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H-Class High Performance Siemens Gas Turbine SGT-8000H series

Answers for energy.

H-Class High Performance Siemens Gas Turbine (SGT-8000H series)

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Abstract

This paper reviews design and validation of the advanced gas turbine SGT-8000H series and the associated combined cycle system SCC-8000H series, introduced by Siemens Energy. The new SGT-8000H series is the result of years of research and development within Siemens Energy. It is based on well proven features of the existing product lines combined with advanced technology.

The first SGT5-8000H gas turbine was fully tested and validated in 2008/2009 under field conditions in a real power plant environment at Irsching 4 Power Station (which is now renamed Kraftwerk Ulrich Hartmann), Bavaria/Germany, in a hosting agreement with E.ON. After extensive simple cycle testing, Irsching 4 was converted to a SCC5-8000H 1S single shaft combined cycle unit, and with the remarkable results demonstrated during commissioning and initial operation, it represents a milestone in fossil fired power plant technology.

Because the SGT6-8000H is scaled directly from the 50 Hz model, it will not require an extensive validation program. Nevertheless, an extensive engine test campaign with several configurations and off-design point testing is being conducted at the Berlin Test Facility to ensure product performance and integrity.

This comprehensive, rigorous approach ensures that subsequent “commercial” engines will be brought to market such that risk are controlled and with full validation based on extensive operating history. Initial commercial customer projects such as the 1200 MW Cape Canaveral and Riviera Clean Energy Centers of Florida Power & Light and the 410 MW unit Bugok III of GS EPS (GS Electric Power & Services, Ltd.), Seoul represent the market introduction phase, with eight total current units.

Product Name	Grid Frequency	Gas Turbine Rated Power	Combined Cycle Rated Power (1x1)	Combined Cycle Rated Efficiency (1x1)
SGT5-8000H	50Hz	375 MW	570 MW	> 60%
SGT6-8000H	60Hz	274 M	410 MW	> 60%

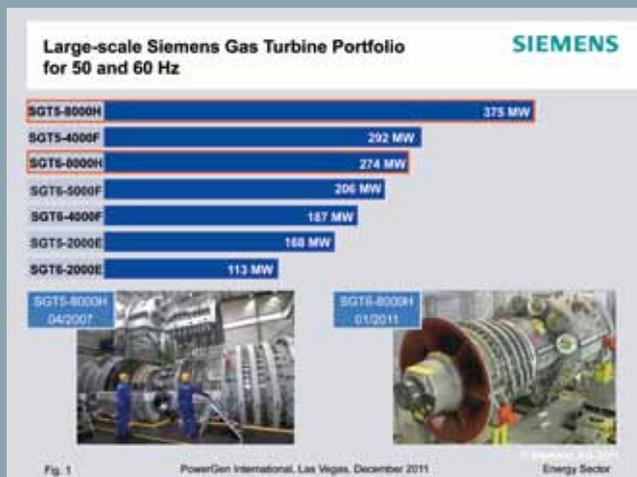


Fig. 1

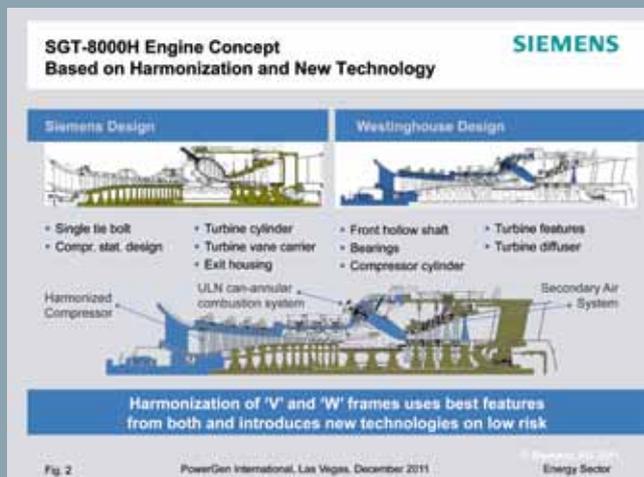


Fig. 2

Introduction

The worldwide need for energy is constantly rising while, at the same time, demand for reliable, affordable, efficient and environmentally-compatible power generation is increasing. In today's highly competitive business environment, customers and power plant operators expect an economical, state-of-the-art product. Increasingly, their purchasing decisions emphasize life-cycle cost analyses that span the entire lifetime of a power plant.

Siemens Energy developed its new generation H-class Siemens Gas Turbine (SGT™), the SGT-8000H series (Fig. 1), taking both environmental protection as well as economical focus into consideration. Siemens Energy brought technical innovations in design and development, process engineering, materials and manufacturing and assembly processes together to transform these new requirements into reality.

