Model-based Boiler Control and Optimization using Soft Sensors in a modern Utility Boiler

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POWER-GEN Europe
Amsterdam
June 9th, 2010

Contents

Introduction

EUtech`s motivation

Why do you focus on combustion and boiler operation?

Because this is where the overall process is least perfect.

There are a number of uncontrolled and unidentified variables that greatly influence combustion performance. These influencing variables include

- mill operating conditions (primary air temperatures, air/fuel ratios, flows, grind, and moisture),
- secondary air non-uniformity (air register settings, forced draft fan bias, and windbox pressure differential),
- coal variability, etc.

If you can't measure it, you can't control it. If you can't control it, you can't optimize it. We want to close this evident gap.

Why is the run for intelligent diagnostics and optimisation?

It is not just a case of intelligent diagnostics being 'nice to have' for companies, but, nowadays, more a strategic necessity to help stay ahead of the competition.

EUtech‵s motivation

Why is a real time approach to optimisation so important?

Continuous optimisation permantely finds the best economic and technical trade-offs without ever stopping. It is as effortless as breathing.

Make it an arduous exercise and it will be forgotten more than once. Human nature is just too forgiving to aspects of comfort.

Is there a noticeable impact and will my investment pay off?

The solutions we propose pay for themselves in less than a year.

Compared to conventional upgrading the capital costs appear negligible.

Moreover, the entire process will now seamlessly integrate into any best practices or TQM approach.

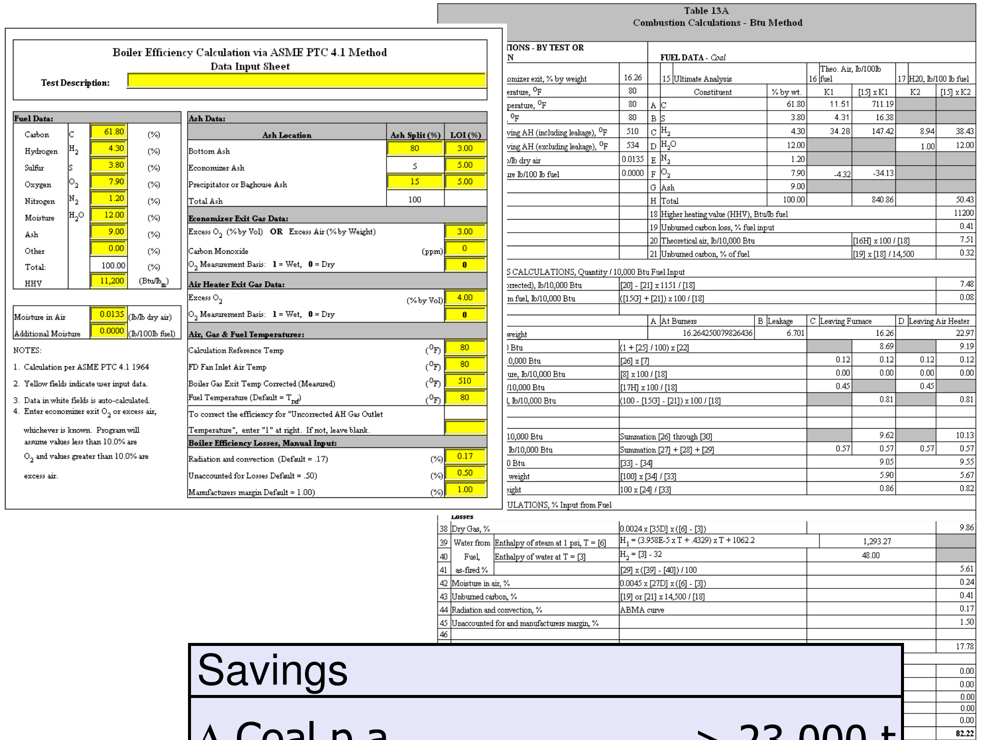
Achieved benefits

Benefits quantified

Plant	
Unit size	630 MW
Lignite LHV	10,300 kJ/kg
PLF	88.5 %

Reference	
Coal flow	660 t/h
O_2 excess	4.0 %
LoI_{ref}	2.9 %
$T_{BoilerExit, ref}$	199 °C
$\eta_{Boiler, ref}$	86.66 %

Optimisation	
Coal flow	655 - 657 t/h
O_2 excess	3.2 %
LoI_{opt}	1.8 %
$T_{BoilerExit, opt}$	191 °C
$\eta_{Boiler, opt}$	87.10 %



Savings	
Δ Coal p.a.	> 23,000 t
Cost per tonne*	26 EUR
Annual savings	~ 600,000 EUR
Δ CO_2 p.a.	> 27,300 t
CO2 Certificate	20 EUR/t
´Carbon benefit´	~ 550,000 EUR
Total benefit p.a.	1,150,000 EUR

Benefits and deliverables

Benefits ...

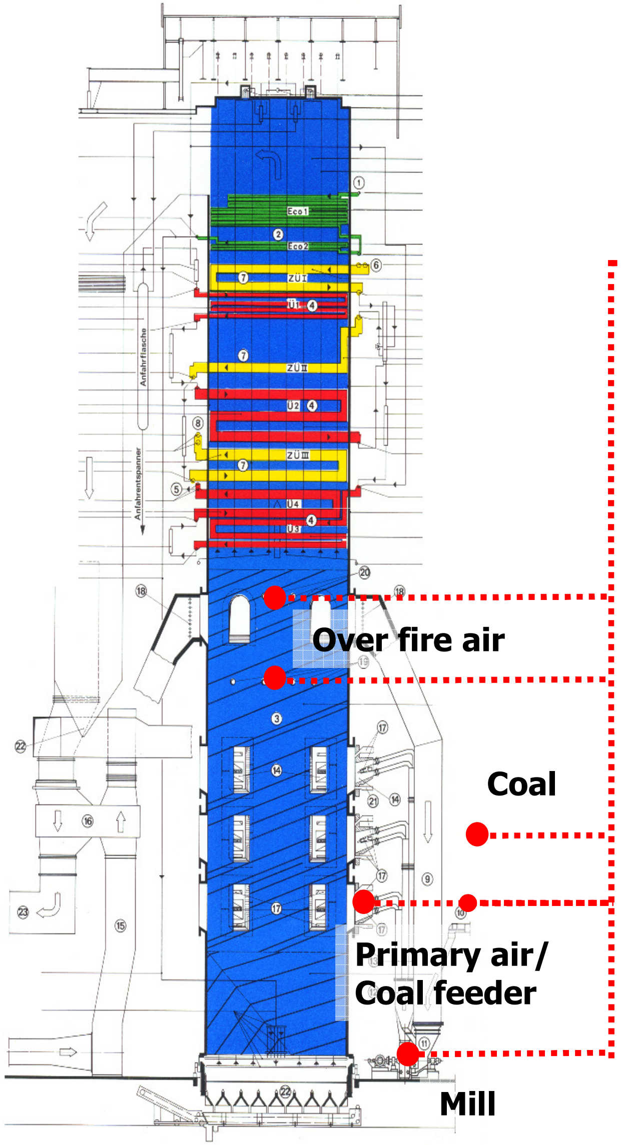
- EUcontrol-boiler is an optimal cost-value ratio option for producing sustained boiler operation under desired conditions (low NO_x, reduced slagging, high efficiency)
- No modification of plant DCS system required
- Highly adaptive, automatically adjusting to changing situations
- Multivariate target optimisation (low NO_x AND low fouling AND high efficiency)
- Customisable to individual plant requirements

... leading to a new value proposition

- Consideration of different operational objectives (technical, commercial, environmental)
- Offering an attractive means to upgrade older boilers at low cost
- Straightforward implementation at lowest risk (model based)

