BIOMASS LOOKING FOR EFFICIENT UTILIZATION –THE REHEAT CONCEPT

Jaroslav Lahoda
Olaf Arndt
Walter Hanstein

Siemens Power Generation (PG)

Brno, Czech Republic & Görlitz, Germany

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Abstract

Through the Kyoto protocol and its country-specific targets, power producers are strongly driven towards CO2-reducing solutions such as biomass energy production. Germany encourages this through new energy legislation, EEG (Renewable Energy Law), which gives higher subsidies for high-efficiency, CO_2-reducing power generation. This has led to increased investment in biomass plants. The impact of the high efficiency requirements has enabled new technology to enter this market segment.

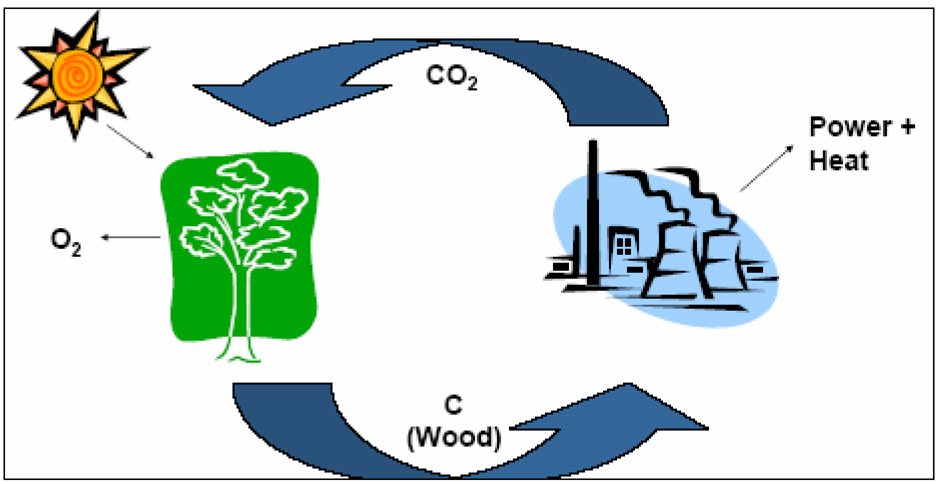

Figure 1: biomass power plant – a closed carbon cycle

Before the new energy legislation was implemented, only wood shavings/straw etc. was economical for use in biomass energy production; today the more expensive fresh wood is used as well. A typical boiler fired with fresh wood generates high steam parameters, mainly high temperatures (480-540°C) where reheat solutions are used to further increase the efficiency of the power plant. The reheat concept is based on live steam run through a high-pressure (HP) turbine. Before entering the low pressure (LP) turbine, the steam is returned to the steam generator to increase its temperature to the live steam parameters (pressure remains as is). Because of the high temperatures necessary for this process, Siemens PG has developed a standard dual-casing reheat concept to fit this new market requirement. The advantage to the power producer is that plant efficiency can thus be increased by as much as five per cent.

At the Bischofferode plant in Thüringen (Germany), Stadtwerke Leipzig uses this concept for a new 20MW greenfield power plant together with a fluidized bed boiler using fresh wood fuel.

The high live steam parameters of 128bara/532degC and the reheat parameters enable an efficiency otherwise unattainable. The solution also maximizes the subsidies set by German legislation

Siemens continues to develop solutions for this market segment. This paper will present the new technical requirements as well as their solution and our experience.

Introduction

During recent years, the development of biomass utilization technologies has been increasingly needed and focused upon as an instrument in the prevention of the global greenhouse effect. In environmental terms, biomass is an extremely valuable source of energy, since it is defined as a CO_2-neutral fuel alternative and a renewable energy source.

Energy recovery from agriculture and forestry residues is a prime focus within this application of energy production. Since the available resources of biomass for producing energy are limited, maximum utilization of the fuel is very important. This means that the technologies to be applied have to be efficient, reliable and cost-effective.

