Update on latest H-class operational experience and innovative plant concepts

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Abstract

More than 18 months ago, the start of commercial operation of “Ulrich Hartmann” power plant in Irsching (unit #4, Germany) marked the dawn of a new era in combined cycle power plant construction. For the first time the magic figure of 60% efficiency was topped. However, not only this world-record efficiency level sparked the interest of the power generation community, but also the successful optimization of the plant’s operational flexibility while ensuring excellent reliability. This is setting benchmarks and enabling an operating regime, which today already meets the rising demand of the future. Fluctuating load demand combined with constant water production even at high ambient temperatures will require combined cycle power plants to provide high performance at base and part load, capacity for fast cycling, grid support and flexible operation of the steam part. Tests already demonstrated that the SGT5-8000H and the related combined cycle exhibit excellent characteristics in terms of grid stabilization.

This paper describes Siemens’ answer to the different regional market requirements and focus on both the SGT-8000H gas turbine series and the corresponding combined cycle power plant solutions for the region. The market introduction of the 8000H class technology was based on an extensive validation and test strategy first in Irsching for the 50Hz frame under real field conditions and later for the 60Hz frame, which is a direct scale of the SGT5-8000H, in the Berlin test facility. This paper will further summarize all field validation activities and results, showing how Siemens is bringing the 8000H to the market based on a comprehensive approach to ensure a risk minimized market introduction. Finally this paper will describe the current commercial experience and the first references within the 50Hz and 60Hz markets.
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1. The challenge – Fluctuating power demand at raising fuel costs

Considering the worldwide trend of increasing demand for eco-friendly power generation, a major concern to power producers aiming to build new plants is to understand the impact of the long-term CO₂ reduction targets on the power generation market of today and the future. Despite all uncertainties related to the potential future changes in regional environmental policies and CO₂ reduction targets, today’s power plant solutions must be capable of running profitably throughout the whole service life, which in the case of combined cycle power plants is typically more than 20 years. Customers expect environmentally-compatible and economical state-of-the-art solutions, which offer a maximum value and long-term investment security, even in a volatile market environment.

In Europe and driven by stringent CO₂ reduction targets, the share of renewable energy resources is rapidly growing. The analysis of the predicted residual load, which is the difference between incoming renewables-based power supply and power consumption, shows an extremely fluctuating course over the year. Based on further statistical analysis a clear shift of the fossil power plants' operating regime from base load towards intermediate and peak load is predicted. Also, the remaining conventional power plant fleet has to be able to cope with much higher load ramps and therefore partly serve as backup, e.g. in case renewables feed-in is interrupted, on short notice.

Considering the ASEAN region, which is characterized by strong economic growth, a continuous increase of power demand of approx. 6% per annum is anticipated over the upcoming years. Accordingly, new generating capacities will have to be built to meet this increase in the years ahead. Inversely to Europe, renewable energy power generation in the ASEAN region is still limited and plays a secondarily role within today’s energy mix. Nevertheless, it is clearly expected that in future the renewable power generation share will increase. Therefore new future power plant investments have to consider the impact of renewables at a very early stage of the planning.
In the Middle East region, the role of efficient power generation is increasing, especially in the countries with high oil and gas production. It’s clear that oil and LNG are marketable products, which in the future still need to secure the states revenues. As an example, power generation in the Kingdom of Saudi Arabia is today based only on fossil resources. With an annual power demand growth rate of approx. 5% and assuming “business as usual”, it is expected in 2030 that the majority of the oil production will be required for the state own power generation and the remaining portion for exports will be dramatically reduced. Therefore, the own oil consumption needs to be reduced by e.g. the use of renewables, introduction of nuclear and optimization of the fossil fleet. The last measure includes three main levers: efficiency improvement of the existing fossil fleet (e.g. conversion of simple cycle to combined cycle), optimized fleet management and highly efficient power plant new builds.

Focusing higher efficiency of new plants, this aspect needs to be considered at full load and part load conditions including steady-state and transient operation modes.

