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Meeting the Asian energy demand with proven heavy duty Gas Turbines

Armin Städtler
8000H Product Manager
# Siemens heavy duty Gas Turbines

The right engine for every power category

<table>
<thead>
<tr>
<th>Model</th>
<th>Configuration</th>
<th>Max Power (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>50 Hz</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>SGT5-8000H</td>
<td></td>
<td>400</td>
</tr>
<tr>
<td>SCC5-8000H 1S</td>
<td></td>
<td>600</td>
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<tr>
<td>SCC5-8000H 2x1</td>
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<td>1200</td>
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<tr>
<td>SGT5-4000F</td>
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<td>307</td>
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<tr>
<td>SCC5-4000F 1S</td>
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<td>445</td>
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<tr>
<td>SCC5-4000F 2x1</td>
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<td>890</td>
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<tr>
<td>SGT5-2000E</td>
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<td>172</td>
</tr>
<tr>
<td>SCC5-2000E 1x1</td>
<td></td>
<td>253</td>
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<tr>
<td>SCC5-2000E 2x1</td>
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<td>512</td>
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<td><strong>60 Hz</strong></td>
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<td>SGT6-8000H</td>
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<td>SCC6-8000H 1S</td>
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<td>430</td>
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<td>SCC6-8000H 2x1</td>
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<tr>
<td>SGT6-5000F</td>
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<td>242</td>
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<tr>
<td>SCC6-5000F 1x1</td>
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<td>360</td>
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<tr>
<td>SCC6-5000F 2x1</td>
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<td>720</td>
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<td>SGT6-2000E</td>
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<td>114</td>
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<tr>
<td>SCC6-2000E 1x1</td>
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<td>171</td>
</tr>
<tr>
<td>SCC6-2000E 2x1</td>
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<td>342</td>
</tr>
</tbody>
</table>
SGT-2000E
Mature, robust, reliable

Two large external silo-type combustors with 2 x 8 hybrid burners for robust combustion allows full fuel flexibility

16-stage compressor with variable inlet guide vanes: fast-acting for grid frequency stabilization

Built disc-type rotor with radial Hirth serrations and one central tie bolt for fast start-up and easy maintenance

Bearing with Hydraulic Clearance Optimization HCO Fast starts w/o rubbing & performance enhancement

4-stage turbine, blades and vanes with Si3D design for enhanced performance
SGT-2000E
current design status

ISO Power: 180 MW
Efficiency: 35.5%

Latest improvement:
Compressor mass flow increase

Download of Hydraulic Clearance Optimization (HCO) from 4000F/8000H

Si3D aero-design enhancement
SGT-2000E: solutions for the full gas range

Standard combustion system covers wide Wobbe Range from 30 to 53 MJ/Nm³
# SGT-2000E Series Applications

<table>
<thead>
<tr>
<th>Customer Segment</th>
<th>Standard Fossil Power Generation</th>
<th>Oil &amp; Gas Business Applications</th>
<th>Industrial Applications</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td><strong>Application</strong></td>
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<tr>
<td>Simple Cycle</td>
<td>IGCC Plant</td>
<td>SSC (CO / HFO)</td>
<td>Power Generation for Oil &amp; Gas Applications</td>
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<tr>
<td>Combined Cycle</td>
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<td>SCC (HFO only)</td>
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<tr>
<td><strong>Fuels</strong></td>
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<tr>
<td>Natural Gas</td>
<td>SynGas</td>
<td>Crude Oil, HFO</td>
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<td>(H&amp;L)</td>
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<td>Light Fuel Oil</td>
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<tr>
<td><strong>Operation Mode</strong></td>
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<tr>
<td>Base, Cycling,</td>
<td>Baseload, Intermediate &amp;</td>
<td>Compressor Drive mode with the</td>
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<tr>
<td>Peaking mode</td>
<td>Peaking mode, dual fuel</td>
<td>option of electricity production</td>
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<tr>
<td>Dual fuel</td>
<td>operation</td>
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<tr>
<td><strong>GT Version</strong></td>
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</tr>
<tr>
<td>series</td>
<td>Drive</td>
<td>SGT-2000E series (CD; CO)</td>
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</tr>
<tr>
<td>SGT5-2000E</td>
<td></td>
<td>SGT-2000E (CD) as Geno-Drive</td>
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</tr>
<tr>
<td>(LC)</td>
<td></td>
<td>SGT5-2000E (LC)</td>
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</tr>
<tr>
<td>SGT-2000E (CO)</td>
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<td>SGT5-2000E (LC)</td>
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<tr>
<td></td>
<td></td>
<td>SGT-2000E series (CD; CO)</td>
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<td></td>
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</tr>
</tbody>
</table>
2000E experience:
Best-in-class fleet availability and reliability

