Design and operation of a local cogeneration plant supplying a multi-family house (9,5 kW electrical / 35 kW thermic power) a field report

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ABSTRACT

This paper presents design and operation of a small cogeneration plant, powered by biomass. The plant is capable of delivering 9.5 kW electrical power to the mains and 30 kW thermal power used for heating purposes.
Such units are not available from stock; hence a prototype has been constructed. Powering an internal combustion engine by wood gas made from woodchips has turned out to be a good and affordable technology for small cogeneration plants. A detailed description of the plant's technology is followed by a report of practical experiences from two years of operation.
Measurements concerning the electrical as well as the thermal efficiency have been done. The measurement setup is presented and the results are discussed.

Description of the plant

Wood chips are used as energy carrier. The wood chips are transported automatically from the storage room via the drying unit into the woodgas generator.

Most wood gas generator designs suffer from producing not only wood gas but also a huge amount of wood tar. The tar causes a lot of maintenance work and will destroy a combustion engine after some hours of operation. To keep the presented plant's maintenance work low and the combustion engine lifetime high, a wood gas generator has been developped which produces nearly tar-free gas. This is achieved by reaction temperatures of about 1400°C. The temperature depends on the gas flow rate, hence it is essential for the gas quality to keep the gas flow constant. So the electrical or the thermal output power of this plant can not be adjusted easily.

The emerging woodgas is cleaned from soot particles by using a cyclone and an electrostatic filter system. The gas has to be cooled down to raise the gas density. The gas is mixed with air, controlled by a lambda probe. The air gas mixture is then fed to a standard motorcar's combustion engine which powers an induction generator connected to the three phase power system.

The combustion gas passes the lambda probe and is aftertreated in a standard three-way catalytic converter in order to reduce the anyway low CO and HC percentage.

The rejected heat of the wood gasifier, the combustion engine's cooling water and the heat of the exhaust gases are fed via heat exchangers to a heating water buffer storage. If required, the heating system as well as the domestic hot water can be fed from this buffer.

Figure 1 shows the functional overview of the cogeneration plant "Turdanitsch 2".

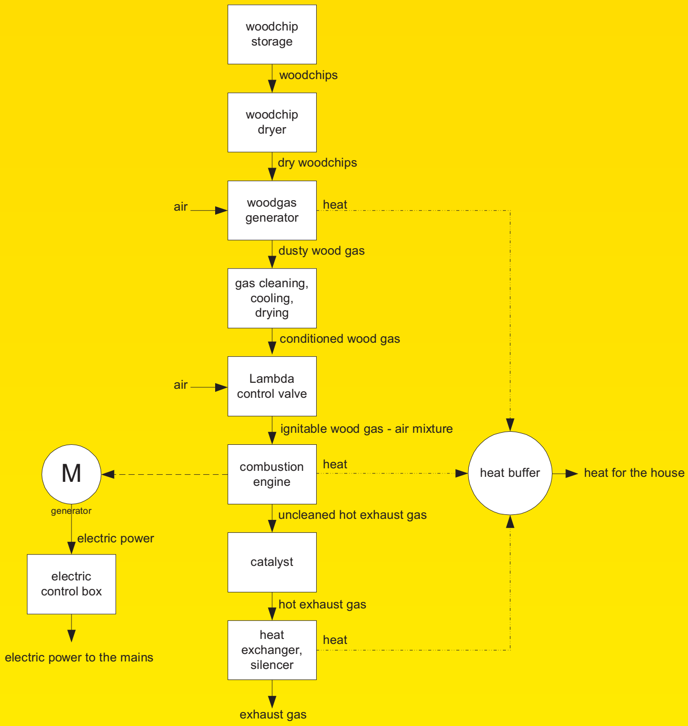

Fig. 1: Functional overview of the cogeneration plant.

An induction machine has been chosen as a generator. Parallel main operation is carried out. Compared to a synchronous generator, no excitation device has to be provided. Neither rotor speed nor polar wheel angle has to be controlled very accurately for switching the generator to the mains.
In a second stage of expansion a rotor speed measurement unit is designed that allows to measure the speed from the voltage induced into the stator windings by residual magnetism. With this the switching of the generator to the mains can be carried out smoothly.
In order to reduce the reactive power that has to be provided by the public mains, capacitors are switched in parallel to the induction machine after connecting the machine to the mains.

