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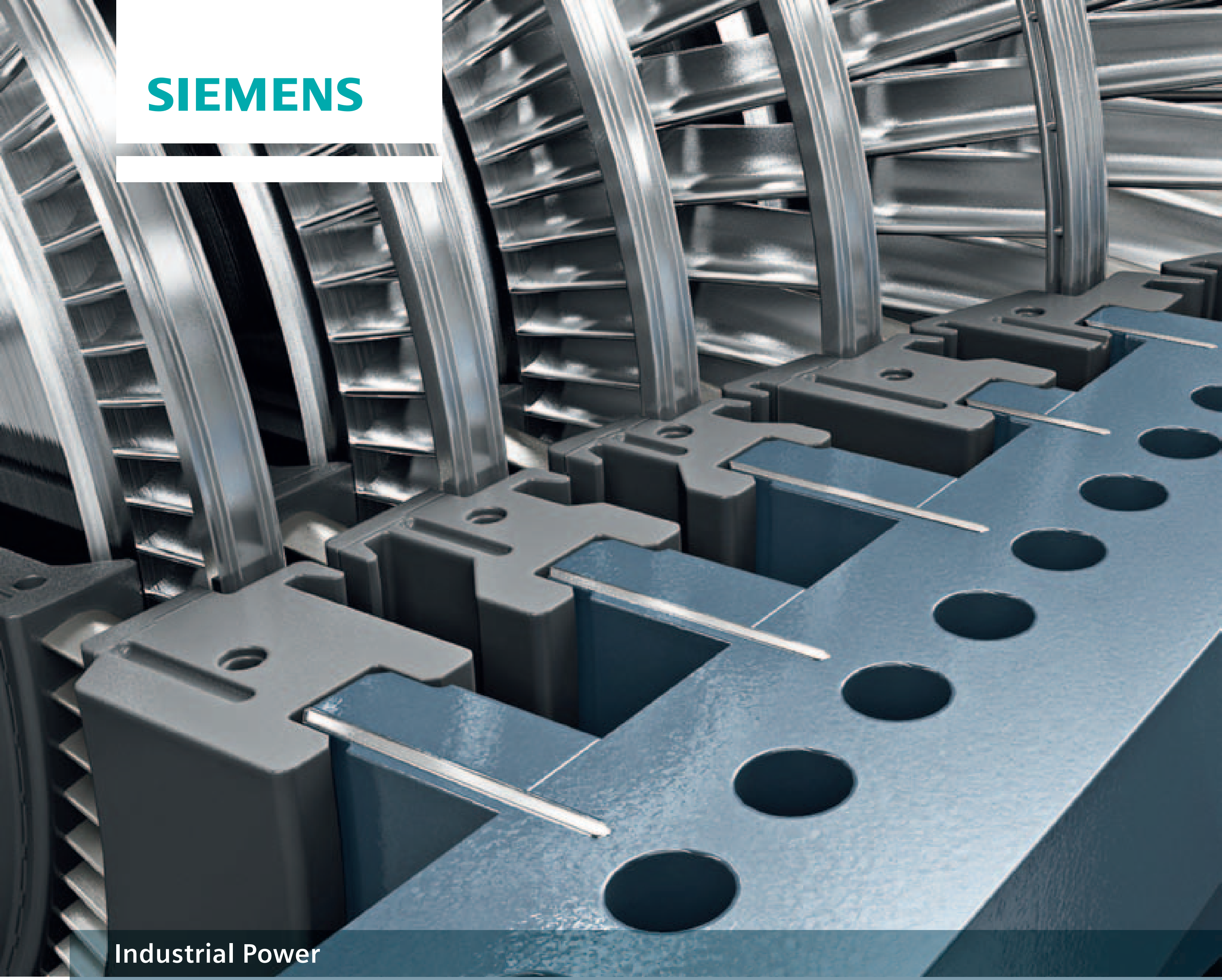


Industrial Power

Steam Turbines for Geothermal Power Plants

SST-400 GEO and SST-500 GEO with Power Output up to 120 MW

Scan the QR code with the QR code reader in your mobile!

siemens.com/energy/steamturbines

Geothermal Energy

Electrical power production from geothermal energy is a mature technology. The first geothermal power plant at Larderello in Italy was constructed more than 100 years ago, and the same resource continues in production today.

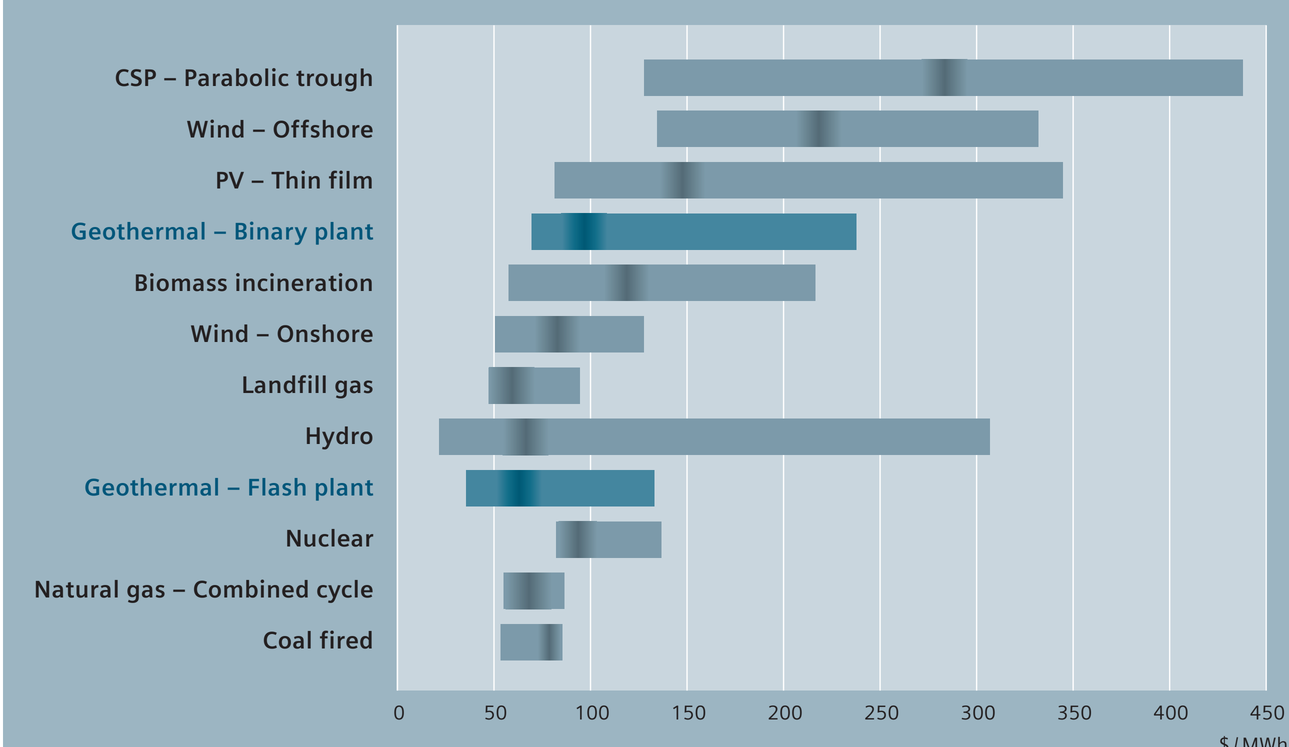
A Proven Technology

Since that time geophysical technology, drilling techniques and steam turbine designs have all improved significantly, resulting in high availability base-load power plants utilizing this natural energy source in many parts of the world.