Fleet operating experience
> 26 Mio EOH
> 279kEOH fleet leader
Fleet reliability is at 99.5%*
Fleet availability is at 95.4%*
Fleet starting reliability is at 97.3%*

*) 12-month rolling average as of April 2015

Paka, Malaysia
2 x SCC5-2000E 2x1

Paguthan, India
SCC5-2000E 3x1

SGT-2000E series: 585 units sold (373 Siemens units, 212 licensed units)
SGT-2000E series:
Fleet experience in 45 countries

EUROPE  50 Hz
- Finland  2
- Sweden  1
- UK  8
- Ireland  2
- Netherlands  3
- Belgium  6
- Germany  2
- Austria  1
- Slovakia  1
- Hungary  3
- Turkey  8
- Israel  5
- Russia  19

ME/ASIA  50 Hz
- Azerbaijan  2
- Iran  14
- Pakistan  8
- Oman  3
- UAE  8
- Bahrain  4
- Kuwait  8
- Yemen  7
- Iraq  14
- Jordan  2

ASIA  60 Hz
- Saudi Arabia  25
- Taiwan  21

AMERICA  60 Hz
- USA  51
- Mexico  2
- Dominican Rep.  1

AMERICA  50 Hz
- Chile  1
- Argentina  5
- Uruguay  2

AFRICA  50 Hz
- Libya  9
- Egypt  10
- Nigeria  8
- South Africa  14

AUSTRALIA  50 Hz
- Australia  16
SGT5-4000F: Proven design for highest operational benefit

**Rotor**
- Robust design w. internal cooling air passages for trusted long term operation and fast start capability
- Easy de-stacking on site due to Hirth serration and central tie rod

**Combustion System**
- Low NOx burners, for dry operation with gaseous & liquid fuels
- Homogeneous outlet profile for minimized mechanical and thermal turbine stress
- Annular chamber with individually replaceable heat shields for easy and fast walk-in maintenance

**HCO**
- Improved performance and minimized degradation by active control of clearances at start up and shut down

**Turbine**
- Four-stages with film cooling and thermal barrier coatings for well balanced turbine load and low lifecycle costs
- High cycling capability due to fully air cooled hot gas path without cooling air coolers

**Compressor**
- Proven design
- Rotating blades of all 15 stages replaceable w/o rotor lift

- Serviceability
- Flexibility
- Performance
Siemens Hydraulic Clearance Optimization (HCO) → High load gradients w/o penalty

- High operational flexibility (fast starts) at **low degradation**
- **Simple, fail-safe** and validated – for about 10 years retrofittable
- Performance increase 2 MW in simple cycle, 3 MW in CC
- 0.3 % pts. in SC and 0.2 % pts. in CC efficiency improvement

Cold start-up and high ramping flexibility w/o. lifetime penalty
SGT5-4000F: current design status

Latest improvement:
Compressor mass flow increase

SGT5-4000F Gas turbine

<table>
<thead>
<tr>
<th></th>
<th>1S</th>
<th>2x1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gross power output</td>
<td>307 MW</td>
<td></td>
</tr>
<tr>
<td>Gross Efficiency</td>
<td>40 %</td>
<td></td>
</tr>
<tr>
<td>Net power output</td>
<td>445 MW</td>
<td>890 MW</td>
</tr>
<tr>
<td>Net efficiency</td>
<td>58,7 %</td>
<td>58,7 %</td>
</tr>
</tbody>
</table>
SGT5-4000F
The largest advanced 50Hz F-Class fleet

**Chile, Argentina**
- 13 Units operating
- > 1 Mio EOH cumulated
- Fleet leader ~ 148,000 EOH

**Middle East**
- 83 Units operating
- > 3.5 Mio EOH cumulated
- Fleet leader ~ 119,000 EOH

**Europe**
- 115 Units operating
- > 5 Mio EOH cumulated
- Fleet leader ~ 131,000 EOH

**Asia**
- 59 Units operating
- > 2 Mio EOH cumulated
- Fleet leader ~ 115,000 EOH
SGT5-4000F
Unmatched availability & reliability

