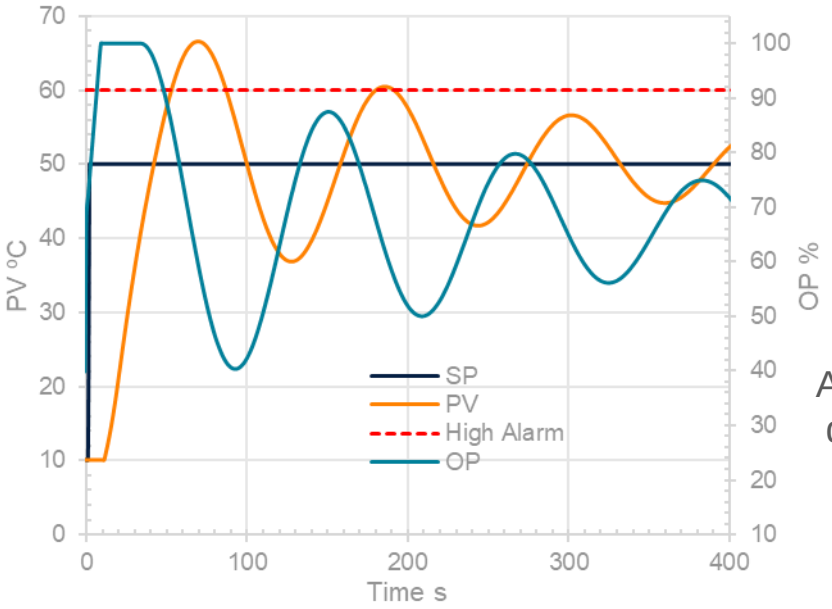


$$OP_{(t)} = u_{ss} + \boldsymbol{K_c} \cdot \left([b \cdot sp_{(t)} - pv_{(t)}] + \frac{1}{\boldsymbol{Ti}} [(sp_{(t)} - pv_{(t)}) \cdot h + u_{(t-1)}] - \frac{\boldsymbol{T_d}}{h} [(-pv_{(t)}) - (-pv_{(t-1)})] \right)$$

It is important to find the correct tunning that ensures that the process is running in:

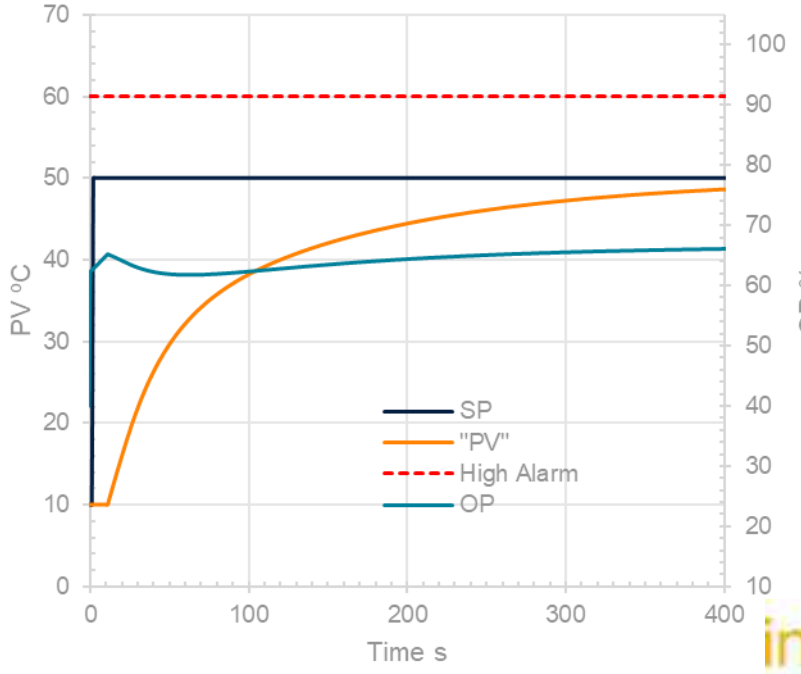
- Safe Conditions, far away from alarms and ESD trips.
- Under the quality standards.
- A reasonable production rate.

Too Fast



Affects the safety quality and stability

Too Slow



Affects the production

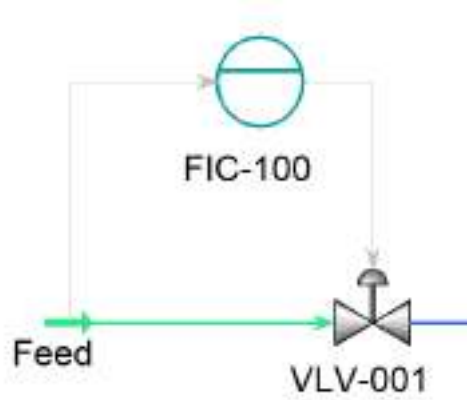
Orchestrating Offshore Symphony

What has in common a PID Controller with a musical instrument?

Need to be **tuned** for desired pitch and sound quality

Adjustments are made based on sound **feedback** to achieve the desired musical expression.

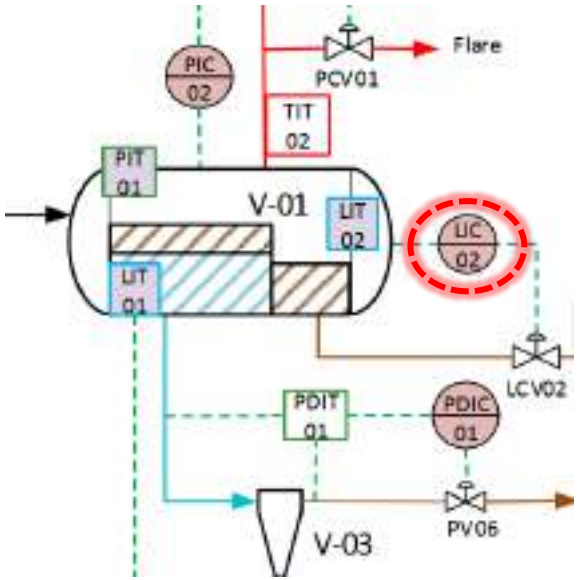
It needs a blending **science** of sound production with the artistry of musical expression

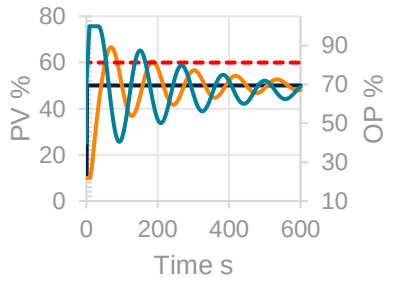


Need to be **tuned** for proper control

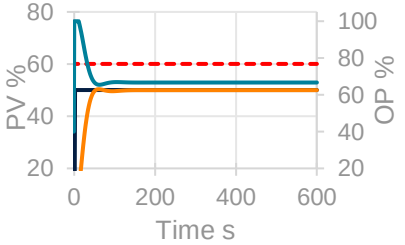
PID controllers are based on **feedback** control

Tuning a PID controller involves both **engineering principles** and a nuanced understanding of the system's behavior





