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OPERATIONAL EXPERIENCE OF 37 MW SIEMENS SGT-750

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Abstract

This paper will describe the operation experience of the SIEMENS SGT-750 gas turbine. A brief overview of the gas turbine will be given. A description of the different engines manufactured. The test engine instrumentation and purpose will be presented, with special attention to the on-line infrared camera installation. Test results will be presented and discussed with reference to operation experience.

1 The SGT-750 Gas Turbine

A brief overview of the SGT-750 gas turbine will be given together with the most important features, a more extensive presentation is made in [1].

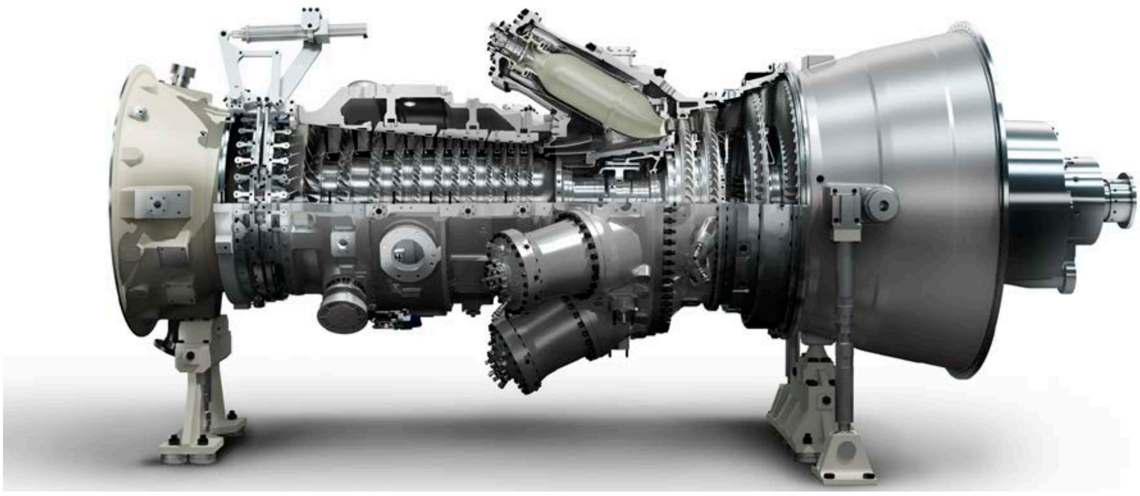

Figure 1: SGT-750 Gas turbine.

The SGT-750 is a twin shaft gas turbine with a free power turbine, see figure 1, and it can be employed both for power generation and as a mechanical drive. This gas turbine attains an efficiency level of 40% as and has a capacity of 37 megawatts (MW). The complete gas turbine unit is mounted on a single foundation frame into which the lube oil tank is integrated. All the auxiliary systems such as start motor and electrically driven back-up systems are mounted on the base frame.

The compressor has 13 stages and a pressure ratio 24:1. Two variable guide vane rows and three compressor bleeds located after stage 3, 6 and 9 are used during start-up and part load operation. Electron beam welding is used to manufacture the compressor rotor, forming a solid rotor body.

The combustion system is a can combustor system with 8 cans. The cans are of double-skin serial-cooled design. The fourth generation DLE burners offer dual fuel on-line switchover capability, increased power turn down range, and good emission control.

The turbine section of the SGT-750 consists of the two-stage air-cooled compressor turbine and the two-stage uncooled counter-rotating power turbine.

The stage 1 vane and blade have both film and convection cooling with compressor discharge air. These blades and vanes have a thermal barrier coating for reduced cooling-air consumption. The stage 2 vane and blade are convection cooled with cooling air from compressor stage 9. The disks are bolted to the rotor with 12 tie-bolts.

The free power turbine can be used for power generation at a nominal speed of 6100 rpm or used as a variable-speed mechanical driver with a speed range of 50-105% of the nominal speed. Blade 3 and 4 are shrouded for dynamic damping. The shrouds have two seal fins each and cover the throat area for improved efficiency.

Vane 3 (first power turbine vane) can be selected with different flow capacities optimized for normal or hot climate. By alternating the flow capacity of vane 3, the speed of the gas generator is optimized to improve performance at the dedicated site.

2 Engines

A description of the four different engines is given below.

