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SYNTHESIS AND IMPLEMENTATION OF BIOGAS PRODUCTION IN WASTEWATER TREATMENT PLANT

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Abstract. In this paper, the problem was to carry out a study on the process of mass production of biogas and to deduce the analysis of an example implemented in the wastewater treatment plant. The main problem is the correct processing of the activated sludge and the extraction of the biogas with its basic components. The method described in the paper is current as a technology in the biogas production industry by treating activated sludge from a wastewater treatment plant. For the extraction of biogas according to EU standards and the possibility to use it at each stage of extraction, methods and technologies specific to this process are used and explained.

Keywords: *biogas, desulphurization, gas flare, co-generation unit, PLC, SCADA, automatic control.*

Rezumat. În această lucrare problema analizată a fost studiul procesului de producere în masă a biogazului, inclusiv pe baza unui exemplu implementat în stația de epurare a apelor uzate. Problema principală este prelucrarea corectă a nămolului activ și extracția biogazului cu componentele sale de bază. Metoda descrisă în lucrare este actuală ca tehnologie în industria producției de biogaz prin tratarea nămolului activ dintr-o stație de epurare a apelor uzate. Pentru extracția biogazului conform standardelor UE și a posibilității de utilizare a acestuia în uz general, la fiecare etapă de extracție se folosesc metode și tehnologii specifice acestui proces, explicate în această lucrare.

Cuvinte cheie: *biogaz, desulfurare, ardere de gaz, unitate de cogenerare, PLC, SCADA, control automat.*

Introduction

Anaerobic digestion of sewage sludge is a well-known, efficient and environmentally friendly technology that allows the production of energy in the form of heat, electricity and fuel for vehicles, as well as the stabilization and reduction of sludge volume. The production of biogas in a wastewater treatment plant can be done in different ways, but the result depends on the correct operation of this system, with well-chosen equipment [1].

Original Biogas is the term used for the mixture of gases (methane, hydrogen and carbon dioxide, etc.) of biogenic origin that arise from the processes of fermentation or gasification of various organic substances. These gases are used by combustion as an energy source (biogenic energy). The energy obtained from this chain, biomass → biogas → electricity and heat, is called renewable energy, for the following reason: carbon dioxide released into the atmosphere by burning biogas, is an amount at most equal to the amount assimilated by plants or feed consumed of animals, in their vegetal period. According to the Kyoto Protocol, this is a closed circuit of carbon dioxide, unlike fossil fuels (methane gas, coal, crude oil) which burn carbon dioxide which was assimilated many thousands of years ago. Typical sewage sludge comprises primary sludge separated from wastewater during pre-settling and excess biological sludge from the activated sludge system [2]. The characteristics of sewage sludge differ somewhat in different countries and areas, for example, due to water consumption and local industry. The total solids content (TS) is usually low and the volume of sludge is higher than if some of the water is removed before sludge treatment. Biological stabilization of sludge aims at the degradation of solid volatiles (VS), the organic content of the sludge, and the subsequent decrease of the sludge volume. Moreover, nitrogen and phosphorus content are important, especially when the stabilized sludge is reused as fertilizer or as a soil improver. Sewage sludge contains readily biodegradable materials and its typical methane production potential is approximately 300-400 m^3 / tVSadded [3]. The amount of wastewater collected through sewerage networks in Moldova is constantly increasing, so the amount of treated water increases, causing an increase in the amount of sludge processed and thus an increase in energy consumption specific to wastewater treatment and sewage sludge. In the coming years, the conditions for disposal and disposal of waste will be tightened in accordance with European regulations. Sludge resulting from the treatment process is classified as non-hazardous waste, which is allowed for storage. Improper treatment of sludge in landfills can lead to its disposal in authorized landfills. The use of renewable energy sources has a negligible impact on the environment, they emit greenhouse gases. Even if by burning, the biomass eliminates an amount of CO^2, this amount is absorbed by it during its growth, the balance being zero. At the same time, these technologies do not produce hazardous waste.

Biogas utilisation plant

Within this part of plant, the following plant components has to be controlled:

- Gas Desulphurization;
- Gas Holder;
- Gas Booster station;
- Gas Flare;
- CHP-units.

The produced gas is a product of the anaerobic sludge stabilization which has a specific energy content of about 6.4 kWh/m^3 because of its methane content. Due to this fact the gas can be used as fuel in combined heat and power stations after a pre-treatment. Therefore, the treated biogas is foreseen to be used for burning in a CHP unit which are providing the required heat for the dewatering pre-heating but also for heating the buildings. The combined heat and power unit generates additionally electrical energy which will be used in the wastewater treatment plant. If the produced gas is not required for heating purposes and the gas cannot be used for the CHP and also the storage capacity of the gas holder is exceeding, then the excess gas has to be burned by the gas flare without electrical and thermic usage. So consequently the gas flare plant is used as a security unit.