Already today the installed power generation capacity in the Middle East region needs to cope with sharp daily load fluctuations and to cover an important peak load demand during the summer season. Looking again to the Kingdom of Saudi Arabia, the daily peak load registered in 2009 was around 6 GW, which is up to 20% of the total demand. During summer time the state’s power generation demand increases typically by up to 80%. Taking in to account potential future energy mix scenarios, where renewables could play a bigger role (as described above), and the installed fossil fleet is expected to deal with even higher load fluctuations (to ensure backup of the renewable fleet). All together, the fossil power generation fleet will play a key role in ensuring the security of supply and therefore operational flexibility will become the main driver for new builds, where operational efficiency is one of its three major pillars.

Thanks to their outstanding dynamic characteristics, combined cycle power plants are able to offer highly flexible solutions based on three major aspects:
– Operational efficiency comprising highest efficiency throughout the whole load range and optimized start-up and shut-down operation

– Power on demand comprising rapid availability by fast starts and high load ramps

– Grid support, also comprising load ramps, stable operation in case of grid incidents and backup power

The evaluation of the different regional requirements (Figure 1) as discussed earlier leads to the following key drivers:

– Investment: lower specific investment (EUR/kW) resulting from economies of scale, while achieving highest reliability and availability

– Performance: increase combined cycle net efficiency to over 60% with a power output over 1100 MW in a 2 on 1, while drastically reducing emissions

– Operational flexibility: reduce startup and shutdown times, increase load ramps for fast load-following ability, and improve turn down capability, part-
load efficiency, and startup reliability

These factors have been considered by Siemens Energy in the development of the SGT-8000H series and the related combined cycle power plants, the SCC-8000H series, taking both environmental protection as well as economical focus into consideration. The 8000H program was started in 2000. It was dedicated to consistently implementing our engineering know-how for the gas turbine and plant. Thus, Siemens Energy can provide the right answer to tomorrows’ energy supply needs already today.
2. Siemens 8000H combined cycle power plant solutions

2.1. SGT-8000H gas turbine: Proven design with highest efficiency & flexibility

Following the merger of Westinghouse Power Generation with Siemens in 1998, the decision was made to develop a next generation family of gas turbines and therewith widen the existing product portfolio based on the H class frames for 50Hz and 60Hz markets (Figure 2). The SGT-8000H series addresses the major market requirements in terms of efficiency, environmental protection, operational flexibility, and economical value.

Figure 2: Siemens Energy large scale gas turbine product portfolio

The SGT-8000H gas turbine series combines the best design features and technologies of the established product lines with some technology innovations and enhancements and is the result of a continuous optimization and harmonization development activities. The functional and mechanical design of the engine was built on the
extensive experience gathered over decades with the predecessor 50Hz and 60Hz engines of both companies Siemens and former Westinghouse, especially the SGT5-4000F and the SGT6-5000F, both engines well known in the region. Proven design features were applied wherever possible, and “Design for Six Sigma” tools were used throughout the process, to deliver a reliable and robust product which meets all requirements (Figure 3). The results of the 8000H development, testing and validation activities were also used as an enabler for the different F class engines upgrades, e.g. the recent 6-5000F engine version which is very successful in Saudi Arabia.

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**Figure 3: Concept of the SGT-8000H series**
Based on the SGT-8000H frames different packages and plant product configurations for both 50Hz and 60Hz markets were developed (Figure 4). A detailed plant solution view will be discussed in the next chapter.

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<tr>
<td></td>
<td>50 Hz</td>
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<tr>
<td>SGT-PAC 8000H</td>
<td>375 MW</td>
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<td>SCC-PAC 8000H 1S</td>
<td>570 MW</td>
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<td>&gt; 60 %</td>
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Figure 4: Configuration and performance overview

The basic engine design is summarized in Figure 5 and has the following features, which account for the high efficiency and the increased operational flexibility: The SGT-8000H series is an integrated product line with common features and an evolutionary design.

- The engine uses the well known SGT5-4000F disc-type hollow-shaft rotor with a single tie bolt. The discs are interlocked and centered using Hirth couplings. This shaft design has smooth and stable running behavior due to the low weight with high stiffness and uniform thermal expansion under all operating conditions. Siemens has over 16 Million EOH (equivalent operating
hours) and more than 750 gas turbines operating with this type of rotor.

- The 13 stages high efficiency axial compressor is Siemens harmonized design, which is offered on the SGT6-5000F as well as the SGT-8000H engines. This design has four variable guide vanes to maintain high part load efficiency and low emissions. This design continues to offer the ability to replace blades without a rotor lift. The 50Hz and 60Hz versions are conceptually identical and are geometrically scaled.