2.1 Engine #1

Engine # 1 is the first manufactured SGT-750 and it is the first test-engine. The engine is manufactured to serial production standard. Engine # 1 was used for commissioning of the new test rig and the SGT-750 for the first time. The engine is equipped with some 1600 measuring points including 750 standard instruments. The measuring scope includes an optical probe for flame characteristics and infrared cameras for compressor turbine rotating blade temperatures.

2.2 Engine #2

Engine # 2 is the second manufactured engine and it is the main test-engine. The engine is manufactured to serial production standard with modified components and/or special purpose components. The engine is equipped with 2850 measuring points including standard instrumentation, optical probe and infrared cameras and telemetry. Telemetry is used both on the gas generator rotor and the power turbine rotor.

2.3 Engine #3

The turbine is deployed in the landfall station of the Nord Stream pipeline in Lubmin, Germany**.**

The Nord Stream pipeline, which links Europe with the large natural gas reserves in Siberia, ends at Lubmin near Greifswald in Germany. The turbine is deployed in a cogeneration plant at the landfall station, where the electric power generated will be fed into the grid. The heat from the SGT-750 will reheat the pipeline gas which has lost pressure during its journey from Siberia under the cold sea, and restore it to the temperature needed for further distribution, compensating for the Joule-Thomson effect which causes cooling of the gas during a pressure drop. The turbine is in commercial operation in the oil and gas industry.

2.4 Engine #4

The turbine is the first 60 Hz unit and will be located in Altamira, Mexico.

When commercially operational in October 2013, the 36-megawatt (MW) facility will supply electricity to textile factories. On the installation site the combined heat and power plant will generate all the process steam needed for producing synthetic fibers. One-third of the total electrical capacity will be used for the facility on site and two-thirds will be fed into the grid for other owner facilities in Mexico.

3 Test engines and instrumentation

In this section the purpose of the test engines is described and an overview of the instrumentation is given. A more detailed presentation of the infrared camera technology will be given.

3.1 Test Engine #1

The purpose of test engine #1 was to reduce time to first start compared to a fully instrumented engine. The first start was achieved on the 3rd of September 2012. The 850 test measuring points are divided into 450 temperature measurements, 150 pressure measurements, and 250 other measurements. The main concentration of instrumentation is in the combustor area. No rotating measurements.

The engine has been used for test rig commissioning, start test on gas fuel, idle and minimum load test on gas fuel, full load test on gas fuel.

In the near future engine #1 will be used for performance tests, power turbine re-matching tests and detailed temperature test.

3.2 Test Engine #2

The main purpose of test engine # 2 is to get detailed information to verify the design and prepare for the future.

The 2100 test measuring points are divided into 1200 temperature measurements, 400 pressure measurements, 250 strain measurements, and 250 other measurements. 25% of the measuring points are located in the compressor area, 30% in the combustor area and the final 45% in the turbines.

Typical tests with engine #2 will be Load tests on gas fuel, Blade dynamics verification tests, Power turbine high load low speed test, Start and stop with transient handling tests and Start Stop and Transient tests on liquid fuel.

3.3 Infrared camera technology

The infrared camera system was first developed for the large gas turbines by Siemens. It was decided during the development of the SGT-750 to incorporate infrared camera technology in the concept. The infrared camera technology was optimized for medium sized gas turbines. All SGT-750 are equipped with infrared cameras, high temperature and vibration resistant optics during engine delivery test and as an option at regular scheduled inspections.

The system can monitor at any power level and during operational performance excursions. This enables early detection of possible deviations to maintain turbine performance.

Compressor turbine blades are monitored on both suction and pressure side, including platforms, see figure 2. In total four cameras are used at the same time. Figure 3 shows actual camera installation.

