ESP and Fabric Filter Technology for Dedusting
- Comparison and Optimization -

Matthias Schneider / STEAG Energy Services GmbH
Kolkata, Raipur, Hyderabad - November 2016
What could be the background for improvements?

- New coal qualities
- More stringent environmental standards
- Changed economic criteria

What has to be observed?

⇒ Investment
⇒ Operating costs
⇒ Maintainability
The Principle of Electrostatic Precipitation

Discharge electrode
with negative high tension
[20-80 kV]

Collecting electrode,
grounded

Dust layer

Rapping mechanism
Saw-Edge-Shaped-Discharge-Electrode between Collecting Electrode
Example for Electrostatic Precipitator

- collecting electrode system
- discharge electrode system, parts under high voltage
Functional principle electrostatic precipitation

1 High Voltage Generator
2 Discharge Electrode
3 Collecting Electrode
  a Raw Gas
  b Clean Gas
  c Precipitated Particulates
Discharge Electrode Rapping
DEUTSCH-Equation
Influence of different parameters on w-value

\[ \varepsilon = \left(1 - e^{-\frac{wxf}{100}}\right) \times 100[\%] \]

\[ f = \frac{F}{V} \left[ m^2 / \frac{m^3}{s} \right] \]

\[ w[cm/s] \]

- Fuel: S +
  - Volatiles +
  - water +

- Combustion temperature: high -

- ash: Na2O +
  - Fe2O3 +
  - K2O +
  - V2O +
  - SiO2 -
  - CaO -
  - Al2O3 -
  - MgO -

- unburnt carbon: 1-10% +

- number of zones: high +

- separation efficiency: high -

- electrode height: high -

- plate spacing: high +
Fabric Filter in Comparison
Details of Fabric Filter

Source: Alstom
Principle Function of a Fabric Filter
Bag cleaning
# Filter Media

<table>
<thead>
<tr>
<th>Fibre</th>
<th>PP</th>
<th>PES</th>
<th>PAC</th>
<th>PPS</th>
<th>APA</th>
<th>PI</th>
<th>PTFE</th>
<th>GLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymer Common trade name</td>
<td>Polypropylene</td>
<td>Poly-ester</td>
<td>Dolanit Ricem</td>
<td>Ryton Procon Toray</td>
<td>Nomex</td>
<td>P84</td>
<td>Teflon</td>
<td>Fibreglass</td>
</tr>
<tr>
<td>Temperature °C</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>continuous</td>
<td>90</td>
<td>135</td>
<td>125</td>
<td>180</td>
<td>200</td>
<td>240</td>
<td>230</td>
<td>240</td>
</tr>
<tr>
<td>peak</td>
<td>95</td>
<td>150</td>
<td>130</td>
<td>210</td>
<td>220</td>
<td>260</td>
<td>260</td>
<td>280</td>
</tr>
<tr>
<td>Resistance</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Acid</td>
<td>5</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Alkali</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Hydrolysis (H₂O)</td>
<td>5</td>
<td>1</td>
<td>4-5</td>
<td>5</td>
<td>2</td>
<td>2</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Oxidation (O₂)</td>
<td>3</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>3-4</td>
<td>–</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Abrasion</td>
<td>5</td>
<td>5</td>
<td>3-4</td>
<td>3-4</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Price rel. to PES</td>
<td>1</td>
<td>1</td>
<td>1.3</td>
<td>4.5</td>
<td>5</td>
<td>6</td>
<td>15</td>
<td>2-3</td>
</tr>
</tbody>
</table>

1 = Bad, 2 = Mediocre, 3 = Generally good, 4 = Good, 5 = Excellent
### Comparison of Fabric Filter / ESP

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Fabric Filter (Pulse Jet Type)</th>
<th>ESP (Horizontal Flow Type)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gasflow</td>
<td>No limitation</td>
<td>No limitation</td>
</tr>
<tr>
<td>Flue Gas Temperature</td>
<td>Critical for bag material; bag clogging may occur, if close to dewpoint</td>
<td>&lt; 450 °C Critical if close to dewpoint because of corrosion</td>
</tr>
<tr>
<td>Dust concentration</td>
<td>No limitation; precautions to be made if dust is abrasive</td>
<td>No limitation; precollecting and gas distribution devices easy to combine</td>
</tr>
<tr>
<td>Dust resistivity</td>
<td>No influence</td>
<td>Most critical parameter for ESP-sizing</td>
</tr>
</tbody>
</table>

