Siemens Fuel Gasification Technology
Status and New Developments

Siemens
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What is Gasification?

Feed is …
- Carbon (C)
- Hydrogen (H)
- Water (H₂O)
- Petcoke
- Liquid residues (e.g. refinery)
- Sulfur (S)
- Nitrogen (N)
- Ash (rock)
- Trace Elements (e.g. Vanadium)

Gasification is …
- Main Reactions:
  - C + ½ O₂ => CO
  - C + CO₂ ⇌ 2 CO
  - C + H₂O => CO + H₂
  - CO + H₂O ⇌ CO₂ + H₂

Products are …
- Syngas: H₂ + CO
- CO₂:
  - Carbon Sequestration (CCS)
  - Enhanced Oil Recovery (EOR)
- Utilization: e.g. Methanol

Coal

Chemicals

Synthetic natural gas

Transportation fuels

Iron

Refinery hydrogen

Power
Siemens Gasification Island Design (500MW size)

- Length: 18 meters
- Outside diameter (incl. flanges): 4.3 m
- Weight: 220 tons
- Capacity: ~ 2,000 tons of coal daily

Proprietary equipment

- Feeder vessel
- Burner
- Gasifier
Siemens offers Gasifier Types for every Feedstock

<table>
<thead>
<tr>
<th>Customer Value</th>
<th>Feedstock’s with more than 3 wt% ash content</th>
</tr>
</thead>
<tbody>
<tr>
<td>Economies of Scale</td>
<td>Lignite’s, Sub-bituminous and Bituminous coals, Hard coals,…</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Size classes</td>
<td></td>
</tr>
<tr>
<td>SFG-200</td>
<td>(150-250 MWth)</td>
</tr>
<tr>
<td>SFG-350</td>
<td>(250-350 MWth)</td>
</tr>
<tr>
<td>SFG-500</td>
<td>(400-600 MWth)</td>
</tr>
<tr>
<td>SFG-850</td>
<td>(650-850 MWth)</td>
</tr>
<tr>
<td>SFG-1000</td>
<td>(850-1000 MWth)</td>
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</tbody>
</table>

**Cooling Screen Design**

- Fuel
- Pressurized water inlet
- Pressurized water outlet
- Burner
- Oxygen, steam

**Refractory Wall Design**

- Burner insert
- Cooling wall
- Refractory lining
- SiC layer
- Cooling water
- Quench water
- Quench
- Total quench
- Gas outlet
- Cooled reactor outlet
- Gas outlet
- Granulated slag

**Feedstock’s with less than 2 wt% ash content**

- Petroleum coke, Bitumen, Tars, Oils, Asphaltenes, Biomass,…

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Refinery Application

Gasification of Petcoke and liquid residues could improve the refinery total efficiency and revenue by co-production of $\text{H}_2$, steam and power.
New Sour Gas Shift (SGS) Technology
Cooperation between Siemens and Clariant

- Inhibited Pre-Shift Catalyst ensures safe operation (no temperature runaway)
- Lower catalyst volume, CAPEX reduction
- No steam consumption, OPEX reduction
- Improves total plant efficiency by ~1%

<table>
<thead>
<tr>
<th></th>
<th>Standard Shift</th>
<th>Siemens/Clariant</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CAPEX</strong></td>
<td>100%</td>
<td>80%</td>
</tr>
<tr>
<td><strong>Consumption</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP Steam (42 bar)</td>
<td>-90</td>
<td>0</td>
</tr>
<tr>
<td><strong>Generation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP Steam (42 bar)</td>
<td>+132</td>
<td>+81</td>
</tr>
<tr>
<td>LP Steam (5.5 bar)</td>
<td>+235</td>
<td>+182</td>
</tr>
<tr>
<td><strong>Net Balance</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MP Steam (42 bar)</td>
<td>+42</td>
<td>+81</td>
</tr>
<tr>
<td>LP Steam (5.5 bar)</td>
<td>+235</td>
<td>+182</td>
</tr>
</tbody>
</table>
Test Facilities

Feeding and gasification/combustion test rigs

- Steam generator and Inert gas facility
- Pulverized fuel dosing and feeding system
- Slurry feeding system
- Waste water treatment and filter press
- Sulerox and Fe2O3 adsorption for desulphurisation
- Gasifier for coal, liquid waste and biomass
- Natural gas compressor and buffer vessel
- Inertgas compressor and buffer vessel
- Oxygen station with gas buffer
- Several cooling cycles and pump stations
- Medium voltage supply 20 kV
- Several low voltage supply systems 230/400 V
- Simatic I&C
Siemens Gasification main Project Landscape
as of November 2014