- The can annular combustion system design is based on the SGT6-5000F and is purely air-cooled. The existing Siemens fleet with over 400 operating units offers more than 8,500,000 EOH of extensive experience with this type of combustion system. Both 50Hz and 60Hz SGT-8000H engines have a common combustor assembly.

- The turbine part of the engine consists of four high efficiency stages with air-cooled turbine blades. Blade R1 uses directionally solidified material and enhanced TBC system. There is no need for single crystals use and steam cooling due to moderate firing temperature. The first stage blade and vane are removable through the combustor without cover lift. Further measure for improved serviceability and shorter outages is the use of a single turbine vane carrier. Similar to the SGT5-4000F, the turbine has a conical flow path, which allows for hydraulic clearance optimization.
A key design feature towards operational flexibility and a major concept decision which had to be made early in the SGT-8000H program, was the selection of the engine cooling method. Siemens Energy gas turbine portfolio has both types of the major cooling technologies: The SGT5-4000F and the SGT6-5000F are both based on purely air-cooled engine concepts, while the SGT6-6000G had a combined air and steam cooled approach. This experience offered a wide information and experience basis, showing the benefits and disadvantages of both technologies. Due to the heavy impact of the steam cooling on the engine operational flexibility and design complexity, the internally fully air-cooled design was selected for the SGT-8000H. This design feature enables faster starts, since there is no need to wait for steam from the water/steam cycle. The avoidance of steam cooling and external coolers enable easier simple cycle and bypass operation, faster load following, and part load operation. Design simplicity especially in terms of sealing designs provides higher engine robustness. SGT-8000H proven design allows achieving outstanding performance and operational flexibility without the higher risk associated to the steam
cooler.

A further key aspect which was incorporated in the SGT-800H was the special focus on design features to enable easy and quick serviceability:

- Replacement of compressor blades without rotor de-stack or lift
- Roll out/in capability of the turbine vane carrier enables exchange of stationary turbine hardware without rotor lift
- All turbine blades removable without rotor lift
- Turbine vane 1 and blade 1 removable without cover lift (access through combustion chamber)
- Turbine blade 4 removable without cover lift (towards the exhaust end)
2.2. **SCC-8000H combined cycle power plant solutions**

As shown in Figure 4 Siemens Energy offers different combined cycle power plant configurations based on single- and multi-shaft arrangements. Additionally, Siemens is unique in offering a flexible scope of supply varying between entire power plant (turnkey scope) over power block / power island and up to an extended power train. This enables Siemens to add – depending on the project specific setup – the regional partners and local knowledge (Figure 6). The portfolio flexibility with regards to different arrangements and scope of supply allows a wide range of technical and commercial (risk and cost) optimizations, allowing best fit to customers’ requirements.

![Different scope variations for Siemens combined cycle power plants](image)

**Figure 6 Siemens offers various scopes to customers adding regional partners & local knowledge**

A major solution within the product portfolio is the proven single-shaft design that was developed in the early 90s. Since then, it has been successfully implemented in the F-class (SCC5-4000F 1S) with about 100 units in commercial operation. The power plant SCC-8000H series was developed based on the SGT-8000H as prime mover, the Irsching 4 test plant and the large F class experience as mentioned above. The design principle comprising the gas turbine, the generator, the coupling, and the steam turbine on a single-shaft has remained the same, as this continues to offer the customer the greatest economy and at the same time supreme operational and financial flexibility. The SCC-8000H series is also characterized by its high degree of harmonization, modularization, and compact design towards footprint and space requirements. Both solutions for 50Hz and 60Hz markets are based on the same
The overall plant design was optimized to provide over 570 MW net power output at ISO conditions and a net efficiency greater than 60%, while keeping the emissions extremely low, in this case 25 ppm NO\textsubscript{x} emissions or less at gas turbine base load (Figure 7). Further performance figures for single and multi-shaft configurations for both 50Hz and 60Hz are shown in Figure 4.

**Figure 7: SCC5-8000H 1S designed for highest efficiency and operational flexibility**

The selected steam turbine type used for SCC-8000H series in the single shaft and multi shaft configurations comprises one combined HP/IP casing and one double-flow low-pressure casing. The advanced steam turbine design is optimized for combined cycle applications, providing enhanced transient thermal behavior for fast loading and fast cycling.

