AUTOMATION AND CONTROL DEVELOPING SOLUTIONS OF ANAEROBIC FERMENTATION PROCESSES

Biró Györgyi *, Lili Mézes, János Borbély***, János Tamás******

University of Debrecen, Centre of Agricultural and Applied Economic Sciences, Faculty of Agricultural and Food Sciences and Environmental Management, Institute of Water and Environmental Management
H-4032 Debrecen, Böszörményi str. 138.
E-mail: gybiro@agr.unideb.hu

Abstract

In Hungary the renewable energy utilisation is planned to achieve 13% by 2020. Biogas production is one of the fields with the largest energy potential. Achieving high efficiency during continuous production despite the mixed and variable composition of input materials is the most common problem which the newly built biogas plants using agricultural raw materials have to deal with. The first experimental fermentors at the Debrecen University Research Centre were built 12 years ago. Control and automation of the four separated bioreactors were executed with ADVANTECH GENIE 3.0 software which granted pre-programmed measurement and points of intervention for pH, temperature, CH_4, CO_2, H_2S, and NH_3. The system became out-of-data, therefore in 2010 it has been redesigned and tested. The system is controlled by Compair Proview SCADA (Supervisory Control and Data Acquisition) software running on Linux platforms. In the recent publication info-technological and technological experiences of the pilot test period are evaluated as well as direction of future development is defined.

Key words: biogas, Linux, Compair Proview SCADA software, Fuzzy

INTRODUCTION

An organic matter with some natural origins like organic manure, food industry by-products and wastes, green vegetal residues, household wastes, communal wastewaters and their sludge is suitable for biogas production (Kacz and Neményi, 1998). The biogas is the gas which arises from organic matters by biological way, with anaerobic bacteria fermentation. The complex organic polymers are degraded simple sugars, amino acids and fatty acids. Then the methanogens convert products of the preceding stages into methane, carbon dioxide, and water (Kovács and Bagi, 2007). The degradation process is complex and depends on a balanced action of several microbial groups (Gujer and Zehnder, 1983). The anaerobic fermentation of wastes is not just a method of environmental protection, but it can also be a renewable energy source. In Hungary the renewable energy utilisation is planned to achieve 13% by 2020 (Bohoczky, 2010, Sembery and Tóth, 2007). Biogas production is one of the fields with the largest energy potential (Bencze Bőcs, 2006; Szunyog, 2008). The most common problem is the mixed and variable composition of input materials, which is used in newly built biogas plants using agricultural raw materials. In despite of this achieve high efficiency during continuous production (Petis, 2007; Petis, 2008).

Nyírbátor large-scale biogas plant reutilise agricultural primer and secondary by-products such as slaughterhouse waste (fat, blood) after the sterilization. The biogas plant uses serial connected 6 mesophilic (38°C) and 6 thermophilic (55°C) Digesters with 17.000 m3 total value. The installation of an additional Digester-pair is currently in progress. The daily biogas yield is between 20-25.000 m3 with 60-65% methane content. In this plant 29% of the biomass is farmyard manure, 13% are fermented products from plant production, 19% is wastes and secondary products of plant production and 39% are animal wastes (Petis, 2005). It is a complex task to provide a consistently high biogas yield because the continuously various raw materials (Tamás et al., 2010). The biogas plant was an experimental contract with our Environmental Research Laboratory of the Debrecen University, Institute of Water- and Environmental Management to determine the optimal input material mixture (Mézes et al., 2007). In the biogas plant the control and the monitoring are indispensable in case of certain parameters - such as pH, temperature and organic loading rate. Primary importance operates these parameters in an optimal interval to effectiveness operation of the biogas plant (Yadvika et al., 2004). The quality and quantity of biogas is being monitored continuously throughout the process. Quality is being checked by a computer controlled gas-analyzer (Chemec, B20) in mezo- and thermophilic Digesters alike. In this biogas plant the organic material overload caused drastic changes in biogas yield, therefore economic deficit appeared (Mézes, 2011). In case of a big agricultural biogas plant the development of control-system means a serious problem (Patzwahl et al., 2001). The manufactured, pre-designed and commercially available software are not enough adaptable and their parameterization are not solved (Nyírcsák and Pongrácz, 2011). Therefore, the aim of the research is to select process regulatory adapted indicators and elaborate a suitable control-system (Djatkov et al., 2012). As a part of this was the evaluation of Compair Proview SCADA (Supervisory Control and Data Acquisition) software and determination of the development trends.