Bad Tuning

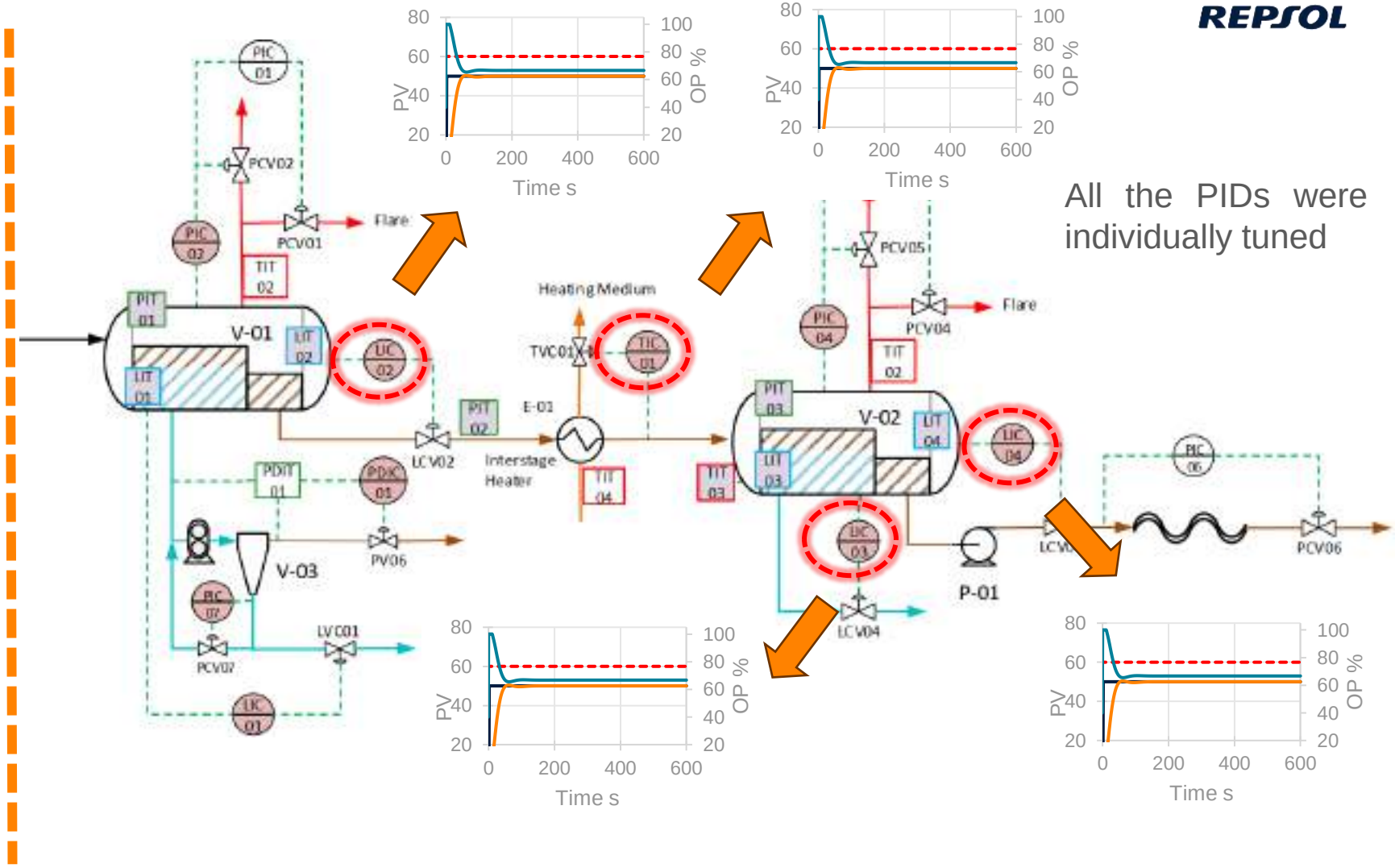


Good Tuning

Orchestrating Offshore Symphony

Multiple Instruments

If all instruments are well-tuned, will a successful symphony be achieved?



All the PIDs were individually tuned

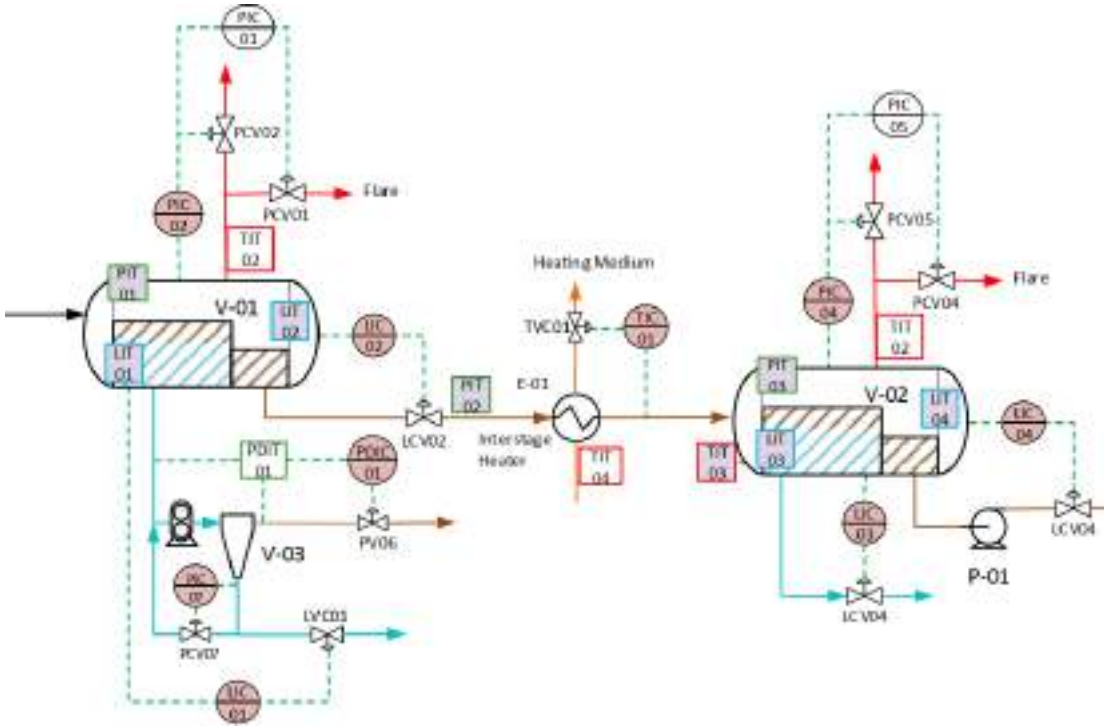
Just as a conductor ensures harmony in a symphony of multiple instruments, the same happens with interactive control loops in a plant.

Orchestrating Offshore Symphony

Multiple Instruments in a Wavy Storm

Just imagine that this symphony needs to be performed in this storm. Would the performance be the same?

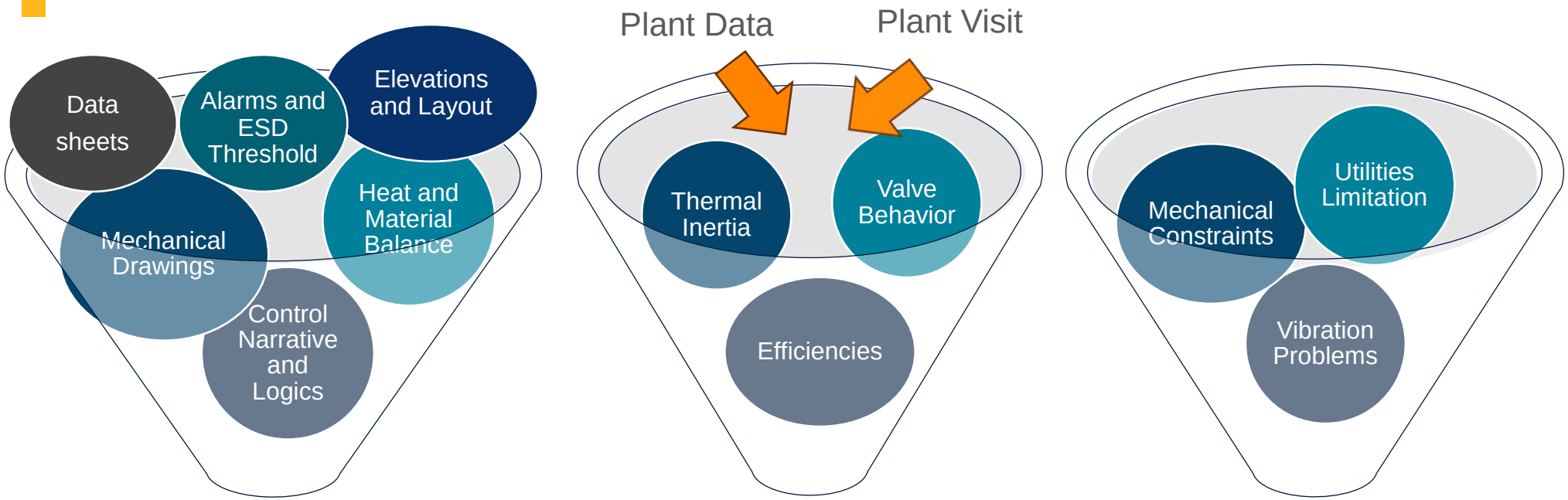
SLUGGING



How will the tuning behave to these perturbations?

