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Energy Rating of Biogas Station

***Abstract**. This paper deals with description of biogas station technology, options for storage of electric power and heat produced by co-generation units in biogas stations. It contains descriptions of various options for utilisation of biogas stations to increase the quality of voltage in the electric power grid. The second part includes operation analysis of a selected farming biogas station and reference to measure required for integration of the biogas station into the system for remote control of its output supplied to the power grid.*

***Streszczenie.** Artykuł dotyczy opisu technologii stacji biogazu, możliwości magazynowania energii elektrycznej i ciepła wytworzonych w jednostkach kogeneracyjnych biogazowni. Przedstawiono opisy różnych możliwości wykorzystania biogazowni do poprawy jakości napięcia w sieci energetycznej. Druga część zawiera analizę funkcjonowania wybranej biogazowni rolniczej i odniesienie do działań niezbędnych do integracji biogazowni z systemem zdalnego sterowania mocą dostarczaną do sieci energetycznej. (**Efektywność energetyczna biogazowni**).*

Keywords: Biogas station; Storage; Co-generation unit.
Słowa kluczowe: biogazownia, magazynowanie, jednostka kogeneracji.

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Introduction

Being one of a few renewable resources of electric power, biogas stations are easily controllable and predictable from performance point of view. Their output can be controlled by remote means, which makes them one of the potential storage resources using biomass as the primary source of energy. However, the performance generated by these resources is fairly low rendering them unsuitable for higher voltage levels. In spite of that, they are mostly situated in the countryside and close to power line ends and very convenient as subsidiary supply units for local distribution grids that have become more prone to quality of electric power due to connection of a large number of photovoltaic power plants within.

I. Biogas Station Operation Principle

As far as the technologies for processing of biomass are concerned, biogas stations (BGS) can be divided into two types - dry and wet. Dry fermentation is far less common, with only a few tens of units located in Europe, mainly in Austria; and it is suitable especially for processing of biomass with large solids content. It is used primarily for processing of bio-degradable municipality waste in combination with composting. On the other hand, wet fermentation is the most common method for anaerobic processing of vegetable biomass and bio waste, whereas the material is processed further in liquid form in reactors with average solids content up to approx. 12 % to preserve its pumpability characteristics. The number of these installations in Europe amounts to several thousand units. It is a continuous biological process operated in large airtight mixing vessels - fermenters. These can be set in horizontal or vertical plane or even combined arrangements. These vessels are provided with basically continuous doses of substrate. The temperature inside fermenters is kept constant at 35 °C under mesophilic conditions or 55 °C under thermophilic conditions respectively. A thermophilic process is characterised by deeper decomposition of organic matter, higher production of biogas, however, that is at the expense of lower process stability.

As this is a process working with a certain settled state, it requires adherence to essential operating parameters some of which have to be observed during the very technology design work:

- Size and efficiency of reactors (depending on mixing intensity)
- Load of reactors by in-feed of organic matter
- Concentration of ammonia nitrogen in reactors

Selected recommended parameters of the wet process:

- 2-stage process or piston flow process
- 60 days delay time
- reactor loads of 3 - 4 kg (of organic matter) / m^3 (reactor) / day
- even concentration of ammonia nitrogen in reactors under 4 g/l

Production of electric power in form of biogas is conveniently supplemented with a balance of specific yield of biogas based on solids, resp. organic solids contained in the input materials. These values are not accurate, yet they present an overall basic idea of options for biogas production in most cases.

Biogas developing in a fermenter is stored in the gas container located right above the fermenter, for wet fermentation, and these elements are separated with a semi-permeable membrane only. The gas container is used to balance the uneven production of biogas with permanent operation of the combined heat and power unit (CHPU). Prior to its entry into the CHPU, biogas is then processed, mainly with respect to remove humidity and sulphur contents that induce highly-corrosive effects.