MATERIAL AND METHOD

Laboratory fermentation system

The anaerobic degradation was examined in the Biodegradation Laboratory of the Institute, who the fermentation areas were 4 stainless steel tanks (the volume was 6 l per each) in incubators. In the incubator were used controlled thermometer probes (Pt100) and ventilators to ensure the optimal conditions mezophilic (38°C) and thermophilic (55°C). The produced biogas went to the detector through a doubled valve-system or to the output pipe. Before the detector the gas flows through a safety gas-washer bottle and a cryogenic inventory. The gas-washer bottle was utilized to remove the organic acid while the cryogenic installment to remove the water. The content of the gas mixture was monitored with Fisher-Rosemount gas-analyzer (CH_4, CO_2), and with MX42A gas-analyzer (H_2S, NH_3) basis of absorbance measurement (Mézes et al., 2008; Bíró et al., 2008). The gas-analyzer analyzed one gas sample from one reactor, the data transfer was achieved with serial RS232 port.

Control and automation system of the lab-scale biogas model digesters were executed with Advantech Genie 3.0 software in the last 10 years, which granted pre-programmed measurement and points of intervention for temperature, biogas yields and quantity and control of solenoid valves. In recent years a lot of experiments were carried out by measuring and control devices supported. In 2010 the Institute's laboratory decided to use a new Compair Proview Scada controlling system running on Linux platforms for supervising experiments and collect process data for further analysis in a higher level than before and this permit of a knowledge-based process control implementation. It is a modern, powerful and general and contains all functions normally required for successful sequential control, data acquisition, communication, supervision. Proview is a distributed system, which means that the system can consist of several computers, connected via a network, preferably Ethernet. A typical Proview system consists of one process control system and one or more operator stations. There are a lot of great advantage against the standard hardware and soft-PLC.

Laboratory fermentation experiment

The raw material was based on the composition formula of examined biogas plants that consist of sterilized slaughterhouse waste, silage, dry fermented product, cattle slurry, liquid fermented product and maize-grits (Table 1). During fermentation experiment we measured the biogas composition and the amount of CH4, CO2 (%), H2S, NH3 (ppm) and the temperature was continuously measured.

Table 1

The amount of input materials

Raw material (quantity in 5l volume)	**5,26 kg dry matter% maize-grits**	**10% kg dry matter % maize-grits**	**26,3% kg dry matter % maize-grits**	**Dry material-content (%)**
Sterilized slaughterhouse waste	220	220	220	30
Silage	160	160	160	38
Dry fermented product	43	43	43	35
Cattle slurry	500	500	500	4
Liquid fermented product	4000	4000	4000	0,9
Maize-grits	11,4	22	57	87,6

RESULTS AND DISCUSSIONS

First time we tested the anaerobic fermentation system under mesophilic condition. The reactor heaters ensured the constant temperature with two Pt100 thermometers (one in the fermentor, one in the thermostat cabinet). These thermometers are controlling by the operator interface panel. We can turn on and off the individual fermentors, so temperature control is independently adjustable. The biogas was measured by Brooks's 5850E mass flow controllers after necessary cleaning. After conversion these regulators are suitable wide range of volume's measuring (20 ml / min ... 20 l / min). The biogas flows through the mass flow meters to the gas analyzer. The regulatory system ensures the flow directions with the control of solenoid valves. The Compair Proview Scada controlling system is running on Linux platforms. The measurement data acquisition control system is based on FitPC2 type industrial computer. Joints of the peripherals (measuring devices, actuators) are ensured Ethernet I/O devices that suited to the computer with Modbus/TCP communication protocols. The Proview have got a lot of great advantages than the general PLC control: hierarchical structure, object libraries, open programmability and flexible peripheral management. These parameters can allow incorporation of sophisticated processing algorithms, the signal conditioning (e.g. signal filtering and scaling), data acquisition and export of data. Proview though has support for creating complex objects and function objects that work upon them. Object oriented concepts such as inheritance, methods and aggregates are supported (Figure 1).

