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FLEXIBLE PACKAGE SOLUTIONS FOR SIEMENS SGT-800

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Abstract

This paper will describe the flexible package solutions for SIEMENS SGT-800 gas turbine. A brief overview of the gas turbine and its performance will be given.

The Siemens gas turbine SGT-800 is now available with two different packages, Classic package and Single lift package. In the Classic package, the generator is placed on foundation and in the Single lift package the gas turbine, gear box and generator are placed on a common base frame. Driving the development for the Single lift package have been the customers demand for more flexible installation requirements; small footprint, short installation and commissioning time at site, high availability as well as enhanced string test possibilities. This has been achieved by rearranging the auxiliary units of the SGT-800 Classic package and fitting them together with the turbine string on a common base frame. No changes have been made to the well proven and robust SGT-800 core engine; the auxiliary systems still supports the same excellent capabilities for fuel and operational flexibility.

1 Introduction

Siemens Industrial Turbomachinery AB, Finspong Sweden has introduced a single lift package arrangement for the SGT-800 gas turbine product. Driving this development has been the customers need for more flexible installation, offering reduced footprint, installation and commissioning times. In addition to package layout changes the gas turbine product has been updated, offering 53MWe of electrical power.

1.1 Package Arrangements

The need for a SGT-800 Single Lift package is driven by the need for small footprint, reduced time for installation and commissioning (especially required in harsh and remote areas) as well as maintaining high availability along with improved factory build options, such as string test possibilities (combined test of all contract equipment). This has been achieved by rearranging the auxiliary units of the SGT-800 Classic package and fitting them together with the generator onto a common base frame.

1.2 The SGT-800 Gas Turbine

SGT-800 is the largest industrial gas turbine manufactured by Siemens Industrial Turbomachinery AB. Launched in 1997 as a 43 MW machine named GTX100 [1], the SGT-800 was soon re-rated to 45 MW and in 2007 further enhanced to 47.5 MW with 37.7% simple cycle efficiency [2][3] and close to 55% combined cycle operation efficiency in a 2x1 configuration, By including cogeneration (district heating) the efficiency further increased to more than 90% [3]. Siemens has continued the stepwise evolutionary development based on experience and proven design solutions in order to always assure high reliability. 2010 saw the release of a new output rating, 50.5 MW with a 38.3% simple cycle electrical efficiency (ISO) and a 2x1 combined-cycle performance of >55% [3]. In 2015 Siemens released the product with revised output of 53.0 MW and with 39.0% simple cycle efficiency and >56% combined cycle efficiency in 2x1 configuration [4].

The SGT-800 is today available to the market in the three different ratings 47.5 MW, 50.5 MW and 53.0 MW.

Up to June 2015 270 SGT-800 units have been sold and have accumulated more than 3.3 million Equivalent Operating Hours (EOH)¹ with the fleet leader exceeding more than 110,000 EOH.

¹ EOH Equivalent Operating Hours – Normalized operation taking into account the impact of specific operation conditions on maintenance intervals

2 SGT-800 Package Solutions

Siemens SGT-800 is now available in two different packages; Single lift package and Classic package. The Classic package was originally developed for the Industrial Power Generation market with strong focus on in-situ maintenance and low cost of included package material, while the Single Lift package has been developed with the main focus to reduce the package footprint and to minimize the installation and commissioning time at site. This gives the customer the opportunity to spend less capital cost for foundation work, installation work and related the costs. With the high availability together with the enhanced string test possibilities the aim has been to give the customer the opportunity to ship the unit fully tested directly to the site. With excellent combined cycle efficiency, reliable Dry Low Emission (DLE) fuel system, high reliability and availability, the SGT-800 has developed into a well-accepted mature product, with a few enhancements further described in section 3.2.1.2. The interest in the product has continued to increase from Power Generation customers as well as O&G customers.

Below a short description of the Classic package will be given as a reference to the Single lift package.

2.1 Classic Package

When the SGT-800 was launched the package arrangement was a traditional gas turbine package, similar to the larger frame gas turbines, with a skid-mounted package incorporating the gas turbine and gearbox on a single base frame, or with the gearbox placed directly on the foundation. Mechanical auxiliary systems are separately mounted on an external skid placed close to the gas turbine. An enclosure covers the gas turbine and the auxiliary system to create a safe operating environment for the gas turbine as well as protect the surroundings from noise emissions.

