cocop

Optimization of Copper smelter

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Horizon 2020

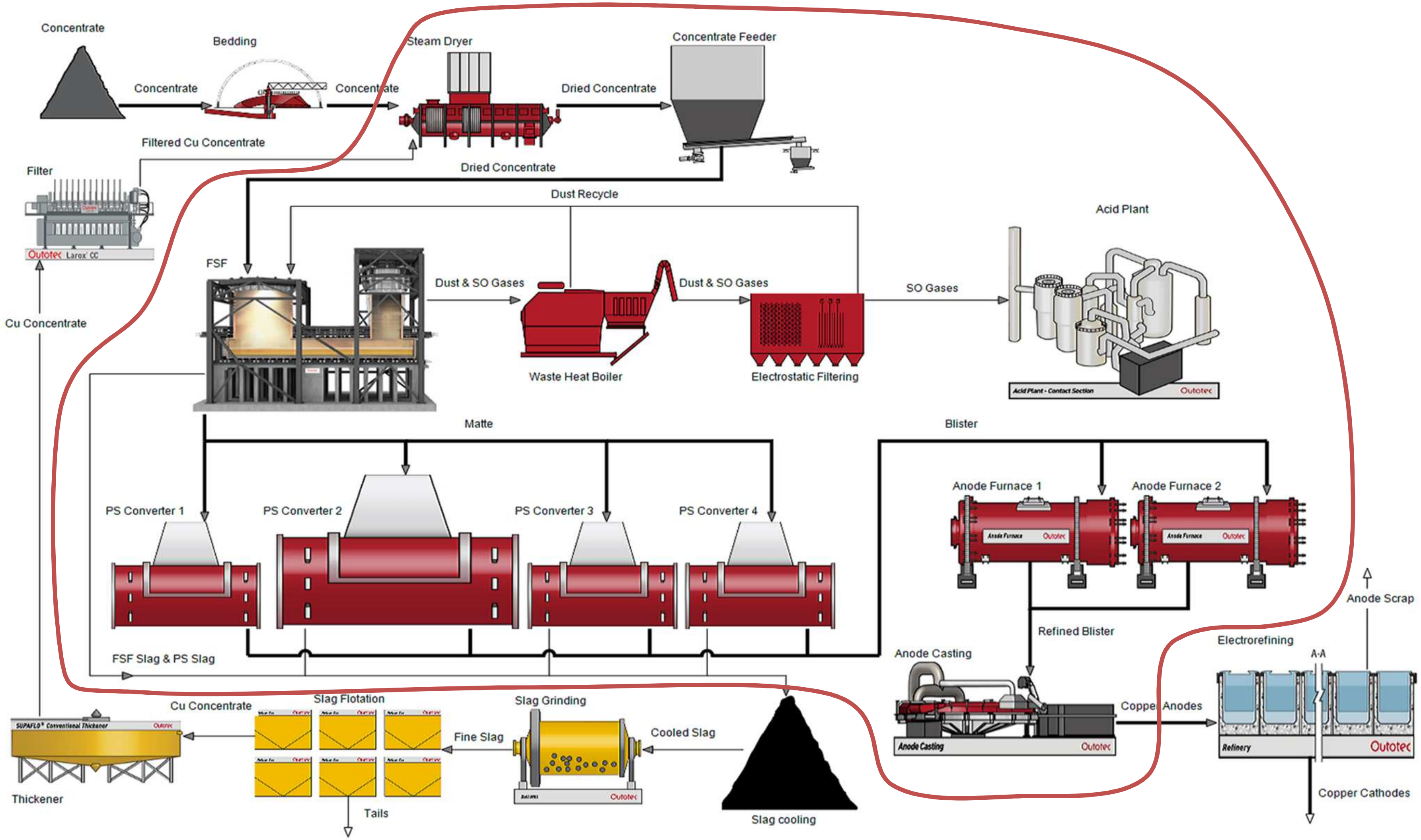
SPIRE PROJECT

@CocopSpire

Introduction

- Goal is to optimize production of (existing) smelter
  - ➢ Tools to support operators in Process Control
    - ✓ Scheduling / Maximizing Feed against the current bottleneck
    - ✓ PSC Advisor / optimizing
  - ➢ Better overall result of whole smelter
    - ✓ Production rate
    - ✓ Recovery
    - ✓ Brick-lining life time
    - ✓ Emissions
  - ➢ COCOP tools are giving information and advice
    - ✓ The operators still have the operating responsibility

