PROCESS SIMULATION CUP
PSC2020- OPTIMAL CONTROL

PHASE 2: MAKE USE OF THE “D” IN PID

DR.-ING. JAN C. SCHÖNEBERGER

BERLIN, 1 APRIL 2020

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OUTLINE

- General Information
- Phase 2
  - Overview
  - Scenario 1: Set-point step change
  - Scenario 2: Disturbance of the flowrate
  - Scenario 3: Shutdown of one engine
- Plant performance with the initial controller settings
- A hint: Learnings from Phase 1

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IS THIS DOCUMENT FOR ME?

- This document is for you, if you want to
  - learn about typical disturbances that can affect the operation of a biogas powerplant
  - understand how the optimization problem of PSC2020 is formulated

- This document
  - introduces the first three scenarios of PSC2020
  - explains how the objective function is calculated
  - gives the parameters used to calculate benefits and costs for each scenario

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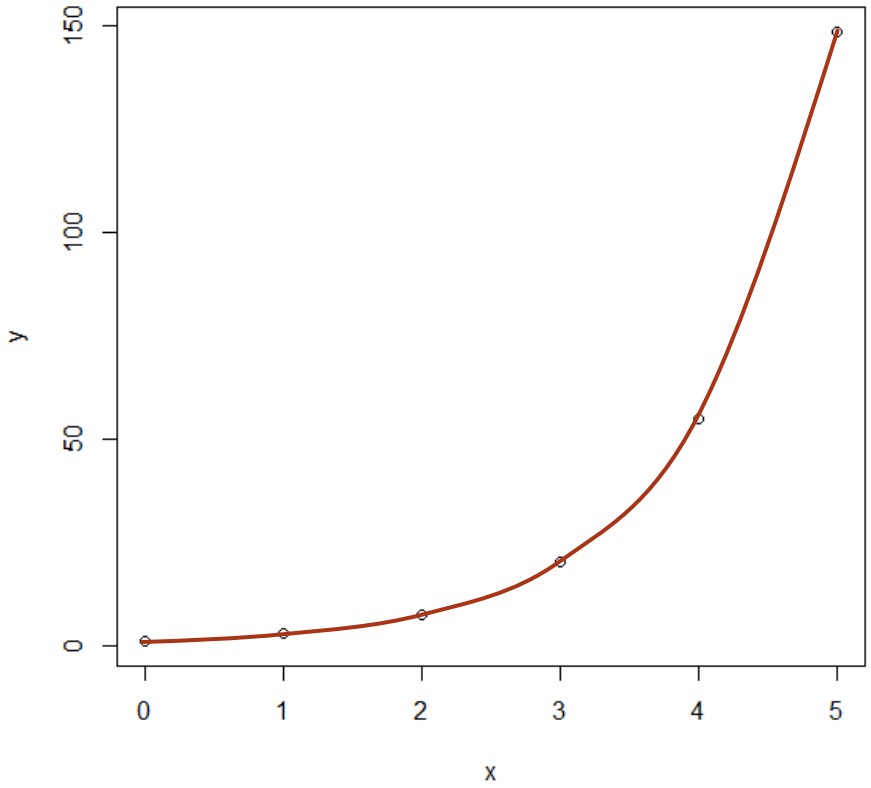
OVERVIEW

Phase 2: Make use of the “D” in PID

- These days we all learn what exponential growth really means!
- Many variables in chemical processes show an exponential correlation
- Having information about the speed of growth (= the derivative) can be very helpful for controlling processes
- This information can be used in a PID controller with the “D” part, which stands for the differential change of the error



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OVERVIEW

Phase 2: Make use of the “D” in PID

- These days we all learn what exponential growth really means!
- Many variables in chemical processes show an exponential correlation
- Having information about the speed of growth (= the derivative) can be very helpful for controlling processes
- This information can be used in a PID controller with the “D” part, which stands for the differential change of the error

- The scenarios in phase 2 are the same as in phase 1
- In phase 2 you can switch on the “D” part of the controllers
- The electricity price has been increased for phase 2. Now you get 100 € as a base price for each scenario
- The contractual penalty applied to the first scenario is relaxed in phase 2. The new penalty is 1 € per unit of Integral Square Error and per Flow Controller.

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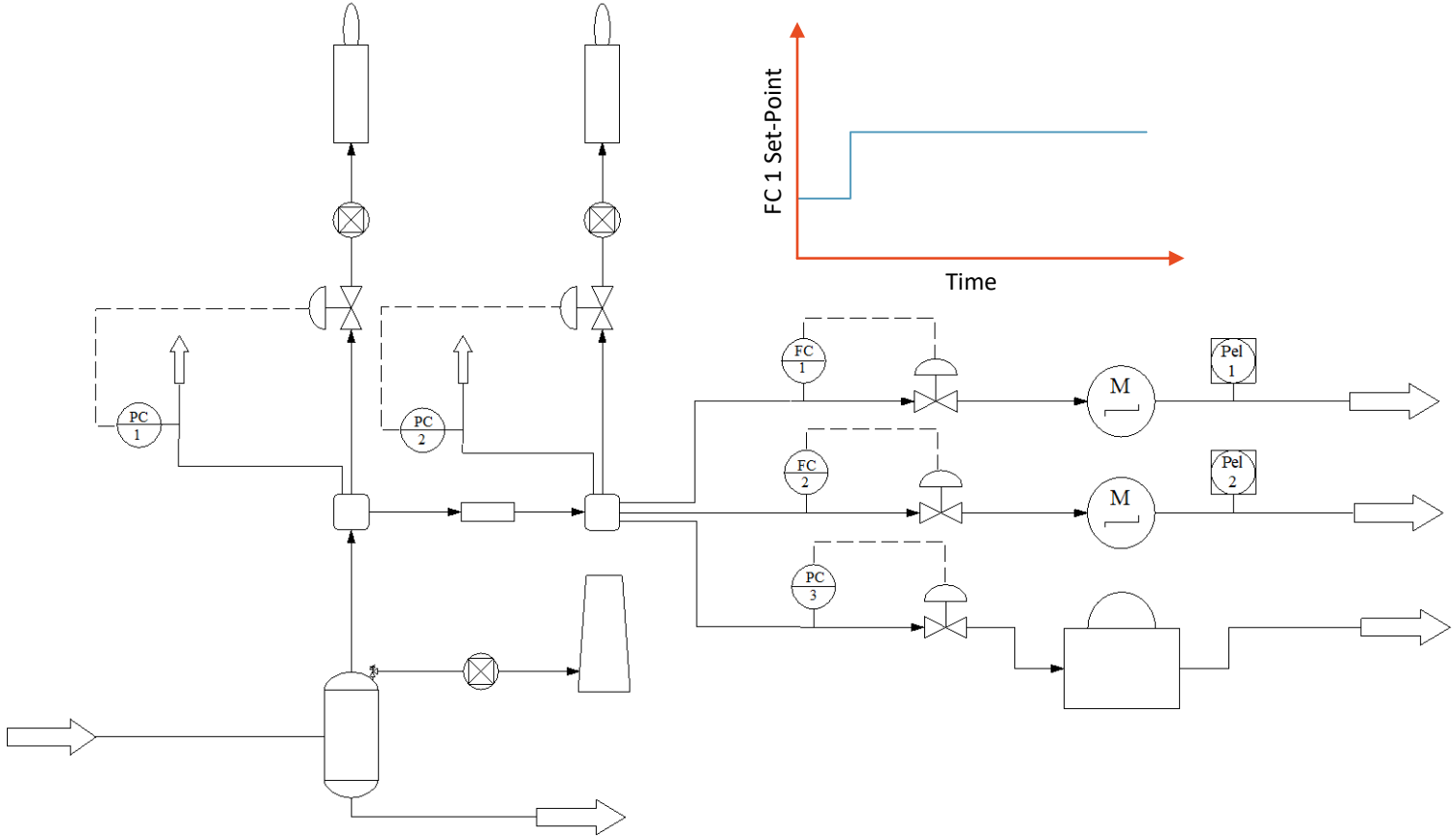
SCENARIO 1: SET-POINT STEP CHANGE

- The flow to engine 1 must be increased by 10% from 140 kg/h to 154 kg/h
- The set-point change is done in one step at time t = 5 min
- The operation period is 60 minutes
- During the operation period 100 € are earned



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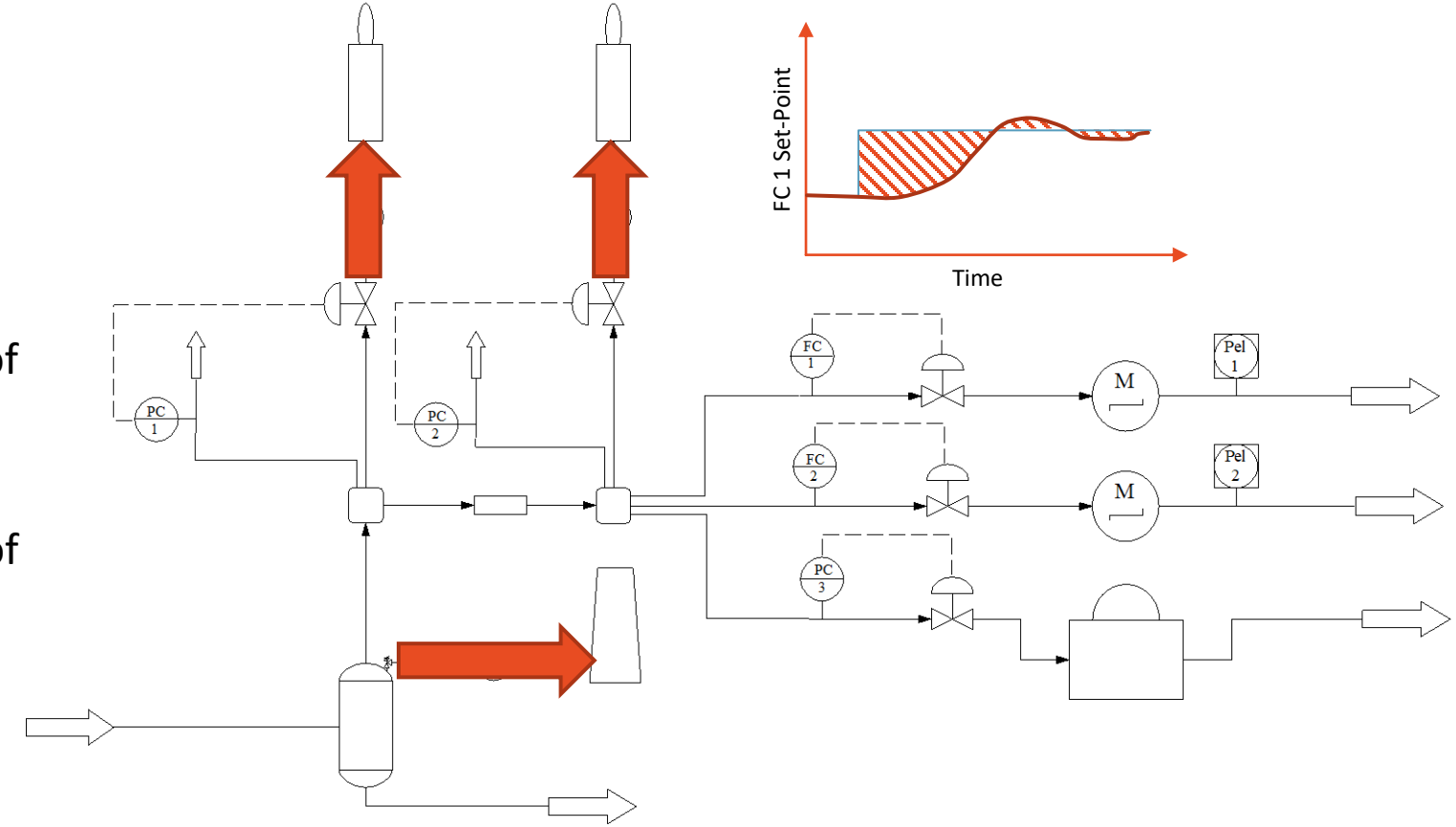
SCENARIO 1: SET-POINT STEP CHANGE