Safe Base Load

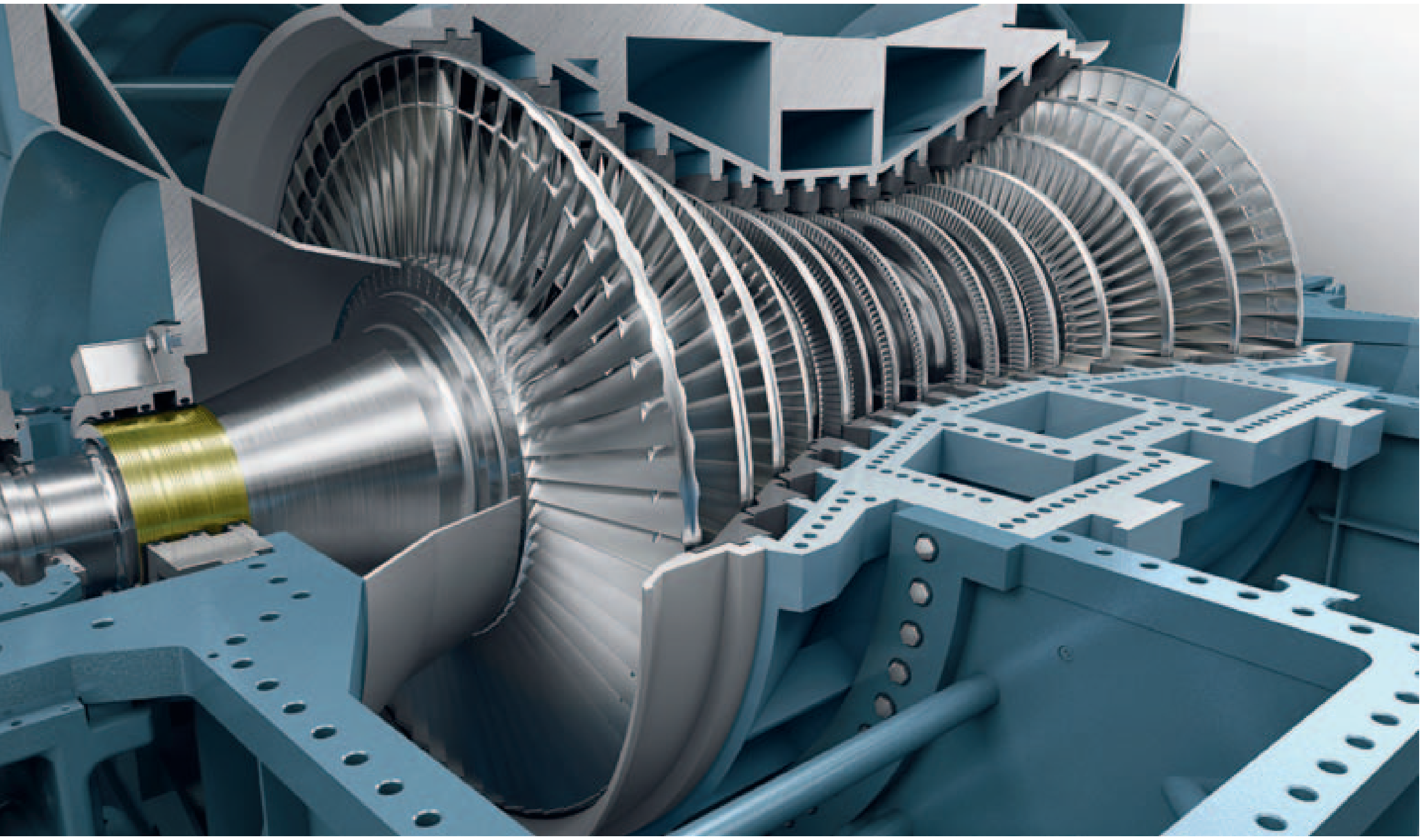
In contradistinction to other popular renewable energy sources, geothermal energy can be used around the clock, regardless of cloudy or windless days, with capacity factors in the range of 90 to 95% making it cost-effective compared to other renewable energy sources.

Levelized costs of energy across power generation technologies, Q4 2012



Range of electricity costs per MWh, dark part is the average value. Based on inflation-adjusted lifecycle cost of producing electricity from a technology assuming a target equity internal rate of return (IRR) of 10%.

Source: Bloomberg New Energy Finance, EIA.



Geothermal Specifics

Detailed design of every geothermal power plant is site-specific depending upon the nature of the geothermal fluid resource and other conditions prevailing at each specific location. Every site and individual well can be different: in respect to temperature, flow rate, non-condensable gases, pressure, pH and solid levels. In consequence, detailed blade path design and selection of turbine materials vary from project to project. Furthermore, the geothermal resources can degrade over time leading to the need for re-rates.

Challenging Cycle Conditions

Geothermal resources most often appear in areas with high seismic activity which must be considered in the turboset design. The turbines themselves frequently face highly corrosive steam which consumes conventional materials. The steam conditions are low but have large volume flows. Therefore, there are several challenges resulting from the geothermal environment, such as:

- Materials selection to avoid early deterioration of geothermal blades.
- Possible corrosion attack that can lead to corrosion-fatigue in geothermal blades.
- Reduced material endurance strength that can lead to catastrophic rotor failures.

Siemens Energy Service has been active world-wide in the geothermal arena for over 20 years, during which time major refurbishments including supply of new rotors and redesign and replacement of complete blade paths have been carried out on machines supplied by all of the major geothermal turbine manufacturers.

Geothermal Steam Turbines

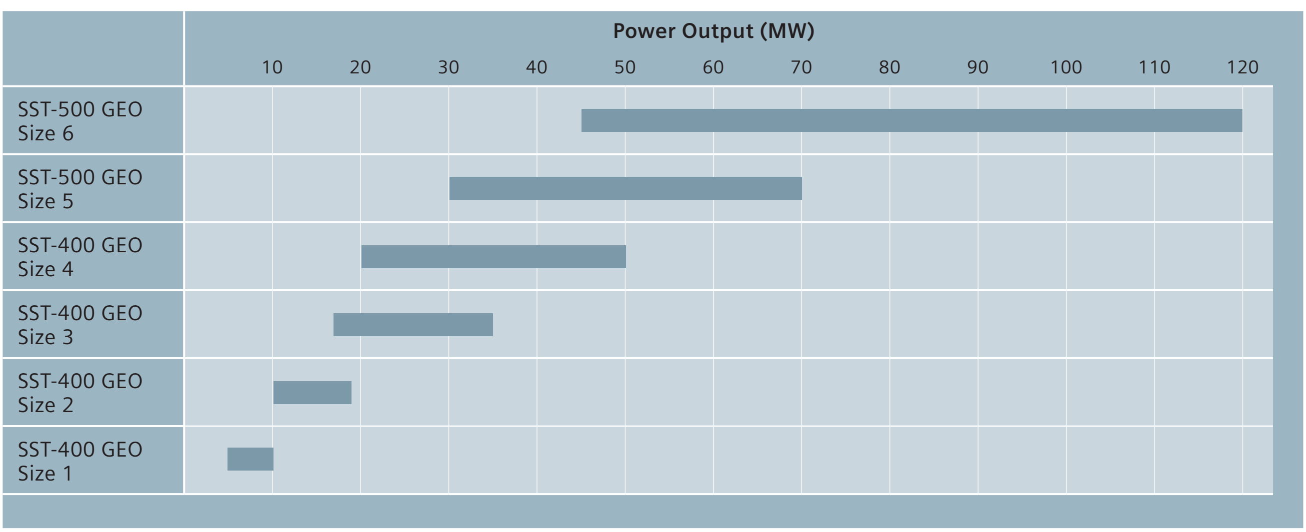
Siemens' family of geothermal turbines was conceived as a set of standardized frame sizes, such that each frame size has a fixed bearing span and basically standard casing, which can be varied on a requisition basis to accommodate a varying number of turbine stages and an inversely varying inlet diameter. For example, a turbine for higher pressure will have a relatively small inlet and a larger number of stages and vice versa.

