The SGT-8000H after 2 years of commercial operation

Autor: Armin Städtler, 8000H Product Manager
Co-Author: Willibald Fischer, Director, GT Product Management
Abstract

The 8000H series has become a standard product in the Siemens portfolio. The first SGT5-8000H based plant in Irsching is running already for about 2 years in commercial operation while at the same time the first 60Hz versions are being commissioned and handed over to customer. Thanks to an efficiency >60% and proven operational track record the SGT-8000H fleet is growing fast - a result of a long term commitment and dedicated engineering work from Siemens.

The 8000H program has come a long way: It started with the challenging goal to achieve world class performance while maintaining a robust design base and ensuring low complexity, e.g. to go for a air cooled design as a main contributor for high operational flexibility - a topic that has become very important for future combined cycle generation. The design phase was followed by the intense 18 month prototype testing in Irsching, the erection of a 1S plant around the SGT5-8000H and re-confirmation of the gas turbine design in the combined cycle commissioning and testing phase – including successful validation of fast starts, large instantaneous load changes, high efficiency of 60.75% (plant, net) and low emissions at part load. Commercial operation started in July 2011 with the gas turbine of course under close monitoring by Siemens experts - the highlights and recent status are presented.

Finally the validation of the 60Hz version in the Berlin Testing Facility during the year 2011/12 is covered. The proven direct scaling method of Siemens generates a physical similarity between SGT5- and 6-8000H that does not necessarily require intense product validation. Nevertheless Siemens decided that a thorough test program shall be undergone also on the SGT6-8000H in order to ensure that already the first 60Hz customers will receive a mature product right from the beginning. The 6-8000H test results are confirming the SGT5-8000H design base, proving the maturity of the SGT-8000H series.
Introduction

The global Energy market has changed significantly:

- State owned utilities/power production monopolys have become an exception while the private power sector significantly increased it’s generation capacity – be it large (semi)private utilities or small to medium IPP’s; all with different business models, priorities and focus, challenging the OEMs regarding the bandwith of their product portfolio.

- CO₂-reduction targets have led - and will lead - to massive additions of renewable energy in many grids, resulting in drastically changed operation regimes of fossil power generation and subsequent impact on the power producers business models.

- The so-called “excess gas/oil production countries” have changed their view on domestic gas consumption and put increasing focus on energy efficiency in order to secure the future income from fossil fuel sales.

- Shale gas exploration and exploitation and thus the massive increase of available fuel gas ressources has led to decrease of gas price in some markets; e.g. the USA is on its way to export more gas than to import

- The number of OEM-independent EPC companies capable to execute large power plant projects increased significantly

- During the introduction of F-class engines in the 1990s OEMs, EPC contractors, power producers as well as finance and insurance industry faced significant challenges due to immature product roll-outs. This increased the risk awareness and tendency to risk avoidance with regards to new technology – a challenge to OEMs as the requirement for more competitive products requires new designs

Looking ahead, it is for sure that some market trends will continue, like the increased focus on efficiency in gas/oil production countries. Or e.g the European trend regarding CO₂ reduction, which will foster smart grid applications, the transition from pure electricity consumers to so-called “prosumers” etc. – even if it is unclear what the impact on the future of large scale combined cycle generation is. Other trends are even more unclear, like gas price development or e.g. the impact of political changes on the power sector.
For sure however is that the Siemens SGT-8000H series is the right fit for current and future market requirements:

- Positioned at the top end of the Siemens Gas Turbine portfolio (Picture 1) due to economy of size a 8000H plant can be built at a similar €/kw compared to F-class while delivering significantly higher efficiency.

- The engine design is based primarily on combination and enhancement of proven Siemens and Westinghouse design heritage (Picture 2) instead of extensive application of new technologies, thus reducing the application risk of this high-performance product while benefitting insurability and financing.

