98,3% Desulphurisation Efficiency – High SO\textsubscript{2} Removal Performance using Limestone FGD at Tusimice Power Plant

Speaker: Klaus Bärnthaler, Franz Hafner, Jan Stancl
PROJECT DESCRIPTION
Horrifying status of environment in Czech Republic in the early nineties → huge investment program by CEZ (FGDs, CFBs and upgrade of control system) brought immediate improvement.

Actual target is to meet future power consumption in Czech Republic.

Some of coal fired power plants at the end of life time expectancy.

Fulfill stringent emission limits.

Exploit and use coal reserves.

Decision of CEZ to renew power plants Tusimice and Prunerov and build a new 660 MW supercritical boiler at Ledvice, at the same time to shut down old and ineffective power plants.

Execution of the projects by Skoda Praha Invest (SPI) as the EPC contractor.

AE&E is the turnkey supplier for the FGD plants.
Power Plants within the Program of Complex Renewal

Current Status

Tusimice II PP
- Current Installed Capacity: 4 x 200 MW
- COD: 1974 – 1975
- Desulphurization: 1997

Prunerov II PP
- Current Installed Capacity: 5 x 210 MW
- Desulphurization: 1996

Ledvice PP
- Current Installed Capacity: 2 x 110 MW, 1 x 110 MW (CFB)
- Desulphurization: 1996, NA

Czech Republic

Prague
Power Plants within the Program of Complex Renewal

Future / Designed Status

**Tusimice II PP**
- Future Installed Capacity: 4 x 200 MW
- COD: 2010 / 2011

**Prunerov II PP**
- Future Installed Capacity: 3 x 250 MW
- COD: 2014

**Ledvice PP**
- Future Installed Capacity: 1 x 110 MW (CFB), 1 x 660 MW
- COD: 2013
Renewal of 4 x 200 MW Units, lignite

In total 16 system packages:

- Coal handling
- Boiler house
- Machine room
- Water treatment

Life time expectancy 25 years

Total efficiency increase 33 % → 38 %
<table>
<thead>
<tr>
<th></th>
<th>Current</th>
<th>Future</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross output</td>
<td>4 x 200 MWe</td>
<td>4 x 200 MWe</td>
</tr>
<tr>
<td>Fuel</td>
<td>brown coal (high S contents; $S_T^D \sim 3%$)</td>
<td>brown coal (high S contents; $S_T^D \sim 3%$)</td>
</tr>
<tr>
<td>Boiler efficiency</td>
<td>86 - 87,6%</td>
<td>&gt; 90%</td>
</tr>
<tr>
<td>$NO_x$ emissions</td>
<td>320 - 440 mg/Nm$^3$</td>
<td>&lt; 200 mg/ Nm$^3$</td>
</tr>
<tr>
<td>$SO_2$ emissions</td>
<td>450 - 500 mg/Nm$^3$</td>
<td>&lt; 200 mg/ Nm$^3$</td>
</tr>
<tr>
<td>Fly ash emissions</td>
<td>60 - 100 mg/Nm$^3$</td>
<td>&lt; 20 mg/ Nm$^3$</td>
</tr>
<tr>
<td>Overall efficiency</td>
<td>33 - 34 %</td>
<td>38,67 %</td>
</tr>
<tr>
<td>Home consumption</td>
<td>9 %</td>
<td>8,6 %</td>
</tr>
</tbody>
</table>
- Wet limestone scrubbing method (high sulfur contents in coal)
- By-product of desulphurization mixed with fly ash + slag → disposed as stabilizate (mines)
- Clean flue gas induced into the cooling towers
- One absorber per two boilers
Demolishing of existing Desulphurisation units – Chiyoda

Turnkey installation of new Wet Limestone Desulphurisation unit for the 4*200 MW (Tušimice) boiler units excluding electrical and control system

Raw gas ducts

2 Absorbers for 4 boilers, made of CS / RL incl. internals (agitators, spraying system, mist eliminator)

Recirculation pumps, Oxidation air blowers

Clean gas duct (into cooling tower; made of FRP)

Process water tank and emergency slurry tank

Civil work: Foundation, Pump building, Electrical Building

New gypsum dewatering system (Eng. by AE, installation by others)

Erection and Commissioning
Volume of wet flue gasses exceeds 1.7 mio Nm³/h per absorber (6% O₂)

Reduction of SO₂ emissions from values reaching 11,326 mg/Nm³ upstream FGD to < 200 mg/Nm³ downstream FGD (dry, 6% O₂)

