Highly efficient biomass plants thanks to reheat solutions

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Abstract

With the rising prices of biomass used as fuel, the demands placed on the efficiency of a power plant are also increasing. High efficiencies allow for economical operation of the power plant and competitive power generation compared to electricity production from conventional energy sources. Industrial steam turbines with a power output of up to 250 MW and live steam parameters of up to 565 ° C / 165 bar achieve maximum efficiency with a double casing reheat solution. Employing this configuration, Siemens installs a benchmark on the biomas market with a high-speed steam turbine, which is coupled to the generator by a gearbox. A second steam turbine directly drives the generator.The paper describes typical configurations for customers operating biomass plant and for those interested in a highly efficient biomass plant operation.

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Biomass power plants on their way to baseload power generation

Biomass power plants provide seven percent of the global industrial heat demand, 2.8 percent of the global residential heat demand, and 2.4 percent of the global electricity demand.

These numbers are yielded from of a steadily growing trend that has been observable for over ten years. In 2016 alone, the share of biomass-fired energy production facilities installed worldwide increased by 6 percent. That this trend will continue in the coming years is hardly to be doubted. Worldwide, combustion is by far the most commonly applied bioenergy technology, either as co-firing or as a 100 percent biomass full-firing. A biomass co-firing business model can help coal utilities to achieve their environmental targets (below 550 gCO2/ kWh). Because biomass is one of the most capital-efficient transitions from coal to full renewables, it offers one possibility for large utilities to comply with renewable targets while using their existing assets. The implementation in large scale coal power plants with low risk is possible over the short term. Indeed, there is an increasing trend toward using biomass power plant to deliver baseload power.

Biopower on the raise

In principle, a distinction must be made between heat generation and power generation. With regard to global heat generation, other renewable energy sources also exhibit a clear upward trend. Among these renewable energy sources, bioenergy – i.e. energy derived from the conversion of biomass where biomass may be used directly as fuel, or processed into liquids and gases - has the largest share for further energy conversion at 90 percent. Solar thermal energy contributes about eight percent and geothermal energy contributes about two percent to global heat supply.

However, global electricity production from biomass also increased by six percent. With an installed 112 GW power capability, bioenergy increased to 504 TW / h. In 2016, from which the above figures are derived, the US accounted for the largest share, at 68 TW/h, followed by China (54 TW/h), Germany (52 TW/h), Brazil (51 TW/h) and Japan (38 TW/h)A broad range of wastes, residues and crops can be used as feedstock for power generation facilities to produce heat, electricity, and transport fuels. We see biomass as any organic, i.e. decomposable, matter derived from plants or animals available for energy conversion. Biomass includes wood and agricultural crops, herbaceous and woody energy crops, municipal organic wastes, as well as manure. Biomass is a cross vertical term, which covers various technologies and markets. We distinguish between edible biomass

as is used for further processing in the palm oil, sugar industry or ethanol production, and non-edible biomass, as is processed e.g. in the pulp and paper industry and by which we mean solid biomass, agricultural waste and also municipal solid waste.

Combined heat and power solutions become financially attractive

Providing a future-proof source of electricity and contributing to lower CO_2 emissions, power produced from biomass is becoming increasingly economically viable. The interests of operators and investors, on the one hand, and those of utilities and grids, on the other, are becoming more closely aligned. This is because ensuring a stable power supply as well as the financial success of the power plant are common goals.

Typical decision criteria for players in the biomass business are first and foremost the return of investment (ROI) and the payback period. Steam turbine performance, being essentially the heart of power generation in a biomass plant, is crucial for a viable payback. Flexibility also plays a major role and centers around questions of grid support, thermal flexibility, and serviceability.

The planning phase requires tight coordination, technical expertise and convincing force. Siemens can support independent power producers with technical consulting, financial services, and by its reputation and references. Acquiring the PPL and the construction approval are the main challenges for WtE projects. Here, Siemens supports and interacts with all involved parties (Fig. 1).

