Siemens gas turbines overview

Heavy-duty gas turbines

Aeroderivative gas turbines

Industrial gas turbines

Industrial 501 (4 to 6 MW)
SGT-100 (5/6 MW)
SGT-200 (7/8 MW)
SGT-300 (8/8 MW)
SGT-400 (13 to 14/13 to 15 MW)

Industrial RB211 (27 to 32/28 to 34 MW)
SGT-500 (19/19 MW)
SGT-600 (24/25 MW)
SGT-700 (33/34 MW)
SGT-750 (38/39 MW)
SGT-800 (48 to 54 MW)
Industrial Trent 60 (53 to 66/54 to 62 MW)

Gas turbines in the range of 0-15 MW
Gas turbines in the range of 16-99 MW
Gas turbines in the range of 100-400 MW

Gas turbines in the range of 50 or 60 Hz

50 or 60 Hz

60 Hz
60 Hz
50 Hz

Gas turbines in the range of 100-400 MW

60 Hz
60 Hz
50 Hz

Gas turbines in the range of 100-400 MW

Gas turbines in the range of 50 or 60 Hz

Gas turbines in the range of 100-400 MW

50 Hz
60 Hz
SGT-800 Industrial gas turbine – Development and status timeline

310 units sold and >4 million fleet hours (Oct 2016)

Development start

Ratings offered to the market today


Evolutionary development step-by-step


Fleet Availability 97.4%
Fleet Reliability 99.5%
MTBF\(\text{(*)}\) 5265 h

Evaluation based on ISO 3977:9
\(\text{(*) Mean Time Between Forced outage}\)
The **SGT-800** industrial gas turbine combines a simple robust design, for high reliability and easy maintenance, with high efficiency and low emissions. It offers broad flexibility in fuels, operating conditions, maintenance concepts, package solutions and ratings.

The excellent efficiency and steam-raising capability makes it outstanding in cogeneration and combined cycle installations. The SGT-800-based power plant, designed for flexible operation, is perfectly suited as grid support.

With a proven, long-term record of successful installations around the world, the SGT-800 is an excellent choice for both Industrial Power Generation and Oil & Gas applications. From Simple Cycle operation to combined cycle with single or multiple units.
SGT-800 Core Engine Design
Available in three ratings 47.5, 50.5 and 54.0 MW(e)

Simple and robust

- Single shaft, with tilting pad type bearings
- Cold end drive
- All welded compressor rotor and bolted 3-stage turbine
- Annular combustor with passive damping
- Robust and Fuel Flexible Dual Fuel DLE system with on-line fuel changeover
- Stable load rejection and load addition capability
- Low gas pressure requirement 27-30 bar(a)
- High exhaust energy giving excellent Cogen / CC characteristics
- Hot and cold climate variants using standard options
- Onsite or offsite service concepts

Simple Cycle

<table>
<thead>
<tr>
<th>Power output</th>
<th>47.5 MW(e)</th>
<th>50.5 MW(e)</th>
<th>54.0 MW(e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical efficiency</td>
<td>37.7%</td>
<td>38.3%</td>
<td>39.1%</td>
</tr>
<tr>
<td>Exhaust gas flow</td>
<td>132.8 kg/s</td>
<td>134.2 kg/s</td>
<td>135.5 kg/s</td>
</tr>
<tr>
<td>Exhaust temperature</td>
<td>541 ºC</td>
<td>553 ºC</td>
<td>563 ºC</td>
</tr>
</tbody>
</table>
SGT-800 strengths are proven reliability, broad flexibility, high efficiency and low emissions

Field of application
- Simple cycle
- Combined Heat Power (CHP)
- Combined cycle power gen
- Power gen for the O&G industry

Available in three ratings
- 47.5 , 50.5 and 54.0 MW(e)

Strengths
- High efficiency in CC and Cogen applications
- Flexible and robust industrial design with high reliability and long time between major overhaul (60 000 EOH)
- A simple fuel flexible DLE system with excellent emission levels
- In situ maintenance or spare core engine removal to workshop. 48h core exchange with single lift package

Fleet ¹) 297 units ordered
- Industrial Power Generation
  - 255 units
    (of which 193 in CC application)
- Oil & Gas
  - 42 units for PG
    (of which 7 in CC application)