- For safety valve emissions 100 €/kg must be payed
- For emissions via one of the flares 1 €/kg must be payed
- The integral square error of FC1 is penalized with 1 € per unit
- The integral square error of FC2 is penalized with 1 € per unit



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SCENARIO 1: SET-POINT STEP CHANGE

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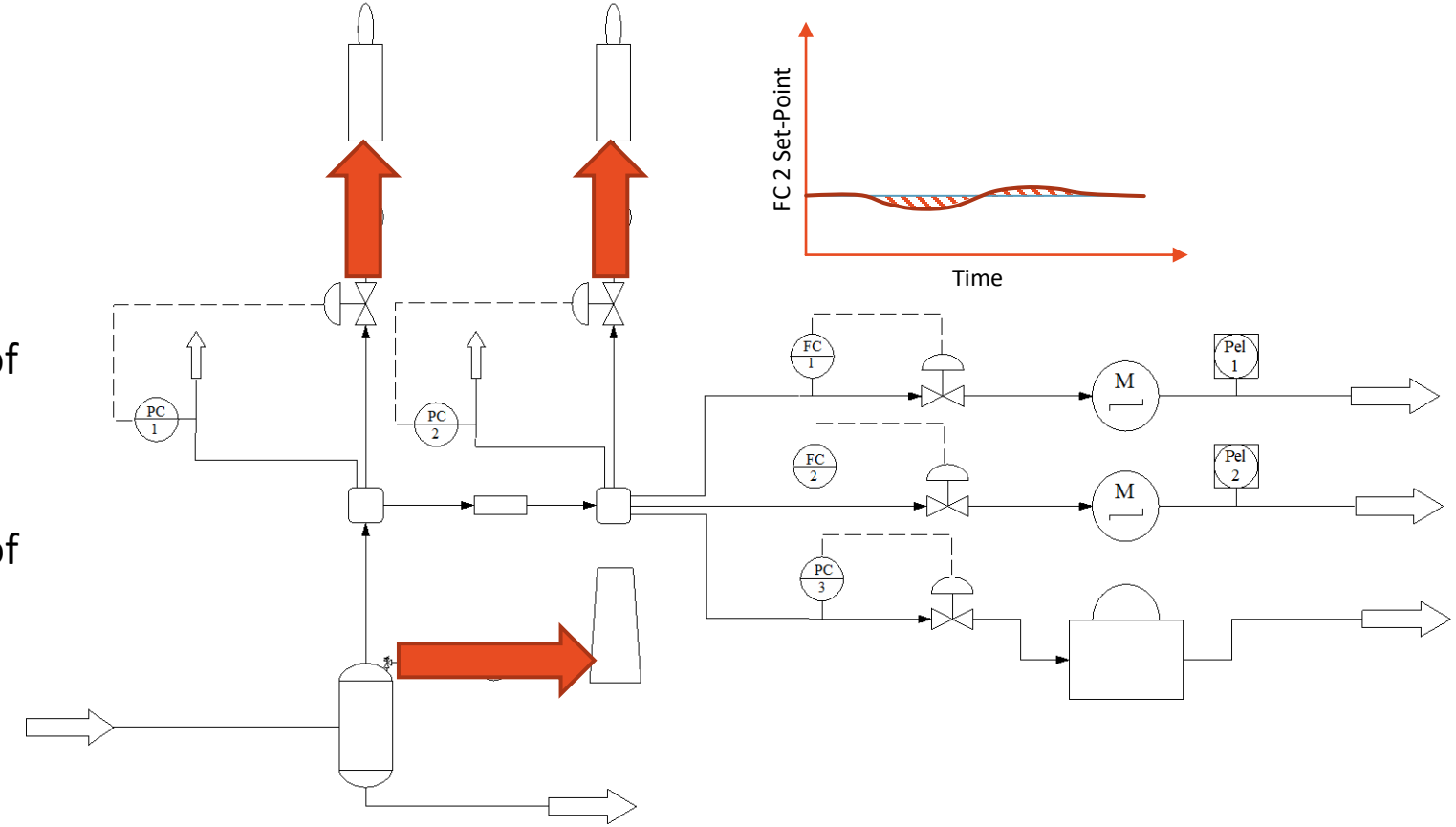

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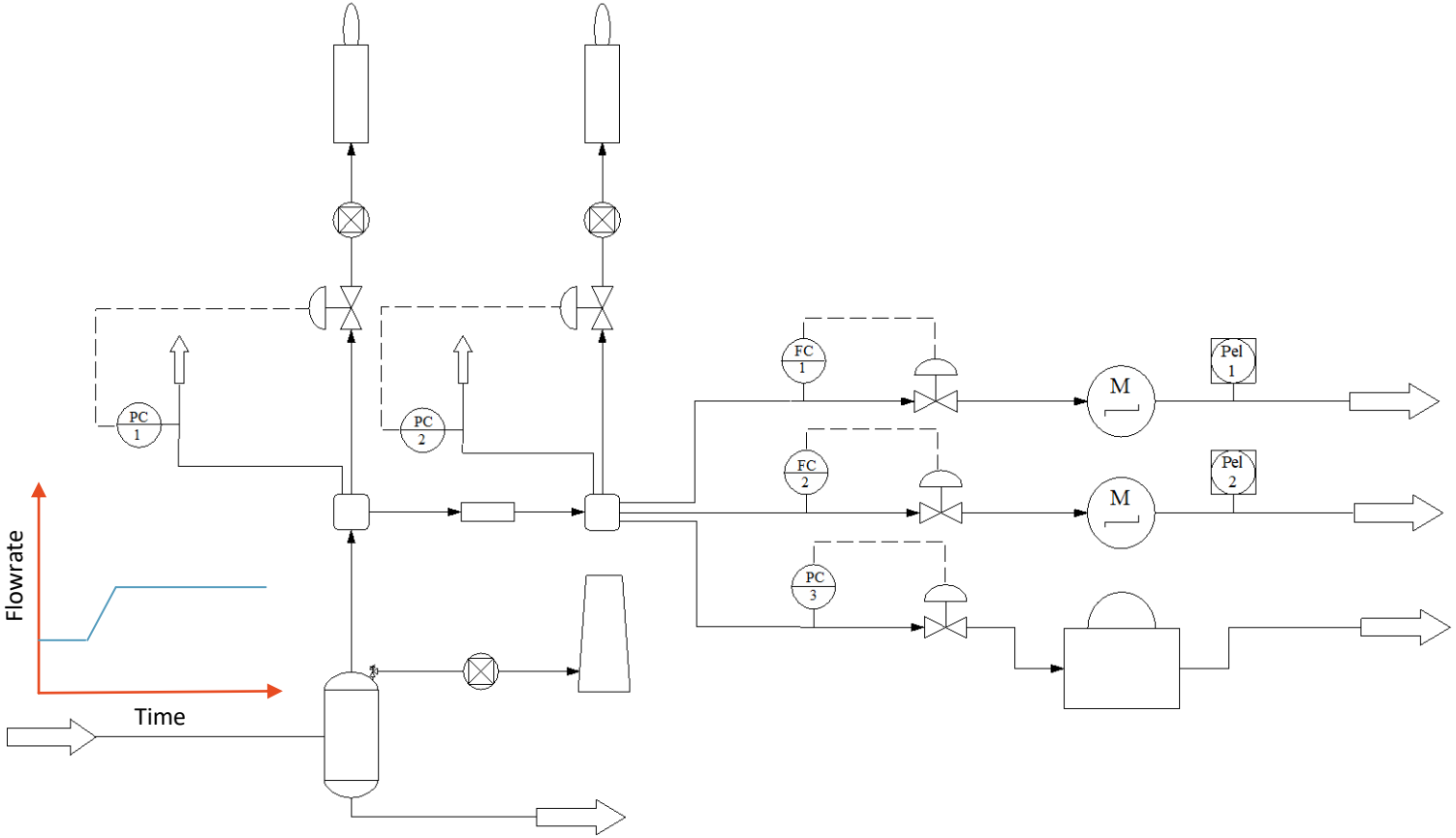
SCENARIO 2: DISTURBANCE OF THE FLOWRATE

- The fermenter is producing more biogas
- The flowrate is increased by 20% from 300 Std. m³/h to 360 Std. m³/h
- The increase is linear in time from t_1 = 5 min to t_2 = 10 min
- The operation period is 60 minutes (100 € are earned)