<table>
<thead>
<tr>
<th>Emission limits [mg/Nm³]</th>
</tr>
</thead>
<tbody>
<tr>
<td>NOx</td>
</tr>
<tr>
<td>Current</td>
</tr>
<tr>
<td>Future</td>
</tr>
</tbody>
</table>
TUSIMICE II
Key Milestones

- Contract between SPI & AEE concluded in 2006
- Erection activities at site started in 7/2007
- Units 23 + 24 (Phase I) commissioned; PAC for FGD 1.2.2010
- Units 21 + 22 shut down in 10/2009, start of Phase II
- FGD ready for flue gas take over
- Scheduled PAC of Phase II in 12/2011
1 x flue gas cooler, 1 x absorber

Clean flue gas inducted into the cooling tower

Reduction of SO$_2$ emissions from values reaching 5,500 mg/Nm$^3$ upstream FGD to <150 mg/Nm$^3$ downstream FGD (dry, 6% O$_2$)

By-product of desulphurization secondary used (civil industry)

Pre-arrangement for the future installation of the 1$^{st}$ CCS in CR

Total efficiency 42.5%

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>NO$_x$</td>
</tr>
<tr>
<td>------</td>
</tr>
<tr>
<td>New Unit</td>
</tr>
</tbody>
</table>
Contract between SPI & AEE concluded in 8/2008

Detail design handed over

Civil work in progress, mechanical erection well ahead of schedule

Scheduled commissioning 6/2012

Scheduled TOC 12/2012
### PRUNEROV II

**Basic Information**

- One absorber per one boiler
- Clean flue gas inducted into the cooling towers
- Reduction of SO$_2$ emissions from values reaching 11,349 mg/Nm$^3$ upstream FGD to <200 mg/Nm$^3$ downstream FGD (dry, 6% O$_2$)
- By-product of desulphurization secondary used (civil industry)

#### Emission limits [mg/Nm$^3$]

<table>
<thead>
<tr>
<th></th>
<th>NO$_x$</th>
<th>SO$_2$</th>
<th>fly ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current</td>
<td>650</td>
<td>500</td>
<td>100</td>
</tr>
<tr>
<td>Future</td>
<td>200</td>
<td>150</td>
<td>10</td>
</tr>
</tbody>
</table>
FGD Prunéřov - Scope of supply

- Demolishing of existing Desulphurisation units – MHI
- Turnkey installation of new Wet Limestone Desulphurisation unit for 3*250 MW (Prunéřov) boiler units excl. electrical and control system
- Raw gas ducts
- 3 Absorbers for EPR II made of CS / rubberlined, incl. internals (spraying system, mist eliminator, agitators, strainers)
- Recirculation pumps, Oxidation air blowers
- Clean gas duct (into cooling tower; made of FRP)
- Process water tank and emergency slurry tank
- Civil work: Foundation, Pump building, Electrical Building
- Erection and Commissioning
- Dewatering system (hydocyclones, vacuum belt filter)
- Limestone supply system (connected to existing milling system)
Contract between SPI & AEE concluded in 12/2008

Preparation of the FGD detail design in progress

Postponement of contract due to delay in the authority permit

Scheduled commissioning and PAC in 2015
<table>
<thead>
<tr>
<th></th>
<th>Tusimice</th>
<th>Prunerov</th>
<th>Ledvice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet flue gas [Nm³/h]</td>
<td>1,690,000</td>
<td>1,012,000</td>
<td>2,003,041</td>
</tr>
<tr>
<td>SO₂ in raw gas [mg/ Nm³]</td>
<td>11,650</td>
<td>11,800</td>
<td>5,850</td>
</tr>
<tr>
<td>SO₂ removal efficiency</td>
<td>&gt; 98,3</td>
<td>&gt; 98,2</td>
<td>&gt; 97,2</td>
</tr>
<tr>
<td>Diameter absorber [m]</td>
<td>14.5</td>
<td>11.5</td>
<td>17.0</td>
</tr>
<tr>
<td>No. of spray banks</td>
<td>5</td>
<td>4</td>
<td>5 + 1(spare)</td>
</tr>
<tr>
<td>Nozzles per spray bank</td>
<td>112</td>
<td>118</td>
<td>156</td>
</tr>
<tr>
<td>Flow per spray banks [m³/h]</td>
<td>11,000</td>
<td>9,800</td>
<td>11,500</td>
</tr>
<tr>
<td>Flow per nozzle [m³/h]</td>
<td>1,637</td>
<td>1,384</td>
<td>1,230</td>
</tr>
<tr>
<td>Mist eliminator</td>
<td>coarse / fine</td>
<td>coarse / fine</td>
<td>coarse / fine</td>
</tr>
</tbody>
</table>
## ETU, ELE, EPR
Comparison of Key Parameters