The remainder left after fermentation, the so called "digestion product" is then pumped into the storage tank to be used further as an almost odourless fertilizer spread over fields and meadows by tank trucks in compliance with the EU nitrate standards. [1]

Own Electric Power Consumption

The electric energy consumed by a BGS is very hard to enumerate in accurate figures, as the volumes differ per technology. Yet it is still possible to identify certain main components of technologies associated with substantial electric power consumption within. The largest consumers of electric power can be found among appliances used to process the input material. Those are heavy electric power consumers as crushers, for example. Further heavy consumers include a pump/pumps for the integrated pumping system of BGS. Another aspect not to be missed is consumption generated by the fermenter contents mixing unit - units, which depends on the fermentation tank size. Further appliances comprise the very CHPU´s (pumps integrated in motor, motor electronics, gas vent) and potential devices for processing of digested product (centrifuge). These are also components with their consumption substantially different from normal values and it can indicate insufficient engineering solution. It is also necessary to point out here that the very consumption of

BGS during operation cannot be stated in claim for the so called "green bonuses" provided within subsidy towards purchasing prices set by the Energy Regulatory Office.

The total operating consumption of electric power may even range in the area of approx. 15 - 30 % of the energy produced, depending on the unit size and technology installed. [2]

Own Heat Consumption

Utilisation of heat is strongly affected by the ingredients in input raw materials. Genuine agricultural BGS would project a heat consumption figure far below levels shown by BGS for processing of waste. The law implies that biologically degradable waste must be deprived of pathogenic germs. This process comprises heating the input raw materials to a high temperature required to kill all hazardous microorganisms. That may be even up to 80 °C for a period exceeding 1 hour. This process needs to be applied especially on kitchen and slaughterhouse wastes. The remaining heat consumed is used to keep the temperature inside fermenter stable. It depends on the quality of fermenter heat insulation and obviously the actual season of the year, rising several times in winter compared to figures achieved during summer months. That is the reason for very broad range of own heat consumption of 30 % to 80 % of energy produced. [2]

II. Co-Generation Unit

The co-generation units currently used within biogas stations are mostly represented by diesel combustions engines modified for biogas combustion purposes. This modification lies in replacement of the fuel system. There are two methods of fuel ignition used, with adding of diesel into fuel to ensure its ignition upon achievement of certain compression and resultant heat-up of fuel to the ignition point. The disadvantage of this system is large consumption of diesel during higher performance operation, when the diesel content might exceed 10 % of the fuel volume. Another option deals with fitting a glow plug in the motor associated with certain technical problems as these motors are not designed for such solutions.

The motor is coupled with generator via a clutch. The electric efficiency of co-generation unit ranges around 30 to 40 % of energy contained in fuel. Together with heat efficiency reaching values of 45 to 60 %, the total efficiency of CHPU amounts to approximately 90 %. [3] Current CHPU designs are being supplemented with the organic Rankin-Clausius cycle (ORC) represented by a modification of power plant Rankin-Clausius cycle with the only different that water vapour driving the turbine is replaced with organic liquid featuring a lower point of volatilisation (70 - 130 °C), while operating pressure is preserved. When using the ORC, flue exchanger is coupled with steam turbines connected to the generator instead of heat off-take. That will increase the electric efficiency up to 45 % (sometimes even more), while the heat efficiency will be reduced at the same time. The heat output of CHPU require to operate the ORC is equal to approx. 10 kWt/kWe of the ORC performance. [4]

III. BGS and Remote Control

The Czech Energy Control Act implies that every BGS must be provided with a remote control system. The latest deadline possible for all resources exceeding 100 kW is 30th June 2013. Different output control modes have been agreed with respect to effective utilisation of biogas. The suggested control system deals with 100 - 75 - 50 - 0 % pattern of the installed capacity. Other renewable resources are mainly managed in accordance with the output control mode with 100 - 70 - 30 - 0 % pattern of the installed capacity. Depending on the nature of electric power production, the power output should be primarily reduced, i.e. by disconnecting other renewable energy resources. [5]

IV. BGS Utilisations Options

Another option for storage is to connect a specific BGS into the electric power grid as a peak power supply to balance grid fluctuations especially at the low voltage level at the end of grid, where these are mostly installed. That prevents additional losses in transfer from large centralised supply units. However, they are disadvantaged by the relatively low output of several hundreds of kilowatts or a few megawatts at maximum.