The Siemens Turbine Family

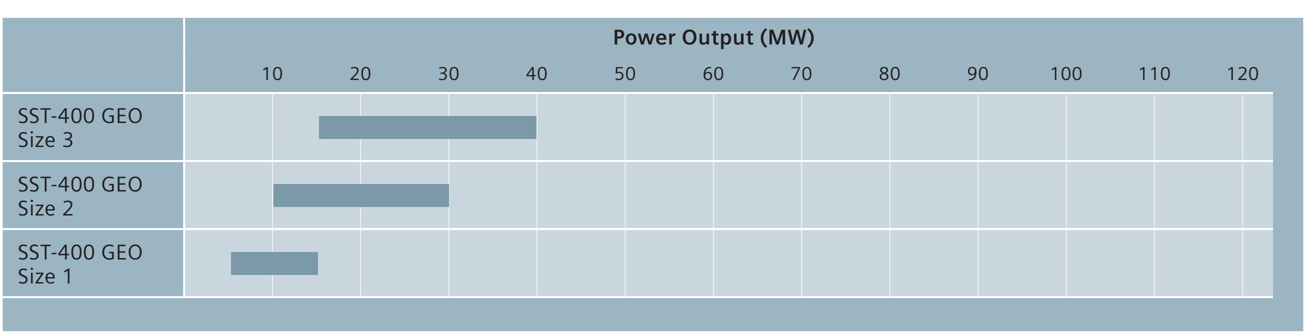
All Siemens geothermal turbines are designed with an impulse type steam path, which due to their greater throat opening are proven by our extensive experience in the after-market to be more suitable for geothermal applications.

The smaller size turbines (SST-400 GEO Sizes 1 to 3) are designed to be suitable for both condensing and back-pressure applications – in the latter case, exhausting to a binary bottoming cycle in a Geothermal Combined Cycle, or to atmosphere. The larger units (Size 4 and above) are designed for condensing applications only.

Geothermal Condensing Application Range



Geothermal Non-Condensing Application Range

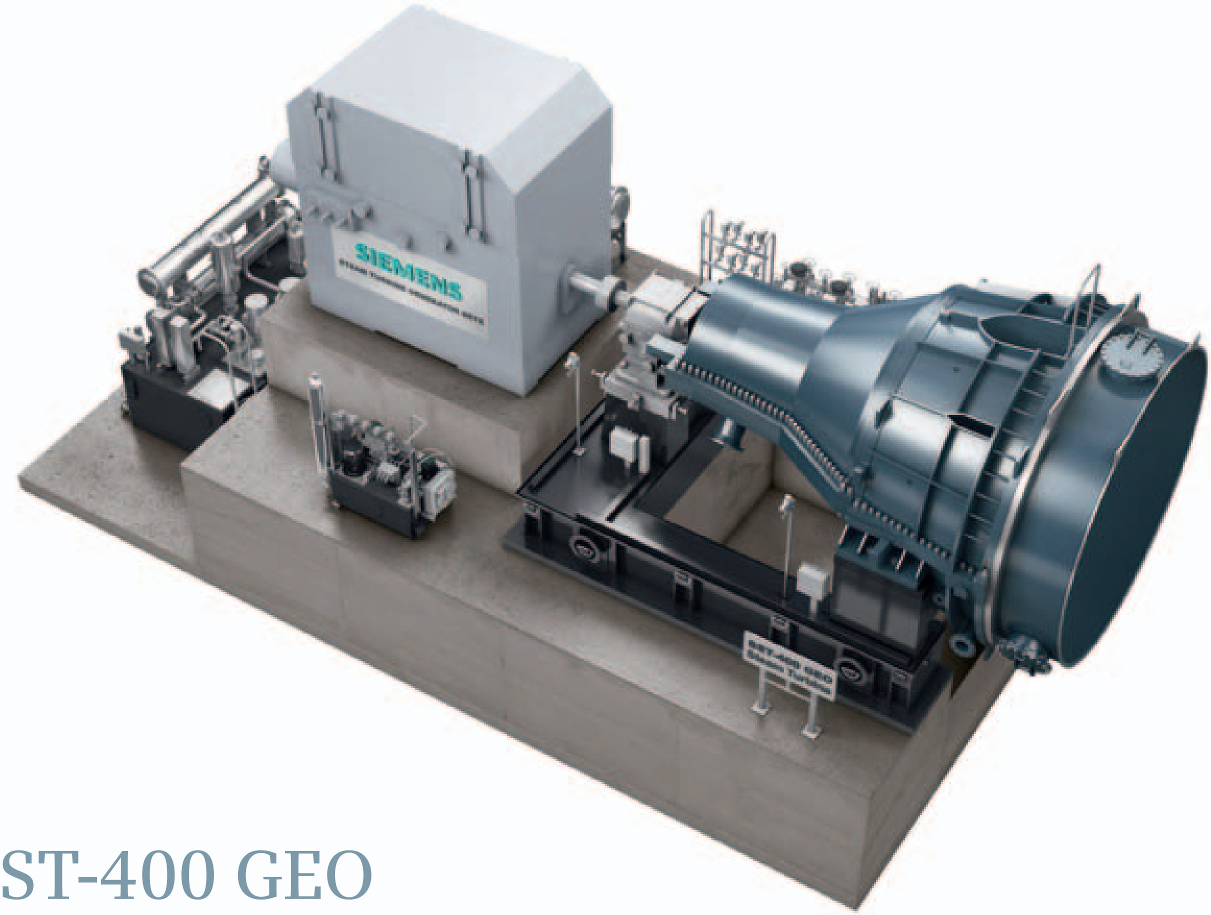


The Geothermal Steam Turbine Range

Siemens SST-400 GEO and SST-500 GEO Leading Parameters

Turbine Type	SST-400 GEO							SST-500 GEO	
Nominal size	**Size 1***		**Size 2**		**Size 3***		**Size 4**	**Size 5***	**Size 6**
Condensing (Con) / Back-pressure (BP)	Con	BP	Con	BP	Con	BP	Con	Con	Con
Power output maximum	10 MW	15 MW	19 MW	30 MW	35 MW	40 MW	50 MW	70 MW	120 MW
Turbine speed (rpm)			5,500 rpm	5,000 rpm			3,000 / 3,600 rpm	3,000 / 3,600 rpm	3,000 / 3,600 rpm
Steam parameter									
Exhaust steam pressure maximum	0.4 bara / 5.8 psia	1.4 bara / 20 psia	0.4 bara / 5.8 psia	1.4 bara / 20 psia	0.4 bara / 5.8 psia	1.4 bara / 20 psia	0.4 bara / 5.8 psia	0.4 bara / 5.8 psia	0.4 bara / 5.8 psia
Inlet steam pressure maximum	12 bara / 176 psia		12 bara / 176 psia		15 bara / 220 psia		15 bara / 220 psia	15 bara / 220 psia	15 bara / 220 psia
Inlet steam temperature maximum	250 °C / 482 °F		250 °C / 482 °F		250 °C / 482 °F		250 °C / 482 °F	250 °C / 482 °F	250 °C / 482 °F
Specification									
50 Hz / 60 Hz	50 or 60 Hz		50 or 60 Hz		50 or 60 Hz		50 or 60 Hz	50 or 60 Hz	50 or 60 Hz
Single flow / double flow	Single flow		Single flow		Single flow		Single flow	Double flow	Double flow
Exhaust configuration	Axial exhaust		Axial exhaust		Axial exhaust		Axial exhaust	Radial exhaust	Radial exhaust
Geared or direct drive	Geared drive		Geared drive		Geared or direct drive		Direct drive	Direct drive	Direct drive
Package Dimensions (typical / examples)									
Turbine L x W x H			3.5 x 3 x 3.2 m				6.5 x 3.9 x 4.5 m		9.6 x 6.4 x 5.1 m
Weight			31 t				100 t		240 t
Generator L x W x H			7 x 4 x 5 m				5.7 x 3.5 x 3.5 m		8.6 x 7.8 x 4.6 m
Weight			35 t				52 t		140 t
Footprint			13.6 x 6 x 5 m				12.6 x 5.1 x 5.3 m		19 x 8 x 6 m

*Sales release planned



SST-400 GEO

The SST-400 GEO is a derivative of the well-proven SST-300 and SST-400 turbine families, optimized for the demanding conditions of geothermal steam cycles. The SST-400 GEO is used in geothermal applications with superheated direct steam, flash or combined cycle, offering outstanding reliability, application-flexibility and economy of operation.