Biomass-fuelled Combined Heat and Power (CHP) plants producing less than 20 MWe are usually based on a Rankine cycle with steam superheating. In this cycle, the steam after the boiler is superheated at constant pressure to a temperature higher than the saturation point

Biomass-fired steam cycle plants typically use single-pass steam turbines. However, during the past decade, efficiencies and more complex design features which were previously characteristic only of large-scale steam turbine generators (> 200 MW), have been successfully transferred to smaller capacity units. Today’s biomass designs with fresh wood include reheat and regenerative steam cycles.

Development of the technology towards higher efficiency

The base case technology is a commercially available, utility operated, stoker-grate biomass plant constructed in the mid-1980's, which is representative of modern biomass plants with an efficiency of about 23%. By the year 2000 the plant efficiency of the stoker plant had increased to 27.7% through the use of a fuel drier. Plant efficiency can be further increased to 32.5% with grate type steam generators and about 35 % with fluidized bed type steam generators due to reheat cycles.

Customer Requirements

Driven by economic considerations and the need for uninterrupted power supply, customer requirements are the same the world over, namely high efficiency, high availability and reliability and easy maintainability.

High efficiency: high efficiency is influenced by the design of the steam water cycle and the efficiency of the key components (combustion system, steam turbine, condensing system.

High availability and reliability: by using proven components the reliability, i.e. the mechanical integrity, of the machinery is ascertained, and this in turn assures the owner of a higher availability of his plant.

Maintainability: The turbines are configured according to a modular construction based on proven standard design units. This makes it easy to access, remove or replace the modules for regular maintenance.

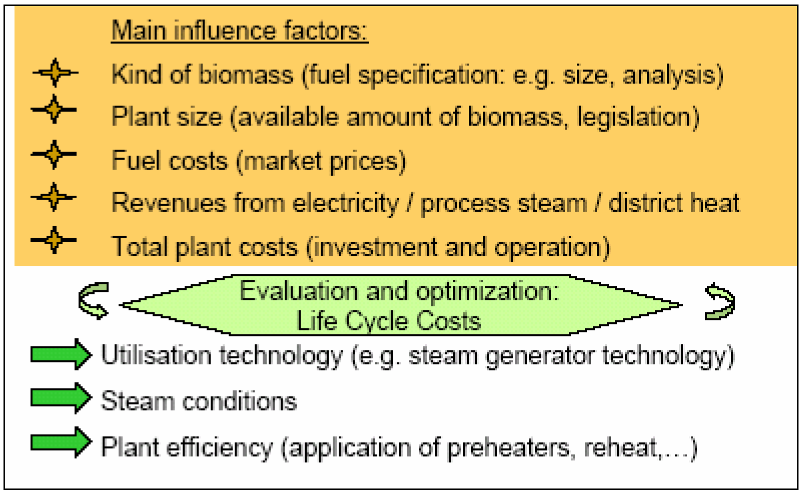

Figure 2: Factors affecting choice of plant

Steam reheating

Reheating is common a means to improve plant efficiency in larger power plants, and has cently also been used in smaller power plants.

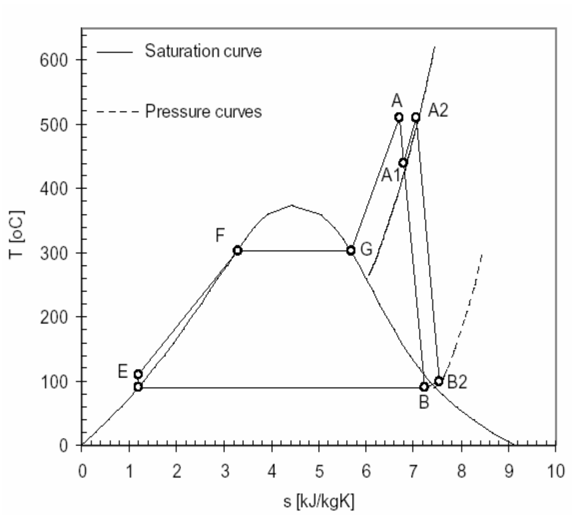

Figure 3:T,s diagram of the steam reheater

The reheat concept is based on live steam run through a high-pressure turbine. Before entering the low pressure turbine, the steam is returned to the steam generator to increase its temperature to the live steam parameters (pressure remains as is). Usually the extraction pressure of the reheated steam is selected so that the steam can be reheated to the same temperature it had before entering the turbine. This makes it possible to use the same material both in a superheater and in a reheater.