BGS as Backup Compensation Supply

One of the options to utilise controlled BGS is to connect it on the same line as a non-controlled, stochastic power supply, e.g. photovoltaic or wind power plant. The BGS serves as a compensation supply in this case and it produces electric power and heat during periods of reduced supply from the primary source only. The specific area would then experience reduction of peak output and achievement of better production stability. As far as their control is concerned, both supply units would have to cooperate together and the BGS would require a larger gas container. For up to half a day production of biogas and with double output motor. It is more convenient rather for collaboration with a photovoltaic power plant that ensures better operation stability compared to wind power plants, which might incur several days of downtime period due to zero wind. [6]

BGS and Supporting Services

Potential connection of BGS as a supporting services will require improvement of its storage capacity for produced biogas. Six hours of downtime will require raising the motor output by 30 %. Stopping, launching and reduction of production have been addressed at existing BGS facilities for standard conditions of power supply connection and disconnection under crisis situations. The existing control software of BGS has been already modified accordingly and enables full remote control of whole BGS operation. As BGS units feature a relatively low output (regularly up to 1 MWe of installed output) and they are greatly dispersed mainly over countryside areas, their significance lies mainly in provision of supporting services to operators of distribution grids.

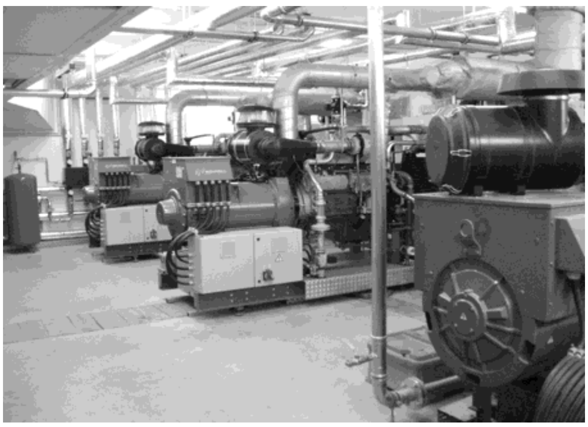

Fig.1. Co-generation units: 2 x 250 kWe and 1 x 340 kWe

Owing to the increase in production of electric power by photovoltaic power plants, this method for BGS utilisation represents one of the options for maintenance of required electric power quality. This method will be even better to exploit following introduction of the so called "Smart Grids".

Provision of supporting services to the transfer electric power grid requires joining of several BGS units into virtual blocks with the minimum output of 10 MW and up to 30 MW in optimal case. The variety of owners possessing individual BGS units poses a problem to utilisation of confined control output only. The reason is, whether all BGS´s reduce their output evenly or in proportion to their nominal output only.

Higher efficiency will be preserved by shut-down of one or more BGS units. That will invoke certain problems associated with distribution of profits. Another disadvantage would be the continuous production of biogas running independent of CHPU operation. That implies the need to provide such services in regular (daily) intervals to avoid non-productive combustion of stored biogas by the safety burner. [6, 7]

Control Using Natural Gas Distribution Network

The natural gas distribution network can be used for distribution of biogas process to match the quality of natural gas. That will help towards achievement of maximum utilisation of energy potential from the obtained fuel. The storage effect of distribution network serves mainly to correct the imbalance between almost stable production of biogas and peak operation of the co-generation unit. This method is not utilised to a greater extent due to significant costs incurred by processing of biogas. It is considered for large power supply units in future. However, further progress of technologies applied for biogas processing might result in reduction of investment amounts required for the technology to such extent that the solution could pay its way for smaller power supply units as well. [8]

