Essential technical parameters for effective biogas production

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Abstract. Rising agrarian raw material prices in 2006 had a negative impact on the biogas sector in Germany, leading to the search for potentials for optimisation of production. A problem is the workload of the block-type thermal power station (BTPS). This is caused by biogas process disturbances, construction errors, technical problems and management mistakes as well as by oversizing of the BTPS. Technical problems appear in particular with BTPS and aggregates, stirring devices and fermenter heatings, measuring and control technology as well as foil caps. The BTPS is an essential part of the economic efficiency of biogas production. A 2% increase in efficiency, to 40%, lowers the costs about 1 Cent kWh_{el}^{-1}. To achieve sufficient stirring power, the device type, heights and angle adjustment are vital. The substrate dosing engine must be adjusted to the particular substrates. The fermentation has to be controlled continuously. Parameters such as substrate amount, temperature, pH-factor, fermenter chamber load, gas amount and composition, ammonium concentration and short-chained fatty acids should be controlled regularly. Large temperature variations can lead to foam formation, resulting in a reduction of the gas yield. Disinfectants, antibiotics and a too tall fermenter chamber load can also have a negative influence. Low methane content often may often result from high sulphur and ammonia content in biogas composition, high aerial dosage accompanying desulphurisation as well as to coarse input material.

Key words: biogas, technology, renewable energy

INTRODUCTION

The development of biogas production has been successful in recent years. In 2006, approximately 800 biogas plants with a total power of about 450 megawatts were established in Germany (Anonymous, 2007). Germany leads the EU with more than 8000 plants as of January, 2008, with an additional 500 kW plants planned. Cultivation of maize for biogas also substantially increased: in 2006: there was an increase from over 90,000 ha to more than 160,000 ha.

With the increase of the agrarian raw material prices worldwide, which were not anticipated to this degree, and the increasing competition for agrarian acreage in cattle-strong regions of Germany, in particular, conditions started to worsen at the end of 2006 for the biogas production sector (Heißenhuber et al., 2008). Only 200 plants were established druing the year (Klinski, 2006) resulting in a clear reduction in sales volume (about 50%) of the biogas plants manufacturers registered in 2007. The causes lie in the strong increase of the prices of the input material from especially tilled renewable raw materials which led to a deterioration of the economic efficiency of biogas production.The results create uncertainty for farmers as well as those planning biogas plants. The legislature is being asked to create dependable basic conditions for the biogas plant manufacturers and plant operators for the short, medium and long term. The changing situation should be used by biogas plant operators (farmers) as an occasion to determine optimisation potentials in biogas production that will increase efficiency. Many biogas plants are operating at a suboptimal level; there is a great need for optimisation of operations (Neumann, 2007).

Economic efficiency depends on plant technology

Economic efficiency of a biogas plant depends upon its operational safety. High quality plant components and their integration into the total process are a condition for economic success. Significant technical problems occur in particular in the following performed plant technology:

- block-type thermal power stations including adjoining aggregates,
- stirring devices (agitators) and fermenter heatings,
- measuring and control technology, and
- foil caps.

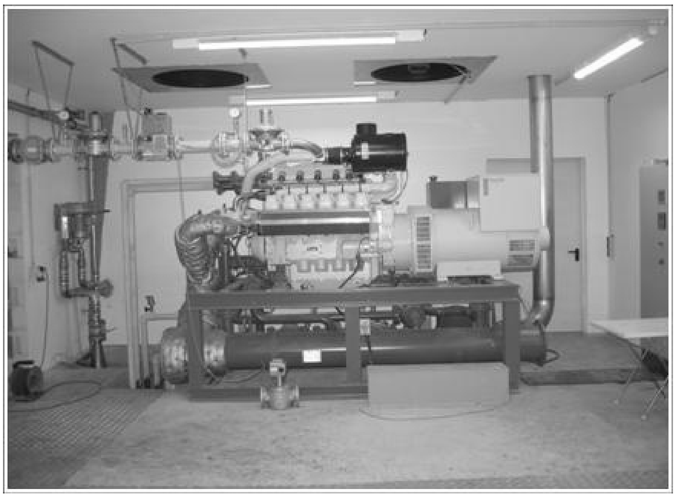

Fig. 1. Block-type thermal power station.