Proven Technology

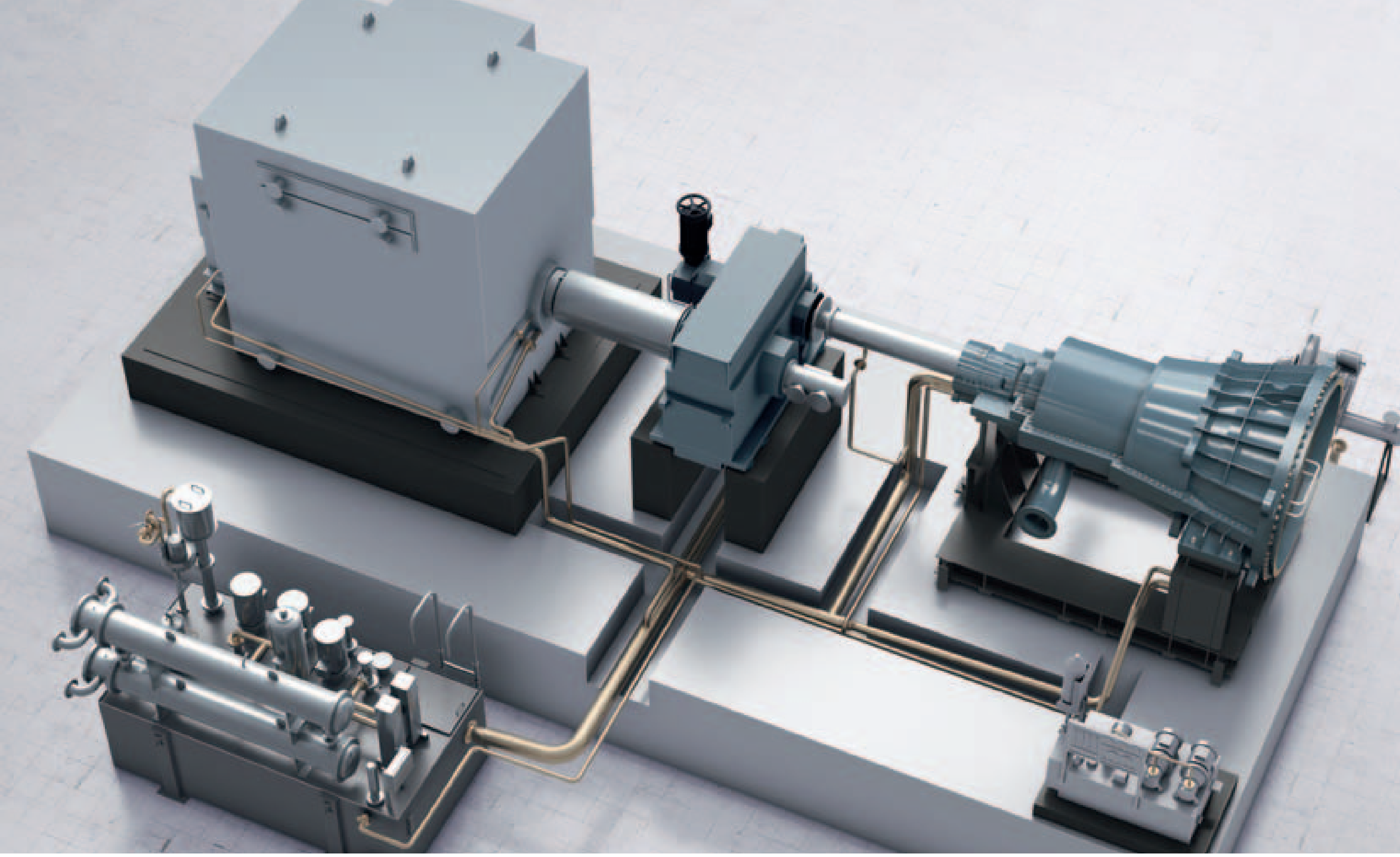
The turbine combines the proven turbine casing and bearing pedestals of the Siemens SST-300 and SST-400 as well as the steam turboset accessories (gears, generator, base frame) with the geothermal steam path and moisture removal features derived in the after-market that have many years of successful operating experience.

SST-400 GEO

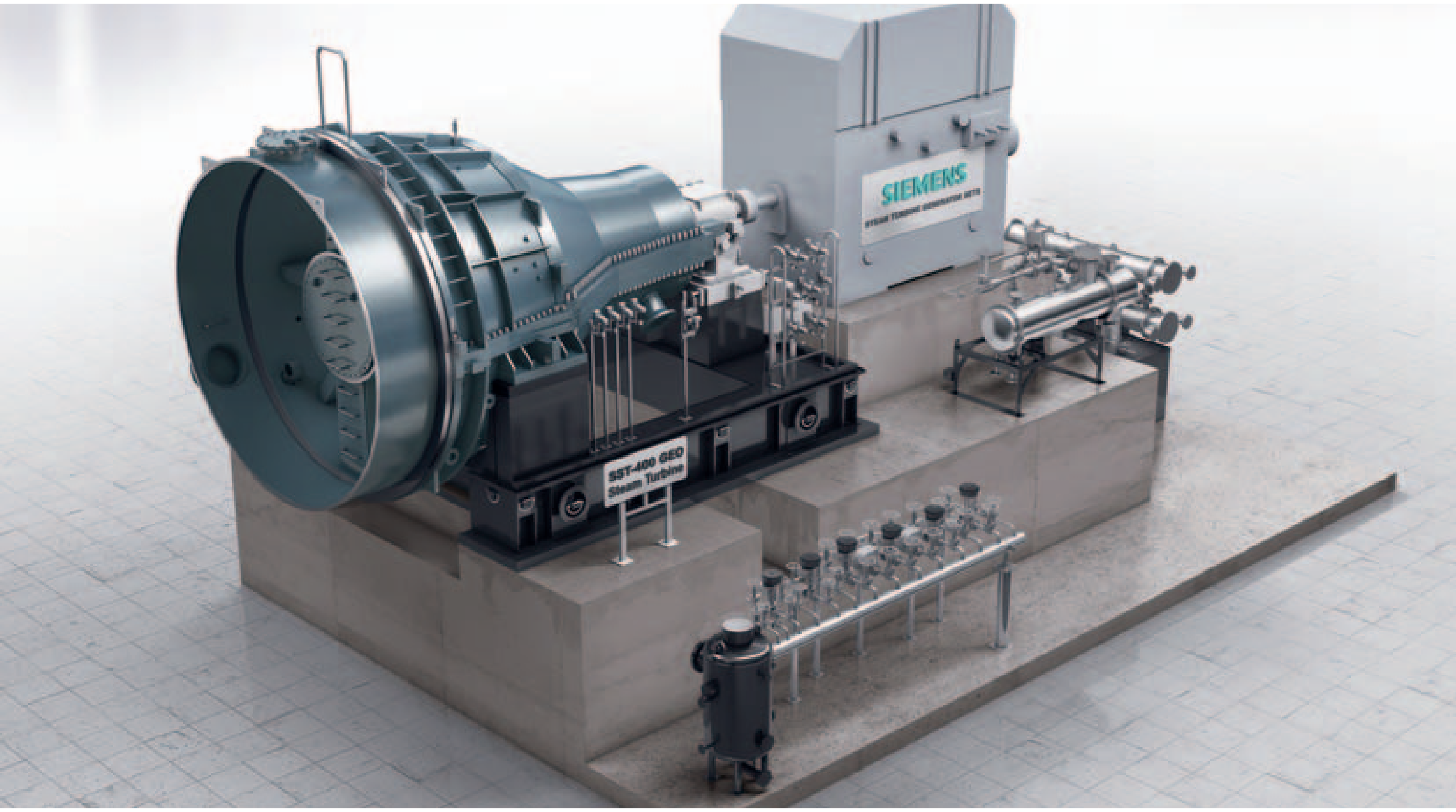
- Power output: **Up to 50 MW** (condensing)
  Up to 40 MW (non-condensing)
- Frequency: **50 or 60 Hz**
- Turbine speed: **max. 6,000 rpm**
- Inlet steam: **Up to 250 °C, (482 °F)/ 15 bara (220 psia)**
- Exhaust steam: **Up to 0.4 bara** (condensing)
  Up to 1.4 bara (non-condensing)

