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ADVANCED SGT6-5000F DEVELOPMENT

Scott Nordlund*[†], Josh Kovac**
Siemens Energy, Inc. ([†]Scott.Nordlund@siemens.com)
*****Siemens Energy, Inc. (Josh.Kovac@siemens.com)***

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Abstract

The SGT6-5000F engine has demonstrated an exceptional operational record over a 15-year, 4.7+ million fleet hour history. Since its introduction in 1993, this F-Class gas turbine has undergone continuous development to improve performance, reliability and operational flexibility and to reduce emissions and life cycle costs. The result is a gas turbine with an excellent operational record and customer value. In 2008, Siemens Energy started production of the latest upgraded version of the SGT6-5000F. The capabilities of this newest offering include a dual-fuel gas turbine which can deliver 150MW of power to the grid within 10 minutes and reach baseload in another 2 minutes, an Ultra Low NOx combustion system (9ppm), and hot gas path components designed for extended maintenance intervals. The first field unit of this latest version was commissioned in June 2009. This paper describes the technological advances now available and demonstrated in the SGT6-5000F gas turbine that further improve performance, reliability, operational flexibility and customer value.

1 Introduction

The hallmark of the SGT6-5000F gas turbine, first introduced in 1993, has been its' steadily increasing capabilities as market requirements have evolved over time. The SGT6-5000F kept pace with the need for rapid expansion in the 1990's with increasing power output and improved thermal efficiency as deregulation and low natural gas prices opened new market opportunities for base loaded gas turbines. Then with the dramatic downturn in the market in the early 2000's, the industry saw changing operating modes. The new challenge required transitioning plants from expected base load operations to nightly and weekend shut downs to remain economically viable. Now, the recent upturn in requirements for gas turbines and expected robust market in the future comes along with the need for a fully flexible gas turbine solution.

The latest evolution of the Siemens SGT6-5000F version, or simply the F(4), will excel within these market requirements with increased power output, improved thermal efficiency, extended maintenance intervals and greatly enhanced operating flexibility. The SGT6-5000F gas turbines leaving the Siemens factory in North America includes options for improved economic viability and success of our customers. These capabilities include fast start (10 minutes to 150 MW), improved starting reliability, single-digit NOx capability, low turndown ratios for reduced CO emissions at part loads and extended operating hours and starts between maintenance intervals.

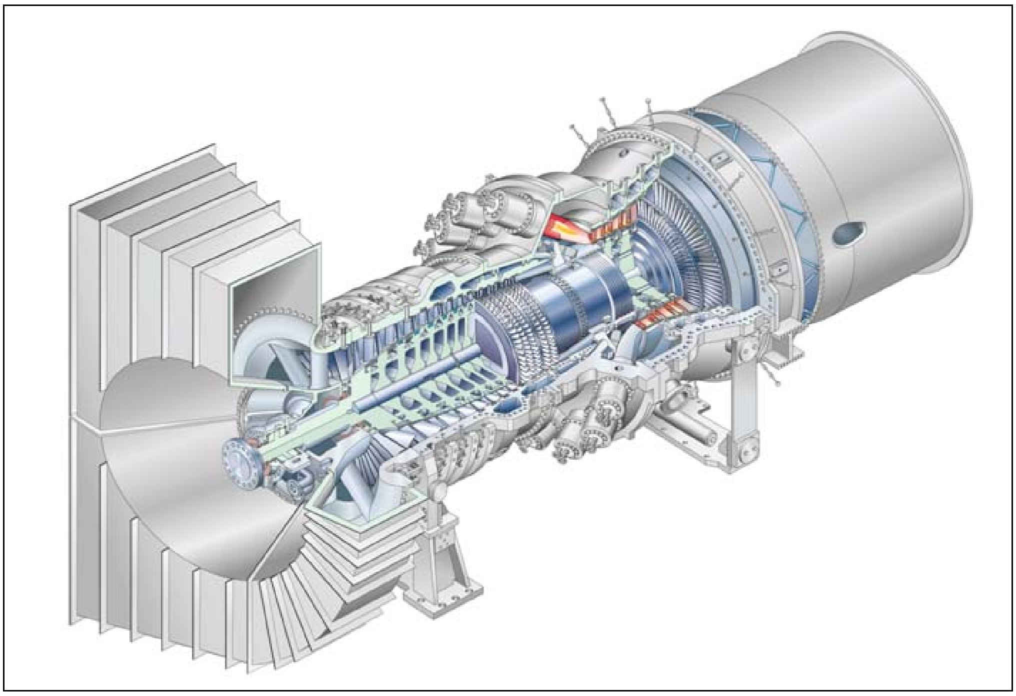

Figure 1. SGT6-5000F(4)

