Siemens SGT-500

Outlook

- Aging design that has reached the end of its life
- Available for production, but no orders forecast
- Sales emphasis has shifted to newer technology products

Orientation

Description. The Siemens SGT-500 (formerly Siemens GT35, and earlier Alstom GT35) is a two-shaft, heavy-duty, 50/60-Hz industrial gas turbine machine in the 15- to 20-MW class.

Sponsor. The GT35 (now SGT-500) was privately developed by Stal-Laval in Sweden, which later became a unit of Alstom.

Power Class. The approximate power output of the SGT-500 is as follows:

Application	Power Output
Electrical Generation	17 MW
Mechanical Load Drive	17.36 MW (23,290 shp)

Status. In production.

Total Produced. At least 175 SGT-500 (formerly GT35) gas turbines of all outputs have been manufactured and installed.

Application. The machine is currently used for utility and industrial power generation, especially baseload power, and for various mechanical load drives, including gas compression. The engine has been made available for marine propulsion/power duty (six machines installed from 1995-97).

The SGT-500 machine has also been made available in a mobile power package version.

Price Range. In current U.S.-calendar-year dollars, estimated prices are as follows: $8.4 million for a basic SGT-500 gas turbine-equipped generating set; $9.6 million for an SGT-500 gas turbine-equipped mechanical drive generating set.

For electrical generation (simple-cycle), the genset price covers a single-fuel skid-mounted gas turbine, an electric generator, an air intake with basic filter and silencer, an exhaust stack, a basic starter and controls, and a conventional combustion system.

For mechanical drive duty, the price covers a gas-fired gas turbine (without driven equipment) with a gearbox, a skid, an enclosure, inlet and exhaust ducts, and an exhaust silencer; basic turbine controls; a fire protection system; starting systems; and a conventional combustion system.

Competition. The SGT-500's chief competition comes from the GE LM1600 (STIG), Kawasaki L20A, and Zorya-Mashproekt UGT-15000 and UGT-16000.

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Contractors

Prime

Siemens Energy, Industrial Turbomachinery	http://www.siemens-energy.com, Ruston House, Waterside S, Lincoln, United Kingdom, Tel: + 44 1522 584000, Fax: + 44 1522 584900, Prime
Siemens, Oil & Gas	http://new.siemens.com/global/en.html, 5101 Westinghouse Blvd, Charlotte, NC 28273 United States, Tel: + 1 (704) 551-5100, Email: support.energy@new.siemens.com, Second Prime
VDEL Groep	http://www.vdlgroep.com, Gebouw 1, Industrieplein 1, Hengelo, Netherlands, Co-producer

Subcontractor

Trestad Svets AB	http://www.trestadlaser.se, Kardanvagen 4, Trollhattan, Sweden, Tel: + 46 520 478 050, Fax: + 46 520 478 060 (Flame Head)

Contractors are invited to submit updated information to Editor, International Contractors, Forecast International, 22 Commerce Road, Newtown, CT 06470, USA; rich.pettibone@forecast1.com

Technical Data

Dimensions

	Metric Units	U.S. Units
Length of Plant Package	24.65 m	80.88 ft
Width	7.0 m	22.97 ft
Height of Exhaust Stack	9.6 m	31.49 ft

Performance

ELECTRICAL GENERATION

	Metric Units	U.S. Units
Electrical Output	17 MW	22,797 shp
Electrical Efficiency	32.1%	32.1%
Heat Rate	11,180 kJ/kWh	10,596 Btu/kWh
Turbine Inlet Temperature	850°C	1,562°F
Turbine Speed	3,600 rpm	3,600 rpm
Compressor Pressure Ratio	12:1	12:1
Exhaust Gas Flow	92.3 kg/sec	203.5 lb/sec
Exhaust Gas Temperature	375°C	707°F
NOx Emissions	< 25 ppmv	< 25 ppmv
	< 50 ppmv (liquid fuel)	< 50 ppmv (liquid fuel)

MECHANICAL DRIVE

	Metric Units	U.S. Units
Power Output	17.36 MW	23,290 shp
Compression Ratio	12.0:1	12.0:1
Efficiency	32.8%	32.8%
Heat Rate	10,976 kJ/kWh	7,760 Btu/shp-hr
Turbine Speed	3,450 rpm	3,450 rpm
Exhaust Gas Flow	92.4 kg/sec	203.7 lb/sec
Exhaust Gas Temperature	376°C	708°F
NOx Emissions	< 25 ppmv	< 25 ppmv
	< 50 ppmv (liquid fuel)	< 50 ppmv (liquid fuel)

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Design Features. The SGT-500 is constructed using 10 basic modules, affording "easy" replacement of modules on site. All module replacement can be performed within the enclosure. Basic standard items are combined with filtering and ducting units to ensure flexible installation. The firm supplies complete turnkey packages, including driven equipment.