The H-class gas turbine combines the best features of the established product lines with advanced technology. The functional and mechanical design of the new engine was built on the experience gained with the predecessor 50 Hz and 60 Hz engines. Proven design features were applied wherever possible, and "Design for Six Sigma" tools were used resolutely, to deliver a competitive product using proven design features wherever possible. (Fig. 2).

Overview: SGT-8000H series Development Program

Following the merger of Westinghouse Power Generation with Siemens in August 1998, the decision was made to develop a Next Generation Family (NGF) of gas turbines. Siemens formally approved the H-technology development program in October 2000 and began basic engineering design in November 2001, almost four years before its public announcement in September 2005. Besides increasing output and efficiency, the intent of the NGF program was also to merge the existing V-engines, W501F and W501G product lines for a harmonized future product portfolio. The result of the NGF program are the advanced SGT5-8000H and SGT6-8000H gas turbines which utilize the experience and technology developed over decades by Siemens and the former Westinghouse (Fig. 3).

Major cycle parameters such as compressor mass flow, firing temperature, exhaust temperature and corresponding combined cycle parameters such as steam temperatures and pressure levels had to be defined in order to meet the intended output and efficiency. One of the major concept decisions which had to be taken early in the program was the selection of the engine cooling method to ensure that hot gas path components withstand the increased temperatures, while maintaining and ensuring operational flexibility needed in today's fluctuating market environment. The SGT5-4000F and SGT6-5000F had purely air-cooled engine concepts, while the SGT6-6000G, a result of the Advanced Turbine System (ATS) program conducted by Westinghouse in conjunction with the Department of Energy of the United States (DOE), had a combined air and steam cooled approach. Based on operational experiences and feedback from customers regarding the growing need for operational flexibility, it was decided that a completely air-cooled concept would be developed for the SGT-8000H series.



Fig. 3

With the annular combustion system used on more than two hundred SGT-4000F turbines and the can-annular combustion system used on hundreds of engines in Westinghouse design, harmonization potential was identified for the combustion system. Based on operational experience and flexibility considerations, it was decided to develop a "Platform Combustion System" (PCS) based on the can-annular combustion system for the SGT-8000H series design. This combustion system went through extensive rig and engine testing beginning in 2005. Final validation was completed in full engine testing at Irsching.

The SGT-8000H series / SCC-8000H series is an integrated product line with common features based on the Siemens and Westinghouse product lines. The extensive fleet experience was used to develop the final feature of this design. The 50 Hz and 60 Hz SGT-8000H series concepts were developed concurrently to assure that validation testing from the first engine developed for the 50 Hz market provided significant proof for the 60 Hz design. The 50 Hz SGT5-8000H engine has been already successfully tested at Irsching 4 power station owned by E.ON Kraftwerke a German electric utility company. The 60 Hz SGT6-8000H utilizes the same (scaled) compressor, identical combustor (fewer number of cans) and a scaled turbine. Nevertheless, an extensive engine test campaign with several configurations and off-design point testing is being conducted at the Berlin Test Facility to ensure product performance and integrity.

Primary Objectives of the SGT-8000H series Program

Customer requirements resulting especially from today's liberalized energy markets and current trends in today's generation portfolio requirements for complementing the substantial market penetration of renewable power were the essential drivers for developing the new SGT-8000H series.

- Combined cycle net efficiency over 60%, resulting in approx. 3% of fuel savings for improved OPEX
- Significantly reduced emissions per kWh produced combined with the lower heat rate and 25 ppm NOx, 10 ppm CO and 330 g/kWh
- Increased turn-down for achievement of high efficiency and low emissions also in part-load operation from 100% – 50% load
- Quick start-up capability of less than 15 minutes and operational flexibility to meet immediate needs in power grids
- Lower specific investment costs (EUR/kW) for reduced specific CAPEX
- Reliability of over 99%, availability of over 94% and serviceability comparable to today's proven F-class technology
- Minimized life cycle costs for increased Net Present Value for the owner of at least 7 – 8%

The SGT5-8000H and SGT6-8000H gas turbine development team involved more than 250 engineers working in Erlangen, Berlin and Mülheim in Germany, as well as in Orlando and Jupiter in Florida. An additional 500 employees were involved in the manufacturing, assembly and preparations for testing the prototype engine. This new turbine was developed in strict compliance with the company's Product Development Process. The design effort incorporated previous lessons learned, applied proven design features wherever possible and "Design for Six Sigma" tools were used systematically to deliver a competitive product focused on life-cycle costs, performance, serviceability, flexibility, reliability, and low emissions.