2 SGT6-5000F Engine Development Background

The SGT6-5000F introduction represented a technology step change made possible by advancements in manufacturing, materials, analytical techniques and airfoil cooling. The improvement in thermal performance was achieved simultaneously with emissions reduction through dry low NO_x technology. This gas turbine, which was designed for both simple cycle and combined cycle (CC) power generation in utility and industrial applications, represented the evolutionary improvement in the successful W501 family. Its design was based on fundamental, time-proven design concepts used in previous models, as well as new concepts and technologies incorporated to increase efficiency, reduce emissions and enhance reliability. It was designed to operate on all conventional fuels, as well as coal-derived low BTU gas for particular variants. New technologies were validated for engine application by extensive rig and two full load engine shop tests, as well as field tests in the initial installation. Figure 1 shows a cross-section of the SGT6-5000F layout. The 13-stage compressor is connected to the 4-stage turbine by a single tie bolt, and the ultra low NO_x combustion system employs 16 can annular baskets.

3 SGT6-5000F Operating Fleet Overview

The 213 SGT6-5000F engines currently in service are employed in peaking, intermediate and continuous duty operation. The fleet has amassed more than 4.7 million operating hours and has demonstrated excellent reliability, availability and starting reliability. These units, plus an additional 27 committed, represent the highest number of any one model of 60 Hz Siemens gas turbines sold. Due to design enhancements, development efforts, and technology cross flow from other Siemens' advanced gas turbines, the simple cycle output has increased from 150 MW to 208 MW and its LHV efficiency from 35% to 38+%. In 1x1 Combined Cycle applications, the net plant output and efficiency are now more than 300 MW and 57.5%, respectively.

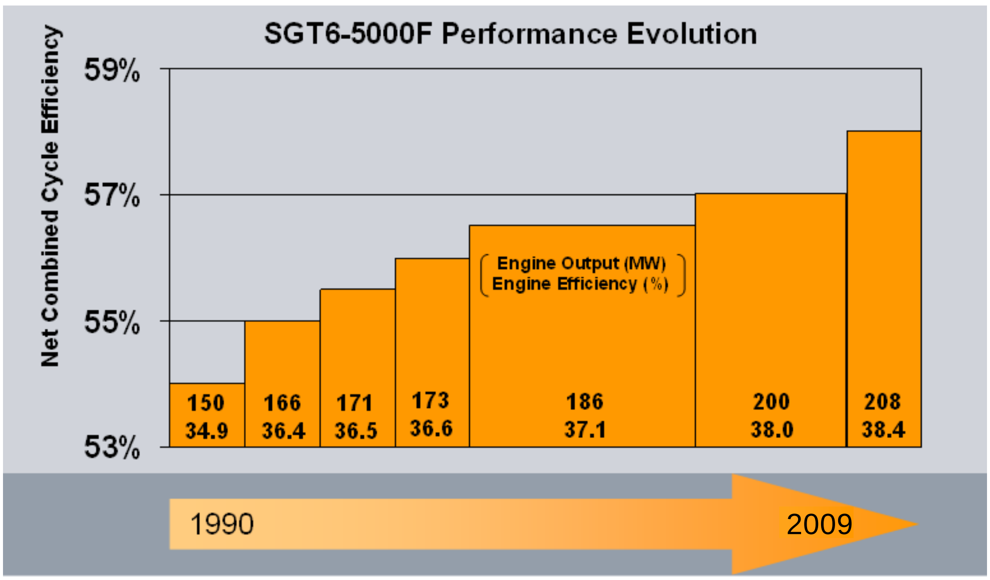

Figure 2. SGT6-5000F Performance Evolution

The criterion by which a gas turbine is judged to be successful is its' operating experience. The specific criteria for success include performance, emissions, mechanical integrity (as defined by RAM and starting reliability), life cycle costs and operational flexibility. All of the above are important, but in the current competitive and changing market environment, operational flexibility and adaptability to this environment have assumed a much greater significance. To be economically viable, the electricity generating plant must respond quickly, efficiently and reliably to any required changes in operating conditions such as load demand, start-stop operation, different fuels, etc., while operating within emissions regulations. The SGT6-5000F has demonstrated over the last 15 years its success in this environment, providing its operators with exceptional service.

The demonstrated median measured fleet values for Availability and Reliability (as of April '09) are 95.6% and 99.7% respectively as shown in Figure 3. The values presented represent a statistical view of the service fleet as opposed to simple averages of these parameters. This provides a more accurate view of the fleet performance. The lead SGT6-5000F engine has accumulated more than 120,000 operating hours. The SGT6-5000F engine has demonstrated its mechanical integrity, operational flexibility and excellent performance through a continuous improvement and dedicated product development effort carried out since its introduction. This includes not only the gas turbine, but also the generator, mechanical auxiliaries (lube oil, fuel, etc.), electrical components and control system.

