Project Reference: NNE5/2000/475 EESD - PART B - PROJECT

„FUZZY LOGIC CONTROLLED CHP PLANT FOR BIOMASS FUELS BASED ON A HIGHLY EFFICIENT ORC PROCESS“

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Project Partners: TURBODEN Srl (Italy), BIOS BIOENERGIESYSTEME GmbH (Austria)
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1 Location and aims of the project

The biomass fired combined heat and power (CHP) plant is located in Lienz, Eastern Tyrol, Austria, in a newly built boiler house (see Figure 1), which was built in order to supply the town with district heat (about 60,000 MWh/a after completion of the network of pipes) and to produce electricity (about 7,200 MWh/a). It will cover the heat requirement of approximately 70 % of all buildings in the supply area by the end of 2003. The network of pipes covers three stages of development, with a final total length of 37.5 km and about 900 units connected.

Figure 1: View of the CHP plant Lienz

First of all the project aimed at the demonstration of the largest European biomass CHP plant based on an ORC process (Organic Rankine Cycle) with a nominal net capacity of 1,000 kW_{el}, which went into full load operation in February 2002. This ORC process represents a further improvement and an up-scaling by a factor 2.5 of the already successfully demonstrated 400 kW_{el} ORC unit in Admont, Austria. The mentioned up-scaling could not only be achieved by an obvious transformation of the 400 kW_{el} ORC process design, the vapour and liquid volume flows as well as the surface areas of the heat exchangers of the 1,000 kW_{el} machine made a new design concept necessary (see Figure 2).

A second key innovation of the project was the first use of an internal heat recovering system, combining a thermal oil boiler with a thermal oil economiser and a combustion air pre-heater to increase the net electric efficiency of the ORC process to about 15 % (related to the NCV of the biomass fuel).

An additional key innovation of the project was the Fuzzy Logic process control system in combination with an Artificial Neuronal Network for analysing, forecasting and optimising the performance of the overall CHP plant. This new process control technology was developed, designed and demonstrated for a biomass CHP plant for the first time in Europe.

In order to decrease harmful emissions, an efficient, multi-stage flue gas cleaning system consisting of a multi-cyclone, an economiser and a wet electrostatic precipitator combined with a flue gas condensation unit was implemented within the overall CHP plant.

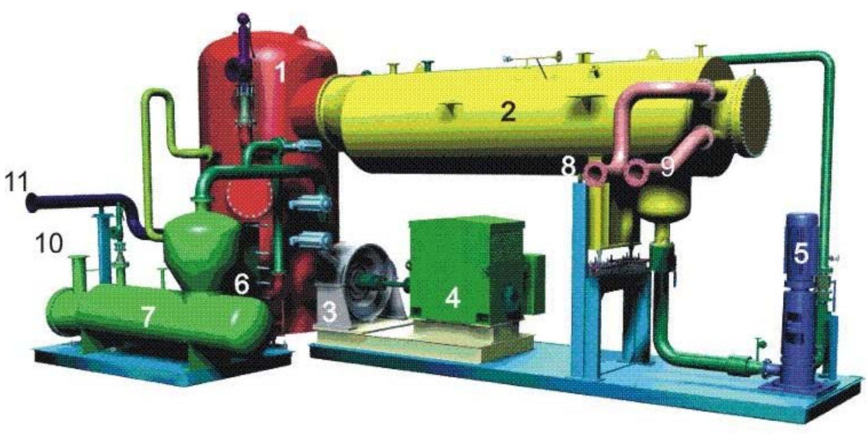

Figure 2: View of the 1,000 kW_{el} ORC process in Lienz
Explanations: 1 … Regenerator, 2 … Condenser, 3 … Turbine, 4 … Electric generator, 5 … Circulation pump, 6 … Pre-heater, 7 … Evaporator, 8 … Hot water inlet, 9 … Hot water outlet, 10 … Thermal oil inlet, 11 … Thermal oil outlet; data source: TURBODEN Srl, Brescia, Italy