Low-Pressure Compressor. A 10-stage axial-flow compressor is driven by a three-stage axial-flow LP turbine at a speed of 5,433 to 5,520 rpm.

High-Pressure Compressor. A 10-stage unit follows the LP compressor. Speed is approximately 7,000 rpm. Total airflow is approximately 203.5 lb/sec (92.3 kg/sec) at a pressure ratio of 12:1.

Combustor. Seven cannular combustors, each with a single atomizing fuel-injection nozzle. The combustors carry a volumetric load of 10 MW/m^3 bar. The injector can be replaced in approximately 15 minutes without removing the combustor can or piping. Combustors, which are dual-fuel capable, are extensively cooled to minimize thermal distortion. The SGT-500 employs the ABB double-cone EV burner, developed and patented by ABB; water or steam can be injected into the combustor section to reduce the NOx level in the gas turbine exhaust. A dry low NOx burner can maintain emissions below 50 mg/MJ of gas fuel, resulting in a NOx level that is 10 percent the level resulting from the employment of conventional burner techniques. NOx emissions levels, with the EV burner (corresponding to 15 percent O_2, dry), are less than 25 ppmv when fired with natural gas.

High-Pressure Turbine. A single-stage HP turbine drives the HP compressor unit, comprising IN738 investment cast blades and X-40 guide vane materials. Turbine inlet temperature is approximately 1,535°F (835°C); maximum TIT is 1,598°F (870°C).

Low-Pressure Turbine. A two-stage axial unit drives the LP compressor spool. It comprises 80 Udimet 500 blades and 80 vanes.

Power Turbine. The SGT-500 is available with either two- or three-stage power turbines designated 93-3 for 3,600-rpm units for the generation market, and 93-5 for 3,450-rpm to 6,300-rpm units for mechanical drive duty. Blades and vanes in the two-stage version are made of Ni 90 and X-40, respectively, while in the three-stage unit, blades and vanes are made of H46.

Operational Characteristics. The SGT-500 has a combustor system that ensures lower emissions (2.5 g/kWh) than those possible with high-speed (5-9 g/kWh) and medium-speed (9-12 g/kWh) diesel engines. The low level is achieved without depending on an external NOx-reduction process, such as selective catalytic reduction. Although the GT35 had already met the proposed IMO NOx emission requirements, an ABB R&D program in 1997 lowered the unit's emissions to 1 g/kWh (50 ppmv at 15 percent O_2) for liquid fuel.

Variants/Upgrades

Note: *The Siemens SGT-500 was formerly the Siemens GT35, and earlier the Alstom GT35.*

GT35. The GT35 is the original designation for the SGT-500 and is the basic machine in the series.

GT35C. The GT35C represents the first upgrade effort of the machine series. Early ratings were 15.1 MW on natural gas and 14.5 MW on distillate fuel.

SGT-500 (GT35C2). The SGT-500 designation refers to the GT35 at a power rating in the 17.0- to 17.3-MW range. Compressor ratio is 12:1. The machine is offered for 50- and 60-Hz operation.

The GT35C2 designation appears on the Det Norske Veritas (DNV) Type Approval Certificate (March 1, 2001) for the GT35 for light craft marine propulsion (at 17-MW normal output power and 18-MW maximum outlet power).

GT35P. ABB developed a coal-fired GT35 combining the pressurized fluidized bed combustion (PFBC) version of the machine, designated GT35P. The approximate output of the GT35P is 17.0 MW.

Mobile GT35. In 1982, Saudi Consolidated Electric Company (SCECO) contracted with ABB for nine turnkey mobile GT35 gensets; it required a mobile capability to reach remote load centers. However, the procurement and deployment of the mobile GT35Cs gave SCECO the ability to vary the load and react quickly to expanded and emergency requirements over a wide-ranging geographical area at minimal expense.

In October 1982, the first three GT35s were shipped to Jizan, Saudi Arabia. The second lot of six mobile units was shipped and available by June 1983.

