Case study: Experiences with gas and steam turbine power plant projects on the Russian market

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Abstract
Looking back in time a few years ago to the booming power generation market, one has seen the Russian electricity demand grow alongside high oil prices and the increasing industry investments. This strong growth, together with aging capacity, has created a need for new investments. Experts estimate that Russia will need an additional capacity of approximately 180GW of electricity generation by 2020, which is almost the equivalent of its installed capacity. The challenge is not only to attract enough capital, but also simply to carry out these huge investment projects as scheduled, ensuring the availability of equipment, engineering and management resources.

Siemens has unique experience as a supplier of key components for gas and steam turbine power plant projects on the Russian market. Since 2001, 29 Siemens SGT-800 gas turbines alone (presently rated at 47MW) have been ordered by customers from Russia, for implementation in different types of power plant, either as single machines or as part of a more complex plant solution. The Moscow City 226-MW combined-cycle power plant was the first plant to be built and is our showcase reference in Russia. The Strogino combined-cycle urban power plant, which has two generator units, each with a capacity of 130MW, is another plant that has been equipped with both gas and steam turbines from Siemens. In June 2009, the Kolomenskoe gas turbine power plant in Moscow, supplied with three SGT-800 units, started up commercial operation. These are just a few examples of Siemens success with supply of turbines to the Russian market, and the main references in this paper.

This paper will not only cover and explain technical features with case studies of these projects, but also share Siemens’ unique expertise and experiences as a key component and power plant supplier on the Russian market. The primary focus of these projects will be power plants based on the SGT-800 gas turbine, the most powerful of the Siemens industrial gas turbines, including where applicable Siemens steam turbines and other Siemens equipment/expertise.
Moscow City is an ongoing project creating an International Business Center in the center of Moscow, Russia. The entire project is scheduled to be completed by the year 2020, and for the purposes of effective construction, the project is subdivided into several separate smaller projects, including skyscraper office blocks, restaurants, retail outlets, parks, hotels and residences for approximately one and a half million inhabitants. The underground area of the complex houses a parking lot and a “mini-metro” station is also connected to Vnukovo and Sheremetyevo airports via a high-speed transport system.
To power this gigantic complex, Siemens has earlier signed two separate turnkey contacts for a 226-MW combined-cycle power plant with cogeneration. The plant consists of two combined-cycle blocks, type SCC-800 2 x 1. Each block is based on two 45-MW SGT-800 gas turbines (the standard at that time) and one 30-MW SST-700 steam turbine, all supplied from the Siemens industrial turbine facility in Finspong, Sweden. The plant provides district heating and power to the new international business center, a complex covering 30 million sq. ft on a 100 hectare site.

Both phases of the Moscow City Power Plant are now in operation, with phase II being the first to come into commercial operation in September 2007 (Phase 1 during the summer of 2009). Each phase (I & II) is a 110-MW combined-cycle power plant, including two 45-MW combustion gas turbines (SGT-800) fired with natural gas, two heat recovery steam generators (HRSG’s), one district heating condensing 30 MW steam turbine (SST-700), one peak water-heating boiler and auxiliary systems. The peak water-heating boilers were designed and constructed by JSC “Drogobuzkotlomash” of Russia.

Hot exhaust gases from the gas turbines generate steam of two pressures in the HRSG. These high pressure and low-pressure steam flows are produced by the HRSG at superheated conditions and fed to the steam turbine, which is connected to a two-stage district heating condenser system. A summer cooler is installed to cater for operation cases when heating water requirements are low. See diagram below.

Fig 2, CHP Principle diagram
**Strogino (phase I & II)**

**Combined-cycle power plant with cogeneration for district heating**

Strogino is the second power plant based on the SGT-800 gas turbine to be commissioned in Russia. Strogino, also located in Moscow, is also a two-phase design, the first phase having been commissioned in March of 2009. Siemens’ customer in this case is the Moscow Unified Power Company Municipality (Moscow Government), which is a spearhead project in the Moscow Power Program. Siemens is installing the plant in cooperation with Elektrozavod, with each phase of the scope including 2 x SGT-800 gas turbines, 1 x SST-400 41.2 MW steam turbine, gas boosters, gas receiving units and instrument air compressors. This plant is also a combined-cycle power plant with cogeneration for district heating, the most efficient and economical form of generation with minimal heat losses.

