Siemens Gas Turbine SGT6-5000F
Application Overview

Answers for energy.
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The advanced technology of the SGT6-5000F gas turbine continues to satisfy the worldwide needs of the power generation marketplace for 60 Hz projects. Siemens introduced the first unit in the W501 series in 1968. Since that time over 560 units of Siemens Gas Turbines (SGT™) have been sold. Siemens evolutionary design philosophy maintains continuity by building on our proven gas turbine technology. To attain high engine reliability, upgrades or new engine designs are based on technologies proven by engine operation or by extensive component testing.

The SGT6-5000F gas turbine exemplifies this evolutionary process. This SGT6-5000F gas turbine combines the efficient, proven design concepts of the W501D5 with the addition of advanced cooling technologies and improved compressor construction. The advanced cooling technologies allow higher flow path gas temperatures while keeping metal temperatures at the level of previous engines. The technology upgrades applied to the SGT6-5000F gas turbine have resulted in an engine with a rated output that is among the highest of the “F” class gas turbines. The SGT6-5000F gas turbine fleet has achieved over 3.4 million hours of reliable operation and net combined cycle efficiencies of 57%.

This gas turbine is ideally suited for simple cycle and heat recovery applications including Integrated Gasification Combined Cycle (IGCC), cogeneration, combined cycle and repowering. Flexible fuel capabilities include natural gas, LNG, distillate oil, syngas and other fuels, such as low- or medium-Btu gas.

The low emissions SGT6-5000F gas turbine engine consists of a 16-stage axial-flow compressor, a combustion system composed of 16 can-annular combustors and a 4-stage turbine. Packaged with the generator and other auxiliary modules the SGT6-PAC 5000F power generation system provides economical power for peaking duty, operational flexibility and load following capabilities for intermediate duty, while maintaining high efficiencies for continuous service. Regardless of the application, the SGT6-5000F gas turbine is the basic building block for a wide variety of power generation systems.

Siemens Simple Cycle applications

The Siemens Simple Cycle (SSC™) SGT6-PAC 5000F power plant, nominally rated at 196 MW, is a self-contained, electric power generating system suited for simple cycle applications. The design of the SGT6-PAC 5000F includes over 50 years of experience in gas turbine technology and power plant design. These following proven features, incorporated into the SGT6-PAC 5000F power plant include:

- Factory assembled fuel, auxiliary, lubricating and electrical packages
- Walk-around enclosures for turbine and auxiliary packages
- Microprocessor-based distributed control system
- Air-cooled generator
- Normal start time - 29.5 minutes to base load
- Optional fast start - 10 minutes to 150 MW.

* SGT6-5000F gas turbine engine was formerly called the W501F.
** SGT6-PAC 5000F power plant was formerly called the W501F Econopac.
Siemens Combined Cycle applications

Siemens has more than three decades of experience in combined cycle plant design. Our first combined cycle experience came in the early 1960s with the installation of the West Texas Utilities plant using a W301, a 30 MW gas turbine. The second generation of combined cycle plants were the PACE (Power at Combined Efficiencies) plants introduced in the early 1970s. The PACE plants used an earlier W501 model, the W501B, as their prime mover and were pre-engineered, standardized combined cycle plants.

The Siemens Combined Cycle (SCC™) SCC6-5000F plant*** design (as shown in Figure 1) is built on the strong knowledge base derived from these previous design efforts. With 1x1 (~293 MW), 2x1 (~591 MW) and 3x1 (~885 MW) configurations, the SCC6-5000F family of combined cycle plants is sized to meet the various base and cyclic load requirements of utilities, independent power producers (IPPs) and merchant plant operators. The development of these designs allows for cost-effective plants that require minimal project specific engineering.

Project capabilities

Siemens is experienced in producing successful power projects. Our comprehensive scope of capabilities includes:

- Total turnkey power plants
- Integrated project management
- Plant engineering and design
- Plant permitting assistance
- Equipment installation
- Plant operation and maintenance.

When we take responsibility for a project, or any portion of it, an integrated project management approach is applied to the task. The planning techniques used are among the most advanced in the industry. Project goals are clearly developed and well communicated. Work packages are created which include drawings, material lists and sign-off sheets. Personal accountability means a personal commitment to quality. Siemens has achieved an impressive record for building plants on schedule and within budget.

*** SCC6-5000F combined cycle power plant was formerly called the W501F combined cycle plant.
Service and support

A global network for service and support

Siemens is equally committed to providing comprehensive service programs that truly support and optimize the performance of your equipment. We begin with technical assistance provided during the installation and start-up of your equipment and continue with a multitude of service options. These include turnkey maintenance inspections, technical field assistance, modernizations and upgrades, repair and refurbishment and control system service and upgrades.

We have established a powerful and responsive service network with more than 4,000 field engineers and technicians in regional service offices around the globe. So wherever you are, wherever your plant is located, we speak the language, we know the market and we are available when you need us… with rapid-response solutions that translate into measurable benefits for you.

Total Maintenance Services

Our comprehensive service approach also means that we have the ability to track unit trends in our global fleet through leading edge diagnostics technology to ensure maximum unit performance and availability. Total Maintenance Services (TMS) is a structured outage planning, implementation and lessons-learned process. It enables our customers to receive regular notifications of the latest engine design improvements and upgrades as well as notices regarding inspection and maintenance activities. Pre-outage planning is a standard feature to ensure preparedness by identifying necessary parts, modifications and upgrades that are available, new training programs, addressing customer questions and concerns, and offering a comprehensive scope of recommendations.

By analyzing data and trends from the entire operating fleet, we can identify and prevent issues before they impact your plant performance. The constant flow of information and documented pre-outage planning initiatives enable our customers to be better informed and prepared for a more efficient and timely outage that meets their goals of unit reliability, outage duration and budget.

Service programs

Our Service Agreements link performance with customer objectives, providing turnkey outage services as well as parts and repairs for scheduled and unscheduled maintenance.

This performance-based contract approach provides incentive for both parties to benefit from on-time completion, high-quality maintenance, project management and advanced, remote monitoring and diagnostics systems. A dedicated program manager is on-call to provide support and a dedicated team of locally based district managers, home office personnel and factory-trained technicians understand and are closely aligned to your objectives. Our flexible service approach enables us to work with you to create a service program that truly meets your requirements.

We want to develop an ongoing partnership to help ensure your project’s long-term success. We are committed to serving our customers well after plant commissioning. That is why we offer comprehensive service options, backed by a global network of resources, to support your equipment throughout its entire life-cycle.
Siemens has provided diagnostic systems design and implementation since the early 1980s. Whether you are a plant owner or operator, our Power Diagnostics® services can help you maximize your plant performance, availability and profitability.

Your power business is unique; accordingly, your business requirements demand the most innovative and effective solutions available. We meet these challenging requirements with one of the most effective monitoring and diagnostics services available to power plant owners. Our Power Diagnostics approach keeps your plant connected to our vast engineering expertise. Data acquired by acquisition systems is transmitted to the Power Diagnostics Center to be analyzed and processed by specialists and engineers. This engineering knowledge, combined with the use of sophisticated tools, provides trending and analysis capabilities to address a broad range of operating needs specific to each customer. This approach facilitates continuous improvement of our solutions to help you enhance your plant’s availability and reliability.

Our Power Diagnostics Centers in the United States and Germany are monitored around the clock with experienced professionals who understand the complexity of your turbine systems and the demands placed on them. These highly skilled and trained engineers recognize the importance you place on keeping your plant on-line to meet business demands. If an abnormal trend is detected, your data will be analyzed, compared to our vast historical operating fleet database, and presented in an understandable manner to your plant staff for timely trend assessment. Analysis results also can help you to schedule outages with more precision. If required, quick-response technical resources also can be dispatched for on-site problem resolution.