Turbine controls, generator control panel, motor control center for package motors and variable-speed drive for starter motor are normally supplied in an external control module or as separate items.

3 Single Lift Package

Main features and the design background of the Single Lift package will be detailed in the following sections.

3.1 Background

The SGT-800 Single Lift package has been designed in order to meet a variety of customers' market challenges in the coming years:

- Operate gas turbines in a more remote and harsh environment
- Operate gas turbines on non-standard gas fuel in order to monetize stranded gas assets
- Provide reliable energy to various energy consumers
- Provide low carbon energy at the lowest possible cost

3.2 Single Lift Package Introduction

With the aim to meet the above variety of future market challenges, the design of the Single lift package is a further development of the SGT-800 Classic package, focus of the development have been customer demands for more flexible installation requirements that a smaller small footprint will give and short installation and commissioning time at site together with high availability as well as enhanced string test possibilities. The design of the package had to be designed in such a way that it not only gains O&G acceptance, onshore & offshore, but also that it will retain its acceptance from the Power Generation customers by having high exhaust heat energy and excellent combined cycle performance. This has been achieved by rearranging the auxiliary units of the SGT-800 Classic package and fitting them together with the turbine string on a common base frame. No changes have been made to the well proven and robust SGT-800 core engine during the design of the Single Lift package and the package can be equipped with any of the available core engine versions as presented in chapter 3.2.1.1 below. The auxiliary systems still supports the same excellent capabilities for fuel and operational flexibility.

With the relocation of the auxiliary systems to the Single Lift skid Siemens has reduced the installation requirement of a large plot space to a minimum. The Single Lift package only need 115m² plot space for the installation compared to 210 m² for the Classic package which is a reduction with more than 50%. This reduced need for plot space, by using the SGT-800 Single Lift design, gives the customer the benefit of utilizing brown and green fields more efficiently by utilizing the plot space to the optimum leading to that less work is needed for exploration and excavation.

3.2.1 SGT-800 Core Engine Overview

SGT-800 is a single shaft gas turbine, Figure 1, and is used for power generation. The three stage power turbine is bolted to the compressor. The compressor has 15 stages and a pressure ratio of 21.4:1. Three variable guide vanes and two compressor bleeds that are used during start-up. During load operation, the variable guide vanes are sued for mass flow control. Electron beam welding is used to manufacture the compressor rotor, forming a solid rotor body.

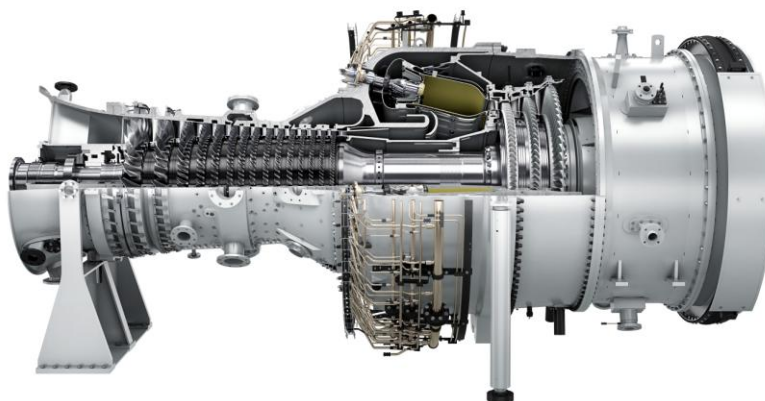


Figure 1: SGT-800 Gas turbine.

The compressor can be optimized for either normal or hot climate. The hot ambient matched compressor will maximize power output and efficiency at higher ambient. This is achieved by selecting an optional set of stator compressor stages 3 to 15 only.

The combustion system consists of an annular type combustor system with 30 DLE burners.

The turbine section of the SGT-800 consists of the three-stage high-efficiency turbine. The stage 1 vane and blade have both film and convective cooling, stage 2 vane and blade have convective cooling and stage 3 is uncooled. Thermal barrier coating is used for reduced cooling-air consumption in stage 1 and 2. The disks are bolted to the rotor with tie-bolts.