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<tr>
<td>Particle Size Distribution</td>
<td>Sensitive for very fine particles because of possible bag penetration, then surface treatment required</td>
<td>Sensitive because of increasing resistivity, particle cohesion and re-entrainment, Corona suppression with submicron particles</td>
</tr>
<tr>
<td>H₂O-Dewpoint</td>
<td>Sensitive for specific fabrics (not PPS)</td>
<td>Positive influence if dewpoint is high (Conditioning effect)</td>
</tr>
<tr>
<td>Acid Dewpoint</td>
<td>Sensitive for specific fabrics; Critical if close to dewpoint because of bag blockage</td>
<td>Positive influence because of conditioning effect; Critical if close to dewpoint because of corrosion</td>
</tr>
<tr>
<td>Parameter</td>
<td>Fabric Filter (Pulse Jet Type)</td>
<td>ESP (Horizontal Flow Type)</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------------------------------------------------------------------</td>
<td>----------------------------------------------------------------</td>
</tr>
<tr>
<td>Specific Collection Area (SCA)</td>
<td>60 - 72 m²/(m³/s); depending mostly on inlet dust concentration and max. pressure drop</td>
<td>60 - 150 m²/(m³/s) at 400 mm spacing; depending on efficiency required and coal type (ash resistivity)</td>
</tr>
<tr>
<td>Specific Active Volume</td>
<td>approx. 6 m²/m³ based on bags with 150 mm diameter</td>
<td>approx. 5 m²/m³ based on 400mm spacing</td>
</tr>
</tbody>
</table>

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# Comparison of Fabric Filter / ESP

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<th>ESP (Horizontal Flow Type)</th>
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<tr>
<td>Reqd. Base Area</td>
<td>approx. 43 m²/m² (7 m bags)</td>
<td>approx. 80 m²/m² (16 m active CE height)</td>
</tr>
<tr>
<td></td>
<td>approx. 65 m²/m² (8 m bags)</td>
<td></td>
</tr>
<tr>
<td>Clean Gas Dust</td>
<td>&lt;&lt; 20 mg/m³</td>
<td>Typical &lt;= 20 - 50 mg/m³</td>
</tr>
<tr>
<td>Total Pressure Drop</td>
<td>&lt;= 15 - 20 mbar</td>
<td>&lt;= 3 mbar</td>
</tr>
<tr>
<td>Spec. Power Consumption</td>
<td>1,5 - 3,0 kW(m³/s) (incl. ID-fan)</td>
<td>0,2 - 1,5 kW/(m³/s) depending on specific ash properties (resistivity)</td>
</tr>
<tr>
<td>Life Time of Internals</td>
<td>5 years for bags 15 years for cages</td>
<td>15 - 20 years</td>
</tr>
</tbody>
</table>

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## Comparison of Fabric Filter / ESP

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<tr>
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<th>ESP</th>
</tr>
</thead>
<tbody>
<tr>
<td>separation efficiency</td>
<td>higher</td>
<td>high</td>
</tr>
<tr>
<td>dependency on coal quality</td>
<td>low</td>
<td>high</td>
</tr>
<tr>
<td>(see also separation efficiency of ESP)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>dangers</td>
<td>risc of fire at high fluegas temp. and high unburnt carbon content</td>
<td>electricity</td>
</tr>
<tr>
<td>maintenance</td>
<td>online</td>
<td>offline</td>
</tr>
<tr>
<td>additional reactions</td>
<td>yes in dust layer</td>
<td>no</td>
</tr>
<tr>
<td>wet flu gases</td>
<td>fouling</td>
<td>corrosion</td>
</tr>
</tbody>
</table>
1. Capital Cost
   no big difference