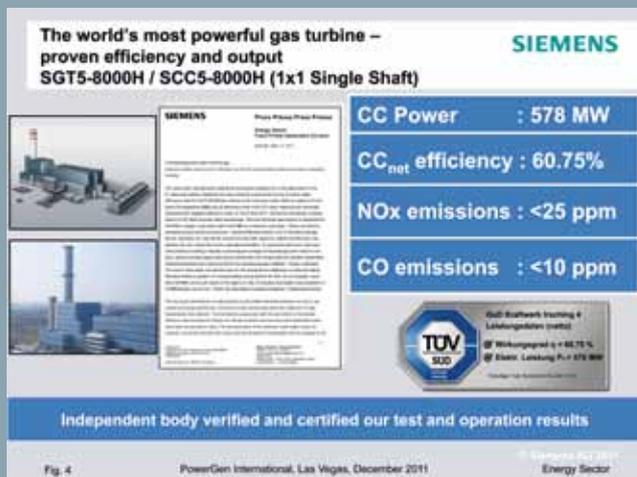


Fig. 4



Fig. 5

SGT-8000H series Main Design Features

The design is based on proven Siemens and Westinghouse technology.

- The engine has a single tie bolt rotor with interlocked discs using Hirth couplings. This design is used in the SGT5-4000F. Siemens has over 16,500,000 EOHs and 757 GTs operating with this type of rotor.
- The 13 stage compressor is Siemens harmonized design, which is offered on the SGT6-5000F as well as on the SGT-8000H series engines. This design has four variable guide vanes to improve part-load performance and blades can still be replaced without a rotor lift. The 50 Hz and 60 Hz versions – identical in design – are aerodynamically scaled.
- The can-annular combustion system design is based on the SGT6-5000F which has over 6 million operating hours. The 50 Hz and 60 Hz engines have the same baskets and burner assemblies.
- The fully air-cooled turbine airfoils use proven base materials. There are no single crystal components and no dependence on steam from the bottoming cycle for cooling. The 50 Hz and 60 Hz versions – identical in design – are aerodynamically scaled.

The SGT5-8000H is the largest operating gas turbine in the world, as noted by the Guinness Book of World Records. The 50 Hz and 60 Hz versions offer high efficiency and low emissions in base-load and part-load.

Operational Flexibility of the H-class Gas Turbine

The gas turbine power generation market has seen significant volatility in recent years due to climate change, changes in natural gas prices and the uncertain future of nuclear and coal power generation. In addition, the foreseeable demand for environmentally friendly power generation has convinced many power producers to

integrate renewable generation capacities with environmentally clean gas-fired power plants. Keeping this key market driver in mind, the SGT-8000H series was designed for operational flexibility with the following key features:

- The engine is fully air-cooled, resulting in the ability to start fast and cycle quickly.
- Increased loading and acceleration rate reduces start-up time
 - Standard loading: 25 minutes to 375 MW
 - Fast Loading: 10 Minutes to 350 MW
- Increased turn-down to achieve high efficiency and low emissions in part-load operation down to 50% load
- Fast start-up capability of less than 15 minutes. Operational flexibility to meet immediate needs in power grids (>500 MW in less than 30 minutes, in combined cycle mode)
- Plant ramp down to minimum load at 100 MW (~20% combined cycle load) or shut down in less than 30 minutes
- Plant cycling operation with over 200 MW load change in less than 7 minutes

Test and Validation of the SGT5-8000H at Irsching 4 Power Station

By spring 2007, Siemens completed the assembly of the first 50 Hz engine at its Berlin plant. The unit was shipped to E.ON's Irsching 4 power station for performance validation under actual service conditions. It was first fired in December 2007 and synchronized to the grid shortly thereafter in March 2008. Full base load output was achieved on April 24, 2008. During the next 16 months the engine went through a rigorous in-service test and validation phase, including a comprehensive endurance test run, that ended on August 28, 2009.

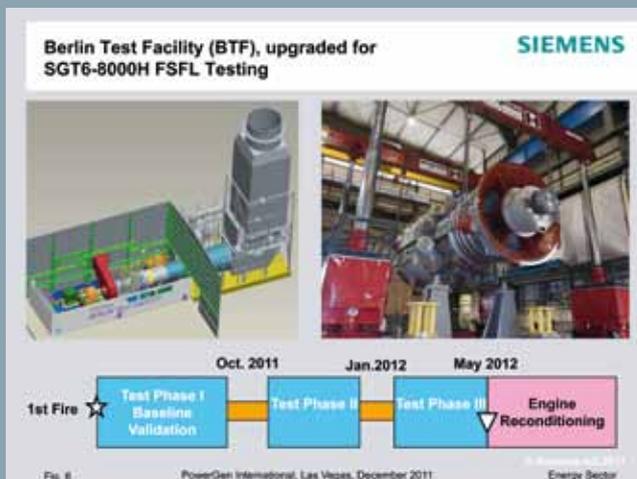


Fig. 6



Fig. 7

The total 18-month validation program consisted of multiple measurement campaigns, covering the full operating range starting from hot commissioning to a final endurance test in open cycle configuration. Although the SGT5-8000H has a commercial rating of 375 MW at ISO conditions, it was loaded to over 400 MW during open cycle testing at Irsching 4 in order to verify design integrity and exploit overall stability limits. During validation at Irsching 4, the unit accumulated 1525 hours of operation, of which 1243 hours were at base-load. Testing and validation were completed on August 28, 2009 and the unit was brought offline for a scheduled conversion to combined cycle.