3.2.1.1 Evolutionary Development

The SGT-800 gas turbine since its introduction has been optimized leading to increased power output, improved efficiency and mass flow.. All upgrades have been based on extensive full-scale engine validation testing and excellent operational feedback. The latest upgrade, driven by the continues requirement for higher power output and heat rate with better efficiency, has been achieved through optimized and re-staggered first stage compressor blades which increase both efficiency and mass flow; optimized cooling layout of turbine guide vanes; and adjusted clearances in turbine stage 1 and 2. Only minor changes of the machining of four stationary components have been required to exploit the built-in performance tuning potential in the turbine section. No changes have been made to castings or materials and importantly the outlet temperature from the combustor remains the same. All improved components are fully retrofittable within the existing 50.5 MW series.

3.2.2 Single Lift Skid

To facilitate easy installation in various environments, for example remote areas or harsh environments, the single lift package is developed as a complete skid-mounted package with single lift capacity of the complete train, i.e. gas turbine, gearbox, generator, mechanical auxiliary systems and enclosure, see **Figure 2**.

By having the auxiliaries relocated to the common base frame the customer also benefits from that the cost for civil and foundation work is reduced as well as installation and commissioning costs compared to the Classic package.

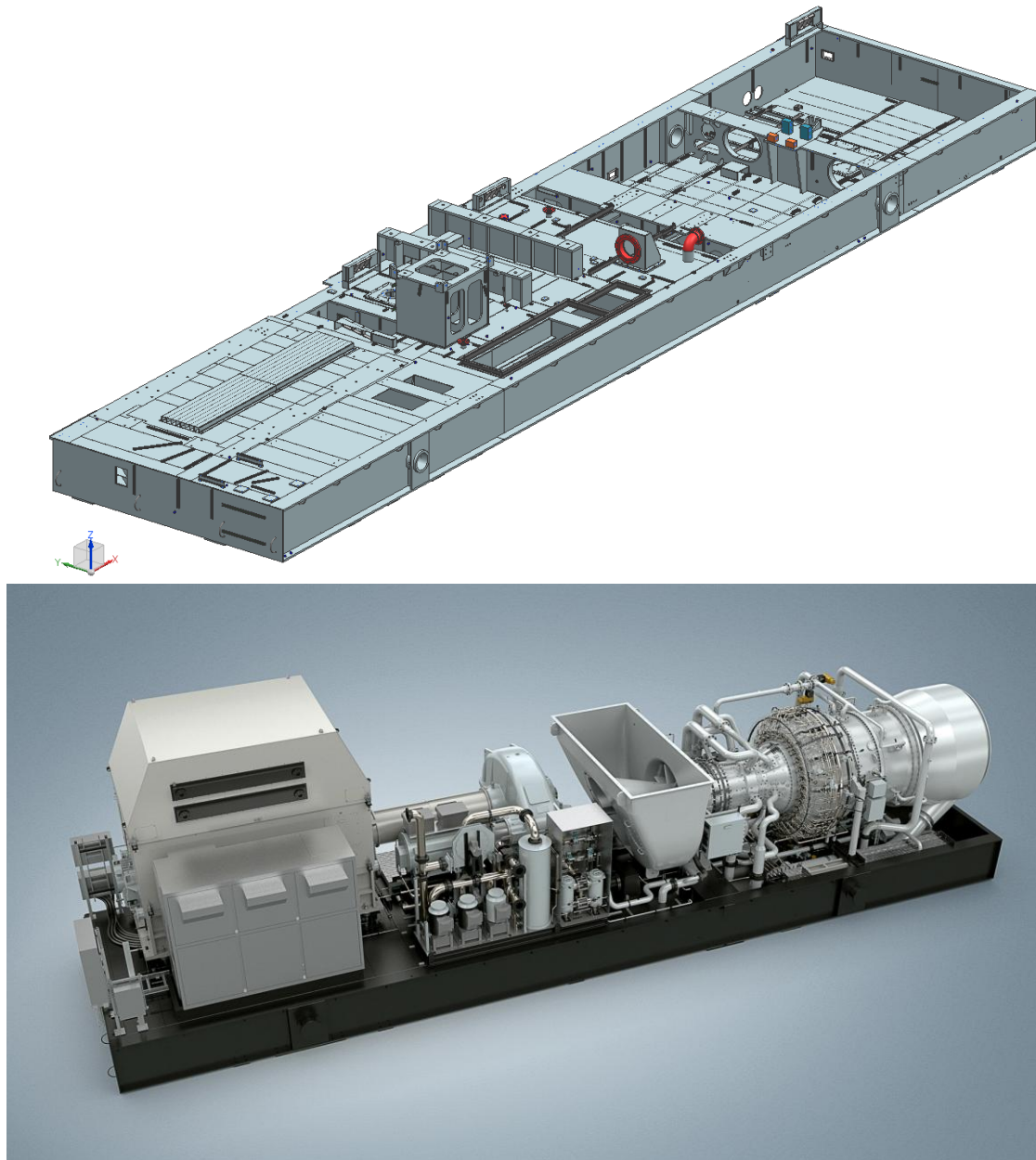


Figure 2: SGT-800 Single Lift Skid.