The copper smelter layout and scope



The optimization challenges

TECHNICAL

- The copper smelter includes batch and continuous processes in series that are affecting each other
- There are common restrictions for several unit process
- Each unit process has its own restrictions
- The feed mixture composition of FSF is subject to changes
- There are temporary restrictions due to breaks of equipment

HUMAN

- There is operator in the loop
  - FSF tapping, crane operations, PSC operations, AF operations
- Use of software must not cause extra work to operators
  - Calculating in the background utilizing process data and analysis automatically
  - Operators have to able to be set abnormal future restrictions easily
- The tool should give the results to operator in a visible and understandable way

General idea of solution

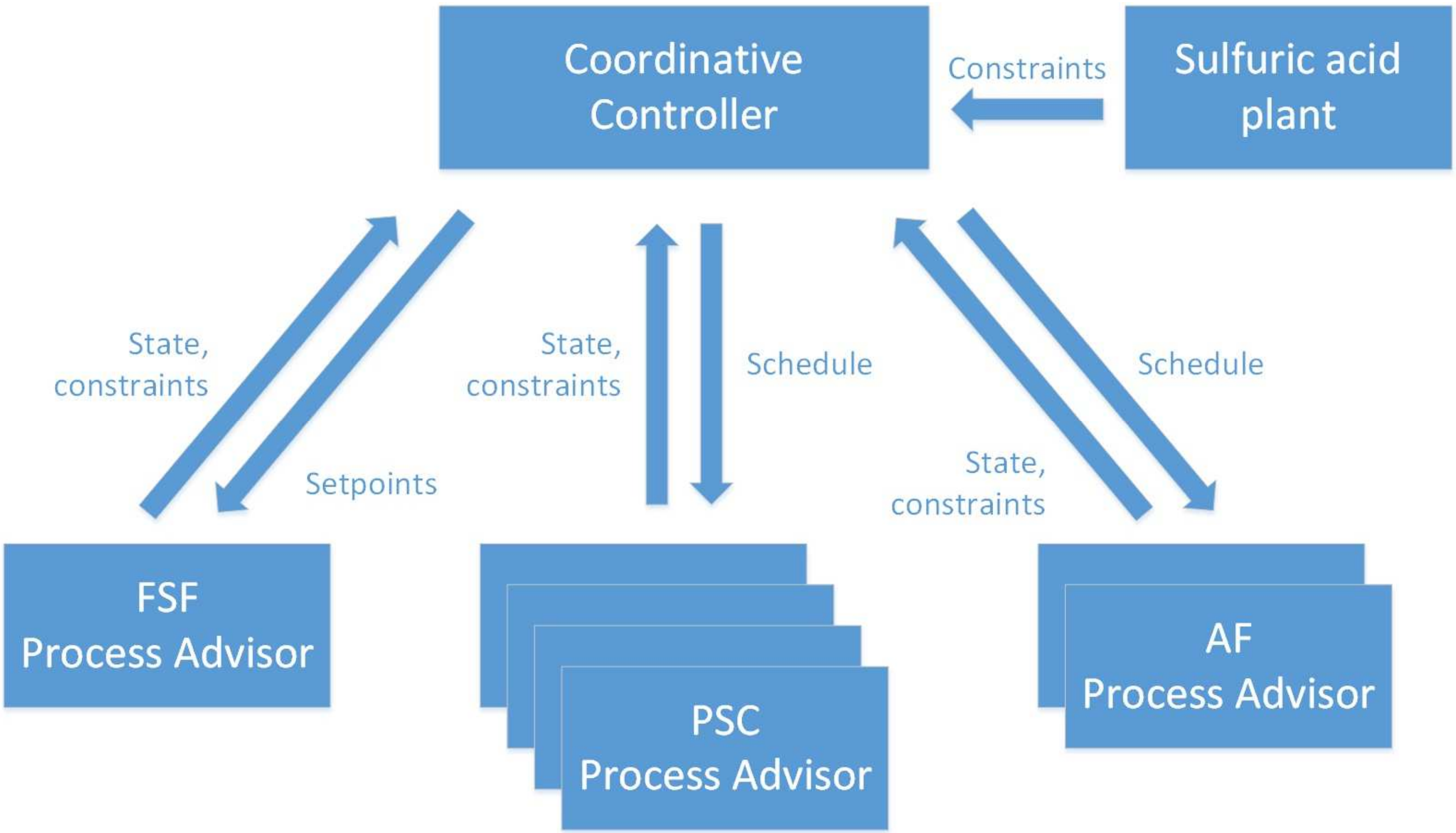
PLANT WIDE OPTIMIZATION

- Calculate schedule for future unit process operations
- Maximize the FSF feed rate against the bottleneck
