SGT-800 GAS TURBINE
CONTINUED AVAILABILITY AND
MAINTAINABILITY IMPROVEMENTS

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**Summary**

Continued enhancement of existing OEM (Original Equipment Manufacturer) products and services is an important part of the OEM’s development efforts. In order to offer, to both future and existing users, gas turbines with high grading for efficiency, reliability, availability and maintainability at low life-cycle cost, Siemens Energy invests significantly and with continuity in the development of its products and services.

Recently, some of the results of these extensive research and development (R&D) programs have been implemented in the SGT-800 gas turbine and its maintenance. This has resulted not only in a power output/efficiency increase from 45 MW/37% to 47 MW/37.5%, but also in a simultaneous increase of the turbine’s availability of about 1% [1-2].

The R&D programs behind these achievements have addressed not only further development of advanced materials and designs for hot gas path components, but also serviceability and maintainability improvement, including advanced repair, non-destructive inspection technology, remote monitoring and diagnostics, and new maintenance concepts with extended maintenance intervals [3].

Operational experience accumulated since 2006 on performed upgrades has confirmed the improvement of power output and efficiency as well as the reliable operation of the new components [2].

**Nomenclature**

SGT - Siemens Gas Turbine  
OEM - Original Equipment Manufacture  
DLE - Dry Low Emission  
R&D - Research and Development  
TBC - Thermal Barrier Coating  
EOH - Equivalent Operating Hours  
CBM – Condition-Based Maintenance  
RE - Rotating equipment  
MP - Maintenance Plan  
RMS – Remote Monitoring System  
CMS – Condition-Monitoring System  
LTP – Long-Term Program  
MTBF - Mean Time Between Failures

**Development history**

The development of the SGT-800 gas turbine (originally known as the GTX100) was started in 1994. The introductory rating was 45 MW power output with a 37% electrical efficiency (ISO) in
open cycle and at 64 MW with 53% efficiency in combined cycle [4]. The first unit was installed in 1997 and by December 2008 a total of 85 units have been sold. Systematic analysis of operating experience has supported continuous product improvement and in 2006 an enhanced SGT-800 with power rating 47 MW at 37.5% electrical efficiency (ISO) in open cycle was introduced by Siemens Energy [1-2]. Since 2006 up to December 2008 a few units from the existing SGT-800 fleet have been upgraded to 47MW power output. Operational experience from upgraded units has confirmed a potential extension of maintenance intervals for upgraded SGT-800 units from 20,000 EOH to 30,000 EOH. The first commercial implementation of this new maintenance plan with extended intervals in one of the upgraded units is planned for mid-2009.

**SGT-800 gas turbine design features**

![Figure 1: SGT-800 gas turbine cross-section](image)

**Compressor design features**

A 15-stage axial compressor (see Figure 1) with pressure ratio of almost 20 has the following design features:

- electron-beam welded compressor rotor (enables: - low vibration; - straightforward torque transfer; - good control of blade tip clearances and still the possibility to replace individual blades in situ),
- stator rings above the rear-stage blades are made from material with low heat-expansion coefficient and are coated with an abradable coating to provide smooth rubbing and minimum radial clearance. Casings in the front stages are also coated with an abradable coating for the same reasons,
- the compressor casing has a vertical-split plane to provide good access to the compressor components for inspection,
- variable guide vanes on 3 stages,
In order to restore compressor performance and to reduce the maintenance cost, the reconditioning and repair processes are under continuous development. At present such processes are available for the following compressor components: - compressor casing and stator rings (recoating of abradable coating to restore the compressor performance by means of restoration of radial clearance); - repair of the rotor seals and stator Honeycombs.

Compressor components are repaired on condition (when it is necessary).

**Combustor design features**

The SGT-800 combustor (see Figure 2) has an annular design and represents Siemens’ third generation of Dry Low Emission (DLE) combustors with low emission levels in the range of 50%-100% load:

- **Natural gas**: NOx: < 15 ppm @15% O₂, CO: < 5ppm,
- **Diesel #2**: NOx: < 42 ppm @15% O₂, CO: < 5ppm (no water or steam injection).

The SGT-800 combustor has single-fuel and dual-fuel capability.

An annular combustion chamber enables the following advantages: it requires less cooling air due to less hot-surface area and better flow inlet into the turbine; simple cross-ignition during start-up. The SGT-800’s low-emission combustor has a convective cooling system and is coated with a Thermal Barrier Coating (TBC). The burners are of a retractable design, which provides high maintainability of the combustor. There are 30 burners in the SGT-800 combustor.

The technology used is lean, pre-mixed fuel in a four-slotted cone/burner (see Figure 3). The technology of the combustion is simple, with no moving parts and just two control valves for pilot gas and main gas. No staging is used for the combustion. No time-based mapping is required, as there are no parameters within the control system that drift over time.