The skid is a welded construction comprising two parallel HEA900 I-beams with two lifting bollards located on the each long side of the package. Aside from facilitating support-; for the gas turbine the skid also have an integral wet skid for the lube oil system. This enables the smallest possible footprint of the package, as well as a high degree of completion from workshop with a minimum of installation needed at site. Installation to the foundation can be made either by multi point for onshore installations or if a less complex foundation is required, typically offshore installations, a three point mount can be selected which then adds an under base frame.

The decision to go with a rigid base frame and not a bolted design was driven by two reasons. A design with split skids bolted together would lead to the customer needing to spend valuable time on site during the installation for alignment of two skids at the foundation as well as aligning the generator with the gas turbine. A bolted design also

requires a very complex bolt interface between two skids in order to handle the deflection and torsional stresses during operation.

To be able to adapt to different requirements during installation of the package, the skid is designed in such a way that it allows for the package to be either lifted on to the foundation or by jacking and sliding the package into position on to the foundation.

3.2.3 Lube Oil Supply Unit

Single Lift package has a lube oil supply unit with three lube oil pumps, lube oil mist fan and lube oil filters that is located on top of the integrated wet skid together with the necessary instrumentation and control equipment. Main components are installed as a module while lube oil heaters and jacking oil pump are installed separately. To maintain the high availability from the classic package same components are used for the lube oil supply unit in both Classic package and Single Lift package. By arranging the components of the lube oil unit in such a way they can easily be accessed, either from the outside or from the platforms inside the package, the serviceability is kept the same as for the Classic package.

3.2.4 Gas Turbine Enclosure

The enclosure is designed to be fully assembled and dressed independently and then lifted on to the skid in the factory workshop. With this concept any and all site enclosure works is re-located to the workshop thus minimizing the activities at site without extending the delivery time compared to the Classic package. To ensure easily access to the different on-skid systems the enclosure is equipped with 6 doors for maintenance purpose. This also provides service access to the auxiliary systems as the lube oil supply unit and lube oil cabinet. For engine roll out folded doors are available, which can be operated without use of tools. The customer can select either right or left side of the sound enclosure to facilitate flexible maintenance independently of the package orientation.

3.2.5 Gas Fuel System

Gas fuel systems components are common with the classic package thus maintaining the same level reliability to the Single Lift package as well as maintaining the fuel flexibility of the Classic package. Further description to the gas fuel system capabilities is given in section 4.

3.2.6 Electrical starter motor

Both the Classic package and the Single Lift package have the common starter motor which provides no impact on reliability to the new package. For the Single Lift package the starter motor has been relocated from a foundation installation to an installation made on common base frame.

3.2.7 Diffuser

Single Lift package diffuser length has been shortened by 39% and the weight by 49% compared to previous versions of diffuser, without affecting the diffuser efficiency, i.e the Single Lift have the same diffuser efficiency as the Classic Package. The shortened diffuser shortens the overall length of the Single Lift package compared to if the Classic package diffuser had been used for the design.

To shorten the installation time on site the diffuser has been divided into two parts, a diffuser part and an exhaust duct section. This enables assembly and alignment of the diffuser in workshop before delivery while only the exhaust duct must be attached at site. Aligning both the diffuser and exhaust duct is done with adjustable rigging screws. The shortened diffuser also have lower thermal losses and less noise emissions than previous diffuser designs.

3.2.8 Highly Degree of Completion

With the core engine and the auxiliary systems placed on one single skid the possibilities are enabled to have the engine and the system assembled, installed and connected in workshop in a controlled environment instead of at the customer site. The relocation also enables the on-skid electrical installation, up to junction boxes placed outside of the sound enclosure, is made in the workshop minimizing the need to enter the enclosure during site installation and commissioning. This includes both signal cabling as well as power cables, for example the starter motor cables.