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Notwithstanding the commonality with previous GT35s, the mobile unit employs unique features. Its compressor contains only 18 stages, as opposed to the 20 of earlier models, yet produces the same compression ratio. Operating efficiencies are also improved with the addition of the novel tip clearance technique employed in the power turbine section. Tip clearance is maintained in the power turbine by the axial movement between the rotor and stator. The power turbine and generator base are connected by supports to the thrust and journal bearing. When hot air is circulated, this connection moves axially, closing the gap between blade and stator and thus eliminating much of the loss associated with startup.

New Package Design in 1997. The GT35's new package design, unveiled in 1997, included the replacement of the truss box with a traditional base frame to better suit the needs of the oil and gas industry. An electric starter motor replaced the air starter featured on the original specification.

Also in 1997, then-Alstom tested the GT35's burner for liquid fuel operation in response to strong interest and demand within the marine sector for environmentally friendly gas turbines. Initial results were that the sector's stringent requirements for NOx emissions from oil fuel were met with ratings below 2.0 g/kWh with a dry fix. The burner is the same AEV design used in the Siemens SGT-800 (formerly Siemens GTX100, and earlier Alstom GTX100) – i.e., each combustor is fitted with three burners. Alstom redesigned the GT10 gas turbine package in 1997 as well.

PFBC GT35. For years, the Swedish firm experimented with the PFBC system and industrial gas turbines. It cooperated with Deutsche Babcock and American Electric Power of the U.S. to design an optimum PFBC gas turbine power module. After years of effort, the company announced it was ready to design complete power plants around two PFBC systems powered by the GT35P machine.

The GT35P machine, a derivative of the GT35 with an intercooler between the HP and LP compressors, formed the core of Siemens' P200 power block module. The module also includes a coal-burning PFBC designed to match the gas turbine inlet temperature and flow conditions. The gas turbine provides the combustor with pressurized air for cooling, fluidization, and combustion. In return, it receives the hot and partially cleaned combustion gas. The energy in the gas is used to drive the compressors and alternator and for preheating the condensate and feedwater in the economizers.

At least four P200 modules were ordered for electric utility combined-cycle installations in Sweden, Spain, and the U.S. The first PFBC GT35 was operational with the Stockholm Energy Company's CHP station in Vartan by 1989; twin GT35Ps operate in the plant's 135-MW combined-cycle configuration.

SGT-500 Combined Cycle. The SGT-500 machine has been offered for combined-cycle power plants. The total power output of the combined-cycle power plant units for 50-Hz or 60-Hz frequencies are 22.8 MW for the KA 35-1 plant and 45.8 MW for the KA 35-2 plant.

GT35 in Marine Propulsion. In 1995, ABB-Stal received an order for four 23,000-hp (17-MW) GT35 gas turbines as the main propulsion machinery for two of Stena Line's new high-speed HSS 900 ferries. The design of the catamaran-type vessel called for two GT35s, one in each hull. The first vessel, *Stena Carisma*, entered service in 1996 but was retired in 2007 due to excess operating costs. The second was scrapped while still under construction; it was only 30 percent complete.

A second order was placed in 1996, for two GT35s for the E.N. Bazan Buquebus B60 high-speed ferry, the *Luciano Federico L*. The GT35s have a combined output of 34 MW and were adapted to burn IF 30-type intermediate fuel oils. This ferry remained in service as of 2012, but by 2016, she had been laid up and listed for sale. She was still laid up in Panama at time of writing.

The GT35C2 was the first gas turbine machine in its class to be awarded the DNV Type Approval Certificate (Certificate No. M-9353, dated March 1, 2001) for light craft propulsion and auxiliary duty. On February 15, 2001, Alstom received DNV Type Certificate No. A-7953 for GT35C2 marine control equipment.

Historical Activity. The following firms are or have been affiliated with the Siemens SGT-500 program:

- ABB Nevsky; St. Petersburg, Russia
- Kværner Energy, Steam & Gas Turbine Division; Oslo, Norway
- Hitachi Zosen Ltd; Tokyo, Japan
- Solar Turbines Inc; San Diego, California
- Sulzer Turbo Ltd, Gas Turbine Department; Winterthur, Switzerland (along with Sulzer Turbosystems International of Houston, Texas).

Program Review

Background. The Siemens SGT-500 was introduced shortly after World War II for use as an aircraft turbine for the Swedish Air Force. When the Air Force decided to utilize the Rolls-Royce Avon instead, the engine was adopted for industrial use as an alternative to Stal-Laval's series of steam turbines rated to 9 MW.

The first Asea Brown Boveri/ABB-Stal GT35 machine entered service – at 9 MW – in 1954 at a Swedish power station, followed by the installation of three units at the Puerto la Cruz power station in Venezuela. Some early machines reportedly operated in excess of 70,000 hours without failure or need of a major overhaul.

