Meeting the Middle East Energy Demand with the Proven 8000H Series

Armin Städtler, Product Manager 8000H
Siemens Structure as of Oct 1 2014
Siemens Power and Gas
Contributing clean energy to the world

**Large Gas Turbines, Generators (PG GT)**
- Gas turbines from 100 to 400 MW
- Electrical generators from 25 up to 2,235 MVA
- Fuel gasifiers

**Distributed Generation (PG DG)**
- Industrial gas Turbines from 5 to 50 MW
- Aero derivative gas turbines from 4 to 64 MW***

**Steam Turbines (PG SU)**
- Steam turbines from 45 kW to 1,900 MW
- Steam turbines for industrial applications & power generation

**Compressors (PG CP)**
- Turbo compressors for
  - Oil & Gas
  - Industrial applications
- Compressor packages incl. drives

**Energy Solutions (PG ES)**
- 50 HZ and 60 HZ Gas turbine power plant solutions
- CHP*
- IGCC**
- Repowering
- Integrated solar combined cycle

**Instrumentation and Electrical (PG IE)**
- Control solutions
- Electrical solutions
- Energy management solutions
- Solutions for distributed and hybrid power generation

* Combined heat and power
** Integrated gasification combined cycle
*** After closing of acquisition from Rolls-Royce Energy. Regulatory approval pending.
Gas Turbine portfolio

50 Hz
- SGT5-8000H: 400 MW
- SGT5-4000F: 295 MW
- SGT5-2000E: 172 MW
- SGT6-8000H: 274 MW
- SGT6-5000F: 232 MW
- SGT6-2000E: 112 MW

60 Hz
- SGT6-8000H: 295 MW
- SGT6-5000F: 232 MW
- SGT6-2000E: 112 MW

Industrial Gas Turbines
- Large-scale Gas Turbines
  - 50 Hz
    - SGT-800: 47/50 MW
    - SGT-750: 37 MW
    - SGT-700: 33 MW
    - SGT-600: 24 MW
    - SGT-500: 19 MW
    - SGT-400: 13/14 MW
    - SGT-300: 8 MW
    - SGT-200: 7 MW
    - SGT-100: 5 MW

Product Naming:
- SGT = Siemens Gas Turbine
- SST = Siemens Steam Turbine
- SGen = Siemens Generator
- SCon = Siemens Condenser
- SGT-PAC = Siemens Gas Turbine Package
- SST-PAC = Siemens Steam Turbine Package
- SCC-PAC = Siemens Combined-Cycle Package
- SSC = Siemens Simple-Cycle (Power Plant)
- SCC = Siemens Combined-Cycle (Power Plant)
SGT5-2000E series
Reliable, robust, fuel flexible

SGT5-2000E: >450 units sold (>260 Siemens units, >180 licensed units)

Fleet operating experience

> 17’0 EOH
> 270 kEOH fleet leader

Fleet reliability is at > 99%*
Fleet availability is at > 96%*

Az Zour (Kuwait), CCPP
8xSGT5-2000E

Muara Tawar (Indonesia), SCPP
6xSGT5-2000E

*) 12-month rolling average as of December 2013

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October, 2014
PowerGen Middle East, Abu Dhabi
SGT5-4000F series
Trusted operational excellence

SGT5-4000F: >330 units sold (>310 Siemens units, 16 licensed units)

Fleet operating experience
>10’6 EOH
>136kEOH fleet leader

Fleet reliability = 99.4%*
Fleet availability = 95.9%*

Glow (Thailand)
CCPP, 1x1

Antalya (Turkey)
CCPP, 2x1

*) 12 Month rolling avg. Dec 2013)
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

Proven efficiency, flexibility and reliability in 11 commercial applications already
SGT-8000H
Rotor & Compressor

**Rotor**
- Disc type, central tie rod
- Self-centering and -aligning discs with hirth serration
- Light and stiff design with internal air passages for faster thermal transients
- Axial & radial bearing at compressor with HCO

**Compressor**
- 13 stages
- 4 variable guide vanes
- Vane carriers at rear stages for clearance control
- Flat flow path for HCO
SGT-8000H
Combustion & Turbine

Combustion System
- Can combustion system, gas & oil #2
- 5-stages for emission compliance over wide load range
- Combustor hardware is removable without cover-lift
  - Combustion firing level, TIT and RIT at similar level as for G-engines