- The purely on-board air-cooling design ensures high operational flexibility while also allowing for easy product integration for EPCs due to no interfaces to water-steam-cycle - while still enabling for combined efficiencies of >60% net. (Picture 3)

- The conservative market introduction approach with intense validation before the start of commercial offering ensured that Siemens gathered sufficient operational experience before even the first commercial projects enter operation, ensuring smooth erection, commission and commercial handover of these units.

The long path to achieve 60% net efficiency

The 8000H program was initiated already in the year 2000, right after the merger from Siemens and Westinghouse. Targets of the program were beyond others: to establish a new common product line based on the best features of the two different design heritages; to include the learnings from the F-class introduction in the design and validation approach; to focus primarily on evolutionary enhancement of existing design features; to develop a robust and uncomplicated design that eases service activities; and finally to develop a gas turbine capable of >60% net combined cycle efficiency. Thus the special challenge was to meet the efficiency goal without adding significant new technologies to the frame. To understand this challenge it must be noted that at that time the best available net efficiencies were in the range of 58% and intense use of steam cooling was said to be the only possible way to achieve higher efficiencies. The development team took up this challenge and after the design phase the first SGT5-8000H was assembled – a purely air-cooled gas turbine, designed to be capable of >60% combined cycle net efficiency. The GT was then shipped to the Irsching test site (located in Bavaria close to the city of Ingolstadt), the site at that time being under full Sie-
mens ownership, control and responsibility (e.g. fuel purchasing, permitting, power-off taking etc.). The engine was first fired in December 2007, followed by an intensive testing phase until August 2009. By then the gas turbine performance was validated and hardware integrity was proven; in parallel the combined cycle design was finalised. After transition of the Irsching site from a Siemens owned simple cycle prototype setup to a standard commercial customer owned combined cycle facility the hot commissioning started in January 2011. Besides the standard commissioning activities there was special focus on the complete turboset and plant, attributed to the fact that the SCC5-8000H 1S powers a significantly larger single shaft plant compared to previous F-class sizes. During this phase topics like fast start/hot re-start capability or UK grid code compliance were validated, proving the high operational flexibility of the 8000H system. Finally in a combined cycle test run under full load conditions, witnessed by TÜV, the world record efficiency of 60.75% (plant, net) could be verified (Picture 4) – the final reward of more than 10 years of dedicated individual contribution of numerous Siemens employees.

Since July 2011 the first SCC5-8000H 1S plant Irsching 4 –renamed to “Kraftwerk Ulrich Hartmann” - is in commercial operation under full customer responsibility and control. It is operated according grid dispatch needs, meaning mainly daily start-stop operation and operation in load following mode. Regular inspections have repeatedly revealed excellent condition of the overall engine, including the hot gas path parts. So after two years of commercial operation it can be concluded that the SGT-8000H series does not only achieve world class performance and flexibility but also represents a robust and reliable design.

Validation Strategy and Results

The whole power industry – OEMs, customers, EPCs as well as financing and insurers – faced significant challenges during F-class introduction in the 90s. As a consequence Siemens decided to limit the risk exposure to its clients for the next gas turbine generation, so the 8000H program had from the very beginning a strong focus on Siemens in-house validation. Already during the design phase numerous individual parts, sub-system and system validation tests have been conducted, e.g. low pressure and high pressure combustion testing. Testing was done in test rigs but partly already in a real engine. At that time a SGT6-5000F was installed in the Berlin Test Facility BTF within the gas turbine factory; this engine was modi-
fied to validate e.g. the compressor design. When it was evident that the individual designs met their expectations their design was finalized and hardware manufacturing started.