SST-400 GEO Design Features

- Robust impulse design and generous clearances result in sustained efficiency and high reliability
- Proven steam path for optimized reliability with low steam parameters
- Ground floor installation with axial exhaust
- Package solution for faster installation and commissioning
- Advanced highly effective moisture removal techniques
- Ease of maintenance due to inlets in casing lower half

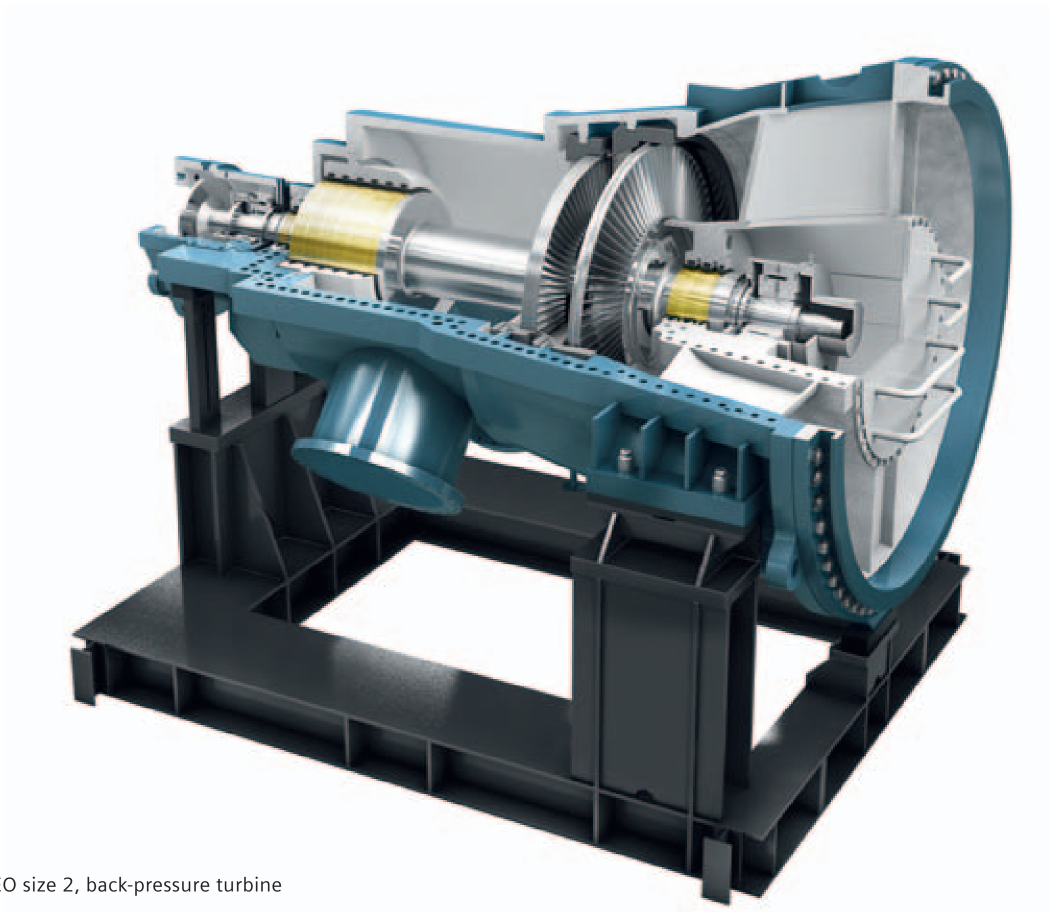


SST-400 GEO size 2 geared drive for condensing and non-condensing application range



SST-400 GEO size 4 direct drive for condensing application range

SST-400 GEO Core Design

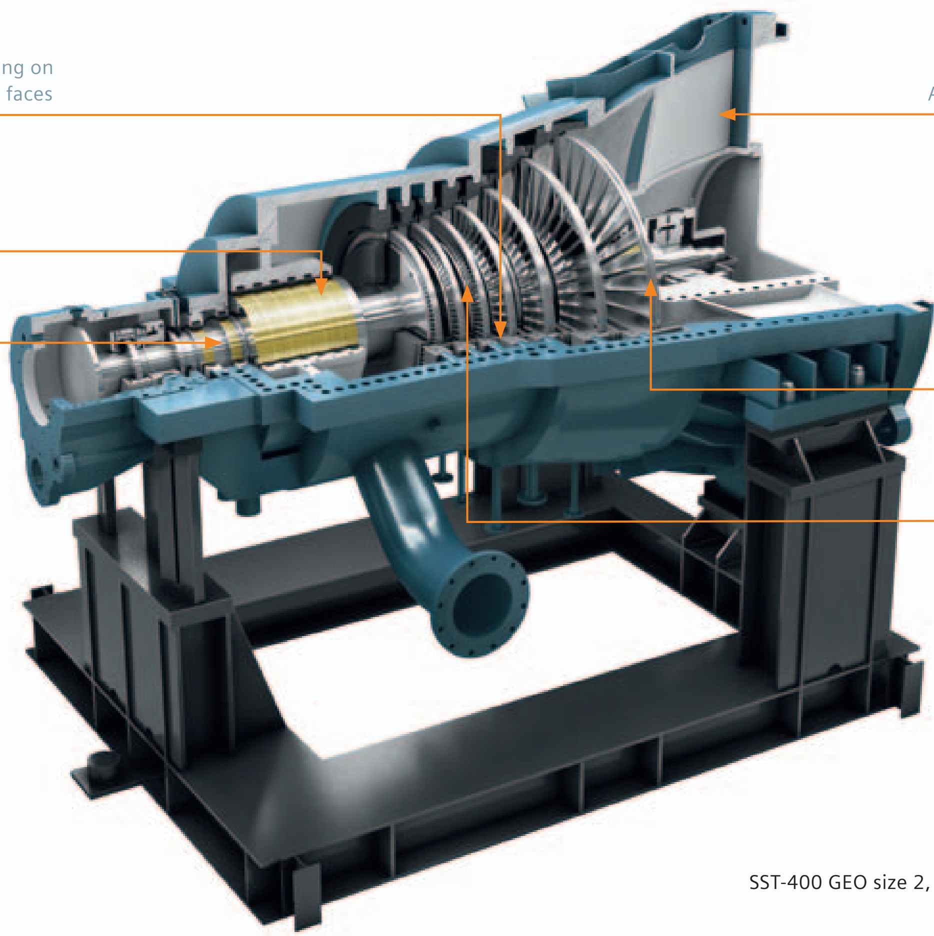


SST-400 GEO size 2, back-pressure turbine

SST-400 GEO Rotor Design

- Monoblock, solid rotor construction
- 2Cr (12Cr, X-5 optional) rotor material for increased corrosion resistance and high impact strength at exhaust temperature
- Modern low stress rotor fillets for geothermal applications
- No steam balance holes to minimize corrosion related cracking risk in condensing applications
- Coating on balance piston, gland steam and interstage seals for increased erosion protection
- Field accessible rotor balance planes

SST-400 GEO Core Design



SST-400 GEO size 2, condensing turbine

SST-400 GEO Casing Design

- Pressure up to 15 bara (220 psia)
- Temperatures up to 250 °C (482 °F) – including superheat
- Design for condensing and non-condensing units
- 309L stainless steel inlay at diaphragm steam seal faces & horizontal joint
- Two inlets in lower half of casing