Model-based control and optimization

Integrated boiler management



EUcontrol-boiler

Advanced Diagnostics & **Boiler operating data (DCS, data base)**

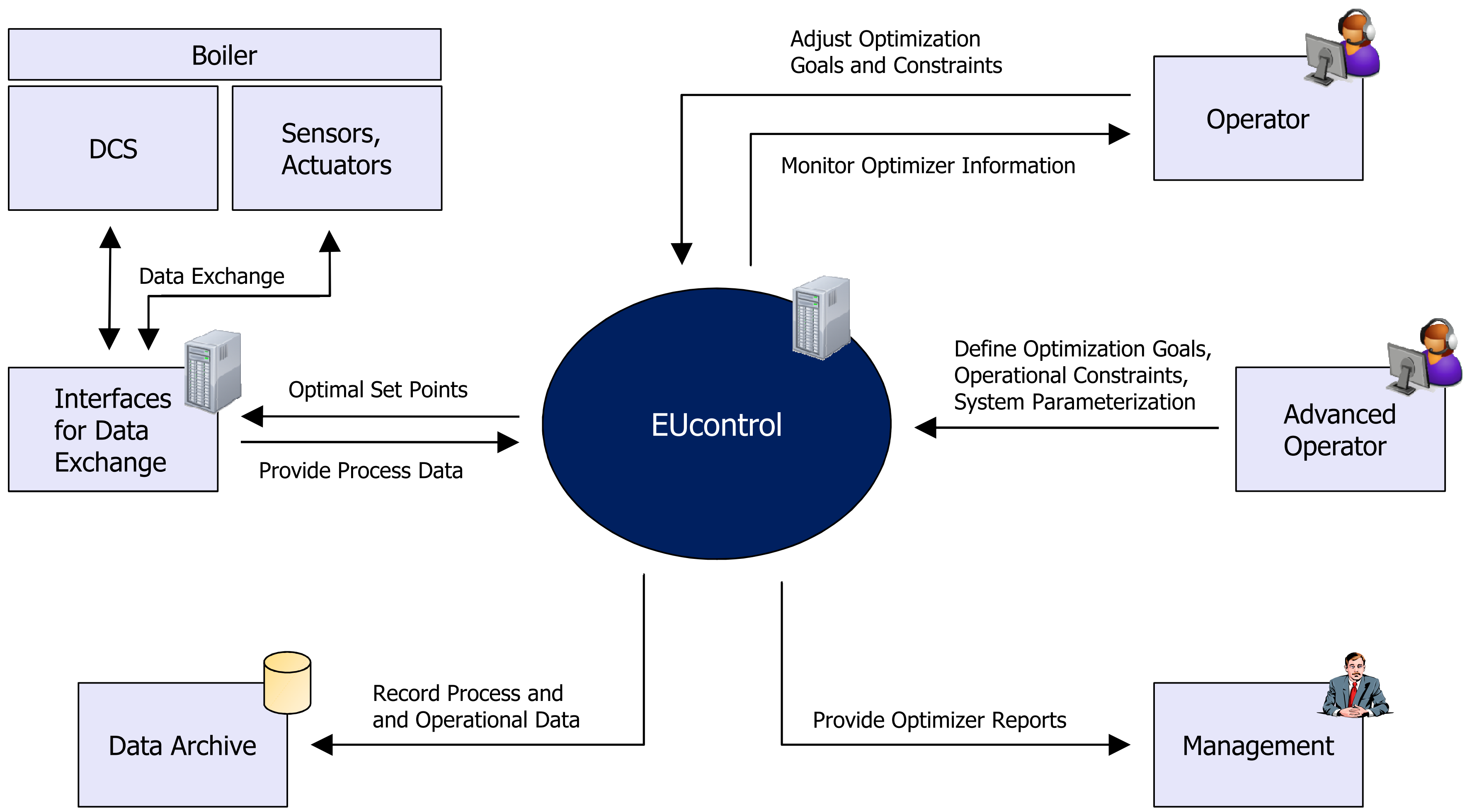
Measurement data analysis &

Adaptive system identification

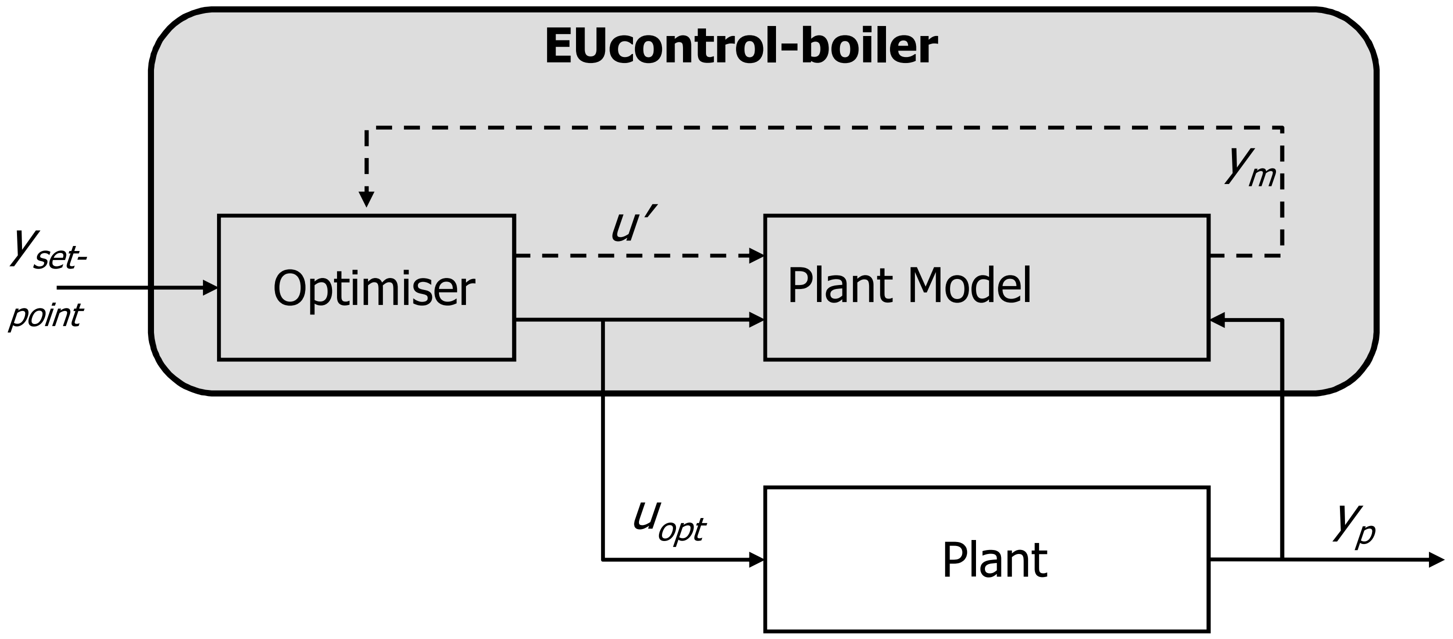
Optimised boiler operation

Optimization suite EUcontrol

System set-up at plant



Structure of EUcontrol-boiler



The plant behaviour is predicted with an (identified) process model. An optimiser calculates the best possible combination of inputs.

Hard and soft constraints can be equally considered. Preferential adjustment of set-points is possible if the degree of freedom is sufficient.