**SGT5-8000H validation**

For the prototype testing at the Irsching site the engine was equipped with close to 3000 sensors for all needs, thereof 600 on the rotor connected with corresponding telemetry: temperatures, pressures, strain gages, accelerometers, clearances, blade vibration, flows and forces were thoroughly monitored. A secured IT environment ensured real time data monitoring and availability for Siemens specialists at locations in Mülheim (Germany) and Orlando/Jupiter (USA). During the first 15 months all operation modes were tested, combustion fuel staging settings for these were optimized and all thermodynamic parameters were checked and validated. With a thermal paint run the thermal surface temperature readings could be compared with the design target to ensure that temperature profiles meet expectations and consequently lifetime prediction of hot gas path parts will be met. In this time frame several inspections were conducted; besides the validation activities these were also used to establish service and outage experience and train service personnel. As an example, the scope of the thermal paint test outage has a work scope comparable to a regulat extended hot gas path inspection. Focus of the last test phase was endurance testing in semi-commercial operation according grid dispatch, e.g. with daily start stop operation as well as several days of continuous operation, which finally proved commercial readiness (Picture 5). The prototype validation phase ended in August 2009.

It was only at that time when Siemens officially started offering activities of the 8000H. The first success was the order from Florida Power & Light (FPL) for their Cape Canaveral and Riviera Beach sites in Florida, USA, followed by the order for Bugok 3 in South Korea.

**SGT6-8000H validation**

Following the SGT5-8000H design the development of a scaled 60Hz sister-engine was initiated when the first positive results from testing in Irsching were available. In contrast to the common OEM approach to test only one type of a scaled engine design, Siemens decided to fully test also the 60Hz Version of the 8000H. In general there are a lot of similarities between scaled engines in aerodynamics, stresses and thermodynamics; in case for the 8000H even the same burner design was chosen with the difference the number of burners only (Picture 6) in order to ensure even transferability of combustion behavior from 50Hz to 60Hz and vice versa. Still on a detailed level there small changes that potentially could bear some risk.
As with the SGT5-8000H, Siemens again intended to keep the introduction risk internal and to ensure that the first commercial customer (FPL) would get an already validated and matured product. So the first SGT6-8000H was finally assembled in January 2011 and put to testbed afterwards, which itself had undergone a major retrofit in parallel to gas turbine manufacturing. Unique feature of the Berlin Test Facility is the connection of the GT to a water break instead of a generator, which allows to operate at 60Hz in a 50Hz environment but also facilitates off-frequency operation to validate full engine Eigenfrequency/vibration behavior (Picture 7). Besides the successful general validation of performance, emissions, thermodynamic behavior and hardware integrity (also under off-speed conditions), one special focus was to validate oil operation on the 8000H. The test results, including again thermal paint testing with focus on hot gas path design, met the expectations, thus confirming the SGT6-8000H but also re-confirming the design base SGT5-8000H. On a side note the BTF was also refurbished with a standard GT control/protection logic (Siemens T3000), as also an immature I&C system can prevent reliable commissioning or operation of an engine. The system was verified and optimised in order to ensure smooth transition of control parameters to commercial sites.

**Track record**

Considering the fact that the SGT-8000H forms a new gas turbine frame and efficiency class, the track record of the 8000H program is no less than remarkable:

The first fire date of the first SGT5-8000H during the simple cycle prototype operation phase was achieved on schedule. The first base load operation was achieved only 9 operation days after 1st synchronization. Later, also the combined cycle extension to a 1S configuration, subsequent commissioning and finally handover for commercial operation was achieved on schedule. During this phase of the 8000H program the SCC5-8000H 1S configuration was the first plant ever to exceed the 60% efficiency barrier, meeting a world record efficiency of 60.75% (plant, net). By today the SGT5-8000H front runner engine at Irsching (Kraftwerk Ulrich Hartmann) has been running commercially for already 2 years very successfully. It has accumulated more than 600 starts and 12000 actual operating hours while demonstrating very good reliability and availability. 

The year 2013 will also see the first SGT6-8000H engines coming online. At the time of writing the first three units at Cape Canaveral site in Florida are on track to meet hand over date
to commercial operation in May 2013. This is remarkable, as the project is setup as a sole product delivery business with only a one-digit number of Siemens supervision staff on site, where all works are conducted by the main EPC contractor. This proves the maturity of the whole 8000H system – engine design, quality of the installation and commissioning procedures, interface documentation as well as the control system setup. It also demonstrates the advantages of a the 8000H cooling air concept that allows easy plant integration by avoiding interferences between the gas turbine systems and the water steam cycle.