The SGT-500's design incorporates the roots of its original aviation concepts combined with the heavy-duty construction necessary for industrial operation. Built-in features include moderate firing temperatures and low stress levels for long life, plus heavy bearings and large combustors for reliability. High-temperature coatings are available for the turbine components when the unit must operate in a hostile environment.

Like the Rolls-Royce Avon (which the Swedish Air Force chose over the original aero-version of the GT35 in the early 1950s) and the Westinghouse W series, the SGT-500 is a rugged, multifuel machine of long lineage.

The engine has remained competitive for the same reasons its long-lived rivals have: it is considered reliable and versatile and requires little maintenance. ABB uprated the GT35 twice and adapted it for marine propulsion. The machine can run on marine diesel and heavy fuel oils, and its shaft generator is strong enough to provide onboard power at idle in dock, partially reducing wear from repeated cycling.

The SGT-500 is also well suited to mechanical drive functions for compressors or pumps, and its special design features make it appropriate for economical baseload power generation. It can be used for power generation where mobile units can be of great advantage, for waste heat recovery schemes, and in combined-cycle and cogeneration applications.

Further GT35 Development. Alstom Power continued to refine and improve the basic GT35 design and produced industrial gas turbines with much higher power capabilities. Late performance figures showed a 17 percent increase in specific power at somewhat lower heat rates. Asea Brown Boveri succeeded in uprating the gas turbine while reducing the number of HP compressor stages to the now-standard eight for both fixed and mobile models. It also changed the aerodynamics of the LP spool.

In 1982, then-Asea Stal uprated the GT35 design from the earlier "B" rating to a "C" rating, with a 15 percent boost in total power output. The power output of the GT35C was 14.5 MW on liquid fuel and 15.1 MW on natural gas. Later efforts raised the power output to 17 MW.

In 1993, ABB-Stal announced that a low NOx version of the GT35 was available for mechanical drive applications. The ISO performance of the model was raised to 23,200 hp and the efficiency to 33 percent.

During the late 1990s, the GT35 was promoted as a powertrain for fast ferries under the designation High-speed Sea Service or Stena HSS. Four such vessels were ordered. The LM1600-powered *Stena Explorer, Stena Voyager* and *Stena Discovery* were ordered to operate around the British Isles, while the GT35-powered *Stena Carisma* was built for Scandinavian use. The second GT35-powered ship was scrapped when only 30 percent complete. All of these ships were withdrawn from operations after less than a decade's service due to poor operating economics. Two of the vessels are now laid up (*Stena Carisma* in Gothenburg and *Stena Explorer* in Holyhead, Wales). The third and fourth ships, HSS *Discovery* and HSS *Stena Voyager*, were scrapped in Landskrona, Sweden, in 2014.

The first SGT-500 sale in five years was made in October 2017 when one unit was ordered by the Saudi Bio-Acids Company. This appears to have been the last sale as well, and an inspection of Siemens corporate data shows that the SGT-500 is no longer listed as an available product. The most likely rationale for this is that it has been replaced in the Siemens portfolio by the aeroderivative gas turbines purchased from Rolls-Royce.

However, a search across the international gas turbine industry shows that there is a significant retrofit, upgrade, and modernization industry for the SGT-500 extant. This appears to be concentrated in countries that are arguably off the beaten track for mainstream upgrade and maintenance activities. Iran in particular appears to be a center for these operations, presumably as a substitute for the non-availability of new-production industrial gas turbines. Thus, there is substantial activity in the SGT-500 sector, although this does not amount to new production.

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Funding

The (now) Siemens SGT-500 gas turbine machine was developed by Stal-Laval using Swedish government funding directed through the Royal Swedish Air Force. The engine was subsequently adapted for industrial use using internal corporate funding.