Is it possible to reduce perturbations?

Scope of work



ASPEN HYSYS Dynamics™ Model

Validation and More Realistic Model

Plant Know How

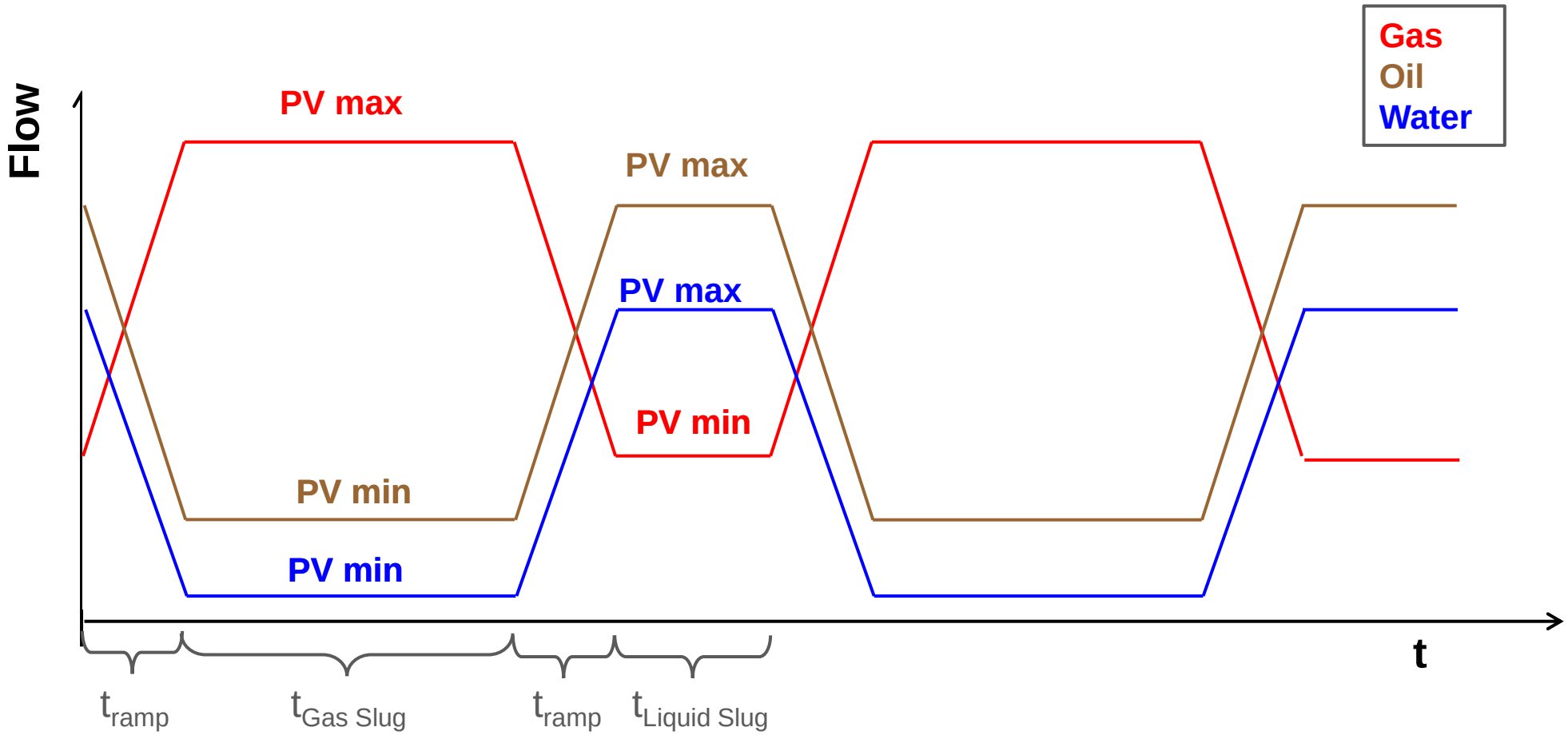
Accurate Plant Decisions

(Tuning, Set Point, Alarms and Logics)