Next unit will be Bugok 3 in a single shaft arrangement in South Korea, which has seen first fire in March 2013 – again on schedule - and is forseen to enter commercial operation in Q3 2013.

**Outlook**

The 8000H series has seen a very thorough market introduction approach – with full validation (50 Hz) before the start of offering activities and full 60Hz validation before the first commercial projects come online (Picture 8). Thanks to this huge effort the 8000H series will become a lon-lasting commercial success for both Siemens and its customers, proven by the number of 22 already sold units (at time of writing, Picture 9+10)) and the many more units under negotiation. Driven by this success and the resulting expected increased bandwith of customer enquiries, the development focus of the 8000H series did also include the establishment of comprehensive package portfolio of associated generators, steam turbine models, train configurations and related auxiliaries (Picture 11). So Siemens today can offer a solution for every customer need:

- delivery scope ranging from pure component business (e.g Prai) up to full turnkey EPC scope (e.g. Irsching, Lausward)
- LP steam turbine tails for all backpressure requirements from direct cooling (e.g. Irsching) to ACC
- HP/IP steam turbine sections for live-steam temperatures of 565°C up to 600°C
- single-shaft and multi-shaft arrangements for differet project sizes and space requirements
- tailored solutions for steam extraction applications (e.g. Lausward)
- right-sized generators for the various configurations
Summary

The Siemens 8000H series validation and introduction strategy has become a benchmark in the power industry considering the minimization of risk exposure to even the first commercial customers. This comparable conservative market introduction approach – with full validation (50 Hz) before the start of offering activities and full 60Hz validation before the first commercial projects come online – is one of the main pillars for securing both Siemens Fossil Power Generation business as well as the customers business models.

The further pillars are:

- proven efficiency level of >60% (plant, net)
- proven excellent operational flexibility
- proven reliability and availability
- proven serviceability and maintainability of gas turbine and plant

As a result the 8000H series has become a commercial success with worldwide 22 already sold units (at time of writing) as well as more units under negotiation. And it will prove – due to portfolio options, excellent performance, flexibility and minised risk exposure to customers – to become a success story for the 8000H customers of all markets or regions - as it has been demonstrated already in the two years of commercial operation of the front runner installation at Kraftwerk Ulrich Hartmann in Irsching.
Abbreviations

IPP  -  independent power producer
OEM  -  original equipment manufacturer
EPC  -  engineering, procurement, construction
SGT  -  Siemens Gas Turbine
SCC  -  Siemens Combined Cycle
BTF  -  Berlin Test Facility
LP   -  low pressure (steam)
IP   -  Intermediate pressure (steam)
HP   -  high pressure (steam)
1S   -  single shaft
I&C  -  instrumentation and control

References

Siemens Large Scale Gas Turbines
Product Portfolio for 50 Hz and 60 Hz

Output in MW @ ISO conditions

<table>
<thead>
<tr>
<th>Model</th>
<th>Output (MW)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGT5-8000H</td>
<td>375</td>
</tr>
<tr>
<td>SGT5-4000F</td>
<td>292</td>
</tr>
<tr>
<td>SGT6-8000H</td>
<td>274</td>
</tr>
<tr>
<td>SGT6-5000F</td>
<td>208</td>
</tr>
<tr>
<td>SGT6-4000F</td>
<td>187</td>
</tr>
<tr>
<td>SGT5-2000E</td>
<td>168</td>
</tr>
<tr>
<td>SGT6-2000E</td>
<td>113</td>
</tr>
</tbody>
</table>

The SGT-8000H series
Harmonized engine concept

Siemens Design
- Single tie bolt
- Compressor stator
- HCO

Westinghouse Design
- Turbine cylinder
- Turbine vane carrier
- Exit housing
- Front hollow shaft
- Bearings
- Compressor cylinder
- Can-Annular Combustion
- Turbine features
- Turbine diffuser

The SGT-8000H concept uses proven features from Siemens and Westinghouse design heritage
SGT-8000H series
Efficient & Flexible