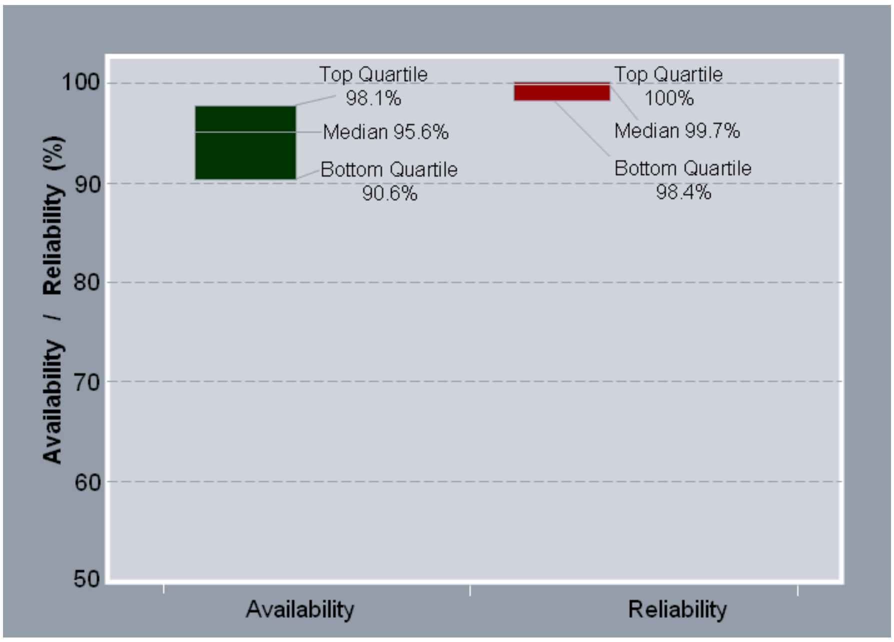

Figure 3. SGT6-5000F Fleet Availability & Reliability

4 Engine Overview

4.1 Siemens Common Platform

With the merger of Siemens-KWU and Westinghouse Power Generation in 1998, the process of integrating two design philosophies, frame architectures, and component configurations began. A "Common Platform" approach has resulted to be applied to all future Siemens gas turbine research and development. The integration of the technical capabilities of the two companies was undertaken via a major R&D integration effort aimed at selecting the best technologies, design philosophies and practices, analytical tools and engine architecture for future development. The elements which make up the common platform have been extensively verified and tested in the lab, in full load and with the analysis of fleet statistics. The result was a cutting edge toolbox available for the development of not only new frames, but also the evolution of the SGT6-5000F.

Over the last 14 years, the evolutionary enhancements of the SGT6-5000F have improved its performance, reliability and emissions. The F(4) represents the Siemens response to the market requirement for not only ever increasing power and improving efficiency, but also operational flexibility This significant improvement was achieved through a concerted development effort. Advancements include:

- compressor technology development,
- combustion system development,
- cooling and leakage air reduction,
- cooling and disc cavity air modulation,
- improved thermal barrier coating (TBC) application on some turbine airfoils,
- selected turbine vane and blade improvements,
- blade tip clearance reduction, and
- exhaust system enhancements.

The F(4)'s demonstrated high performance level attests to the success of these efforts.

4.2 Component Design

The Siemens "Common Platform" approach has yielded significant improvements in terms of engine component capabilities, robustness and reduced life cycle costs. In the paragraphs to follow, some detail is provided about the integration of the common platform into the SGT6-5000F and the benefits realized from this effort in terms of the engine value to the customer. Figure 4 below provides a longitudinal view of the F(4) with several "platform" items clearly visible: 13 stage compressor with 3 rows of variable stator vanes in addition to the variable inlet guide vanes, single tie bolt rotor and single piece exhaust casing.

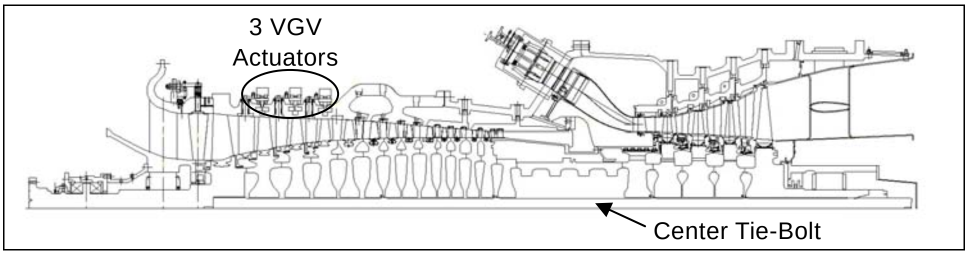

Figure 4. SGT6-5000F(4) Longitudinal Section

4.2.1 Compressor

Efficiency, superior durability, and expanded operational flexibility were the targets of the compressor enhancements in the F(4). While maintaining the same design point pressure ratio and inlet mass flow as the previous variant, and incorporating the best features and experience from the operating fleet and technology innovation, the augmented design allows a stage count reduction from 16 to 13. State-of-the- art design tools were employed to incorporate detailed research, analysis, lab testing, and extensive expertise in aerodynamic and mechanical analysis, leading to revised compressor design that provides optimized compressor performance at both on- and off-design levels.