18 SFG-500 gasifiers shipped/installed for 5 projects
Additional 24 SFG-500 gasifiers being fabricated
NCPP
Reference Plant Achievements

Front view NCPP plant

SFG-500 achievements

- longest continuous single gasifier runtime: 160 d
- longest continuous plant runtime (4+1): 230 d
- total achieved plant availability: 92%
- CO + H2 content (effective syngas): > 92%
- fast start-up / shut-down capabilities: < 2 h
- high fuel flexibility: 7 to 28 % ash content

Commercial operation and high availability since 2011
in average more than 5300 t/d methanol production achieved
NCPP Site Impression

Gasifier during installation

Black water treatment plant

CO shift

Gasifier building

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Shenhua Ningxia Coal Group – 80.000 BBL/d CtL
World largest CtL Plant, Ningxia, China

Facts and Figures
- Gasifier manufacturing China
- **24 x 500 MW SFG gasifiers**
- Sub-bituminous coal
- Ash content: typ. 10–20 wt%
- Moisture: <30 wt%

Input / Output
- > 2,300 t/h coal input
- > 2,700,000 Nm³/h syngas
- 110 t/h Naphta
- 352 t/h Diesel
- 42 t/h LPG

Schedule
- PDP finished
- Hardware procurement ongoing
- Construction started
- 2016: Commissioning
Polygeneration – A Flexible Clean Fuel Utilization

- Gasification
- Gas Clean Up
- Power Generation
- Downstream Conversion Processes
- Chemical Feedstocks
- SNG
- Clean Transportation Fuels
- CO2 for Enhanced Oil Recovery
SFGT Based Advanced Polygeneration Concept

Addition of renewable power for auxiliaries (already today)

Processes not needed in case of sufficient power from renewables (long-term future)

Polygeneration allows stepwise integration of fossil and renewable energy
Up to 90% CO₂ reduction possible

Gasification

CO₂

Chemicals (Urea, SNG, MeOH, Diesel)

Power (to grid or for auxiliaries)

Addition of renewable power for auxiliaries (already today)

Air Separation

H₂O = H₂ + 0.5 O₂

“Green” H₂

H₂ for adjusting stoichiometric ratio (i.e., reduced/no CO shift and CO₂ capture)

“high” power demand

“high” power demand

H₂ Storage

O₂ Storage

Steam

Combined Cycle

Syntheses

Steam

Combined Cycle

O₂

O₂

O₂

H₂O = H₂ + 0.5 O₂

Polygeneration allows stepwise integration of fossil and renewable energy
Up to 90% CO₂ reduction possible
Summit Power, Texas Clean Energy Project

Key Features
- 200 MW green Power (90% carbon capture)
- 2 M tons-per-year CO2 for EOR
- 750 ktons-per-year Ammonia/Urea
- Project financed; Coal supply and offtake agreements (power, ammonia/urea and CO2)
- Total invest ~ $ 3 BN
- $ 450M direct funding from U.S. DoE plus up to $ 625M investment tax credits

Partners
- Owners group: Summit; Nobel; CHS; Siemens; HQC
- EPC Contractor Gasisland: HQC / SNC-Lavalin
- Technology suppliers: Siemens; Casale; Linde

Siemens Scope
- Power Island
- Gasifier Island Basic Engineering
- Supply of Gasifier, Feeder Vessel, Scrubbing system
- O+M Management

Customer: Summit Power Group
Location: Odessa, TX, USA
Plant type: Coal to Fertilizer and Power
Configuration: 1x SFG-850 Gasifiers plus SGT6-8000H gas turbine operating on H2 natural gas mixture
Financial Close: June 2015
Com. operation: December 2018

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## Innovation Concept SFG-1000

### Design evolution based on NCPP experience

<table>
<thead>
<tr>
<th>Innovation</th>
<th>Description</th>
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</table>
| **Capacity Expansion** | • 47 m³ reactor volume  
• 4000 t/d coal  
• 260000 Nm³/h CO+H₂ |
| **Process Design** | • Compact feeding  
• Improved water cycle  
• Filter cake recycle |
| **Equipment Design** | • Multiple Burner concept  
• Combination of water quench with fly ash washing capability |

[Diagram: Process Design Flowchart]
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