Testing and Validation of Large Gas Turbines

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Abstract

No matter how demanding the conditions are: Siemens gas turbines are perfectly tailored to the needs of the customers. New technologies are quickly and effectively validated at Siemens' own test centers and on customer sites worldwide. The test facilities of the Gas Turbine Plant Plant in Berlin (Germany), in Casselberry (U.S.A.), the Clean Energy Center in Ludwigsfelde (Germany) as well as on-site testing in cooperation with customers ensure the full testing and validation coverage and demonstrate the full functionality. With this Siemens is generating trust for its own technologies, for the insurer and of course for the customer.

All test centers are fully integrated in the Siemens global engineering organization for Research and Development (R&D) in component and full engine testing. New designs are validated fast to provide state-of-the-art technologies to new customers as well as existing customers to support them operating their assets in the most profitable way taking the wide range of local governmental requirements into account. New technology will be provided by the means of e.g. flexibility improvement, efficiency increase and emission reduction.

This paper explains how Siemens makes every new gas turbine and technology reliable before market introduction and describes the features and technical details of the various Siemens’ own test facilities and the derivable benefits for the power plant operators.
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Nomenclature

CAPEX       Capital expenditure
CEC         Clean Energy Center
ELVis       Engineering Life Visualization
I&C         Instrumentation and Control
IP          Intellectual Property
OPEX        Operating expense
PDP         Product Development Process
R&D         Research and Development
SAMS        Siemens Advanced Maintenance Services
SLM         Selective Laser Melting
TBC         Thermal Barrier Coating
1. Introduction

Siemens gas turbines are efficient, reliable, environmentally sustainable; and in operation all over the world. Always newest state-of-the-art, precisely tailored to the customers' requirements. The customer expects an economic, competitive product with a high efficiency, great reliability, high flexibility and service kindness at low life time costs. [1] Siemens offers innovative solutions which make every power plant even more flexible – no matter how ambitious the conditions may be. Siemens consistently enhances its products and designs. New technologies are quickly and effectively validated at Siemens' own test centers – like at the Clean Energy Center in Ludwigsfelde near Berlin (Germany) and the in-house full scale engine test facility of the Berlin Gas Turbine Plant. Technical innovations in design and development, process engineering, materials and manufacturing as well as assembly processes collectively support Siemens in constantly transforming new customer requirements into reality. Siemens has been continually developing technologies focused on market requirements such as improved base and part-load efficiency, reduced emissions, increased gas turbine and combined-cycle flexibility resulting in the highest reliability and availability. These include developments in the field of combustion with ultralow NOx premixed combustion system; SAMS (Siemens Advanced Maintenance Services) technologies and digital services allowing for improved prediction of parts life under a variety of operating conditions; improvements in Thermal Barrier Coating (TBC) technology as well as innovative manufacturing technologies like Selective Laser Melting (SLM).

The Siemens own comprehensive and consequent validation approach enabled successful introduction of new technologies and solutions for example at following sites including the 1,200 MW Cape Canaveral Clean Energy Center of Florida Power & Light, the 410 MW unit Dangjin III of GS EPS (GS Electric Power & Services, Ltd Seoul, Korea) and the 600 MW cogeneration power plant Lausward (Block Fortuna, Stadtwerke Düsseldorf AG Düsseldorf, Germany) (Figure 1). Comprehensive on-site testing laid the foundation for successful upgrading of commercial operated gas turbines to state of the-art technology like demonstrated in the cogeneration power plant of Vuosaari (Helsinki, Finland) and the combined-cycle power plants of Manchester Street Power Station (Providence, U.S.A.) and Santa Rita (Santa Rita, Philippines).
2. The Siemens portfolio overview

The Siemens gas turbines range has been designed and tailored to help meet customers’ challenges in a dynamic market environment. Our models range from 4 to 400 MW, fulfilling the requirements of a wide spectrum of applications in terms of efficiency, reliability, flexibility, and environmental compatibility as shown in Figure 2: aero derivative gas turbines ideally suited for power generation and mechanical drives in the oil and gas industry, industrial gas turbines as an ideal choice for both industrial power generation and mechanical drive applications and heavy duty gas turbines designed for large simple and combined-cycle power plant as well as cogeneration applications [2].

![Figure 2: Siemens Gas Turbine portfolio](image)

The Siemens gas turbines offer an optimized Levelized Cost of Electricity index (CAPEX and OPEX) and an excellent return of invest ensuring the maximum customer value.