The other advantages of reheat are that the heat is added to the steam cycle at a higher average temperature than to a non-reheat cycle. This improves the cycle efficiency and allows the steam turbine to provide a greater output for the same heat .There will also be less steam going to the condenser and therefore lower cooling water losses and smaller cooling system.. The moisture content in the LP turbine will be reduced if the steam is reheated after it has expanded through the HP turbine. This will increase efficiency and also minimize erosion caused by water droplets. The reheat cycle allows higher inlet pressure and/or lower exhaust pressure while retaining the moisture content at low levels. All these factors increase the steam cycle efficiency and lower turbine aging.

Example of efficiency improvements using reheat:

Non-Reheat Cycle
for a combined cycle power plant
Inlet pressure, bara/psia 131/1900
Inlet temperature, °C/°F 540/1004
Exhaust pressure, bara/psia 0.069/1.0
Exhaust moisture content 14.5%
Mass flow to condenser 100%
STG power output, MW 89.6
Total CC net power output, MW Base

Reheat Cycle
for a combined cycle power plant
Inlet pressure, bara/psia 131/1900
Inlet temperature, °C/°F 566-566/1050-1050
Exhaust pressure, bara/psia 0.069/1.0
Exhaust moisture content 7.5%
Mass flow to condenser 87%
STG power output, MW 92.6 (+3.35 %)
Total CC net power output, MW +3.25
(using the same GTG) +1.23%

Example of efficiency improvements using reheat:

Non-Reheat Cycle
for a biomass power plant
Inlet pressure, bara/ 135/
Inlet temperature, °C/ 535/
Exhaust pressure, bara/ 0.075 !
Exhaust moisture content 13.5%
Mass flow to the turbine, kg/s 48,14 !
STG power output, MW 49.9

Reheat Cycle
for a biomass power plant
Inlet pressure, bara/ 134,5/
Inlet temperature, °C/ 537-538/
Exhaust pressure, bara 0.1 !
Exhaust moisture content 7%
Mass flow to the turbine, kg/s 38,91 !
STG power output, MW 49

The Siemens steam turbine reheat solution

The reheat concept was conceived with the basic aim of providing the most efficient turbine solution at a competitive price for certain applications. Today’s typical power plant is expected to operate either in a steady base load condition, or as a frequently activated supplier of power, available on demand. Demands for frequent starts require attention to the basic mechanical design. Biomass power plants in Germany or Austria operate only under full load conditions for 8000-8760h/a because of the subsidies. This is why this concept is based on well proven steam turbines. For power output up to 60MWel Siemens PG recommends the SST-PAC 400 reheat turbosets and for higher power outputs over 60MW el, SST-PAC 800/600 reheat turbosets or the SST-PAC 700 are the recommended solution.

SST-PAC 400 reheat turbosets

With such references as:

Königs Wusterhausen	20 MWel, Germany
Bischofferode	20 MWel, Germany
Eberswalde	21 MWel, Germany
Simmering	23 MWel, Vienna /Austria

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SST-PAC 400 reheat turbosets are the most successful solution in the biomass power plant market with reheat cycles.

The SST-PAC 400 reheat turboset consists of geared high pressure and low pressure turbines from our standard range with the same speed and one gear for both. The generator is located, as for a non-reheat solution, behind the gear unit. Each turbine can be optimized for its specific requirements. The high pressure turbine is optimized for a small volume flow of high-pressure, high temperature steam, while the low pressure turbine is optimized for the large steam flow volumes at a lower steam pressure. The gear unit is located on top of the lube oil unit, between low pressure turbine and generator.