To help you optimize your plant operating availability and enhance your bottom line, Power Diagnostics is invaluable in assisting with the detection of impending operational problems, thereby helping to minimize unplanned outages and maximize power generation availability.
SGT6-5000F gas turbine

General description
Designed for both simple and combined cycle applications, the SGT6-5000F gas turbine can operate on conventional gas turbine fuels and a wide range of alternate fuels subject to review by Siemens. The gas turbine consists of a 16-stage, high efficiency axial compressor, combustion chamber equipped with 16 Dry Low NOx (DLN) emissions or conventional combustors arranged in a circular array around the engine centerline, and a 4-stage reaction type turbine. The gas turbine is coupled directly to the generator at the compressor end.

Ambient air is drawn through the inlet manifold and inlet casing into the compressor. It is pressurized to approximately 16 atmospheres and guided into the combustors, where it is mixed with fuel and ignited, raising the temperature of the mixture. The compressed and heated mixture (gas) then expands through the turbine, dropping in pressure and temperature as the heat energy is converted into mechanical work. A portion of the power developed by the turbine is used for driving the compressor, with the balance of power used to drive the generator. Expanded gases are then exhausted into the atmosphere through an exhaust stack for a simple cycle application or through a Heat Recovery Steam Generator (HRSG) and exhaust stack in a combined cycle application.

Design features
SGT6-5000F gas turbine features, such as cold-end generator drive, two-bearing design, horizontally split casings, can-annular combustors and tangential strut supports have been used in this gas turbine family since the early 1950s. The axial exhaust concept, introduced in 1970 on the W501AA, improves performance and provides greater flexibility for multiple unit plant arrangements especially when applied to combined cycle power plants. Design features summary:
- A two-bearing rotor used to simplify alignment
- Bearings that operate at below atmospheric pressure to prevent shaft seal leakage
- Readily accessible bearings that can be removed and replaced without lifting the gas turbine covers
- Compressor blades that can be removed for inspection and reinstall without disturbing blades in other rows and without removing the rotor from its casing
- Low temperature environment of the exhaust bearing permits the use of less expensive and readily available lubricating oil
- Individual turbine blades that can be removed for inspection or replacement with the rotor in place and without disturbing other blades
- Compressor diaphragms and turbine blade rings that can be taken out for inspection or be replaced with the rotor in place
- Field balancing, two end and one center balance planes are easily accessible
- Multiple boroscopic inspection ports in the compressor and turbine flow paths to permit inspection of the blading without lifting covers
- Turbine supports for free expansion and contraction due to temperature changes without disturbing the shaft alignment
- Cooling circuits designed to protect the gas turbine parts from the high temperature gas stream for better reliability and longer life
- A tangential strut support system for the turbine-end bearing – a Siemens patented feature – for maintaining the bearing on centerline for all conditions of load and temperature.
Major assemblies

Casings

Engine casings are horizontally split to facilitate maintenance with the rotor in place. Inlet casings are cast from nodular iron or fabricated from cast steel. The compressor section casings are cast steel while the combustor, turbine and exhaust casings are alloy steel.

Eight radial struts support the inlet bearing housing while six tangential struts support the exhaust-end bearing housing. Airfoil-shaped covers protect the tangential struts from the blade path gases and support the inner and outer diffuser cones.

Tangential struts maintain alignment of the bearing housing by rotating it, as required, to accommodate thermal expansion. Individual inner casings (blade rings) are used for each turbine stationary stage and can be readily replaced or serviced with the rotor in place. Similar blade rings are in the compressor for stages seven through sixteen. The blade rings have a thermal response independent of the outer casing, thereby permitting the blade rings to remain concentric to the rotor. This allows for a minimum clearance between rotating and stationary airfoils in order to increase flowpath efficiency.

Rotor assembly

The rotor consists of the compressor and turbine rotor components bolted together and supported by two tilting-pad bearings. A direct lubricated, double acting thrust bearing located at the compressor end of the gas turbine accommodates engine thrust. The compressor rotor is comprised of multiple discs equipped with load carrying keys between discs, aligned using a spigot fit and clamped together by 12 through bolts.

The turbine rotor is made up of interlocking discs using CURVIC® couplings that are held together by 12 through bolts. The CURVIC couplings consist of mating curved teeth that are located around the circumference of adjacent disc faces, which interlock and provide precise alignment and torque carrying abilities. This proven turbine rotor design has accrued millions of hours of reliable service in all sizes of our gas turbines.

Any turbine or compressor blade can be removed for inspection and replaced without lifting the rotor.

Air inlet system and compressor

The air inlet system, consisting of the inlet filter, inlet silencer and associated duct work, delivers air to the compressor. The compressor is a 16-stage axial flow design and achieves a 17-to-1 pressure ratio. Inter-stage bleeds for starting and cooling flows are located at the 6th, 10th and 13th stages. The compressor is equipped with one stage of variable inlet guide vanes to improve the compressor low speed surge characteristics and part load performance in combined cycle applications.

The compressor blade path design is based on an advanced three-dimensional flow field analysis computer model. All rotor blades incorporate an improved root design that has flat contact faces (as do the turbine blade roots), which allows the blades to be removed in the field with the rotor in place. The blades of the first six stages are 17-4 PH (17% Cr precipitation hardened stainless steel). Rows seven through sixteen blades use AISI 616 stainless steel.

Each stage of stationary airfoils consists of two 180° diaphragms for easy removal. An inner shroud sealing system is used on the SGT6-5000F gas turbine. The seals are supported by machined seal rings, which can be removed to facilitate inspection and maintenance of shrouds and seals. One row of exit guide vanes is used to direct the flow leaving the compressor. Stationary airfoils and shrouds utilize corrosion and heat-resistant stainless steel throughout.

Compressor rotating and stationary airfoils are coated to improve aerodynamic performance and provide corrosion protection.
Combustion system

The combustion system consists of 16 can-annular, dry low emissions (25 ppm or 9 ppm NOx systems are available) or conventional combustors.

The presence or absence of flame and the uniformity of the fuel distribution between combustors are monitored by thermocouples located downstream of the last stage turbine blades. These can also detect combustor malfunctions when at load. Ultraviolet detectors are used to sense ignition during starting.

Transition ducts, one for each combustor, direct the hot gases from the combustors to the turbine blade path. The transitions are air-cooled and the same design is used in both simple and combined cycle applications.

Turbine section

The turbine design of the SGT6-5000F gas turbine maintains moderate aerodynamic loading by the use of a 4-stage turbine. Furthermore, improvements in aerodynamic airfoil shapes have been made possible by using a fully three-dimensional flow analysis computer model. A sophisticated airfoil design approach was utilized to target high aerodynamic efficiency.

The 1st and 2nd stages on the turbine rotor contain 72 and 66 freestanding blades, respectively. The 3rd and 4th stages contain 112 and 84 blades, which incorporate integral Z-tip shrouds. The shrouding of blades allows increases in mass flow and thus an increase in the power output. The shrouded blade design prevents flow induced non-synchronous vibration due to aero-elastic interaction between blade structure and flow.

The 1st and 2nd stage rotating blades are precision cast of equiaxed IN-738. The 3rd and 4th stage rotating blades are precision cast of equiaxed CM-247. All rows have long blade root extensions to minimize the stress concentration factor that results when load is transferred between cross sections of different size and shape. Roots are multiple serration type with four serrations used on the first two rows and five serrations on the last two stages.

The 1st turbine stationary row consists of 32 precision-cast, single-vane segments of ECY-768 alloy coated with thermal barrier coating (TBC) for improved thermal resistance. Consistent with previous proven W501 designs, 1st row single vanes are removable, without lifting any covers, through access ports in the combustor shell. Inner shrouds are supported from the torque tube casing to limit flexural stresses and distortions, thus maintaining control of critical 1st row vane angles. In the 2nd turbine stationary row, there are 24 two-vane segments precision cast of ECY-768 alloy, which are also treated with TBC. The 3rd turbine stationary row consists of 16 three-vane segments and the 4th turbine stationary row consists of 14 four-vane segments. Both are precision cast of X-45.