Timetable

Month	Year	Major Development
	1954	GT35 design effort begins; first order placed
	1956	GT35 introduced at 9 MW
	1965	GT35 uprated to 11 MW
	1983	GT35C enters production
	1986	First GT35P ordered for installation in Europe (Spain)
Jun	1986	Asea, Kværner Brug (Kværner Eureka) sign agreement
	1989	First PFBC GT35 becomes operational in Sweden
	1993	First GT35 with dry low NOx technology commissioned in Germany
	1993	ISO rating of machine for mechanical drive raised to 23,200 hp
Mid-	1995	Stena Line orders four GT35s for HSS 900 catamaran-type vessels
Mid-	1996	First of Stena Line's HSS 900s begins service
Mar	1999	ABB and Alstom announce creation of ABB Alstom Power
Jun	1999	EU approves ABB and Alstom's creation of ABB Alstom Power
May	2000	Alstom acquires ABB's 50 percent share of ABB Alstom Power; ABB Alstom Power becomes Alstom Power
Mar	2001	DNV issues Type Approval Certificate for GT35C2 for light craft
Mar	2002	Three GT35s ordered for offshore Iran duty
Apr-Aug	2003	Siemens PG acquires part of the gas turbine business of Alstom SA
Nov	2004	Siemens redesignates its entire product line; the GT35 becomes the SGT-500
Sep	2006	SGT-500 receives DNV preliminary approval on heavy fuel oil
	2007	Stena Line's HSS 900s start to be withdrawn from service due to fuel costs
May	2013	Edo Cement orders three SGT-500 units for electric power generation for the Okpella Cement Factory located in the Nigerian state of Edo
	2014	Last of Stena Line's HSS 900s withdrawn from service; second pair scrapped.
Oct	2017	One SGT-500 unit ordered by Saudi Bio-Acids Company

Worldwide Distribution/Inventories

Country	Year Installed	Total
Algeria	1972 (2), 1987 (1), 1995 (3), 1996 (1)	7
Angola	1979 (1), 1980 (1), 1981 (1), 1987 (1), 1988 (1)	5
Australia	1984 (1), 1985 (1), 1988 (2)	4
Bangladesh	1979 (1), 1981 (1)	2
Barbados	1990 (1), 1995 (1)	2
Bermuda	1988 (1), 1995 (1)	2
Czech Republic	1996 (2), 1997 (1)	3
Denmark	1987 (2), 1988 (1)	3
Egypt	1966 (2), 1978 (3), 1980 (3), 2005 (4)	12
Germany	1993 (1), 1998 (1)	2
Greece	1984 (2), 1995 (3), 2001 (1)	6
India	1983 (4), 1985 (2), 1986 (3)	9
Indonesia	1983 (2), 1998 (1)	3
Iran	1990	1
Iraq	1983	4
Malaysia	1984 (2), 1986 (1)	3
Moldova	1980	2

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Country	Year Installed	Total
Mozambique	1989	1
Netherlands	1968 (3), 1980 (1)	4
Nigeria	1980 (2), 1982 (1), 1983 (1), 2014 (3)	7
Norway	1978 (1), 1985 (3)	4
Oman	1978 (1), 1979 (2), 1980 (1), 1984 (2), 1985 (4)	10
Russia	1998 (1), 1999 (1), 2002 (1)	3
Saudi Arabia	1980 (5), 1981 (16), 1982 (8), 1983 (16), 1985 (2), 1987 (3), 1988 (2), 1996 (4), 2018 (1)	57
Spain	1987 (1), 1988 (2), 1997 (2)	5
Sudan	1969 (1), 1984 (1), 1985 (1), 1986 (1)	4
Sweden	1956 (1), 1969 (1), 1972 (1), 1978 (1), 1981 (1), 1988 (2), 1990 (2), 1997 (2)	11
Thailand	1992 (1), 1994 (4)	5
Turkey	1969 (1), 1970 (1)	2
UAE	1977 (2), 1978 (1), 1979 (1), 1980 (3), 1981 (4), 1982 (4), 1983 (2), 1984 (3), 1998(3)	23
U.K.	1973 (1), 1974 (1), 2007 (1)	3
U.S.	1989	2
Venezuela	1959 (2), 1961 (1), 1962 (2), 1963 (2), 1973 (1), 1982 (1), 1998 (2)	11
Vietnam	1988	1
TOTAL		**223**

Early in 2016, Siemens stated that 175 SGT-500 machines had been installed. The FI I&M Database has identified 223 units. The discrepancy appears to be that Siemens does not include a number of very old installations and marine applications in its inventory.

Forecast Rationale

Introduced in 1955, the SGT-500 is one of the oldest gas turbines in Siemens' inventory. It was primarily developed for the austere working conditions of heavy oil operations.

The SGT-500 still sees some duty in the oil and gas industry, besides being used for power generation and cogeneration and in combined-cycle and some offshore operations. The machine has nearly finished its life-cycle, as it is being replaced, most likely in this decade, by newer and more efficient models.

Forecast International believes SGT-500 production has ceased and that this machine is now in the "available for production" class at best. It ceased to be listed in corporate literature during 2018 and is no longer actively marketed. Therefore, this report has no production chart.

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