Siemens Combined Cycle Reference Power Plant SCC5-4000F 1S

400 MW-Class 50 Hz

Answers for energy.
Siemens SCC5-4000F 1S – The next step in advanced single-shaft plant technology

The Siemens Combined Cycle (SCC™) single-shaft reference power plant has evolved over the years to be the plant of choice for combined cycle power plants in the 400 MW-class in the 50 Hz world. The first single-shaft plant with a Siemens F-class gas turbine was built in 1997. Currently, there are more than 40 Siemens single-shaft plants in service or under construction/commissioning throughout the world.

The primary focus of our Reference Power Plant (RPP) program is to develop plant designs that offer high customer benefit through low life-cycle costs. Furthermore, the modular concept used in the RPP program allows easy adaptation to specific customer needs and site requirements.

The combination of world-class gas and steam turbine and generator technologies with trend setting power plant system integration results in a highly efficient plant that provides reliable low-cost electricity.

The base design of the SCC5-4000F 1S RPP provides an optimum balance between capital cost, plant performance, as well as operational and maintenance considerations.

Pre-engineered modular options have been developed to further address individual needs. Plant exhaust emissions are minimized by the proven Siemens dry low NOx Hybrid Burner Ring (HBR) combustion system.

The SCC5-4000F 1S RPP is designed around advanced, well-proven and reliable Siemens equipment, including:

- One Siemens Gas Turbine (SGT™) SGT5-4000F
- One Siemens Steam Turbine (SST™) SST5-3000 or SST5-5000 (depending on ambient conditions)
- One Siemens hydrogen-cooled Generator (SGen™) SGen5-2000H
- The Siemens Power Plant Automation system (SPPA™)

All three main components are arranged on a single shaft. A Synchronous Self-Shifting (SSS) clutch is installed between the generator and steam turbine. This provides high operating flexibility and reliability.
Logical evolution in RPP development

The requirements for power plants dramatically changed with the advent of deregulated and liberalized markets. Economic factors, such as life-cycle costs, net present value and internal rate of return became the customer’s focus. In response, Siemens launched its Reference Power Plant development program in the 1990s with special emphasis on life-cycle cost optimization.

The main focus of the Siemens single-shaft RPP development is a core base design called the Power Block. This comprises the complete turbine building including all associated equipment therein, the complete water/steam cycle including the Heat Recovery Steam Generator (HRSG), and additional adjacent components and systems such as the electrical transformers and the Power Control Centers (PCCs).

The RPP development starts with customer requirements and includes feedback from project execution and operation and maintenance experiences.

During the development, modern design methods including Quality Function Deployment, FMEA and Six Sigma are used.

Site specific requirements, such as water supply systems mainly influence the scope outside the Power Block and can easily be adapted. Economic modeling of design variants inside the Power Block, such as redundancy of feedwater and condensate pumps result in a base design that is optimized from the customer’s point of view.

By optimizing the core of the plant, i.e. the Power Block, only a limited number of variants and options are required. This results in a large number of plants with an identical design of the Power Block. This replication in turn allows Siemens to select the suppliers of all of the major components, thereby allowing the use of proven equipment and proven suppliers.

This Siemens RPP approach offers significant advantages for the customer, including:

- Low initial investment
- Reduced lead time
- Higher availability and reliability
- Increased quality and lower risk
Two main variants are available for the SCC5-4000F 1S reference power plant. These are characterized by the implementation of two different steam turbines:

- The SST5-3000 incorporates a single-flow axial exhaust low-pressure steam turbine providing best economical benefit at medium to high condenser back pressure. The typical application for the SST5-3000 is in combination with a wet cooling tower at ambient temperatures above 12°C (54°F) or with an air-cooled condenser.

- The SST5-5000 incorporates a two-flow low-pressure steam turbine with increased exhaust area, which makes it the choice for low condenser back pressure. The typical application for the SST5-5000 is in combination with once-through cooling or a wet cell cooling tower at ambient temperatures below 12°C (54°F).

Application of either of the two depends not only on specific cooling conditions, but also on the economic evaluation of efficiency and power output.

Both designs incorporate a carefully selected number of pre-engineered options. This allows flexibility to adapt the SCC5-4000F 1S to specific customer requirements and site conditions.

Examples of options include fuel oil as a back-up fuel, different cold end variants (cooling tower, once-through cooling, or air-cooled condenser), a drum-type or BENSON® Once-Through HRSG, etc.