Block-type thermal power stations (Fig. 1): A significant problem is maintaining a full workload. In many block-type thermal power stations producing biogas, the middle workload amounts to only 5500 to 6000 full load hours per year: 8000 hours per year represents optimal efficiency (Schlegel et al., 2007). So the engines should have good efficiency for the partial load (Krautkremer, 2007). Poor efficiency results from down-times caused by massive process disturbances, mistakes in plant construction, technical problems and management mistakes as well as by over-sizing of the block-type thermal power stations. The efficiency of the block-type thermal power station-engine plays an essential role in the economic efficiency of biogas production (Fig. 2).

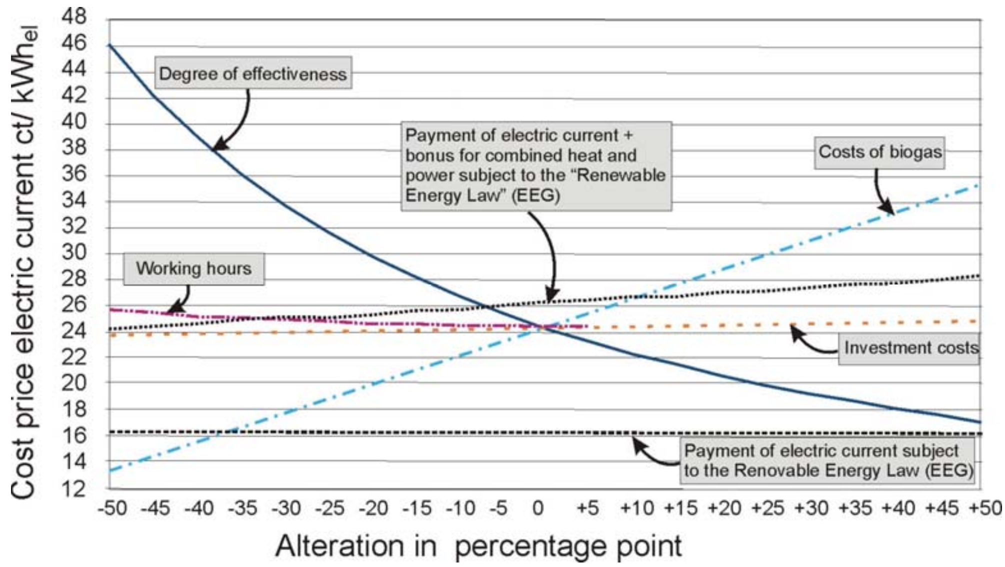

Fig. 2. Sensitivity of a block-type thermal power station with 500 kW_{el} and use of biogas from renewable materials (Hofmann et al., 2005).

An improvement of about two percentage points on 40% would lower the cost prices of electric current about 1 Cent kWh_{el}^{-1}. On the contrary, lowering efficiency by about 2 percentage points would raise the cost prices of electric current by 1.2 Cent kWh_{el}^{-1} Deteriorating efficiency has greater consequences than improvement because of the exponential curve course. The engines are also susceptible to major disturbances or damages if the oil change intervals are too long, variations of the quality and amount of gas, or the engine overheats due to faulty chilling circulations. Poor quality or the acidification of the engine oil can lead directly to engine troubles. A regular analysis of the oil quality as well as the constant control and servicing of the technology including the chill circulations is extremely important.