Depending on the frequency and plant configuration, different generators within the H\textsubscript{2} and H\textsubscript{2}O cooled product lines are used. Both types are contributing to the overall...
plant efficiency increase based on its outstanding performance. Due to the large plant output, the 50Hz single-shaft solution is using – as a unique configuration – a generator with direct radial hydrogen cooling for the rotor winding and water cooling for the stator winding. This frame is mainly characterized by its high efficiency and reliability beyond 99%.

As the SGT5-8000H provides a high exhaust temperature of approximately 625 °C, a further efficiency increase was achieved based on an advanced three pressure reheat water steam cycle (up to 600°C inlet temperature and 170 bars inlet pressure) with a BENSON type heat recovery steam generator (HRSG) and condensate polishing. Siemens is the unique OEM with extensive operating experience of advanced combined cycles based on the 600°C technology. Alternatively, the SCC-8000H product line can be offered with live steam temperatures of 585°C and lower. The selection of the appropriate bottoming cycles can be done flexibly, by optimization of the life cycle cost and consideration of the specific customers’ requirements.

Additional efficiency improvement measures were based on the use of fuel preheating at 215°C, reduction of pressure losses in the HRSG and piping, feed water pumps with variable speed drives, etc. The combination of all efficiency improvement measures enables the major step over 60% efficiency at base load and an efficiency increase of up to 1,7%-Pt. compared to typical F class over the main operation range.

The Benson-type HRSG for high steam parameters is an essential component in addition to the "rotating equipment". The HRSG is designed and built by Siemens. As this component is of major importance for boosting efficiency and flexibility, the decision was taken to develop and build it in-house on the basis of the available experience with previous Benson boilers, such as in the projects Karstoe, Simmering and Timelkam. Due to the increased thermal cycle parameters, advanced high temperature materials known from the 600 °C steam power plant technology were used for the HRSG design. For both design standards DIN and ASME Siemens Energy provides solutions with proven materials for up to 600°C water / steam cycles. Depending on the plant configuration economics main steam parameters for 50Hz and 60Hz may be decreased to 150bar and 585°C to enable e.g. the use of a drum type
All flexibility features – well known from our SCC5-4000F series – were implemented in SCC5-8000H. The FACY (FAst CYcling) concept with its key components is summarized in Figure 8.

The implementation of the FACY concept in combination with the hot start on-the-fly allows a hot start-up time reduction down to less than 30 minutes in comparison to “conventional” hot starts. The concept is based on a procedure for parallel start-up of gas and steam turbines, while monitoring and controlling the temperature gradients within limits acceptable for all critical plant components and long term operation experience with different steam conditions in the Siemens turbine design. A new start-up sequence, which avoids gas turbine load hold points, was implemented. The main innovation here is the early steam turbine starting point with earlier acceleration and loading of the turbine. The FACY technology allows for higher number of starts and faster cycling without compromising plant lifetime consumption. Rapid power
supply using FACY technology is achieved with a higher average efficiency of up to 14%-Pt, which drastically reduces fuel consumption during the startup phase and hence clearly reduces fuel consumption. Similar figures are achieved during fast shut down.
3. Operational experience

3.3. Test and validation of the SGT5-8000H and SCC5-8000H

The 8000H program was started in 2000, and after thorough development and engineering successful component testing paved the way to the first field installation in a simple cycle configuration built by Siemens for E.ON Kraftwerke at the Irsching site in Germany.

First firing took place in December 2007. First synchronization to the grid occurred on March 7, gas turbine base load was achieved on April 24, 2008, and the field validation program was successfully completed in August 2009, after over one and a half years in simple cycle operation. 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 (1200 hours non-stop full load) in open cycle configuration. This validation phase confirmed its functionality, operational capability, performance, serviceability, integrity, and stability limits.

Following completion of GT field validation in August 2009, extension and conversion to a combined cycle power plant started at Irsching and was completed on schedule in December 2010. The conversion to a complete combined cycle power plant went off without hitch within a very tight time frame of only 16 months. With the re-ignition of the gas turbine in its new configuration for the first time in January 2011 and steam admission just few weeks later, the commissioning phase, including the final test and validation of the entire combined cycle power plant, was begun. Only few days after this, in March 2011, it was possible to run the plant at combined cycle base load for the first time. The further commissioning activities up to June 2011 were marked by tests to validate the performance of the components and the overall thermal cycle and to demonstrate the plant's high operational flexibility and capability in meeting the most stringent grid requirements, to optimize the startup times and load rejections, and to verify its output and efficiency.