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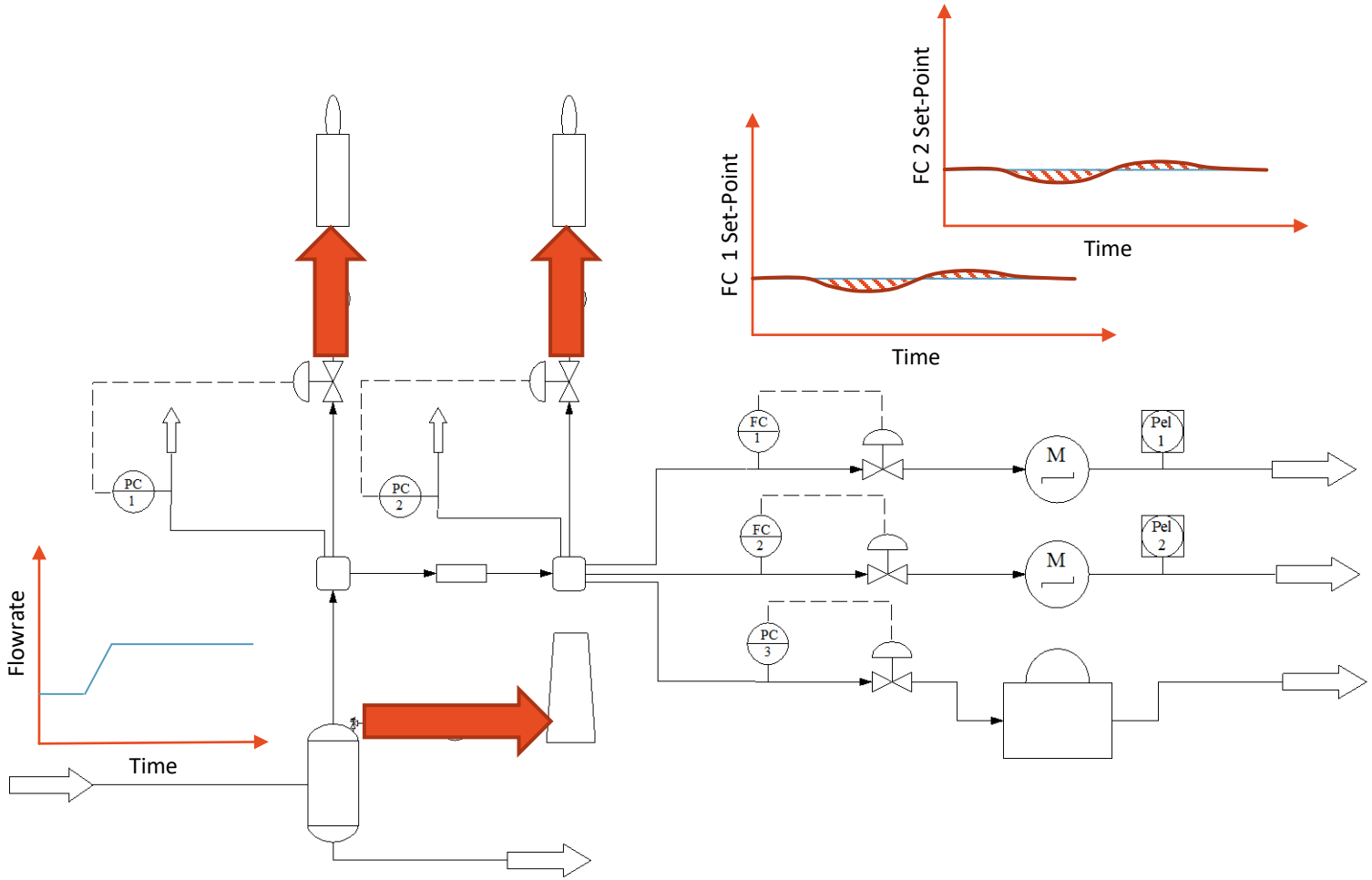
SCENARIO 2: DISTURBANCE OF THE FLOWRATE

- For safety valve emissions 100 €/kg must be payed
- For emissions via one of the flares 1 €/kg must be payed
- The integral square error of FC 1 is penalized with 1 € per unit
- The integral square error of FC 2 is penalized with 1 € per unit



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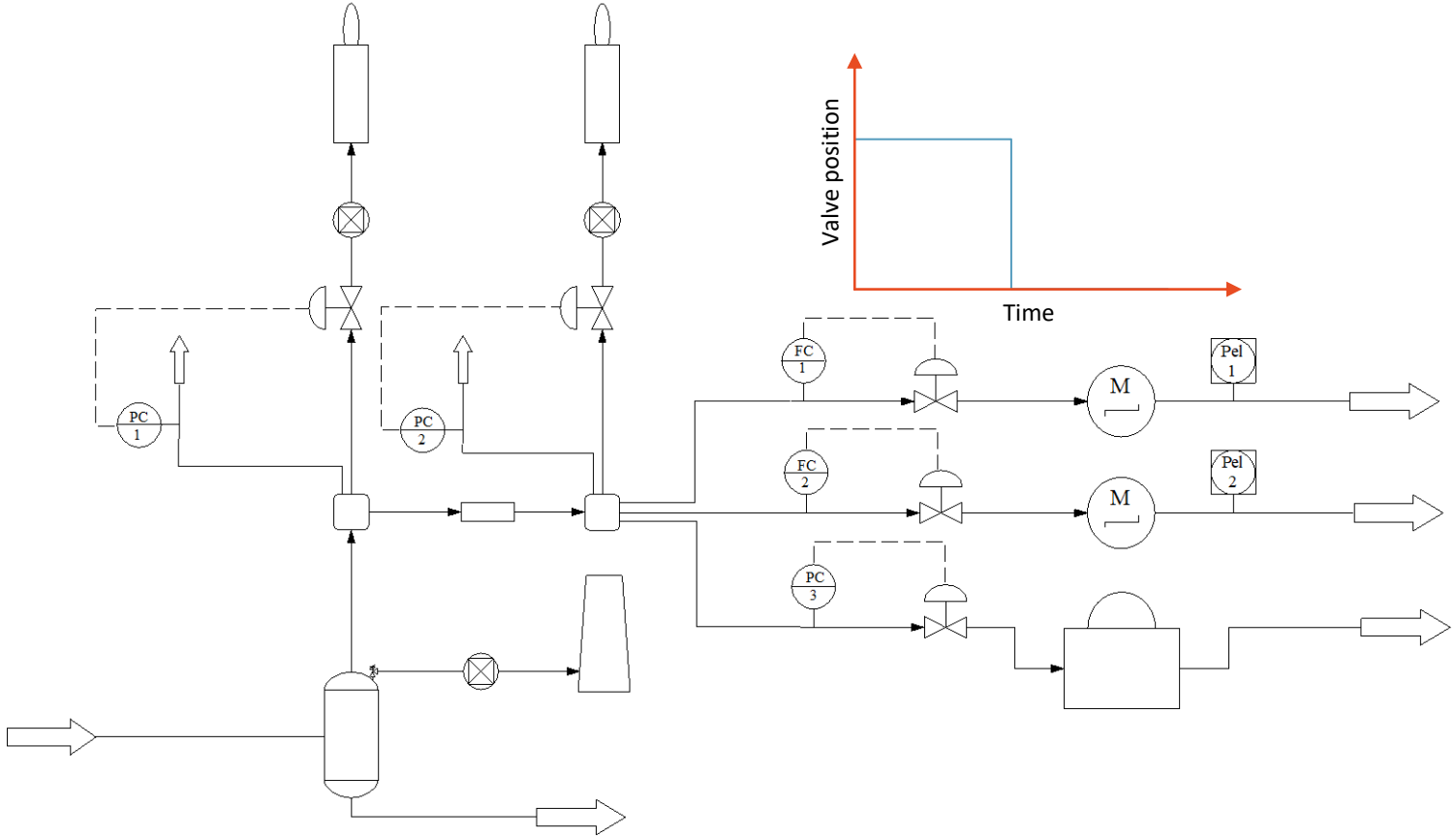
SCENARIO 3: SHUTDOWN OF ONE ENGINE

- Engine 1 is shut down due to an emergency
- The flow to engine 1 is reduced to zero in one step
- The control valve of FC 1 is closed completely a t = 5 min
- The operation period is 60 minutes
- During the operation period 100 € are earned



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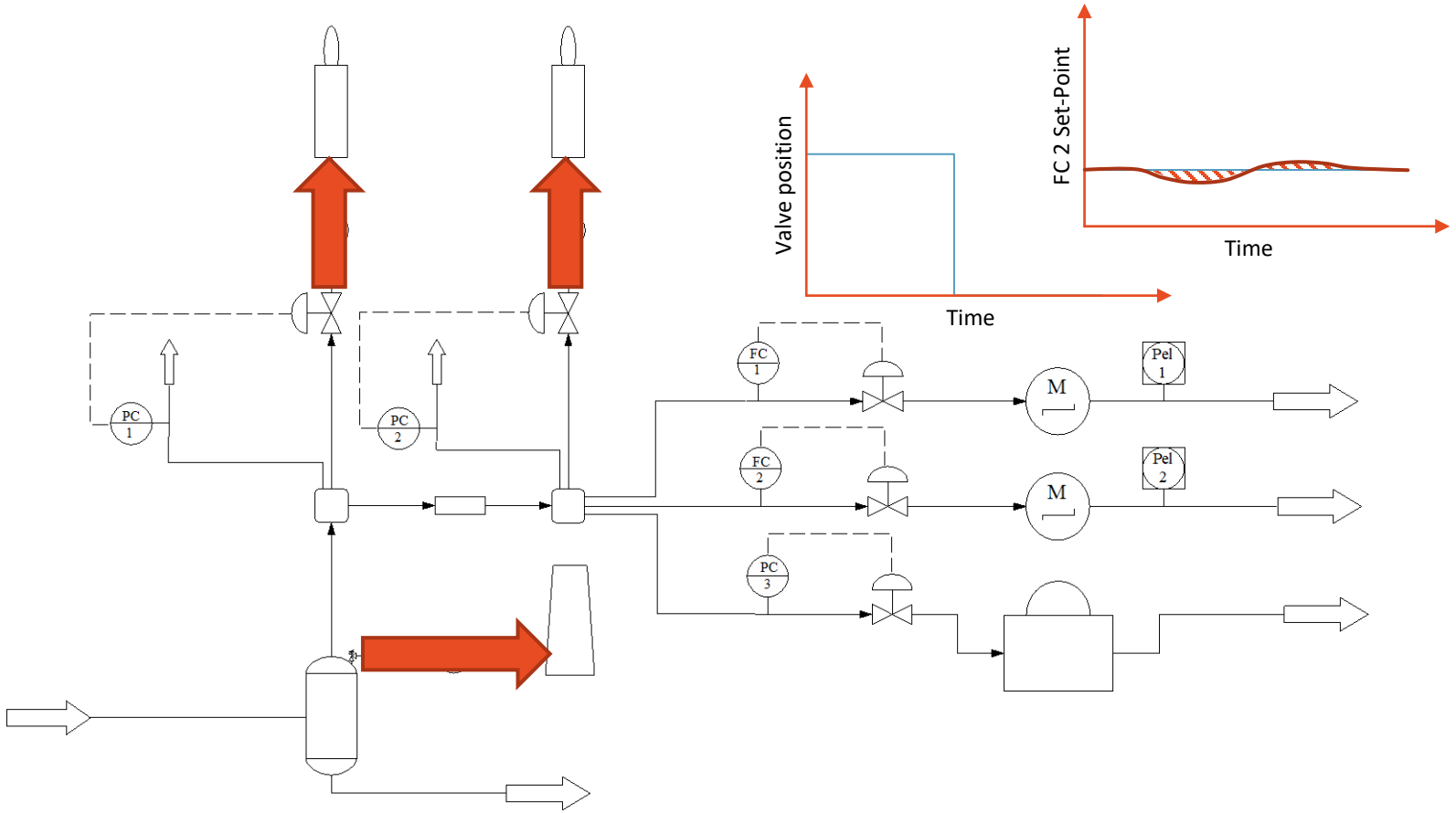
SCENARIO 3: SHUTDOWN OF ONE ENGINE