Mechanically the same design philosophy has been used, meaning all customer piping interfaces is situated outside of the skid and the sound enclosure.

With the systems assembled, installed, connected and fully tested in a package workshop test in the workshop the Single Lift reaches a very high degree of completion in a controlled workshop environment before the shipment is made. With this highly degree of completion the installation and commissioning times at site are kept to a minimum, as low as 60 working days between turbine delivery to site to handover to customer, this is a reduction by almost 50% from the Classic package. This short time gives the customer the opportunity to have gas turbine installations made where installation and commissioning windows are narrow, for example due to weather reason. This concept also reduces site costs, in terms of manpower, extended crane and other equipment hire.

3.2.9 Enhanced String Test Capabilities

With the highly degree of completion and testing described above the Single Lift gives enhanced string test capabilities with the alignment already done in the workshop the equipment can be lifted or slided into test position onto the test bed without further need of alignment. With the relocation of the auxiliary systems the need for a lifting crane is minimized.

As the mechanical and electrical interfaces are located outside of the package and with a package already tested in a workshop test the string test installation is simplified and the time needed for the test is decreased leading to lower cost for the customer.

Single Lift and the Classic package use the same slave equipment for the string test, such as load banks, fuel supply, and auxiliary power system and, depending on the scope of the string test, air intake and cooling system.

The customer has the option to either fully test the SGT-800 core engine in a ‘so called’ mechanical running test or choose to fully test the entire package before shipment. This will allow the unit to be ready for customer operation after 60 days or less of site installation and commissioning.

3.2.10 Increased Availability

The Classic package has achieved an excellent average fleet availability and reliability of 97.4% and 99.6%, respectively and a mean time between forced outage of 5306 hours. A key improvement for the Single Lift package compared to the Classic package is the introduction of a quick core engine exchange, see Figure 3. With the quick core engine exchange introduced its possible to exchange the core engine in 48 hours for either scheduled or corrective maintenance, resulting in less downtime for the customer. This increases the serviceability of the core engine and the availability of the package while it still maintains the flexibility to perform service on site or off site.



Figure 3: Siemens Single Lift package with the core engine extracted

4 Flexible Fuel Operation

Both the Classic package and the Single Lift package uses the well proven 3rd Generation Dry Low Emission system and share the same components allowing that the same flexible fuel operation is kept, but for the Single Lift package, with rearranged piping to fit into the single lift skid. The SGT-800 combustion system uses an annular combustor with thirty removable DLE burners installed.

The flexibility comes from the inherent design of the simply but robust DLE system including the burner. The patented DLE burner, Figure 4, consists of a split cone forming four air slots where main gas is injected followed by a mixing section with film air holes. Near the base of the cone, central gas or main liquid is fed and intensively mixed with the compressor air. The pilot fuel injection is positioned at the burner tip. The flame is positioned in the burner outlet with pilot flame at the tip of the burner. During operation the flame is controlled by fuel ratio between the pilot flow and the main gas flow. In order to stabilize the flame during low load operation the flame is reduced corresponding to the load and the pilot flame is increased to support the main flame in order to avoid flame instability, the opposite conditions occurs during higher load.

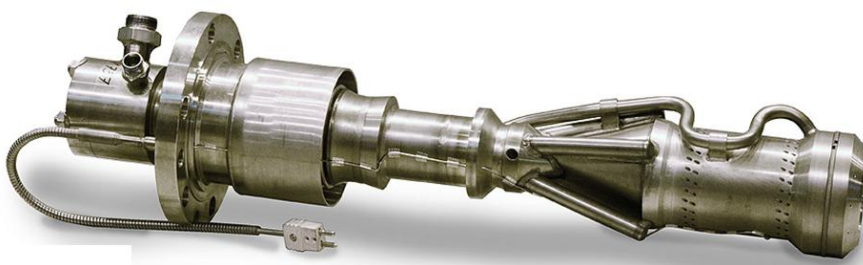


Figure 4: The 3rd generation DLE burner

The gas flow to pilot and main streams are controlled by two independently motor operated control valves. Due to the system not having the complexity of burner staging it is by its design very robust. The absence of burner staging make the system very capable of handling both load variations, as step loads and load rejections, as well as the flexibility to operate on a wide variety of fuels. The system has in full engine operation and tests proven its capability to operate on fuel gas with Wobbe index range between 22 – 80 MJ/Nm³. The benefit of increased and proven fuel flexibility is clear as it allows the gas turbine owner to make full use of opportunity fuels and to supply power at low fuel cost [5].