Each row of vane segments is supported in a separate blade ring, which is keyed and supported to permit radial and axial thermal response independent of possible external cylinder displacements. Segmented isolation rings support the vane segments. Ring segments located over the rotating blades form the flow path outer annulus. Isolation and ring segments both act to limit thermal conduction between the flow path and the blade ring, thus mitigating blade ring clearance changes in the turbine section. The interstage seal housings are uniquely supported from the inner shrouds of rows 2, 3 and 4 vane segments by radial keys. This permits the thermal response of the seal housings to be independent of the more rapid thermal response of the vane segments.

Cooling system

Comprehensive cooling methods enable the SGT6-5000F gas turbine to operate at high performance firing temperatures while using conventional materials.

Compressor bleed air from the 13th, 10th and 6th stages is used to provide cooling air to turbine blade ring cavities at the 2nd, 3rd and 4th stages, respectively. This supply of bleed air also cools the 2nd, 3rd and 4th stage vanes and ring segments and provides
cooling air for the turbine interstage disc cavities to shield the interstage seals and disc faces from hot blade path gases.

Direct compressor discharge air is used to cool the 1st row vane. The 1st row vane cooling design uses state-of-the-art concepts with three impingement inserts in combination with an array of film-cooling holes and a trailing edge pin-fin system. “Showerhead” cooling is used at the leading edge of the 1st row vane, while film cooling is used at selected pressure and suction side locations. This limits vane wall thermal gradients and external surface temperatures, while providing an efficient re-entry for spent cooling air. Pin-fins, used successfully for the first time on the WS01D5 1st row vane, are used to increase turbulence and surface area, thereby optimizing the overall trailing edge cooling effectiveness. (See Figure 2.) The design of the 1st row vane is such that the Low Cycle Fatigue (LCF) design criteria is satisfied by control of wall thermal gradients.

For the 2nd row vane, 13th stage compressor bleed air is ducted directly to the twin insert system. The 2nd row vane cooling is a less complex version of 1st row vane cooling. It uses twin impingement inserts with film-cooling holes and a trailing edge pin-fin system. Film cooling is used at one location on the suction side and at the exit of the aft insert on the pressure side.

Compressor bleed air from the 10th stage is used to supply cooling air to the 3rd stage blade ring cavity. Cooling air is directed to the inlet cavity of a three-cavity multipass convective-cooled vane airfoil. Leading edge cavity flow also supplies the interstage seal and cooling system, while the third pass cavity exits at pressure side gill holes on the vane surface. The 4th stage vane is uncooled, but does transport 6th stage compressor bleed air for the 4th row inter-stage seal. (Figure 3 depicts the cooling system.)

Rotor cooling air is extracted from the combustor shell. The air is externally cooled and returned to the torque tube seal housing to be used for seal air supply and for cooling of the turbine discs and 1st, 2nd and 3rd stage turbine rotor blades. This provides a blanket of protection from hot blade path gases.

The 1st stage blade is cooled by a combination of convection techniques via multipass serpentine passages and pin-fin cooling in the trailing edge exit slots. (See Figure 4, page 12.) Air supply for blade cooling is high-pressure compressor discharge air that has been cooled and returned to the turbine rotor via four supply pipes in the combustor shell. Cooling air flows outward through three slots in the root and is conveyed radially through the blade shank. Showerhead film cooling is used for the leading edge region. The 2nd row rotor blade is also precision cast and is cooled by a combination of convection
techniques via serpentine passage and pin-fin cooling in the trailing edge exit slots. The 3rd row blade is precision cast with single pass convective cooling holes.

Figure 4 - Row 1 blade cooling

The cooling system maintains the NiCrMoV turbine discs at a temperature sufficient to keep the disc below the creep range.

Exhaust cylinder section

The exhaust cylinder fabrication is composed of the bearing housing, inner and outer cones of the exhaust diffuser and outer case, all joined together by means of a strut system. The strut system consists of six bearing struts equally spaced around the circumference but positioned tangentially with respect to the bearing housing.

These struts extend from the bearing housing to the outer case. In the hot gas section of the exhaust diffuser, the bearing struts are protected from the hot exhaust gas by envelopes of cooler air around them. This results in a strut system that is less sensitive to transient temperatures. Growth of the outer case and struts is accommodated by bearing housing rotation.

The system provides a low stress, rigid support, capable of holding the bearing on center for variations of load and temperature.

Axial exhaust manifold section

The exhaust manifold section consists of the exhaust manifold, expansion joint with flow liner and exhaust transition. The exhaust gas flows through the manifold and flow liner into the transition and is then discharged into the stack.

The manifold acts like a muffler in which the flow is slowed down without becoming excessively turbulent. This flow stabilization further improves the gas turbine performance. All parts of the exhaust system section, with the exception of the expansion joint, are fabricated from a high strength, low alloy steel.

The exhaust manifold is composed of one outer and inner cylinder held together by means of two hollow struts. The outer cylinder has the shape of a truncated cone. The inner cylinder, in conjunction with the inner cone of the exhaust diffuser, forms an enclosed chamber around the gas turbine centerline. An access passage to this chamber and a channel for the pipe and conduit lines going to the bearing area are provided through the hollow struts.

The manifold is connected to the exhaust transition by means of an expansion joint made from a high temperature-resistant material. The expansion joint’s primary function is to accommodate the axial growth of the unit due to thermal expansion and to prevent any external load from being imposed upon the exhaust manifold.

The axial exhaust configuration is ideally suited for waste heat recovery applications such as combined cycle, cogeneration and repowering.
Scope of supply definitions

**SGT-PAC**
- Gas turbines for fuel gas
- Fuel gas system
- Generator auxiliaries
- Gas turbine generators
- Fire protection
- GT-electrical and I&C
- Options

**SCC Thermal Equipment**
- SGT-PAC
- SGT-PAC + HRSG
- Steam turbine incl. auxiliaries
- Generator incl. auxiliaries
- ST electrical and I&C
- HRSG
- Options

**SCC Power Island**
- SCC Thermal Equipment
- Condenser incl. air removal system
- Boiler feed pumps
- Condensate pumps
- Critical valves
- Fuel preheater with filter, metering station, etc.
- Power island control
- Options

**SCC Turnkey**
- SCC Power Island
- Building structures
- Cranes and HVAC
- Plant cooling systems
- Water treatment
- Raw water system
- Waste water system
- Tanks
- Plant piping/valves
- Electrical equipment
- Plant control system
- Additional fire protection/ civil engineering
- Erection/commissioning
- Further options

**Performance/Delivery**
**Cycle optimization/Performance wrap**
**System integration/Optimized operability**
**Total EPC plant wrap**

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**SGT-PAC**
Gas turbine, generator, auxiliaries and controls for supplied scope, inlet and exhaust systems.

**SCC Power Island**
SGT-PAC plus HRSG, steam turbine, condenser, major pumps, critical valves and controls for supplied scope.

**SCC Turnkey**
SCC Power Island plus buildings, structures, plant cooling, power control centers, electrical, switchgear, fuel delivery piping, plant control system, balance of plant construction, erection and commissioning.

Remark:
Visible differences between Thermal Equipment and Power Island are small and therefore not shown.
General description

The SGT6-PAC 5000F plant is designed to provide the user with a complete power generating system. Components and subsystems are selected to form a compact plant housed within enclosures.

The SGT6-PAC 5000F plant features modular construction to facilitate shipment and field assembly. Subsystems are grouped and installed in auxiliary modules. Each module of the SGT6-PAC 5000F plant is factory assembled to the extent permitted by shipping limitations to minimize field assembly. Pipe rack assemblies that provide interconnecting piping between the standard modules are supplied, eliminating the need for extensive piping fabrication during construction.