In terms of operational flexibility the following exemplary results were achieved
under combined cycle operation conditions:

- Fast cycling dynamic load tests showed excellent capability to effectively contribute to grid stabilization and to run in a fast load following mode. Load gradients up to 35 MW/min. were demonstrated and the plant achieved over 200 MW load increase and decrease in less than 7 minutes, while all systems were running under perfectly stable conditions.

- Grid support capability (Figure 9): The UK grid code is beyond the most stringent in the world. In terms of primary and secondary frequency response, the Irsching 4 plant surpassed the UK grid code target as a 12% load increase initiated by a simulated frequency drop was demonstrated in less than 10 seconds. In order to fulfill the island formation requirement a load reduction of 45% within 6 seconds as an instantaneous answer to the detected frequency deviation in the gas turbine controller was achieved. Such capabilities are indispensable to allow effective grid stabilization, avoidance of grid blackouts or in order to maintain plant island load in case of significant grid disturbances.

Test runs also have demonstrated, under the supervision and verification of the independent certified body TÜV, the world class performance of:

- Plant net power output of 578 MW
– Plant net efficiency of 60.75% with compliance to the emission limits

Until December 2012 the SGT5-8000H has achieved in the Irsching 4 power plant in sum more than 19,000 equivalent operating hours and 500 starts. While an inspection in summer 2012 confirmed the excellent engine condition, especially of the hot gas path. This is even more impressive considering that the plant in Irsching is run in a daily start/stop mode, imposing maximum stresses to the hardware every day. At the same time Irsching 4 shows outstanding plant availability and starting reliability, which is very necessary for such a daily start/stop operating regime.

3.4. Test and validation of the SGT6-8000H

The SGT6-8000H is a full scaled design (geometry factor 1.2) to the SGT5-8000H. The major difference is the number of burners (12 instead of 16) and the related design adjustments (e.g. casing; transition from burner to turbine vane 1) in order to be able to use the same combustion system for 50 and 60Hz Version.

Siemens has a vast and long lasting experience in scaling gas turbine design (e.g. SGT5-2000E/SGT6-2000E or SGT5-4000F/SGT6-4000F). This approach allowed Siemens to achieve a relative short design phase for the SGT6-8000H; in fact, the design of the SGT6-8000H was initiated during the validation phase of the SGT5-8000H while the first commercial contract was signed only 2 years later. Of course the approach to start design after having already 50Hz validation results available significantly increased the confidence in achieving the desired design targets. There is still some remaining risk in scaling, especially for the non-scaled design parts. Examples are turbine inlet temperature profile; the specific transition-piece from combustor to turbine inlet and even production processes for the individual parts.

Siemens experience in scaling allows for precise prediction of the items in question. However, in order to further limit the implementation risk of such a scaled prototype for both customer and Siemens, it was decided to perform a stringent test- and validation program also for the SGT6-8000H. Even if the risk for such an event is low, any unexpected prototype issue will cost both OEM and customer valuable time and money, if experienced during commissioning in a commercial project. Siemens
policy is to avoid this. Therefore the 60Hz 8000H engine was implemented in the Berlin Test Facility within the Berlin gas turbine factory. Connected to a water brake instead of a grid connection via a generator, the engine can be operated at the design frequency of 60Hz as well as any desired under- and over-frequency despite being located in a 50Hz region. After a significant rebuilt of the test center in 2010/2011 the first SGT6-8000H was operated for a ca. 10 months test phase.

Focus of the validation phase was threefold. One target was to confirm the design of the scaled engine like hardware integrity, thermodynamical behavior, emission profile etc. Second target was to confirm the validation results of the SGT5-8000H and thus the design base. Third target was to add some additional test topics that were not conducted in Irsching like oil operation or sub-25ppm NOₓ operation. The test program was structured accordingly. The first test phase consisted of a baseline testing while oil operation or sub-25ppm NOₓ testing was conducted after
corresponding outages.