![Fig. 3, SGT-800 in workshop](image)

**Kolomenskoe**

**Cogeneration plant with district heating.**

Another power plant that started commercial operation in 2009 is the Kolomenskoe cogeneration plant that generates electricity and district heating for the city of Moscow. The Kolomenskoe gas turbine power plant is part of the Moscow government’s power generation
program to supply high-efficiency, eco-friendly heat and power to Moscow. It will generate 136 MW of electricity and 171 Gcal per hour of district heat and operate with an overall plant efficiency of approximately 83 percent.

The end customer and sole investor for the project, for which Siemens supplied the three SGT-800 gas turbines, the instrumentation and control system as well as site services, is NaftaSib Energia, which is part of NaftaSib group. The Siemens scope of supply also includes site service, including supervision of the installation, commissioning and training of the customer personnel. Siemens also delivered the instrumentation and control system SPPA-T3000 to further enhance the flexibility and environmental friendliness of the power plant. Site service is provided by the Russian organization of Siemens Energy. With its very low NOx emissions, the advanced SGT-800 gas turbine supports eco-friendly, highly efficient power generation in the heart of the Russian capital. Thanks to the successful cooperation between NaftaSib Energia and Siemens, the project was completed exactly within the scheduled time frame of two years.

The Moscow government professed itself very pleased with the Kolomenskoe power plant project. As of today, it is the only one of eight projects within the program of construction, which has been implemented on time despite the world economic crises, even though some of the projects started earlier. It is the first time in Russian power generation history that a power plant has been built at a noise level of 41 decibels, the current Russian sanitary norm being 85 decibels. These results lead to the possibility of building such power plants even in the housing zone.

**Tuapse - cogeneration of electricity and steam**

One of the most recent contracts signed by Siemens Energy is once again with the Russian oil and gas company Rosneft. The order is for the delivery of six SGT-800 industrial gas turbines with an output of 47 megawatts each. The gas turbines will be used for generating electricity and steam to accommodate the expansion of the Rosneft refinery in Tuapse, an important petroleum port where the Grozny-Tuapse oil pipeline ends at the Black Sea. The crude oil processed there is oil produced in Western Siberia and Southern Russia and transported via Transneft’s pipeline system and by rail.
Commissioned in 1929, Tuapse Refinery is Rosneft’s oldest refinery. Located in Russia’s Krasnodar region, the refinery, with a capacity of roughly 5 million tones per year, is the only such facility on that seacoast. Its product mix primarily consists of gasoline, naphtha, diesel and fuel oil. Located adjacent to an oil-loading terminal, the refinery exports approximately 90% of its products. Rosneft is now seeking to more than double the refinery’s capacity to increase its depth from 56 to 95%, by implementing a major expansion and upgrade.

The six power generating units include the 100th SGT-800 unit to be produced since its introduction. A critical project requirement for the gas turbines being supplied to the Tuapse refinery is low NOx emissions during operation while using various fuels. The SGT-800 can burn a wide range of fuels of varying quality and subsequent initiatives have been taken to increase the gas turbine’s fuel flexibility still further. The first three gas turbines will be delivered by October 2010, with the remaining three units to follow in October 2012. These projects illustrate some of the versatility of the Siemens installed equipment in Russia, from isolated equipment to full turnkey. Other installations of interest are, for example, Perm TEC-6, a Siemens power-island installation based on 2xSGT-800 and 1xSST-600, and Priobskoe (phase I, II, & III): This component sale of 7xSGT-800 represents the first Siemens oil and gas reference in Russia, the customer again being Rosneft.

The SGT-700 gas turbine has also been a strong seller on the Russian market, in both power generation and mechanical drive applications. Sochi, on the Black Sea coast, is the site of the first two SGT-700 power generation sets delivered to Russia. The SGT-700’s are installed in the recent 76-MW combined heat and power plant, which provides power generation and district heating for the town of Sochi. Since this is one of Russia's major resorts on the Black Sea Coast there are high demands on the environmental impact of the plant and, of course, the demand for uninterrupted power supply, which SGT-700 fulfils. The plant is crucial for the area’s power supply, especially in the winter period, which means that availability and reliability are extremely important to the customer. To ensure continuous operation the units are therefore equipped with dual-fuel technology (liquid fuel operation as back-up).

**About our components**

*As supplied to the projects defined in this paper.*

The reason for the particular popularity of the SGT-800 is that it is designed specifically for power generation and cogeneration, and has a very high efficiency in combined cycle. It is the
largest of the Siemens industrial gas turbine range (5 to 47 MW) and the obvious choice where there is a need for a constant and reliable power supply. At 31.2 MW electrical output, the SGT-700 is a smaller but versatile mid-range machine, adapted for both power generation and mechanical drive. It shares the same combustion technology as the SGT-800, both of them meeting stringent emissions requirements with dual-fuel DLE technology without need for complicated control systems or water injection.