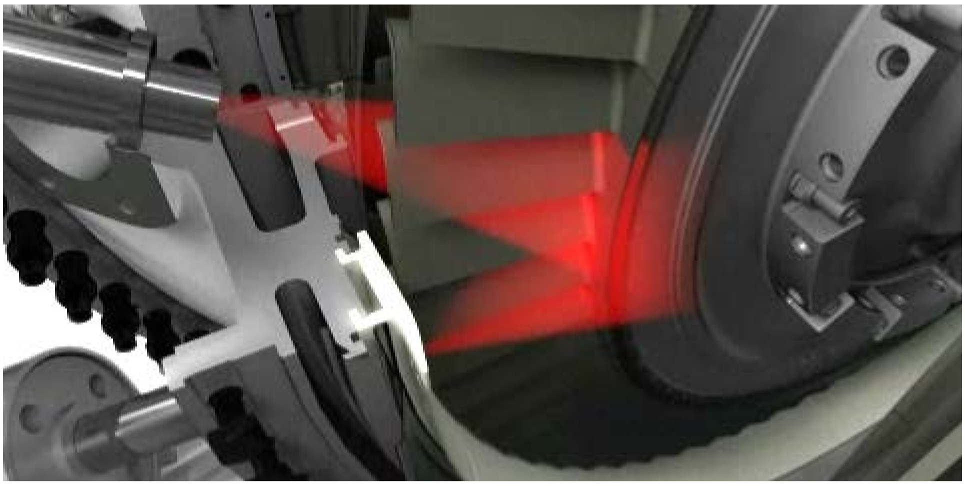

Figure 2: Camera suction and pressure views.

Figure 3: Infrared cameras installed on the gas turbine, two out of four visible.

The system shows high resolution images, suction and pressure side, of rotating blades in operation. The actual surface temperature of the blade can be analyzed online. The system can also be used for defect detection such as cracks, platform rub, cooling hole blockage, and TBC defect/ delamination/ spallation.

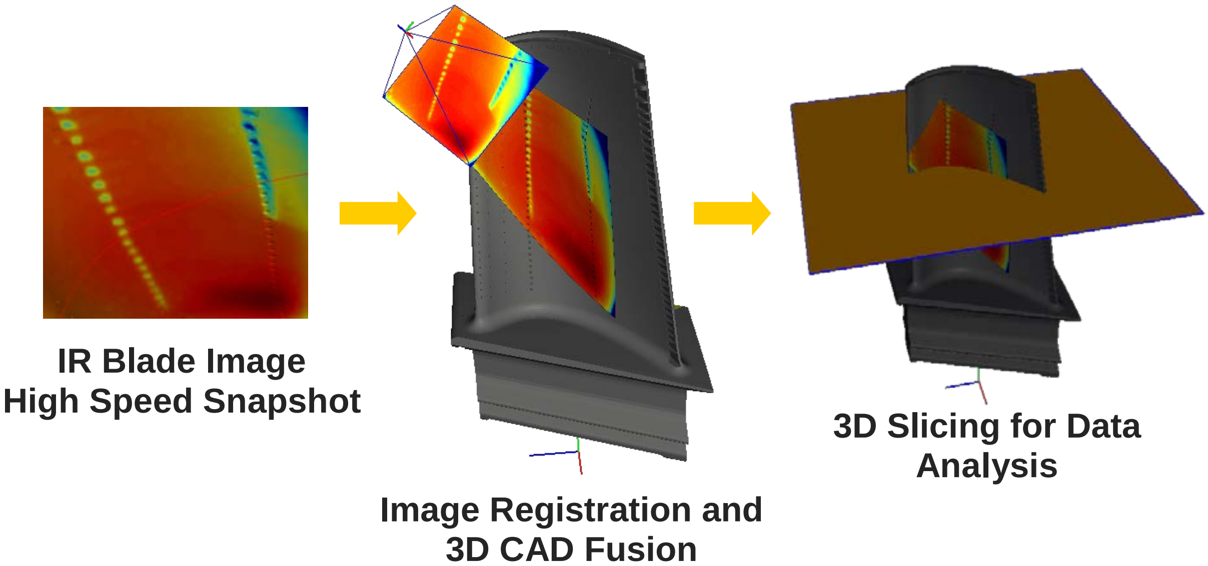

Figure 4: Process for 2D image to 3D thermal mapping.

Figure 4 describes the process used to transfer the high speed IR blade image to a thermal mapped 3D view of the blade. Each blade on the turbine wheel can be analyzed in detail.

The SGT-750 online infrared camera will help with service and performance validation. The future benefits of the system will be blade life maximization and optimization, cost savings for the gas turbine operators with maximum turbine availability.

4 Test results

Test results and design validation will be discussed in this section.