Gas desulphurization

The function of the biogas desulphurization system is removing H2S from biogas biologically. The control philosophy overview is:

a) The gas produced in each digestion tank will be collected on one biogas line and pass through the gravel filter located in Gas Room which is for coarse gas cleaning. The gravel filter also serves to separate and drain off condensation in the digestion gas. After the gravel filter, biogas passes through a desulphurization plant will be installed where the gas is undergone a desulphurization process. The biogas flowrate will be measured on the biogas line just before the desulphurization system. This flowmeter controls the operation of the aeration blower of the desulphurization system in order to prevent supplying excess air to the desulphurization unit.

b) Desulphurization system is the biological type and mainly consist of following components:

- Two centrifugal recirculation pumps;
- Two nutrient feeding pumps for biomass media;
- One blower for providing air to the biomass media;
- Hot water system including hot water pump;
- Ambient ex-sensors for controlling the leakage in control room.

c) The control of the whole plant will be carried out by an own local control panel is not part of the main PLC program. Status of operation and faults has to be transmitted to SCADA [4]. Biogas quality at the outlet of the desulphurization unit will be monitored with an inline biogas analyzer with following parameters:

- CH_4, H_2S, CO_2, O_2.

Biogas holder

The function of the biogas holder is an intermediate storage of biogas. After the desulphurization plant, the gas holder tank follows. The gas holder tank is directly integrated in the main gas pipe. There are two automatic condensate traps installed prior to and right after the gas tanks. These condensate traps are placed in a small chamber in front of gas holder. The removed and collected condensate flows into the drainage line which is transferring the drainage to condensate pumping shaft which also collects the drainage from desulphurization unit and gas room. Condensate collected from biogas utilization plant is pumped into the existing internal pipeline with the help of condensate pump. The control of the condensate pump takes place by two level switches placed in the shaft. The task of the gas holder is to store intermediately the peak gas production during the day so that the CHP can be fed with gas also in times when the gas production is low. The gas holder is equipped with level measurement transmitter. These are required for the control of the gas holder, gas flare and gas boiler as well as combined heat and power unit [5]. Biogas Holder is equipped with one blower which is functioning continuously in order to maintain the rigidity of the outside membrane of gas holder and maintain the necessary pressure in the biogas system over the interior membrane. Furthermore, the Biogas Holder is equipped with a mechanical excess pressure safety device for security reason.

This safety device compensates and balances every unusual pressure which is beyond the allowance. Several pre-set values have to be created and adjusted in the SCADA system, to ensure a proper operation of the gas utilization plant. So the level detector is quite important for the biogas management.

Biogas booster blowers

The function of the biogas booster blowers is delivering the biogas to CHP's with requested pressure. A ceramic filter will be provided on the biogas line after the biogas holder in gas room for further filtering of humidity in the biogas before sending it to the CHP's. Two gas blowers are installed in gas room in order to feed the biogas to two CHP-units. Capacity of the gas blowers are selected as to serve one CHP unit in his maximum capacity. These gas blowers are equipped with frequency converters in order to adjust the speed in accordance with the capacity signal (50-100%) receiving from CHP unit. A fine tuning related to the CHP capacity and blower speed will be done during commissioning phase. During operating with one CHP unit, an automatic exchange between duty and stand-by aggregate has to be provided to get even or similar operation times by a timer. In case of a failure at the duty aggregate, the stand-by aggregate takes over the job automatically. During operating with two CHP's, both of the blowers will function in accordance with the capacity signals (50-100%) receiving from two CHP units.

The following prerequisites have to be met for the operation of the biogas booster blowers in Automatic mode:

- The high temperature switches on the blower bearing are not activated and there is no other fault with the equipment;
- The low pressure switches on the suction side of the blowers are not activated;
- The high pressure switches on the discharge side of the blowers are not activated;
- The level in the biogas holder is not at or below Low level;
- Biogas quality (CH_4 and H_2S) is acceptable.