Siemens design tools represent the culmination of proven, best practices merged from Siemens and Westinghouse, and allow for routine front-to-back compressor 3D CFD multistage analysis, unsteady blade row interaction, forced response analyses and aero-elastic analysis. New sealing design was incorporated to provide better leakage control over the complete operating range. Six Sigma methodologies were utilized throughout the development to implement the technologies into a robust design. The result was targeted off-design performance, improved surge margin and turndown ratio capability, wider allowable under/over frequency range and a more robust mechanical design. The high efficiency airfoils were made more robust with increased thickness to chord ratios for better FOD resistance and greater tolerance to ice ingestion. In addition to the variable inlet guide vanes (IGV), three front stage stator rows were made variable for improved part load performance and operational flexibility through ambient temperature insensitivity. The stators on the downstream stages were cantilevered (without inner shrouds), with tight clearances between the stator ends and the disc rims.

4.2.2 Compressor Operational Experience

In demonstrating the full capability of the design efforts, Siemens employed the Berlin Test Facility, BTF, to validate the improved compressor design. The tests were conducted over a wider operating range than would be possible in a power plant connected to the electrical grid. The compressor was instrumented with 800 sensors. These included temperatures, static pressures, radial Kiel head probes, radial traverses with 5-hole probes at various stages inside the compressor, strain gages on stators and rotating blades, Kulites to measure dynamic pressure, non-contact stress measurement probes for monitoring blade vibration and tip clearance probes. The test program incorporated starting sequence optimization, overall efficiency and inlet mass flow measurement, compressor characteristics definition, surge margin definition, vibratory stress measurement, tip clearance measurement and under/over speed tests. To date, the compressor which is still in operation in the Berlin Test Facility has accumulated approximately 500 operating hours, 1100 equivalent starts and 13 surge tests from full speed no load all the way to base load. Surge test results confirmed that surge margins were in line with analytical predictions and the mechanical robustness of the compressor was demonstrated, with no damage incurred from the multiple surge events. Test data analysis confirmed that the platform compressor's key parameters, such as mass flow, efficiency, operating range and aero mechanical behavior met or exceeded expectations. Also, taking advantage of common platform, this compressor has undergone additional validation on the first SGT5-8000H engine.

During first F(4) unit commissioning in June 2009 the improved compressor design matched all performance expectations including efficiency and mass flow.

4.2.3 Rotor

As part of the common platform integration into the F(4), the rotor is constructed with a single center tie bolt. The single tie bolt rotor has been in operation for many decades in the existing Siemens fleet with an excellent operational and maintenance track record. To date, greater that 500 units operating with single tie bolt rotors have amassed over 12 million hours and 149,000 starts. The center tie bolt with its significantly reduced parts count and simplified tie bolt tensioning sequence, allows ease of rotor assembly. The rotor is balanced in the shop using low speed balance only, with no requirement for a high speed balance or rotor over speed operation in a sub-atmospheric balance facility. No nickel-based alloys are used in the rotor construction; rather the rotor uses upgraded steel discs in the turbine section, allowing for greater flexibility in turbine blade cooling air temperature.

4.2.4 Combustion System and Turbine

The upgrade of the combustor system and turbine sections where undertaken with two major requirements. First, the new components had to meet extended maintenance interval requirements while improving thermal capabilities. Second, the combustion and turbine design were undertaken with a product requirement specification for complete retrofit-ability into the SGT6-5000F fleet. To achieve these goals, design changes included aerodynamic, materials, coating systems and cooling technologies upgrades within the Siemens common platform toolbox.

The combustion system was equipped with state of the art low emission technology as well as an equipment protection package, that, together cultivate a system capable of extended operation intervals between required inspections. Combustion system options which incorporate the increased maintenance intervals include both Ultra Low NOx (ULN) systems as well as Dry Low NOx (DLN) systems. Installation of these advanced combustion systems also include the Combustor Dynamics Protection System (SPPA-D3000). Combustion dynamics sensors, which use transistors to measure dynamic pressure, were installed in the combustors to detect low and high frequencies. When dynamic fluctuations exceed a preset value, the control system tunes the combustor away from the instability.

As noted in Section 4.6.1, the combustion system mechanical design and manufacturing processes were improved and the transition aerodynamic shape and cooling design were enhanced, allowing for an increase in the combustor inspection interval by over 50% on hours and 100% on starts.

The enhanced turbine section resulted in increased efficiency, power output, service life, and lower repair costs. Turbine stage 1 design has new aerodynamic, cooling, coatings and materials design, Stage 2 includes improved cooling, materials and coatings technology and stages 3 and 4 utilize new coatings technology. The fourth stage vane and blade designs contribute to improved efficiency and increased maximum shaft power limit. Additionally, rotor cooling air optimization supports enhanced efficiency by way of targeted hot running blade tip clearances.