Data structure

Plant model

INPUT (u)

1. Manipulated variables

- Primary air (1...8)
- Coal hopper (1...8)
- Σ Secondary air
- OFA 1
- OFA 2
- O_2 Excess

2. Measured (dist.)

- Output power
- Soot blowers

3. Unmeasured (dist.)

- Coal quality

Plant model (Boiler)

4. Constraints

- FD fan pressure drop
- Mill temperature
- Mill arrangement

OUTPUT (y)

- NO_x
- T_{FEGT}
- CO
- η
- $\perp\sigma_T$
- T_{Mill} (1...8)

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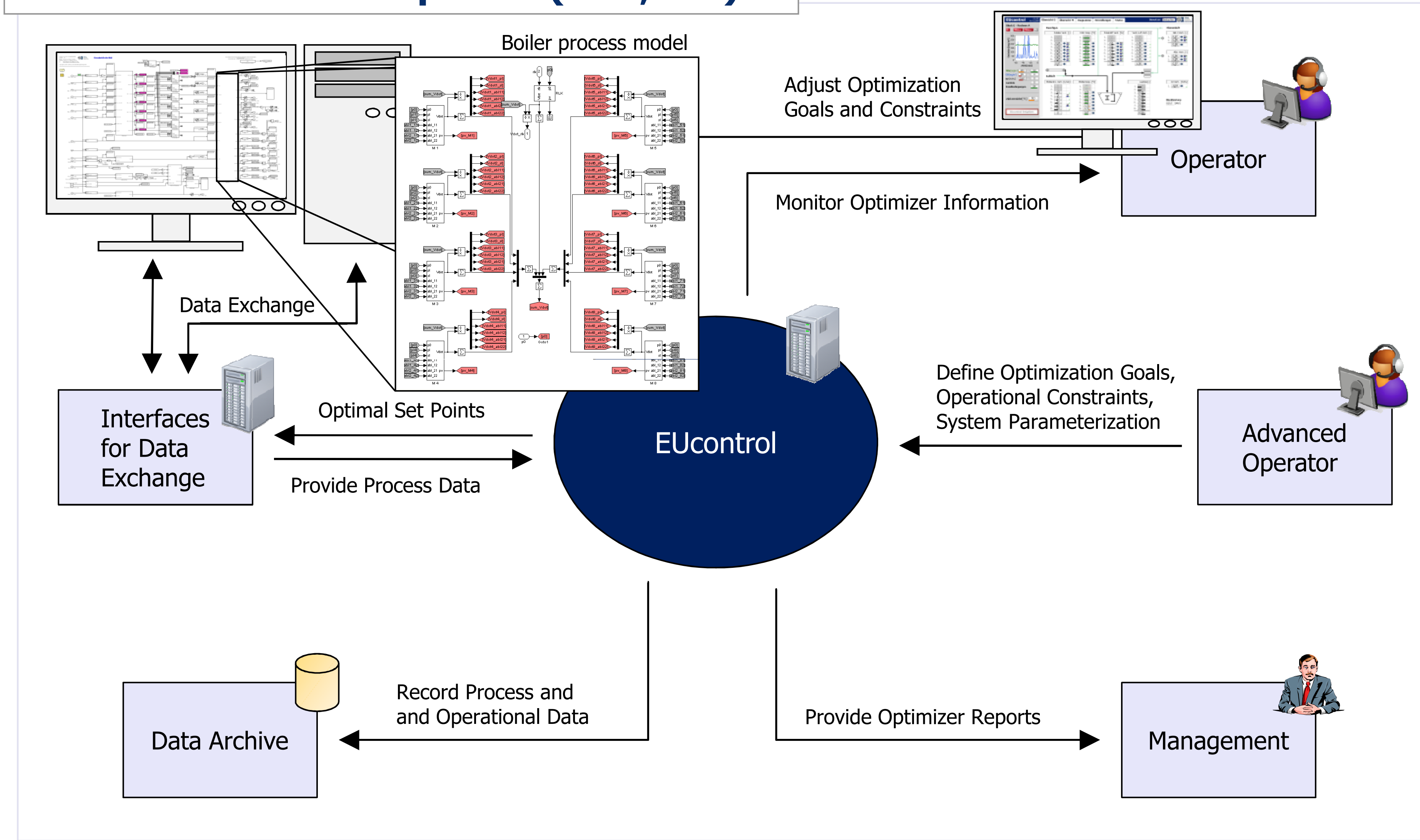
Optimization suite EUcontrol

Model-based development (RCP, HiL)



Soft sensors

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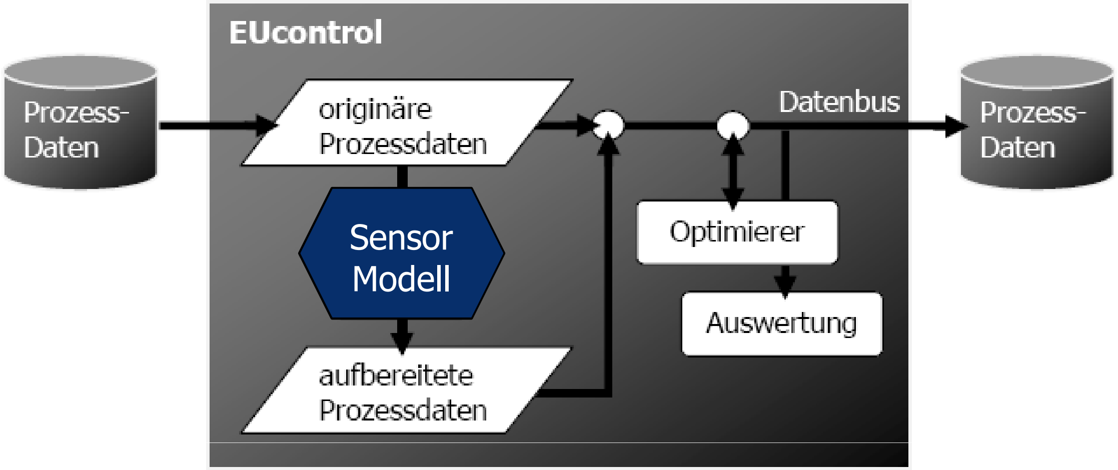
Soft Sensors in EUcontrol