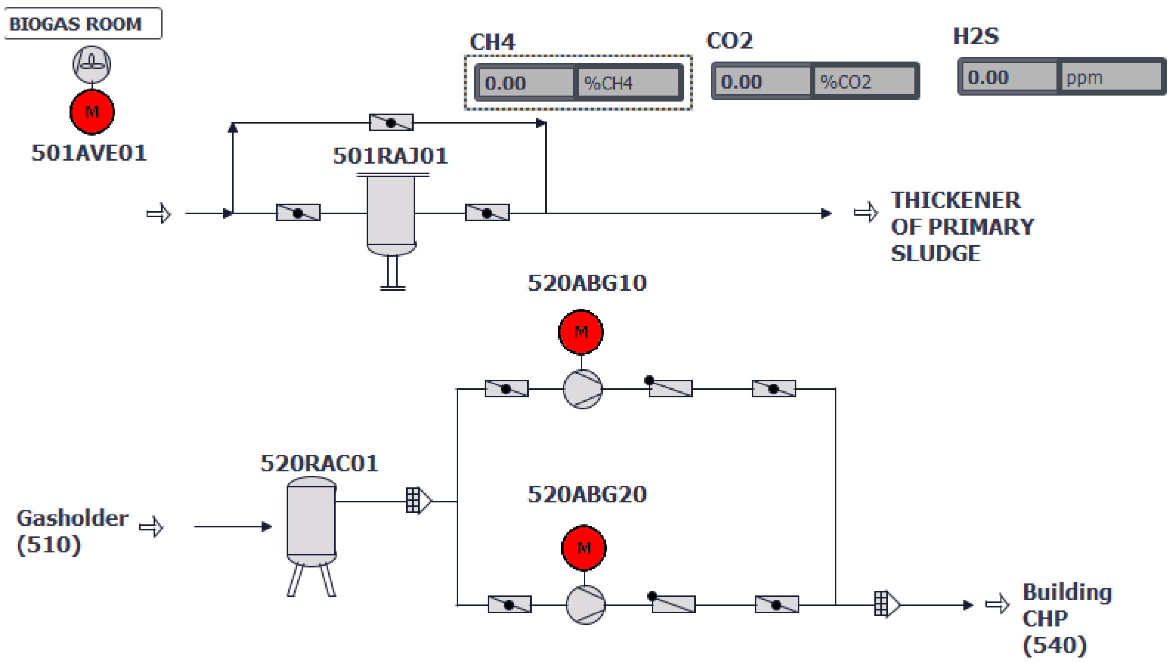

Figure 1. Biogas room [14].

Local control panel(s) for the biogas blowers shall be located in gas room, including an emergency stop button, automatic / manual switch and, for each device, safety separators, on / off buttons, motor speed control button, motor speed display, operation signals, fault / alarm shall be available [7]. The selector switches at the distribution board have to be in "AUTO" position in order to have the possibility of automatically operation. The demand for operation of the gas blower(s) in "AUTO"-mode will come from the CHP unit(s) when enough biogas is stored within the gas holder for CHP operation (level is above low level). In case biogas blowers were in function (together with CHP's) when the level dropped below the Low level, biogas blowers will remain in function until the closing cycle of the CHP's are completed (switch off signal will come from CHP unit(s). Discharge of each blower is equipped with flow failure switch. In case of no flow is observed on the discharge line of the blower after a pre-set amount of time (e.g. 5 sec), blower will stop immediately and an alarm will be triggered on PLC/SCADA system for operator's check [11].

Biogas flare

The function of the biogas flare is burning excess biogas in case of an emergency. The combustion of biogas is carried out in the emergency flare, if the gas is not consumed by one of the gas consumers and the gas tank is filled up. The Gas Flares are switched on and off according to level in the biogas holder. Please refer to Biogas Holder chapter for conditions of switching on and off of the gas flare. When the starting signal is received from the biogas holder, the gas flare will first ignite the pilot light with opening pilot valve (Figure 2).

The flame detection is effected through a signal produced by the Thermocouple mounted inside the pilot and controls the burning process as follows:

- If the flame detector fails to recognize any flame the main gas valve closes and an alarm is generated;
- In case of successful ignition (thermocouple reaches 80 ˚C), system opens the main gas valve, switches on the biogas flare blower and ignites the main burner of the flame of the pilot burner.