- For safety valve emissions 100 €/kg must be payed
- For emissions via one of the flares 1 €/kg must be payed
- The integral square error of FC 2 is penalized with 0.1 € per unit



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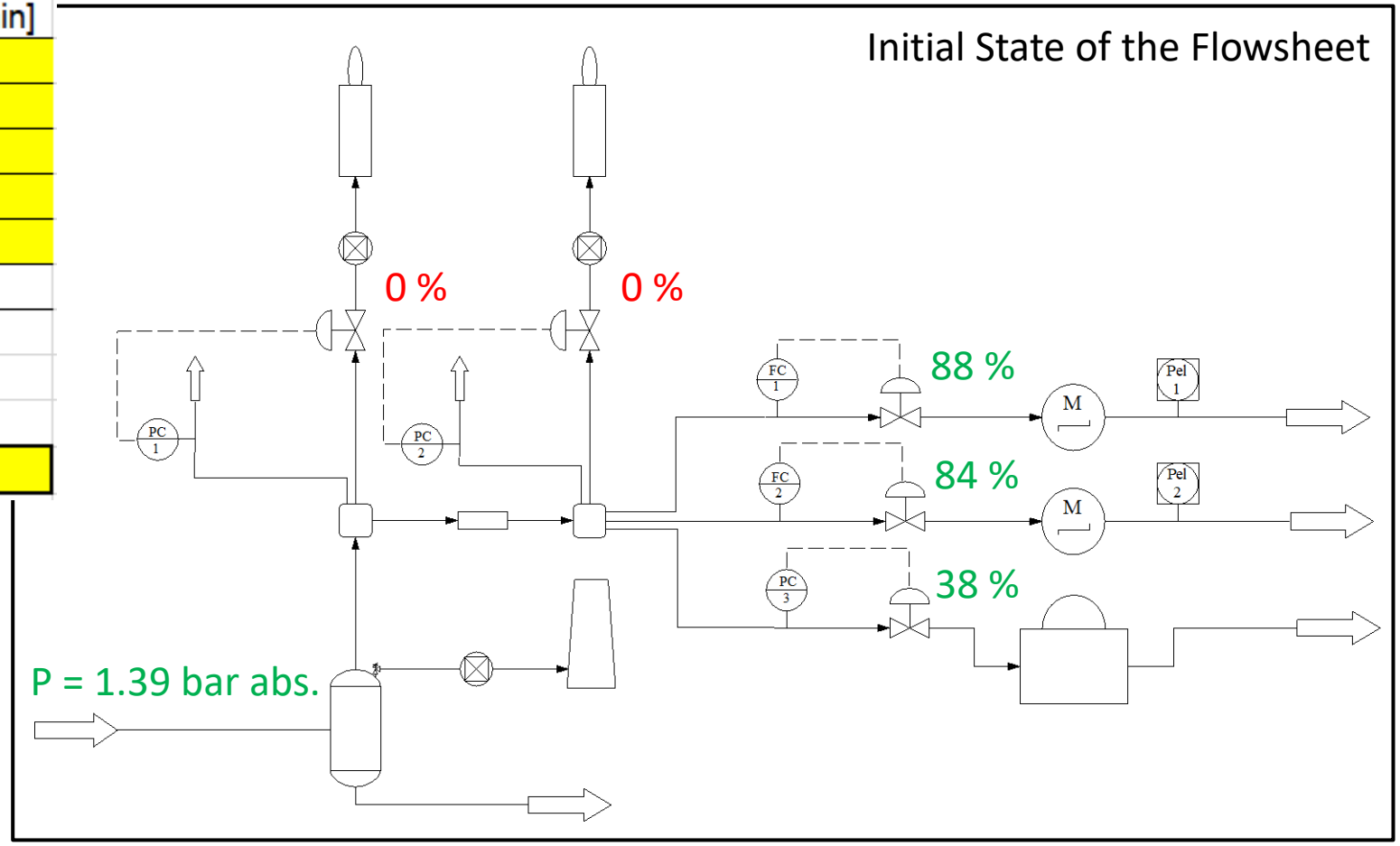
INITIAL CONDITIONS & CONTROLLER SETTINGS

Controller Settings			
	PB [%]	Ti [min]	Td [min]
PC1	100	1	0
PC2	100	1	0
PC3	100	1	0
FC1	100	1	0
FC2	100	1	0
Pel1	100	1	0
Pel2	100	1	0
Scenario Selection			**1**



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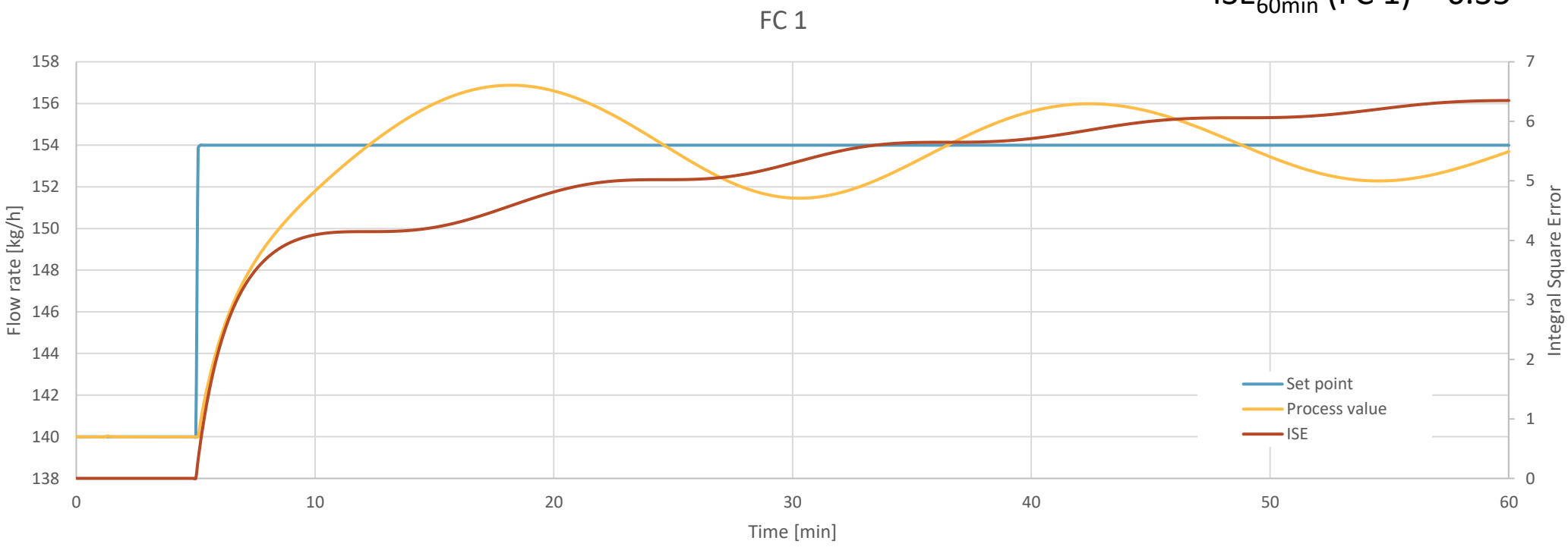
SCENARIO 1 – FC 1

ISE_{60min} (FC 1) = 6.35



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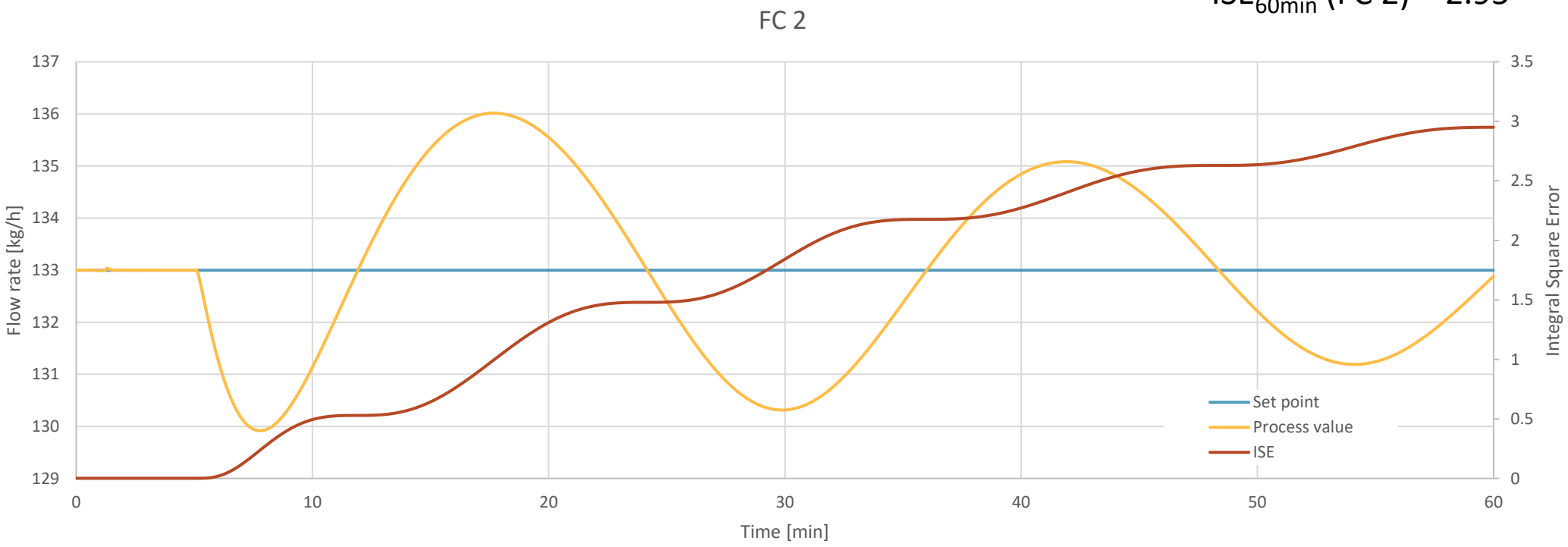
SCENARIO 1 – FC 2