The **SGT-800 gas turbine** is an industrial gas turbine of modular design. It is of single-shaft design, driving the electric generator through a parallel shaft reduction gear. The gas turbine is mounted on a steel base frame with an integral oil tank and other auxiliaries. The package is based on a single-fuel gas turbine, fired by natural gas and including a dry low NOx combustion system. A sound enclosure is located over the gas turbine and gearbox to ensure 85 dBA external noise limits at 1 metre. The enclosure is fitted with ventilation units, gas detection and fire suppression systems, and access ways for personnel during maintenance. Combustion air is cleaned through a three-stage static type of intake filter. An anti-icing system and silencer are located at the air intake duct.

When equipment is to be supplied in combined cycle, Siemens has a range of steam turbines which can be matched to its gas turbines, to provide the ideal solution for the customer.

The **SST-700 steam turbine**, as supplied to the Moscow City power plants, is a multi-stage district-heating condensing turbine. The steam turbine and its electric generator are mounted directly on the turbine's concrete foundation.

The steam turbine lube-oil reservoir is placed beside the steam-turbine gearbox and the AC generator. An accessible sound enclosure is located over the gear to ensure required noise levels are adhered to.

The water/steam circuit consists of a heat recovery steam generator (HRSG) which generates steam by extracting heat from the exhaust gas flow of the gas turbine. The HRSG is designed as a dual-pressure, natural circulation boiler comprising:

- Stack with silencer
- Low Pressure (LP) Economizer
- LP Evaporator with steam drum
- LP Superheater
- High Pressure (HP) Economizer
• HP Evaporator with steam drum
• HP Superheater

The layout concept represents an optimal utilization for the site conditions. The advantages of this concept are:

• Short connections between all major plant components (piping and cables) resulting in reduced energy losses.
• Short distances providing for easy operation and maintenance.
• Adequate separation between the power train and the balance of plant components to facilitate maintenance.

The smaller **SST-400 steam turbine**, as supplied to the Strogino plant, has also been refined to fit combined cycle applications. The SST-400 product line was designed and developed to meet current market trends and requirements by the use of standardized sets of components with high flexibility for adaptation to project-specific requirements, e.g. bleeds, extractions, second admission typical for double-pressure HRSG’s of combined cycles, etc. The sustained demand to reduce investment cost of steam turbines for industrial applications over the last 20 years has led to introduction of the concept of a gearbox between the steam turbine and the generator for generator-drive steam turbines in the power range up to 60 MW.

One positive economic side effect of this development is the potential to reduce the rotation speed of the generator to half synchronous speed and thus use a four-pole generator, which is cheaper than a two-pole machine. The concept of a four-pole generator and an appropriate gearbox, together with the well-optimized standard components, forms the basis for a “kitset” design. The degree of standardization and effective production methods ensure economically effective solutions.

The blade path uses reaction blading, which, from the efficiency point of view, is less sensitive to operation off the optimum or guaranteed load point. That brings a significant advantage and the benefit of decreased fuel consumption for plants.

The turboset concept allows for a modern axial exhaust layout, if preferred. This brings the customer the benefit of cost reduction in terms of civil works. The turbine is mounted on a
skid, the generator is anchored to the concrete foundation and the gearbox in between is mounted on an oil tank which integrates the active parts of the oil system into a single central package, thus minimizing the risk of oil leakage. This turbine is highly flexible in operation: it has been proven successful in combined-cycle power-plant (CCPP) applications, not only together with Siemens gas turbines but also with gas turbines of other brands.

Figure no.4 – “kitset” design of the Siemens’ SST-400 condensing steam turbine

**Conclusion**

Russia continues to be faced by the challenge of financing and timely execution of huge investment projects to provide sustainable and reliable energy for its residential and industrial areas, ensuring the availability of equipment, engineering and management resources. Single-source supply of equipment and solutions is of great benefit to the customer since this ensures compatibility of equipment, facilitates repeatability and simplifies supply and project management. Over the last few years Siemens has shown that it has the versatility and competence to provide specific customer solutions with selected components from its rich product portfolio, reinforced by its global resources. Siemens continues to invest in research and development to further refine its products – efficiency, fuel flexibility and environmental capabilities in gas turbines to meet market and customer demands are some prime examples of this continued development. Some of these refinements have already been implemented in the equipment described in this paper: more precise details will be given in the verbal presentation.
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