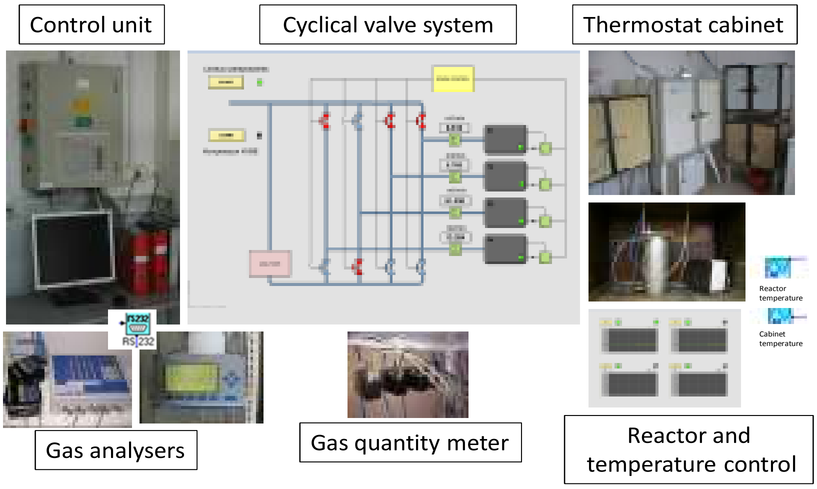

Fig. 1 Anaerobic fermentation system

During the different experimental settings were examined the gas data. The Proview can allow uptake of trend curves. A trend curve is a signal value, for example of type temperature, pressure or flow that is stored with a specific time interval. The trend curves are viewed in a curve window. Figure 2 shows the gas flow versus time (ml/min).

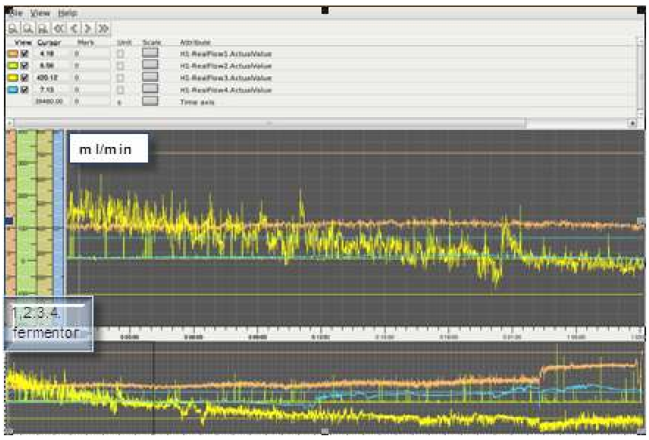

Fig. 2 Gas flow versus time (ml / min)

The generated gas quantity occupies a prominent position within the system. The gas measuring is a complex task. During the measurements we got one gas volume measuring and gas quality information per fermentor. Therefore, the SCADA signal processing algorithm provides a variety of information channels with time-stamp supply. During the evaluation it is used as a reference, so we will get from the raw measurement data actually gas components. Graphics are often used as an interface between the operator and the process. The graphical interface displays temperature and gas data (Figure 3).

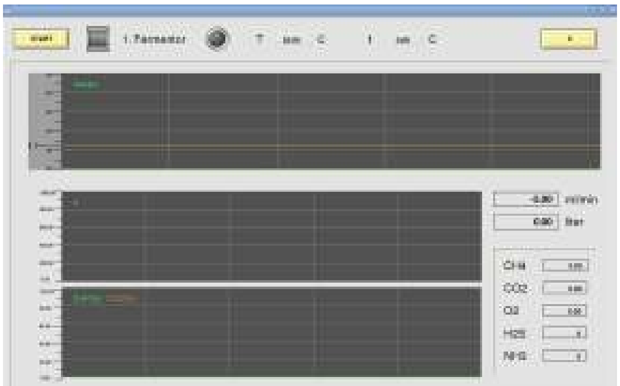

Fig. 3 The graphical interface of temperature and gas data

Between the gas data of the experiments were not a significant difference (Table 2). Based on the results the gas meter and the cyclical valve system were functioned properly.

Table 2

Biogas yields and biogas quality in the course of laboratory experiments

Experimental settings	**Biogas yields (liter/30 day)**	**CH_4 %**	**CO_2 %**	**H_2S ppm**	**NH_3 ppm**
5,26 kg dry matter% maize-grits	700,18	47,4	36,7	27,9	29,6
10 kg dry matter% maize-grits	605,30	48,5	34,6	28,8	32,5
26,3 kg dry matter% maize-grits	700,29	46,1	36,5	30,3	28,1

Signal conditioning and filtering algorithms were inserted to the data processing. In the recorded gas mass flow was observed large amplitude fluctuations (Figure 4). This is not relevant information; however it is disturbing effects in the gas volume. Preliminary studies were excluded that thermal noise caused the signal fluctuation in the equipment.

Fig. 4 Original and filtered methane gas signal

Further analysis showed that the volume variation caused mainly the processes in the fermentor, secondly the gas-dynamic behavior of gas meter. Increasing of the gas pipe cross-section, the length of the pipe, placement of gas buffer tanks, installation of mixing units and application of filters in electronic signal processing were reduced the fluctuation during the measurement.