Turbine
- Four stage turbine w. on-board air cooling, supply pressure control
- b1, v1, b4 removable without cover lift
- Single turbine vane carrier for shorter outages and conical flow path with HCO
SGT-8000H
Hydraulic clearance optimization HCO

HCO – simple and fail-safe turbine clearance protection

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October, 2014		PowerGen Middle East, Abu Dhabi
A. Städtler, Siemens Power & Gas,
The SGT-8000H concept uses proven features from Siemens and Westinghouse design heritage, avoiding risky new technologies.
Siemens SGT-8000H series
Technology step

Design base:
Siemens advanced frames*
>500 units in operation
avg. availability: >95%
avg. reliability: >99%

Firing temperature increase
~ 20K
compared to proven design

Massflow increase
~ 5%
compared to proven design

Pressure Ratio increase
~ 0.5 bar
compared to proven design

* Several of the following criteria is met: GT efficiency >38%,
4 stage turbine, TBC with advanced cooling, at least 1400°C firing temperature level

Moderate and evolutionary design step - especially in the high risk areas
What can You expect from SGT-8000H?

Current Status of F-Class Fleet

<table>
<thead>
<tr>
<th>Frame</th>
<th>Availability</th>
<th>Reliability</th>
<th>Start Reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGT6-5000F (~150 units reporting)</td>
<td>94.9%</td>
<td>99.3%</td>
<td>94.3%</td>
</tr>
<tr>
<td>SGT5-4000F (~200 units reporting)</td>
<td>95.6%</td>
<td>99.1%</td>
<td>97.0%</td>
</tr>
<tr>
<td>Siemens Advanced Frames (50/60 Hz)</td>
<td>95.4%</td>
<td>99.3%</td>
<td>95.8%</td>
</tr>
</tbody>
</table>

Expectation SGT-8000H

8000H is based on 4000F and 5000F heritage without adding significant technology /risks, so the expectation is that 8000H will see similar values mid term

Experience SGT-8000H

The 8000H fleet leaders have the following status:
- >98% availability (no major outage yet)
- >98.9% reliability
- >99% start reliability

Availability and Reliability are expected to be on same level as proven F-Class. Current 8000H operating experiences perfectly underline this expectation.
SGT-8000H
Direct scaling approach

Scaling rules 50Hz to 60Hz version

<table>
<thead>
<tr>
<th>50Hz</th>
<th>60Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed</td>
<td>x 1.2</td>
</tr>
<tr>
<td>Dimensions</td>
<td>/ 1.2</td>
</tr>
<tr>
<td>Power, Mass Flow</td>
<td>/ 1.44</td>
</tr>
<tr>
<td>Stresses &amp; Temperatures</td>
<td>x 1.0</td>
</tr>
<tr>
<td>Efficiency</td>
<td>x ~1.0</td>
</tr>
</tbody>
</table>
### SCC-8000H series

**Performance and configuration overview**

<table>
<thead>
<tr>
<th>Configuration</th>
<th>50 Hz</th>
<th>60 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGT-PAC 8000H</td>
<td>400 MW</td>
<td>286 MW</td>
</tr>
<tr>
<td></td>
<td>40 %</td>
<td>40 %</td>
</tr>
<tr>
<td>SCC-8000H 1S</td>
<td>600 MW</td>
<td>430 MW</td>
</tr>
<tr>
<td>SCC-8000H 1x1</td>
<td>&gt; 60 %</td>
<td>&gt; 60 %</td>
</tr>
<tr>
<td>SCC-8000H 2x1</td>
<td>1.200 MW</td>
<td>860 MW</td>
</tr>
<tr>
<td></td>
<td>&gt; 60 %</td>
<td>&gt; 60 %</td>
</tr>
<tr>
<td>SCC-8000H 3x1</td>
<td>- -</td>
<td>1.290 MW</td>
</tr>
<tr>
<td></td>
<td>- -</td>
<td>&gt; 60 %</td>
</tr>
</tbody>
</table>
SGT-8000H gas turbine series
Scaling and validation approach

Validation SGT5-8000H
Irsching-4 Plant
Testing in simple & combined cycle

Scale
50Hz → 60Hz

Validation SGT6-8000H
Berlin Test Center
Testing in grid-independent environment

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<tr>
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<tbody>
<tr>
<td>50Hz</td>
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<td>60Hz</td>
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</tbody>
</table>