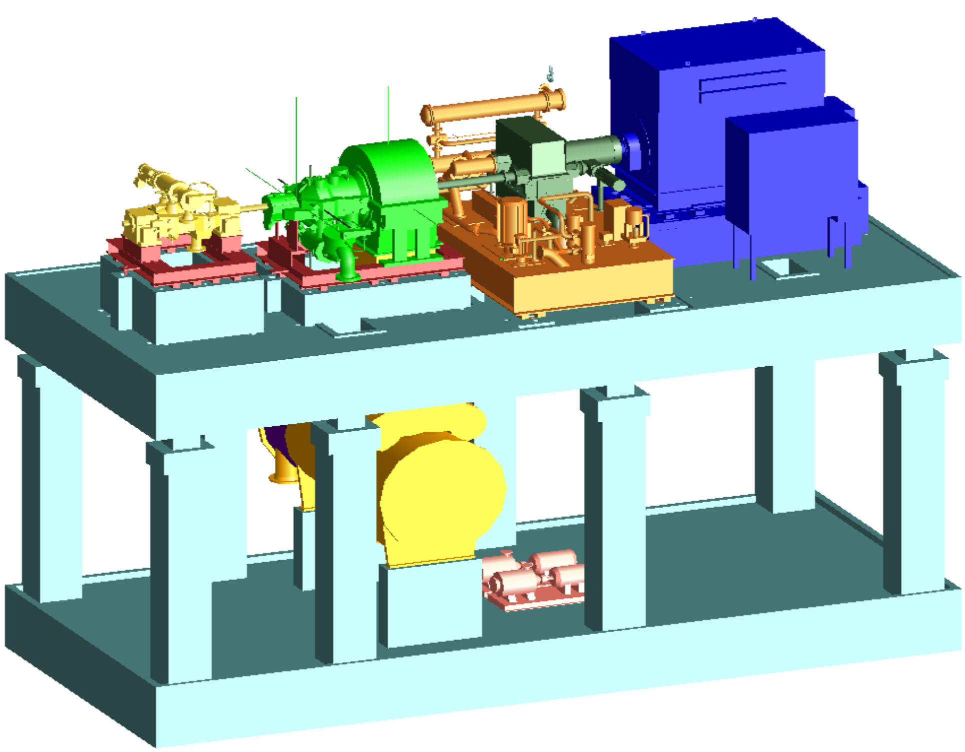

Figure 4: SST-PAC 400

SST-PAC 700

The SST-PAC 700 consists of a high speed, geared, high pressure (HP) turbine and a direct drive intermediate/low pressure (IP/LP) turbine from our standard range. The generator has dual end drive and is placed between the two turbine modules. Each turbine can be designed for optimized speed and for its specific requirements by separating the HP turbine from the IP/LP turbine. The HP is optimized for a small volume flow of high-pressure, high temperature steam, while the IP/LP is optimized for the large steam flow volumes at a lower steam pressure.

The SST-PAC 700 reheat STG unit can be adapted to a variety of steam data and different exhaust pressures by combining a standard frame size SST-700 high-pressure turbine with selected modular parts from the SST-900 IP/LP turbine series. This flexible design allows for internal and/or external steam extractions and enables cost effective solutions with high performance. Selecting an axial exhaust directly into an in-line condenser also enhances performance. An axial exhaust also results in reduced civil costs, since a low profile foundation is less expensive than a table top foundation. Building costs can also be reduced due to the lower height of the building.