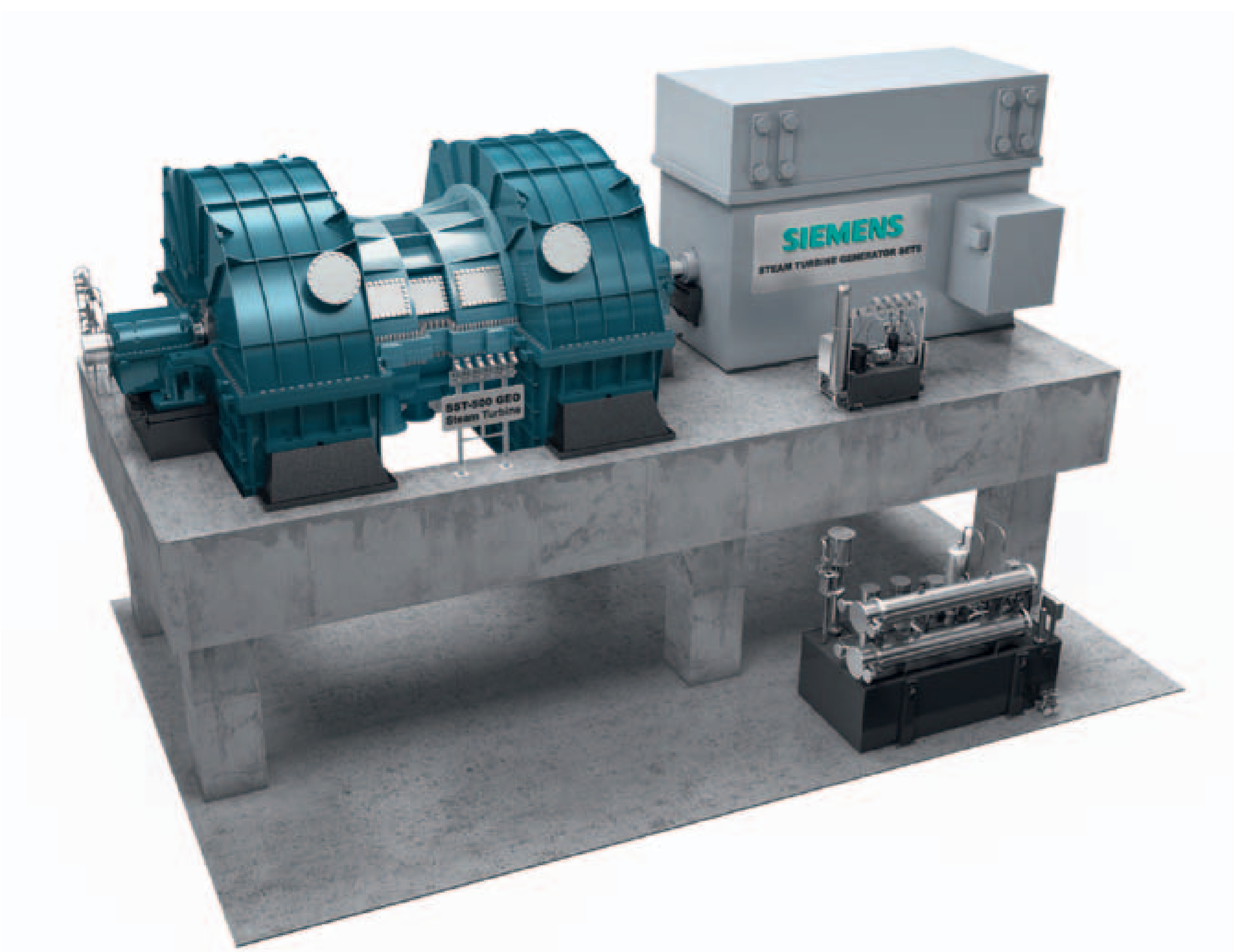
SST-500 GEO

The SST-500 GEO is a derivative of the SST-500, which is a single casing, double flow condensing turbine, especially designed for low steam parameters. The turbine is ideal for the handling of large steam volume flows of main supply and – for dual flash applications – admission steam over a wide range of power.

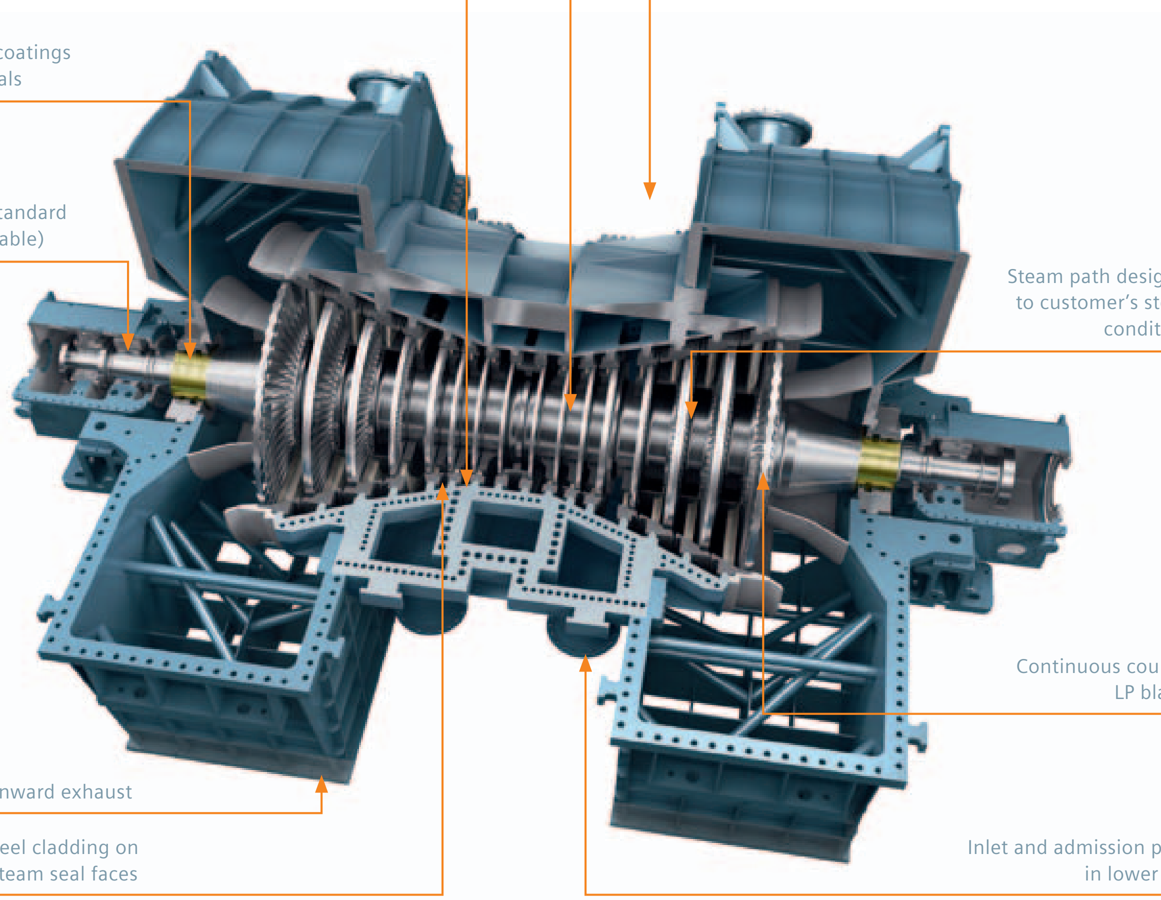
SST-500 – Design Features

The SST-500 GEO turbine is designed with two main steam inlets. The steam flows into the turbine by means of two tangential inlets to equalize thermal and blade stress. For dual flash applications, one or two additional steam inlets per flow are realized for admission steam with lower parameters.