The targets of the SGT6-8000H test program were fully achieved. The data retrieved confirmed both performance prediction of SGT6-8000H and SGT5-8000H; all engine parameters (temperatures, pressures etc.) were as expected; predicted temperature profiles were confirmed via thermal paint testing; under- and over-frequency behavior of the engine was confirmed; operational behavior on both fuel gas and fuel oil met the requirements. Lessons learned from the validation phase are implemented in the production engines for the commercial projects; as a result any impact on the commercial projects could be avoided. So it can be concluded that the approach to validate also the scaled SGT6-8000H proved to be beneficial for both Siemens and the Siemens customers. With the Berlin testing the accumulated operation experience of the 8000H series by December 2012 is already at 650 starts and 23,000 EOH.
4. Market launch and first commercial references

With the successful conclusion of the related validation and testing phases, Siemens Energy is the first OEM to have a gas turbine engine and a combined cycle plant in commercial operation with efficiency far beyond 60%. Siemens impressively demonstrated that world-record technology doesn’t come at a disadvantage e.g. on reliability and instead brings significant advantage to customers. The 8000H technology has a clear advance of years on the gas turbine and combined cycle market.

The next units coming online are the units from Florida Power & Light. FP&L ordered six SGT6-8000H GT packages for the sites in Riviera Beach and Cape Canaveral in a multi-shaft configuration (3 on 1) to provide approximately 1200 MW electrical energy each. The first units at Cape Canaveral are just being commissioned and will see commercial operation mid of 2013, followed after 1 year by the units in Riviera. Shortly after the FP&L contract the next order from South Korea for the supply of a complete combined cycle power plant equipped with the SGT6-8000H in a single shaft configuration was placed. As a consortium leader, Siemens is installing the 400MW class power plant Bugok 3 as a turnkey project. In 2012 further seven units were successfully sold in South Korea, and another order of 3 engines was placed again by FP&L for their Port Everglades site, proving their confidence in the 8000H after their insight in the Berlin Test results and the successful project execution on Cape Canaveral site, which had 1st fire on Nov 19, 2012. Following the success in Asia, Siemens Energy also received an order for turnkey erection of the Lausward combined cycle power plant with district heat extraction in Düsseldorf, Germany, and another SCC5-8000H 1S configuration in Turkey. Notable on the Lausward project is the fact that with an electrical unit output of around 595MW in single shaft arrangement and a plant net efficiency of over 61%, the 8000H in Lausward CCPP will set again a new world record. In addition, the generated thermal energy will be used for the district heating system in the city of Düsseldorf. Never before has it been possible to extract more than 300 MWth of district heat from a single power plant unit in combined cycle operation. Thus, the overall fuel utilization will be in the range of
85 percent, making the SGT5-8000H the core of one of the most efficient and 
environmentally sustainable plants in the world.

5. Conclusion

This paper provides an overview regarding the Siemens 8000H series product 
portfolio. The core of Siemens’ H class plants is the SGT5-8000H providing world 
class performance and excellent reliability. With a fully air-cooled concept avoiding 
interfaces like external coolers it is easily integrated in any kind of power plants, for 
pure power production or in combination with any kind of heat extraction or 
desalination.

The main elements of the different solutions for 50Hz and 60Hz were presented. The 
standard Siemens’ H class product portfolio is based on single shaft and multi shaft 
arrangements and can be extended to further solutions, serving any specific customer 
need. The product portfolio offers several solutions from a pure GT package to a full 
turnkey solution, all drastically reducing life cycle costs and specific investment costs.

The SGT-8000H is fully field tested and validated by the SGT5-8000H testing in 
Irsching and the SGT6-8000H testing in Berlin Test Facility. An overview about all 
activities prior to market introduction was shown and which demonstrates Siemens’ 
approach in keeping the overall technology risk in house and hence not forcing the 
customers to take more risk compared to a standard F class unit. The SCC-8000H 
series has accumulated more than 650 starts and 23.000 EOH, with the front runner 
Irsching 4 having seen already more than 19.000 EOH and 500 starts, proving the 
maturity of the design and at the same time confirming the expectations towards 
engine reliability.

Siemens 8000H product lines are the result of a long term development program with 
significant financial investments, demonstrating Siemens commitment to meet 
customer’s expectations and to durably improve customer’s value. Since commercial 
availability 20 units were sold. This great success confirms the achievements in 
design, test and validation over more than a decade.
6. References


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