The basic bill of materials for a SGT6-PAC 5000F plant typically includes the following equipment and assemblies:

- SGT6-5000F Gas Turbine
- Open air-cooled generator
- Brushless excitation and voltage regulator system
- Starting package
- Electrical package
- Lubricating oil system package
- Instrument air system
- Hydraulic oil system
- Gas fuel system
- Inlet air and exhaust gas systems
- Compressor water wash package
- Piping packages
- Cooling systems
- Fire protection
- Voltage transformer and surge cubicle.

Optional Equipment:

- Auxiliary transformer
- Isolated phase bus
- Evaporative cooling system
- Dual fuel combustion system
- Liquid fuel system
- Totally Enclosed Water-to-Air-Cooled (TEWAC) Generator
- Hydrogen-cooled generator
- Water injection package (supplied with liquid fuel system for NOx control).
Generator

The open air-cooled (OAC) Siemens Generator (SGen™) is equipped with a cooling air filter, silencers, inlet and exhaust ducting, brushless exciter, acoustical enclosure, and necessary instrumentation. The main three-phase terminals are located on top of the acoustical enclosure at the excitation end of the generator for isolated phase interface. Internal cooling is provided via shaft-mounted axial blowers, which direct filtered ambient air through the generator’s major internal components. A solid coupling connects the generator to the compressor at the cold end of the gas turbine.

Totally enclosed water-to-air-cooled (TEWAC) (as shown in Figure 5) or hydrogen-cooled generators are also options.

Generator cooling system

For open air-cooled generators, the cooling air is drawn into the generator through a pad type filter and a silencing section contained in the inlet duct. The cooling air is forced through the generator via shaft-mounted blower fans located on either end of the generator shaft. As the forced air passes through the generator’s major internal components, the heat is absorbed into the air and exhausted through the exhaust duct.

When selected, a TEWAC system provides a closed cooling air circuit. Cooling water is circulated through tube banks to exchange heat energy between the closed circuit generator cooling air and water. The internal active cooling paths, including the shaft-mounted blowers, are identical in both OAC and TEWAC designs. Cooling water is supplied by a fin-fan cooler or from a plant cooling water system.

Brushless excitation and voltage regulator system

The brushless exciter and voltage regulator system functions to supplies generator field excitation and controls the output of the AC generator terminal voltage. The brushless exciter has a shaft-mounted rotating armature and diode wheel. The voltage regulator supplies the stationary DC field to the brushless exciter, either under automatic or manual control. A static excitation system is an option.

Starting package

The base starting system is a modular package, with a fabricated steel bedplate and a steel enclosure for outdoor installation. The starting system includes an AC electric motor, a torque converter with charging pump, a turning gear, a turning gear motor, a clutch and associated instrumentation. The welded steel, all-weather enclosure (for outdoor application) is complete with access stairs, a door and a maintenance platform. Louvered openings on the enclosure provide natural ventilation.

An optional static starting system is available for simple cycle applications. The static start package includes a static frequency converter, a static excitation system, a two-speed turning gear (with a DC motor for slow spin and AC motor for acceleration to 120 rpm), a clutch and associated instrumentation. The static starting system is used when the fast start option, (150 MW in 10 minutes) is selected.

The starter package (whichever utilized) provides breakaway torque for initial rotation of the turbine generator, and the torque necessary for acceleration to self-sustaining speed. The starting system disengages once the unit reaches self-sustaining speed. During cool-down periods, the turning gear, a component of the starting package, provides for a slow roll of the combined turbine and generator rotor.
Auxiliary packages

Electrical package
The electrical package contains equipment necessary for sequencing, control and monitoring of the gas turbine and generator. This includes the gas turbine control system, motor control centers, generator protective relay panels, voltage regulator, fire protection system, battery and battery charger. The batteries are in an isolated section of the package and are readily accessible from the outside. Redundant HVAC units are provided in the electrical package to ensure a clean environment for the temperature sensitive electrical and control equipment.

Lubricating oil system package
The lube oil package is a factory manufactured weather-resistant skid for the lubricating oil system. The lubrication system provides clean, filtered oil at the required temperature and pressure for lubricating bearings of the gas turbine, generator and starting package. The lube oil package includes a lube oil reservoir, which provides a mounting base for the following lube oil system components:
- Main and alternate AC motor-driven pumps
- Emergency DC motor-driven pump
- Vapor extraction blowers
- Duplex filter assembly
- Accumulators.

The lube oil cooler assembly is located on top of the lube oil package roof. The lube oil system is supplied complete with interconnecting piping, valves and instrumentation.

Instrumentation air system
The turbine enclosure houses the compressed air reservoir and a pressure switch and gauge panel. The pressure switch and gauge panel contains all of the required pressure switches, gauges, regulating and safety valves, air filters and descanters. These components clean, dry, control, monitor and direct the instrument air to various valves and instruments. For combined cycle installations, the most efficient source of compressed air is typically the plant service air compressors. For simple cycle installation, an optional reciprocating air compressor can be provided.

Hydraulic oil system
A Hydraulic Oil Power Unit (HPU) is supplied when the engine is equipped with a DLN combustion system. The HPU provides high pressure hydraulic oil to operate the gas fuel stage throttle valve and the inlet guide vane actuators. The HPU is a self-contained unit mounted on a fabricated steel skid assembly and is located outdoors adjacent to the gas turbine enclosure and the mechanical package enclosure.

The major components are:
- Stainless steel fabricated oil reservoir
- AC motor-driven high pressure charge pumps; fully redundant (2 x 100%) mounted and driven by the high pressure pump motor spindle shaft
- Hydraulic oil cooler, radiator type fan
- Filter (100% redundant duplex) housings assembly
- Safety relief valves, pressure regulating valves
- Hydraulic accumulators
- Electric immersion heaters
- Instrumentation for local and remote monitoring of pressure and temperature
- Interconnect tubing assemblies (stainless steel).

Gas fuel system
The principal components of the gas fuel system are located inside the turbine enclosure. For the base unheated fuel design, the fuel filter/separators are installed outdoors adjacent to the gas turbine enclosure. The piping assemblies and valves are supplied as spool sections for field erection. The major components of the base fuel system include:
- Fuel filter/separators
- Fuel throttle valves for each fuel stage with associated instrumentation
- Overspeed trip and shut off valve(s)
Auxiliary packages

- Main pressure control valve and start pressure regulating valve
- Vent valve
- Fuel flow monitoring orifices with associated instrumentation.

Instrumentation to monitor the critical parameters is centralized and mounted on a fuel control panel located inside the turbine enclosure. Pressure gauges to locally monitor the fuel pressure are typically located on this panel. Field installed interconnecting piping assemblies that direct the fuel to the turbine-mounted fuel manifolds are supplied.

For the optional heated fuel design, an additional filter/separator for the pilot stage and a pilot overspeed trip/shut off valve are supplied. The pilot filter separator is also located outdoors adjacent to the turbine enclosure.

The heated fuel option is typically applied in combined cycle applications. The fuel is heated using a low energy water source thus utilizing energy to improve the net combined cycle efficiency.

**Liquid fuel system (optional)**

For liquid fuel applications (either dual or single fuel), a liquid fuel system is supplied. The liquid fuel system consists of factory-assembled components, including an AC motor-driven fuel pump, a suction side duplex fuel filter with transfer valve, and a control valve, installed on a bedplate. Interconnecting piping to this gas turbine is also included.

**Liquid fuel/water injection system (optional)**

When a liquid fuel system is required, a factory-assembled demineralized water injection skid is furnished. This water injection skid is assembled on a bedplate and includes an AC motor-driven injection pump with suction strainer, manifolds, control valves and instrumentation. When liquid fuel and water injection systems are required, an additional skid for the primary fuel and water scheduling components is provided and is located inside the turbine enclosure. In a typical liquid fuel installation, this skid contains liquid fuel flow dividers, liquid fuel control valves, water injection valves and a local instrument panel.

