PROCESS SIMULATION CUP
PSC2020- OPTIMAL CONTROL

PHASE 2: MAKE USE OF THE “D” IN PID

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BERLIN, 1 APRIL 2020
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
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.
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
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
SCENARIO 1: SET-POINT STEP CHANGE

- For safety valve emissions 100 €/kg must be paid.
- For emissions via one of the flares 1 €/kg must be paid.
- The integral square error of FC1 is penalized with 1 € per unit.
- The integral square error of FC2 is penalized with 1 € per unit.
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)
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
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 at $t = 5$ min
- The operation period is 60 minutes
- During the operation period 100 € are earned
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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- A hint: Learnings from Phase 1
INITIAL CONDITIONS & CONTROLLER SETTINGS

<table>
<thead>
<tr>
<th>Controller Settings</th>
<th>PB [%]</th>
<th>Ti [min]</th>
<th>Td [min]</th>
</tr>
</thead>
<tbody>
<tr>
<td>PC1</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>PC2</td>
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</tr>
<tr>
<td>FC1</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>FC2</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pe1</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pe2</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

Sc_P = 1.39 bar abs.

Initial State of the Flowsheet
SCENARIO 1 – FC 1

ISE_{60\text{min}} (FC 1) = 6.35
SCENARIO 1 – FC 2

ISE_{60\text{min}} (FC 2) = 2.95
SCENARIO 1 – PC 1

Safety valve emissions = 0.00 kg
Flare 1 emissions = 0.00 kg
SCENARIO 1 – PC 2

Flare 2 emissions = 0.00 kg
SCENARIO 1 – PC 3

![Diagram showing pressure fluctuations over time for PC 3 with set point and process value lines.](image-url)
### Scenario 1 – Result Page

#### Controller Settings

<table>
<thead>
<tr>
<th>Controller</th>
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<tbody>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>PC2</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>PC3</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td>FC1</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>FC2</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pel1</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pel2</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

#### Scenario Selection

| Selection | 1 |

#### Scenario Results

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Safety Valve</td>
<td>0.00 kg</td>
</tr>
<tr>
<td>Emissions Flare 1</td>
<td>0.00 kg</td>
</tr>
<tr>
<td>Emissions Flare 2</td>
<td>0.00 kg</td>
</tr>
<tr>
<td>ISA FC1</td>
<td>6.35</td>
</tr>
<tr>
<td>ISA FC2</td>
<td>2.95</td>
</tr>
<tr>
<td>ISA Pel1</td>
<td>0</td>
</tr>
<tr>
<td>ISA Pel2</td>
<td>0</td>
</tr>
</tbody>
</table>

#### Benefit

- 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 €**
SCENARIO 2 – FC 1

$\text{ISE}_{60\text{min}} (\text{FC 1}) = 17.26$
SCENARIO 2 – FC 2

ISE_{60\text{min}} (FC 2) = 22.15
**SCENARIO 2 – PC 1**

Safety valve emissions = 00.00 kg
Flare 1 emissions = 37.98 kg
SCENARIO 2 – PC 2

Flare 2 emissions = 0.02 kg
SCENARIO 2 – PC 3

PC 3

0 10 20 30 40 50 60
Time [min]

1.17 1.18 1.19 1.2 1.21 1.22 1.23 1.24
Pressure [bar (abs.)]

Set point
Process value
SCENARIO 3 – FC 1

ISE_{60\text{min}} \ (FC \ 1) = \text{Not relevant}
SCENARIO 3 – FC 2

$ISE_{60\text{min}} (FC 2) = 110.97$
SCENARIO 3 – PC 1

Safety valve emissions = 0.00 kg
Flare 1 emissions = 2.24 kg
SCENARIO 3 – PC 2

Flare 2 emissions = 0.29 kg
SCENARIO 3 – RESULT PAGE

**Controller Settings**

<table>
<thead>
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<td>0</td>
</tr>
<tr>
<td>FC1</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>FC2</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pel1</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Pel2</td>
<td>100</td>
<td>1</td>
<td>0</td>
</tr>
</tbody>
</table>

**Scenario Selection**

3

**Scenario Results**

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Emissions Safety Valve</td>
<td>0.00 kg</td>
</tr>
<tr>
<td>Emissions Flare 1</td>
<td>2.24 kg</td>
</tr>
<tr>
<td>Emissions Flare 2</td>
<td>0.29 kg</td>
</tr>
<tr>
<td>ISA FC1</td>
<td>110.97</td>
</tr>
<tr>
<td>ISA FC2</td>
<td>110.97</td>
</tr>
<tr>
<td>ISA Pel1</td>
<td>0</td>
</tr>
<tr>
<td>ISA Pel2</td>
<td>0</td>
</tr>
</tbody>
</table>

**Benefit**

100.00 €

<table>
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<th>Penalty Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Penalty for Safety Valve Emissions</td>
<td>0.00 €</td>
</tr>
<tr>
<td>Penalty for Flare 1 Emissions</td>
<td>2.24 €</td>
</tr>
<tr>
<td>Penalty for Flare 2 Emissions</td>
<td>0.29 €</td>
</tr>
<tr>
<td>Penalty for Controller Error FC 1</td>
<td>0.00 €</td>
</tr>
<tr>
<td>Penalty for Controller Error FC 2</td>
<td>11.10 €</td>
</tr>
<tr>
<td>Penalty for Controller Error Pel 1</td>
<td>0.00 €</td>
</tr>
<tr>
<td>Penalty for Controller Error Pel 2</td>
<td>0.00 €</td>
</tr>
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**Profit**

86.37 €
### PHASE 2 SCENARIO SUM-UP

#### Result

<table>
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<tr>
<th></th>
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<th>Scenario 2</th>
<th>Scenario 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benefit [€]</td>
<td>100.00</td>
<td>100.00</td>
<td>100.00</td>
</tr>
<tr>
<td>Penalty for Safety Valve Emissions [€]</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Penalty for Flare 1 Emissions [€]</td>
<td>0.00</td>
<td>37.98</td>
<td>2.24</td>
</tr>
<tr>
<td>Penalty for Flare 2 Emissions [€]</td>
<td>0.00</td>
<td>0.02</td>
<td>0.29</td>
</tr>
<tr>
<td>Penalty for Controller Error FC 1 [€]</td>
<td>6.35</td>
<td>17.26</td>
<td>0.00</td>
</tr>
<tr>
<td>Penalty for Controller Error FC 2 [€]</td>
<td>2.95</td>
<td>22.15</td>
<td>11.10</td>
</tr>
<tr>
<td>Penalty for Controller Error Rel 1 [€]</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Penalty for Controller Error Rel 2 [€]</td>
<td>0.00</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>Profit [€]</td>
<td>90.70</td>
<td>22.59</td>
<td>86.37</td>
</tr>
</tbody>
</table>

**Total profit:** 199.66€
General Information

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Plant performance with the initial controller settings

A hint: Learnings from Phase 1
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!
A HINT: LEARNINGS FROM PHASE 1

- In phase 1 a total number of 10 parameters had to be tuned
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- 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!
THANK YOU!

JS@CHEMSTATIONS.EU