4.2.5 Combustion System and Turbine Operational Experience

The design improvements to the combustion and turbine noted above were made using not only the latest Siemens analytical tools but also using empirical data from the field. Taking into account current hardware performance and identifying the distress modes, improvements to the life cycle costs have been realized with these new designs. As with all other new components, the combustion system and turbine systems designs have been fully verified using both rig testing and full scale, instrumented engine testing in the Berlin Test Facility. Following engine testing in late 2006, validation sets have been installed in multiple engines in the fleet to ensure both the combustion and turbine hardware meet expectations on performance, mechanical robustness, maintenance interval, repair cost and overall part life. As of this writing the validation lead sets both in customer units and the Berlin Test Facility continue to operate, having accumulated over 3,000 equivalent starts and 70,000 operating hours. Lead sets have accumulated over 400 starts and 15,000 hours.

During first F(4) unit commissioning in June 2009 the improved turbine design hardware matched all performance expectations including efficiency and swallowing capacity.

4.2.6 Exhaust System

Starting in 2007, SGT6-5000Fs began shipping with an upgraded exhaust system which is also integrated into the F(4). The development of the improved exhaust system focused on increased pressure recovery (i.e. thermal efficiency), improved mechanical robustness and greater operational flexibility. As all Siemens gas turbine design efforts are now undertaken with the common platform approach, the redesigned exhaust is no different. The design leverages the excellent experience with a "single piece" exhaust system from the Siemens fleet of gas turbines. There are several major changes included in the redesign involving the exhaust casing, diffuser flow path, main bearing support struts, and other components.

The upgraded exhaust system is currently in operation at the Siemens Berlin Test Facility where the expected improvements have been verified against analytical predictions. Temperatures, pressures and dynamic aero-mechanical parameters measured as predicted. The test facility affords the opportunity to put a very high number of thermal cycles on the exhaust system. The single piece exhaust system installed in Berlin, will for the foreseeable future be the fleet leader in terms of cycles and will prove out its' expected long term durability. In summary, these aerodynamic, material and mechanical design changes work together to allow higher exhaust temperature capability, increased aerodynamic efficiency and improved operational flexibility enabling fast start times and low turndown ratios.

4.3 Future Upgrades

SGT6-5000F gas turbine performance, reliability and operational flexibility have improved, while emissions and life cycle costs have decreased steadily since its introduction. This was accomplished by planned development programs, which facilitated the introduction of new technologies and concepts, as well as a structured process for field technical issue resolution. The result was a more competitive product and added value to our customers.

The SGT6-5000F gas turbine will undergo continued enhancement for both new and in-service plants. Future product enhancement process will concentrate not only on performance and emissions, but also on operational flexibility, reliability, availability, maintainability, lower life cycle costs, longer component lives, improved service factors and increased repair intervals. Near-term planned enhancements are additional NOx emissions reduction, improved CO turndown performance, automated engine control settings optimization, and extensions to maintenance inspection intervals with reduced fallout rate for service run components.

5 Operational Flexibility

5.1 Emissions

The original SGT6-5000F gas turbine incorporated diffusion flame DF-42 combustors with 42 ppm NO_x (@ 15% O_2) emissions on natural gas. Through continuous combustion system development, NOx emission was reduced to 15 ppm with the premixed dry low NO_x (DLN) combustors and now to <9 ppm with the ultra low NOx (ULN) combustors. In addition to reducing NO_x, the ULN combustion system controls CO, volatile organic compounds (VOC) and particulate emissions. This development also addressed potential fuel flexibility issues, as more LNG enters the U.S. market, and expanded operating range (turndown), where low CO emissions are required.

The starting point for latest development was the premixed DLN combustor. NO_x reduction was achieved through temperature and heat release strategy modification by staging the combustion process. The current DLN combustor design uses 4 fuel stages to mix the natural gas with combustion air. These stages come on line independently, as the engine is ramped up in power. At all loads the fuel is injected continuously through the pilot nozzle and is not premixed, thus limiting the achievable minimum NO_x emissions. The modifications required to achieve sub 9 ppm NO_x in the ULN, 5-stage system concentrated on a premixed pilot design and support housing design changes. The pilot and the main pre-mixers on the combustor support housing now employ swirler fuel injection, where the fuel is injected off the swirler vanes, thus providing more injection points and better mixing. The ULN combustion system validation included CFD modeling, high pressure single basket rig testing and a full-scale engine test in the Berlin Test Facility (BTF), which allowed testing over a wide load range. Refer to Figure 5 for photograph of the BTF. The value of the BTF was demonstrated in field engine validation where the ULN system operated within the design emissions and dynamics parameters on the first day of testing. The new combustor design demonstrates emissions and combustion dynamics virtually not affected by fuel temperature variations, such as when the engine loses the fuel heater and the fuel temperature drops, or with variations in fuel composition. The thermal loading on the hot parts, such as the combustor liner, transition and the first stage turbine vane, is very similar to the existing 25 ppm NO_x system.