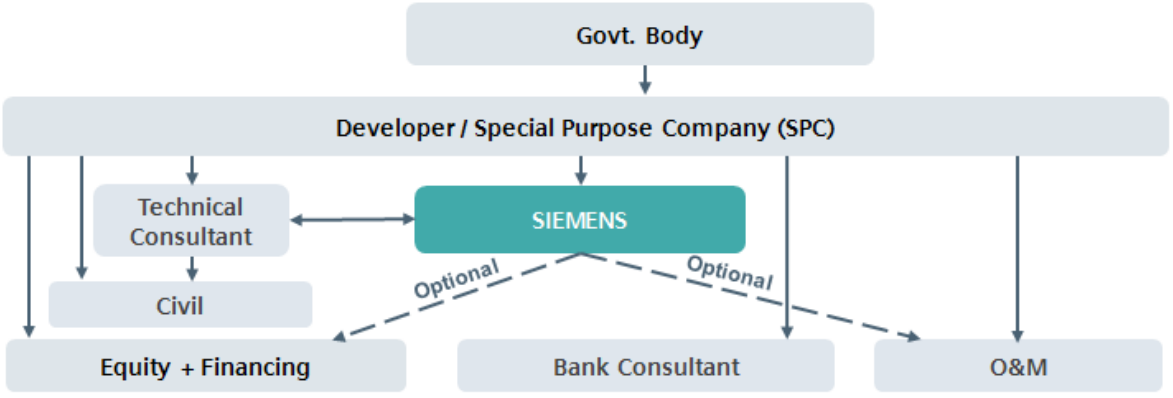

Figure. 1
Siemens supports independent power producers with technical consulting

Being active in the biomass business for decades, Siemens has extensive experience when it comes to finance consulting, consulting service in the conception phase for the whole power plant (selecting the right concept, optimization of the heat cycle for the whole

power plant, and support in preparing the specifications and selecting the suppliers) and of course the core-business itself, the turbo-set (steam turbine with extended scope and generator).

Steam turbines in biomass-fueled plants

The steam turbine-generator set plays one of the major roles in any biomass plant. Its performance accounts for the efficiency of the plant and heavily influences the ROI. In the long run, low maintenance and service costs offset the initial costs over the entire lifetime, coupled with the efficient use of the fuel, which further lowers the overall costs. With reliable equipment backed by comprehensive servicing and maintenance options, Siemens optimizes the degree of availability and thus maximizes the amount of revenue from the grid.

Customized industrial steam turbines

As a market leader for industrial steam turbines, Siemens offers a comprehensive range of reliable and versatile steam turbines for the power output range from <1 to 250 MW. Siemens industrial steam turbines are designed for easy constructability, serviceability, fast startup and economical operation. Siemens steam turbines have been installed in over 200 biomass-fueled plants worldwide with a proven record of applicability and availability and offer a long life cycle thanks to reliable equipment.

Siemens references show the that most biomass plants worldwide are in use within a capacity range of 5 to 115 MW. Inlet steam is typically available with 65 to 100 bar and up to 520°C, highly efficient biomass plants trending in Asian countries use inlet steam of 140 to 170 bar and 540 ° C and gain higher power output of more than 100 MW. Siemens industrial steam turbines are in operation as single (for the typical) or dual-casing (for the highly-efficient) solution (Fig. 2).

Frequently customers also require steam extraction especially in combiniation with district heating applications or when the production processes, e.g of a sugar mill, which is energy-independent by using its bagasse as fuel, uses process steam. Depending on the type of steam turbine used, the above-mentioned models allow for several steam extraction with steam temperatures of up to 72 bar at 400 ° C.

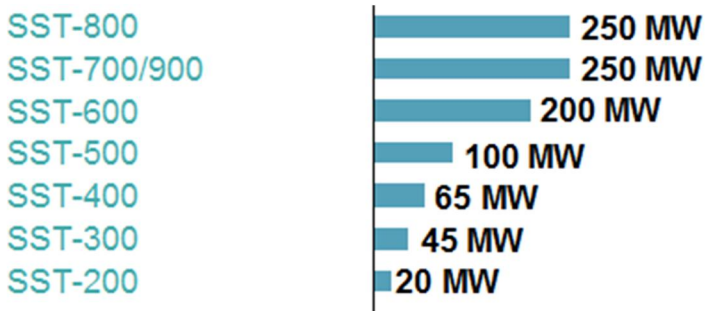

Figure 2:
Steam turbines are typically used in biomass applications

The Enhanced Platform design – Efficiency is key in many biomass plants

Numerous components influence the efficiency of a steam turbine: the design of the blades is the most crucial point. Here the industrial steam turbines profits from the years of experiences out of the utility steam turbines used at the big CCPP or big fossile steam power plants. The highest efficiency optimized blades design used at this business, which is driven by highest efficiency, are the heart of the industrial steam tubines.

