Combustion Optimization & SNCR Technology for coal fired power stations and retrofit experience

Matthias Schneider / STEAG Energy Services GmbH
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STEAG Energy Services Group

Revenue € 167 million
(consolidated)

Employees 1,615
(consolidated)

data 2015

STEAG Energy Services

Energy Technologies
Design, site supervision and commissioning of power plants

Plant Services
Operation & Maintenance, catalyst management and regeneration, personnel services

Nuclear Technologies
Decommissioning and dismantling of nuclear plants, safety, radiation protection and realization of final disposal sites

System Technologies
Energy Management Systems, process optimization by sensor-based solutions, user trainings

Information Technologies
Operation Management Systems, Communication Technologies, Site IT

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Energy Technologies Engineering

• Conceptual design
• Basic Engineering
• Tendering
  - Preparation of tender documents
  - Management of tender processes
  - Bid evaluation, contract negotiation
• Detail engineering
• Site services
  - Site Management
  - Supervision / Management of erection and commissioning
  - Performance tests
• Project Management (technical, related to EPC / supply contracts)
Experience is essential

Which type of boiler?
Which type of burner?
Which type of mill?

How many mills and burners?

How to connect the systems?
- Windbox or individual air supply?
- Common coal pipe or individual?
Steag optimization experience with own and 3rd parties for more than 75 years

- Bergkamen A 780 MW
- Bexbach 1 780 MW
- Walsum 7/9/10 1350 MW
- Herne 2/3/4 960 MW
- Bergkamen
- Bexbach
- Duisburg-Walsum
- Herne

- Iskenderun 1/2 1,320 MW
- Vöerde A/B 1,522 MW
- West 1/2 712 MW
- Weiher 3 724 MW
- Iskenderun
- Vöerde
- Weiher

- Lünen 6/7 507 MW
- Mindanao 1/2 232 MW
- Termopaipa IV 165 MW
- MKV, HKV, MHK *) 466 MW
- Lünen
- Mindanao
- Paipa
- Völklingen-Fenne

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Combustion Optimization and SNCR Systems
What is the goal

- Stable, monitorable flame
- High efficiency
  - low air ratio, even O₂ ratio
  - Low un-burnt carbon in ash
  - Low RH spray
  - Low exhaust gas temperature
- Low emissions (NOₓ)
- Even distribution of flue gas temperature at furnace exit
- Avoidance of flame impingement on the walls
- Avoidance of slagging and fouling
- Applicability of a wide coal range
What is the reality

- Uneven distribution of coal to the individual burners (deviation up to 30 to 40%)

- As a consequence high air ratio necessary

- Uneven distribution of flue gas temperature entering the convective path
- Lower steam output

- Slagging, Fouling, Corrosion

- High NO\textsubscript{x} values

- No low load operation possible
What is possible

- Max deviation of coal about 5 % to 10 %
- \(\text{NO}_x\) depending on coal 350 to 450 mg/m³
- Air ratio 1.15 to 1.17
- Minimum load 10 to 15 % of MCR
What are the tools beside software

- Rotating classifier
- Balancing of the coal flow to the burners
- Balancing pressure drop of the coal pipes
- Fine grinding
- Single burner air control offers more possibilities for optimization than wind box design
Combustion optimization
Primary NO$_x$-Measures

“Reduce the air ratio in certain zones as far as possible. But avoid: poor flame stability, too high amount of unburnt carbon in filter ash, corrosion risk for evaporator walls, slagging and so on. “

It is the art of engineering to reach low NOx-values while avoiding those unwished side effects.
Example for bad coal distribution

Deviation of coal mass flow from average level 40

Deviation of velocity from average level 40

R > 0.09
Better coal distribution
other example

Typische Staubverteilung

Pipe 1
Pipe 2
Pipe 3
Pipe 4
Pipe 5
Pipe 6
What can be achieved by CFD?

- Optimum furnace design
- Even distribution of coal and air
- Avoiding wall corrosion by avoidance of air lean areas close to the wall
- Optimized arrangement of burners inside the boiler
- Simulation of flow field and combustion at various loads
- Simulation of radiative and convective heat transfer

Limited:
- Increase of flame stability
- Avoidance of slagging and fouling
Example for temperature distribution furnace mid plane
CFD Simulation of furnace and hopper design - \(O_2\) plots

Old arrangement of hopper

Optimized arrangement of hopper
Optimized furnace and hopper design based on CFD Simulation