2. Operating Costs

<table>
<thead>
<tr>
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<th>Fabric Filter</th>
</tr>
</thead>
<tbody>
<tr>
<td>pressure loss</td>
<td>2,2 mbar</td>
<td>16 mbar</td>
</tr>
<tr>
<td>equivalent electricity consumption</td>
<td>130 kW</td>
<td>960 kW</td>
</tr>
<tr>
<td>electricity consumption</td>
<td>650 kW</td>
<td>80 kW</td>
</tr>
<tr>
<td>total consumption</td>
<td>780 kW</td>
<td>1040 kW</td>
</tr>
<tr>
<td>difference in consumption</td>
<td>- kW</td>
<td>260 kW</td>
</tr>
<tr>
<td>maintenance</td>
<td>1 %/a</td>
<td>6 % +)</td>
</tr>
<tr>
<td>difference maintenance</td>
<td>- %/a</td>
<td>5 %/a</td>
</tr>
</tbody>
</table>

+) change of filterbags every 3-4 years
   capital cost of bags 15-20 % of total investment

Example 350 MW unit
4000 operation hours a year
volume 40x40x20 m
Capital Cost of Pulse Jet Fabric Filters vs. ESP

Capital Cost incl. Erection [MIO €]

Specific Collecting Area @ 400mm Duct Spacing [m²/(m³/s)]

ESP
PJFF

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Comparison of Fabric Filter / ESP Electrostatic Precipitator

Pro
1. Low pressure drop (< 2.5 mbar)
2. Low maintenance effort
3. High lifetime expectancy (>15-20 years) without any major overhaul
4. Insensitive against boiler tube leakage
5. Low total energy consumption and operation cost
6. Low maintenance time required
7. High reliability

Contra
1. Dependence of collection efficiency and ESP-size on changing fly ash properties
2. Relatively big installation volume
3. Relatively high investment cost
4. Low DeSO$_x$-effect behind FSI- or Spray Dryer installations
Comparison of Fabric Filter / ESP
Fabric Filters

Pro

1. Clean gas dust content independent from boiler load and ash type (less than 30 mg/Nm³)
2. Clean gas dust content less than 10 mg/m³ without problems
3. Safe and simple sizing procedure
4. DeSO₅ₓ-effect in ash layer on filter bag behind FSI- or Spray Dryer installations
5. Relatively low investment cost

Contra

1. High pressure drop (15 - 20 mbar)
2. Limited lifetime of filter bags dependent on bag material
3. Low emergency operation temperature
4. Sensitive to flue gas temperature lower than dew point
5. Sensitive to boiler tube leakage
6. Maintenance time needed for changing of filter bags (approx. 1.000 hrs per FF every 5 years)
7. Pre-coating needed for commissioning
CFD Modelling for ESP Optimisation
Power Plant Voerde

**Unit Voerde A/B**
Net capacity: 2 x 760 MW
Fuel: Hard coal

**Unit West I/II**
Net capacity: 2 x 350 MW
Fuel: Hard coal
Reasons for Retrofit Project – Project aims

- Improvement of environmental norms
  - FGD retrofit: SO$_2$ clean gas concentration $400 \rightarrow 200$ mg/m$^3$ (STP) dry
  - ESP optimization: fly ash concentration $50 \rightarrow 20$ mg/m$^3$ (STP) dry
- Boiler load increase $2 \times 710$ MW$_{\text{gross}} \rightarrow 2 \times 760$ MW$_{\text{gross}}$ (+ $2 \times 50$ MW$_{\text{gross}}$)
  $\rightarrow$ (Utilization of max. possible rated thermal input)

- Increase of efficiency
- Improvement of profitability
- Reduction of maintenance costs
- Improvement of competitiveness
Boiler/Turbine: Utilization of existing reserve capacity
DeNOx: Utilization of existing reserve capacity
ESP: Optimisation, static reinforcement
Raw gas ducts: Static reinforcement
ID-Fans: Retrofit, capacity increase
FGD: New scrubbers
Stack: New wet stack
Prior to modification

**ESP inlet and outlet sections**

- Inlet section diffuser
- "X-Richtblech" flow-directing plates
- View of the aisle upstream of the first bay of collecting electrodes
- Collecting and spray electrodes with supports
- Outlet section
Prior to modifications