3. The Siemens evolutionary design circle

The Siemens evolutionary design circle ensures competitive products for the new unit and service business. This development philosophy is based on the proven design and the fleet experiences of more than 6,750 installed heavy duty, industrial, and aero derivative gas turbines in more than 60 countries worldwide.
Using the design circle (Figure 3) Siemens validates new technical developments in a proven three step testing approach which fully corresponds with the Product Development Process (PDP).

**Figure 3: Siemens evolutionary design circle**

4. **Three step testing approach – from prototype to production**

The prototype components, gas turbines and technical solutions pass through a series of tests designed to meet the precise needs of the customer.

1. Material and component tests for example at the Clean Energy Center (CEC), Ludwigsfelde, Germany
2. In-house full scale engine test at the test facility of the Gas Turbine Plant Berlin, Germany
3. On-site tests at customer sites for long time validation and test of gas turbine operation in interrelation to other power plant systems

Rapid engineering and prototyping through concentrated research manufacture and development capabilities are the basis of this testing approach. Our measurement and analysis techniques are always to the latest state-of-the-art and being continuously further developed. The close distance of manufacturing and testing at the Gas Turbine Plant Berlin and the Clean Energy Center ensures rapid prototyping and supports the time-to-market time frame. Our gas turbine experts cooperate worldwide, since an excellent cooperation is a common purpose among all people involved within the PDP. The individual testing procedure for validation of new developments, technology downloads, or incremental changes and improvements will be selected in accordance to the target group and the timeline (new gas turbine developments or service upgrades). The Siemens three step testing approach verifies the lowest technical and commercial risks and is fully accepted by insurers thus supporting the commercial success of power plant operators.
4.1 Component testing

Siemens opened in 2015 the Clean Energy Center (CEC), an in-house component testing facility in Ludwigsfelde, just 40 minutes away from the Berlin Gas Turbine Plant (Figure 4). The decision for an in-house component test center was based on the ideas to concentrate R&D relevant activities at one location only, high availability and accessibility of the testing facility [3]. The Siemens own testing facility is independent from outside and enables Siemens to decide when and who to test a component. There is a high need for extended IP protection. As a result, the CEC saves not only time but money, while helping to raise rapid prototyping to an entirely new level. This is a huge benefit for customers. Siemens helps them adopting the latest technologies on a fast track. This fast track between generating ideas, validating new components and introducing technical solutions leads to the shorter time-to-market time frame.

![Figure 4: Clean Energy Center (CEC)](image)

The CEC houses three fully equipped, isolated test cells for combustion system testing: two for the “big” power plant turbines with capacities up to 400 MW, and one for the “small” industrial gas turbines with capacities up to 66 MW. The Siemens experts can accurately duplicate almost any customer specifications, testing under realistic high pressure conditions, simulating a specific ambient temperature or creating the precise fuel mixture that will later be used. All relevant key parameters such as output, efficiency, emissions, and flame stability are monitored, measured and analyzed.

The characteristics and technical parameters of the component test facility are following:

- Three test cells including combustion test rig equipped with multiplex data acquisition connection
- State-of-the-art measurement devices
- High fuel flexibility
- High pressure fuel tank farm for liquid fuels (e.g. light oil and kerosene) and fuel gases
- High pressurized natural gas supply via pipeline including gas pressure regulation station
- Natural gas compressor
• Natural gas preheating system
• Three air compressors to pressure up to 50 bar
• Two separated air preheating systems up to 600°C
• On-site multi-functional work shop capabilities for parallel preparation of test campaigns and instant adaptation to changed validation needs
• Maximum flexibility for test scenarios

The successful component validation is supported by key enhancements in collaboration. Gas turbine component testing and validation specialists have to deal with huge data streams to analyze their behavior. The Siemens specialists use the "ELVis" (Engineering Life Visualization) software, an "Intranet web-based", real-time data visualization system for big data, which provides real-time data access to engineers independent of their home location (Figure 5). ELVis is a Siemens own software development, contains the latest data cloud technologies and is protected by five patents. ELVis used for the in-house testing activities at the CEC and the Berlin test facility. An additional enhancement to the ELVis software is the implementation of collaboration rooms in main engineering locations like Orlando, Charlotte, Mülheim and Berlin. Through the use of live Audio and HD video feed, engineers from all locations are able to interactively support the test phase without ever having to leave their location. Working in such a cohesive room environment enables the team to exchange immediate feedback during and after testing and helps ensure that critical test data and decisions are simultaneously discussed and transferred. ELVis and the collaboration rooms strongly support the rapid prototyping and time-to-market process.