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

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

Translational protection of clearances for reduced degradation with hydraulic clearance optimization (HCO) active clearance control

Performance features:
- Excellent start-up and load acceptance
- Robust design for economic and reliable operation

Flexibility features:
- Modular design for easy maintenance and upgrading
- Optimized for maximum performance in a variety of applications

Designed for >60% efficiency in combined cycle and best in class operational flexibility
SGT5-8000H Irsching
Summary 2008-2009 Prototype Validation

- 1st fire achieved on schedule
- Stable and reliable ignition from 1st start
- Base load within 9 days of operation from 1st synchronisation
- High starting reliability already achieved very early
- Overall integrity, Performance, Emissions confirmed
- Endurance Testing

Hardware integrity, vibration, performance, emissions and operational flexibility fully confirmed

SGT-8000H series
Direct scaling approach

<table>
<thead>
<tr>
<th>Scaling rules 50Hz to 60Hz version</th>
</tr>
</thead>
<tbody>
<tr>
<td>50Hz</td>
</tr>
<tr>
<td>Speed</td>
</tr>
<tr>
<td>Dimensions</td>
</tr>
<tr>
<td>Power, Mass Flow</td>
</tr>
<tr>
<td>Stresses &amp; Temperatures</td>
</tr>
<tr>
<td>Efficiency</td>
</tr>
</tbody>
</table>

Picture 5

Picture 6
**SGT6-8000H Validation**

*Berlin Test Facility*

---

**SGT-8000H series**

*Validation Approach*

<table>
<thead>
<tr>
<th>Event</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Program Launch – Concept Phase</td>
<td>01 Oct 2000</td>
</tr>
<tr>
<td>1st Fire of SGT5-8000H</td>
<td>Dec 20, 2007</td>
</tr>
<tr>
<td>SGT5-8000H Endurance test run (1200hrs)</td>
<td>Jul-Aug 2009</td>
</tr>
<tr>
<td>SGT5-8000H Validation Phase completed</td>
<td>Aug 28, 2009</td>
</tr>
<tr>
<td>Combined Cycle Commissioning, Irsching 4</td>
<td>Jan 08 – July 22, 2011</td>
</tr>
<tr>
<td>1st SGT6-8000H completed, Berlin Factory</td>
<td>Jan 2011</td>
</tr>
<tr>
<td>SGT6-8000H Validation Phase complete</td>
<td>Aug 17, 2012</td>
</tr>
</tbody>
</table>

Siemens philosophy is to conduct thorough validation for a new engine platform like 8000H – even for the scaled engine.
### SGT6-8000H

**References**

<table>
<thead>
<tr>
<th>Description</th>
<th>Location</th>
<th>COD</th>
</tr>
</thead>
<tbody>
<tr>
<td>2 x 3xSGT6-8000H</td>
<td>USA, FL</td>
<td>08/2013</td>
</tr>
<tr>
<td>1 x SCC6-8000H 1S</td>
<td>South Korea</td>
<td>08/2013</td>
</tr>
<tr>
<td>1 x SCC6-8000H 1S</td>
<td>Daegu City</td>
<td>11/2014</td>
</tr>
<tr>
<td>1 x SCC6-8000H 1S</td>
<td>Bugok III (GS EPS)</td>
<td>08/2013</td>
</tr>
<tr>
<td>1 x SCC6-8000H 1S</td>
<td>South Korea</td>
<td>03/2014</td>
</tr>
<tr>
<td>3 x SCC6-8000H 1S</td>
<td>POSCO Power</td>
<td>08/2014, 12/2014, 02/2015</td>
</tr>
<tr>
<td>3 x SGT6-8000H</td>
<td>FPL Port Everglades</td>
<td>05/2016</td>
</tr>
<tr>
<td>1 x SCC6-8000H 2x1</td>
<td>Ansan (Posco E &amp; C) South Korea</td>
<td>05/2013</td>
</tr>
<tr>
<td>1 x SCC6-8000H 1S</td>
<td>South Korea</td>
<td>11/2014</td>
</tr>
</tbody>
</table>