Old arrangement of hopper

Optimized arrangement of hopper
Coal parameters are influencing the combustion behavior
Propagation velocity of coal flame
Furnace Cross Section Heat Release Rate in MW/m²
Furnace Volume Heat Release Rate MW/m³
Mobile measuring vehicle

- Pulverized-coal measuring module
- Fly ash measuring module
- PC / fly ash analysing module
- Extensive gas analyzing module
- Portable gas analyzing module
- Calibration module for gas analyzers
- Temperature measuring module
- Volume flow rates measuring module
- Measuring module for turbines
- Measuring module for pumps
- Measuring module for condensers
- Measuring-value data logging and processing module

Length: 8.000 m overall
Width: 2.500 m
Height: 3.200 m
Gross vehicle weight: 8.990 kg
⇒ Most important is to ensure an even distribution of coal to the individual burners
⇒ Reduction of NO\textsubscript{x} values depending on quality of the coal blend
⇒ Air ratio between 1.15 and 1.17 is a goal for a new boiler
⇒ Tools to reach these goals: Balancing of the coal ducts, individual control of the air ratio of single burners, fine grinding
⇒ All of this can be a solid foundation for the use of software tools for further optimization of the entire combustion system. By software an optimization is possible but it cannot correct mistakes in design of the hardware.
Selective Non-Catalytic Reduction (SNCR) Systems

- 18 Installations
- Boiler types include stokers, front wall fired, roof fired, tangential fired, cyclone and opposed wall fired units
- Unit size from 15 to 620 MW
- Coal and Wood
- 35-50% urea reagent and 19% aqueous NH$_3$ systems
- Achieve NO$_x$ reductions in the range of 25% to 35%, with STEAG POWITECH up to 40 – 45% Turnkey Installation

Current Projects:
- PNM San Juan (350 & 650 MW)
- Iberdrola Lada Station, Spain (350 MW)
- Völklingen Power Station (195 MW)
NOx reduction as a function of temperature and oxygen

- NOx reduction = function of O₂
- Optimal temperature window between 2 – 3 % O₂ and 900 – 1050 °C
- Actual temperature window between 2 – 3 % O₂ and 900 – 1200 °C

Urea
\[ \text{NH}_2\text{CONH}_2 + 2 \text{ NO} + \frac{1}{2} \text{ O}_2 \rightarrow 2 \text{ N}_2 + \text{ CO}_2 + 2 \text{ H}_2\text{O} \]

Ammonia
\[ 4 \text{ NH}_3 + 4 \text{ NO} + \text{ O}_2 \rightarrow 4 \text{ N}_2 + 6 \text{ H}_2\text{O} \]
Measures for SNCR range adjustment

Temperature measurement:
- with suction type pyrometer:
  - at different levels and depths of indentation
  - using existing ports / hatches
- with acoustic temperature measurement:
  - measurement at one level
  - preparation of boiler (see next slide)

Ammonia (urea) test injection:
- test injection with urea solution:
  - at different boiler loads (typical load profile)
  - at different levels and with (arrangement on basis of the temperature measurements
Acoustic temperature measurement – Preparation of boiler

Lateral buckling in boiler wall:

Opening for transceiver unit:

Boiler tube/flange

Transceiver unit (acoustic horn)

Flange with transition cone
Acoustic temperature measurement – Arrangement

Air pressure: 80 - 120 psig (5.5 - 8.3 bar)

C = \sqrt{\frac{\alpha \cdot R}{M}} \cdot T

Source: Bonnenberg & Drescher
Acoustic temperature measurement –
Temperature profiles at 195 MW Power Station

Source: Bonnenberg & Drescher
Transceiver unit

Transition cone

Source: Bonnenberg & Drescher
Iberdrola Lada Station
SNCR Project

• Unit Particulars:
  - Opposed fired unit with 2 levels of OFA
  - Full load 360 MW
  - B&W DRB Burners (early generation)

• Partnership between EPC company

• Project Scope

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<th>STEAG SCR-Tech</th>
<th>INERCO</th>
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<td>• Urea Storage System</td>
<td>All Process Design &amp; Assistance in Purchasing</td>
<td>All Supply and A&amp;E System</td>
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<tr>
<td>• SNCR Zone</td>
<td>All Process Design, Equipment Design &amp; Purchasing Assistance</td>
<td>All equipment Supply</td>
</tr>
<tr>
<td>• Burner Design</td>
<td></td>
<td>Design and Supply</td>
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<tr>
<td>• CFD Modeling</td>
<td>All Modeling, Burner through Boiler</td>
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<tr>
<td>• BOP</td>
<td></td>
<td>Design and Supply</td>
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Iberdrola Lada Station
SNCR Project