Depending on inlet conditions (pressure, volumetric flow), the turbine will be provided with one or two main stop and control valves for main steam, and up to four main stop and control valves for admission steam. All valves are installed in the steam inlet pipes. The SST-500 GEO turbines are designed for installation on a turboset foundation.



SST-500 GEO Core Design

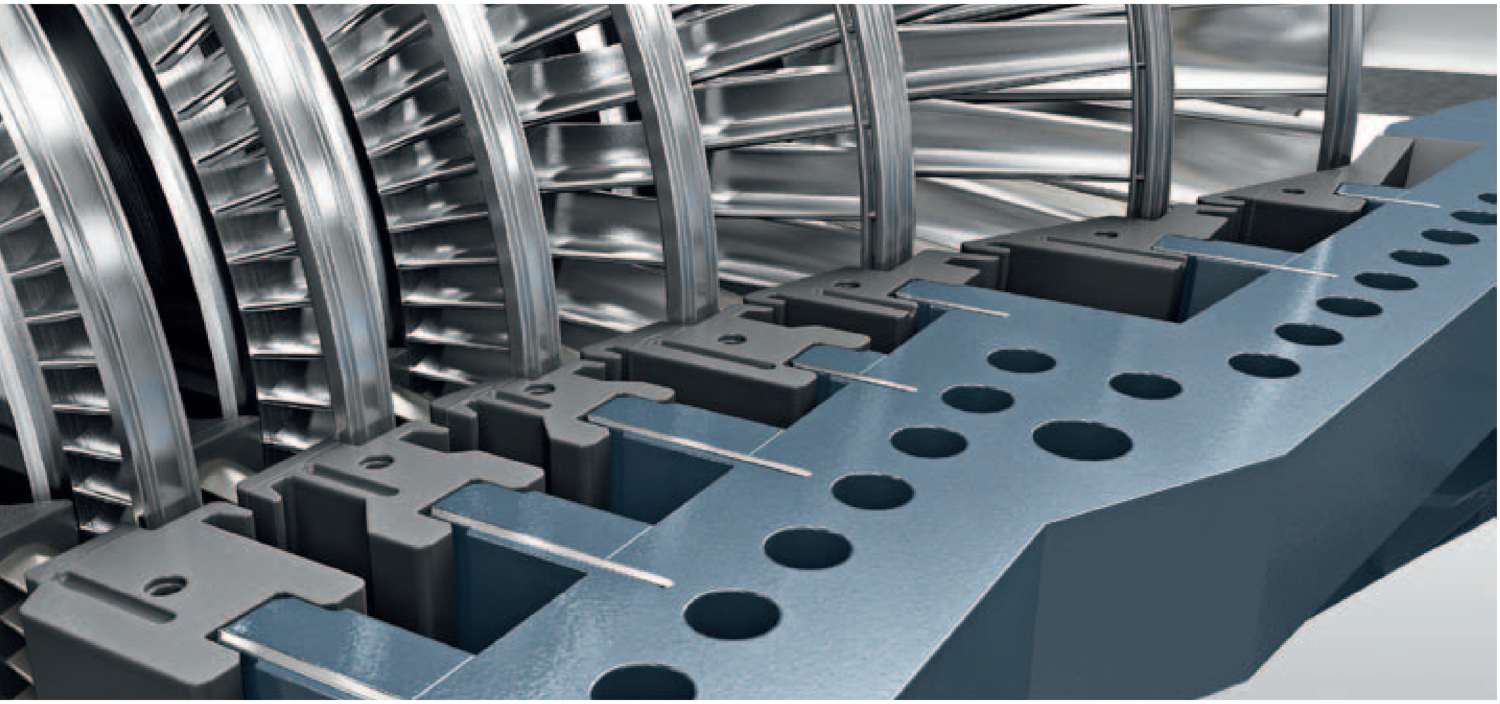


Design Features

- Robust impulse design and generous clearances result in sustained efficiency and high reliability
- Proven steam path for optimized reliability with low steam parameters
- Table top installation – down exhaust (up could be possible)
- Advanced highly effective moisture removal techniques
- Ease of maintenance due to inlets in casing lower half

SST-500 GEO

- Power output: Up to **120 MW** (50 Hz)
  Up to **110 MW** (60 Hz)
- Speed: **Direct drive** (3000/3600 rpm)
- Inlet Steam: **Up to 250 °C, (482 °F) / 15 bara (220 psia)**
- Exhaust steam: **Up to 0.4 bara** (condensing)



Siemens Geothermal Turbine Design

Due to the demanding geothermal conditions special adaptions have been made to the steam turbines:

Custom Steam Path Design

Each turbine is designed uniquely for the particular resource conditions by adapting the blade path within the standardized casing. At the same time, the inlet nozzles and emergency and control valves are sized to suit the steam pressure and mass flow.

Blades

Modern airfoil impulse type blade shapes are adopted for best overall turbine efficiency. Furthermore, modern blade roots reduce the peak stress and resist stress from corrosion cracking. Integral, continuously coupled shrouds lower the alternating stress and help to resist corrosion-assisted fatigue. On the last stage(s) laser applied Stellite®, brazed Stellite® strips or flame hardening techniques are utilized on the blade leading edge to resist erosion. Widely spaced nozzles are applied to minimize the effect of scaling from deposits and risk of blockage.

Materials

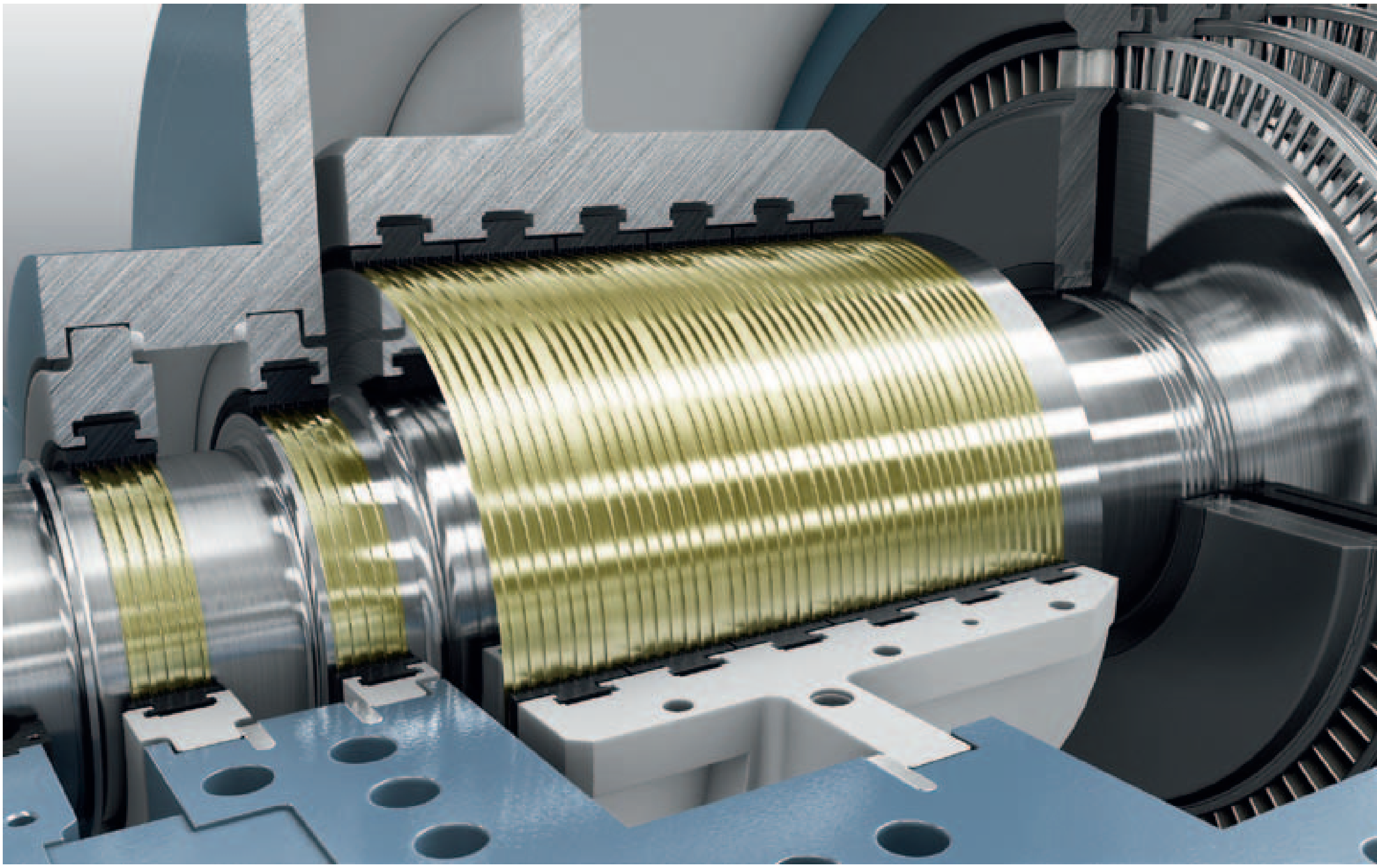
The materials of all steam path components are specifically selected according to the particular conditions and the specific steam chemistry of the application to resist corrosion and corrosion-related cracking.