For efficient use of the produced thermal energy, the plant has to be operated in a heat led mode. If the rejected heat cannot be dissipated the plant shuts down. In this case no electrical power is generated. As there is no electric energy storage system implemented, it is necessary that in this case the electric power company provides the necessary electric energy to our household. If the heating water buffer storage can not provide enough heat, the plant has to be started up again.

Operation experience

The plant is only in operation during winter, when heat is required. During more than 3500 operating hours (winter 2006/07 and 2007/08) no major faults occurred. The first and only bigger breakdown occurred in December 2008, when the timing belt of the internal combustion engine ripped off.
Normal operation of the cogeneration plant is quite simple and done by laities. The work is reduced to about 15 minutes of preparation per start-up (every 2 to 4 days, depending on the amount of needed heat), and about 10 minutes for the starting procedure itself. If the plant is in operation, no further attendance is required. The plant stops and shuts down automatically when enough heat is generated or if faults occur. The preparation for start-up consists of cleaning up the gas filter system and the ashtray of the wood gas generator, and visually checking the whole system.
Figure 2 shows the plant at the development status of January 2008.

Fig. 2. The plant in January 2008.

Efficiency analysis

For this purpose several additional energy-counters have been installed. Table I shows average efficiency data that has been determined by now.
The biggest inaccuracy with efficiency analysis is to determine the consumed primary energy of the plant. By now only the volume of the consumed woodchips is measured, with only rare information about the packing density. The energy content of the consumed woodchips can not be determined exactly too. Packing density, moisture content and ligneous crop are not homogenous, so just average values can be taken.

Table I

Consumed amount of spruce woodchips	0,06483	m³/h, loose
Average moisture content after drying unit	18,26	%
Average electric output power	6,48	kW
Maximum electric output power	9,34	kW
Average generated electric power	7,03	kW
Auxiliary electric power during operation	0,55	kW
Average thermal power output	26,55	kW
Electric efficiency	13,32	%
Thermal efficiency	54,52	%
Overall efficiency	67,84	%

Efficiency improvement

Output power as well as efficiency can be increased by optimising the gas conditioning process:
- ✓Cleaning the gas with lower flow losses improves the filling of the cylinders of the combustion engine.
- ✓Better cooling of the gas increases the gas density.
- ✓Modifying the compression rate of the combustion engine or turbo charging of the engine.
- ✓Optimization of the exhaust gas heat exchangers will result in higher thermal power output.
- ✓Improving transportation of the woodchips, electronics, water pumps and fans will reduce the electric energy consumed by the plant.

Government aid and basic financial conditions

Whereas the building up of commercially available biomass heating systems is funded **in Austria**, no government aid is available in case of self-construction prototypes. The whole project as well as the research and development work carried out (the application of a patent is under examination) are financed privately.
The electric power is payed according to the Austrian law concerning green electricity [5]. The fees are 0,12 €/kWh when using saw mill residue as a heating material and 0,16 €/kWh when using wood chips from small trees as a heating material. The fee does not depend on time of day or season. Hence on an average 1400€ are earned per year, the consumption of wood chips is about 90m³.
The energy produced equals the one of 8000 liters heating oil. As wood is carbon neutral, an amount of 23 t of carbon dioxide is saved.

Conclusion

Even though the cogeneration plant "Turdanitsch 2" is just a prototype which works not yet at maximum possible efficiency, it could be shown that the concept of combined heat and power generation is efficient even for small scale units fed from biomass. The high market price for wood chips makes the mere generation of electrical power from biomass unprofitable. The break even point can only be reached when utilizing the rejected heat for heating purposes.
For rural regions with high potential of waste wood the presented technique could be an option to increase the income for the population. In countries like Austria where the majority of electric energy is produced by hydropower plants, wood gas cogeneration plants could support the hydropower plants in winter, when heat is needed and the water levels of the rivers are low.