Tuning Methodology

Slugging Pattern Simulation

WELL OUTLET FLOWS

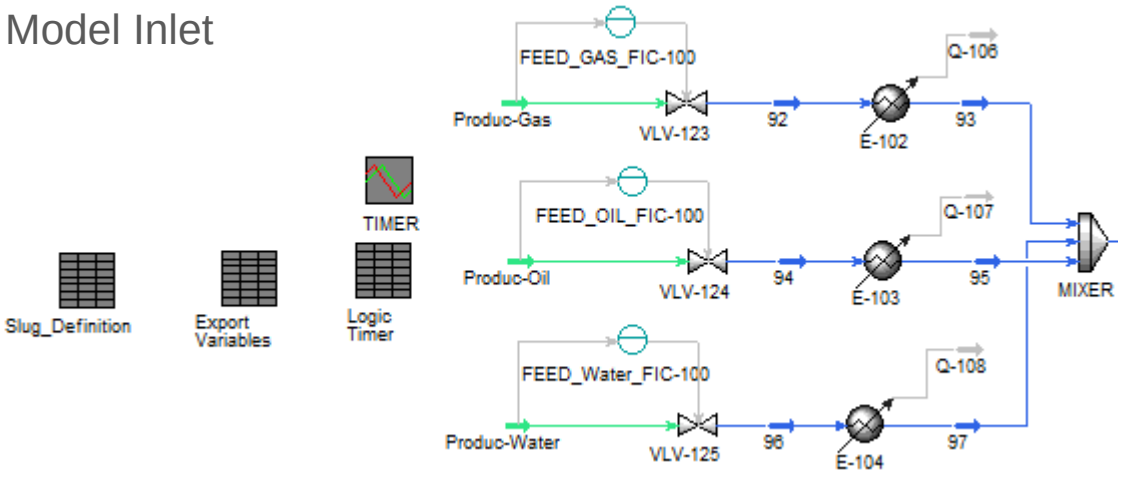


Tuning Methodology

Slugging Pattern Simulation

PID Controllers + Logical Operations

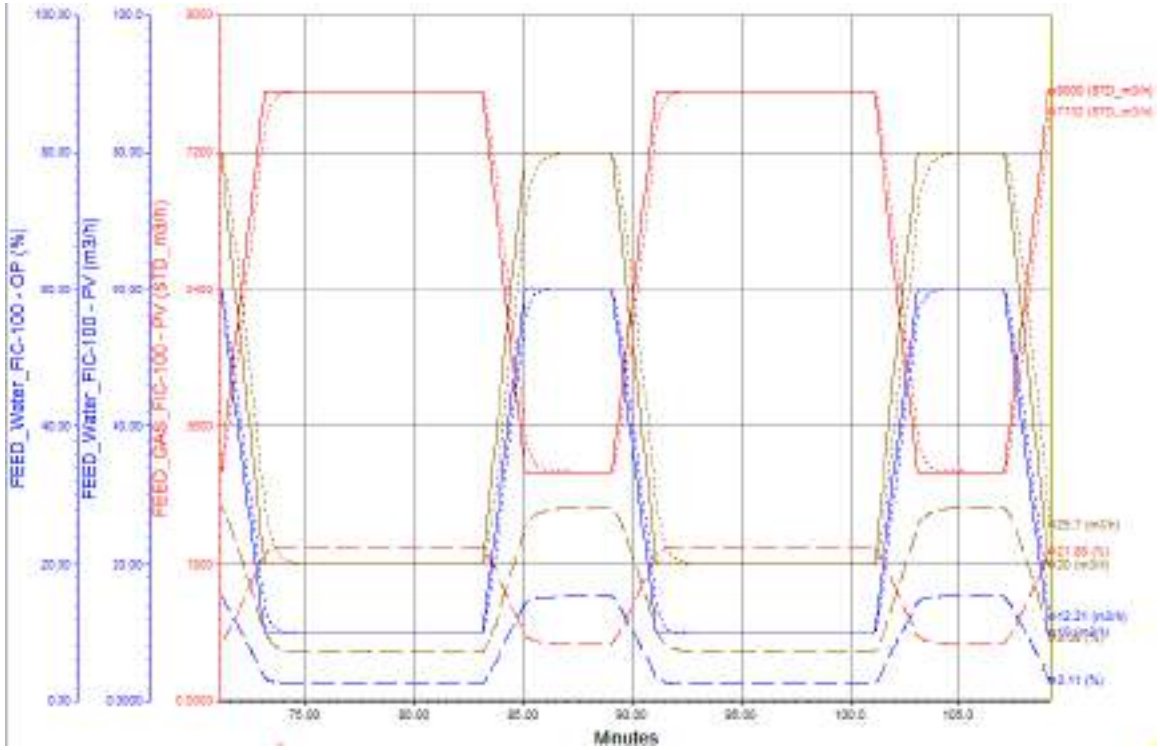
Model Inlet



Spreadsheet: Slug_Definition @OIL

	A	B	C	D	E
1		Std Vol Flow Min (...	Std Vol Flow Max...		
2	GAS	3000	8000		
3	OIL	20.00	80.00		
4	WATER	10.00	60.00		
5					
6		Slug duration (min)	Period (min)		Ramp Duration (m...
7	Gas Slug	12.00	18.00		2.000
8	Liquid Slug	6.000			
9					
10	ACTIVATE (0/1)	1.000			

Result

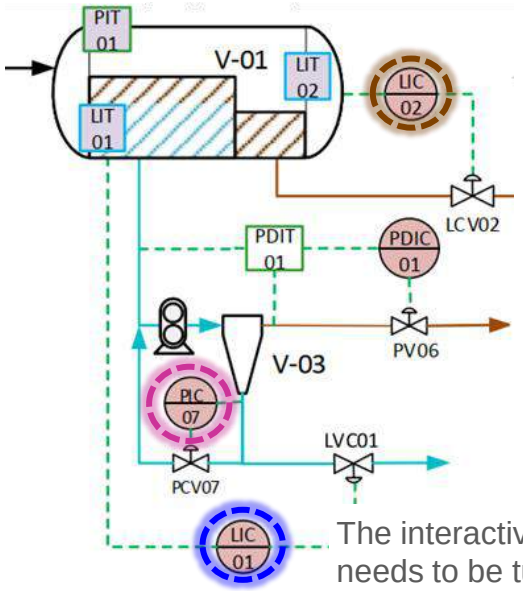


FEED_GAS_FIC-100 - SP		Solid
FEED_GAS_FIC-100 - PV		Dotted
FEED_GAS_FIC-100 - OP		Dashed
FEED_OIL_FIC-100 - SP		Solid
FEED_OIL_FIC-100 - PV		Dotted
FEED_OIL_FIC-100 - OP		Dashed

FEED_Water_FIC-100 - SP		Solid
FEED_Water_FIC-100 - PV		Dotted
FEED_Water_FIC-100 - OP		Dashed

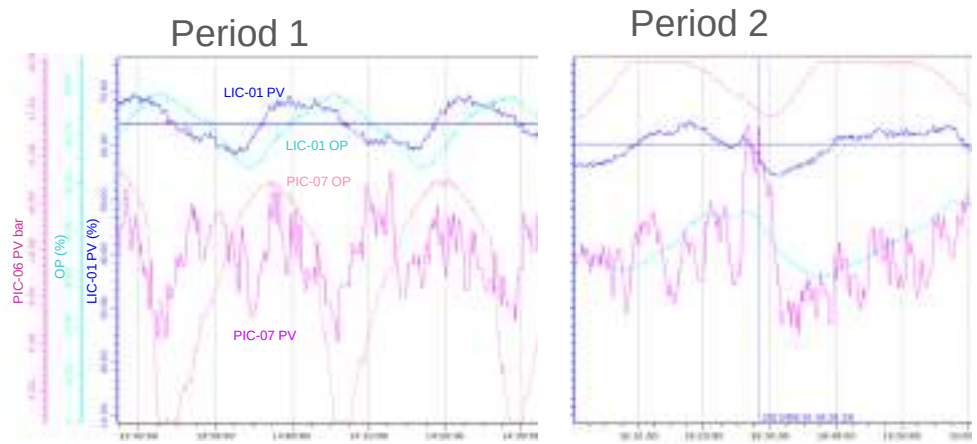
Tuning Methodology

1) Find Interactive Loops



The interactive loops needs to be tuned together!

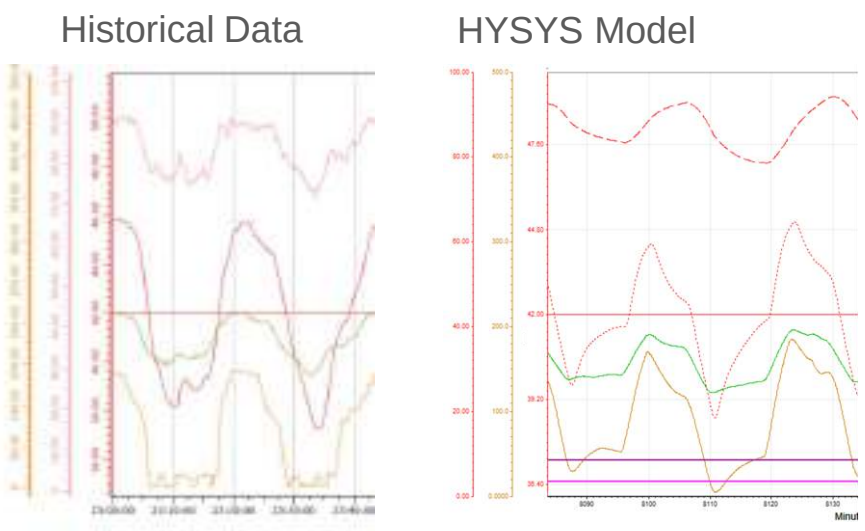
2) Review Historical Data



The saturation of PIC07 affects the level

Oil Chamber has more alarms than water chamber

3) Model the Feed



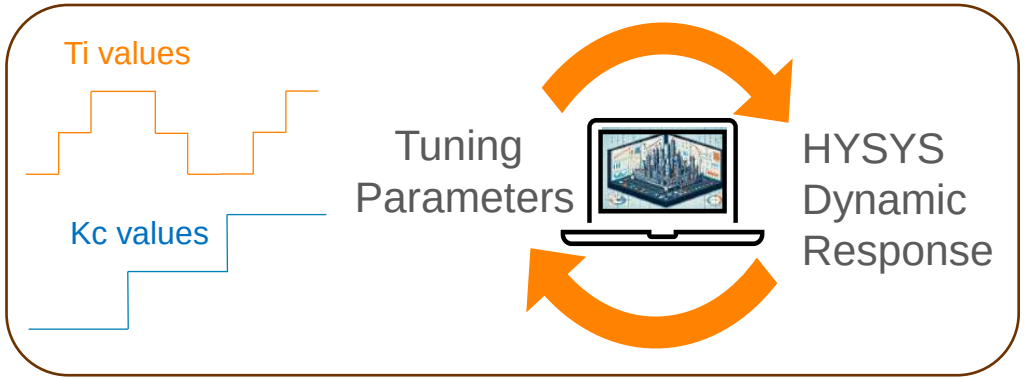
Using the Slugging patterns to simulate the same plant behavior

4) Set Control Strategies

Trade off: oil vs water perturbations. More aggressive water controller will stabilize oil flow