Since then, the Irsching 4 plant has been converted into a single-shaft combined cycle power plant. After commissioning and initial combined cycle testing, the plant was turned over to E.ON for commercial operation in July 2011. The plant has been renamed Kraftwerk Ulrich Hartmann. The superior H-class performance of the new plant was demonstrated with 578 MW net output and 60.75% net efficiency in a world record testrun in spring 2011. (Fig. 4)

Increased operational flexibility was also demonstrated in reality, with optimized plant start-up times, less than 21 minutes at hot condition, ramp rates, grid code response times etc., representing a new and unprecedented level of advanced combined cycle technology (Fig. 5).

Next Steps towards SGT6-8000H

The 60 Hz SGT6-8000H, rated at 274 MW, is a direct scale of the 50 Hz SGT5-8000H. The design of the SGT6-8000H is based exactly on Siemens proven aerodynamic scaling rules. A scaling factor of 1:1.2 is applied consistently across the entire cross section of the turbine. The only exception is the combustion system, in which exactly the same components, such as burners and baskets, are used as in the 50 Hz model.

In order to reflect the reduced mass flow of approx. 1 : 1.44, 12 can-combustors are used on the 60 Hz model instead of 16. Based on this approach with many other proven examples, validation efforts for the SGT6-8000H can be based on the comprehensive information gained during the SGT5-8000H test program and only limited time and effort will be required to provide sufficient evidence for the integrity of the 60 Hz model.

Test and Validation Approach for SGT6-8000H

The first SGT6-8000H unit was recently installed in the test center of our Berlin manufacturing plant and is currently undergoing an eight month test program (Fig. 6).

As of submission of this paper, detailed design, manufacturing, final assembly and commissioning of the SGT6-8000H have already been finalized and the production of the first commercial engines are in progress. The first of these engines will be tested at the Berlin Test Facility for validation before being shipped to the customer site in Florida.

Market Launch / First Commercial Orders Secured

The first commercial order was secured with Florida Power & Light (FPL). FPL selected the SGT6-8000H for modernization of its Cape Canaveral and Riviera Beach power plants based on the world class performance and operational flexibility demonstrated by the SGT-8000H series. Each of the new 1.200 MW combined cycle units will comprise of a 3 x 1 configuration, with three gas turbine-generator sets, three HRSGs and one steam turbine. The Cape Canaveral plant will commence commercial operation in 2013 and Riviera Beach will follow in 2014.

The first project in Asia is represented by the 410 MW single shaft combined cycle unit Bugok III of GS EPS (GS Electric Power & Services, Ltd.), Seoul Korea (Fig. 7), which will also start commercial operation in 2013.



Fig. 8

Summary

Overall, the SGT-8000H series program has reached all design targets and will serve as the basis for Siemens future advanced gas turbine and combined cycle:

- Increase of combined cycle net efficiency to over 60%
- Reduced emissions per produced kWh
- High efficiency and low emissions also in part-load operation
- Fast start-up capability and operational flexibility
- Reduced investment costs per kW
- High reliability and availability
- Lowest in lowest life cycle costs

While it seemed impossible at launch time, more than 60% combined cycle efficiency has been designed, manufactured, installed and proven during initial operation. Not only was efficiency and performance of gas fired generation technology shifted beyond existing borders, Siemens H-class technology has also added operational flexibility beyond existing F-class technology. It can be characterized as "Beyond 60% – Pioneering H-class Efficiency at world class flexibility".

Based on detailed evaluation of test data and comparison with design predictions, Siemens Energy is now able to offer the world class performance of the SGT-8000H series for full commercial application as follows:

Performance Rating	SGT5-8000H	SGT6-8000H
Gas Turbine Power Output	375 MW	274 MW
Gas Turbine Efficiency	40%	40%
Combined Cycle (1x1) Power Output	570 MW	410 MW
Combined Cycle (1x1) Efficiency	> 60%	> 60%

In conclusion, approximately 20 years after the introduction of today's F-class gas turbine and combined cycle technology, Siemens new advanced 8000H-class represents the most advanced and modern technology for economic and environmentally friendly gas fired power generation (**Fig. 8**).

The new SGT-8000H product line and its implementation into a state-of-the-art combined cycle power plant is the result of a long term commitment during a multi-year program with significant financial and manpower investment. It shows Siemens commitment to meet customer expectations and continuing the successful partnership for improved customer value.

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