### SGT5-8000H

**References**

<table>
<thead>
<tr>
<th>Description</th>
<th>Location</th>
<th>COD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 x SCC5-8000H 1S</td>
<td>Irsching 4 Germany</td>
<td>07/2011</td>
</tr>
<tr>
<td>1 x SCC5-8000H 1S</td>
<td>Lausward, SWD Germany</td>
<td>09/2015</td>
</tr>
<tr>
<td>1 x SCC5-8000H 1S</td>
<td>Samsun Turkey</td>
<td>02/2015</td>
</tr>
<tr>
<td>2 x SCC5-8000H 1S</td>
<td>Prai, Malaysia</td>
<td>01/2016</td>
</tr>
<tr>
<td>1 x SCC5-8000H 1S</td>
<td>Germany</td>
<td>N.N.</td>
</tr>
<tr>
<td>1 x SCC5-8000H 1S</td>
<td>Lausward, SWD Germany</td>
<td>N.N.</td>
</tr>
</tbody>
</table>

**SGT-8000H total: 22 units sold**
## 8000H series
Configuration Overview

<table>
<thead>
<tr>
<th></th>
<th>50 Hz</th>
<th>60 Hz</th>
</tr>
</thead>
<tbody>
<tr>
<td>SGT-PAC 8000H</td>
<td>375 MW</td>
<td>274 MW</td>
</tr>
<tr>
<td></td>
<td>40 %</td>
<td>40 %</td>
</tr>
<tr>
<td>SCC-PAC 8000H 1S</td>
<td>570 MW</td>
<td>410 MW</td>
</tr>
<tr>
<td>SCC-PAC 8000H 1x1</td>
<td>&gt; 60 %</td>
<td>&gt; 60 %</td>
</tr>
<tr>
<td>SCC-PAC 8000H 2x1</td>
<td>1.145 MW</td>
<td>824 MW</td>
</tr>
<tr>
<td></td>
<td>&gt; 60 %</td>
<td>&gt; 60 %</td>
</tr>
<tr>
<td>SCC-PAC 8000H 3x1</td>
<td>- -</td>
<td>1.236 MW</td>
</tr>
<tr>
<td></td>
<td>- -</td>
<td>&gt; 60 %</td>
</tr>
</tbody>
</table>
Permission for use

The content of this paper is copyrighted by Siemens and is licensed to PowerGen Europe for publication and distribution only. Any inquiries regarding permission to use the content of this paper, in whole or in part, for any purpose must be addressed to Siemens directly.

Disclaimer

These documents contain forward-looking statements and information – that is, statements related to future, not past, events. These statements may be identified either orally or in writing by words as “expects”, “anticipates”, “intends”, “plans”, “believes”, “seeks”, “estimates”, “will” or words of similar meaning. Such statements are based on our current expectations and certain assumptions, and are, therefore, subject to certain risks and uncertainties. A variety of factors, many of which are beyond Siemens’ control, affect its operations, performance, business strategy and results and could cause the actual results, performance or achievements of Siemens worldwide to be materially different from any future results, performance or achievements that may be expressed or implied by such forward-looking statements. For us, particular uncertainties arise, among others, from changes in general economic and business conditions, changes in currency exchange rates and interest rates, introduction of competing products or technologies by other companies, lack of acceptance of new products or services by customers targeted by Siemens worldwide, changes in business strategy and various other factors. More detailed information about certain of these factors is contained in Siemens’ filings with the SEC, which are available on the Siemens website, www.siemens.com and on the SEC’s website, www.sec.gov. Should one or more of these risks or uncertainties materialize, or should underlying assumptions prove incorrect, actual results may vary materially from those described in the relevant forward-looking statement as anticipated, believed, estimated, expected, intended, planned or projected. Siemens does not intend or assume any obligation to update or revise these forward-looking statements in light of developments which differ from those anticipated.

Trademarks mentioned in these documents are the property of Siemens AG, its affiliates or their respective owners.