Chamber	Residence Time (Min)
Water	23
Oil	4

5) Try different Tuning Parameters

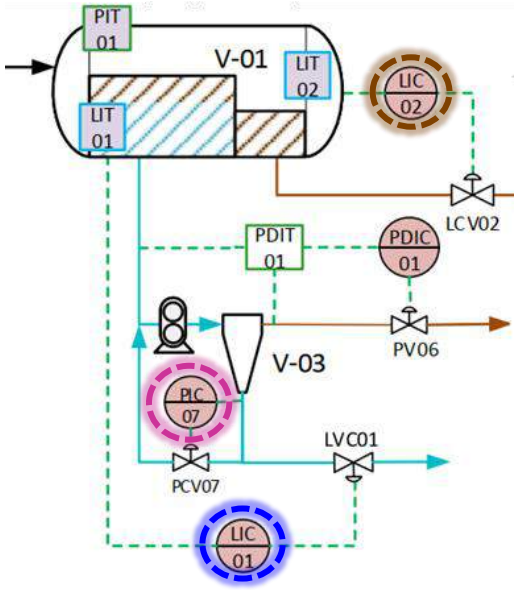


Multiple scenarios are automatically tested using Python Scripts

Tuning Methodology

6) Analyze HYSYS Results

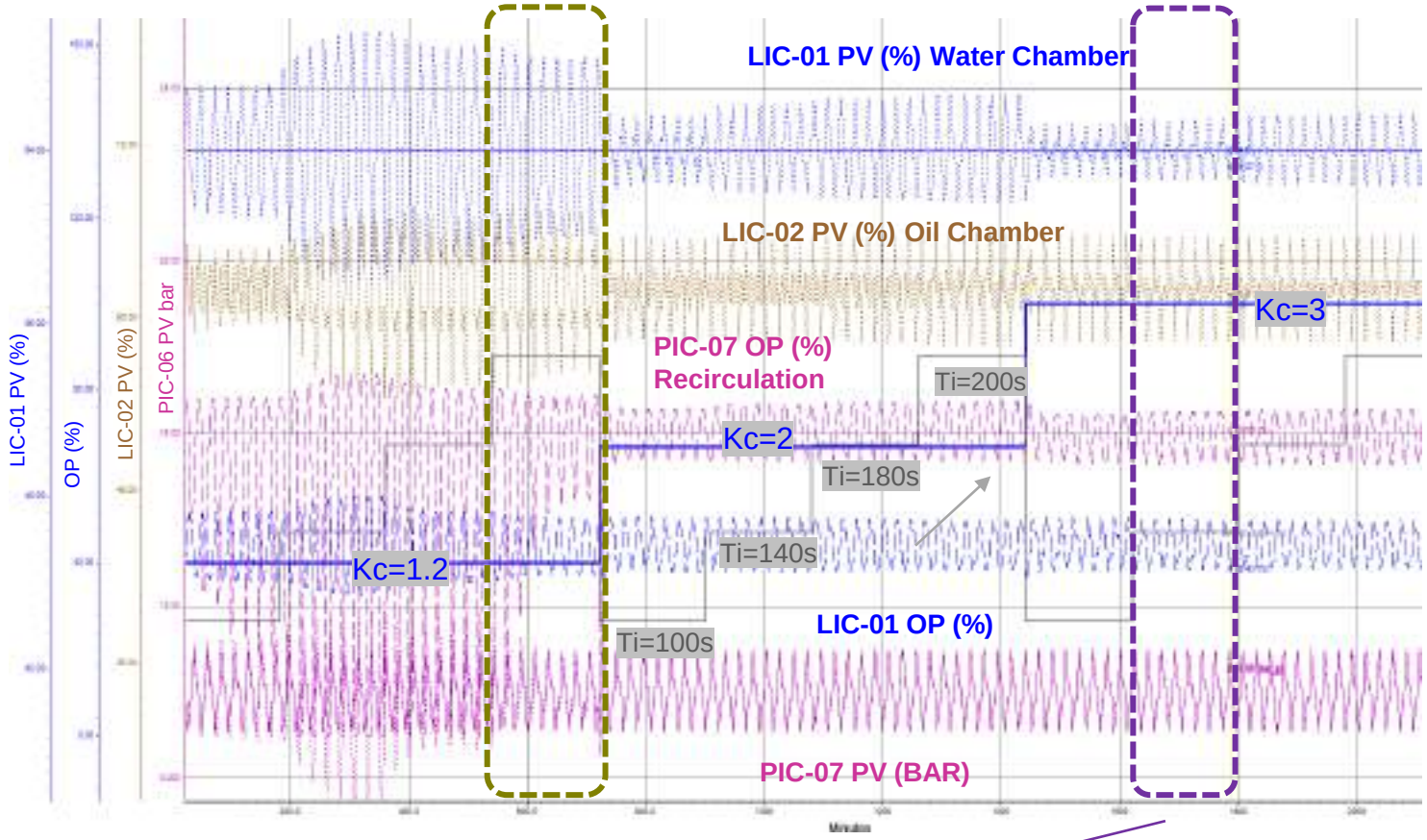
Effect of the change in **LIC-01** tuning parameters in the loops **PIC-07** and **LIC-02**



Changing the tunning in **LIC-01** will have a significant impact in the performance of the other loops!

LIC-01	
Kc	Ti (s)
1.2	140

Initial



7) Choose the right tuning

LIC-01	
Kc	Ti (s)
3	140

Plant Results

HP Separator: Water Level

Objective: Reducing fluctuations in Water level to reduce fluctuations in Oil Level ✓

