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Biogas Equipment for Electricity and Heating

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The paper gives an example of a biogas plant used for electricity and heat production. First, the role and importance of the biogas plant is presented, then an overview of the raw materials used for biogas production is given, a project of the biogas plant with constituent elements is given, as well as a description of the technological process and elements of the biogas plant. The calculation of biogas consumption for the needs of the power plant of 0.999 MW has also been performed.

Key words: **biogas plant, biogas, power plant, heat energy.**

Introduction

THE biogas plant is a complex microbiological-biochemical-technical system. It differs from most other types of power plants in that the combustion process, i.e. of biogas, preceded by biochemical conversion of organic matter of the substrate into biogas. In general, the biogas production and use chain can be divided into: substrate production; biogas production; use of biogas; utilization of fermentation residue [1, 2].

During the first phase, energy crops or fodder are produced to produce manure. Subsequently, the resulting biogas substrates need to be transported and stored. In the second phase, biogas is produced, and in the third phase biogas is used to generate electricity and heat [3, 4, 5]. After completion of the anaerobic process, the fermentation residue is temporarily stored and then distributed on agricultural and other surfaces, i.e. used for plant production, thus rounding the chain of production and use of biogas.

Biogas is produced by the process of microbial degradation of organic matter under anaerobic conditions (without oxygen) and in the presence of anaerobic bacterial species. Today, most commonly, the term "biogas" refers to gas produced in anaerobic fermenters and controlled conditions, that is, gas produced in biogas plants [6, 7].

The biogas composition is as follows: Methane CH_4 ca 50 - 55%; Carbon dioxide CO_2 ca 45 - 50%; Nitrogen N_2 ca 0 - 3%; Hydrogen N_2 ca 0 - 1%; Oxygen O_2 0 - 1%; Hydrogen sulfide H_2S ca 0 - 2%.

Most of the existing biogas plants are those that use exclusively manure, substrates, manure, energy crops, harvesting and other residues from agriculture and primary processing of agricultural products [8, 9, 10]. The construction of biogas plants aims to protect the environment, but also to decentralize electricity generation and profit [11, 12].

An example of a biogas plant

The following facilities / units are designed for the construction of the biogas power plant:

- Reception pit.
- In the receiving pit, the receiving, shredding and homogenization of the substrate that forms the mixture: manure and organic waste and maize silage is carried out. From the receiving pit, the substrate is transported to the digester.
- Anaerobic digester is a concrete structure made on the basis of patented technology, technological dimensions 22x63m, height 5 m. Organic mass (substrate) treatment is carried out in the anaerobic digester. The product of anaerobic digestion is treated organic waste and biogas.
- Container with equipment that supports the operation of the anaerobic digester, the outer dimensions of the container are 8.74x2.35 m.
- Power plant with associated substation, measuring 27x10.5 m, in which: Machine room with unit for combined heat and power production based on internal combustion engine (CHP), power 0,999 MW + 1,05 MWt, control room with power cabinets, room for separation of treated digestate and placement of separated solid phase.
- Laguna, to accommodate the liquid phase of the digestate after separation. The lagoon is earthy with foil and sloping edges, square in shape, with approximate internal dimensions of 87 m at the top and 80 m at the bottom.
- Precast concrete substation (MBTS) of transmission ratio 0,4 / 20kV, overall dimensions 5.09m x 4.3m x 3.3m.

For the purposes of the biogas plant, the substrates given in Table 1 are used.

- Table 2 provides data relevant to the digester and the substrate.
- Table 3 provides information relevant to the power system connection.

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- Table 4 provides data relevant to thermal energy.

Table 1. Overview of the substrate entering the digester

Raw material	Quantity t/day	Dry matter content%
Pork manure	14	7,7
Cow manure	17	20
Factory bulls manure	34	10
Corn waste sugar	9,84	25
Whey	40	5,3
Corn silage	28	33
Recycled water	70	2,5
Fresh water	20	0
Other waste	0	0

Table 2. Digestor and substrate relevant data

Gross / net volume of digesters	6930/6100m^3
Quantity of biogas produced in a digester	480 m^3/h
Medium methane content	55 %
Daily mass input of material	220-240 t/ day
Daily production of the solid fraction after separation (with 65% humidity)	20-25 t/day
Daily intake of fluid in the lagoon (with 2-3 dry weight)	125-130 t/day