2 Technical description of the CHP plant Lienz

The CHP plant essentially consists of two biomass fired boilers, an ORC process, a solar collector panel and an oil-fired peak load boiler as well as a heat recovering unit combined with a flue gas cleaning system. The fuel conversion unit is composed of the two biomass combustion plants, a hot water boiler with a nominal capacity of 7,000 kW_{th} and a thermal oil boiler with a nominal capacity of 6,000 kW_{th}. The thermal oil boiler supplies the ORC process (with a nominal net electric power of 1,000 kW). The heat recovering unit with a nominal capacity of 2,000 kW_{th} increases the overall plant efficiency and covers a thermal oil economiser, located behind the thermal oil boiler, and a hot water economiser which recovers energy from the flue gases of both biomass-fired boilers. The solar collector panel is installed on the roof of the CHP plant, consists of a 630 m² collector surface and achieves a thermal power of up to 350 kW. An oil fired boiler with a nominal capacity of 11,000 kW_{th} is installed for peak load coverage and as a stand-by system.

Forest and industrial wood chips, sawdust and bark (average water content between 30 and 55 wt.% (w.b.)) from the regional forestry and wood industries are utilised as biomass fuel. The total annual biomass fuel consumption will amount to about 100,000 m³ in the final development stage. The oil fired peak load boiler covers only approximately 4 % of the entire thermal energy production regarding the overall plant design. Concerning biomass storage, an open and a roofed area with a total storage capacity of 15,000 m³ has been planned.

The flue gas cleaning unit consists of two stages. In the first stage the coarse fly ash particles are precipitated in multi-cyclones which are placed downstream of each biomass-fired boiler. In the second stage, fine fly ash and aerosol precipitation take place in a wet electrostatic filter integrated in a heat recovery and flue gas condensation unit. In this plant configuration, dust emissions in the clean flue gas of about 10 mg/Nm³ (dry flue gas, 13 vol% O_2) and the avoidance of water vapour formation at the stack outlet at temperatures above –5 °C are achieved.

3 Performance and results achieved of the ORC process and the Fuzzy Logic control system as well as environmental impact of the overall project

The principle of electricity generation by means of an ORC process corresponds to the conventional Rankine process. The substantial difference is that instead of water an organic working medium with favourable thermodynamic properties is used - hence the name Organic Rankine Cycle. The different components of the ORC process as well as the working principle are shown in Figure 2 and Figure 3.

The overall electric efficiency of the CHP plant (= net electric power produced / fuel power input into the biomass-fired thermal oil boiler [NCV]) has been considerably increased by a new and improved approach of coupling the thermal oil boiler with a thermal oil economiser and a combustion air pre-heater (see Figure 3). Using this approach, the thermal efficiency of the biomass-fired thermal oil boiler reaches 85 % (= thermal power output / fuel power input [NCV]), which is about 12 % higher than corresponding values from conventional biomass-fired thermal oil boilers. This increased thermal efficiency correspondingly also raises the overall electric efficiency of the CHP plant (= net electric power produced / fuel power input into the biomass-fired thermal oil boiler [NCV]) to about 15 % (see Figure 4).