**Air inlet and exhaust gas systems**

Air that is drawn into the gas turbine is filtered via a two-stage pad filter. A self-cleaning pulse filter is also an available option. After passing through the filter, the inlet air duct guides the air into the compressor inlet manifold. This manifold is designed to provide a smooth flow pattern into the axial flow compressor. An inlet silencer provides sound attenuation. After passing through the combustor and turbine sections, combustion gas discharges axially through a transition section and into an exhaust stack for simple cycle applications.

In combined cycle applications, the exhaust transitions direct the exhaust gases into the HRSG before exiting the stack.

**Compressor water wash package**

The compressor water wash package is provided for both on-line and off-line compressor cleaning. This package incorporates an AC motor-driven pump, an eductor for detergent injection, piping, valves, orifices, interconnecting piping and a detergent storage tank assembled on a bedplate.

**Piping packages**

SGT6-PAC 5000F plant piping is designed and manufactured to minimize field work. Each of the major pipe modules is factory assembled to reduce field connections.

The turbine pipe package is located adjacent to the gas turbine and in the gas turbine enclosure. It contains valves and piping assemblies for the turbine cooling air system and the lube oil system. The turbine cooling bleed valve is also located within the turbine piping package.
Cooling systems

Lube oil cooler
An air-to-oil fin-fan lube oil cooler (water-to-oil cooler, optional) and the associated temperature control valve are mounted on top of the lube oil package roof. The temperature control valve maintains the lube oil temperature within the design range by controlling the flow of oil through the cooler.

Rotor air cooler
Rotor cooling air is extracted from the combustor shell, cooled by an external cooler, and introduced into the turbine section to be used for sealing purposes and to cool the appropriate rotating discs and rotating blades.

The rotor air cooler system supplied for simple cycle applications is an air-to-air fin-fan heat exchanger fitted with a variable speed motor-driven fan. The energy removed from the cooling air is released to the surrounding air.

For SCC6-PAC 5000F package or SCC6-5000F Turnkey combined cycle applications, the rotor air cooling system may include an air-to-water heat exchanger (kettle boiler) instead of a fin-fan cooler. With the kettle boiler, the energy removed from the cooling air is recovered and used to produce low-pressure steam. This steam is introduced into the steam circuit to improve the plant efficiency.

Fire protection system
The fire protection system gives a visual indication of actuation at the local control panel. There are two independent systems:

- An automatically actuated dry chemical system is provided for the exhaust bearing area of the turbine. The system consists of temperature sensing devices, spray nozzles, a dry chemical tank, interconnecting piping and wiring.
- The FM-200® fire suppressant system is provided for total flooding protection of the turbine enclosure and the electrical control package in accordance with the U.S. National Fire Protection Agency standards.
- The CO2-based fire suppressant system is also available as an option.

VT and surge cubicle
A Voltage Transformer (VT) and surge cubicle is provided as a separate unit for connection to an isolated phase bus. It contains two three-phase sets of voltage transformers and one set of surge arresters.

Auxiliary transformers (optional)
The optional auxiliary power transformer may be included as part of the SGT6-PAC 5000F bill of material.

Isolated phase bus (optional)
The optional isolated phase bus, located at the starting package end of the gas turbine unit, carries power from the generator terminals to the customer connection. The VT and surge cubicle connects to the bus assembly.

Auxiliary packages

Inlet air system
Generator enclosure
VT & surge cubicle
Excitation package
Starting package

Figure 6 - SGT6-PAC 5000F arrangement diagram

Figure 6 - SGT6-PAC 5000F simple cycle arrangement diagram depicts the location of the major components described above.
SGT6-PAC 5000F plant arrangement diagram

**Figure 7 - SGT6-PAC 5000F simple cycle plant general arrangement drawing**

**Key:**

1. Gas turbine (GT)
2. GT enclosure
3. Generator (OAC)
4. Generator air inlet filter
5. Turbine air inlet duct and silencer
6. Turbine air inlet filter
7. Fuel gas main filter/separator
8. FM-200® fire protection
9. Exhaust transition
10. Exhaust stack
11. Rotor air cooler (fin-fan)
12. Dry chemical cabinet
13. Water injection pump skid
14. Fuel oil pump skid
15. Hydraulic supply skid
16. Lube oil package
17. Lube oil cooler (fin-fan)
18. Electrical package
19. Compressor wash skid
20. Starting package
21. Brushless excitation
22. VT & surge cubicle
23. Isolated phase bus duct (by others)

**Comment:** Items 13 and 14 only required with Dual Fuel.

**Notes:** The equipment shown is representative information. This design is subject to change at the discretion of Siemens. All dimensions shown are in feet and inches (metric).
SGT6-PAC 5000F simple cycle performance

Following is the net reference performance for the SGT6-PAC 5000F power plant.

**Conditions:** Natural gas or liquid fuel meeting Siemens’ fuel specifications. Elevation: sea level; 14.696 psia barometric pressure, 60% relative humidity, 59 °F (15 °C) inlet air temperature, 3.4 in. water (87 mm water) inlet loss, 5 in. water (127 mm water) exhaust loss, air-cooled generator and .90 power factor (pf).

<table>
<thead>
<tr>
<th>Combustor type</th>
<th>DLN Dry</th>
<th>Conventional Water injection</th>
<th>Conventional Steam injection</th>
<th>DLN* Steam augmentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel</td>
<td>Natural gas</td>
<td>Natural gas</td>
<td>Natural gas</td>
<td>Natural gas</td>
</tr>
<tr>
<td>Net power output (kW)</td>
<td>196,000</td>
<td>207,790</td>
<td>215,650</td>
<td>219,400</td>
</tr>
<tr>
<td>Net heat rate (Btu/kWh) (LHV)</td>
<td>9,059</td>
<td>9,442</td>
<td>8,736</td>
<td>8,846</td>
</tr>
<tr>
<td>Exhaust temperature (°F/°C)</td>
<td>1,079/582</td>
<td>1,052/567</td>
<td>1,072/578</td>
<td>1,092/589</td>
</tr>
<tr>
<td>Exhaust flow (lb/hr)</td>
<td>3,988,800</td>
<td>4,105,581</td>
<td>4,123,828</td>
<td>4,120,363</td>
</tr>
<tr>
<td>Exhaust flow (kg/hr)</td>
<td>1,809,308</td>
<td>1,862,279</td>
<td>1,870,556</td>
<td>1,868,984</td>
</tr>
<tr>
<td>Fuel flow (lb/hr)</td>
<td>82,542</td>
<td>91,205</td>
<td>87,579</td>
<td>90,272</td>
</tr>
<tr>
<td>Fuel flow (kg/hr)</td>
<td>37,441</td>
<td>41,370</td>
<td>39,726</td>
<td>40,947</td>
</tr>
</tbody>
</table>

* Steam injected through the combustor section casing into the compressor discharge air to increase output.