- Optimize the target FSF matte grade

UNIT PROCESS OPTIMIZATION

- Develop unit process advisors
- Digital twin of unit process to be able to monitor the process
- Calculate control parameter suggestions to operator

Simplified software architecture

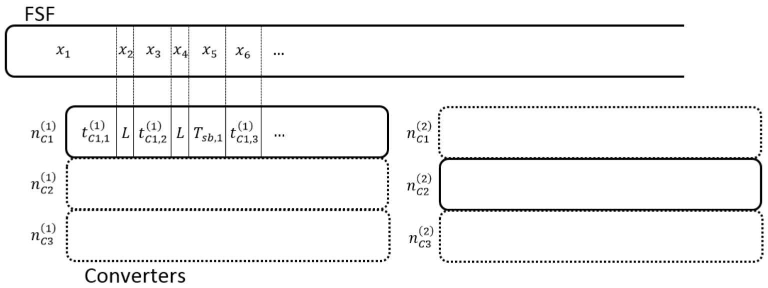


Scheduling

- Visualize to the future what, where and when are produced. For example:
  - Matte tappings
  - PSC blowing times
  - AF processing and anode casting
- The purpose is to give up-to-date forecast for different process sectors
- Maximize the FSF feed rate against bottleneck
  - The bottleneck is not always easy to be seen
  - Enable to maintain the feed rate near the maximum

Scheduling algorithm

- Optimization problem formulated as a continuous time scheduling problem
  - ➢ Long time horizon and differing time scales in operation stages make discrete time formulations difficult
  - ➢ Mixed batch-continuous solution – Production rate and timing of batch operating stages simultaneously considered