Involvement of BGS in Electric Power Equalizing Market

The law in energetics stated that every BGS operator must be registered for this particular market. Each registered participant then has the opportunity to participate in the equalizing market and offer its control capacity within short-term electric power trading transactions. Those are simple transactions between producers and the power grid operator. As it is mostly negative control energy, this is a good opportunity for BGS. The disadvantage of overall shut-down is mainly the increased heat load on certain parts resulting in substantial reduction of their service life. It is therefore better to reduce the output to approximately 30 % of the installed output. Even though the minimum output is not limited, the BGS would be more convenient when connected into a virtual block with higher output. [7]

V. Farming Biogas Station

The biogas station is situated in the premises of farming enterprise concerned with pork farming, besides other. The input raw materials for production of biogas include maize silage and pig's slurry, which represents a sufficient source of liquid for the implemented wet fermentation technology. The slurry is stored in three containers for subsequent pumping into fermenters in adequate quantities. The BGS is formed by two cylindrical fermenters and one joint dofermenter. One of the reasons for this layout was to utilise the exhaust heat for heating in adjacent pigsties.

Parameters of BGS

The installed output of BGS is 1,090 kWe and its calorific power is 1,080 kWt. The initial set-up included 3 cogenerating units (CGU) only; those were two diesel units with output of 2 × 250 kWe and one petrol unit with output of 340 kWe (see Fig. 1). Due to excess in biogas production, these units were further supplemented with another diesel with identical output of 250 kWe.

The raw gas from gas contained is subject to processing prior to its supply to co-generation units. There are two condensing units to remove humidity from biogas (see Fig. 2). The biogas is then fed through filter cartridges containing active carbon to remove sulphur, which is strongly corrosive. Such purified biogas is then supplied into particular co-generation units.

The co-generation units are situated in the building engine plant with all equipment necessary for control of the whole biogas station. The plant roof is fitted with coolers for summer operation. Also the outlet pipe of exhaust system is directed upwards to reduce noise emissions into the environment. Suppressors are used to reduce the noise level.

All heat produced during winter months is used for heating within the entire premises of the farming enterprise comprising an office building, several halls and sties. The biogas station was connected to the existing heat supply lines and replaced the aged gas boiler plant. That brought savings in construction of the heating system. The farm is currently building a connection to the after harvest line for utilisation of heat to dry grain during summer months. The hot-water pipe circuit is separated from the circuit of co-generation units by means of plate heat exchanger.

The display also shows an overview of individual devices and their operation status (see Fig. 3). Excessive biogas is combusted by the safety burner that used to be utilised to significant extent prior to linkage to the last co-generation unit.

Fig.2. Biogas quality alteration device (dehumidification and de-sulphurizing)

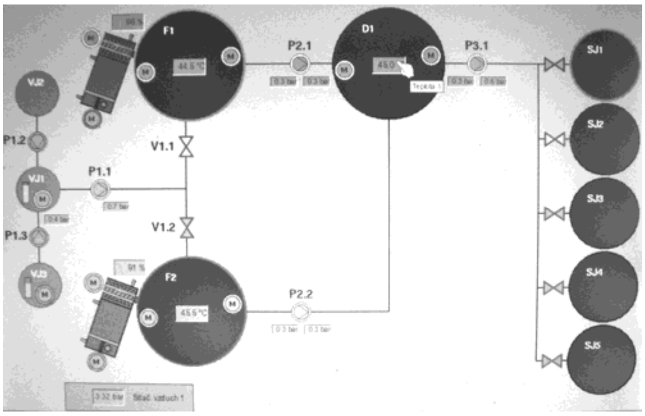

Fig.3. Overview diagram of the BGS control system

The electric power is fed through a transformer station rated 0.4/22 kV into the outside line operated by a power distributor. The transformer station comprises one transformer unit with the maximum output of 1,250 kVA and the nominal current of 1,804 A.

BGS Operation Analysis

The BGS under analysis with co-generation of electric power and heat has been in operation since December 2011. Time courses of both most important values that characterise operation of this BGS and other such units, i.e. the amount of biogas produced and then consumed in the CGU; and the amount of energy from biogas produced and supplied into the electric power distribution network are shown in the following figures (see Fig. 4, 5 and 6).