ISE_{60min} (FC 2) = 2.95



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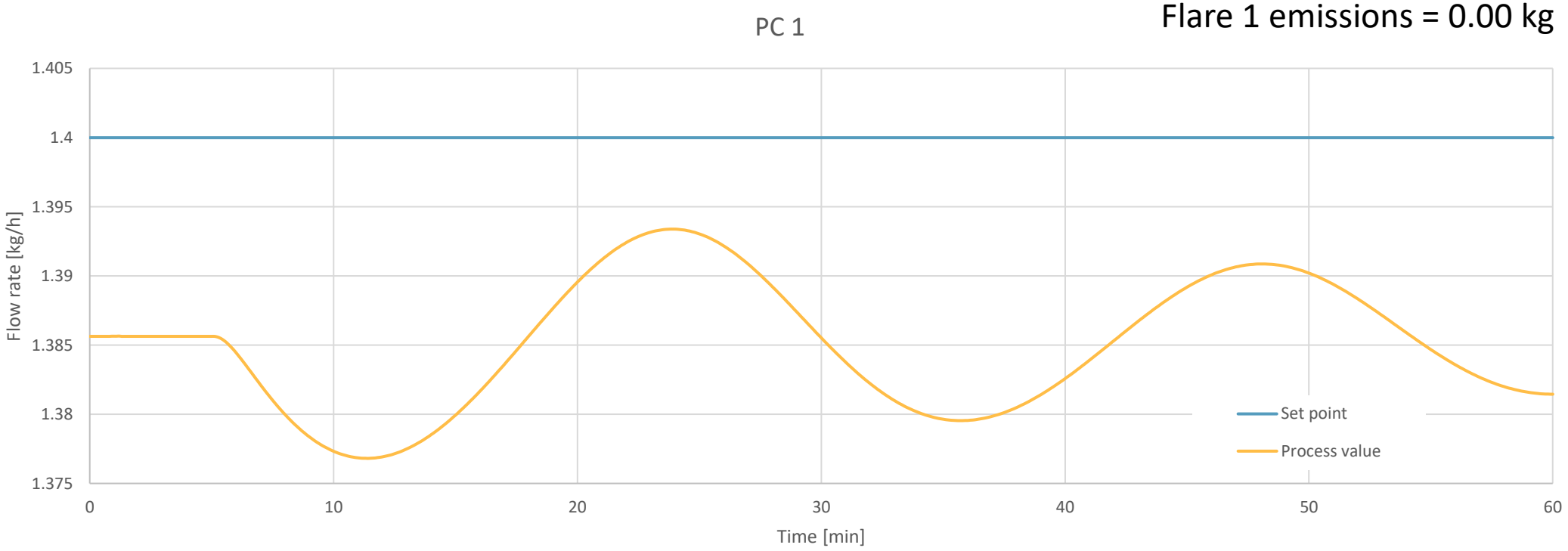
SCENARIO 1 – PC 1

Safety valve emissions = 0.00 kg
Flare 1 emissions = 0.00 kg



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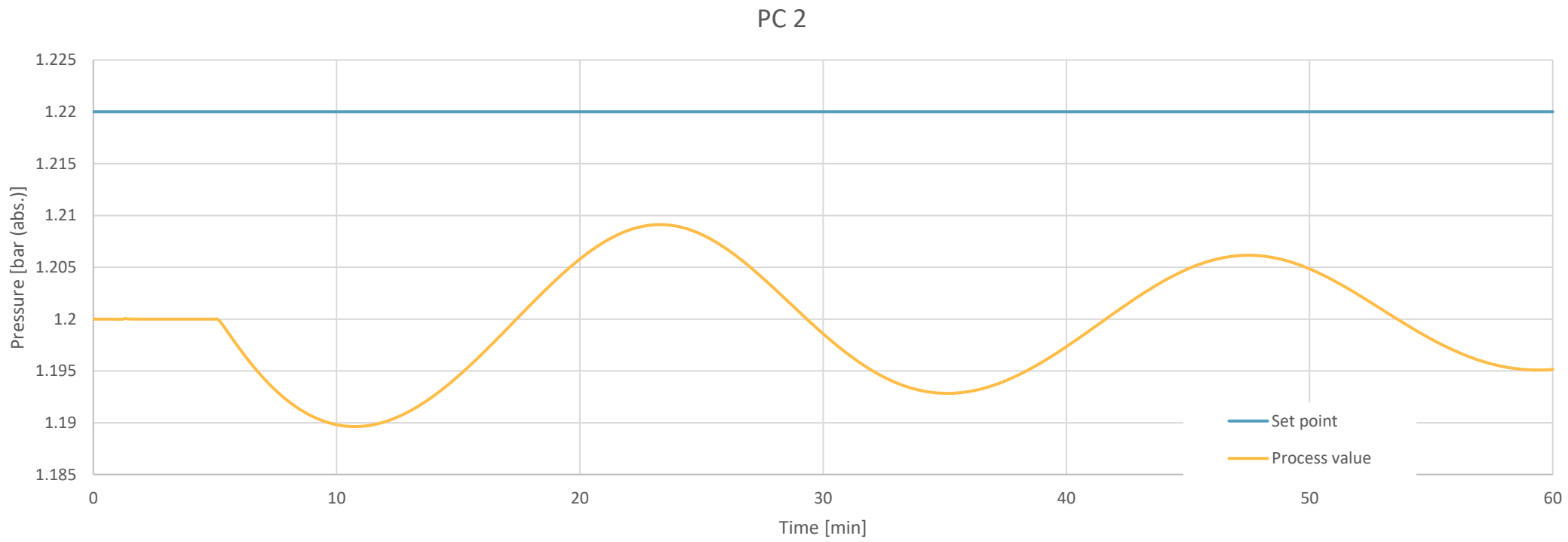
SCENARIO 1 – PC 2

Flare 2 emissions = 0.00 kg



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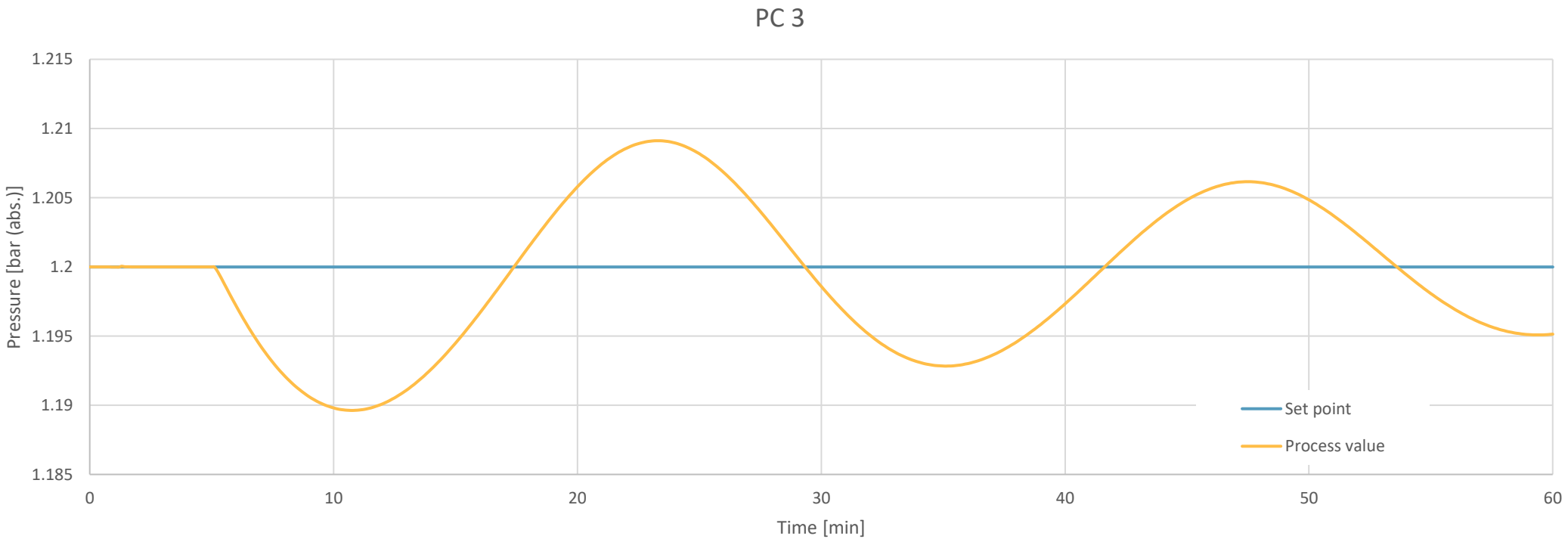
SCENARIO 1 – PC 3



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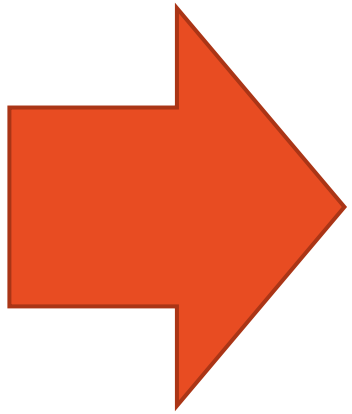
SCENARIO 1 – RESULT PAGE

Controller Settings			
	PB [%]	Ti [min]	Td [min]
PC1	100	1	0
PC2	100	1	0
PC3	100	1	0
FC1	100	1	0
FC2	100	1	0
Pel1	100	1	0
Pel2	100	1	0
Scenario Selection			**1**



Scenario Results		
Emissions Safety Valve	0.00	kg
Emissions Flare 1	0.00	kg
Emissions Flare 2	0.00	kg
ISA FC1	6.35	
ISA FC2	2.95	
ISA Pel1	0	
ISA Pel2	0	
Benefit	100.00	€
Penalty for Safety Valve Emissions	0.00	€
Penalty for Flare 1 Emissions	0.00	€
Penalty for Flare 2 Emissions	0.00	€
Penalty for Controller Error FC 1	6.35	€
Penalty for Controller Error FC 2	2.95	€
Penalty for Controller Error Pel 1	0.00	€
Penalty for Controller Error Pel 2	0.00	€
Profit	**90.70**	**€**