¹) Status end of May 2016

<table>
<thead>
<tr>
<th>Power Generation</th>
<th>47.5 MW Version</th>
<th>50.5 MW Version</th>
<th>54.0 MW Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power output [MW(e)]</td>
<td>47.5</td>
<td>50.5</td>
<td>54.0</td>
</tr>
<tr>
<td>Fuel</td>
<td>Natural gas. Options available for other gases within specification and dual fuel with gas and Diesel no2.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Frequency [Hz]</td>
<td>50 / 60</td>
<td>50 / 60</td>
<td>50 / 60</td>
</tr>
<tr>
<td>(Electrical) Efficiency</td>
<td>37.7%</td>
<td>38.3%</td>
<td>39.1%</td>
</tr>
<tr>
<td>Heat rate [kJ/kWh / Btu/kWh]</td>
<td>9,547 / 9,048</td>
<td>9,389 / 8,899</td>
<td>9,206 / 8,725</td>
</tr>
<tr>
<td>Turbine speed [rpm]</td>
<td>6,608</td>
<td>6,608</td>
<td>6,608</td>
</tr>
<tr>
<td>Compressor pressure ratio</td>
<td>20.1:1</td>
<td>21.0:1</td>
<td>21.4:1</td>
</tr>
<tr>
<td>Exhaust gas flow [kg/s] / Temperature [°C]</td>
<td>132.8 / 541</td>
<td>134.2 / 553</td>
<td>135.5 / 563</td>
</tr>
<tr>
<td>NOx Emissions (with DLE, corrected to 15% O2 dry)</td>
<td>≤15 ppmV</td>
<td>≤15 ppmV</td>
<td>≤15 ppmV</td>
</tr>
</tbody>
</table>
Absence of burner staging allows for rapid load changes. Continuous flow in fuel pipes in entire load range.
### SGT-800 Industrial gas turbine – DLE combustion system capability

<table>
<thead>
<tr>
<th>Burner type</th>
<th>Fuel</th>
<th>NO\textsubscript{x} @ 15% O\textsubscript{2}</th>
<th>CO @ 15% O\textsubscript{2}</th>
<th>NMVOC @ 15% O\textsubscript{2}</th>
<th>PM10 (incl CPM)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas burner</td>
<td>Natural gas</td>
<td>≤ 15* ppmv</td>
<td>≤ 5 ppmv</td>
<td>1 ppm</td>
<td>1.5 lb/h</td>
</tr>
<tr>
<td>Dual fuel burner</td>
<td>Natural gas</td>
<td>≤ 15 ppmv</td>
<td>≤ 5 ppmv</td>
<td>1 ppm</td>
<td>1.5 lb/h</td>
</tr>
<tr>
<td>(15-20% of total sales)</td>
<td>Diesel No.2</td>
<td>≤ 25-42 ppmv</td>
<td>≤ 5 ppmv</td>
<td>6 ppm</td>
<td>3 lb/h</td>
</tr>
</tbody>
</table>

* < 9 ppmv available with conditioned operation parameters

Emission Guarantees are issued separately in each project, depending upon site conditions, required load range and other project specific data.
SGT-800 Gas Turbine Power Generation – Measured NOx and CO (DLE) on Natural Gas

Impressive NOx and CO performance demonstrated
SGT-800 Gas Turbine Power Generation
– Operational Flexibility

- Robust DLE system to handle transients like
  - Full load rejection with < 5% over speed
  - Large load steps – high inertia single shaft
  - Quick start capability – full load in 10 min

Flexible + Reliable = SGT-800

Absence of burner staging allows for rapid load changes. Continuous flow in fuel lines.
SGT-800-based Power Plant

- Industrial Power Plants for Combined Cycle and Combined Heat and Power

- Plant scope flexibility
  From gas turbine and steam turbine only, to full turnkey plant

- One or multiple SGT-800 gas turbines provide the core of a powerful combined-cycle plant
  >56% CC net efficiency

- High exhaust gas temperature of SGT-800 for excellent steam-raising capability
  >90% CHP efficiency

- EconoFlex™: Flexible combined cycle power plant
  Grid support: Perfectly suited as back-up to renewable power sources in the grid. 10-minute start, frequent starts and stops, fast load-following

- Island mode operation
- Multiple power blocks
- Phased construction

**Simple Cycle**

<table>
<thead>
<tr>
<th>Power output</th>
<th>47.5 MW(e)</th>
<th>50.5 MW(e)</th>
<th>54.0 MW(e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electrical efficiency</td>
<td>37.7%</td>
<td>38.3%</td>
<td>39.1%</td>
</tr>
</tbody>
</table>

**Combined Cycle 1x1**

<table>
<thead>
<tr>
<th>Net plant output</th>
<th>66.6 MW(e)</th>
<th>71.4 MW(e)</th>
<th>75.9 MW(e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net plant efficiency</td>
<td>53.8%</td>
<td>55.1%</td>
<td>56.0%</td>
</tr>
</tbody>
</table>