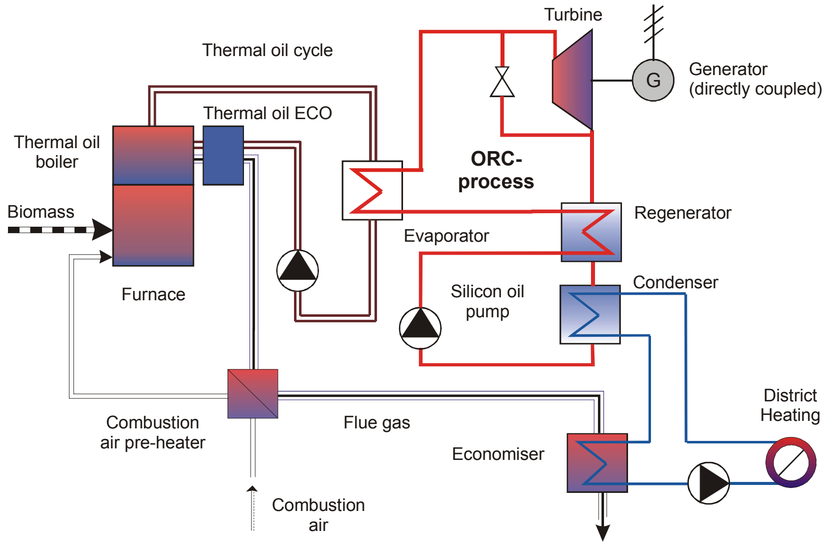

Figure 3: Working principle of the 1,000 kW_{el} ORC process in Lienz

The ORC unit in the biomass CHP plant in Lienz has been in successful and almost continuous operation since February 2002. According to operation data already evaluated, the net electric efficiency of the ORC plant (= net electric power produced / thermal power input by the thermal oil) amounts to 18 % at nominal load and about 16.5 % at 50 % partial load at feed water temperatures of 85 °C. This underlines the excellent partial load behaviour of this technology which is especially relevant for heat controlled operation of the overall CHP plant. Moreover, the new biomass CHP technology based on the ORC process is an economically and technologically interesting solution for small-scale applications due to the fact that it allows highly automated and multi-fuel operation with relatively low operation and maintenance costs.

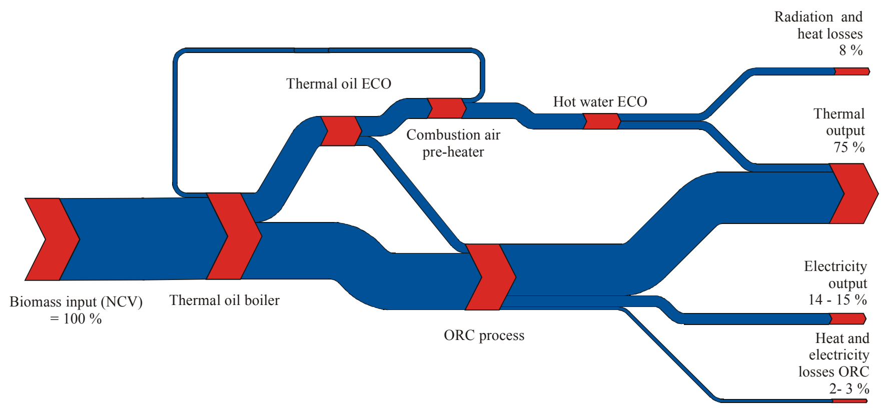

Figure 4: Energy flow chart for nominal load of the CHP plant Lienz

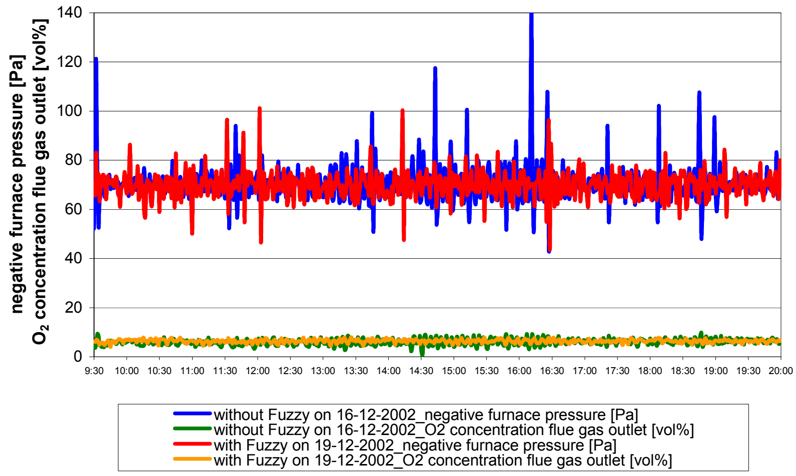

Figure 5: Comparison of the process control systems between 16-12-2002 and 19-12-2002 regarding relevant combustion process parameters of the thermal oil boiler at nominal load conditions