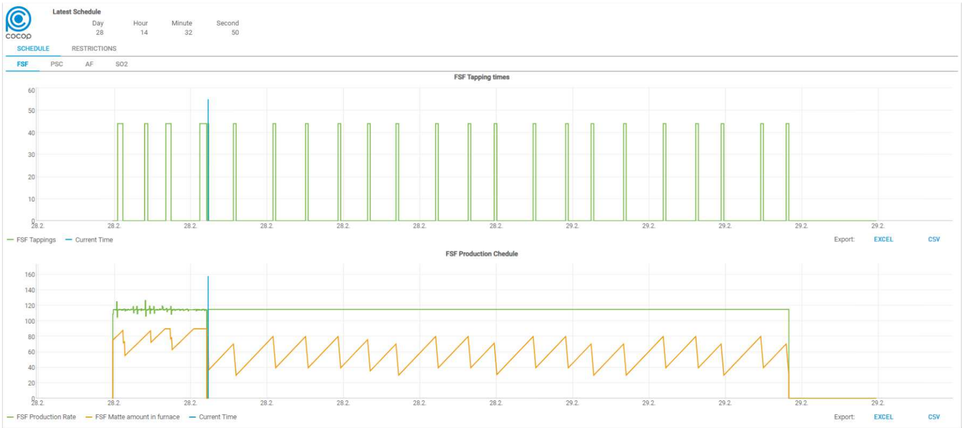


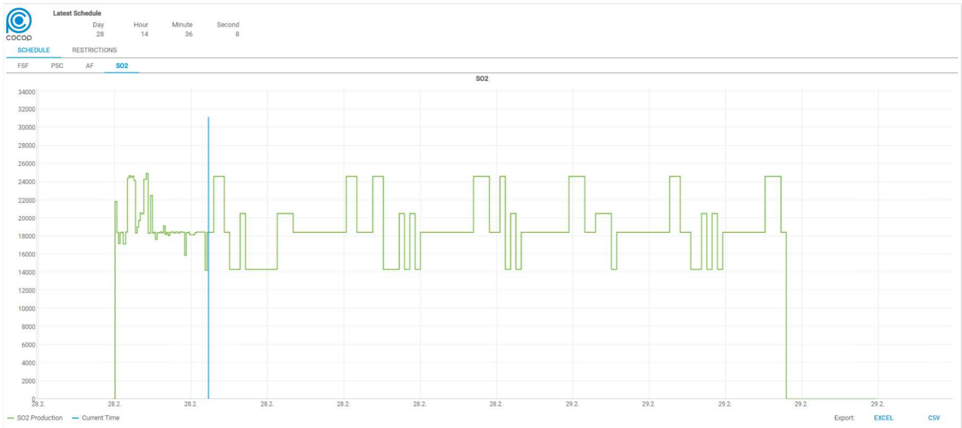
- Batches in general: start state -> processing -> end state
- Defined candidate structure for batch stages
  - ➢ Load -> Slag blow -> Load -> etc for $n_{C1}^{(1)}$
  - ➢ Different structure for $n_{C1}^{(2)}$
- Connect structure to continuous production
  - ➢ ρ_{max} = max prod. rate -> produced amount x_j -> time length $t_{Ci,j}^{(k)}$

$$\rho_{max}^{-1} x_j \leq t_{Ci,j}^{(k)} \leq \rho_{min}^{-1} x_j$$

Prod. rate : Extent variables

Calculated scheduling results presented in web UI



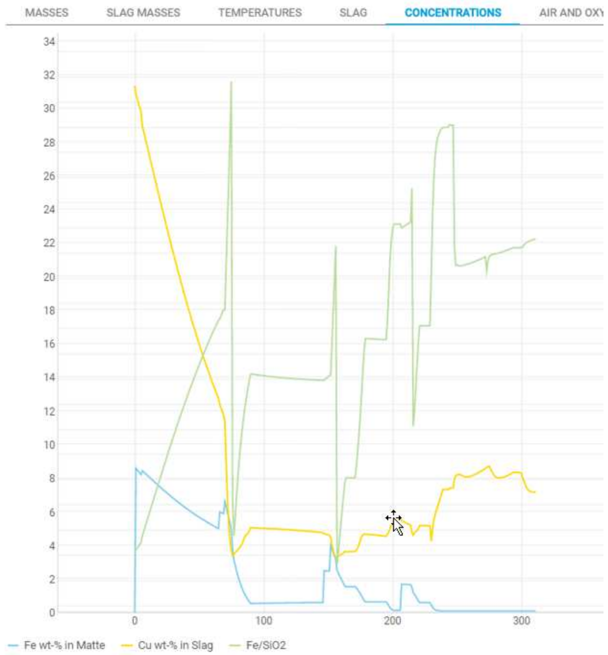


PSC advisor

- The purpose is to help operators to improve PSC operations
- Calculate process state with thermodynamic model
- Visualize the results to the operators
  - Masses (matte, slag, blister)
  - Temperature and slag liquidus temperature estimate
  - Compositions (Matte Fe-%, Slag Cu-% ja Fe/SiO2)
- Recalculate the PSC batch, if FSF matte state estimate changes
  - Kalman filter smoothing to calculate FSF matte composition and temperature for past matte ladles
- Calculate advise for next slag blowing step when new matte ladle arrives
  - Blowing time
  - Silica Flux amount
  - revert amount