Figure 5. Berlin Test Facility

During first F(4) unit commissioning in June 2009 sub-9ppm NO_x emissions were obtained from baseload operation down to 38% load.

5.2 10 Minute Start-Up Time to 150MW

In response to meeting the need to provide reliable, responsive output for spikes in power demand, Siemens has reduced the time to baseload by over 50%. A start enabled by a mechanical starting motor from initiation to full power was approximately 30 minutes. The improved start time capability provides 5 minutes from start initiation to minimum load, followed by a 30 MW/minute loading rate, such that 150 MW load is reached within 10 minutes (see Figure 6), and full load is achieved in 12-13 minutes.

To achieve the improved start capability the following steps were taken:

1. Static frequency converter (SFC) (static start, where generator operates as a motor) replaced the mechanical starter motor. SFC allows more efficient and faster rotor acceleration than the equivalently sized mechanical starting motor.

2. Turning gear (TG) speed was increased from 3 rpm to 120 rpm.

The higher TG speed enables the generator rotor wedges to lock up, prevents compressor blade locking mechanism wear, and locks turbine blades into running position. Higher TG speed also helps the engine cool down faster, because the turbine parts are cooled faster and tip clearances are similar to the cold tip clearance.

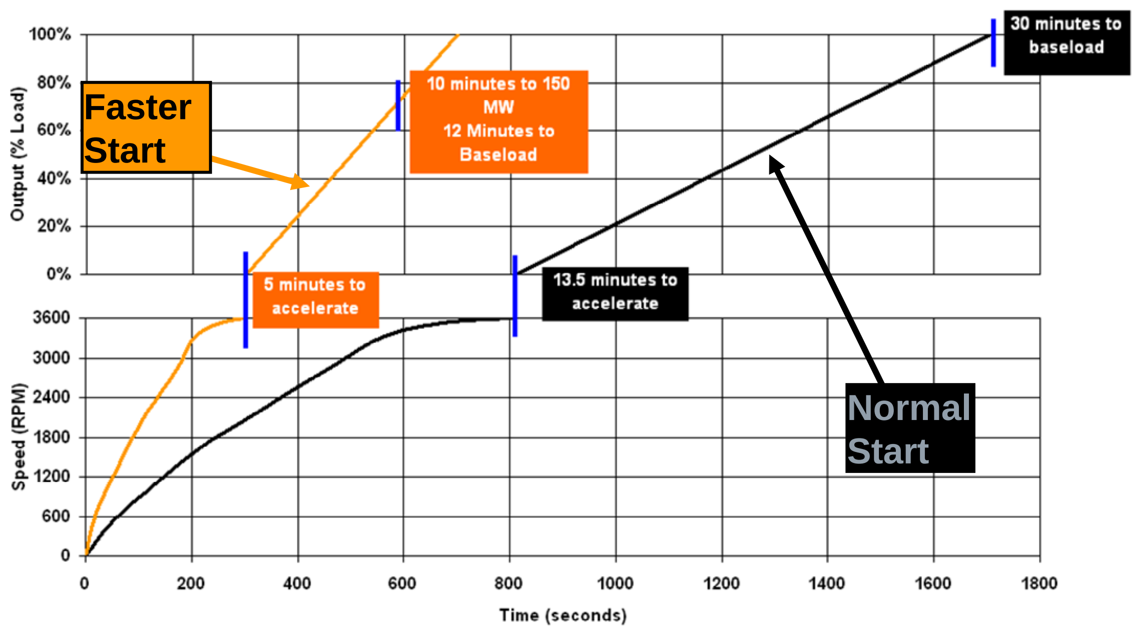

Figure 6. Fast Start / Fast Load Rate Reduces Startup Time by Over 60%

During first F(4) commissioning in June 2009 sub-10 minute start-up time to 150 MW was demonstrated. A time of 5 minutes was required to achieve synchronization followed by a loading rate of 30MW/min.

5.3 Part Load CO Emission Reduction

Reduced low load CO emissions were achieved by operational modifications and bypassing supplemental cooling air around the combustor. The result of bypassing air around the combustor is increased combustor flame temperature, which leads to reduced CO production. With the required equipment and operational changes, CO emission is kept <10ppm down to at least 40% load, without alteration to the internal architecture of the combustion system. The result is greater flexibility in cyclic operational mode and better use of equipment in a highly volatile market.

During first F(4) unit commissioning in June 2009 sub-10ppm CO emissions were achieved down to 38% load when functioning with the air bypass system. This was achieved simultaneously with sub-9ppm NO_x.

5.4 Outlet Temperature Control

Engine control parameter settings were previously based on a function of exhaust temperature versus combustor shell pressure. This relationship defined the base load firing temperature to which the engine was ultimately controlled. Engine control parameter settings are now based on a relationship of exhaust temperature, compressor inlet temperature, and load. The Siemens system employing this relationship is called Outlet Temperature Corrected (OTC) control. OTC optimizes part load performance reduces NOx drift and reduces the need for seasonal tuning. A standard control method for V-engines for over 20 years, OTC represents another demonstration of the common platform approach. A comparison of OTC with legacy control methodology is shown in Figure 7. Note the improvement in part load turbine inlet and exhaust temperature maintenance.