4.1 General test results

In general the testing of the SGT-750 has been very successful. The commissioning of the first engine in the test rig only took 10 days. On the 3rd of September 2012 first fire was achieved and idle conditions where reached, with gas generator speed of 7660 rpm and power turbine speed of 6100 rpm. On the 25th September full load conditions were reached.

Two test days were used to establish start motor operation and three days where used for start sequence definition. Three days were spent breaking in the new gear box in the test rig. Ten days were spent to fine tune emissions.

On the 22nd of November 2012 the mechanical running test of engine #3 started and lasted three test days. The engine started smoothly and operated as expected.

The 6th of February engine # 4 started on the first attempt and the mechanical running test was performed during four test days.

All engines tested have shown the same behavior and very similar performance.

4.2 Performance

The SGT-750 was launched at 35,93 MWe and 38,7 % efficiency at ISO conditions. During testing of all engines, power and efficiency have consistently been better than first estimated. This has enabled an update of the technical data for the gas turbine, see table 1.

Table 1: SGT-750 ISO performance data.

		Launch data	New data	Change
GT Power (shaft)	MW	37,11	38,19	2,9%
GT Thermal Efficiency (shaft)	%	40,0	40,7	1,7%
GT Power (electric)	MW	35,93	37,03	3,1%
GT Thermal Efficiency (electric)	%	38,7	39,5	2,1%
Exhaust temperature	°C	462	458	-4°C
Exhaust gas mass flow	Kg/s	113,7	114,2	0,4%

The shaft power has increased 2,9% to 38,19 MW with 1,7% better shaft efficiency at 40,7%. In power generation applications the new power rating is 37,03 MW electric, 3,1% better than launch data, and the efficiency is 39,5% , 2,1% better than initial.

The exhaust temperature has decreased 4°C to 458°C. Exhaust mass flow has increased 0,4% to 114,2 kg/s.

4.3 Rapid design validation

The installed measuring equipment on the engines, the optical probe and the infrared camera technology has enabled rapid design validation. The hot section measuring points have been monitored during testing and are with in design limits. This includes burners, cans, transition ducts and compressor turbine blades.

Figure 5 shows infrared camera view of compressor turbine blade 1 during operation. The image can be in either gray scale or color. The temperature levels can be analyzed online during testing. The infrared camera technology has helped to reduce validation time and risk.

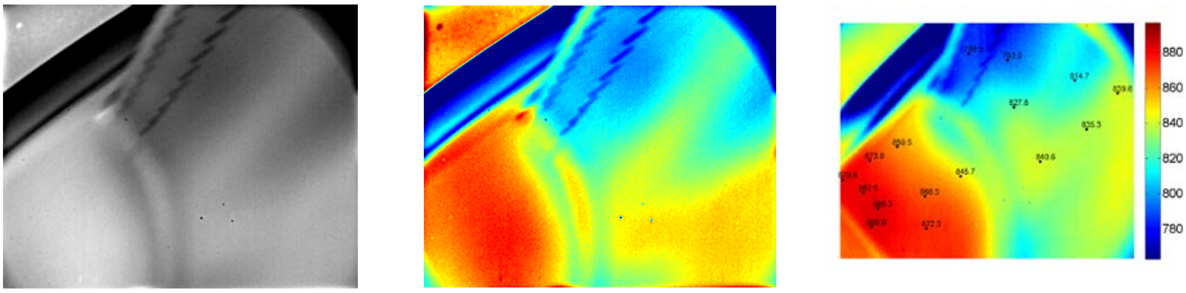

Figure 5: Compressor turbine blade 1, full speed test September 2012.

5 Operation

Engine # 3 had an effective contract date in November 2011. One year later mechanical completion was achieved. Onsite performance test was completed in April 2013. So far the engine has about 120 firing hours.

Next operational period is expected to start autumn 2013.

6 Conclusion

The testing and initial operation of the SGT-750 confirms the design. The power and performance of the gas turbine has been confirmed and improved. The updated rating for the SGT-750 in power generation is 37,03 MW and 39,5 % efficiency and in mechanical drive 38,19 MW and 40,7 % efficiency.

References

[1] Hellberg Anders, Et al. SGT-750 – 37 MW GAS TURBINE. *19th Symposium of the industrial application of gas turbines committee*, Banff, Alberta, Canada, 11-IAGT-305, 2011.

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