Table 3. Data relevant to the power system connection

Power of power plant at generator output	0,999 MW
Generator voltage	400 V
Frequency	50 Hz
Rpm	1500 o/min
Estimated annual availability	8000 h
Generated electricity on an annual basis	8000 MWh
Maximum installed power of the plant's electrical appliances and auxiliaries	140 kW
Max. the concurrent power of the plant's electrical appliances and auxiliary plants	120 kW
Annual own electricity consumption (8%)	640 MWh

Table 4. Data relevant to thermal energy

Thermal power of CHP plant	1,05 MW t
The temperature of hot water produced is flow / return	65/85 ºC

Description of the technological process and elements of the plant

Anaerobic digestor

Anaerobic Digestor is a patented renewable energy system designed to be used in the treatment of organic waste and / or biomass and biogas production. From the biogas generated, electricity is generated in a three-phase generator directly coupled to an internal combustion engine that burns biogas [13, 14].

Inside the digester is a patented heat exchanger system for heating the digester as well as a nozzle system for inflating biogas to agitate the digestate.

The container consists of: a digester heating system consisting of circulation pumps, recirculation pumps, regulating and shut-off valves, expansion vessel, internal and external piping and agitation system i.e. mixing in a digester consisting of a biogas blower (compressor), regulating and shut-off valves, internal and external piping.

The main characteristic of this digester is the guaranteed retention time of the substance in the digester, which achieves the maximum degradation of the material, which has the positive consequence, a high quality digestate, at the exit of the digester and increased production of biogas, which is produced as a product of anaerobic digestion [14, 15].

Available biodegradable biomass and / or organic waste, as renewable resources, are collected in the receiving pit directly next to the digesters, where they are mixed, ground and homogenized and pumped directly into the first chamber of the anaerobic digester.

During the first phase in the concrete anaerobic digester, the freshly introduced material is mixed and heated to a temperature of 36-38 ° C. Waste heat from the electrical co-generator system is used to heat the digester to the optimum temperature required for methanogenic bacteria to grow. The first phase of the system is designed to allow the growth of acid-forming bacteria. These bacteria break down complex organic material into more volatile fatty acids and acetic acid. Inserted substrate / materials from the first phase of the digester, gravitationally goes to the second phase of the reservoir.

The second phase is also the longest phase, due to the slower growth of methanogenic bacteria. These bacteria convert volatile fatty acids and acetic acid, produced in the first stage of the digester into biogas, which is predominantly methane (50-60%) and 〖CO〗 _2 (40-50%). Waste heat from the electrical co-generator system will also be used during the second phase to maintain the fluid temperature in the pool at 36-38°C, thereby canceling heat loss through the walls of the digester.

After the second phase of the system, the treated digestate will flow gravitationally into the receiving pit, from where it will subsequently be pumped from the digester to the separator.

The biogas that is produced is collected in the reservoir and used as fuel in the CHP plant. These generator sets are commercially available, natural gas piston engines adapted to run on biogas. All electricity generated by the generator would be supplied to the Distribution System Operator. The system would continuously produce biogas, electricity and thermal energy. Waste heat, converted to hot water, comes from engine cooling, and exhaust gas cooling. Approximately 30% of the heat produced annually is used in the digester heating system. The rest of this heat energy can be used to produce hot water, i.e. for heating buildings or other technological needs.

About 10% of the solid biomaterial from the anaerobic digester, rich in methanogenic bacteria, is recycled from the end of the second and reused at the beginning of the first stage in the reservoir as a "seed" to begin the process of working the methanogenic bacteria. The rest of the 90% solid material is pumped from the digester outlet to the solid phase separation device.

Energy - heat and electricity combination plants

Machine room with combined heat and power (CHP) unit, the basic elements of which are: internal combustion biogas engine with two-stage turbocharger, (1500 rpm), three-phase asynchronous generator producing 400 V electricity, directly connected to engine, engine block heat exchangers and flue gas side heat exchanger.

The heat generated by the CHP unit comes from waste heat from the following sources: turbocharger cooling - 1 degree, engine oil cooling, engine block cooling, flue gas cooling.

The power of the first three sources is 580-600 kW while the power of the heat exchanger on the flue gas side is 450-470 kW which is a total of 1050 kW. The transfer of heat in the form of hot water to consumers outside the plant from all four above-mentioned heat exchangers (hydraulically connected) is via a central heat exchanger of 1050 kW.

In case there is no need for heat energy, an engine air cooler is located outside the facility whose capacity is adapted to the operating conditions of the CHP plant.

In addition to the engine air cooler, a turbocharger air cooler with an approximate power of 60 kW is also anticipated.

Biogas from a 10 mbar pressure digester is fed to the engine via a blower that raises the pressure to 100-200 mbar and the appropriate biogas treatment equipment.