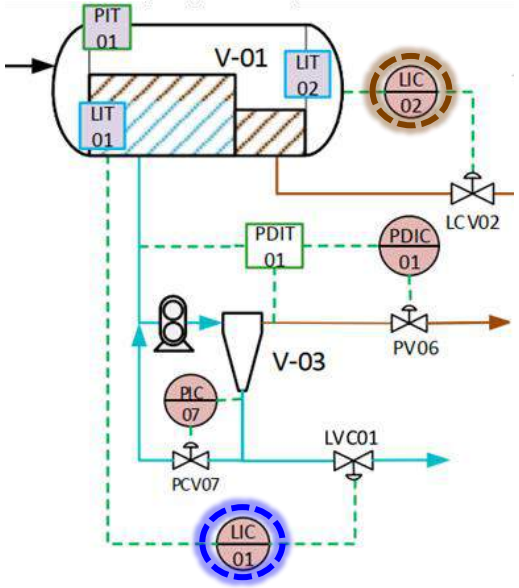
Initial

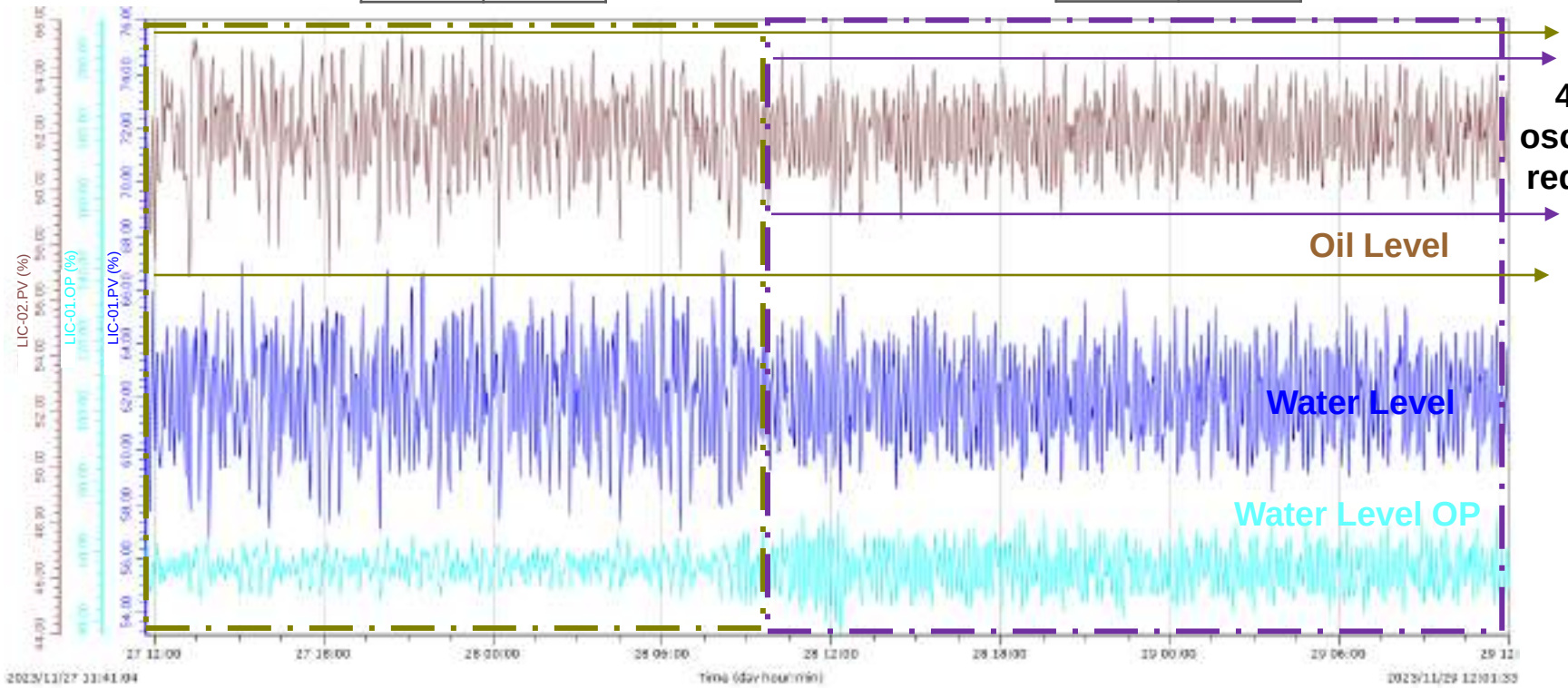
LIC-01	
Kc	Ti (s)
1.2	140

Proposed

LIC-01	
Kc	Ti (s)
3	140

HP Separator

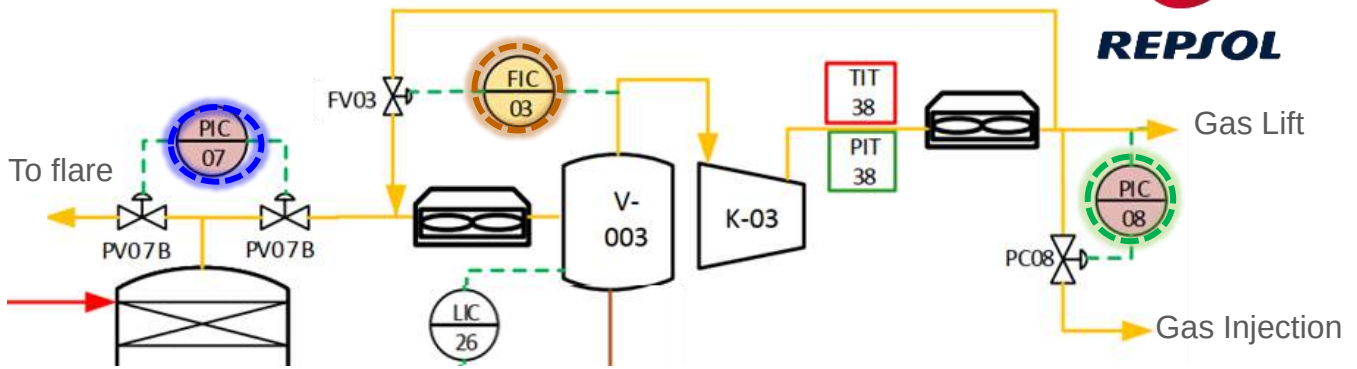




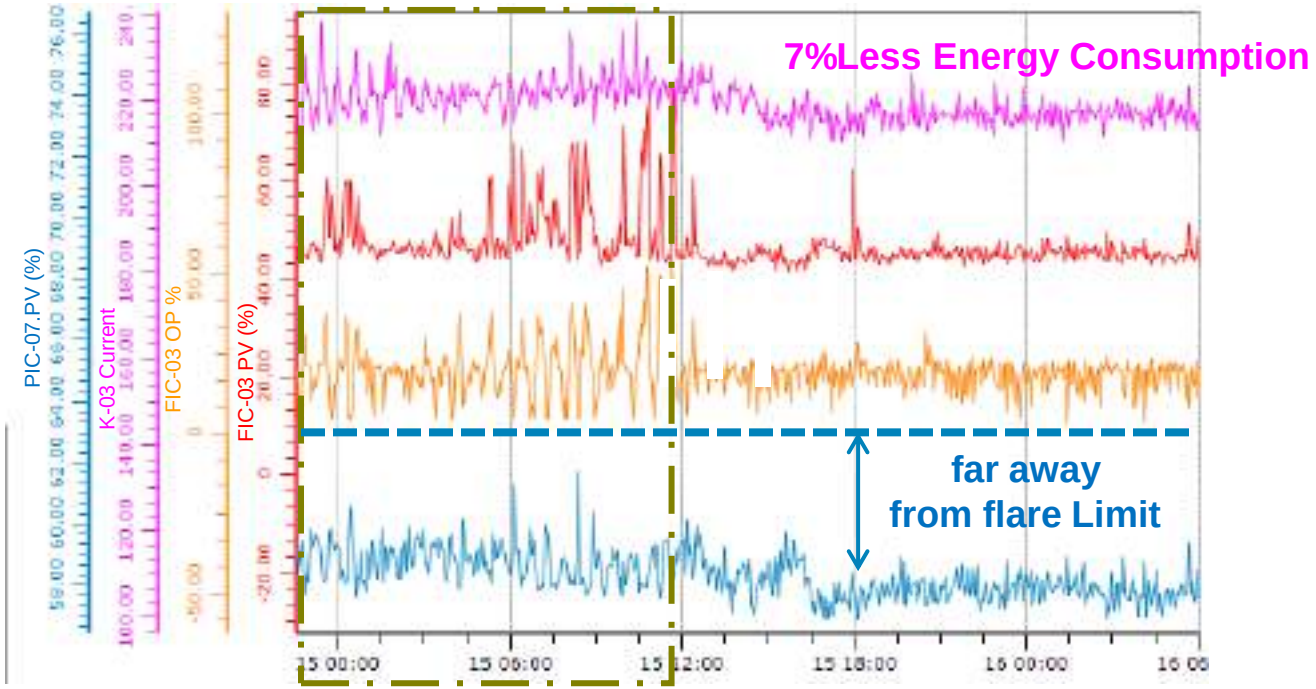
Plant Results

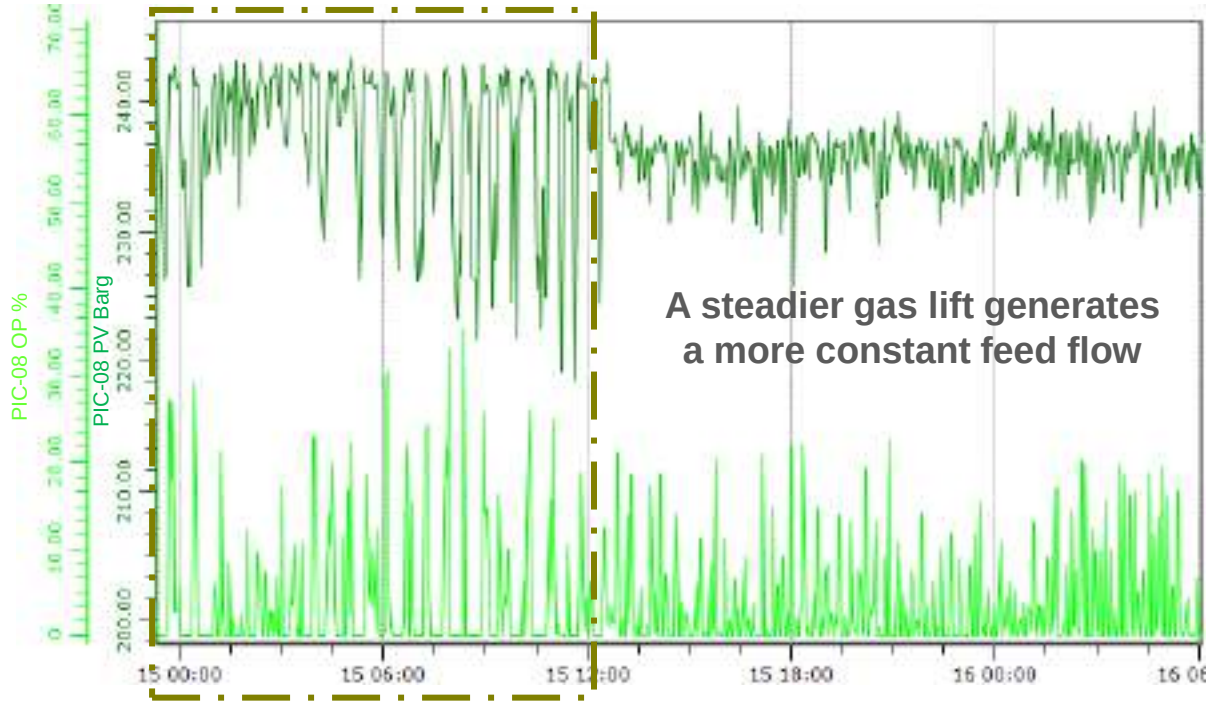
Gas System

Objective: Reducing fluctuations in the gas system by changing set points, reducing loop interaction.