Stirring devices (Figs 3 and 4) and fermenter heatings (Fig. 5): Stirring devices in biogas plants should not only prevent swimming and settling layers or contribute to their resolution, but also mix fresh and fermented substrate. In addition, the mixing activity in the fermenter should achieve a steady temperature. The gas in the fermenter chamber should be prepared for escaping by mixing. Contingent on the application of plant material, a relatively low energy concentration of the whole ration with a high portion of hardly fermentable substances arises (Mumme et al., 2007). If the dry substance content of the substrate is too high in the fermenter, insufficient functioning of the stirring device in the fermenter chamber can leave a residue of gas in the chamber, which can extend and block security armatures and gas lines. In extreme cases, the fermenter could burst. A common fermentation of energy plants with economic fertilizers turns out to be advantageous for several reasons. The liquefaction effect of the fertilizers during the mixing process lowers costs (Hopfner-Sixt et al., 2007).

If the installed stirring device power is too low, mixing times are extended and increase current consumption. Also important are the slow-running stirring device with long shaft (Fig. 3) or diving-engine (Fig. 4) stirring devices, the heights and angle setting, the type, quality and dry substance content of the used substrates. Frequent damages in stirring devices are caused by the penetration of humidity into the engine space of the diving-engine stirring devices. A strong layer formation in the fermenter can cause higher resistance. This can lead to a fracture in the propellor or to a bending of the shaft. Corrosion can cause other damages in the bearings. Damages can be reduced as the operator manages the substrate composition, as well as by planning the size of the fermenter, type of the substrate, form, position and corresponding power of the stirring devices.

Fig. 3. Stirring device with long shaft (slow).

Fig. 4. Stirring device with diving-engine (faster).

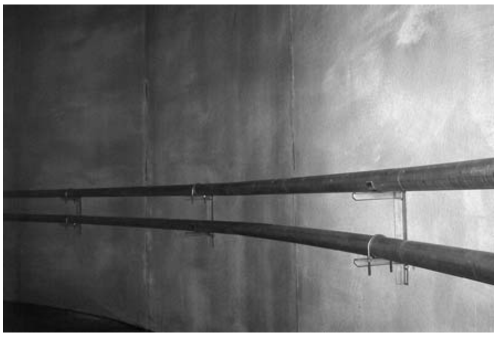

Fig. 5. Fermenter heating tubes.

Substrate dosing engine: Aside from the composition of the substrate mixture, substrate conditioning has the potential to optimize production efficiency of the entire plant (Scholwin et al, 2004).

The substrate dosing engine should be tuned optimally to the used substrates to reach a good milling, particularly of fiber-rich material. Inadequate tuning can result in bridge formations and blockages which can lead to disturbances of the dosage Continuous laboratory analysis of the substrate can often recognise changes in the process and the operator can intervene quickly. The costs for the analyses are minimal compared to those of a plant malfunction.

Measuring and control technology: To achieve successful practice of a biogas plant in the long term, the fermenting process must be continuously controlled so that the active micro-organism groups in the fermenter find good environmental conditions and a balance forms in the fermenter. Only few plants are satisfactorily equipped with measuring technology for supervision of the process. But parameters such as mass of supplied substrates, fermenting temperature (Fig. 6), pH factor, dwell time, space load, biogas amount and composition, ammonium concentration and short-chained fatty acids should be controlled regularly. If the dwell time of the substrate in the fermenter is too short, methane bacteria can leach because of methane's longer generation time. As a result of this process the dismantling speed diminishes (Grepmeier, 2002).Thus disturbances can be recognised in the fermentation process and countermeasures can be initiated. In addition, the kinds, time and frequency of the substrate input can be recorded. If a substrate dosing engine exists, the engine can weigh the substrate. If liquid components are supplied to the fermenter, the capture of this biomass occurs with the flow measuring instruments which work electronically.

Fig. 6. Temperature detector.

Fig. 7. Flash protection at the foil cap.

Foil caps: During the operation gas mixtures capable of explosion exist in the gas space of the fermenting chamber. Sparking is to be avoided. The stirring device should be worked beneath the surface. Additionally, a flash protection device (Fig.7) should be installed close to the foil cap.