** Steam augmentation with liquid fuel available on a case-by-case basis.

**Correction curves**

To estimate thermal performance of the SGT6-PAC 5000F plant at conditions other than those noted above, the following correction curves are provided:

- Correction for compressor inlet temperature (Figure 8)
- Correction for excess exhaust pressure loss (Figure 9)
- Correction for excess inlet pressure loss (Figure 10)
- Correction for barometric pressure* (Figure 11)

*Barometric pressure (BP) can be calculated from the site elevation (ELE) using: BP = 7.08601 E-09 x ELE - 5.29221 E-04 x ELE + 14.696
Correction curves

To estimate thermal performance of the SGT6-PAC 5000F at conditions other than those noted, the following correction curves may be used:

**Figure 8 - SGT6-PAC 5000F simple cycle turbin plant corrections for variations in compressor inlet temperature deviation**

**Figure 9 - SGT6-PAC 5000F simple cycle turbin plant corrections for variations in exhaust stack temperature deviation**

**Figure 10 - SGT6-PAC 5000F simple cycle turbin plant corrections for variations in exhaust inel pressure loss**

**Figure 11 - SGT6-PAC 5000F simple cycle turbin plant corrections for variations in barometric pressure deviation**
SGT6-PAC 5000F technical data

SGT6-5000F gas turbine

<table>
<thead>
<tr>
<th>Type</th>
<th>Axial flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of stages</td>
<td>16</td>
</tr>
<tr>
<td>Rotor speed</td>
<td>3600 rpm</td>
</tr>
<tr>
<td>Pressure ratio</td>
<td>17:1</td>
</tr>
<tr>
<td>Inlet guide vanes</td>
<td>Variable</td>
</tr>
</tbody>
</table>

Combustion system

<table>
<thead>
<tr>
<th>Type</th>
<th>Dry Low NOx</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration</td>
<td>Can-annular</td>
</tr>
<tr>
<td>Fuel</td>
<td>Gas fuel only</td>
</tr>
<tr>
<td>Number of stages</td>
<td>16</td>
</tr>
<tr>
<td>Fuels</td>
<td></td>
</tr>
<tr>
<td>Natural gas pressure range</td>
<td>475 to 500 psig - Nominal @ gas turbine inlet separator inlet flange</td>
</tr>
<tr>
<td>Liquid fuel (option)</td>
<td>50 to 90 psig @ fuel oil skid interface flange (Demineralized water injection required)</td>
</tr>
</tbody>
</table>

Turbine

| Number of stages | 4         |
| Number of cooled stages | 3       |

Bearings

<table>
<thead>
<tr>
<th>Journal bearing</th>
<th>Titting pad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quantity</td>
<td>2</td>
</tr>
<tr>
<td>Thrust bearing</td>
<td>Drive end</td>
</tr>
<tr>
<td>Type</td>
<td>Titting pad</td>
</tr>
<tr>
<td>Number</td>
<td>1</td>
</tr>
<tr>
<td>Drive</td>
<td>Cold end, direct coupled</td>
</tr>
</tbody>
</table>

Generator

<table>
<thead>
<tr>
<th>Type</th>
<th>ANSI/IEC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard</td>
<td>Base</td>
</tr>
<tr>
<td>Type</td>
<td>Open air-cooled (OAC)</td>
</tr>
<tr>
<td>- Option</td>
<td>Total enclosed water-to-air-cooled</td>
</tr>
<tr>
<td>- Hydrogen-cooled</td>
<td></td>
</tr>
<tr>
<td>Excitation</td>
<td>Base</td>
</tr>
<tr>
<td>- Option</td>
<td>Static</td>
</tr>
<tr>
<td>Nameplate rating</td>
<td>MVA 249 MVA</td>
</tr>
<tr>
<td>Power factor</td>
<td>0.90</td>
</tr>
<tr>
<td>Voltage</td>
<td>15 kV</td>
</tr>
<tr>
<td>Current</td>
<td>8200 A</td>
</tr>
<tr>
<td>Frequency</td>
<td>60 Hz</td>
</tr>
<tr>
<td>Speed</td>
<td>3600 RPM</td>
</tr>
<tr>
<td>Field current</td>
<td>1544 A</td>
</tr>
<tr>
<td>Field voltage</td>
<td>270 V</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>59°F / 15°C</td>
</tr>
<tr>
<td>Cold gas temperature</td>
<td>32°C</td>
</tr>
<tr>
<td>Insulation class</td>
<td>Class F</td>
</tr>
<tr>
<td>Operation class</td>
<td>Class F</td>
</tr>
<tr>
<td>Short circuit ratio</td>
<td>0.45</td>
</tr>
<tr>
<td>Direct axis impedance</td>
<td>Saturated X' = 2.13 per unit X&quot; = 0.26 per unit X&quot;&quot; = 0.19 per unit</td>
</tr>
</tbody>
</table>

Starting system

<table>
<thead>
<tr>
<th>Electric motor started</th>
<th>AC Motor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Starting time to base load</td>
<td>30 min (base)</td>
</tr>
<tr>
<td>Turning gear</td>
<td>DC Drive</td>
</tr>
</tbody>
</table>

Recommended inspection intervals

<table>
<thead>
<tr>
<th>Inspection type</th>
<th>Hours</th>
<th>Starts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas turbine</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Combustor</td>
<td>8,333</td>
<td>450</td>
</tr>
<tr>
<td>Hot gas path</td>
<td>25,000</td>
<td>900</td>
</tr>
<tr>
<td>Major overhaul</td>
<td>50,000</td>
<td>1,800</td>
</tr>
</tbody>
</table>

* A fast-start option is available to provide 150 MW in 10 minutes.

SGT6-PAC 5000F plant weights and dimensions

Shown below is a typical list of the major pieces of equipment along with their approximate shipping weights and nominal dimensions.

<table>
<thead>
<tr>
<th>Item</th>
<th>Weight</th>
<th>Length</th>
<th>Width</th>
<th>Height</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas turbine</td>
<td>462,000 lbs</td>
<td>33 ft 0 in</td>
<td>13 ft 0 in</td>
<td>15 ft 0 in</td>
<td></td>
</tr>
<tr>
<td>Electric motor starting package</td>
<td>36,500 lbs</td>
<td>22 ft 6 in</td>
<td>11 ft 6 in</td>
<td>16 ft 3 in</td>
<td></td>
</tr>
<tr>
<td>Electrical package</td>
<td>33,000 lbs</td>
<td>32 ft 0 in</td>
<td>12 ft 6 in</td>
<td>11 ft 3 in</td>
<td></td>
</tr>
<tr>
<td>Lube oil package</td>
<td>60,000 lbs</td>
<td>25 ft 0 in</td>
<td>12 ft 0 in</td>
<td>12 ft 0 in</td>
<td></td>
</tr>
<tr>
<td>Lube oil cooler (fin-fan)</td>
<td>29,000 lbs</td>
<td>25 ft 0 in</td>
<td>12 ft 0 in</td>
<td>13 ft 8 in</td>
<td>with support structure</td>
</tr>
<tr>
<td>Lube oil cooler (duplex plate)</td>
<td>16,000 lbs</td>
<td>13 ft 6 in</td>
<td>11 ft 10 in</td>
<td>7 ft 1 in</td>
<td>with support structure</td>
</tr>
<tr>
<td>Turbine piping package</td>
<td>35,800 lbs</td>
<td>40 ft 0 in</td>
<td>10 ft 10 in</td>
<td>11 ft 11 in</td>
<td></td>
</tr>
<tr>
<td>Rotor air cooler (fin-fan)</td>
<td>27,000 lbs</td>
<td>22 ft 0 in</td>
<td>13 ft 6 in</td>
<td>12 ft 0 in</td>
<td></td>
</tr>
<tr>
<td>Generator Aeropac ll</td>
<td>550,000 lbs</td>
<td>47 ft 0 in</td>
<td>13 ft 0 in</td>
<td>14 ft 9 in</td>
<td>acoustic / weather enclosure; ships separately</td>
</tr>
</tbody>
</table>

Heaviest piece lifted

<table>
<thead>
<tr>
<th>Weight</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Air cooled generator</td>
<td>550,000 lbs</td>
</tr>
<tr>
<td>Bladed gas turbine rotor</td>
<td>110,000 lbs</td>
</tr>
</tbody>
</table>
SCC6-5000F combined cycle plants

General description

Combined cycle plants can be made up of various combinations of gas turbines, HRSGs and steam turbines. The scope of supply can be a SGT6-PAC 5000F package, SCC6-PAC 5000F power island or SCC6-5000F turnkey plant.

A typical 2x1 combined cycle power plant consists of two SGT6-5000F gas turbines each with a dedicated HRSG that supplies steam to a shared steam turbine. The gas turbines will primarily burn natural gas with optional provisions to burn liquid fuel as a backup. Each gas turbine will be coupled with a three-pressure reheat HRSG, which will generate steam to operate the steam turbine. Generators attached to the two gas turbines and the steam turbine will supply electrical power to the grid.