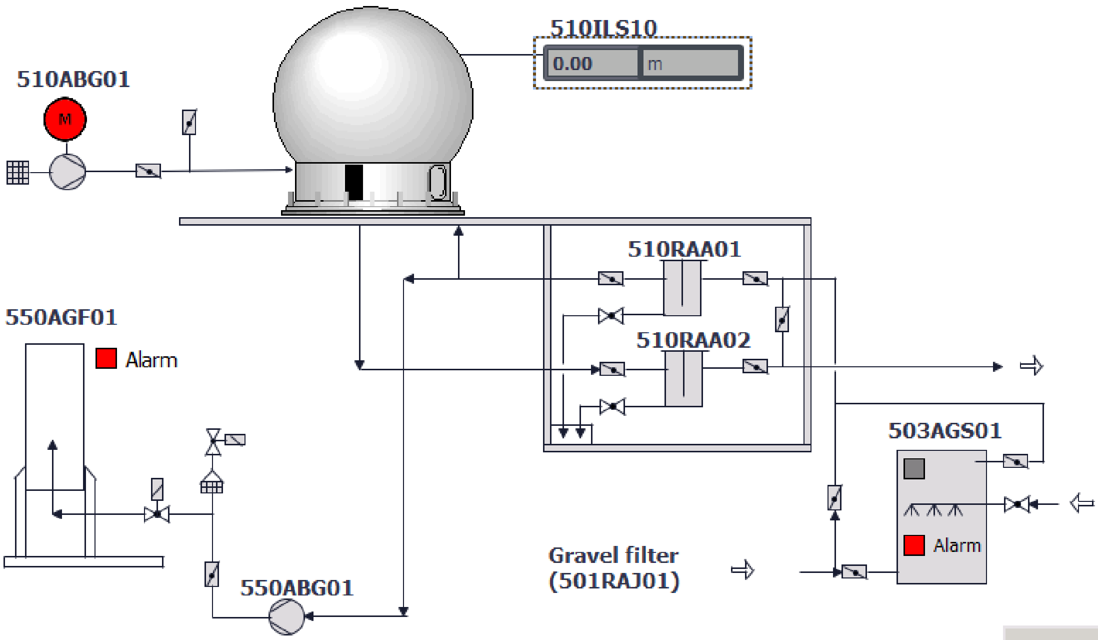

Figure 2. Desulphurization system, Biogas holder, Biogas flare [14].

The automatic control belongs to the local control panels of the gas flares and is not part of the main PLC program.

Cogeneration building

The function of the cogeneration building is utilization of the biogas for thermal and electrical energy production. The control philosophy overview is:

a) Control philosophy overview – CHP units

The operation of the CHP-units is carried out by their local control panel. Start and stop signals for CHP-units will be sent by the main PLC according to the filling degree of the gas holder supervised by the level measurement. Quality of the biogas measured after desulphurization unit will also have a control over the operation of CHP-units; if CH_4 or H_2S quality is not acceptable for a certain amount of time (e.g. 2 hours – time that may change the content in gas holder), CHP unit will not be allowed to function. After upgrading the existing control panels of the CHP Units with biogas operation, it will be also possible to adjust the capacity of each CHP-unit from PLC/SCADA system by sending 4-20 mA signals to the local control panel of each unit. Capacity of the CHP-Units will be used to control the frequency of the biogas blowers that will feed the "Active" CHP-Units. A fine tuning on the CHP-Unit capacity and biogas blower operation frequency will be done during commissioning and will be integrated into PLC system for coordinating the operation of both equipment which are placed in separate buildings. The generated power will be synchronized with the network and be fed via the step up transformer to the Medium voltage switchboard.

b) Heat recovery system of CHP units

Hot water circuit for dewatering pre-heating system consists of one twin hot water circulation pump, one automatic 3-way-control valve and one temperature sensor in the heating water return line. Twin hot water circulation pump for dewatering pre-heating delivers the water to the dewatering pre-heating heat exchanger. This twin pump is equipped with frequency converter. Operation of the twin hot water pumps for building heating is done manually by the operator. Twin hot water pump will function continuously with a frequency pre-set by the operator on PLC/SCADA when the switch of the twin pump is set as "Remote/Auto" on his local control panel. Operation signal from the twin hot water pump should start the aero term ventilations located in these buildings automatically.

c) Cogeneration building

A gas detector for CH4 and smoke is placed at the cogeneration building. Signals of this gas detector have to be transferred to PLC / SCADA for alarm, indication and recording purposes. In case that 20% limit value is detected in present gas concentration: start operation of the room ventilation until no gas (methane) is detected anymore in the cogeneration building and a warning will be triggered – high gas level is monitored and operated by the PLC program. In case that 40% limit value is detected in present gas concentration: close the motorized butterfly valve on the biogas feeding line to the CHP-Units and all drives within the corresponding places will be switched off immediately [15].

Conclusions

The energy recovery of the sludge from the municipal treatment plants must also constitute for the Moldavian operators, a technological priority beneficial for the environment and for the reduction of the final costs of wastewater and sludge treatment, presenting the following advantages:

- The risk of environmental pollution with organic pollutants, viruses and pathogens is completely eliminated due to high temperatures during the heat treatment process;
- The sludge from municipal wastewater treatment can be exploited energetically even for a low organic load of the influent, being able to obtain an energy gain of over 30% of the electricity consumption of the treatment plant, so a proportional increase in energy efficiency by 30%.

- In addition to the energy gain from final sludge treatment, the resulting amount of waste decreases significantly from dehydration to ash by more than 15 times, proportionally reducing transportation and storage costs.

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