The principle of the Fuzzy Logic control system is basically the existence of a linguistic and a technical level. Fuzzyfication and defuzzyfication are used for the smooth transition of information between the linguistic base of the process operator and the technical level. Defuzzyfication transforms a verbal manipulated variable back into an exact technical value while fuzzyfication goes ahead with the opposite step. Decisive for the working principle of Fuzzy Logic is the availability of a verbal measured variable and the output of a real manipulated variable.

Figure 5 illustrates as an example the negative furnace pressure level in the combustion chamber and the O_2 concentration in the flue gas at the outlet of the thermal oil boiler with and without the Fuzzy Logic control system. Through the stabilised rotation of the flue gas ventilation system and the possible fast reaction of the secondary air fans, the occurring fluctuations of the respective levels of negative furnace pressure and O_2 concentration in case of using Fuzzy Logic are lower than otherwise.

The new Fuzzy Logic process control system can reduce the emissions as well as stabilise (smoothen) the operation of the CHP plant and therefore increases the efficiency and availability of the overall plant and its components. For the thermal oil boiler the efficiency could be increased by about 2 % in comparison to an operation with the conventional control system.

Regarding the environmental impact of the project, the residential and industrial heating systems replaced by the CHP plant Lienz are mainly coal and oil fired boilers, which results in a substantial reduction of CO_2 of about 23,000 t/a as well as of other harmful emissions like SO_2(–18 t/a), CO (–100 t/a), dust (–2 t/a) and NO_x (–13 t/a).

4 Investment and financing of the project

The total investment costs of the project amounted to about 23.1 Mio. €. National funding institutions funded the overall project with 30 % (Kommunalkredit Austria AG and the Provincial Government of Tyrol). Additionally the innovative components have been funded from the European Commission. Concerning the calculation of the electricity production costs, only the surplus investment costs of the CHP plant Lienz (which amount to about 2,765 €/kW_{el}) in comparison to a conventional biomass combustion plant with a hot water boiler and the same thermal output had to be considered. Taking 5,000 full load operating hours per year, a biomass fuel price of 0.015 €/kWh, a funding rate of 0 %, a payback time of 10 years and an interest rate of 6 % p.a. into account, the specific electricity production costs calculated for the 1,000 kW_{el} ORC process in Lienz amount to approximately 0.12 €/kWh_{el}. For an ORC unit with a nominal electric capacity of 500 kW and the same basic conditions, the specific electricity production costs increase by approximately 15 % mainly due to higher specific investment costs (economy-of-scale effect). The most relevant cost factors are the capital costs, representing more than 60 % of the overall specific electricity production costs as well as the fuel costs, which account for about 20 % of the specific electricity production costs.

5 Further potential and outlook

An economically meaningful application of the technology mentioned is possible in all countries which have initiated special funding programmes for the enhanced production of electricity from renewable energy sources (like Austria, Germany, Switzerland, Italy and the UK). The greatest application potential of biomass CHP plants based on an ORC process represent medium-sized wood manufacturing industries and sawmills, decentralised waste wood combustion plants and biomass district heating plants (newly erected or retrofitted systems). Concluding, the ORC technology as well as the Fuzzy Logic control system have proven their suitability and advantages for small-scale biomass CHP applications and are available on the market. Compact ORC modules are available in container size with nominal capacities between 400 and 1,500 kW_{el}. At present about 15 new biomass CHP plants based on the ORC technology are in the design or implementation stage in Austria, Germany and Italy. Ongoing developments for the ORC process focus on a further improvement of the electric efficiency as well as on standard ORC module developments which can be produced in small series in order to reduce the investment costs (short term reduction potential of 20 % given).

6 Contact data of the project identifiers

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