PRACTICAL EXPERIENCES WITH POWER UTILIZATION OF BIOMASS ENERGY IN GERMANY

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SUMMARY

This paper shows the experiences with processing and utilization of biomass energy in Germany. In the first parts of the paper are general described the most important methods of biomass processing and its characters. Further are mentioned the rules for grid connection of these distributed sources with two examples of such power calculations. Finally are described two power plants in Bayern, which represent two most frequent utilizations of biomass energy.

Keywords: *biomass, biogas, combustion, fermentation, heating value, grid integration, voltage change*

1. INDRODUCTION

Biomass is defined as an organic material. It concerns of all live nature. When we speak about biomass in context with power engineering, we most often mean the wood and logging waste, straw and other farming residues and eject of stocks. When we pass away food energy, then the energy from biomass combustion is the oldest, which have humans ever utilized.

2. METHODS OF BIOMASS PROCESSING

Energy is possible to obtain from biomass trough the use of thermo-chemical or biochemical transformation. We differ the biomass as "dry" (e.g. wood) and as "wet" (e.g. sewage).

Most often in power engineering we utilize two technology processing - direct combustion (condensing Rankin cycle) and anaerobic fermentation (biogas).

2.1. Direct combustion and gasification of biomass

From dry biomass by high temperatures are liberated the combustible gas components, so-called wood gas. The air causes the burning, i. e. it is a simple combustion. Concerning the warming without air, the wood gas is dissipated to the combustion area, where it is combusted like other gas fuels. Some part of forming warm is used to gasification the next biomass. The advantage is an easy power regulation, lower emissions and higher efficiency. The wood gasification plants are used more and more. At first sight they don't vary from the common combustion plants [1].

Biomass is very complicated fuel, because the share of gasification parts during the combustion is very high (by wood about 70%, by straw about 80%). The forming gases have various combustion temperatures. Therefore it also becomes, that in reality only part of fuel is combusted. By a smoke it is shown, whether the combustion is entire. The blacker is smoke, the worse is combustion. White smoke isn't caused by incomplete combustion, but by water vaporization from wood.

Condensing plants have generating capacity up to tens of MW.

2.2. Biogas, fermentation

It is combined heat and power cycle, where beside a heat production is also obtained an electrical energy. As a fuel is in combined heat and power plants used a biogas, gained from an anaerobic digestion. The biomass substrate is fouled with the absence of air on biogas, which compounds largely from: 65 – 80 % of methane
20 – 35 % of carbon dioxide.

Combined heat and power plant is composed of a power generator, most often powered by a gas-engine or by a gas-, steam- turbine. The piston engine is modified for biogas combustion. The off-heat from motor cooling system or from exhaust gases-water heat exchanger is utilized in gasification cycle and for object and water heating. Efficiency of power production is by these plants between 20 and 35 %, heat efficiency between 50 and 60 % and total efficiency up to 90 %.

Combined heat and power plants have today the generating capacity up to hundreds of kW.

3. CHARACTERS AND HEATING VALUES OF BIOFUELS

Heating values of wood and next vegetable fuels balance not only according to kind of wood or vegetable, but also with a humidity, on which are these fuels more sensitive (see table 1). Storaged wood material at natural airing reduced its water content up to 20 % in one year, rape straw at equal conditions up to 13 %.

1 kg of wood with zero water content has an energy content about 5,2 kWh. However it is practically impossible to fully dry the wood, residual

water content is about 20 % of raw wood material. Because some part of energy is during the combustion process consumed for an vaporization of the water, it is necessary to count with the energy content of about 4,3 to 4,5 kWh. By increasing the water content is the wood energy content decreasing, until the water content is so high, that the combustion is impossible. At the same time by increasing the water content is also hardly decreasing the combustion efficiency.