Initial





Plant Results

LP Separator: Oil Level and Oil Pressure

Objective: Reducing fluctuations in Oil Level and Oil Pressure in LP Sep ✓

Initial

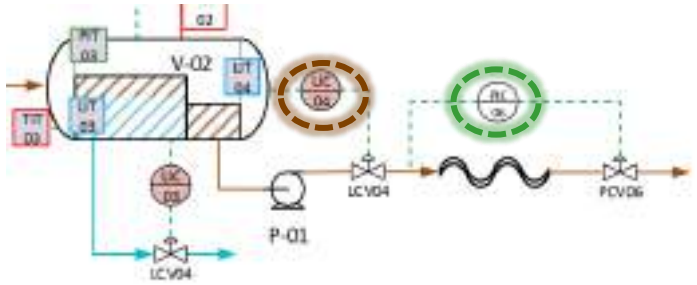
LIC-04		PIC-06	
Kc	Ti (s)	Kc	Ti (s)
3	200	3	60

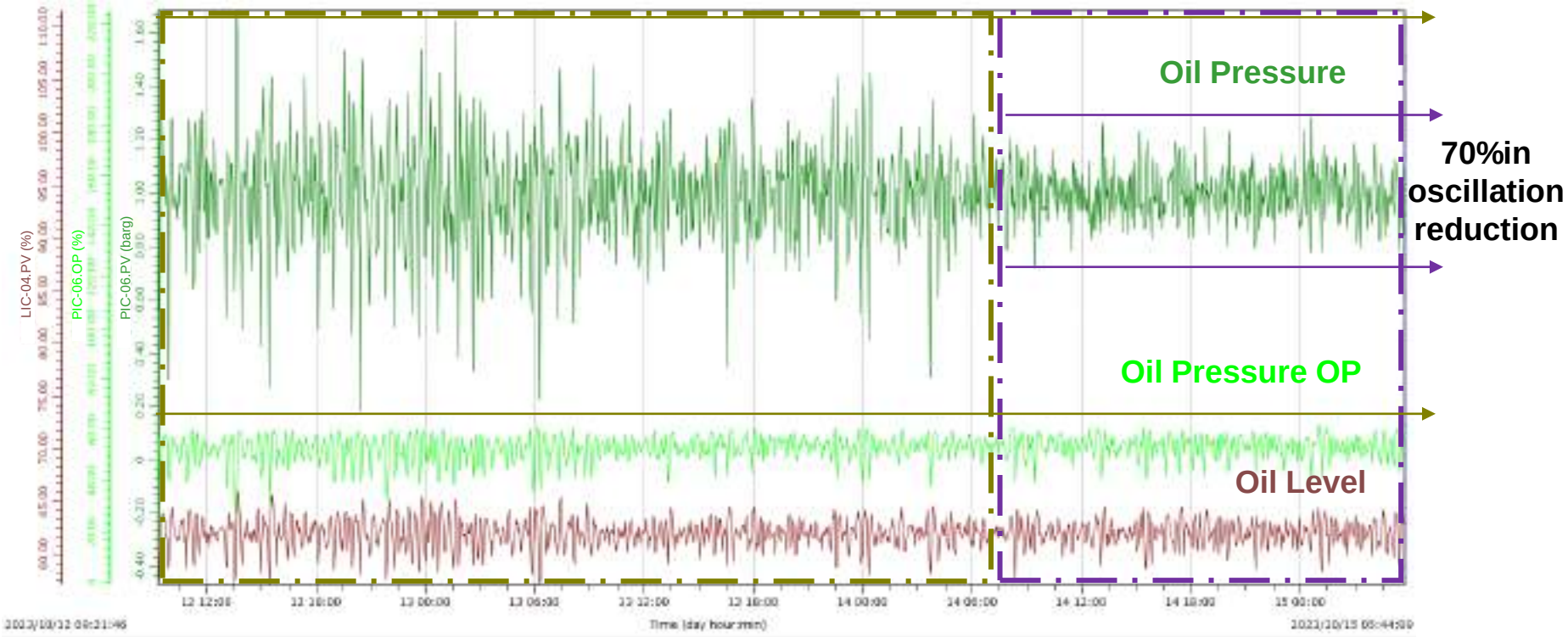
Proposed

LIC-04		PIC-06	
Kc	Ti (s)	Kc	Ti (s)
3	90	3	12

+ 2.6s PV Filter

LP Separator

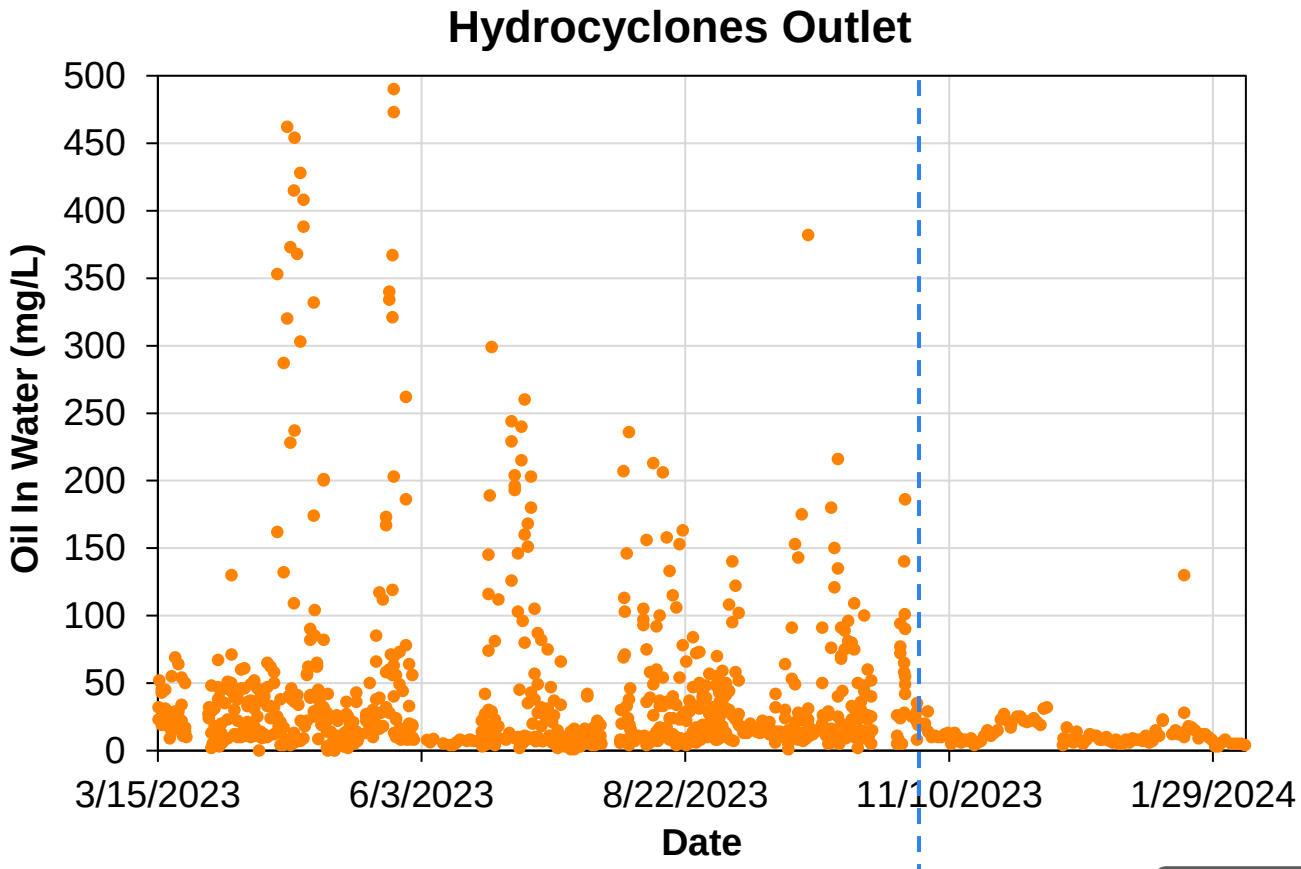




Plant Results

KPIs

- **Product Quality Lab Analysis**



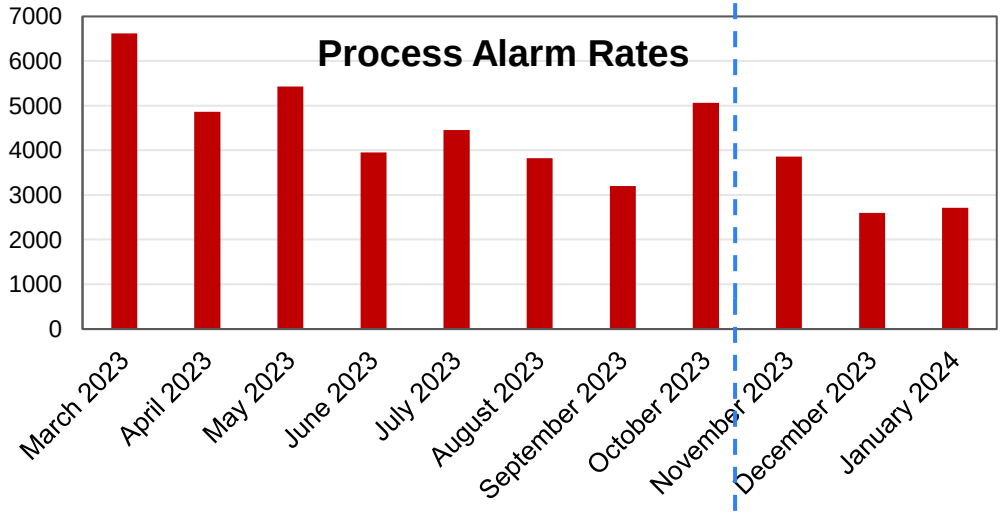
- **Trips**

Since the beginning of the project there has been none trips related to the process

- **Energy Consumption**

Achieving stable operation in the compressor could lead to an energy consumption reduction of up to 7%.

- **Monthly Alarms Counter**



Beginning of Loop Tuning Implementation

Conclusions