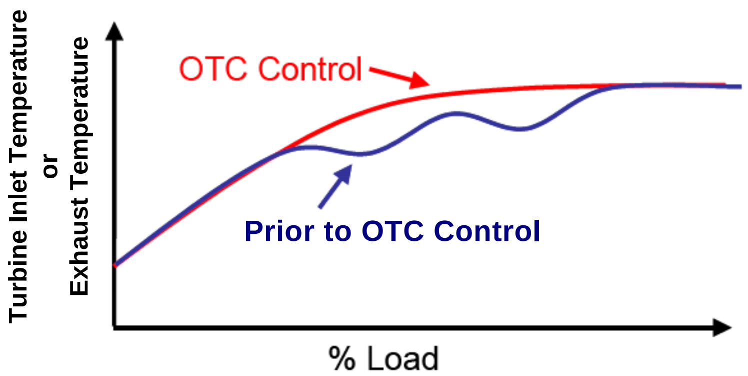

Figure 7. OTC Control Effect on Turbine Inlet and Exhaust Temperatures

5.5 Increased Combustion System Inspection Interval

Combustor basket and fuel nozzle mechanical design and manufacturing processes were improved to address low-life areas and the transition aerodynamic shape and cooling design were enhanced. These improvements allowed an increase in the combustor inspection interval by over 50% on an hours based maintenance cycle from 8,000 equivalent base load (EBH) operating hours to 12,500 hours and by over 100% on a starts based maintenance cycle from 450 equivalent starts (ES) to 900 equivalent starts. This increase in starts capability will eliminate the need for combustor inspections altogether for a starts based engine since it aligns with a Hot Gas Path Inspection. This lengthens the interval between maintenance inspections while improving operational flexibility for units that operate the required hardware.

5.6 Trip Factor Reduction

Maintenance intervals are calculated using operational data in a mathematical formula. One component of this equation that accounts for rapid temperature changes experienced by the turbine hardware is the number and type of trips experienced in operation. A “Trip Factor” is assigned a value depending on the severity of the trip across the load range. The maximum full load Trip Factor was reduced from 20 to 8 equivalent starts due to thermal and structural design improvements to turbine and combustor components, with corresponding reductions in Trip Factors from part load conditions. This change allows the operator to run the engine for longer periods between maintenance inspections thereby reducing life cycle costs and enhancing operational flexibility. See Figure 8 below for a summary of the inspection interval increase and trip factor reduction.

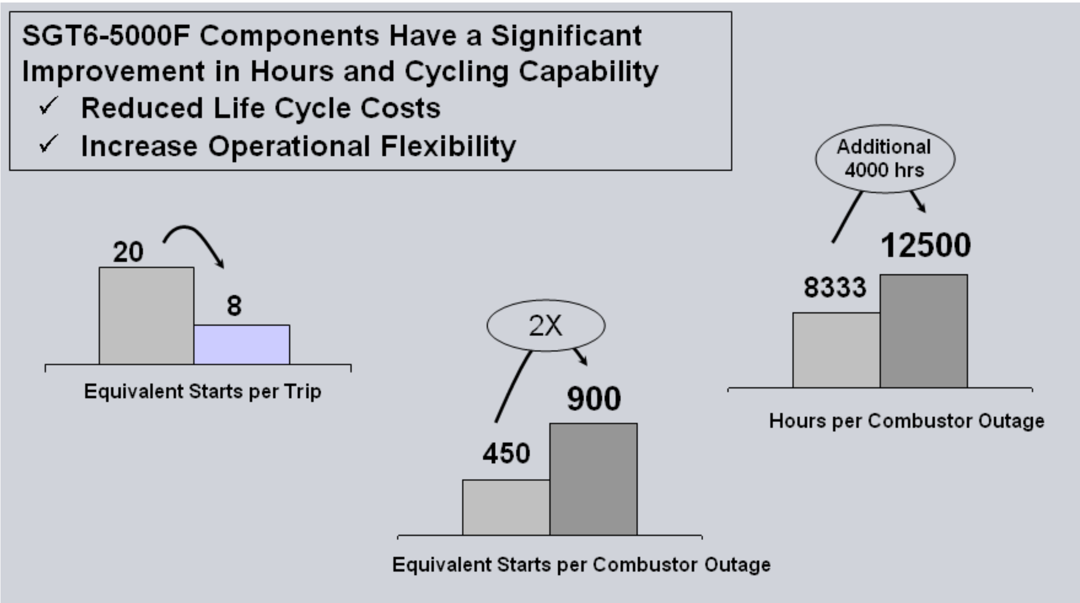

Figure 8. Extended Maintenance Intervals & Reduced Trip Factors

5.7 LNG Capability

Due to natural gas supply market volatility, increasing prices and declining domestic production, liquefied natural gas (LNG) is becoming an attractive alternative fuel choice for gas turbines. LNG imports are expected to increase in the future with imminent operation of several terminals and many others announced for construction. LNG consists of methane, which is the main constituent in natural gas, along with heavier components, such as ethane, propane and butane. Depending on the level of heavier constituents, LNG could result in a higher or lower flame temperature than traditional natural gas and potentially impact the safe and environmentally sound operation of gas turbine plants.