Ductwork and guiding arrangements

Guide vane level in duct section between air heater and ESP

Gas distributing wall made of "X-Richtblech" flow-directing plates

Perforated guide vanes and dividing wall for distribution to two ESP trains
Prior to modifications
CFD Modelling for ESP Optimisation
FLUENT model of the ESP

With variation of modification options

Guide vanes with extensions arranged on various levels

Inflow grate

Pressure drop at ESP outlet

Edge areas of gas distributing walls

Gas distributing walls made of "X-Richtblech"

Different hopper partitioning wall arrangement options

Guide vanes with extensions arranged on various levels
CFD Modelling for ESP Optimisation

velocities before modification

Velocity pattern
CFD Modelling for ESP Optimisation
Velocities after modification

Velocity pattern
CFD Modelling for ESP Optimisation Modifications

- **Hopper interior**
  - grid of sloping plates in the first hopper row
  - standard separation wall in the second hopper row

- **Extension of guide vanes and inlet flow grate**
  - extension of two guide vanes

- **Gas distributing walls**
  - partial replacement of plates to implement the determined pressure drop coefficients

- **Outlet pressure drop**
  - Installation of an outlet wall with vertically staggered pressure drop coefficients
The Emission limit value for dust of 20 mg/m³(i.N.)\(_{dr}\) will be observed under all conditions.
**Charge Carriers** improve **performance**
Charge Carrier: Sulfur trioxide (from SO$_3$ conversion)
Charge Carrier: Water Molecules
Charge Carrier: Sodium (Na$_2$O), Potassium (K$_2$O)
Iron(III) oxide (Fe$_2$O$_3$): catalytic action to convert SO$_2$ to SO$_3$

*low resistivity → high particle migration velocity*

**neutral particles** reduce **performance**
Natural Insulators: Silica (SiO$_2$), Alumina (Al$_2$O$_3$)
Tend to neutralize SO$_3$: Lime (CaO), Magnesia (MgO)

*high resistivity → low particle migration velocity*
SO$_3$-Conditioning
Theory & Operating Results
with/without SO$_3$-Conditioning

Opacity
Plant Load

“Coal Spots”

Resistivity $\Omega/\text{cm}$

Temperature

- Normal Boiler Outlet Temperature Range
- No Conditioning
- 5 ppmv SO$_3$
- 10 ppmv SO$_3$

Novemvber 2016
SO$_3$-Conditioning Plant Layout

- **Air**
  - Compressor Air (dry)
  - Liquid Sulfur (140 °C)

- **Blower**

- **Air Heater**
  - 400 °C

- **Sulfur Burner**
  - (Self-ignition at 250 °C)

- **Catalyzer**
  - (450 °C)

- **Liquid Sulfur Tank (140 °C)**
- **Liquid Sulfur Pipe**

- **Condensate**

- **IP-Steam (secured)**
  - 3.5 bar

- **SO$_2$**

- **SO$_3$**

- **H$_2$SO$_4$**

- **H$_2$O**

- **Injection Nozzle Pipes**
  - SO$_3$ 350 °C
  - H$_2$SO$_4$
  - SO$_3$

- **Flue Gas**
  - 110 - 140 °C

- **M**
- **PI**
- **TI**
- **IP-Steam (secured)**

November 2016
SO$_3$-Conditioning
Sulfur Tank & SO$_3$ Pipe
Operation temperature: 135 °C, content: 36 metric tons

Sulfur Pumps

SO$_3$ Pipe to the injection point
SO₃-Conditioning
Control Panel (Container)
SO$_3$-Conditioning
Summary

- Great Flexibility for Coal Quality
- Keeping the future Emission-Limit of 20 mg/Nm$^3$ without expensive ESP-Extension
- Installation of the SO$_3$-Conditioning Plant during Operation. Only short outage necessary for assembly of the injection tube and nozzles
- Investment costs relatively low
- Operation and maintenance costs relatively low
- SO$_3$-Conditioning Plant fully integrated in the DCS
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