Major equipment

A typical 2x1 turnkey combined cycle plant consists of the following major equipment:

- Two SGT6-5000F gas turbines with air-cooled generators
- Two three-pressure level reheat HRSGs with stacks (fired as an option)
- One multi-cylinder reheat condensing steam turbine with air-cooled generator
- One water-cooled condenser using a forced-draft cooling tower
- One integrated plant distribution control system
- Balance of plant (BOP) equipment consisting of pumps, transformers, power electrics, etc.
- HV switchyard.

Major equipment descriptions

Gas turbine

The SGT6-5000F gas turbine as outlined in the general description can be applied in a combined cycle application.

Heat recovery steam generator

The three-pressure, reheat HRSGs produce steam, which drives the steam turbine. The exhaust gas flows horizontally through the HRSGs releasing heat through the finned tubes to the water/steam cycle.

Depending on specific project requirements, the HRSG can be either a drum-type or a once-through design.

The sections of the drum-type HRSG contain economizer tube bundles, evaporator tube bundles with associated steam drums, and a superheater tube bundle. Feedwater is pumped through the economizer sections for optimized performance.

The once-through, BENSON® technology HRSG has an advanced superheater outlet design to enhance fast start capability, making the plant better suited for operating regimes between intermediate and continuous duty. The feedwater is passed through a condensate polishing system and pumped through the sections of the boiler.

Either HRSG design can be supplied with provisions for SCR and/or CO catalyst.
Steam turbine
The steam generated in the HRSG is supplied to a two-cylinder, reheat, condensing steam turbine with high efficiency blading. Depending on the back pressure or the amount of HRSG supplemental firing, the steam turbine is optimized as either a single-flow axial exhaust condensing type, a dual-flow side or a down exhaust condensing type.

The single-flow turbine consists of a single-flow HP turbine element and a combined IP/LP element. The dual-flow turbine consists of a combined HP/IP turbine element and a double flow LP turbine element.

Main steam is supplied directly to the HP turbine inlet valves. Hot reheat and IP induction steam enters through the IP turbine inlet valves. In the dual-flow steam turbine, LP induction steam enters the steam path through a port normally located in the crossover pipe. In the single-flow steam turbine, LP steam enters the steam path through an induction port appropriately located in the turbine blade path. Upon exiting the LP turbine, steam exhausts into a water-cooled or air-cooled condenser.

100% steam turbine bypass system
The condenser is designed to accommodate the exhaust from the steam turbine plus the miscellaneous drains from the steam system. The condenser is also designed to allow 100% steam bypass of the steam turbine.

Condensate pumps
Condensate is pumped from the condenser hotwell by 2x50% condensate pumps (one full capacity pump for each HRSG). The condensate then passes through the low temperature economizer section in the HRSG prior to entering the LP steam drum and boiler feedpump section. For redundancy, an optional 3x50% arrangement is available.

Boiler feedwater pump island
A boiler feedwater pump island concept is employed using 2x50% pumps (one full capacity pump for each HRSG) headered together. These pumps supply feedwater to the HP and LP boiler sections of the HRSGs. The pumps are electric motor-driven and are located adjacent to the HRSG nearest the steam turbine. The pumps take suction from the condensate pump discharge after the low temperature economizer raises the pressure to the appropriate level to supply the feedwater to the boiler section(s).

Cooling system
A typical combined cycle plant incorporates a water-cooled condenser using a forced-draft wet cooling tower. Additional arrangements include a condenser with once-through cooling, air-cooling or a hybrid cooling tower.
SCC6-5000F combined cycle plants

Control, protection and monitoring

Control, protection and monitoring functions for the SGT6-5000F gas turbine-based power plant are performed by the Siemens Power Plant Automation (SPPA™) system known as the SPPA-3000. This microprocessor-based distributed control system located within the electrical package has the flexibility to accommodate a wide range of plant configurations and interface options.

Although the SGT6-PAC 5000F power plant control system is provided specifically for the gas turbine-generator unit and its direct auxiliaries, it is expandable to accommodate additional control system automation processors and cabinets of the same manufacturer on the network, in the central control room or other locations.

Balance of Plant (BOP) functions may include thermal equipment, circulating water loops, switchyard monitoring and SCADA interface for a complete combined cycle plant.

Supplemental HRSG firing (option)

Supplemental HRSG firing (duct firing) is available as an option to increase the plant output by introducing additional heat energy into the gas turbine exhaust stream. By adding burners strategically located in the HRSG, plant output can be increased by over 6% with moderate duct firing and over 20% with heavy duct firing.

Site layout and arrangement of equipment

Using a modular approach, the Siemens Reference Power Plant (RPP) can readily be configured to satisfy a number of site or customer specific requirements.

Figure 12 - SCC6-5000F 2x1 combined cycle plant general arrangement drawing (as shown on page 26) illustrates the base design configuration for a single fuel (natural gas only), outdoor arrangement with a cooling tower.

BOP equipment will be provided in accordance with Siemens RPP designs as modified to suit site-specific requirements. Pre-engineered options are available to address customer requirements.

The overall site and building arrangements were developed to optimize space requirements while maintaining ample access for operation and maintenance activities.

The gas turbine-generators, steam turbine-generator, condenser and associated auxiliaries are normally located outdoors but can also be placed in a building as an option. The HRSG and associated auxiliary equipment are located outdoors.

Figure 13 - SCC6-5000F 1x1 combined cycle plant general arrangement drawing (as shown on page 27) illustrates the base design configuration for a single fuel (natural gas only), outdoor arrangement with a cooling tower.
SCC6-5000F plant arrangement diagrams

Figure 12 - SCC6-5000F 2x1 combined cycle general arrangement drawing

Key:

1. SGT6-5000F Gas Turbine (GT) enclosure
2. GT generator (TEWAC – below inlet filter)
3. GT air inlet filter
4. Fuel gas filter/separator
5. Rotor air cooler (kettle boiler type)
6. Heat Recovery Steam Generator (HRSG)
7. Fuel gas preheater
8. Power control center
9. Generator breaker
10. Auxiliary transformer
11. GT generator transformer
12. Boiler feedwater pumps
13. Steam turbine
14. Surface condenser
15. ST generator (TEWAC)
16. Vacuum pumps
17. Main condensate pumps
18. Gland steam skid
19. Lube oil skid
20. Isolated phase bus duct
21. ST generator transformer
22. Cooling water pipe
23. Cooling tower
24. Cooling tower pump
25. Demineralized water storage tank
26. Compressed air system
27. Control room building
28. Roads
29. Generation building (option)
30. Bridge crane (option with generation building)

Notes: The equipment shown is representative information. This design is subject to change at the discretion of Siemens. All dimensions shown are in feet and inches (metric). Cooling tower location to be determined by prevailing winds.
Figure 13 - SCC6-5000F 1x1 combined cycle plant general arrangement drawing

Key:
1. SGT6-5000F Gas Turbine (GT) enclosure
2. GT generator (TEWAC)
3. GT air inlet filter
4. Fuel gas filter/separator
5. Rotor air cooler (kettle boiler type)
6. Heat Recovery Steam Generator (HRSG)
7. Fuel gas preheater
8. Power control center
9. Generator breaker
10. Auxiliary transformer
11. GT generator transformer
12. Boiler feedwater pumps
13. Steam turbine
14. Surface condenser
15. ST generator (TEWAC)
16. Vacuum pumps
17. Main condensate pumps
18. Lube oil skid
19. Isolated phase bus duct
20. ST generator transformer
21. Cooling water pipe
22. Cooling tower
23. Cooling water skid
24. Gland steam skid
25. Demineralized water storage tank
26. Compressed air system
27. Control room building
28. Roads
29. Generation building (option)
30. Bridge crane (option with generation building)

Notes:
The equipment shown is representative information. This design is subject to change at the discretion of Siemens. All dimensions shown are in feet and inches (metric). Cooling tower location to be determined by prevailing winds.
Combined cycle performance

The performance of combined cycle power plants varies with the site conditions, the equipment selected, and the thermal cycle design. For the SGT6-5000F gas turbine based combined cycle turnkey plant, the components and the cycle have been selected to provide increased performance.