The diversity of the biomass driven industry and their requirements leads to the necessity for a flexible design. This flexibility in industrial parameters which is primarily given by the properties of the biomass fuel requires products with capability to match a wide range of steam parameters and variety of controlled or uncontrolled extraction needs, as well as the ability to adapt to the wide range of either backpressure or condensing application.

Additinaly to this biomass driven requirements the increasing amount of renewables power capacity leads to changes of the operational flexibility needs. The variation in regular operation as well as the need to increase cycling capabilities is increasing and leads to product and design needs which reliably meet these requirements.

All those different design requirements are covered by the “Enhanced Platform” design which is the base for all industrial steam turbines in the power output range between 2 to 250MW.

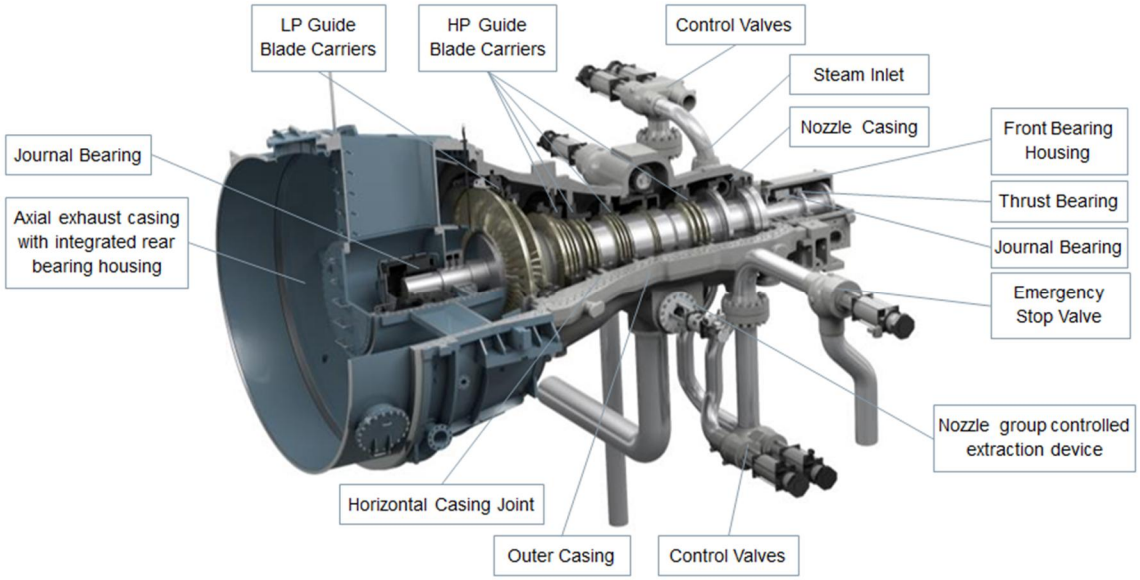

Figure 3:
Example of a SST-600 with a controlled extraction and axial exhaused

The very succesfull industrial steam turbine used as a sigle casing solution especially for non reheat applications is the front inlet steam turbine platform called SST-600 (Fig 3). The strength of the design is the full flexible set up of the outer casing which is used for very customer specific requirements. The semi-standardized steam trubines families SST-200, SST-300 and SST-400 are the most succesfull representatives of the SST-600 platform especially at the biomass business with moderat biomass fuel conditions. The benefit of this semi-standardized product is, on the one hand, highest efficiency due to the customized blade part which covers all customer needs, on the other hand the standardized components such as outer casing, base frage and all necessary systems, which were developed as a very compact, robust and efficient steam tubine systems with a very short delivery and/or installation time due to a plug and play ability (Fig 4).

