Siemens SGT6-5000F Gas Turbine Technology Update

Abstract

This presentation will update the industry on the latest developments of Siemens’ SGT6-5000F gas turbine. Since its introduction into the market in 1993, the SGT6-5000F gas turbine has been in continuous evolutionary development to improve performance, emissions, reliability, fuel flexibility, and operational flexibility. The focus of the discussion is on the evolution of the SGT6-5000F gas turbine design and the current offerings for performance, fuel flexibility, emissions, and operational flexibility.

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Session 5B: Gas Turbine Technology and Product Advancements

Conference Track: Gas Turbine Technologies II
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1. Introduction

A large portion of the 60 Hz power generation market is experiencing a competitive electricity market coupled with increasingly strict environmental regulations and fluctuating fuel prices. At the same time, the amount of weather dependent renewable generation, in the form of solar and wind power is steadily increasing, resulting in a need for more flexible operation from non-weather dependent generating assets. Siemens has continuously invested in the SGT6-5000F gas turbine in order to meet these energy demands in the 60 Hz power generation markets.

![Figure 1: SGT6-5000F Performance Evolution](image)

The SGT6-5000F was introduced into the market in 1993 with an ISO rating of ~150 MW. Continuous investment in the SGT6-5000F product line has resulted in the evolution to the latest SGT6-5000F product offering with an ISO rating of 242 MW while expanding fuel flexibility and operational flexibility and reducing emissions. The SGT6-5000F fleet has grown to 316 operating units and has accumulated +11,100,000 operating hours with reliability consistently >99%.

2. SGT6-5000F Gas Turbine

The SGT6-5000F design is a combination of the design features from Siemens’ large gas turbine portfolio and is well suited for the wide range of requirements (high reliability, fuel flexibility, operational flexibility, low emissions, and high power output and efficiency) from
the 60 Hz power generation markets. The SGT6-5000F leverages the increased mass flow capability of the SGT6-8000H compressor for high power output on hot days. The ULN (ultra low NOx) combustion system has demonstrated a wide range of gaseous and liquid fuel flexibility with low emissions. The SGT6-5000F continues to utilize a 4-stage turbine and the operating temperatures allow the use of proven conventionally cast material for high reliability and long service intervals. The rotor discs are fabricated from a relatively flexible steel material and are coupled together through a single tie bolt with torque transmitted from disc to disc via Hirth serrations which facilitate fast starts and long life without a service life penalty.

Figure 2: SGT6-5000F Design Features

New component designs are subject to rig testing and full scale, instrumented engine testing in the Berlin Test Facility to further the goal of providing a quality and reliable gas turbine product to our customers. The latest SGT6-5000F product offering completed testing in the Berlin Test Facility in 2014.
<table>
<thead>
<tr>
<th>Commercial Date</th>
<th>2005</th>
<th>2009</th>
<th>2014</th>
<th>2015</th>
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<tr>
<td>Test Date</td>
<td>2003</td>
<td>2005</td>
<td>2006</td>
<td>2013/2014</td>
</tr>
</tbody>
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**Off nominal testing…**
- Compressor surge limits
- Transient operation
- Emissions (start-up, turn down)
- Fuel transfers
- Load rejections

Figure 3: Berlin Test Facility

The testing of the latest SGT6-5000F in the Berlin Test Facility included base load performance, fast ramping transient operation, low load turn down emissions, start-up emissions, and a wide range of operational scenarios. Since full scale engine testing in Berlin, the first two SGT6-5000F units with this configuration have achieved commercial operation in a 2x1 combined cycle power plant located in the United States.
3. Fuel Flexibility

Fuel flexibility is a key power generation market requirement and Siemens has continuously invested in the SGT6-5000F ULN (Ultra Low NOx) combustion system in order to expand the fuel capabilities and provide our customers with flexibility in the event that the fuel landscape for the power plant changes.

Gas turbines have historically been supplied with pipeline quality natural gas (+/-5% Wobbe Index relative to methane); however recently the fuel gas compositions being evaluated for power plant projects have started to push the limits of gas interchangeability. The oil and gas reservoirs (estimated to be ~24.4 million cubic meters of recoverable gas in North America) in Shale Plays are being explored with unconventional recovery techniques and the gas composition from these Shale Plays reflects a higher variation in the concentration of both higher hydrocarbons such as ethane and propane (high Wobbe) and a higher concentration of CO₂ and N₂ (low Wobbe).