**Combined Cycle 2x1**

<table>
<thead>
<tr>
<th>Net plant output</th>
<th>135.4 MW(e)</th>
<th>143.6 MW(e)</th>
<th>153.7 MW(e)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net plant efficiency</td>
<td>54.7%</td>
<td>55.4%</td>
<td>56.7%</td>
</tr>
</tbody>
</table>
EconoFlex™
– Plant Indicative Performance

Starts (<12h shut down):
- 230 MW 3x1 (w DF) configuration
  - Full load CTG 150 MW within 10 minutes
  - Full plant load, including STG within 40 min

Emissions Compliant Ramp Rate:
- 10 MW/min/CTG between Pmin and Pmax while emission compliant
- 30 MW/min with 3 CTGs ramping plus STG following ramp

• Efficiency:
  - Multiple small CTG units giving good turndown ratio and excellent part load heat rate

Emissions:
- 10% turndown on a 230 MW with 3x1 configuration

* CTG @ 100% & witt HRSG duct fired to 1,300 F

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### SCC-800 3x1C

<table>
<thead>
<tr>
<th></th>
<th>1x1</th>
<th>2x1</th>
<th>3x1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant Net Power</strong> (Pmax with duct fired*)</td>
<td>MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>72</td>
<td>151</td>
<td>230</td>
</tr>
<tr>
<td><strong>Net Efficiency, HHV</strong></td>
<td>BTU/kWh</td>
<td>7,812</td>
<td>7,477</td>
</tr>
<tr>
<td><strong>Plant Net Power</strong> (Pmax with out duct fired)</td>
<td>MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>65</td>
<td>135</td>
<td>206</td>
</tr>
<tr>
<td><strong>Net Efficiency, HHV</strong></td>
<td>BTU/kWh</td>
<td>7,538</td>
<td>7,167</td>
</tr>
<tr>
<td><strong>Plant Net Power</strong> (Pmin with out duct fired)</td>
<td>MW</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>22</td>
<td>50</td>
<td>78</td>
</tr>
<tr>
<td><strong>Net Efficiency, HHV</strong></td>
<td>BTU/kWh</td>
<td>10,774</td>
<td>9,537</td>
</tr>
</tbody>
</table>

---

Combined Cycle Economy with Simple Cycle Flexibility

Approximate performance: free & clean, natural gas, 60°F @ 14.891 psi

1CTG 30% load
2CTG 30% load
3CTG 30% load
HRSG DF 1,300 F

EconoFlex™
“Economy with Simple Cycle Flexibility”
**EconoFlex™ – Green House Gases**

**Multi-stage Generating Power Block**
- Based on 54 MW SGT-800 gas turbine
- Offered in Power Blocks with multiple CTGs, each with 99% reliability, provide unparalleled plant reliability
- Designed primarily for sequential ramping so that CTGs are predominantly operating at base load efficiency, even when plant is at part load.

**Exceptional Turndown & Part Load Heat Rate**
- Allows economical turndown and load following
- Possibly the very best **average** heat rate
- Possibly the lowest GHG emission rate (i.e. BACT)
- Economical turndown maintains STG readiness for fast restart of CTGs that have been shut down

**CO2 emissions are below over a wide operation range 1,000 lb/MWh (40-240M)**

<table>
<thead>
<tr>
<th>SCC-800 3x1C</th>
<th>1x1</th>
<th>2x1</th>
<th>3x1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Plant Net Power</strong>&lt;br&gt;(Pmax with duct fired*)</td>
<td>MW</td>
<td>72</td>
<td>151</td>
</tr>
<tr>
<td><strong>Green House Gases</strong>&lt;br&gt;lb/MWh(g)</td>
<td>889</td>
<td>886</td>
<td>866</td>
</tr>
<tr>
<td><strong>Plant Net Power</strong>&lt;br&gt;(Pmax with out duct fired)</td>
<td>MW</td>
<td>65</td>
<td>135</td>
</tr>
<tr>
<td><strong>Green House Gases</strong>&lt;br&gt;lb/MWh(g)</td>
<td>855</td>
<td>831</td>
<td>823</td>
</tr>
<tr>
<td><strong>Plant Net Power</strong>&lt;br&gt;(Pmin with out duct fired)</td>
<td>MW</td>
<td>22</td>
<td>50</td>
</tr>
<tr>
<td><strong>Green House Gases</strong>&lt;br&gt;lb/MWh(g)</td>
<td>1,136</td>
<td>1068</td>
<td>1041</td>
</tr>
</tbody>
</table>