To provide reliable operation and to avoid damage to combustor components, the SGT-800 combustor is equipped with a pulsation-monitoring system.

**Figure 2**: SGT-800 annular DLE combustor  
**Figure 3**: 3rd generation DLE burner
Development of repair solutions for the SGT-800 combustor is an essential part of Siemens’ cost reduction program. Currently the developed reconditioning and repair processes of the combustion chamber:

- local weld repair,
- exchange of outer and inner liners and front panel,
- TBC recoating,
- repairs of the burners.

are included in the standard maintenance plan.

**Turbine design features:**

- the SGT-800 turbine (see Figure 4) has a three-stage design. First- and second-stage blades and vanes are cooled, third-stage blades and vanes are uncooled, all three turbine disks are cooled,

![Figure 4: SGT-800 three-stage turbine](image)

- the turbine stator is equipped with a cooling arrangement to provide radial clearance control,
- the turbine section is handled as a module to support high maintainability,
- first- and second-stage blades are shroudless. Single crystal blades on the first stage have a film and convective cooling system, blades on the second stage have a convective cooling system,
- third-stage blades are shrouded,
- first-stage guide vanes are single and have a film and convective cooling system. Inner and outer platforms of the guide vane are coated with TBC and have an impingement cooling system,
• second-stage guide vanes are single have a convective cooling system. Inner and outer platforms of the guide vane are coated with TBC and have an impingement cooling system,
• all blades and vanes are coated with oxidation-resistant coatings,
• to minimize the leakages on the third stage, third-stage vanes are integrated into segments, each segment consisting of two vanes.

Currently the following repair capabilities are included in the standard maintenance plan:
• weld repair and recoating of blade 1. The latest repair solution is based on laser welding technology (laser cladding),
• weld repair of vanes 1 and 2
• recoating of vanes 1 and 2..

**SGT-800 47MW rating**

The SGT-800 gas turbine upgrade to 47 MW power output and 37.5 % efficiency is based on positive accumulated operating experience, proven reliability and the long life of its components, including hot section components.

The power output and efficiency increase has been achieved by means of [2]:
- gas turbine inlet mass flow increase by 1.4%,
- improvement of the seals in the turbine section and
- cooling-air reduction in the cooled blades and vanes.

The combustor outlet temperature has been kept the same as for the 45 MW rating.

Cooling-air reduction has been achieved by optimization of the cooling system of blades and vanes and by application of TBC on blade 1. All modifications of blade 1 and guide vanes 1 and 2 have been done without changing their casting models. Cooling optimization of guide vanes 1 and 2 has been achieved by modifications of their inserts. Positive operating experience from TBC-coated blades has already been gathered from the SGT-800 with the 45 MW rating.

The power upgrade is a part of Siemens Energy’s strategy for the SGT-800. The upgrade is now the SGT-800 standard and can easily be implemented on the existing units (this requirement was one of the boundary conditions for the upgrade). An upgrade is preferably performed during a level C inspection.
Operating experience

The total accumulated operating experience of the fleet in commercial operation (more than 40 units) at the end of 2008 is about 800,000 Equivalent Operating Hours and 8900 starts. The fleet leader had accumulated more than 57,000 EOH.

The operating statistics (defined in accordance with ISO 3977-9 [5]) shows good and mature records (March 2009):

- Reliability Factor 99%,
- Availability Factor 96.5%,
- Start reliability 94.1%,
- Mean time between failures (MTBF) is more than 2000 hours.

The data from the operating statistics are based on the input from 45% of the SGT-800 fleet in commercial operation and include all types of applications and designs.

Maintainability improvement

Continued improvement of the SGT-800 performance and reliability has been supported by significant R&D investments. To meet the challenges of the market and to improve our customers’ operating-plant competitiveness and to ensure their mutual profitability, new and innovative maintenance concepts and appropriate technologies and tools have to be developed and employed.

Thus, during the last three years the SGT-800 R&D portfolio has been extended by a number of additional projects dedicated to serviceability and maintainability improvement.

These R&D programs include the development of maintenance tools, advanced repair, non-destructive inspection technology, remote monitoring, condition monitoring, diagnostics and new maintenance concepts including maintenance with extended intervals, cycle-based maintenance and finally condition-based maintenance [3].

Some of the results of these developments, that directly support SGT-800 maintainability improvement and maintenance interval extension program, are briefly presented below.

Maintenance tool development to improve SGT-800 maintainability

Accumulated experience and analysis of performed inspections, maintenance and overhauls of the current SGT-800 fleet showed that maintainability and as a result maintenance down-time could be further improved by means of maintenance tools development and modernization.