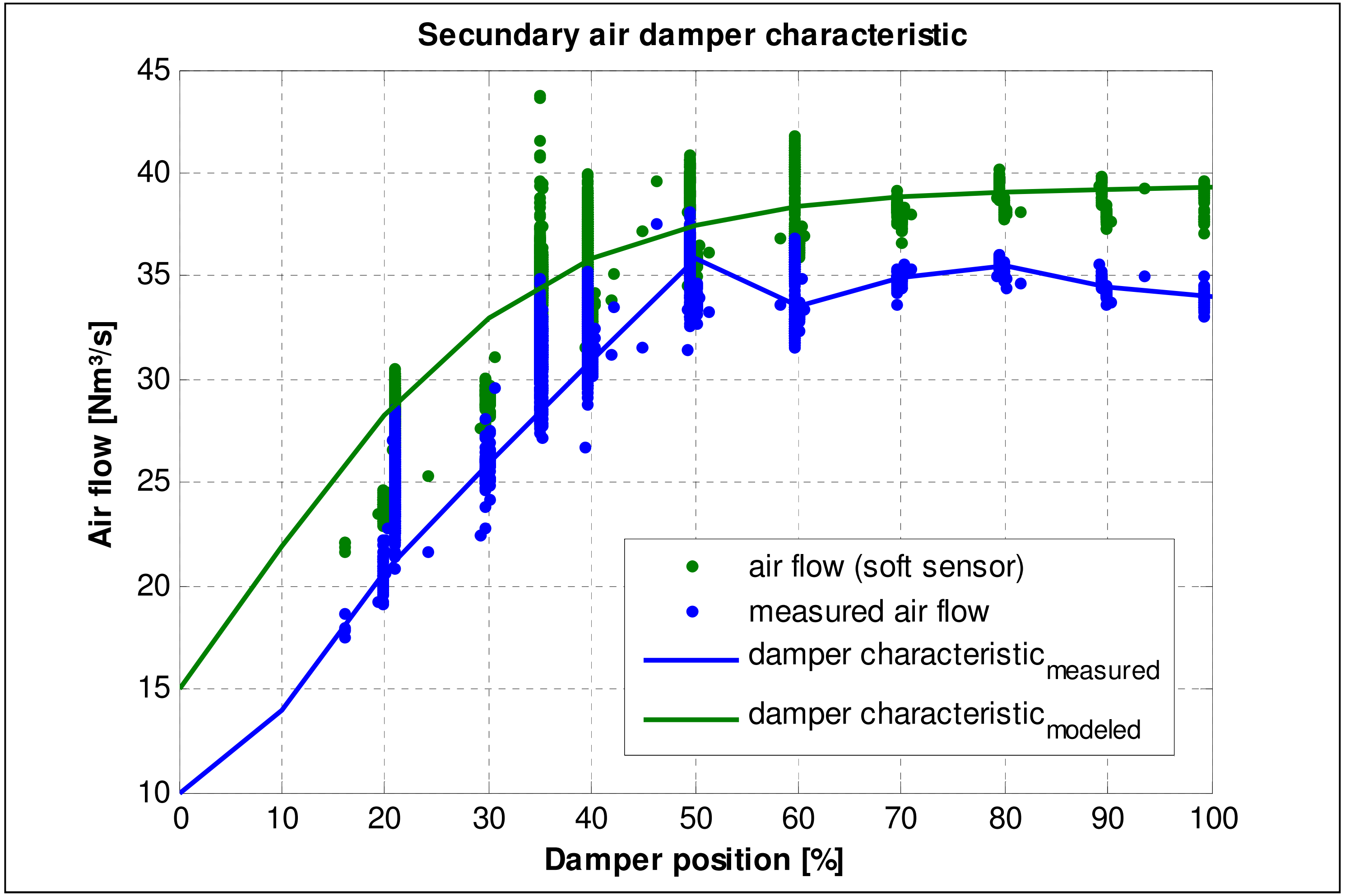
Flow diagram EUcontrol



Advantages

- Reduced measuring hardware requirement
- Inherent sensor validation, fault detection and diagnostics
- Provision of real-time data for advanced control requirements
- Allowing straightforward what-if analysis

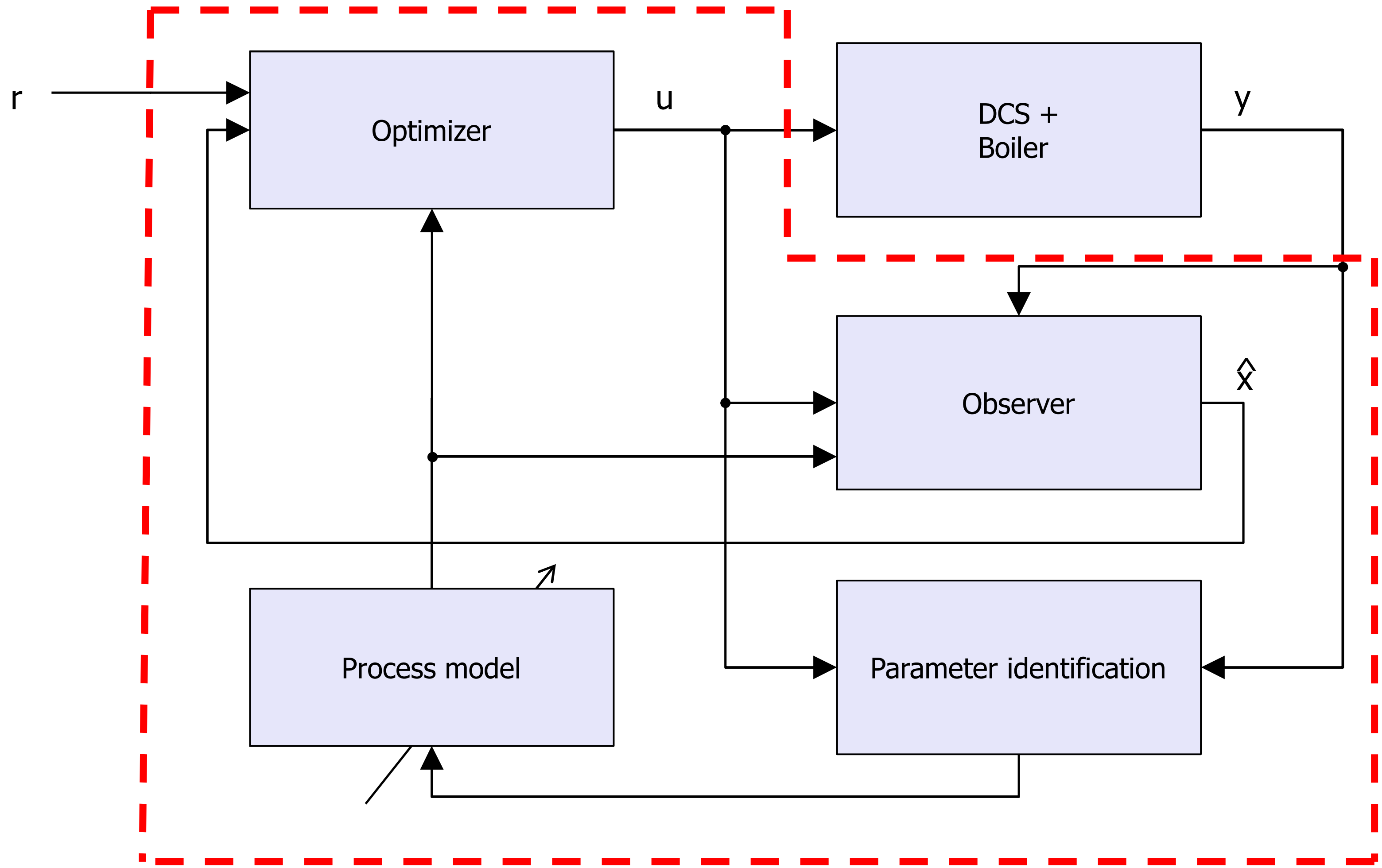
Secondary air flow „measurement“ using soft sensor



Model predictive control

Model predictive control

MPC with adaptiv process model



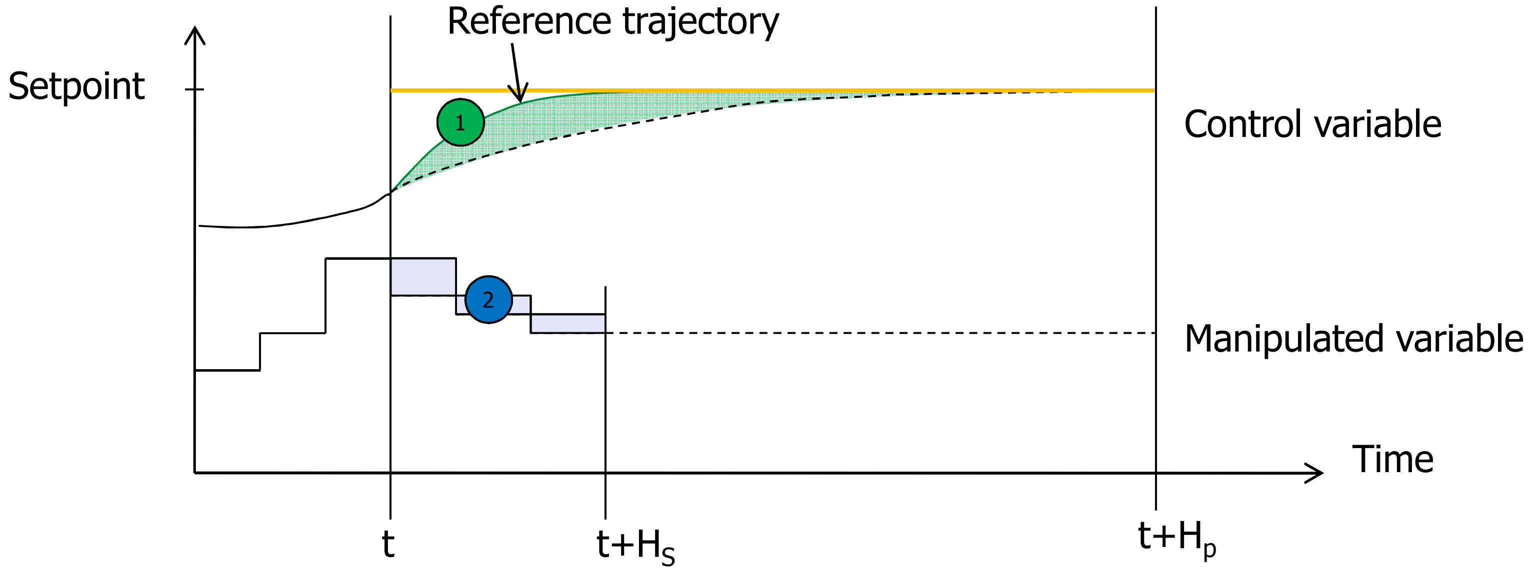
Model predictive control

Strategy

- Prediction horizon H_p
- Control horizon H_S
- Optimization of control action within control horizon under consideration of system development within prediction horizon resp. cost function:

$$I = \sum_{Hp}\sum_{Ziele} w_{1,i}(y_i - r_i)^2 + \sum_{MV} w_{2,i}(\Delta u_i)^2 + \sum_{MV} w_{3,i}(u_i - r_u)^2 + \sum_{RB} w_{4,i}(\max(y_i - M_i, 0))^2$$

(1) (2)



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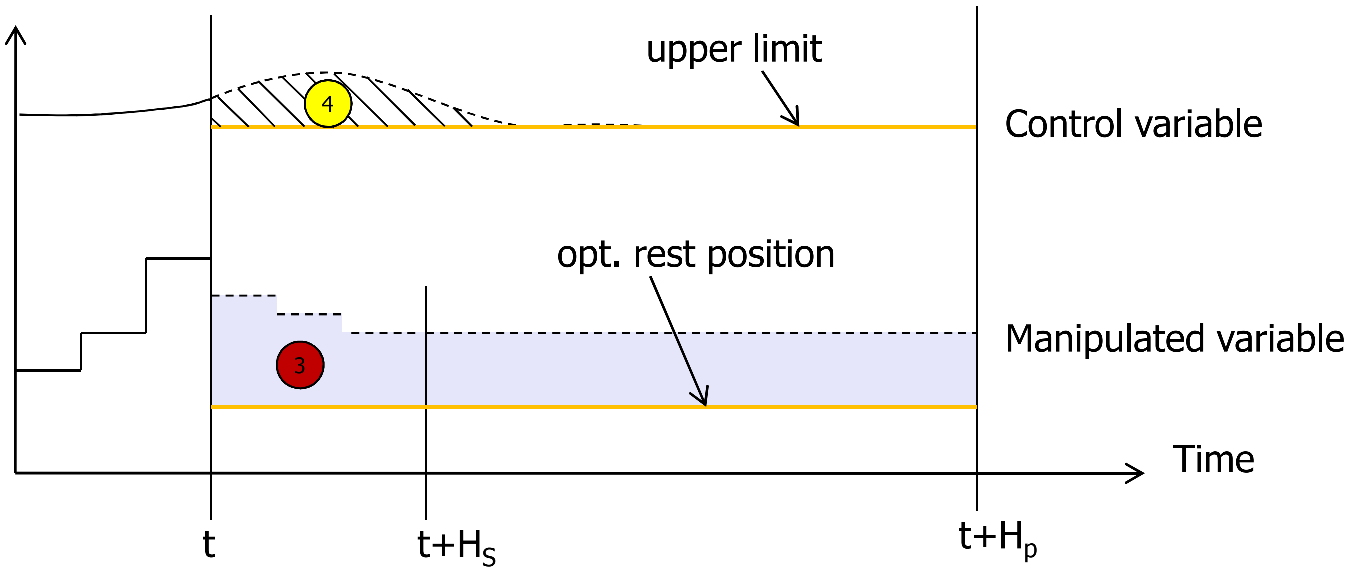
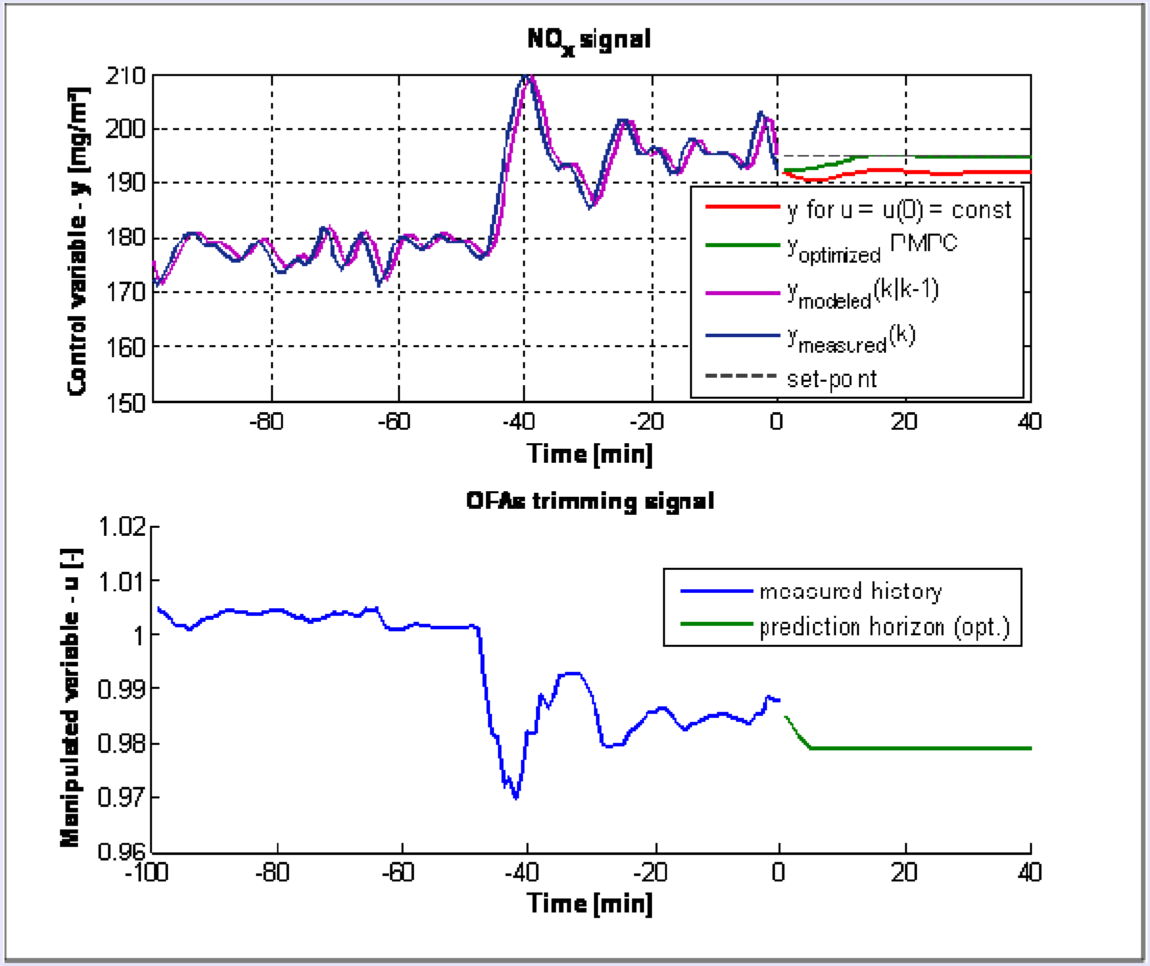
(1) (2) (3) (4)