<table>
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<tr>
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<th>Prunerov</th>
<th>Ledvice</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sump volume [m³]</td>
<td>3,900</td>
<td>2,500</td>
<td>4,600</td>
</tr>
<tr>
<td>Flow oxidation air [m³/h]</td>
<td>22,000</td>
<td>11,000</td>
<td>15,600</td>
</tr>
<tr>
<td>El. consumption [kWh/h]</td>
<td>4,930</td>
<td>3,650</td>
<td>7,500</td>
</tr>
<tr>
<td>Water consumption [m³/h]</td>
<td>160</td>
<td>230</td>
<td>101</td>
</tr>
<tr>
<td>Gypsum moisture [%]</td>
<td>-</td>
<td>12</td>
<td>&lt; 8</td>
</tr>
<tr>
<td>CaCO₃ in gypsum</td>
<td>&lt; 2</td>
<td>&lt; 2</td>
<td>&lt; 1.5</td>
</tr>
<tr>
<td>Availability [%]</td>
<td>99</td>
<td>98.8</td>
<td>99</td>
</tr>
</tbody>
</table>
CFD optimized scrubber design
screw settings and general parameters (FLUENT)
- Pressure based solver, steady-state
- two phases, two-way-coupling, Eulerian-Lagrangian model, discrete random walk turbulence model (discrete phase)
- $k-\varepsilon$ turbulence model (continuous phase)

spray generation (Matlab)
- basis: measurements of the nozzle manufacturer (droplet size distributions)
- injection informations are tabulated in a list (e.g. position, mass flow, diameter, temperature)
- description of one nozzle by at least 17 different droplets

User-Defined-Functions (UDFs)
- droplet-wall interaction
- evaporation and condensation
- $SO_2$ chemisorption
Design Data
- diameter $\varnothing 14.5 \text{ m}$
- volume flow $1.690.000 \text{ m}^3/h_{\text{ntp}}$
- $\text{SO}_2$ at inlet $11.600 \text{ mg/m}^3_{\text{ntp,dry}}$

Spray Bank Design:
- 5 spray banks
- double header concept
- 112 nozzles / spray bank
- slurry/spray bank $11.000 \text{ m}^3/h$
Upwards velocity (m/s) at 1\textsuperscript{st} and 5\textsuperscript{th} spray bank
SO$_2$ mass fraction [-]
Design Data
• volume flow $1.012.000 \text{ m}^3/\text{h}_{\text{ntp}}$
• $\text{SO}_2$ at inlet $11.350 \text{ mg/m}^3_{\text{std, dry}}$

Spray Bank Design - First approach
• diameter $\varnothing 11 \text{ m}$
• 4 spray banks
• 98 nozzles / spray bank
• slurry/spray banks $4 \times 9.100 \text{ m}^3/\text{h}$

Spray Bank Design - Final geometry
• diameter $\varnothing 11.5 \text{ m}$
• AE&E splash rings
• Increased height of absorption zone
• 118 nozzles / spray bank
• slurry/spray banks $4 \times 9.800 \text{ m}^3/\text{h}$
Upward velocity (m/s) at 1st and 4th spray bank
Final geometry

First approach

mass fraction of SO$_2$ in different cross sections
Conclusions
Conclusions

- ČEZ in cooperation with SKODA PRAHA invest and AE&E adopts latest technologies to improve air pollution control in Czech Republic
- For high and low sulfur applications different strategies were developed to reach separation efficiency > 98% in the FGD Systems;
- For high sulfur applications the number of spray banks could be reduced due to higher suspension flows in the spray bank and in the single nozzles;
- Flue gas velocity in the scrubber has to be limited to values < 4 m/s to minimize bypass effects near the scrubber walls and the main headers;
- A proper spray bank design (single main header vs. double main header) is very important for an optimized contact between flue gas and droplets in the absorption zone;
- Using a strong CFD modelling tool is mandatory to optimize the nozzle position in the spray bank; Including the SO₂ mass transfer in the simulation is the only way to get fully information from the simulation results;
Thank you for your attention