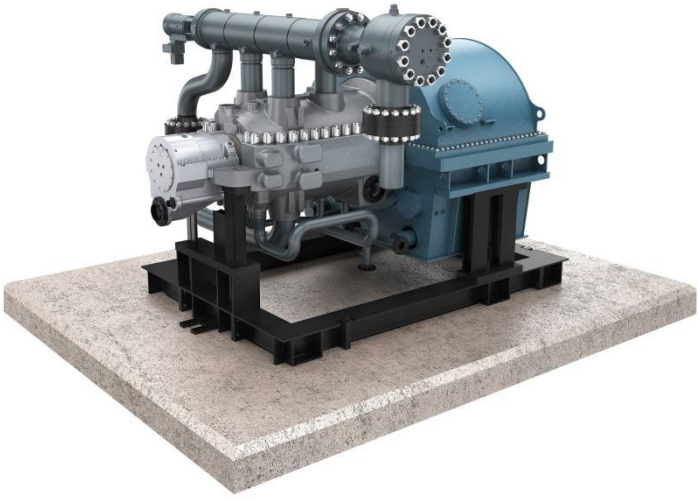

Figure 4:
SST-300 pre-configured

Reheat solutions for biomass application

In additional to the medium power density biomass fuel, the biomass fuel with highest power density like “wood pellets” defines another important part of biomass business. To get the highest ROI by using this high level fuel, the request on highest efficiency out of the steam water cycle is a must. The reheat application is dominating this part of biomass business. The live steam is routed through a high-pressure (HP) turbine, returned to the steam generator to increase the steam temperature, afterwards routed through an immediate and low-pressure (IP/LP) turbine. Raising the temperature of steam that is moving from an HP turbine to an LP turbine generates higher output for same amount of fired fuel (Fig 5).

A dual casing reheat solution with SST-300 or SST-400 combined with SST-600 steam turbine has a long tradition at this segment. The high reliable and proven technology is a reliable part of the biomass plant with a short delivery time and very fast installation time. The pre-defined casing configurations (called fixed casings) consists of a fast-spinning high-pressure backpressure turbine and a combined intermediate/low-pressure condensing turbine connected with a generator. This fixed design enables short manufacturing periods, fast ex-works delivery and makes these turbines much more cost-effective. To deliver a double-casing reheat solution, thermodynamic optimization of the blade path was first improved and various turbine topologies examined and compared, always with a view to the feasibility of turbine design and construction, the level of efficiency, and costs.

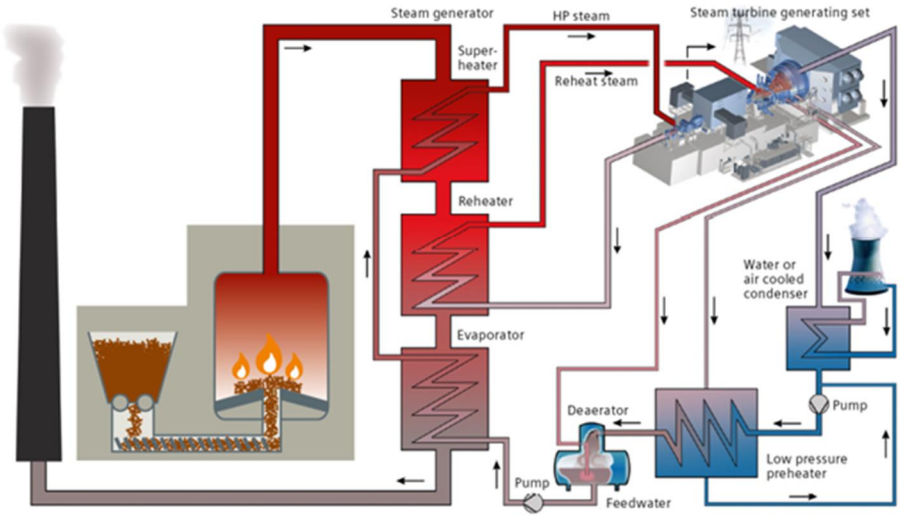

Figure 5:
Steam reheat system

Single casing solution

Other members of the reheat solution family are the single casing reheat steam turbines starting with SST-400, SST-600 up to SST-800 SCRH.The compact design combined with most modern technology allows the inlet and reheat steam temperature up to 540°C. The state of the art blade and sealing technology make this steam turbine very atractive for power output up to 65 MW. The tailor-made steam turbine design allows controlled extraction of the steam, which is fed back into the cycle for reheat purposes and then re-admitted to the steam turbine (Fig 6). The innovative turbine topology in the SST-800 with two “head-to-head” inner casings in combination with a newly designed secondary steam system allows for a significantly shorter distance between bearings, which not only has a positive impact on price but also offers rotordynamic and thermomechanical benefits.