Safe gas turbine operation on LNG with acceptable emissions, combustion dynamics, reliability and parts life was successfully demonstrated at a customer site for the SGT6-5000F combustion system.

6 Integration into Flexible Combined Cycle Power Plants

To capitalize on the operating flexibility of the SGT6-5000F gas turbine, the bottoming cycle must be skillfully designed to address and alleviate component and system limitations. Siemens has leveraged it’s knowledge and expertise with the BENSON® once through HRSG technology and performed extensive transient analysis with key HRSG suppliers to design the 275 MW SCC6-5000F 1x1 Flex-Plant™ 10 (or simply Flex-Plant™ 10). Integrated at the core of the Flex-Plant™ 10 is the highly flexible SGT6-5000F. This combined cycle plant incorporates a simplified single-pressure bottoming cycle with modified drum and reduced steam temperatures and pressures. Figure 9 below depicts a graphic from the fully developed 3-D model of a two-unit Flex-Plant™ 10. Other attributes include pipe pre-warming, high-capacity attemperators, and turbine stress controllers.

The Flex-Plant™ 10 has a net power output of 275 MW at greater than 48% efficiency. Starting from turning gear, it can generate 150 MW within 10 minutes with NOx emissions of 9ppm. With the installation of SCR and CO catalysts, stack emissions compliance is reached in about 20 minutes. Utilizing the fast start gas turbine has the additional advantage of greatly reducing start up emissions from a traditional combined cycle plant. Expected start-up emissions are 152 lb/start for CO, 12.4 lb/start for NOx and 13 lb/start for VOC.

Figure 9. Flex-Plant 10 Depiction

With a 10-minute start capability to 150MW, the 1x1 Flex-Plant^{TM} 10 is designed for peaking to intermediate duty. With net efficiency that is 6-7% points higher than aero-derivative and ICAD products, 275 MW combined cycle plant offers considerably higher efficiencies without compromising operational flexibility.

The SCC6-5000F 2x1 Flex-Plant^{TM} 30, rated at 618MW, is more of a conventional combined cycle with some fast start capability and world class efficiency of greater than 57%. Intended for intermediate to continuous duty, start times (30 min to baseload) are faster than traditional CC units due to higher loading rate in part enabled by use of a once-through Benson HP HRSG and a Turbine Stress Controller. Combined with high startup efficiency, startup emissions are extremely low. Additional features enhancing operational flexibility for both Flex-Plant^{TM} offerings include high-capacity attemperator, condensate polishing plant faster steam purity, auxiliary boiler, drain and vent automation, mechanical vacuum pumps for the condenser, fast warm-up of main steam piping, and Low Load CO technologies.

7 Summary

The 213 SGT6-5000F gas turbines in peaking, intermediate and base load operation have achieved more than 4.7 million operating hours and have established an impressive service record. The lead unit has been in operation for more than 120,000 hours. The fleet median Reliability and Availability are 99.7% and 95.6%, respectively. The SGT6-5000F is capable of producing 208 MW at 38.4% efficiency in simple cycle operation and >300 MW at 57.5% in CC applications, with a maximum shaft power capability over 250 MW. On natural gas fuel, NO_x emissions capability is <9 ppm and <42 ppm on distillate oil fuel with water injection. A concerted development effort over many years has provided performance improvements and emissions reductions. In response to current market demands for cyclic and start/stop operational modes, design enhancements were incorporated to further enhance operational flexibility. The starting reliability was improved and starting time to 150MW reduced to 10 minutes. The turndown capability was reduced to 40% load. The outlet temperature correction control system was implemented to enhance part load performance and emissions. The Trip Factor was reduced from 20 to 8 and the combustor/transition inspection interval was increased to 12,500 hours and 900 starts. Compressor redesign efforts contributed to more advantageous part load performance and increased operational flexibility. Selected turbine vane and blade aerodynamic enhancements and cooling optimization improved performance and durability, as did the exhaust system improvements. All of the above enhancements resulted in a product with superior performance, low emissions, excellent durability and wide operational flexibility. To further enhance its value, the engine is available for operation in IGCC applications and on LNG.

The SGT6-5000F gas turbine has demonstrated its capability in the current market conditions by its performance, reliability, availability, low emissions and operational flexibility. It is now, and will continue to be, a very efficient and reliable low cost electricity generator, which is critical in changing market conditions.

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