Part of Siemens design philosophy is to test new fuels at full firing temperature and full pressure in a combustion test rig facility prior to establishing performance and emissions data points.

Full Firing Temperature and Full Pressure Combustion Rig Testing

Figure 5: Combustion Rig Testing

After completion of the latest combustion testing, the fuel flexibility of the SGT6-5000F has been expanded to +20% Wobbe Index and -50% Wobbe Index while maintaining 9 ppm NOx emissions and the allowable variation in Wobbe Index while the gas turbine is operating has
been extended to +/-20%. Extending the Wobbe Index range to +20% gives customers the flexibility to operate up to ~50% volume Ethane or 25% volume Propane mixed with natural gas without changing combustion hardware. Extending the Wobbe Index range to -50% gives customers the flexibility to operate up to ~50% volume Nitrogen (or CO₂) mixed with natural gas without changing the combustion hardware. Extending the allowable Wobbe Index variation to +/-20% while the gas turbine is operating gives customers the flexibility to continue generating power despite potentially big changes in gas composition. The ULN combustor is also flashback resistant up to 25% hydrogen content in natural gas.

The SGT6-5000F with the ULN combustor was the first F-class gas turbine to demonstrate 25 ppm NOx on distillate oil in 2013. The liquid fuel capabilities of the SGT6-5000F ULN combustor also include Arabian Super Light (ASL) crude oil. Based on extensive liquid fuel combustion rig test experience, Arabian Extra Light, propane, bio-diesel, alcohols, and Jet-A oil, are acceptable fuels for operation with the ULN combustor. Further testing with the ULN combustor on liquid fuels is on-going in order to eliminate the need for water injection which is typically required in order to control emissions.

Figure 6: Fuel Flexibility Summary

The ULN combustor can operate on a wide range of gaseous and liquid fuels while the DF42 style combustor nozzle is utilized for fuels outside the ULN range of operation such as syngas (low Wobbe) or 100% gaseous propane (high Wobbe).
4. Operational Flexibility

Fast start capability and low load turn down are operational flexibility features that help power plant operators meet grid demands and manage start-up emissions. The SGT6-5000F was the first 60Hz F-class fast start power plant to operate commercially in 2009 and is capable of generating 150 MW in less than 10 minutes from turning gear speed and load follow grid demands at 30 MW/min.

![Fast Start Operation Diagram](image)

Figure 7: Fast Start Operation

Since the first fast start plant, Siemens has commissioned more than nine SGT6-5000F fast start power plants in both simple cycle and combined cycle. Fast start operation has been tested in the Berlin Test Facility and is capable of achieving 200 MW in less than 10 minutes from turning gear speed and ramping at 40 MW/min without a maintenance penalty.

Turndown capability provides power plant operators the flexibility to reduce load and fuel consumption while maintaining emissions compliance when power demand is low. The SGT6-5000F is capable of low load turndown to 30% gas turbine load (equivalent of 20% combined cycle load) over a wide range of ambient conditions while maintaining <9 ppm emissions.
The SGT6-5000F low load turn down operational flexibility feature is an air management system that has been installed in multiple commercially operating power plants.

5. Summary

Efficient energy production is needed in all power generation markets. Siemens Power & Gas is continuously developing retrofittable enhancements for the SGT6-5000F to support the objective of profitable energy production. The latest SGT6-5000F offering delivers 242 MW of net power at an efficiency of >39.1% in simple cycle at ISO standard conditions. The power output and mass flow of the SGT6-5000F gas turbine allow flexibility in combined cycle power plant configuration. For example, a 2x1 SCC6-5000F power plant solution with the SGT6-5000F at its core will deliver ~723 MW of net power on a 21°C day, and the exhaust mass flow permits an additional +80 MW of duct firing per gas turbine / HRSG. The SGT6-5000F fleet is expanding in the 60 Hz power generation market along with the wide range of requirements from the various countries.
Siemens continues to invest in the SGT6-5000F to support energy demands from all 60 Hz power generation markets with reliable, efficient and flexible power plant solutions.

Figure 9: SGT6-5000F Power Plants Around the World