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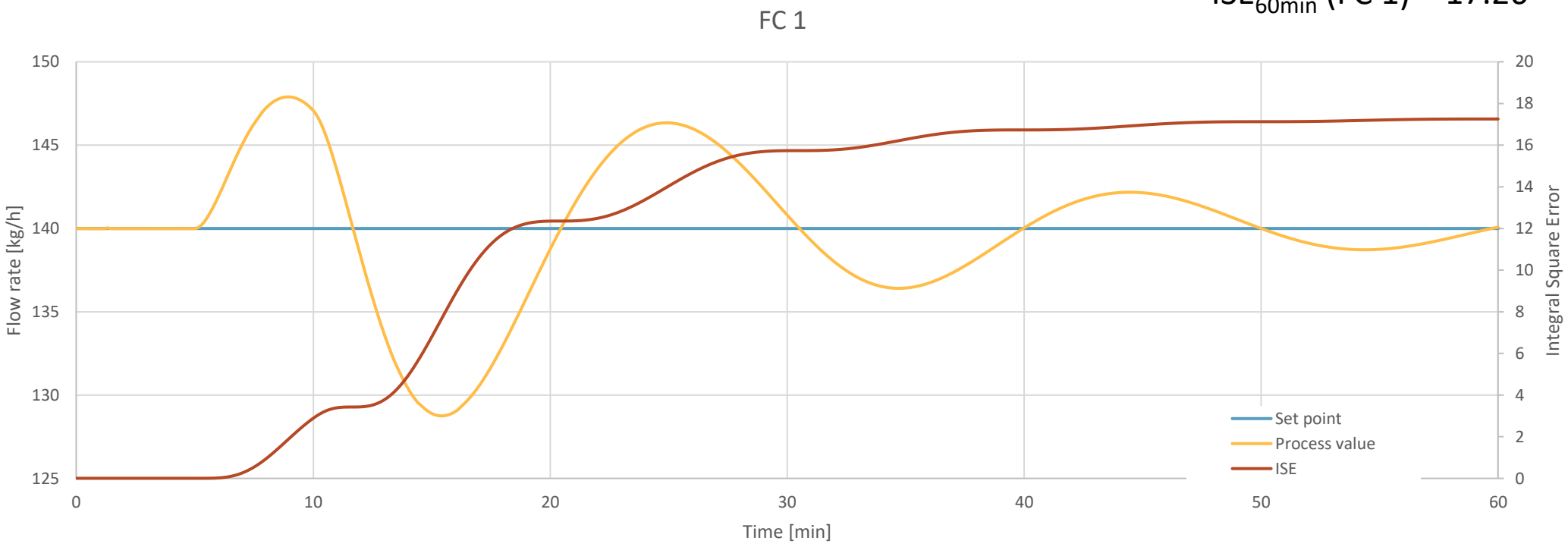
SCENARIO 2 – FC 1

ISE_{60min} (FC 1) = 17.26



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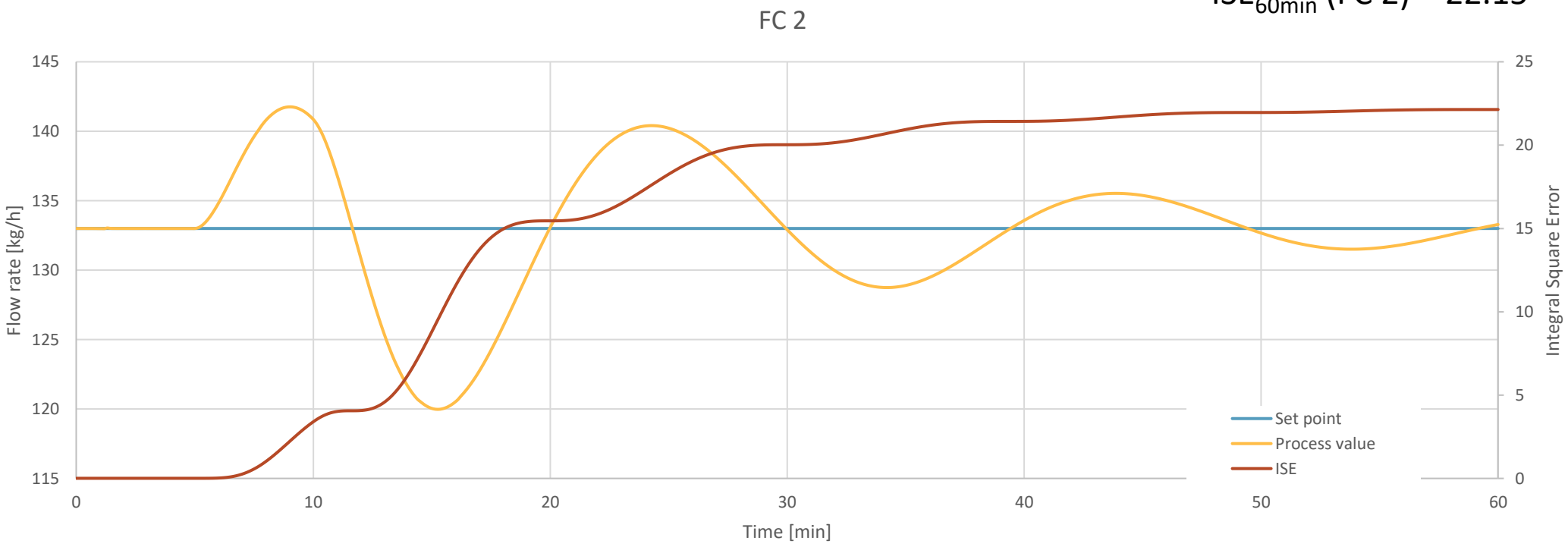
SCENARIO 2 – FC 2

ISE_{60min} (FC 2) = 22.15



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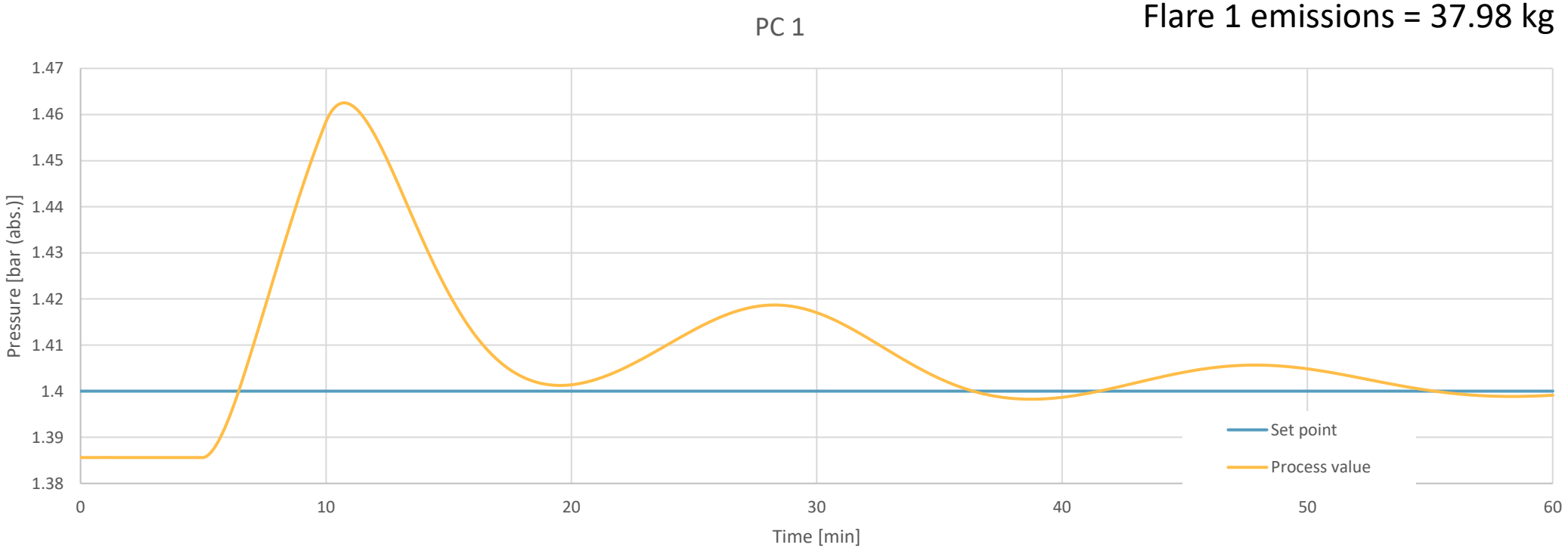
SCENARIO 2 – PC 1

Safety valve emissions = 00.00 kg
Flare 1 emissions = 37.98 kg



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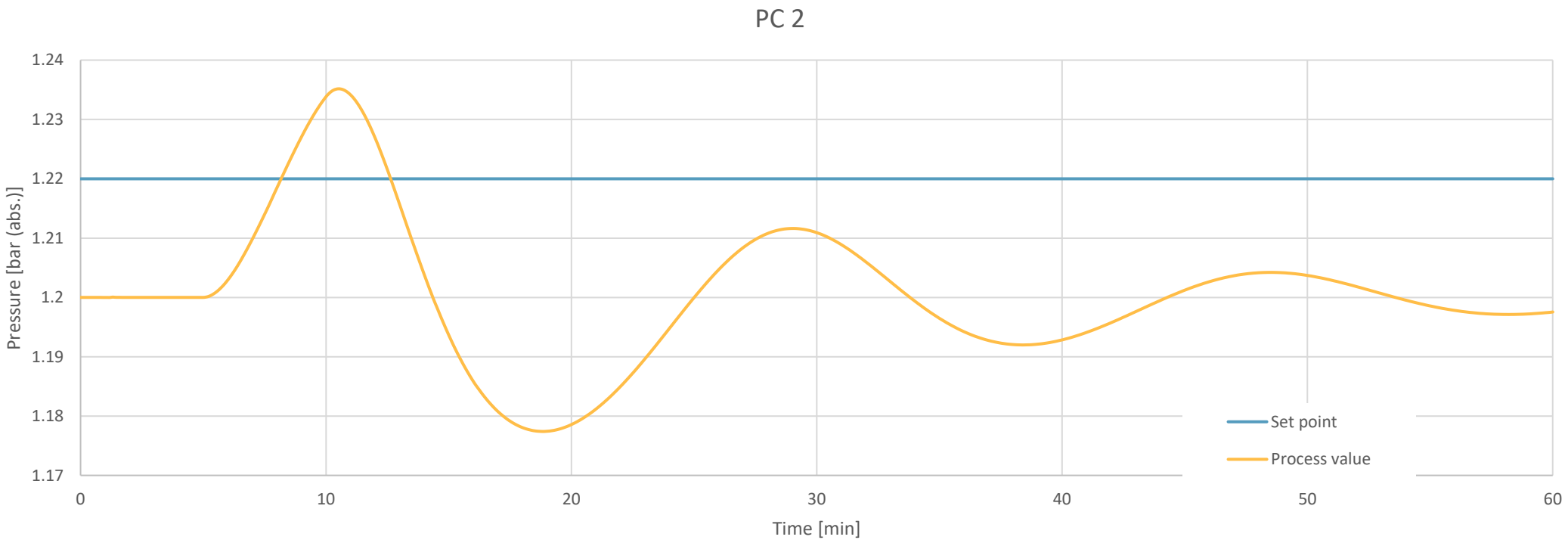
SCENARIO 2 – PC 2