* CTG @ 100% & with HRSG duct fired to 1,300 F
**EconoFlex™**  
– Expected CCPP emissions per stack

### Fast Start Up:
- 10 minute startup to 50 MW/CTG
- 150 MW for 3x1 simultaneous CTG start
- 35 minute to combined cycle base load (VWO) Hot start (< 12 hr. shutdown) Simultaneous CTG startup

### Ramping up/down:
- Automatic Generation Control (AGC) of the combined CTG & STG output between Pmin and Pmax, including HRSG duct firing
- Load Sharing control of nxCTG & STG output between Pmin and Pmax, while emission compliant

### Optional Synchronous Condenser Mode:
- Each CTG is supplied with SSS clutch to allow generators to remain synch’ed when CTGs are shut down
  - Minimizes CC operation by providing inertia to grid and stabilizing grid when upsets occur when plant or power block is shut down.

### Stack Emissions

<table>
<thead>
<tr>
<th>Stack Emissions</th>
<th>Expected Values</th>
</tr>
</thead>
<tbody>
<tr>
<td>3xCTG 100%</td>
<td></td>
</tr>
<tr>
<td>NO₂ @ 15% O₂ dry</td>
<td>lb/h</td>
</tr>
<tr>
<td>w/o SF*</td>
<td>3.5</td>
</tr>
<tr>
<td>w SF*</td>
<td>3.6</td>
</tr>
<tr>
<td>NH₃ slip</td>
<td>lb/h</td>
</tr>
<tr>
<td></td>
<td>3.3</td>
</tr>
<tr>
<td>CO @ 15% O₂ dry</td>
<td>lb/h</td>
</tr>
<tr>
<td></td>
<td>2.2</td>
</tr>
<tr>
<td>VOC @ 15% O₂ dry (as CH₄)</td>
<td>lb/h</td>
</tr>
<tr>
<td></td>
<td>2.5</td>
</tr>
<tr>
<td></td>
<td>2.6</td>
</tr>
<tr>
<td>PM2.5 &amp; CMP</td>
<td>lb/h</td>
</tr>
<tr>
<td></td>
<td>1.4</td>
</tr>
<tr>
<td></td>
<td>2.1</td>
</tr>
<tr>
<td>PM 10 – (2.5 &amp; CMP)</td>
<td>lb/h</td>
</tr>
<tr>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td></td>
<td>0.15</td>
</tr>
<tr>
<td><strong>Total PM10</strong></td>
<td>lb/h</td>
</tr>
<tr>
<td></td>
<td>1.5</td>
</tr>
<tr>
<td></td>
<td>2.25</td>
</tr>
</tbody>
</table>

* Emission per CTG stack after emission control system
EconoFlex™ – Excellent transient response

- **Strong Transient response**, up to 70% step load within 10 seconds, initial response 10 MW/s, per CTG.
- **High Inertia Single Shaft** design reduces **Rate of Change of Frequency** (RoCoF) in a transient situation.
- **In Load Control** mode a changed load set point results in **ramped output**, up to 150 kW/s, per CTG.
- **Grid Frequency Disturbance** transient responses as per above, 10 MW/s with no load control ramping.
- No restrictions to Power Management System or regulation (including AGC) with respect to load sharing/shedding, the **DLE does not hamper / limit** the CTG control response.
- **High Grid Stabilization** service through rotor train inertia and generator reactive capability, which can be increased by oversized generator.

2.5 Hz frequency drop for a 70% (33 MW) instantaneous load step
SGT-800 – about 4 million operating hours
Fleet experience in all regions

310 Siemens SGT-800 are under contract
thereof 268 units for Industrial Power Generation
42 units in Oil & Gas applications

NORTH AMERICA
USA 11

EUROPE
Austria 1
Belgium 2
France 3
Germany 17
Italy 2
Latvia 2
Lithuania 1
Malta 3
Netherlands 2
Poland 2
Portugal 2
Slovenia 3
Sweden 4
Switzerland 2
Turkey 6
UK 2

RUSSIA & CIS
Belarus 1
Kazakhstan 6
Russia 51
Ukraine 4

ASIA
China 8
Indonesia 2
Singapore 2
South Korea 6
Thailand 64

LATIN AMERICA
Argentina 8
Bolivia 23
Colombia 3
Peru 1
Venezuela 3
Other countries 13