With a turnkey plant scope, we control the design and supply of critical components, thus providing the customer with a single point of contact for performance related issues. Turnkey combined cycle performance is shown in the table below.

Figures 14 through 19 provide factors to estimate the performance for different compressor inlet air temperatures and barometric pressures. Figure 20 (as shown on page 30) is a typical cycle diagram for 2x1 combined cycle configuration.

Options are available to increase the plant output on hot days. An inlet air evaporator cooler and/or supplemental HRSG firing can be added to increase the plant output. The combined cycle 2x1 base and output performance (as shown on page 30) shows the typical base plant and typical performance enhanced plant data (including evaporative cooler and supplemental firing options).

### Typical SCC6-5000F turnkey combined cycle plant performance

<table>
<thead>
<tr>
<th>Plant designation</th>
<th>Cooling configuration</th>
<th>SCC6-5000F 2x1 turnkey</th>
<th>SCC6-5000F 1x1 turnkey</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cooling configuration</td>
<td>Cooling tower</td>
<td>593.0</td>
<td>294.9</td>
</tr>
<tr>
<td>Net power (MW)</td>
<td>Once through</td>
<td>594.8</td>
<td>295.9</td>
</tr>
<tr>
<td>Net heat rate (Btu/kWh)</td>
<td>Air-cooled</td>
<td>587.6</td>
<td>292.2</td>
</tr>
<tr>
<td>Steam turbine back pressure in. Hg</td>
<td>1.58</td>
<td>1.00</td>
<td>2.48</td>
</tr>
<tr>
<td>Conditions:</td>
<td>Elevation: sea level;</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>compressor inlet temp.: 59°F, inlet and exhaust losses and auxiliary loads includes for net power.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Correction curves

- Figure 14: SCC6-5000F turnkey 2x1 and 1x1 power plant correction is output and heat rate (cooling tower cooling system)
- Figure 15: SCC6-5000F turnkey 2x1 and 1x1 power plant correction is output and heat rate (once through cooling system)
SCC6-5000F plant performance

Correction curves

**Figure 14 - SCC6-5000F turnkey 2x1 and 1x1 power plant correction to output and heat rate (forced-condenser cooling system)**

**Figure 17 - SCC6-5000F turnkey 2x1 and 1x1 power plant correction to output and heat rate (forced-condenser cooling system)**

**Figure 18 - SCC6-5000F turnkey 2x1 and 1x1 power plant correction to output and heat rate (cooling tower system)**

**Figure 19 - SCC6-5000F turnkey 2x1 and 1x1 power plant correction to output and heat rate (forced-condenser cooling system)**
Combined cycle 2x1 base and output enhanced performance

<table>
<thead>
<tr>
<th>Operating conditions</th>
<th>Base plant</th>
<th>Plant with performance options</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporator cooler</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Supplemental firing</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Ambient temperature (°F/°C)</td>
<td>59/15</td>
<td>105°F</td>
</tr>
<tr>
<td>Relative humidity (%)</td>
<td>60</td>
<td>35</td>
</tr>
<tr>
<td>Barometric pressure (psia/bar)</td>
<td>14.69/1.033</td>
<td>14.69/1.033</td>
</tr>
<tr>
<td>Fuel</td>
<td>Natural gas</td>
<td>Natural gas</td>
</tr>
<tr>
<td>Fuel heating value (LHV)</td>
<td>21511 Btu/lb</td>
<td>20980 Btu/lb</td>
</tr>
<tr>
<td>Fuel heating value (LHV)</td>
<td>50034 kJ/kg</td>
<td>48800 kJ/kg</td>
</tr>
<tr>
<td>Fuel HHV/LHV ratio</td>
<td>1.1</td>
<td>1.1</td>
</tr>
<tr>
<td>Generator power factor</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>ST backpressure (in.-HgA/mbar)</td>
<td>1.5/50</td>
<td>3.19/108</td>
</tr>
<tr>
<td>ST throttle pressure (psia/bar)</td>
<td>1817/125</td>
<td>2277/157</td>
</tr>
<tr>
<td>ST throttle temperature (°F/°C)</td>
<td>1050/565</td>
<td>1050/565</td>
</tr>
<tr>
<td>ST reheat pressure (psia/bar)</td>
<td>351/24</td>
<td>442/30</td>
</tr>
<tr>
<td>ST reheat temperature (°F/°C)</td>
<td>1050/565</td>
<td>1050/565</td>
</tr>
<tr>
<td>Gross plant output (MW)</td>
<td>598 (1)</td>
<td>592.9 (2)</td>
</tr>
<tr>
<td>Net plant output (MW)</td>
<td>590 (1)</td>
<td>580.1 (2)</td>
</tr>
<tr>
<td>Net plant heat rate (Btu/kWh)</td>
<td>5960 (1)</td>
<td>6227 (2)</td>
</tr>
<tr>
<td>Net plant efficiency (%)</td>
<td>57.2 (1)</td>
<td>54.8 (2)</td>
</tr>
</tbody>
</table>

(1) based on once through cooling  (2) based on cooling tower

Figure 20 - Cycle diagram with drum-type boiler
The reliable SGT6-5000F gas turbine technology can be used in low-Btu fuel (syngas) applications, such as Integrated Gasification Combined Cycle (IGCC) and Bitumen upgrader projects where syngas fuel is available.

The SGT6-5000F gas turbine has been analyzed for operation in syngas applications. Few changes are needed when compared to a natural gas fueled gas turbine. The major change is to a dual fuel (syngas and natural gas) combustion system specifically designed for IGCC and other syngas applications. Other changes include the addition of a fuel mixing skid, local N₂ storage for purging the fuel system during start up and shut down, control system changes, and additional monitoring systems needed due to the high H₂ and CO fuel.

The modified combustion system was designed to operate on either syngas or natural gas or both. The syngas capable design is a diffusion combustor derived from the proven DF42 combustion system utilized on natural gas and distillate oil fueled SGT6-5000F engines and on syngas/natural gas in two W501D5 gas turbines at the LGTI IGCC project from 1987 to 1995. The fuel nozzle is designed to accommodate multi-fuel operation, diluent injection, fuel transfers and cofiring. The gas turbine combustor cover plates are modified for syngas operation.

Syngas is the primary fuel for IGCC applications. Natural gas is used for start up and as a backup fuel. During the start up process at 30% load, the gas turbine is transitioned to syngas and taken to base load. The principal components of the syngas system are located outside the turbine enclosure.

After the syngas flows through the syngas saturator and heater in the BOP piping, it is blended with N₂ (as a diluent) at the blending station and supplied to the inlet of the syngas strainer. Exiting the syngas strainer, the syngas is routed through similar components as the natural gas system including the overspeed trip, throttle, and isolation valves and into the syngas manifold.

Based on the proven SCC6-5000F 2x1 combined cycle plant, a nominal 600 MW IGCC power island design has been developed (as shown in Figure 21). This includes a steam bottoming cycle that is fully integrated with the gasification island and a larger steam turbine to maximize plant output.

In addition to the power island Siemens equipment scope of supply may include most of the major compression solutions for today’s IGCC plants, including air separation units, main air compressors and O₂, N₂ and CO₂ compression solutions. Depending on the needs of the IGCC project, Siemens can participate in a broader role in the project up to and including supplying the total plant as a member of an EPC Consortium.

The SPPA-T3000 control system normally supplied with a SCC6-5000F 2x1 combined cycle plant can be expanded to control the entire IGCC plant, including the gasification island(s), gas clean-up systems and the air separation unit(s).