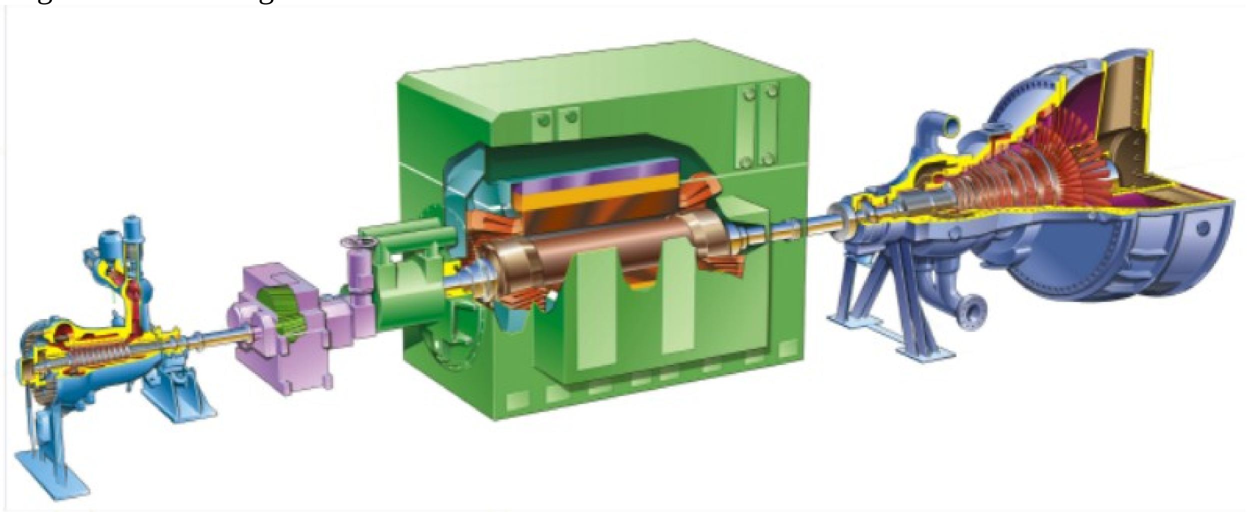

Figure 5: Reheat solution with SST-700 and SST-900 for larger plants

SST-700 HP turbine

The small and extremely thermoflexible HP turbine module, with its short bearing span, is of well proven, reliable and efficient barrel design. It has no horizontal casing flange and it can accept high pressure / high temperature steam, as well as quick load changes. It is ideal for the small volume flows of HP steam, as it operates at optimum speed and yields high efficiency. The geared barrel casing HP turbine modules have a very long and successful history operating alone as back pressure turbines or together with LP turbine module combinations to fit the volume flow requirements for non-reheat condensing applications. For reheat applications, the HP is combined with IP/LP turbine modules for solid fuel power plants and for combined cycle applications.

Technical data

HP Max inlet temp, °C / °F 585/1085

Max inlet pressure, bara/psia* 165/2390
Max inlet volume flow, m3/s / ft3/s 3.5/123
Max exhaust volume flow, m3/s / ft3/s 13.6/480

IP/LP
Max inlet temp, °C / °F 565/1049
Max inlet pressure, bara/psia* 40/580
Max inlet volume flow, m3/s / ft3/s 17/600
Max exhaust volume flow, m3/s / ft3/s 2040/72040
**at maximum temperature*

SST-900 IP/LP turbine

The second unit (the LP module) of the dual casing, is a direct drive (3,000 or 3,600 rpm) turbine, which has a reduced inlet pressure, but still accepts a high steam temperature. The high temperature reheat steam is directed into the casing via two pipes in the upper half and two pipes in the lower half of the casing, symmetrically placed for best possible thermoflexibility..

The LP turbine is equipped with an inlet volute and a short horizontally split inner casing to protect the outer casing from the highest temperatures. The inlet volute supplies steam evenly over the circumference of the first turbine stage, leading to high aerodynamic efficiency. LP blades are selected from a series of well proven, utility-type freestanding blades for 50 Hz and 60 Hz operation.

References of Biomass Plants with Reheat Cycle

A number of biomass plants with reheat solution have been delivered and planned by Siemens PG. These include Königs Wusterhausen, Bischofferode and Eberswalde in Germany and Simmering in Vienna, Austria.