5 Installation Example

In below sections two highlighted examples will be given where the installation of SGT-800 Single Lift package gives valuable benefit for the customer.

5.1 SGT-800 Single Lift Offshore Installation Example

The company has developed a high efficiency combined cycle concept suitable for fixed and floating off/near shore installations. The concept can be used for installations in arctic areas as well as in various climatic areas around the globe. Below is pictured a SCC-800 4x1C concept, Figure 5, with the structure for a tempered building operating in harsh arctic conditions.

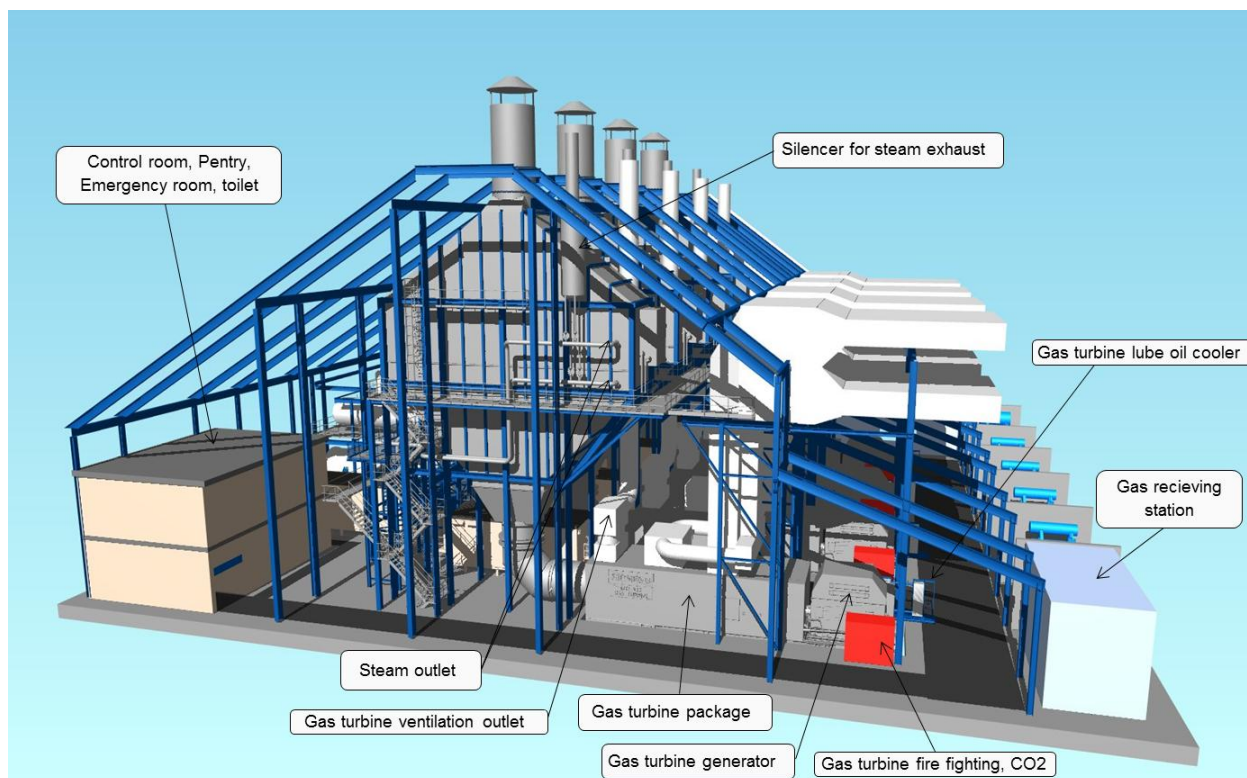


Figure 5: SCC-800 4x1C concept for arctic installation

The concept is based on the SGT-800 Single Lift package with three point mount, a vertical once through Steam Generator (minimum foot print, minimum make up water consumption) and a packaged condensing steam turbine. The SCC concept is available in 1x1 up to 6x1 configurations from typically 70 to 450 MW.