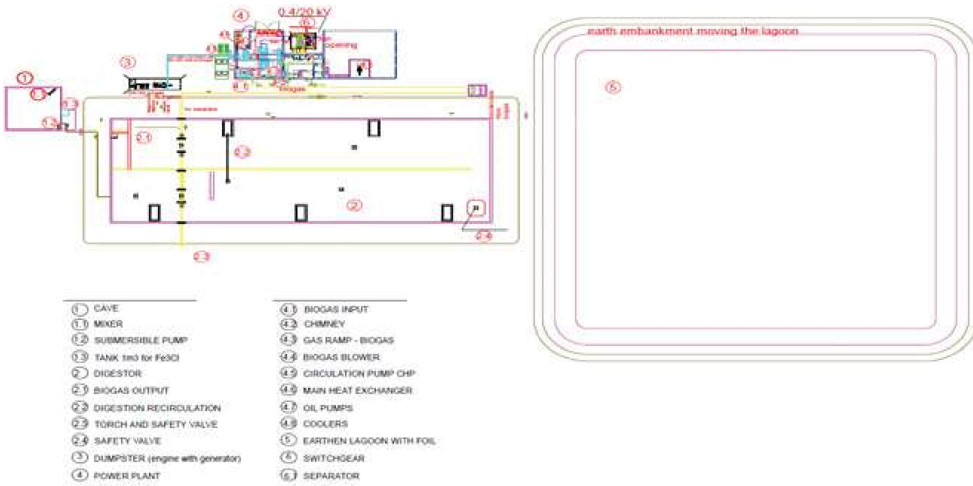

Figure 1. Biogas plant

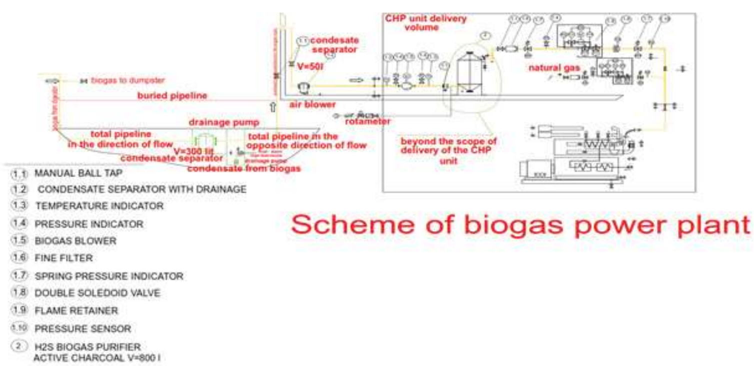

Figure 2. Scheme of biogas power plant

Biogas consumption budget

The pipeline for the transport of biogas is dimensioned in the worst case, i.e. for a minimum methane contentof 50%.

Power output of CHP plant generator Pel = 999 kWel

Heat value of biogas with a minimum methane content of 50% H = 18000 kJ / m^3 (5.0 kWh / m^3)

CHP electric power efficiency, i.e. set generator η = 40.5%

Engine biogas consumption

$$B = \frac{P}{\eta H} = 493 \text{ m}^3/\text{h}$$

The plant is dimensioned for capacities or flows of 500 m^3 / h.

Conclusions

Biogas plants are very efficient in decomposing or fermenting waste. Instead of consuming energy, they produce it, and are different from all other systems.

In addition to environmental, the main advantages of biogas plants are the production of biogas and fertilizers. Additional benefits include: generation of electricity and heat, production of biomethane, and savings on the capital costs of waste management systems when constructing new facilities. Biogas production prevents methane emissions into the atmosphere, which is the best way to reduce global warming [11, 12].

The implementation of the project achieves: reduction of energy dependence on imported fossil fuels, improved awareness of the use of renewable energy sources, increase of energy efficiency, increase of economic activities at the local level and thus local development, environmental protection.

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Biogasno postrojenje za proizvodnju električne i toplotne energije

U radu je dat primer biogasnog postrojenja koje se koristi za proizvodnju električne i toplotne energije. Najpre je predstavljena uloga i značaj biogasnog postrojenja, zatim je dat prikaz sirovina koje se koriste za dobijanje biogasa, dat je projekat biogasnog postrojenja sa sastavnim elementima, kao i sam opis tehnološkog procesa i elemenata biogasnog postrojenja. Takođe je izveden proračun potrošnje biogasa za potrebe elektrane snage 0,999 MW.

Ključne reči: **biogasno postrojenje, biogas, elektrana, energana.**