Königs-Wusterhausen

The Königs-Wusterhausen biomass power plant came into operation in October 2003. The 20 MW power station, located south of Berlin, will generate nearly 160,000 million kWh per year, enough to supply 55,000 households. The power plant has a fluidized bed boiler that uses waste and scrap wood and cull from the region to generate 64 tons of steam with a pressure of 87 bars and a temperature of 477° C. With an electrical efficiency of over 35 per cent, the biomass power plant is equipped with highly efficient flue-gas treatment systems and will save 120,000 tons of carbon dioxide emissions annually.

Bischofferode

Bischofferode plant in Thüringen (Germany), Stadtwerke Leipzig, 20MW greenfield power plant. The power plant has a fluidized bed boiler that uses fresh wood from forestry with live steam parameters of 128bara/ 532deg C and a reheat temperature of 532deg C.

Eberswalde

The 21MW power station with grate type steam generator, located north-east of Berlin was ordered by the customer in July 2005. The live steam parameters of 80 bara/ 480deg C and the reheat temperature of 470deg C in reheat solutions enable not only an efficiency otherwise unattainable but also maximization of the subsidies set by German and European legislation.

The Simmering plant in Vienna

Figure 6: The Simmering biomass plant in Vienna

Some main factors exercise decisive influence on the economic efficiency of the plant. The kind of biomass (elementary analysis), the amount of biomass available (determines plant size), the total price of the biomass (including a forecast in future price development) and the total plant costs (investment costs, operating and maintenance costs, average costs of capital) have to be weighted. The results of these economic calculations will lead to a specific preferred technology.

These are issues which Wien Energie took into consideration when planning their 23 MWe biomass power plant project in Simmering / Vienna, Austria. Wien Energie, the Austrian Federal Forest Association (ÖBf) and District Heating Vienna are building this plant on part of an existing old power plant site in Simmering. When completed, it will be one of the world´s biggest biomass power plants exclusively fed with fresh wood from forestry. Commercial operation is scheduled for mid-2006.

Siemens PG is the turnkey supplier of the Simmering plant. The steam generator is a Foster-Wheeler CFB boiler (Circulating Fluidized Bed) with reheat system, with a maximum thermal output of approximately 64.6 MW. The plant will produce 23.4 MWe electricity in summer and 15.06 MWe plus 37 MWth for district heating in winter.

As fresh wood is a rather expensive fuel the Simmering biomass power plant was designed for very high efficiency. The CFB boiler technology with its reheat system guarantees maximum fuel utilization for economizing resources of fresh wood. The plant has a fuel consumption of approx. 184,000 t/a (approx. 23.4 t/h) forest residual wood chips. It will provide electricity to approx. 45,000 households and heat to approx. 12,000 households.

The main focus of the Simmering plant is round-the-year electricity generation (base load power plant, design point - operating hours 8,000 h/a) and the supply of district heating in winter. The plant is designed to run at high availability and with the highest possible number of operating hours at full load.

The reheat system can decisively increase the efficiency of the plant. During the winter season the plant runs at its highest efficiency: in operation with heat extraction, the plant will reach a total efficiency of approximately 83%. During summer, when no heat extraction is in operation and the plant operates fully in condensing mode. the plant will produce a power output of approximately 23.4 MWe_{gross} with an electrical efficiency of 36%.

The operation of the plant will reduce Vienna´s CO_2 emissions by 144,000 t/a CO_2 and save approximately 32 million m^3/a natural gas or approx. 120,000 t/a brown coal.

Conclusion

The selection of the basic concept of biomass plant depends on the economic calculation of the overall project. When we evaluate the various technical possibilities for plant efficiency improvement, we can confirm that reheating is a technology that has substantial influence on the overall efficiency of the plant.
Today’s technological state-of-.the-art, the current prices of biomass fuel and electricity tariffs contribute to making it economically feasible to build biomass plants with a reheat solution, and thereby to increase the profitability of the overall investment .

Figure 7: Flow diagram with reheat cycle for a Biomass power plant