Model predictive control

Real time visualization

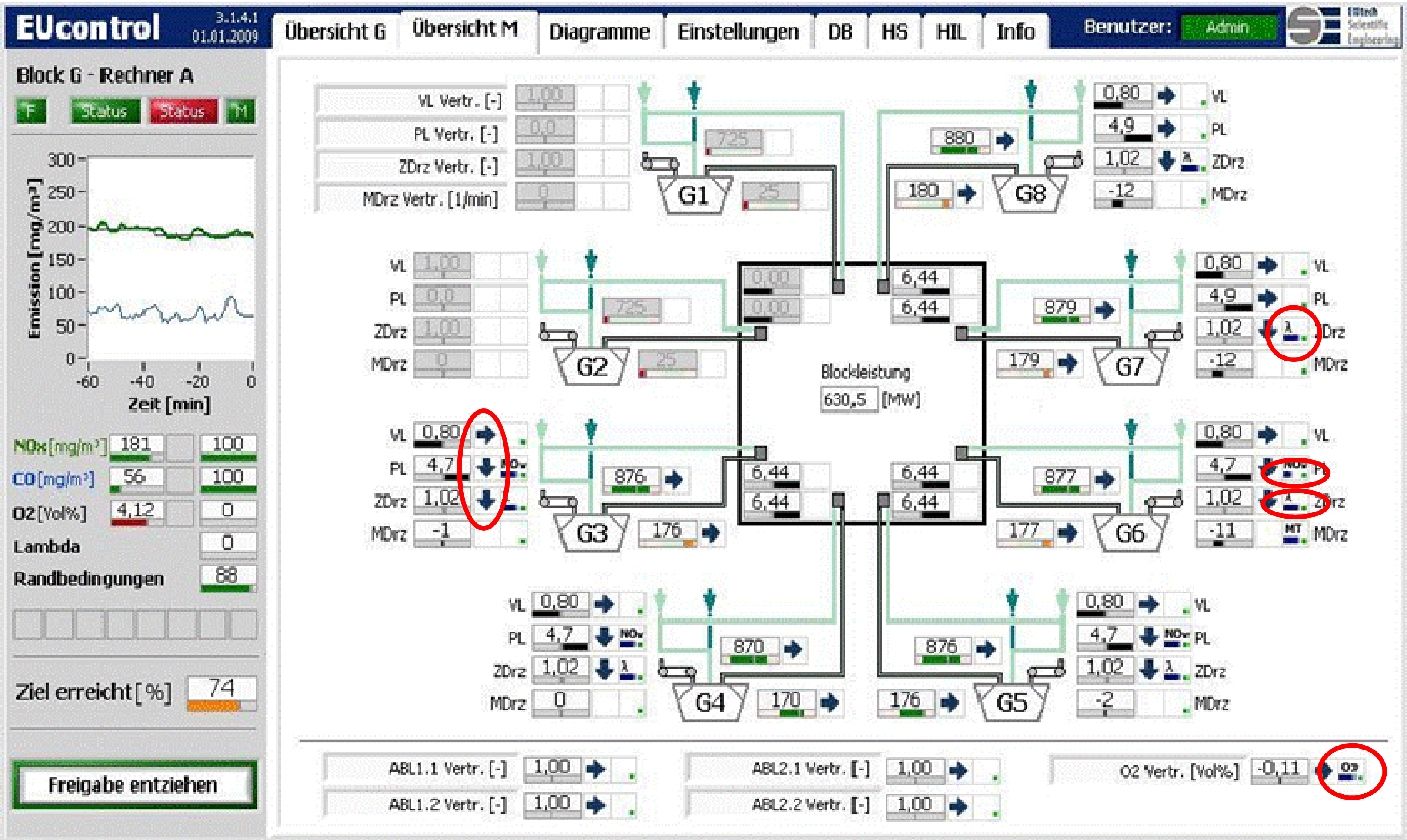
- Visualization of
  - Historical data
  - Prediction horizon
  - Target values



Predicted effect on the control variable (green line) as opposed to unmanipulated operation (red line)