Our flexible scope of supply ranges from a Power Train, Power Island, Power Block to a complete Turnkey Plant.
Scope of supply

**SCC Power Train**
- SGT-PAC
  - SST-PAC w/o condenser
  - Steam turbine incl. auxiliaries w/o piping
  - Generator incl. auxiliaries
  - SSS Clutch
  - ST electrical and I&C
  - Options

**SCC Power Island**
- HRSG
- Condenser incl. air removal system
- Boiler feed pumps
- Condensate pumps
- Critical valves
- Fuel pre-heater with filter, metering station etc.
- Power Island controls
- Options

**SCC Power Block**
- Detailed design of turbine building, foundation and structures
- HVAC inside Power Block area
- Cranes inside turbine building
- Water/steam cycle
- Cooling water system with wet cooling tower and circulating water pumps
- Service- and closed cooling water system
- Electrical equipment
- Power Block controls
- Fire fighting inside Power Block
- Options

**SCC Turnkey**
- Additional fuel supply systems and cooling systems
- Water treatment
- Raw water system
- Waste water system
- Tanks
- Additional
  - Buildings/structures
  - Cranes/hoists
  - Fire protection/fighting
  - Plant piping/valves
  - Electrical plant
- Erection/Commissioning
- Further options

**Power Train equipment**
- Performance/Delivery

**System integration/ Optimized operability**

**Replication of standardized components**

**Total EPC plant wrap**
The main building is a compact structural-steel building of rectangular design and houses the gas turbine, generator and steam turbine along with their associated components.

The main gas turbine auxiliaries are arranged on a steel platform along side the gas turbine. The common lube oil system for gas turbine, generator and steam turbine is arranged at ground floor level.

All generator auxiliaries are directly arranged next to the generator either on the main steel platform or on the ground floor.

The auxiliary components for the water/steam cycle and the closed cooling water system are located in an annex to the turbine building. The air-intake filter house is located above the annex at the side of the main bay of the turbine building. The filtered air is led straight into the gas turbine compressor by way of an aerodynamically optimized oblique steel-fabricated duct, in which a silencer is installed.

Access to the building is provided via the entrance bay next to the turbine-generator set. Adequate access for inspection and maintenance is provided for all main and auxiliary equipment.

An overhead traveling crane runs the full length of the turbine building and is capable to lift all the heavy equipment in the building including the generator. Special attention has been given to provide short moving distances and adequate dismantling and laydown areas for major maintenance operations, as well as good accessibility to buildings and components for maintenance.

The HRSG as well as the annexed feed-water pumps are designed for outdoor installation.

The pre-fabricated and pre-tested Power Control Centers (PCCs) for electrical and I&C equipment are located outdoors close to the turbine buildings to ensure short connection runs.

The central control room and administration building are arranged close to the turbine building. Layout provisions are made in the plant for a workshop and storage building.

A forced-draft cooling tower is arranged behind the turbine building with the circulating water pump also in outdoor installation. In case of once-through cooling, the water intake and outfall structure is designed according to site requirements.

Site terminal points
The SCC5-4000F 1S base design incorporates the following terminal point assumptions:

- Natural gas fuel supply at required conditions at the site boundary
- Raw, fire fighting and potable water from municipal supply at required conditions at site boundary
- Demineralized water tank hook up
- Effluent discharge to municipal connection at site boundary
- Electrical termination at high-voltage bushing of the generator step-up transformer
Plant arrangement

Plot plan SCC5-4000F single-shaft with oil tank and cooling tower
Advanced turbine-generator technology

**Single-shaft power train**
The gas turbine, generator and steam turbine are arranged on a single-shaft basis. The steam turbine is coupled with a SSS clutch to the generator. This design shows various advantages over 1x1 multi-shaft arrangements including:

- Smaller footprint due to a more compact arrangement
- Higher efficiency (one hydrogen-cooled generator instead of two air-cooled generators)
- Higher availability due to less components

**SGT5-4000F gas turbine**
Since its introduction in the mid-1990s, the SGT5-4000F has become the workhorse of the 50 Hz fleet. Reliable and efficient, it is the most advanced proven gas turbine in its class today.

Features/benefits of the SGT5-4000F are as follows:

- Four-stage turbine for moderate stage loading
- Disk-type rotor with Hirth serrations and central tie bolt for rotor stability
- Low NOx Hybrid Burner Ring (HBR) combustion system for reduced environmental impacts
- Dual fuel capability (on-line transfer)
- Variable inlet guide vanes for improved part-load efficiency
- All blades removable with rotor in place for easy maintenance and shorter outages
- Unique design features for field serviceability
SST5-3000 steam turbine
The SST5-3000 steam turbine comprises a single-flow barrel-type high-pressure turbine and a combined intermediate- and low-pressure turbine element with single-flow axial exhaust. This turbine is mainly applied for wet cooling tower or air-cooled condenser operation.

SST5-5000 steam turbine
The SST5-5000 steam turbine comprises a combined high- and intermediate-pressure turbine element and a two-flow low-pressure turbine with a single-side exhaust. The larger exhaust area provided with this low pressure steam turbine enables better performance at sites with access to cold cooling water.

SGen5-2000H generator
The SGen5-2000H is a hydrogen-cooled two-pole generator. This well-proven generator design provides high efficiency and low operation and maintenance costs. It is shipped to the site pre-assembled to facilitate ease of construction.