Certified staff is necessary for reacting to disturbances and interruptions

The complexity of the process of the biogas production requires certified staff. Therefore, training, as well as the exchange of experience with other biogas operators is a must. Certified staff is most important during the start-up phase but may be necessary thereafter, as well.

The staff must react to some disturbances in the fermenting process, the causes for which are varied. Wide variations of temperature and pH-value influence the activity of the bacteria leading to process disturbances, e.g. foam formation, which can reduce gas yield up to 30%. However, foam formation can be also caused by too much fat and protein: transformation of the substrates is influenced substantially by the protein-energy relationship. The whole energy of protein-rich substrates cannot be used (Öchsner, 2006). In this context the regular entry of micro-organisms which are involved in the fermenting process causes a stabilisation of this process by increasing the buffer capacity. This is essential for the neutralisation of acids formed during the fermenting process (Karpenstein-Machan, 2005).

Low gas yield can have many causes: If the gas yield is too low, the causes can lie in the concentrated impact of disinfectants, antibiotics and in an excessive fermenter chamber load. Also possible, an insuffucient dry substance content in the liquid manure and congested gas lines. Low methane content, a common occurrence, frequently traces back to too much sulphur or ammonia content and excessive aerial dosage during the desulphurisation. Input of grain that is too coarse can also increase the oxygen entry and decrease the methane content. If the input substrates are processed or chopped up faultily, the result can be not only a lower gas yield but also a higher oxygen entry into the fermenter. If the pH-factor drops too strongly, the problem may lie with the substrate supply or the overstressing of the fermenter chamber load, resulting in an increase of the organic acids, decrease of the pH-value and a disturbance of the biochemical balance. Therefore, steady filling of the fermenter and a well-balanced nutrient composition in the substrate (among other things C/N - relation) should be constant.

Chemical pre-treatments of the substrates with different procedures can have a positive effect on the specific methane yield. With input material rich in cellulose, the hydrolysis velocity has an important impact on the whole fermenting velocity; breaking up the cellulose before the fermentation can make sense (Kaltschmitt & Hartmann, 2000). If the biogas processing is disturbed by high contents of hydrogen sulphide, the cause is the application by substrates with high protein contents and non-functioning desulphurisation of the biogas. It can result in corrosion damages in the technology or as irregular operation of the engine. A change of the substrate composition as well as the application of iron salts and active coal filter can improve the situation.

Another problem is the formation of sinking layers which can result from the application of e.g. chicken manure and biological rubbish which are not mixed with sufficient intensity. If the heavy materials (e.g. sand) are already drawn off in the dump and the stirring device works with frequent relatively short mixing intervals, this problem can normally be minimised. Swimming layers often appear with the use of substrates with high dry substance contents, e.g. litter manure and silage. Too low mixing intensity in the fermenter is another cause. A reduction of dry substance content of less than 12% and frequent short mixing intervals afford remedial action.

Other optimisation potentials exist in improving the energy efficiency by creation and reinforcing of possibilities for reusing the rejected heat. Additional options include the breeding of plants which are rich in yield, the involvement of alternative plants, as well as the optimisation of cultivation procedures including the appropriate crop rotation systems.

CONCLUSIONS

After a number of highly successful years the biogas sector is currently facing challenges. High raw material prices in the agricultural sector negatively affect the economic efficiency of the biogas plants, and draught is a factor. Economic optimisation of a permanently successful biogas plant operation, especially one which combines farming and biogas production, requires both technological and farm management skills.

The following conditions are recommended for an economically efficient and technologically sound biogas operation:

1) Choosing suitable technology, with expert and regular servicing

2) Knowledge about and careful selection of substrates

3) Adaptation to specific plant conditions

4) Exact monitoring and recording of the process to allow for adjustmnent and intervention in a timely manner when necessary

5) Attention to improved nutrient composition by coordinating the choice, method of preparation and dosage of substrates

6) Expedient use of rejected heat

These measures have the potential to improve energy efficiency despite increased prices of raw materials and can make an important contribution to stabilising economic efficiency, as well.

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