Fluent Model Inner SA
Model Inner SA

Fluent Model Outer SA
Model Outer SA

Fluent Model Outer SA Vectors
Model Outer SA Vectors
Iberdrola Lada Station
Temperature

Burners out of Service
(6 FW and 6 RW)

Gas Temperature
200°C
1400°C

Burners in Service
(12 FW and 12 RW)

1700°C
Flue Gas Temperature
500°C

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There are generally higher CO concentrations adjacent to the waterwalls in the lower furnace in Cases 2 and 3.
Iberdrola Lada Station
Heat Flux
• San Juan Station Units 1 & 4
  – San Juan Unit 1 - 360 MW’s
  – San Juan Unit 4 – 550 MW’s
• Performed a Demonstration Test with Urea
• SNCR System
  – Urea Storage
    o Single Storage for both Units
    o Wet or Dry supply
    o Solutionizing System (converting dry urea to wet)
  – Urea Circulation System
  – Water Boost System
  – Chemical Hardness System
  – Urea Injection System
    o 3 elevations with 6 injectors each (Unit 1)
    o 2 elevation with 10 injectors each (Unit 4)
SNCR plant on San Juan PP Unit 4

- Two path boiler
- 550 MW
- Boiler cross section
  15.5 m x 18.3 m
Ammonia (urea) test injection

Testing plant with:
• metering and mixing module
• pumping module
• storage container for urea solution and
• temporary installation of injector

Source: Mehldau & Steinfath
General SNCR process basics – Injection lance

1. Cap for Body (Gehäusedeckel)
2. Body for Mixing Chamber (Mischkammergehäuse)
3. Air Nozzle (Luftdüse)
4. Nozzle for Reagent (Flüssigkeitsdüse)
5. Hole for cooling Air (Kühlluftbohrung)
6. Nozzle for cooling Air (Kühlluftdüse)
7. Fastener for Protection tube (Schutzrohrhalter)
8. Set Screw (Feststellschraube)
9. Set Screw (Feststellschraube)
10. Inside Tube (Lanzenrohr)
11. Protection Tube (Schutzrohr)
12. Lance tip (Lanzenspitze)

Source: Mehldau & Steinfath
STEAG’s Ammonia Systems

• STEAG’s experience brought to the US in the early 1990’s.
• Have designed the Ammonia Systems many US utilities.
• Have O&M of systems since the mid-1980’s.
• Full Scope, EPC capabilities.
• Aqueous or Anhydrous ammonia
• Design of both pressurized and atmospheric systems
PNM San Juan Station

Urea Storage / Solutionizing System

Dilution Water
PNM – San Juan Station

SNCR Injectors

Chemical Mixing Skids (2 units)
PNM San Juan Station

Local DCS Indication Panel

Sample PLC Based System
Chemical Hardness Skid
MKV Fenne –
General process flow

Source: Mehldau & Steinfath
Acoustic temperature measurement – control

Principal Design of an acoustic Gas temperature measurement system agam

230 W
50 Hz

Control unit

Analogue signal
4-20 mA

Unit of evaluation with temperature profile display

T=1058°C

RS422

Signal-/ Shift cable

Piezo microphone

Transmitter/ Receiver

Solenoid valve

Furnace

Service Air

Source: Bonnenberg & Drescher
# General comparison of SCR and SNCR

<table>
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<th>SCR</th>
<th>SNCR</th>
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<tr>
<td>- NOx removal efficiency &gt; 80%</td>
<td>- NOx removal efficiency max. 40-50%</td>
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<td>- NH₃-Slip &lt; 3 mg/Nm³</td>
<td>- NH₃-Slip &lt; 20 mg/Nm³</td>
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<td>- Additional fan capacity due to pressure loss at the catalyst, mixing, heat transfer system, flue gas ducts</td>
<td>- Higher reducing agents supply</td>
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<tr>
<td>- Additional energy input for the heating of the flue gas (only with Tail-end SCR)</td>
<td>- Sometimes pollution of the fly ash or the by-product of the flue gas cleaning with ammonia</td>
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| - SO₃ react at low temperature cat. to Ammonium-bi-sulfate:  
  - Increasing of the pressure loss due to deposits  
  - Corrosion by Ammonium-bi-sulfate  
  - Negative impact on availability | - Lower susceptible to faults because operating critical components are redundant implemented |
| - Investment cost (app. 5-10 times higher as for SNCR) | - Low Investment- and operation costs |
| - High operation costs | - Nearly no expense for maintenance |
| - High maintenance costs (fan, heat transfer system, Cat.-Regeneration/exchange) | |