Design and operation of a local cogeneration plant supplying a multi-family house (9,5 kW electrical / 35 kW thermal 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 35 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 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, the wood gas generator has been developed 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 motor'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".

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 ladies. 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 15 minutes of shutdown per day. A technician is not required for a start-up. After each start the plant needs a 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.

Table I

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Electric output power</td>
<td>7.03 kW</td>
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<tr>
<td>Average generated electric power</td>
<td>6.48 kW</td>
</tr>
<tr>
<td>Maximum electric output power</td>
<td>9.34 kW</td>
</tr>
<tr>
<td>Auxiliary electric power during operation</td>
<td>0.55 kW</td>
</tr>
<tr>
<td>Thermal output power</td>
<td>26.55 kW</td>
</tr>
<tr>
<td>Efficiency</td>
<td>1.19</td>
</tr>
</tbody>
</table>

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 operation 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 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.

Fig. 1. Functional overview of the cogeneration plant.

Fig. 2. The plant in January 2008.