Valves

High performance butterfly control and trip valves are designed for the specific geothermal steam environment. These components are an integral part of the control, monitoring and safety system that utilize the SIMATIC S7. This operator-friendly control easily interfaces with the plant distributed control system (DCS). These systems have been designed to meet the demanding European and international safety standards and leverage the strength of Siemens control systems.

Advantages of Siemens Geothermal Steam Turbines

- Available in condensing and non-condensing variants
- Non-condensing turbines suitable for atmospheric exhaust or ORC bottoming cycle
- Designed for harsh conditions
- Suitable for air- and water-cooled plants
- Tailored to customer requirements
- Design tools and adaptations have been proven on a wide range of applications



Siemens Moisture Removal System

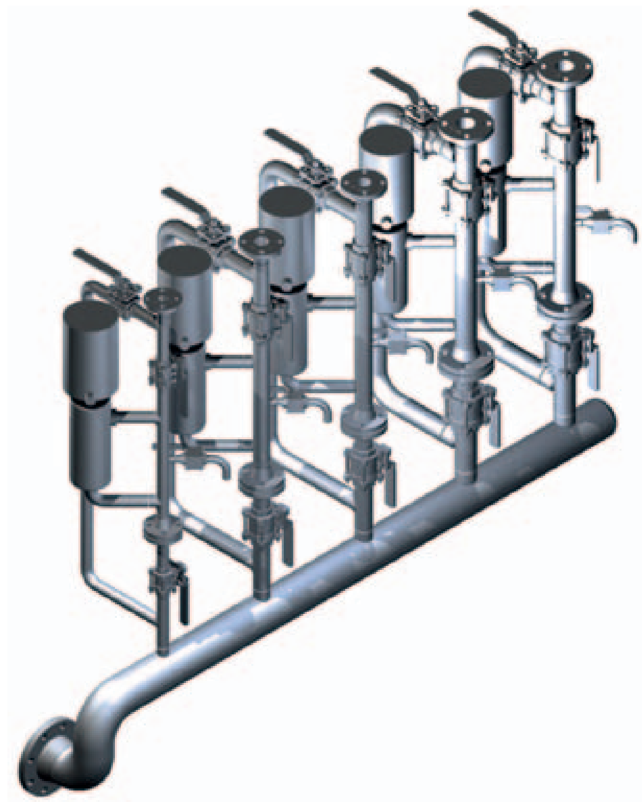
Geothermal steam generally enters the turbine at a state of saturation. As this steam expands through each stage, moisture droplets begin to form. Ideally, the liquid droplets should be removed from the turbine at each stage in order to prevent impingement on the rotating blades as well as improve overall turbine efficiency.

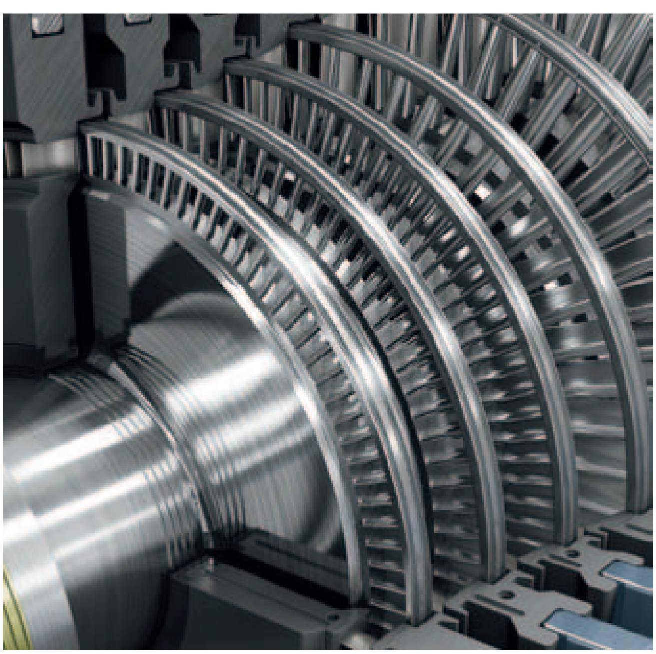
The total Siemens Moisture Removal System (MRS) is comprised of highly advanced individual stage moisture separators coupled with an optimally designed orificed drain system. This drain system is designed to remove the maximum amount of water from each stage, yielding a reheat effect for continual maximum turbine efficiency.

Drain System

The design includes external orifices which ensure proper moisture removal. Real-time feedback of any potential drain system blockage through the use of a float switch system and visual alarm arrangement is also a standard feature, as is serviceability of the orifices. An on-line serviceability arrangement allows for continued operation during servicing of the orifices. On-line water washing is also possible using a built-in by-pass loop.

With the Siemens Moisture Removal System, turbine efficiency is maximized and droplet impingement is minimized.





Stage Drain System for Moisture Removal

- Diaphragm moisture separators at each stage
- Centrifuged water collected/removed
- External stage specific orifice plates meter flow
- Isolation/by-pass valves for on-line maintenance
- Oversize piping for online water wash and clog prevention at turbine
- Efficiency optimization based on reheat effect
- Immediate feedback via float switch arrangement
- Single block and bleed for safety

Machining of geothermal steam turbine casing, Siemens facility Goerlitz, Germany.

Proven Technology

Development of a geothermal steam turbines portfolio has been a joint project of two units of Siemens – Siemens Siemens Energy Power Generation Steam Turbines, world leader in turbine technology, and Siemens Energy Service, offering comprehensive services for gas and steam turbines, generators and compressors.

Siemens Experience

Siemens has more than 20 years experience in geothermal innovations. In 1992 the company repaired its first geothermal rotor wheel weld. In 1996, they redesigned their first geothermal rotor blade and wheel. 1997 the first geothermal weld repair with 12% chrome steel took place. The first geothermal full steam path upgrade followed in 1999. The first SST-400 GEO steam path was installed in 2000.

History in Geothermal Innovations

- 1992 First geothermal rotor wheel weld repair
- 1996 First geothermal rotor blade/wheel redesign
- 1997 First geothermal weld repair with 12% chrome steel
- 1999 First geothermal full steam path upgrade
- 2000 First SST-400 GEO steam path installation
- 2010 First SST-500 GEO steam path installation

Geothermal Power Plant
Milford, Utah, USA

Blundell Plant

The 26 MW condensing turbine uses a complete SST-400 GEO turbine, installed by Siemens Energy Service. This steam path has been operating successfully for over 12 years. The steam path used here is the model for the SST-400 GEO and is reference unit for this frame. The original casing was replaced with a design which has the same features as the SST-400 fabricated casing. This first geothermal casing was completely machined and validated at the Siemens manufacturing facility in Goerlitz, Germany.

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