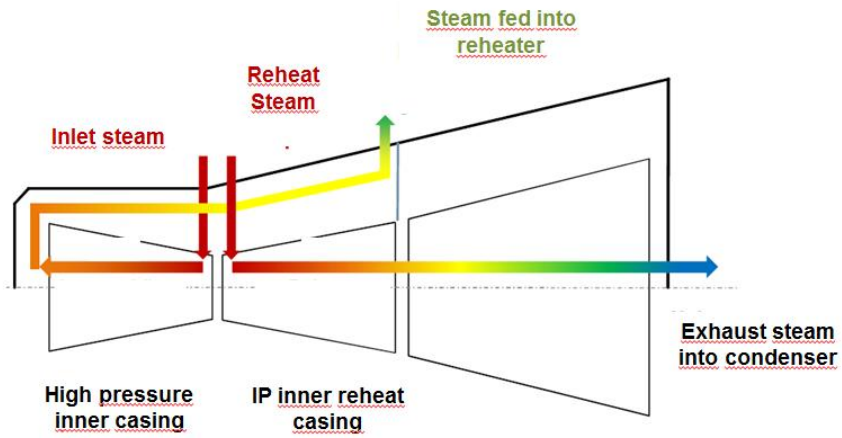

Figure 6:
Single casing reheat solutions

High efficient double-casing solutions

With the SST-700/900 steam turbine the highest reheat temperature can be transformed into pure energy. This dual casing solution combines the benefits of both geared and direct driven steam turbines to get the maximun on efficiency out of the steam.

The SST-700/900 configuration is designed as low-level arrangement. This keeps the foundation simple, reduces the size of the turbine building, and simplifies the piping systems and all other related arrangements. The design consequently also reduces initial costs significantly (Fig 7). In combination with the highest efficiency is this configuration the best possible choice for high efficiency biomass projects.

Furthermore, thanks to the modular design, the components developed can be used not only for biomass projects but in other areas as well. CSP and conventional coal-fired generation profits from this invative arrangement.

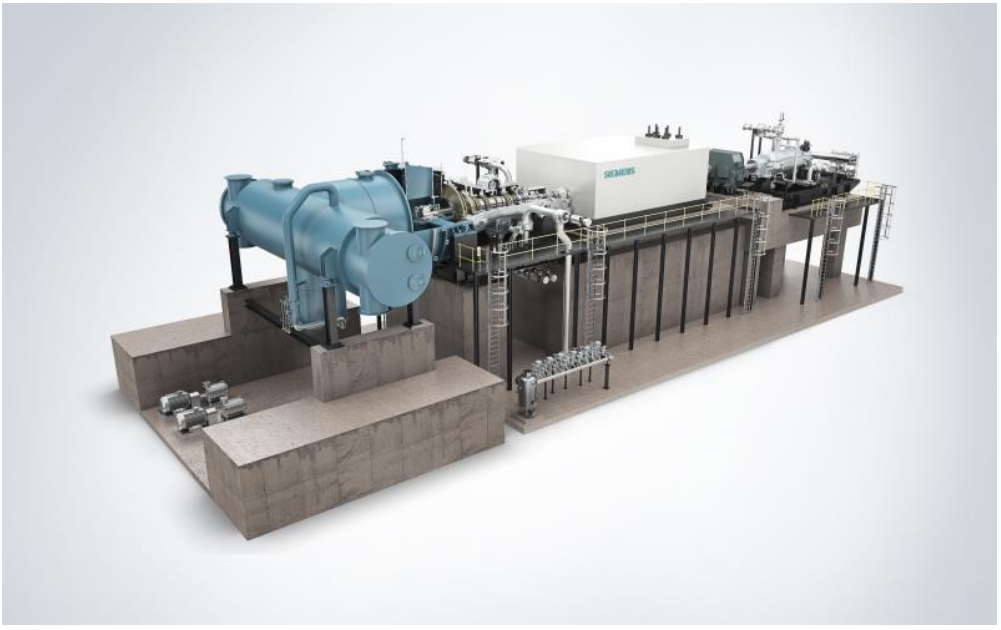

Figure 7:
Double-casing reheat solution, head-to-head set up

Summary

Reheat solutions significantly increase the overall efficiency of a biomass plant and are therefore an optimal solution to produce more energy without having to use more fuel. Siemens offers single-casing reheat solutions up to 65 MW and dual-casing reheat solutions for higher steam temperatures and highest efficiency solution. A standardized package of highest efficiency solution steam turbines that follow the design philosophy Enhanced Platform offers an economical solution for biomass applications.This fixed design enables short manufacturing periods, fast ex-works delivery and makes these turbines much more cost-effective.

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