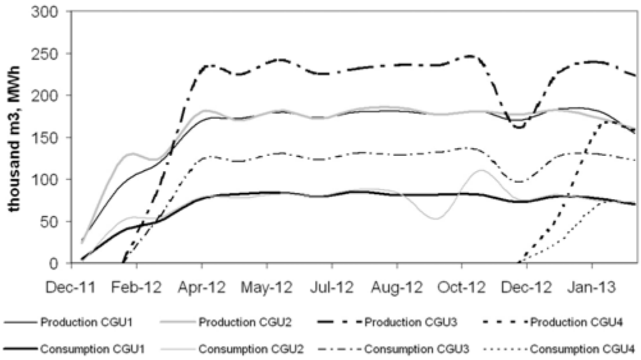

Fig.4. Course of biogas consumption and electric power production at individual co-generation units

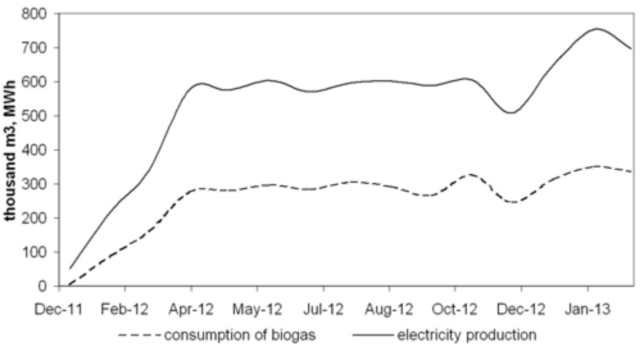

Fig.5. Course of biogas consumption and electric power production for the whole biogas station

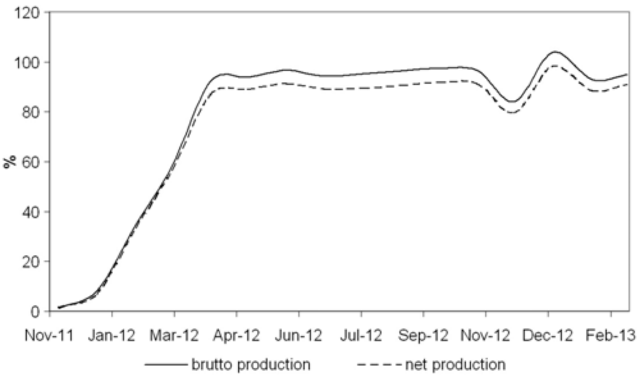

Fig.6. Course of terminal production and supply of electric power into the electric power distribution network (utilisation percentage of BGS)

The graph in Fig. 5 shows the apparent almost constant course of output from all co-generation units. The drop at the third CGU in November 2012 was caused by alterations necessary for linkage of the fourth CGU.

The graph in Fig. 5 shows progressive launch of production of the biogas station, beginning with initiation of two CGU's with output of 2 × 250 kWe and the third CGU with the output of 340 kWe started up about two months later. The graph in Fig. 7 shows the long-term utilisation of biogas station exceeding 90 %. The variation at the end of the last year was caused by connection of another co-generation unit and associated adjustments.

Outlook for BGS Utilisation

With respect to the planned installation of remote control system, it will be possible to manage the output supplied by the BGS under analysis into the electric power distribution network within the 100 - 75 - 50 - 0 % mode pattern reflecting on its installed capacity. As the BGS is currently operated at almost 95 % level of the output, the capacity of containers will require extension with respect to the above stated reasons. That can be achieved by means of a technologically and financially unexacting extension (augmentation) of both fermenters to enable these absorb immediate overproduction of biogas in periods of reduced output from CGU or even its complete shutdown.

Conclusion

This paper outlines certain future options for utilisation of biogas stations as storage power supply units with growing demand to parallel the progressing development of renewable energy resources, especially unstable photovoltaic power plants. Biogas station units represent a convenient source of energy for their fast start-up and easy remote control using dispatching control system. They are disadvantaged by their low output, which will be compensated by their connection into virtual blocks with higher output in future.

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