Figure 5: Online monitoring and data analyzation in real-time
4.2 Full engine testing at Berlin test facility

In order to ensure the comprehensive testing and validation of heavy duty gas turbines Siemens operates a full scale engine test facility the Gas Turbine Plant Berlin. This Berlin in-house test facility allows the validation of large gas turbines under realistic and even under the extremes of real gas turbine operating conditions.

The Berlin test facility was commissioned in 1972 with a capacity of 120 MW (Figure 6).

Several modernizations allow a current maximum capacity of 400 MW (Figure 7). The individual test engine is connected to a water brake which gives Siemens the flexibility to test 50 and 60Hz engines independent of the grid frequency. This water brake is the largest water brake in world. Another important feature of the test facility is the air pre-heating system to increase the ambient air up to 30 K by using the hot water from the water brake and a special heat exchanger in the filter house/air intake. This help simulating different climate conditions like hot ambient conditions or just simply supports engine tests at ISO conditions in strong winter times.
Thanks to the water brake large gas turbines can be tested at variable speed. The programmable controller provides flexibility for control parameter optimization, off-design operation and surge tests.

The characteristics and technical parameters of the full engine test facility are following:

- 400 MW capability to operate 50 and 60 Hz engines independent of the grid
- Continually fuel gas and oil operation
- Fuel pre-heating and Wet Compression
- Field Service training during engine re-build
- Standard instrumentation and I&C similar to power plant
- Testing instrumentation: over 12,000 additional measurement channels
- Real time data stream to worldwide engineering hubs

The exhaust energy is used for fuel gas pre-heating. The engine starter motor can switched during operation in generator mode and provides electrical power to cover house load (Figure 8). For example the fuel compressor has a demand of 8 MW. In addition the huge water pumps for the water brake cooling loop, four cooling tower and a couple of fuel skids need lot of electricity during operation. Wet Compression is also possible to validate extended gas turbine limits for peak load operation.
The gas turbines to be tested are instrumented with up to 6,000 measuring points to record all relevant operating parameters and in addition all design parameters to be validated during the test runs.

Following technical topics are being analyzed in the course of prototype testing:

- Thermodynamics: power output, efficiency, turbine outlet temperature, mass flow
- Combustion stability of different fuels, with and without water injection
- Cooling air consumption
- Surface temperatures of hot gas path components
- Vibration characteristics of compressor and turbine blades and vanes
- Compressor and turbine aero-thermodynamics
- Radial clearances and strains in different operating modes

The successful full engine validation is also supported by key enhancements in collaboration. Gas turbine testing and validation specialists have to deal with huge data streams to analyze the turbine behavior. Outfitted with nearly 12,000 channels, the latest Siemens test engine may generate an astonishing 12 terabytes (Tb) of data every eight hours (Figure 9). Using the "ELVis" software provides real-time data access to engineers independent of their location in Orlando, Charlotte, Mülheim and Berlin.

Figure 9: A SGT6-8000H being tested in 2015
4.3 Full engine testing – on site

After intensive material, component and full engine testing at the CEC and the Berlin test facility demonstrating the full functionality of new technologies Siemens has set-up a co-operation with customers worldwide to perform long term validation (Figure 10). Through the validation in power plants within commercial operation Siemens ensures the promised life time of the individual components and the full functionality of technical solutions under real conditions within the total plant in operating mode. But why the customer is interested in to get a first time application? The answer is just as simple. Customers always have a special demand on their power plants to be the most competitive in their region. With the pre-tested first time application the customer gets newest technology as first hence increasing the power plant’s profitability. Siemens - at the same time – has got the possibility to stress new implemented components and solutions under real conditions over a long period of time. During this long term validation the gas turbine is equipped with additional measuring equipment. This allows Siemens to analyze the behavior and the interaction of new components validating new technologies and solutions on a long run. The additional measuring equipment enables Siemens for an advanced optimization of the customer’s gas turbine and power plant for the requested operational regime. In the end it is a Win-Win situation for the customer and Siemens.

Figure 10: Implementation of new technology during regular service measures on-site
5. Conclusion

Based on the evolutionary design circle as part of the Siemens own Product and Development Process including comprehensive test procedures and a detailed evaluation of test data in comparison with its design predictions, Siemens continues to offer world class state-of-the-art products and solutions to support our customers operating their assets in the most profitable way ensuring their success and competitiveness.

Rapid engineering and prototyping through concentrated research, manufacture and development capabilities meet measurement and analysis techniques to the latest state-of-the-art at the in-house and on-site testing facilities. Our gas turbine experts cooperate worldwide and through excellent collaboration answering the various demanding customer demands.

References


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