Flare 2 emissions = 0.02 kg



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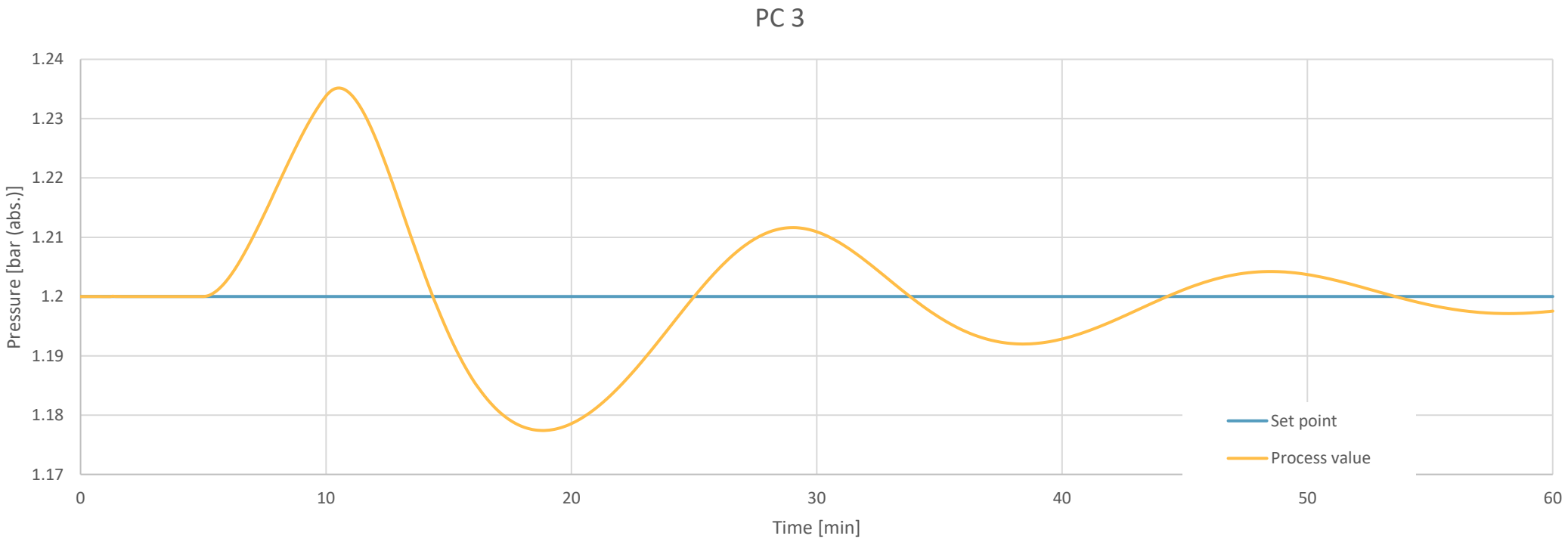
SCENARIO 2 – PC 3



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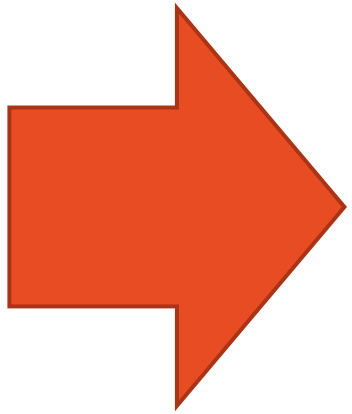
SCENARIO 2 – RESULT PAGE

Controller Settings			
	PB [%]	Ti [min]	Td [min]
PC1	100	1	0
PC2	100	1	0
PC3	100	1	0
FC1	100	1	0
FC2	100	1	0
Pel1	100	1	0
Pel2	100	1	0
Scenario Selection			**2**



Scenario Results		
Emissions Safety Valve	0.00	kg
Emissions Flare 1	37.98	kg
Emissions Flare 2	0.02	kg
ISA FC1	17.26	
ISA FC2	22.15	
ISA Pel1	0	
ISA Pel2	0	
Benefit	100.00	€
Penalty for Safety Valve Emissions	0.00	€
Penalty for Flare 1 Emissions	37.98	€
Penalty for Flare 2 Emissions	0.02	€
Penalty for Controller Error FC 1	17.26	€
Penalty for Controller Error FC 2	22.15	€
Penalty for Controller Error Pel 1	0.00	€
Penalty for Controller Error Pel 2	0.00	€
Profit	**22.59**	**€**

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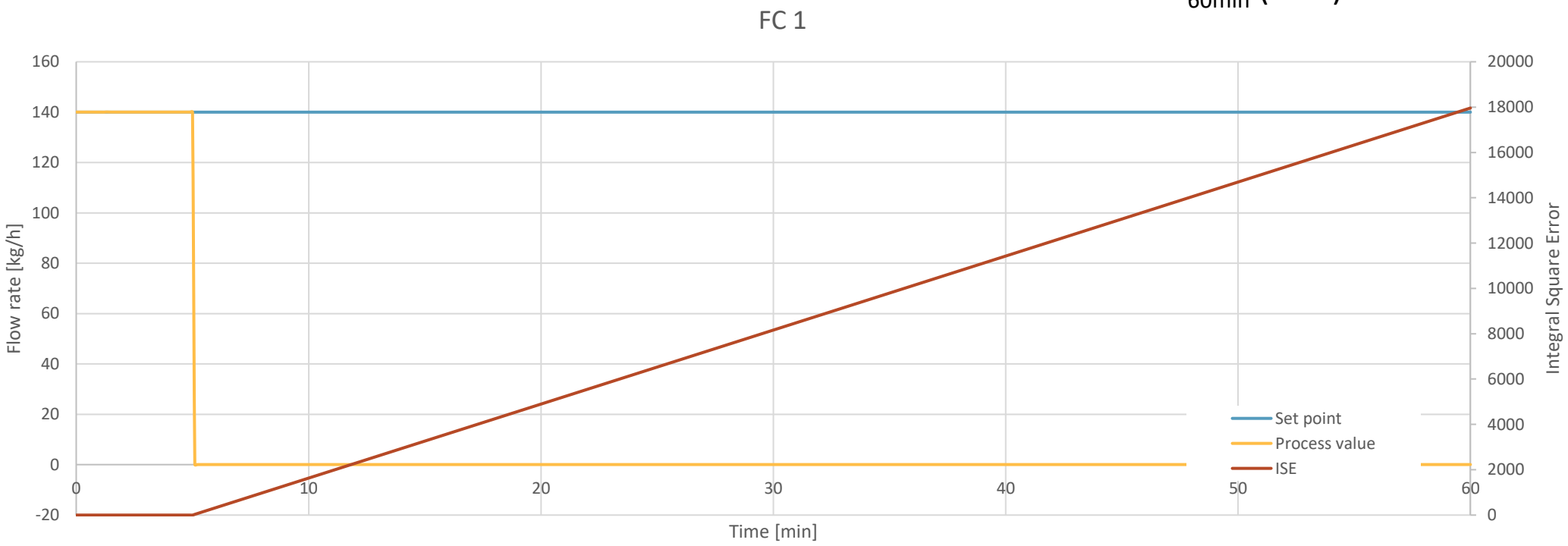
SCENARIO 3 – FC 1

ISE_{60min} (FC 1) = Not relevant



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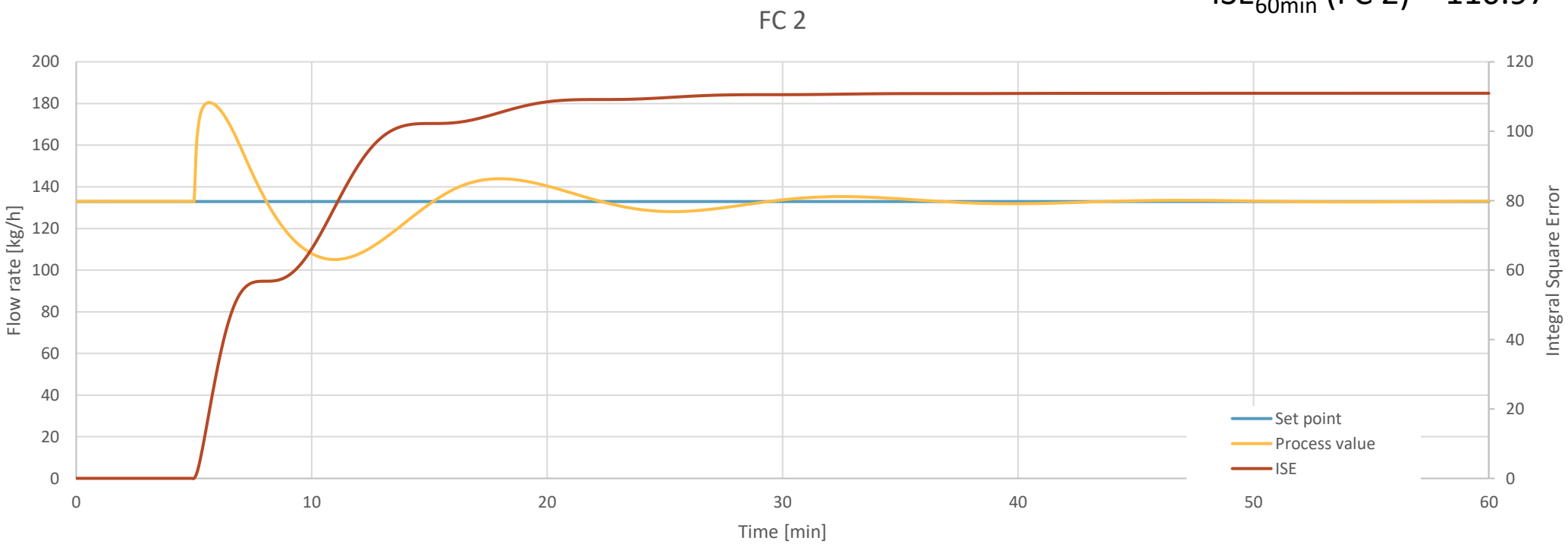
SCENARIO 3 – FC 2