EUcontrol User Interface

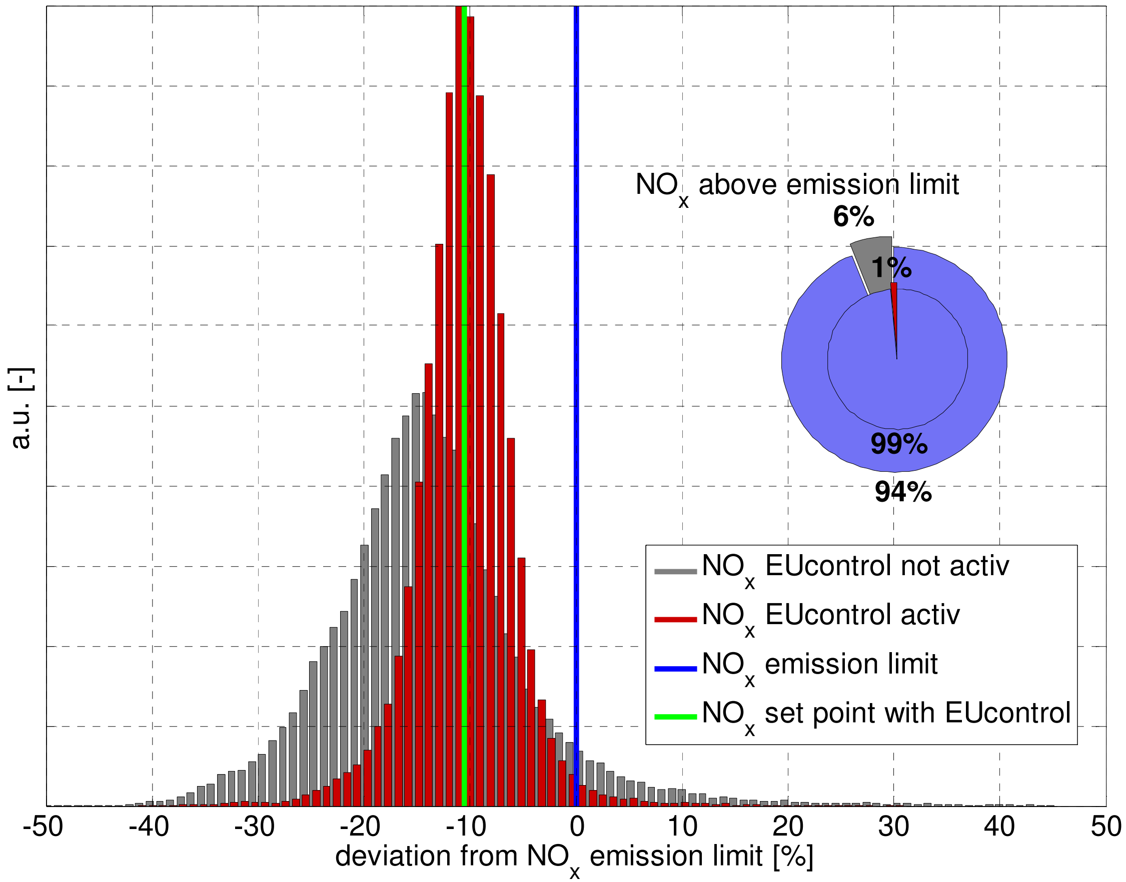
Controls at fingertips



Results

Optimisation - results

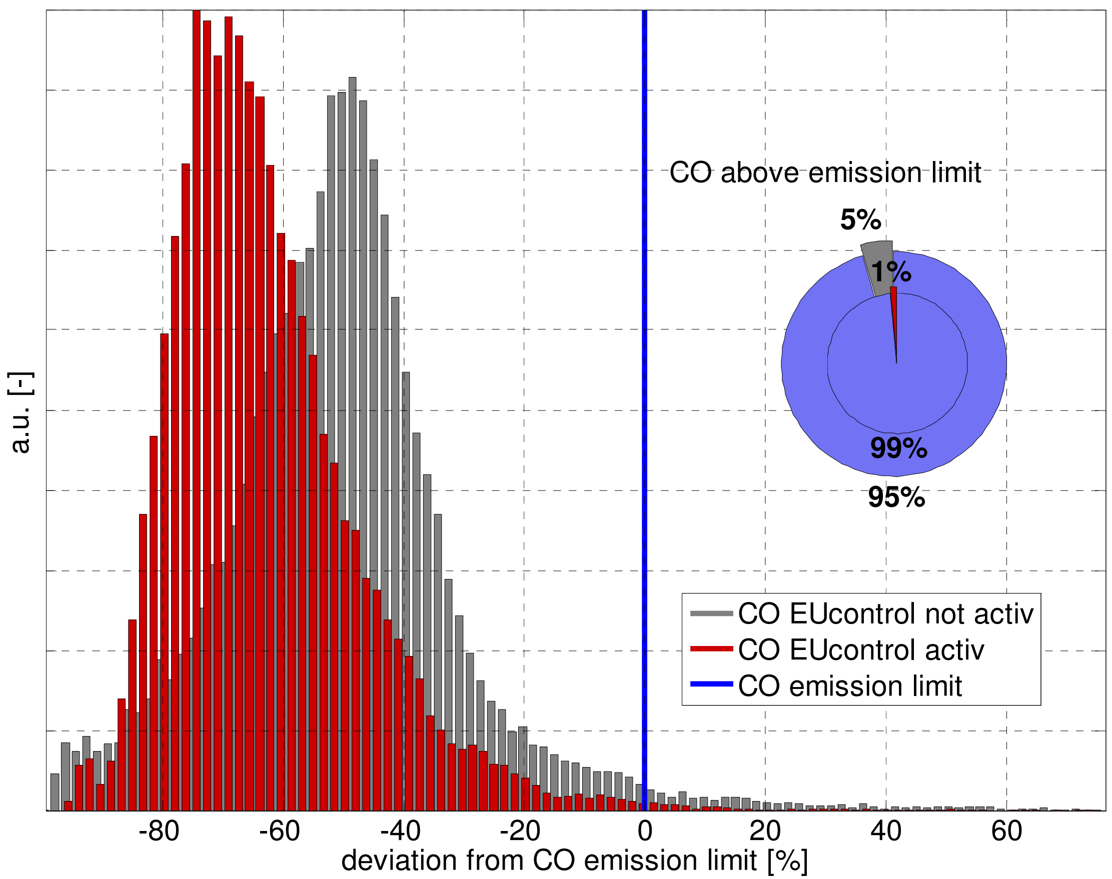
Result of optimised settings (optimisation goal)



- NO_x control
- Significant improvement of operation conditions while reducing slagging and fouling

Optimisation - results

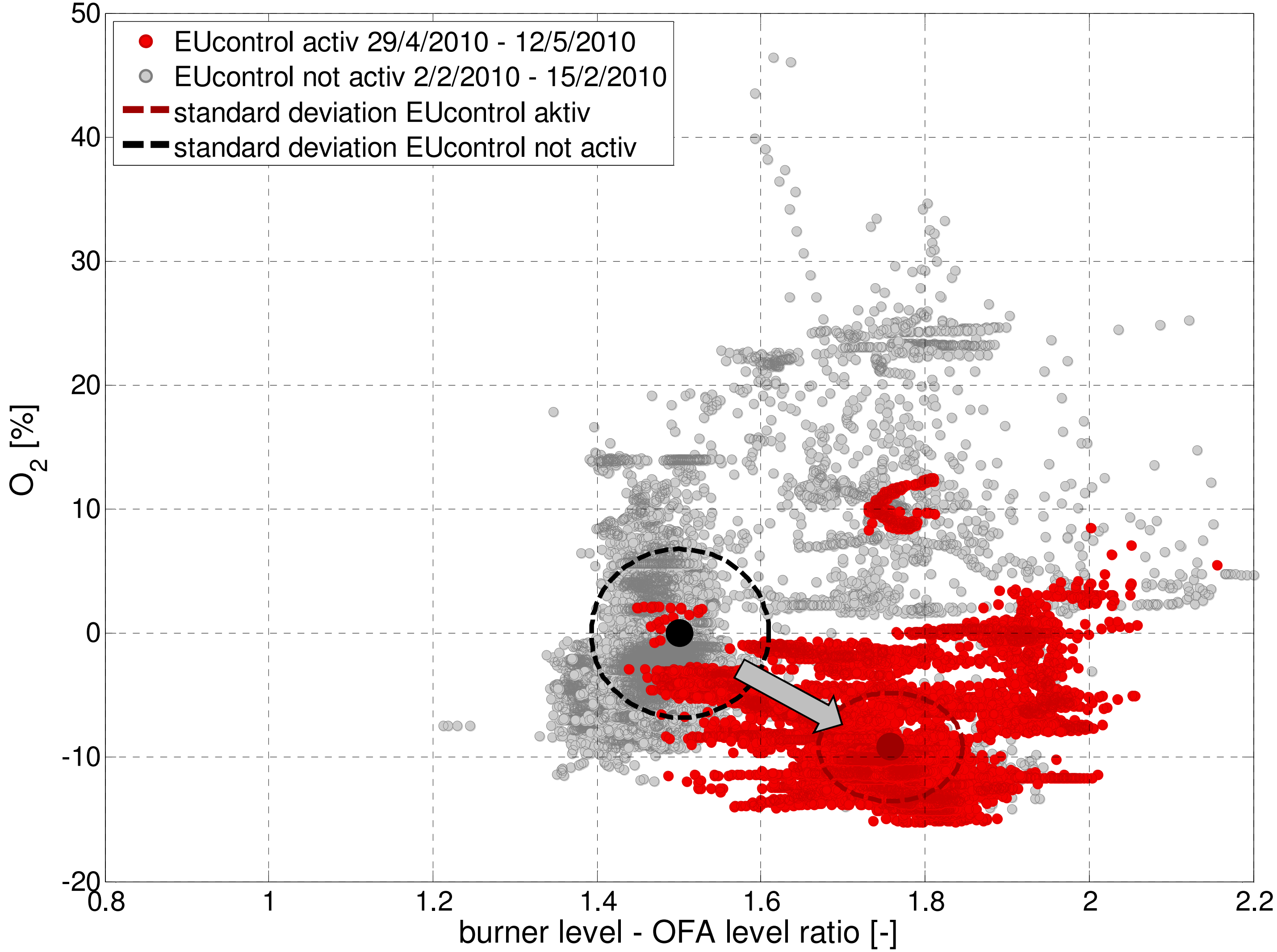
Result of optimised settings (optimisation goal)