Fuel	Water content [%]	Heating value [MJ/kg]	Mass density [kg/m³]
Wood parts	0	18,56	355
	10	16,40	375
	20	14,28	400
	30	12,18	425
	40	10,10	450
	50	8,10	530
Wood chips	10	16,40	170
	20	14,28	190
	30	12,18	210
	40	10,10	225
Straw-corn	10	15,50	120 (boxes)
Straw-maize	10	14,40	100 (boxes)
Tow	10	16,90	140 (boxes)
Straw-rape	10	16,00	100 (boxes)

Tab. 1 Influence of fuel humidity on heating values and specific materiality [1, 5]

4. GRID INTEGRATION OF DISTRIBUTED SOURCES

General, the most important parameter for an evaluation of grid connection such new renewable sources is a voltage change, evoked by the their operation. $\Delta U \leq 2\%$ in any point of the appropriate high voltage grid [2]. This condition has to be fulfilled: a) for current grid state

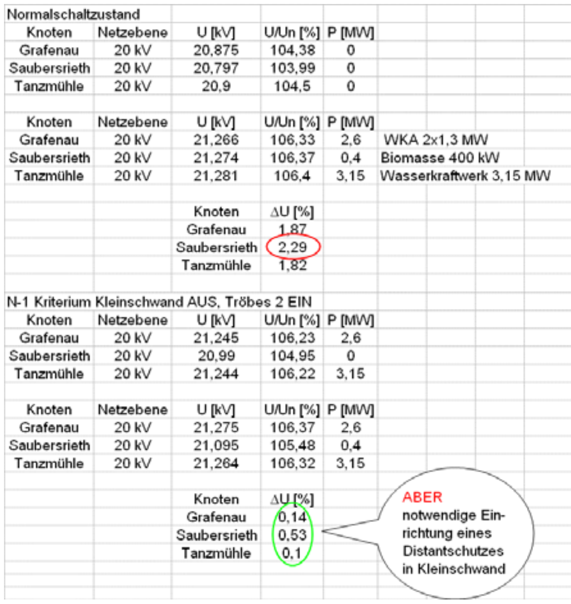
b) for a N-1 criterion.

Except that it is further necessary to control specially for photovoltaic- and wind plants other parameters – e.g. harmonics, flicker, impacts on CT signal.

The mentioned limit of 2% has not any physical foundation, it is only some recommendation for power companies. In certain conditions (connection concept, grid concept) it is also possible to permit greater value. It results from it for power companies a finding of such solution, which would enable the most effective setting of renewables. At the same time must not be abused the grid stability, but should be at the most satisfied the interests of investors.

4.1. Evaluation of grid connection of new distributed source; biomass 400 kW

The point of common connection is situated in a 20 kV grid. Beside in the area work 2 wind turbines with the installed power of 2x1,3 MW and a water power plant with the power of 3,15 MW. The calculation according to the criteria of the previous paragraph was carried out in a specialised software SINCAL [8]. The results are shown in figure 1. As the referential points for voltage change calculation were chosen the points of common connection of each distributed sources.



Normalschaltzustand

Knoten	Netzebene	U [kV]	U/Un [%]	P [MW]
Grafenau	20 kV	20,875	104,38	0
Saubersrieth	20 kV	20,797	103,99	0
Tanzmühle	20 kV	20,9	104,5	0

Knoten	Netzebene	U [kV]	U/Un [%]	P [MW]	
Grafenau	20 kV	21,266	106,33	2,6	WKA 2x1,3 MW
Saubersrieth	20 kV	21,274	106,37	0,4	Biomasse 400 kW
Tanzmühle	20 kV	21,281	106,4	3,15	Wasserkraftwerk 3,15 MW

Knoten	ΔU [%]
Grafenau	1,87
Saubersrieth	2,29
Tanzmühle	1,82

N-1 Kriterium Kleinschwand AUS, Tröbes 2 EIN

Knoten	Netzebene	U [kV]	U/Un [%]	P [MW]
Grafenau	20 kV	21,245	106,23	2,6
Saubersrieth	20 kV	20,99	104,95	0
Tanzmühle	20 kV	21,244	106,22	3,15