Dummy compressor casing. To provide good access to compressor components during inspection and maintenance, the compressor casing has been designed with a vertically split plane. Since the
compressor casing is a part of the supporting structure, one of the two vertical halves of the compressor casing always has to be assembled during compressor maintenance. As a result, the attachment of the rear inner stator requires the compressor casing to be disassembled and assembled repeatedly during the maintenance and repair of the compressor. To avoid this, a dummy compressor casing has been designed (see Figure 5). During maintenance this replaces one of the halves of the compressor casing and enables work with the rear inner stator. This allows for a reduction of down-time during level C/D inspection with approx. 1 day. Moreover, the compressor-casing dummy reduces the risk of damage to blade and guide vanes.

Figure 5: SGT-800 Compressor Maintenance tool - dummy compressor casing

Remote monitoring and condition monitoring systems (RMS/CMS)
STA-RMS – Siemens Turbomachinery Remote Monitoring System is a common remote and condition-monitoring system that has been developed for all Siemens Energy Industrial Applications rotating equipment (gas turbines, steam turbines and compressors) and provides a wide range of functionalities:

- monitoring, trending and analysis of main engine parameters (e.g. speed rotation, pressures, temperatures),
- performance monitoring and analysis,
- vibration monitoring and analysis,
- emission monitoring and analysis (for gas turbine),
- automatic report generation.

Siemens believes that operators will have many benefits from this system as it shares accumulated OEM knowledge and experience with the operator. The most recent development of the Siemens’ STA-RMS (see Figure 8) provides a powerful tool for the operator to follow up his rotating
equipment, predicts its future maintenance and provides a way for optimization of the rotating equipment and the plant’s operation.

The STA-RMS concept is presented in Figure 6 and includes the following levels:

- **Level 1** - data collection on site. Data collectors have been designed for the various rotating equipment for industrial applications within Siemens Energy.
- **Level 2** - data transfer and remote access. A common Siemens cRSP solution (common Remote Service platform) has been developed and implemented.
- **Level 3** - data storage in a common Siemens Energy Industrial Applications database, RMS database.
- **Level 4** - data presentation in the form of graphs, KPIs (statistics), trends, automatic reports, automatic diagnostics, common Siemens Energy Industrial Applications RMS web interface.
- **Level 5** - different plug-ins or customer support services: condition-based maintenance (currently under development), evaluated reporting, remote services, business evaluations, help desk, advanced diagnostics (under development).

![Figure 6: Remote Monitoring System concept and structure](image)

**Extension of the maintenance intervals**

A Maintenance Plan (MP) with minimized downtime is strongly requested by many users. The target for the SGT-800 downtime reduction was the establishment of a new MP with increased availability via planned outage-hour reduction:

- reduction of the current inspections and site activities downtime due to improvement of the maintenance processes and tools (see above),

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extension of the maintenance intervals from 20,000 EOH to 30,000 EOH.

Our latest SGT-800 engine and hot gas components modifications enable not only the enhancement of power output and efficiency, but also the extension of components’ life and, as a result, extension of the time between overhauls.

The extension of the maintenance intervals from 20,000 to 30,000 EOH enables the operator to save two level B/C overhauls by performing three overhauls instead of five, see Figure 7 and 8. For the whole life cycle the planned outage hours were reduced by more than 30%. This modification increases the availability of the SGT-800 by about 1%.

Extension of the maintenance intervals and reduction of the number of major inspections (level B/C overhauls) requires more information about the engine and its components’ condition to mitigate the risk associated with extended maintenance interval. This is why MP with extended maintenance intervals will be offered to the customers in conjunction with a Long Term Program (LTP) and installation of an RMS/CMS system (see above).

The extended intervals MP will initially be implemented on the SGT-800, 47 MW installations, with a base-load operation profile. The development of the extension programs for other operation profiles is planned as a next step.

Current MP and MP with extended maintenance intervals are shown in Figures 7 and 8.

The extended-intervals MP component-replacement schedule is presented in Figure 9.
## Conclusions

- Continued improvements and modifications of the SGT-800 gas turbine component enable high reliability and availability.

The operating statistics show good and mature records (end of March 2009):
- Reliability Factor 99.5%,
- Availability Factor 96.5%,
- Start reliability 91%,
- Mean time between failures (MTBF) more than 2000 hours.

- The positive operation experience and the results of the latest development and extended R&D programs have made it possible to develop the extension of maintenance intervals from 20,000 to 30,000 EOH.

- As a result of maintenance interval extension from 20,000 to 30,000 EOH the availability of the SGT-800 could be increased by about 1%.

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**Figure 9**: SGT-800 extended-intervals component-replacement schedule

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References


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