Fleet Experience:
>345 units sold; >270 units operating
> 12.5 Mio EOH cumulated
> 148.000 EOH (fleet leader)

Fleet reliability: 99,3%
Fleet availability: 95,8%
Fleet GT starting reliability: 97,6%

Status 08/2015, 12month average

reliable power supply – key for economical growth in Asia
SGT-8000H
Efficient, Flexible, Reliable

- **Evolutionary 3D blading**
  - 4 stages of fast acting variable-pitch guide vanes (VGV) allowing for improved part load efficiency and high load transients

- **Proven rotor design**
  - (Hirth serration, central tie rod, internal cooling air passages) for world class fast (cold) start and hot restart capability

- **HCO for reduced clearance losses**

- **Advanced Can Annular combustion system**

- **> 60% combined cycle efficiency**

- **3D Four stage turbine with advanced materials and thermal barrier coating**

- **High cycling capability** due to fully internally air cooled turbine section

- **Transient protection of clearances for reduced degradation with hydraulic clearance optimization (HCO) active clearance control**

- **Performance features**

- **Flexibility features**

**Designed for >60% efficiency in combined cycle and F-class operational flexibility and reliability**
Independent view on technology risk

- ~50% of failure mechanisms by compressor or turbine
- Main drivers are fatigue mechanisms from temperatures and loadings
- Long term validation needed (despite high costs of testing and ROI delay)


Uneven distribution of heat and unexpected problems with new materials can also arise with newer designs. Concerns over adequate testing of new technologies by original equipment manufacturers (OEM) are clearly well-founded in view of the overhead costs involved. Validating and testing new designs will ideally involve replicating the likely operating and demand conditions, which is an extremely expensive process.

Low cycle fatigue, erosion, corrosion and fretting are among time/start-stop dependent phenomena while creep and aging of Thermal Barrier Coatings are among those phenomena that depend on time and temperature. These effects are very difficult to estimate based on a few hundred hours of operation and require long term validation in the order of thousands of hours.
8000H Fleet leader Inspection
about 14,000 fired hours

Blade 4
SGT-8000H
Fast Growing Fleet of High Performance Gas Turbines

- 73 SGT-8000H have been sold
- 16 GTs are in commercial operation
- >155,000 Fired Hours cumulated

• (50Hz: 40; 60Hz: 33)
• (50Hz: 2; 60Hz: 14)
• (50Hz: 12; 60Hz: 122)
SCC5-4000F & SCC5-8000H
Standard Flexibility defined

Power

Flex Operation Line

Standard Operation Line

Time to Sync
5 min

Fast Start Up
Purge after shutdown
4F 30 MW/min
8H 35 MW/min
GT transient load gradient (for cold start)

Primary Frequency Response
3%/s GT Gradient
10% rated load jump

Secondary Frequency Response
4F 50 MW/min
8H 35 MW/min and higher
GT transient load gradient

Manual Operation
4F 50 MW/min
8H 35 MW/min and higher
GT transient load gradient

BLOC
Grid Sustaining at under-frequency

Peak Power
Extra Power by
- Evap cooler
- Inlet Chilling
- suppl. firing

Part Load
Lower Minimum Turndown
well below 50% CC load

Fast Shut Down
4F 30 MW/min
8H 35 MW/min
GT transient load gradient
Siemens Fossil Energy Portfolio
From Product to Plant

Power Plant
- Full Turnkey Power Plant

Power Block
- Power Island
  - Water/steam cycle
  - Closed cooling water system
  - HVAC
  - Cranes, lifting devices
  - Buildings & structures
  - Fire fighting

Power Island
- Power Train
  - Turbine Package
    - GT/GN/ST/Condenser
    - Auxiliary Systems
    - Enclosures
    - Air Intake
    - Power Control Center
  - Electrical equipment
  - DCS (implementation only, specification by partner or customer)

Power Train
- Power Train
  - HRSG
  - Main pumps
  - Cooling tower
  - Fuel gas performance preheating & final chance filter
  - DCS

Tailored Scopes and Solutions to fit all project needs
Proven Plant concepts
highest efficiency and operational flexibility

Specific features included in our advanced plant cycle design for most flexible and reliable operation
Thank You very much for Your Attention !!!
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