Knoten	Netzebene	U [kV]	U/Un [%]	P [MW]
Grafenau	20 kV	21,275	106,37	2,6
Saubersrieth	20 kV	21,095	105,48	0,4
Tanzmühle	20 kV	21,264	106,32	3,15

Knoten	ΔU [%]
Grafenau	0,14
Saubersrieth	0,53
Tanzmühle	0,1

Fig. 1 Evoked voltage changes [3, 6]

In the current grid state is the limit for ΔU breaked. It results from it an impossibility of connection of such a power rating. It is also caused by the point of common connection, which is situated at the very end of the 20 kV grid. The N-1 criterion is enough fulfilled. However, to be able to operate the grid in a such state, it would be necessary to install a distance protection to the point of simulated line failure. But this is not in the interest of grid operator.

4.2. Evaluation of grid connection of new distributed source; biogas 300 kW

The point of common connection is situated in another distribution grid of high voltage 20 kV. The calculation was also carried out in a specialised software SINCAL [8]. The results are shown in figure 2.

In this case the both voltage conditions are enough fulfilled. It is also caused by a very good grid concept and also thereby it is the first installation of such distributed source in the grid. The last calculation has to do with the maximum permissible power of that source. According to the N-1 criterion it can be 900 kW.

Normalschaltzustand					
Knoten	Netzebene	U [kV]	U/Un [%]	P [MW]	
Albersrieth	20 kV	20,998	104,99	0	
Knoten	Netzebene	U [kV]	U/Un [%]	P [MW]	
Albersrieth	20 kV	21,034	105,17	0,3	Biogas 300 kW
		Knoten	ΔU [%]		
		Albersrieth	0,18		
N-1 Kriterium Leitung von Altenhammer in Steinfrankenreuth AUS					
Knoten	Netzebene	U [kV]	U/Un [%]	P [MW]	
Albersrieth	20 kV	20,144	100,72	0	
Knoten	Netzebene	U [kV]	U/Un [%]	P [MW]	
Albersrieth	20 kV	20,277	101,39	0,3	
		Knoten	ΔU [%]		
		Albersrieth	0,67		
Maximale installierte Leistung der Anlage aus der Sicht des N-1 Kriteriums					
Knoten	Netzebene	U [kV]	U/Un [%]	P [MW]	
Albersrieth	20 kV	20,536	102,68	0,9	
		Knoten	ΔU [%]		
		Albersrieth	1,96		

Fig. 2 Evoked voltage changes [3, 6]

5. BIOMASS POWER STATIONS

5.1. Biomass cogeneration station Zolling, 20 MW

The power station is situated on the premises of a hard coal power station 450 MW, near the city of Munich. This large-scale biomass station (see figure 2) produces electricity in 110 kV grid and feeds heat into the existing district heating network.

Fig. 3 Technological scheme [7]

The main biomass fuels are wood chips. These are bought from the specialized company, which transports them by heavy trucks. After the discharge, the wood chips pass throw the separation. It consists of three levels:

- In the first level are excluded all wood parts longer than 12 cm. This is done because of the parameters of the fire-grate boiler, since longer parts would not be burned.
- In the second level are excluded all parts containing any plastic material.
- In the third level are excluded all parts containing metals, which would probably create unpleasant melting on the fire grate.

Each of the level has its own container, which are then transported back to the company on their costs.

So sorted out wood chips pass then to two chip silos (2 x 500 m^3). Both full silos cover the fuel demand of the power station for 4 days. From the silos pass the chips by a conveyer to the boiler, where they burn one hour. The solid parts after the burning are used in waste disposal. The feed-water is cooled by air condensers.