- CO control
- Significant improvement of combustion quality

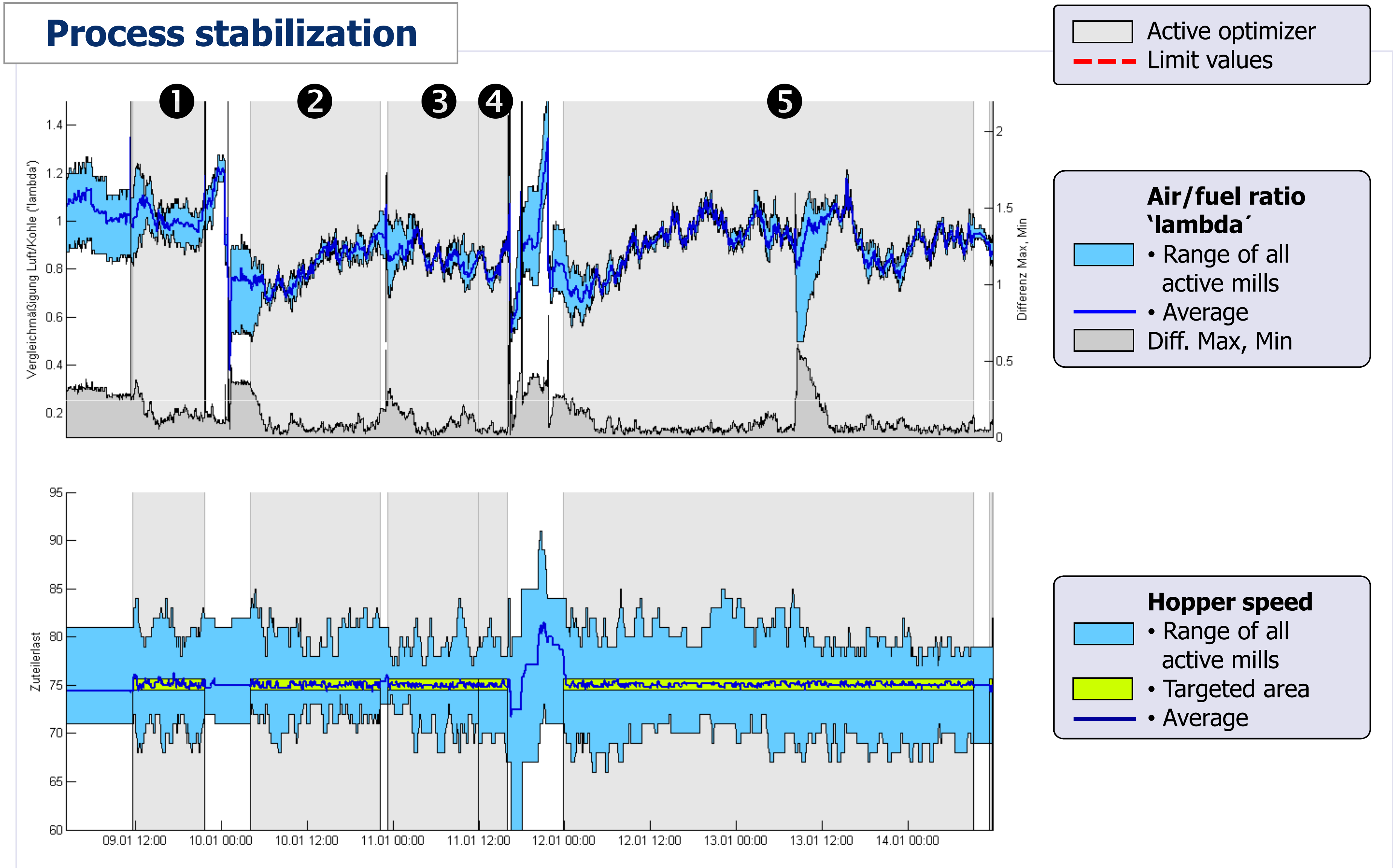
Optimisation: λ operating mode

Enhance boiler operation - O_2 and air-fuel ratio



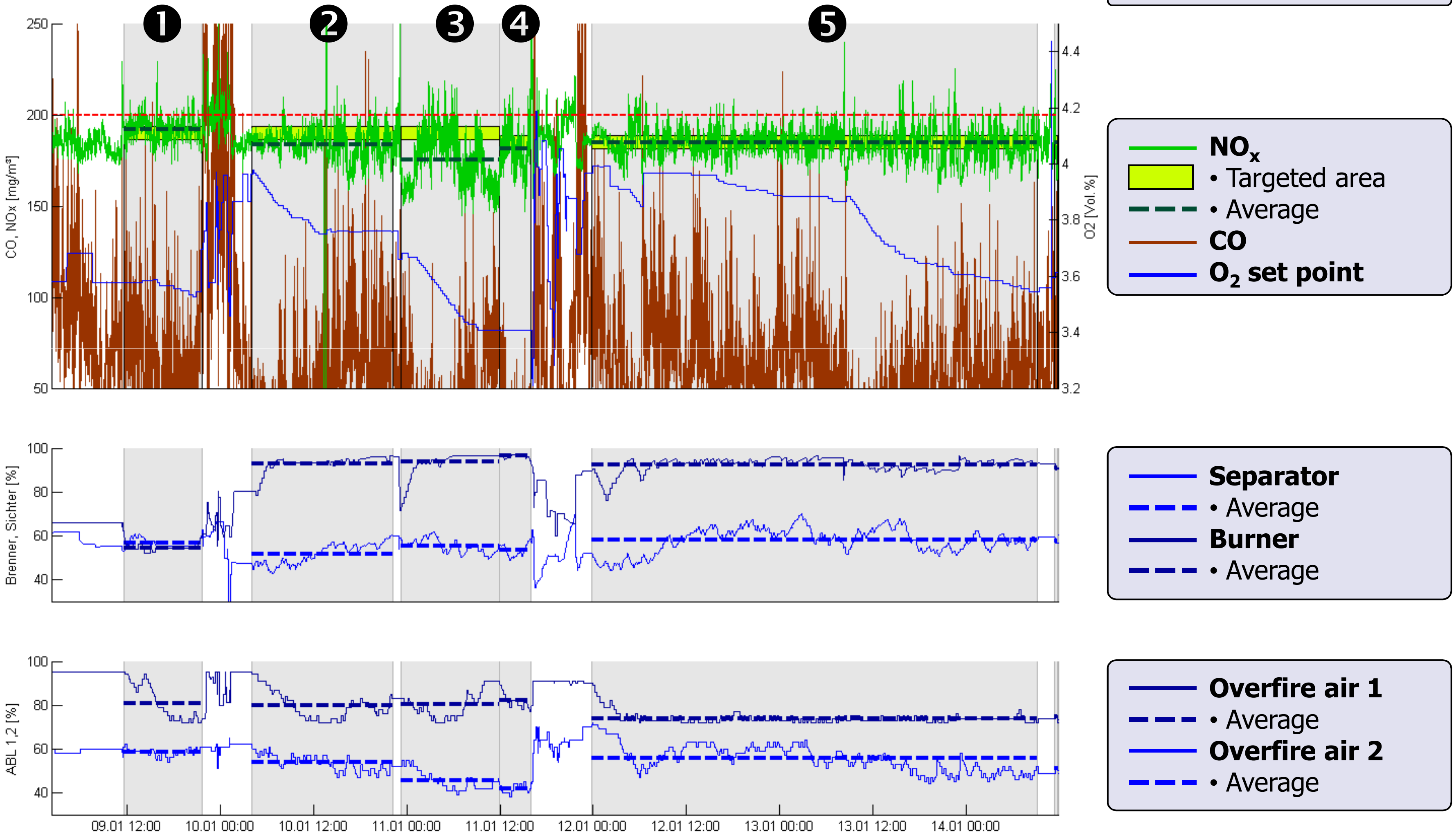
Optimisation: Fuel-air staging mode

Process stabilization



Optimisation: λ operating mode

Improve NO_x, CO, O_2 and damper positions



Proceeding

Steps to success...

- Site familiarisation and review of existing plant equipment
- Identify performance objectives
- Identify additional equipment requirements
- Review of available data and data quality
- System identification using available data
- Combustion parametric testing using Design of Experiments
- Build prediction models for control/optimisation
- Build process/plant model for model-in-the loop testing (hardware-in-the loop)
- Operate in advisory mode
- Extend to closed loop

Typical project time is 4 – 5 months

EUtech Scientific Engineering

Summary

Summary

Benefits

- Improved efficiency (0.3 to 1%)
- Reduced O_2 (- 5 to - 10%)
- Reduced NO_x and CO emissions (- 5 to - 15%)
- Reduce slagging and fouling, limit soot blower operation
- Reduced LoI
- Less material stress in furnace due to more even temperature distribution

Thank you for your attention

For more information, please visit us at booth G100