AFRICA
Algeria 2
Egypt 3
Libya 5
Nigeria 3
Tanzania 3

MIDDLE EAST
Iraq 11
Israel 6

AUSTRALIA
Australia 17

Other countries 13
# SGT-800 Gas Turbine Reference
- **Roseville Energy Park – Combined Cycle Utility**

## Project Summary

<table>
<thead>
<tr>
<th>Project / Country</th>
<th>Roseville Energy Park, USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer</td>
<td>Roseville Electric</td>
</tr>
<tr>
<td>Application</td>
<td>Combined Cycle power generation plant</td>
</tr>
</tbody>
</table>
| Technology            | 2 x SGT-800 gas turbines and 1 x SST-900 steam turbine  
Electricity generated: 120 MW nominal to 160 MW peak |
| Start                 | 2005                      |
| Complete              | 2007                      |
| **Challenge**         |                           |
| Public power reliability  |                           |
| Absent competitive options |                           |
| Led the city to explore self-generation of its electricity |                           |
| **Solution**          |                           |
| Two SGT-800 gas turbines and a SST-900 steam turbine can be used independently to allow the municipality to use its own resources in varying combinations to meet the prevailing power needs of the community |                           |
| Use of the current power grid depending on prevailing costs or highest efficiency |                           |
| **Benefits**          |                           |
| Higher base-load (unfired) output and higher efficiency |                           |
| Summer peaking resources during normal operations are no longer an event |                           |
| The city is able to consistently produce power at rates below the state power grid |                           |
| Natural gas fuel supports the city’s philosophy of reducing environmental harm |                           |
# SGT-800 Gas Turbine Reference

## – El Centro – Combined Cycle Power Island Utility

<table>
<thead>
<tr>
<th>Project Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Project / Country</strong></td>
</tr>
<tr>
<td><strong>Customer</strong></td>
</tr>
</tbody>
</table>
| **Application** | Combined Cycle Power Island
  Used as a Load Following/Balancing Plant because of number of renewables on the system. Fast ramps achieved for successful operation of the plant. |
| **Technology** | 2 x SGT-800 gas turbines, 1 x SST-600 steam turbine, 2 x HRSG, 1 x condenser
  Electricity generated: 144 MW |
| **Start** | 2010 |
| **Complete** | 2012 |
| **Challenge** | • Reliably energy supply to approximately 145,000 customers in Imperial and parts of Riverside and San Diego countries.
  • Repower the aging facility to meet the needs of customers using efficient and clean sources of energy |
| **Solution** | • Two SGT-800 natural gas turbine generators, two heat recovery steam generators, a condenser and a Siemens SST-600 steam-turbine generator installed in a combined cycle configuration
  • State-of-the-art NOx and CO emissions control systems |
| **Benefits** | • Increased power output with state-of-the-art combined cycle technology
  • Improved fuel efficiency over prior technology
  • Control technology will save water
  • Designed for challenging emission regulations |

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# SGT-800 Gas Turbine Reference
## – City of Holland – Combined Heat and Power Utility

## Project Summary

<table>
<thead>
<tr>
<th>Project / Country</th>
<th>Holland Energy Park, USA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer</td>
<td>Holland Board of Public Works</td>
</tr>
<tr>
<td>Application</td>
<td>Combined Heat and Power Plant</td>
</tr>
<tr>
<td>Technology</td>
<td>2 x SGT-800 gas turbines, 1 x SST-400 steam turbine DCS SPPA-T3000 Electricity Generated: 125 MW in summer and 145 MW in winter</td>
</tr>
<tr>
<td>Start</td>
<td>2014</td>
</tr>
<tr>
<td>Complete</td>
<td>Planned 2016</td>
</tr>
</tbody>
</table>
| Challenge               | • Old, coal-fired generation station along the city’s water front which is insufficient for the growing energy demand  
                          • Heat needs of the expanding underground snowmelt system operated from the thermal energy from the power plant |
| Solution                | • A Combined Cycle solution with two SGT-800 gas turbines and a SST-400 steam turbine provides the cost efficient power  
                          • Waste heat from the circulating water system will provide heat for the expanded snowmelt system. |
| Benefits                | • Higher thermal efficiency of the plant  
                          • Reduced fuel costs using less expensive natural gas supplies  
                          • Expansion of the snow melt footprint for the City’s downtown businesses  
                          • Capability for future expansion  
                          • Reduced emissions by using natural gas (cleaner fuel and more environmentally friendly than a traditional coal-fired plant)  
                          • CO2-emissions at the site will be reduced by approximately 50% |
Thank you

Stefan Linder
Regional Director

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Power and Gas Division

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Fax: +1 281 856 4499
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