Slugging is one of the major issues to deal in the operation of mature assets


Initial PID tuning parameters are no longer valid with lower production rates or slugging


Traditional PID tuning rules are not valid for interactive controllers or with slugging patterns

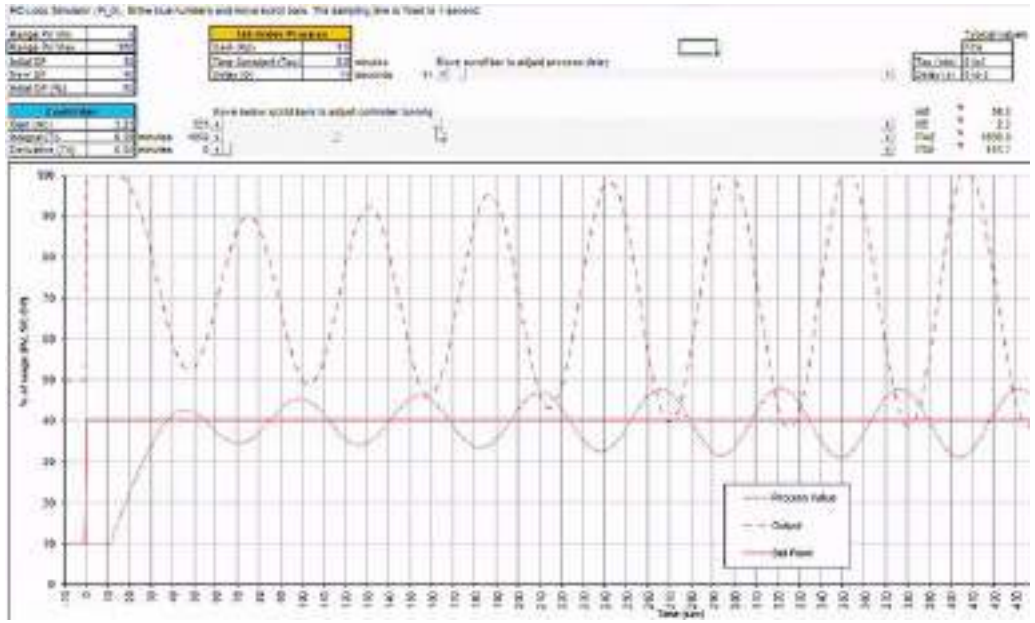

Aspen HYSYS Dynamics™ can reproduce the whole asset behavior with the required detail


Massive plant data analysis is strictly required for process understanding and model calibration

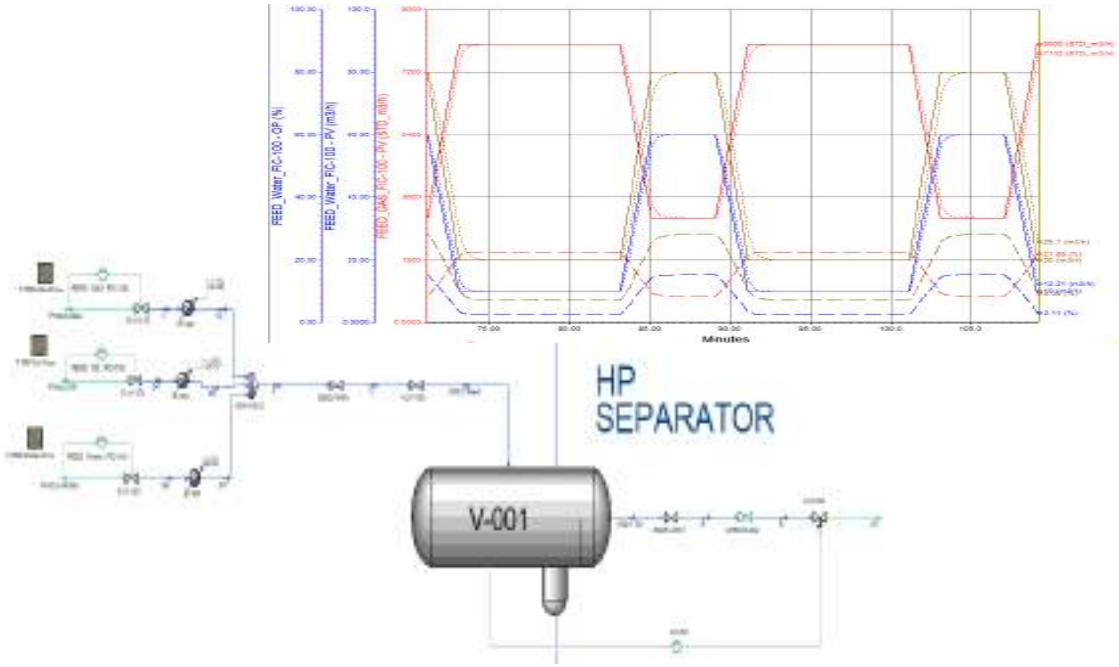

Value: a more stable plant (up to 70% reduction in oscillation) avoids trips, reduces energy consumption, and allows production rate increases.

Your Free Take Aways

Interactive Excel sheet to tune a PID loop



HYSYS Dynamic example simulating slugging



Scan for more details!

Thank you!