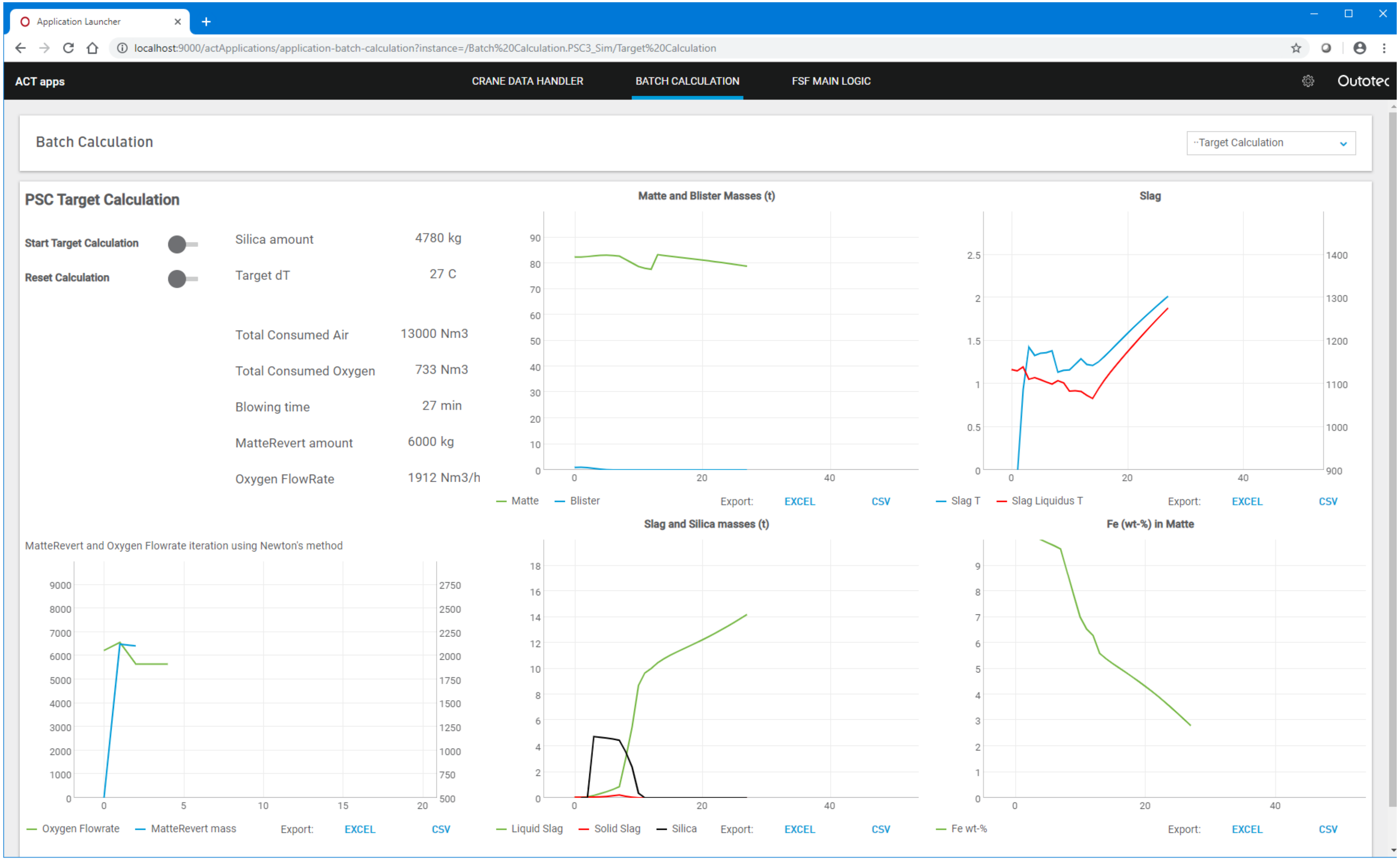
PSC advisor UI

Simulated results presented in web UI



Copper pilot case of COCOP project, March 2020

PSC advisor – UI page for future slag blow



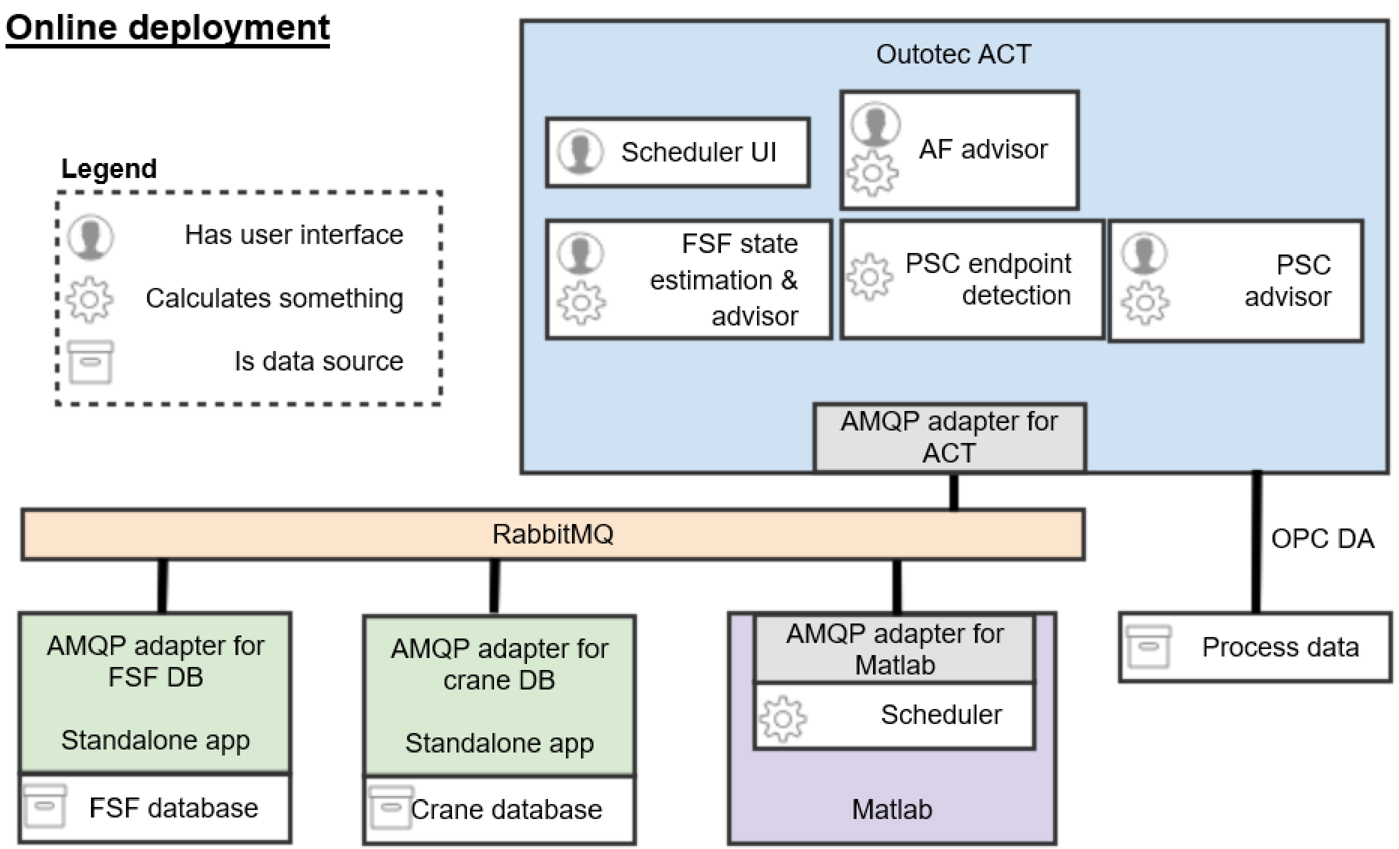
Copper pilot case of COCOP project, March 2020

Online testing in a copper smelter

- 2 weeks online test period
- Developers present at site:
  - ➢ The developers made notes
    - ✓ How the system was accepted
    - ✓ If the system affected to the actual operation
  - ➢ For verification and validation
  - ➢ For impact evaluation and collecting KPI information

ICT architecture in online testing

- The system was implemented in two virtual computers in the network of the test smelter



Test period impact to process

- Scheduling tool had a small positive effect to FSF feed rate:
  - ➢ There was contribution only in situations when the feed rate was depending on downstream operations.
- PS Converting:
  - ➢ More mixed revert was added to the slag blow than normally
  - ➢ Also blowing times and silica flux amounts were better optimized
  - ➢ Operators followed simulated variables that can not be measured
    - ✓ There is a learning curve for the operators to utilize new information

Conclusion

- The COCOP Cu case tools were developed successfully
- Online testing was performed in a full scale smelter
  - ➢ Positive impact to desired variables
    - ✓ Production
    - ✓ Usage of circulated material
    - ✓ Emissions

Thank you for your attention!

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Horizon 2020

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