Generating capacity	20 MW_{el} 30 MW_{therm}
Fuel	wood chips, quality AI-AIV
El. efficiency	31 %
Boiler Steam capacity Combustion temperature	fire grate 72 t/h 940 °C
Emission control	Calcite method, NO_x: SNCR
Annual fuel consumption	110.000 tun
Annual power production	100.000 MWh_{el} 4.700 MWh_{therm}
Redemption price	8,5 ct/kWh guarantee for 20 yrs
Total costs	45 mil. €

Tab. 2 Technical specifications and quality of wood chips

5.2. Biogas Irlbach, 500 kW

The power station is situated near the city of Straubing, on the private land of the farm. As a medium for the biogas production is used a mixture of the farming and brewery rests, as seen in table 3. The station is connected to the 20 kV grid and the waste heat is used for heating the neighbouring castle and swimming pool.

Fig. 4 Technological buildings of biogas station [6]

The whole yard is made of 5 reservoirs:
2 small at 200 m^3 – a) sewage reservoir
b) mixing reservoir
3 large – a) main fermenter 2.280 m^3
b) end fermenter 2.280 m^3
c) residue reservoir 3096 m^3

The medium is transported from the neighbouring storages to a press, from where it passes by the conveyer to the mixing reservoir. There is the medium mixed with sewage and this mixture is pumped to the main fermenter, from where is extracted the most of biogas. The mixture is again pumped to the next fermenter, where the process ends and the biogas is also extracted. The residues are then pumped to last reservoir and are used for fertilization.

Biogas	CH_4 = 52 %
Annual biogas production	1.894.116 m^3
Motor	combustion
Generator	Asynch. 500 kW
Transformer	0,4/20 kV 630 kVA
Annual power production	2.500 MWh_{el}

Medium	**Annual usage**
Maize	3.000 t
Farm silage	2.000 t
Plant silage	1.500 t
Corn	360 t
Sewage	1.600 t
Sugar beet	1.000 t
Potatoes	1.000 t
Brewery	900 t

Tab. 3 Parameters of the plant

6. CONCLUSION

We are expecting, that biomass will be progressively developing in the near future. From energetic point of view it will be the most utilized technology from all types of renewable sources [4].

REFERENCES

[1] Brož, K., Štúryk, B.: Renewable energy sources, ČVUT, Praha, 2003 (in Czech)
[2] ČEPS – www.ceps.cz
[3] Novák, P, Nechanický, M.: Practical experiences with integration and operation of renewables in distribution grids, Elektrotechnika a Informatika, ZČU, Plzeň 2005
[4] Parliament of ČR: Law of subsidies for power and heat production from renewable energy sources
[5] Noháčová, L., Noháč, K., Mühlbacher, J.: Potential and other features of renewable energy sources in Czech Republic and thein possibilites of utilizing in the energy scenarios in brauch power engineering, Alexandria University, Egypt 2004
[6] Novák, P.: Netzeinspeisung von erneuerbaren Energien in Mittelspannungsnetze. Firm presentation, E.ON Bayern, Regensburg 2005
[7] E.ON Kraftwerke: Neue Energie aus Biomasse, Hannover 2004
[8] SINCAL, Siemens Network Calculations, www.sincal.de/

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Doc. Ing. Zbyněk Martínek, CSc. was born on 22.4.1955. He finished his university study in 1983 (M.Sc. Eng.) in specialization Electric Power Engineering, Institute of Technology Pilsen. Next professional practice in every year till present is: 1983-1984 Scholarship Holder, Institute of Technology in Pilsen, 1984-1986 Teacher I, II, Institute of Technology in Pilsen, 1986 Lecturer-Science Study, 1989 Senior Lecturer, Institute of Technology in Pilsen, 1990 Ph.D. (CSc.) in Power Engineering, University of West Bohemia in Pilsen, 1997 Associate Professor, 1997 till now Associate Professor at University of West Bohemia in Pilsen, Department of Electric Power Engineering and Ecology.

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