Installed net performance of a 2x1 power block is at ISO conditions 150 MW, at generator terminals, with an efficiency of >56%. Main equipment of a 2x1 configuration can be accommodated within 70x30 meter of the main deck. Auxiliaries are normally installed on a lower deck or in the void inside a barge.

With the SGT-800 Single Lift fully assembled in the workshop and fully string tested at the test beds at the fabrication yard final commissioning at site can be minimized along with possible risk picture at installation site.

Maintenance of gas and steam turbines is done onboard, basic design incorporate necessary service areas and handling requirement of turbine parts. With the Single Lift package core engine exchange in 48 hours the customer gets the highest possible availability of the power generating installation.

With the power plant / barge built and commissioned in a yard and then shipped to site the barge will, by the nature of its “plug&play” concept, be able to generate power within 26-30 months from order.

5.2 SGT-800 Single Lift Onshore Installation Example

Project in the Middle East area with a site simple cycle power rating requirement at an ambient temperature of 50°C:

A Single Lift package with the selection of a hot ambient optimized compressor offers the customer 26% more power output and 5.8% Heat Rate reduction compared to the SGT-800 normal ambient matched compressor, Figure 6. The 26% more power gives the customer the possibility to install less units leading to lower capital expense and additional savings in plot space and related savings for civil works, this in addition to the savings made for the installation and commissioning works by selecting the Single Lift package over a traditional site built package.

Further, the customer will benefit from the 48 hour quick core exchange with a reduction by 40 days in the downtime, with an available spare core, over a period of fifteen years of operation. The customer will achieve an operational benefit from the Single Lift by increasing availability of more than 960 hours for producing power.

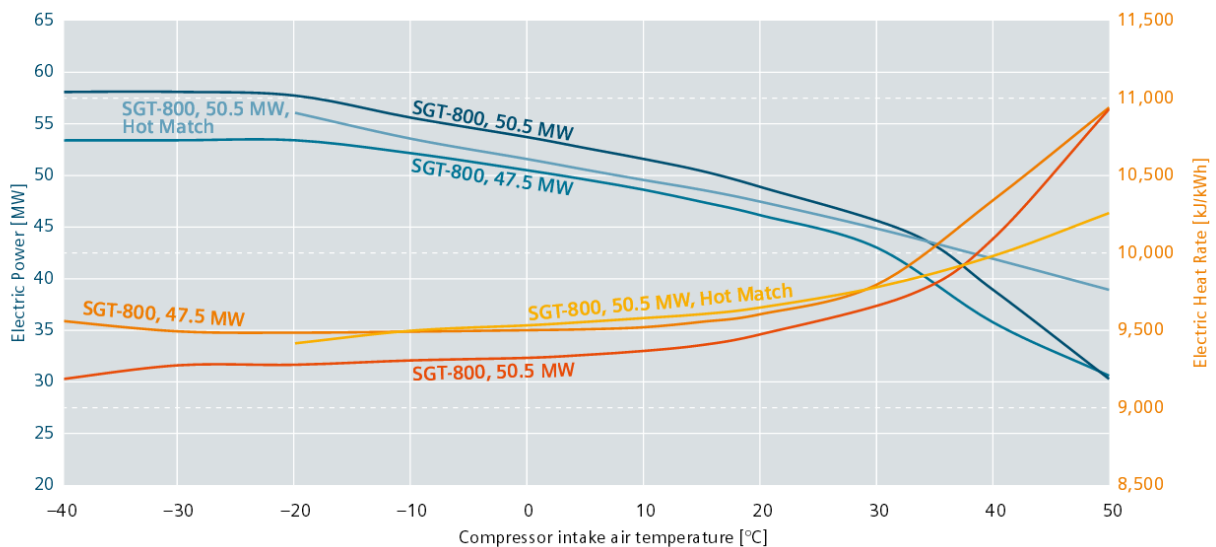


Figure 6: SGT-800 High Ambient Temperature Capability

Summary

With the Single Lift package Siemens has accomplished a package that has small footprint is fuel flexible and have a highly degree of completion prior shipment. This gives the customer the opportunity to reduce their cost for equipment transportation, excavation of the plot space and the site logistics needed. The package also gives the opportunity to the customer to save cost spent on labor and daily allowances as less time is spent on installation and commissioning. The Single Lift package concept is of great importance in remote or harsh environment where labor can only be at site for limited time or where the availability of labor in the region is the limiting factor and must be efficiently utilized.

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