SSS clutch
A Synchronous Self-Shifting (SSS) clutch is located between the generator and the steam turbine. This allows individual gas turbine start-up without the need for cooling the steam turbine. Once the steam parameters match the requirements of the turbine, the steam turbine turns and synchronizes automatically with the generator. The SSS clutch has been used successfully since 1995 in numerous Siemens single shaft power plants.
Plant design base and performance data

**Water/steam cycle and cooling system**

To provide high efficiency a triple-pressure reheat cycle is used. The plant design includes options for both a drum-type and a BENSON® Once-Through HRSG.

The BENSON® HRSG, designed and patented by Siemens, provides greatly improved operating flexibility with faster start-up and load change capability. Condensate and feedwater pumps are arranged in a booster set-up for low power consumption. Both main pumps are configured as 2x100% pumps for high availability.

The base design contains a wet cell cooling tower. Available options for cooling include an air-cooled condenser or once-through cooling.

Plant auxiliaries are directly cooled by means of a closed cooling water system using heat exchangers.

### The SCC5-4000F 1S is designed with the following conditions:

<table>
<thead>
<tr>
<th>Boundary</th>
<th>SCC5-4000F 1S RPP design base</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grid frequency</td>
<td>50 Hz</td>
</tr>
<tr>
<td>Ambient temperature</td>
<td>-20°C to 40°C (-5°F to 105°F)</td>
</tr>
<tr>
<td>Site elevation</td>
<td>Design 0 m</td>
</tr>
<tr>
<td>Fuel</td>
<td>Main fuel: Natural gas, LHV: 50,012 kJ/kg (Methane at ISO conditions: 21,502 Btu/lbm)</td>
</tr>
<tr>
<td></td>
<td>Back-up fuel: Fuel oil Cat.II, LHV: 42,600 kJ/kg/18,315 Btu/lbm</td>
</tr>
<tr>
<td>Steam parameter</td>
<td>565°C/125 bar (1,050°F/1,815 psi)</td>
</tr>
<tr>
<td></td>
<td>565°C/30 bar (1,050°F/435 psi)</td>
</tr>
<tr>
<td></td>
<td>235°C/5 bar (455°F/75 psi)</td>
</tr>
</tbody>
</table>
The advanced Siemens SCCS-4000F 1S

The Siemens SCCS-4000F 1S is a new milestone in the sector of 400 MW-class 50 Hz combined cycle plants. Not only is it one of the most powerful and efficient F-class plants on the market today, but even more important it is the most environmentally friendly with its significant reduction in emissions and water consumption. It builds on years of experience and includes feedback from executed projects. Additionally, it incorporates the feedback of customer interviews and QFD workshops to include the latest market developments. It is the answer to meet any 50 Hz combined cycle power plant needs in the future.

The use of our world-class gas turbine, steam turbine and generator technology combined with our expertise to design and build world-class combined cycle power plants helps to ensure that your plant will remain a sound investment for many years to come.

With the mentioned boundary conditions the following performance is achieved:

<table>
<thead>
<tr>
<th>Performance</th>
<th>SCCS-4000F 1S (SST5-3000)*</th>
<th>SCCS-4000F 1S (SST5-5000)**</th>
</tr>
</thead>
<tbody>
<tr>
<td>Net plant power output $P_{net}$</td>
<td>423 MW (ISO ambient conditions, reference design)</td>
<td>434 MW (10°C/50°F ambient temperature, once-through cooling)</td>
</tr>
<tr>
<td>Net plant power efficiency $\eta_{net}$</td>
<td>58.4% (ISO ambient conditions, reference design)</td>
<td>58.9% (10°C/50°F ambient temperature, once-through cooling)</td>
</tr>
<tr>
<td>Net plant heat rate</td>
<td>6,164 kJ/kWh (5,842 Btu/kWh)</td>
<td>6,112 kJ/kWh (5,793 Btu/kWh)</td>
</tr>
<tr>
<td>Plant NOx emissions</td>
<td>Main fuel: ≤ 25 ppmvd (Base load)</td>
<td>Main fuel: ≤ 25 ppmvd (Base load)</td>
</tr>
<tr>
<td>Plant CO emissions</td>
<td>Main fuel: ≤ 10 ppmvd (Base load)</td>
<td>Main fuel: ≤ 10 ppmvd (Base load)</td>
</tr>
<tr>
<td>Plant CO2 emissions</td>
<td>342.1 kg CO2/MWhe (Natural gas)</td>
<td>339.2 kg CO2/MWhe (Natural gas)</td>
</tr>
</tbody>
</table>

* Standard design; ISO ambient conditions
** 10°C/50°F ambient temperature, once-through cooling

Project and site-specific performance data for this and other Siemens combined cycle products can be obtained through SIPEP, the Siemens Plant Performance Estimation Program. For access to SIPEP please contact your Siemens sales representative.