ISE_{60min} (FC 2) = 110.97



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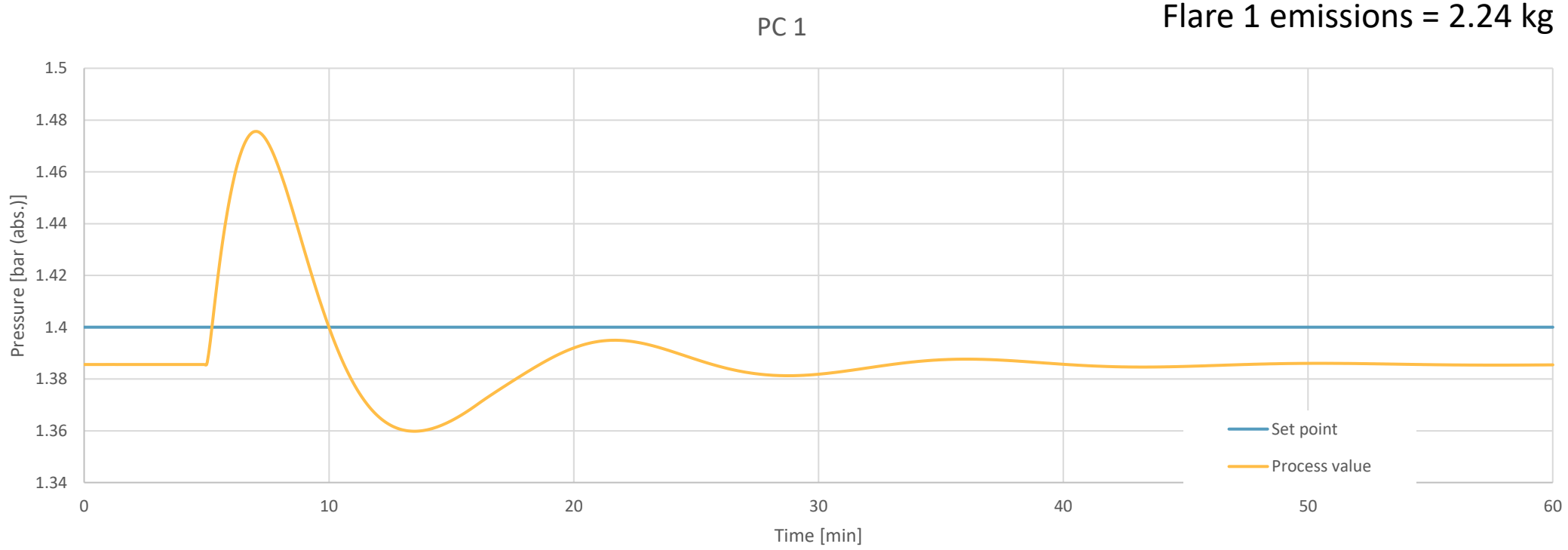
SCENARIO 3 – PC 1

Safety valve emissions = 0.00 kg
Flare 1 emissions = 2.24 kg



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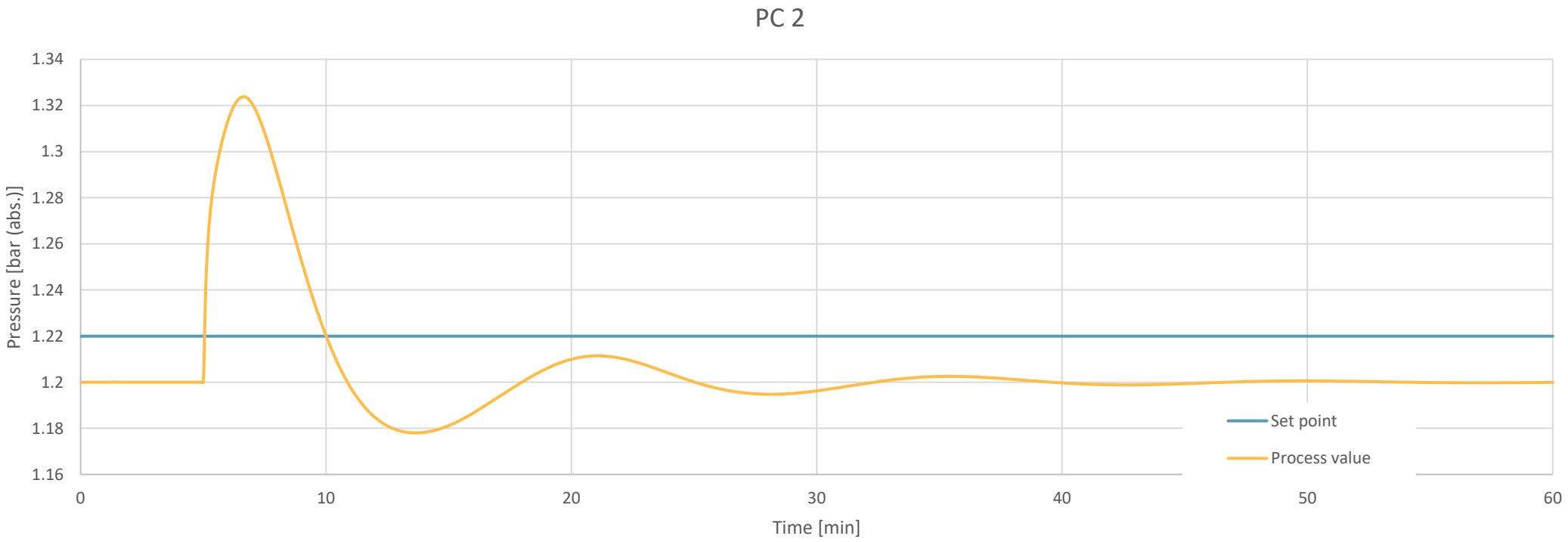
SCENARIO 3 – PC 2

Flare 2 emissions = 0.29 kg



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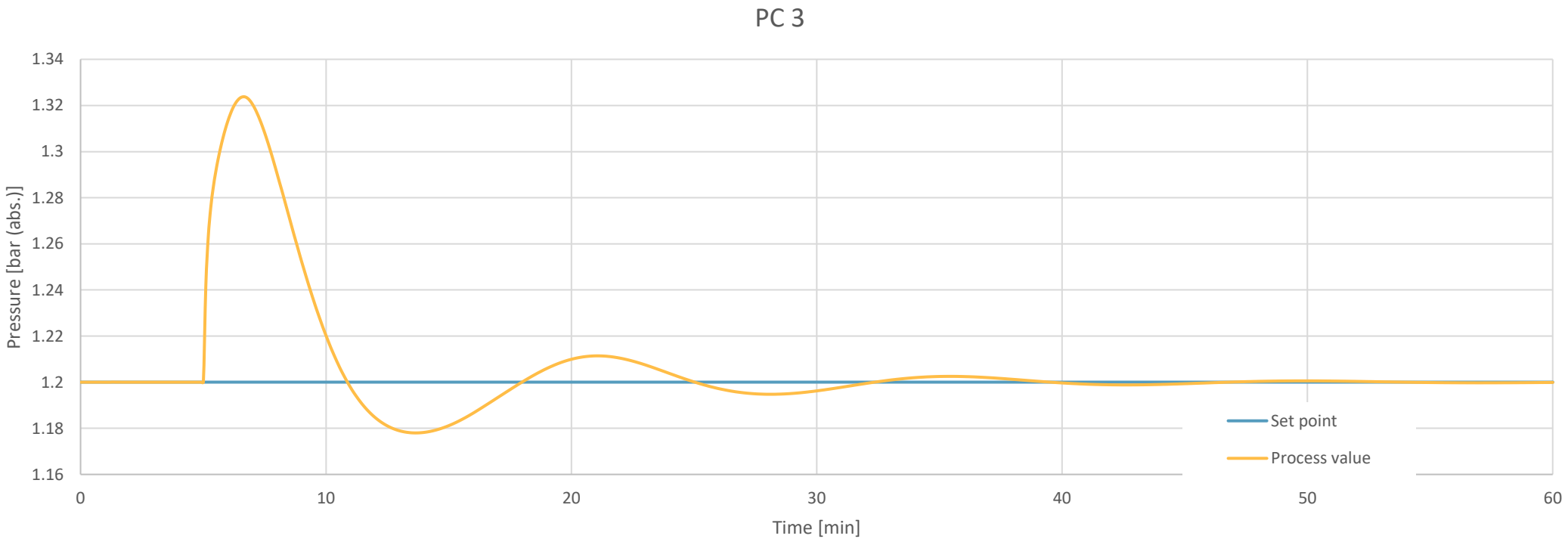
SCENARIO 3 – PC 3



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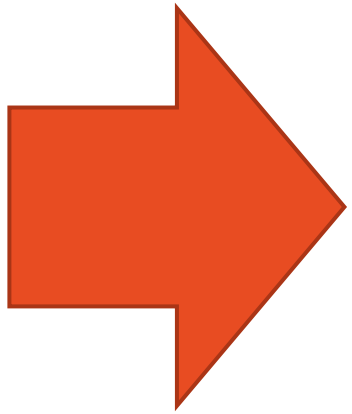
SCENARIO 3 – RESULT PAGE

Controller Settings			
	PB [%]	Ti [min]	Td [min]
PC1	100	1	0
PC2	100	1	0
PC3	100	1	0
FC1	100	1	0
FC2	100	1	0
Pel1	100	1	0
Pel2	100	1	0
Scenario Selection			3



Scenario Results		
Emissions Safety Valve	0.00	kg
Emissions Flare 1	2.24	kg
Emissions Flare 2	0.29	kg
ISA FC1	########	
ISA FC2	110.97	
ISA Pel1	0	
ISA Pel2	0	
Benefit	100.00	€
Penalty for Safety Valve Emissions	0.00	€
Penalty for Flare 1 Emissions	2.24	€
Penalty for Flare 2 Emissions	0.29	€
Penalty for Controller Error FC 1	0.00	€
Penalty for Controller Error FC 2	11.10	€
Penalty for Controller Error Pel 1	0.00	€
Penalty for Controller Error Pel 2	0.00	€
Profit	**86.37**	**€**

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PHASE 2 SCENARIO SUM-UP

Result

	Scenario 1	Scenario 2	Scenario 3
Benefit [€]	100.00	100.00	100.00
Penalty for Safety Valve Emissions [€]	0.00	0.00	0.00
Penalty for Flare 1 Emissions [€]	0.00	37.98	2.24
Penalty for Flare 2 Emissions [€]	0.00	0.02	0.29
Penalty for Controller Error FC 1 [€]	6.35	17.26	0.00
Penalty for Controller Error FC 2 [€]	2.95	22.15	11.10
Penalty for Controller Error Pel 1 [€]	0.00	0.00	0.00
Penalty for Controller Error Pel 2 [€]	0.00	0.00	0.00
Profit [€]	90.70	22.59	86.37

Total profit: 199.66€

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A HINT: LEARNINGS FROM PHASE 1

- In phase 1 a total number of 10 parameters had to be tuned
- In phase 2 a total number of 15 parameters must be tuned
- It is important to find out which parameter have
  - a high impact on the profit,
  - a low impact on the profit, or
  - no impact on the profit at all!

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- In phase 2 a total number of 15 parameters must be tuned
- It is important to find out which parameter have
  - a high impact on the profit,
  - a low impact on the profit, or
  - no impact on the profit at all!

And here is the hint:

You can switch of a part of the controller (P, I, and / or D) by setting its value (PB, TI, and /or TD) to zero!

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THANK YOU!

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