8000H philosophy: keep the risk inhouse by thorough GT validation before customer rollout
Validation hot topics
What testing can prove

<table>
<thead>
<tr>
<th></th>
<th>fully instrumented test bed</th>
<th>Commercial project</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>base load</td>
<td>part load</td>
</tr>
<tr>
<td>GT Design Concept</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>GT Performance</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>GT vibration behaviour</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>GT grid code compliance</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>GT long term integrity</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>Plant integration (&amp; schedule)</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>CC operation &amp; performance</td>
<td>☐</td>
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</tr>
</tbody>
</table>

Siemens’ comprehensive testing approach covered all relevant aspects for GT and combined cycle – and it is completed successfully
SGT5-8000H
Technology proven at Ulrich Hartmann CCPP

22.07.2011 PAC/Commercial Operation

May 2012 12.000 EOH 1. Comb. Inspection
day

engine in excellent condition

June 2014 >16.000 EOH Opportunistic Inspection
day

engine in excellent condition

Engine in excellent condition. Lifetime prediction confirmed.

* According IR4 contract definition

A. Städtler, Siemens Power & Gas,
### Fleet status

#### Leading Units

<table>
<thead>
<tr>
<th>Leading Units</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
<th>2016</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>50Hz (Germany)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>60Hz (USA)</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>60Hz (Korea)</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
<tr>
<td>60Hz (Korea)</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>60Hz (USA)</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>60Hz (Korea)</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>50Hz (Turkey)</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>50Hz (Germany)</td>
<td>1</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1</td>
</tr>
<tr>
<td>50Hz (Malaysia)</td>
<td>2</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td>2</td>
</tr>
</tbody>
</table>

#### EOH (Equivalent Operating Hours)

- **Total**
- **50Hz**
- **60Hz**

>100k EOH and >1800 starts have been accumulated
38 SGT-8000H sold - 11 GTs in commercial operation - p, eff. & timeline met

⇒ Siemens 8000H is the first successful H-class in the market
The air-cooled SGT-8000H design together with validated concepts enable fast project implementation.

- USA: 5 weeks ahead of schedule
- USA: 2 months ahead of schedule
- Korea: 2 weeks ahead of schedule
- Korea: 24 months execution time

SGT-8000H Commissioning times are on same level as proven F-Class
SGT-8000H
Technology application risk overview

<table>
<thead>
<tr>
<th>Compressor/Rotor</th>
<th>Hot gas Path</th>
<th>Plant design</th>
</tr>
</thead>
<tbody>
<tr>
<td>• replaceable b/v w.o. rotor lift (except IGVs)</td>
<td>• no firing temp increase</td>
<td>• No additional complexity</td>
</tr>
<tr>
<td>• Rotor destack on site</td>
<td>• Stage1 &amp; blade4 replaceable w.o. cover lift</td>
<td>• Simple plant integration</td>
</tr>
<tr>
<td>• HCO</td>
<td>• all b/v replaceable w.o. rotor lift</td>
<td>• Service friendly layout</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>risk reduction by design</th>
<th>risk reduction by validation</th>
<th>Plant design</th>
</tr>
</thead>
<tbody>
<tr>
<td>• 2005: full BTF test</td>
<td>• 2005: full BTF validation</td>
<td>• Irshching validation</td>
</tr>
<tr>
<td>• Irshching validation</td>
<td>• 2011: full load BTF validation</td>
<td>• 2011: BTF validation</td>
</tr>
<tr>
<td>• 2011: BTF validation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>commercial experience</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Fleet leader in operation since 07/2011 w.o. issues</td>
<td>• 3rd party EPC contracts handover on schedule</td>
</tr>
<tr>
<td>• In total 11 units in commercial operation w.o. issues</td>
<td></td>
</tr>
</tbody>
</table>

Customer risk
- ✓ Performance risk
- ✓ Functionality risk/cost (outside LTP)
- ✓ Delayed handover/commercial operation
- ✓ Unavailability (Unplanned / forced outages)

The proven SGT-8000H series does not increase any power projects risk
Summary SGT-8000H

- Designed & validated for robustness
- Proven in commercial operation (5 units over 8000 hours)
- Proven customer benefits
  - economy of size
  - no additional plant complexity
  - no added project risk

The proven SGT-8000H series is the perfect fit to meet the energy demand of the region
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