CONCLUSIONS

Biological procedures of biogas production have widespread documentation although wide range of input materials, large number of technological variables and nonlinearity of these procedures clearly states that the traditional FDI controlling is inadequate. Our experiences form more than a decade proved to be important during the efficient shaping of knowledge based adaptive controlling. Design and realization of the controlling system's signal transmitter and noise filter system had been completed first. Simulations were done regarding the elimination of violator effects, and errors caused by the procedure itself. Efficiency of filter circuits was analysed by simulation results. Filters were designed based on these results. We stated that by using these circuits, significant decrease in disturbing signal changes level could be reached; therefore controlling features could be increased.

Further tests we will make regarding optimization of fermentation procedures that focused on component ratio of biogas and increasing efficiency of microorganisms. Based on our measurement and experimental results we will expand our system by a professional software module based on FUZZY algorithm controlling (FLC-Fuzzy Logic Controller). An intelligent system that includes a predictive model and a control was developed to predict and control the performance of a biogas production. The predictive model was based on fuzzy C-means clustering, fuzzy inference and neural networks. Appropriate pH level is provided for the microorganisms as well as optimal temperature based on quality and quantity analyze of gas components. CH4 and CO2 prove to be most effective of several indicator components and C/N ratio and NH3 content can be controlled by fuzzy algorithm. Intervention parameters are temperature, stir intensity and acid dosage. Based on previous measurements we are going to set each indicator's fuzzy membership values, which regulates external conditions of biogas production.

Acknowledgements

Our research work was funded by Baross Gábor Program REG_EA_KFI_09-POTOABIT project.

REFERENCES

1. Bencze Bőcs B., 2006, Speciális környezeti kérdések Magyarországon, különös tekintettel az alternatív energiaforrások alkalmazási lehetőségeire. Diplomadolgozat. Budapesti Corvinus Egyetem
2. Biró Gy., Mézes L., Nyírcsák M., Tamás J., Borbély J., 2011, Anaerob fermentációs folyamatok automatizálási és vezérlési megoldásainak fejlesztése. Informatika a felsőoktatásban 2011 konferencia, Debrecen. CD Kiadvány. ISBN: 978-963-473-461-1.
3. Bíró T., Mézes L., Hunyadi G., Petis M., 2008, Effects of biomass recipes on the output liquid phase of biogas production. Cereal Research Communications. Supplement. 36, 5, 2071-2074.
4. Bohoczky F., 2010, Megújuló energiaforrások hasznosítása Magyarországon. HURO Alternatív Energia Konferencia. Debrecen, 2010.07.01.
5. Djatkov D., Effenberger M., Lehner A., Martinov M., Tesic M., Gronauer A., 2012, New method for assessing the performance of agricultural biogas plant, Renewable Energy, 40, 104- 112.
6. Gujer W., Zehnder A.J.B., 1983, Conversion processes in anaerobic digestion. Water Science & Technology, 15, 127-167.
7. Kacz K.., Neményi M.. 1998, Renewable energy sources (in Hungarian: Megújuló energiaforrások). Mezőgazdasági Szaktudás Kiadó, Budapest, 10, 144, 153.
8. Kovács L. K., Bagi Z., 2007, Biogas (in Hungarian: A biogáz), szerk.: Bai A., Száz magyar falu könyvesháza Kht. Budapest, 37-48.
9. Mézes L., Bíró T., Hunyadi G., 2007, Sertéstelepek biogáz-ellátásának egy lehetséges technológiai alternatívája. Országos Környezetvédelmi Konferencia. Tanulmánykötet. Balatonfüred. 68-76.
10. Mézes L., Bíró T., Tamás J., 2008, Results of biogas production experiments based on agricultural and food industry wastes. Tamás J., Csép N.I., Jávor A. (szerk.) "Natural resources and sustainable development." Acta Agraria Debreceniensis. Supplement. 297-303.
11. Mézes L., 2011, Optimizing the Agricultural and Food Industrial Biogas Production. Ph.D. Thesis. University of Debrecen. Kerpely Kálmán Doctoral School. Debrecen
12. Nyírcsák M., Pongrácz I., 2011, Autonóm rendszer használata mérés-adatgyűjtésre, telemetriai célokra. Az elmélet és a gyakorlat találkozása a térinformatikában II. (szerk.: Lóki J.) 137-142.

13. Patzwahl S., Nacke T., Frense D., Beckmann D., Kramer K-D., Tautz T., Vollmer G-R., 2001, Microcontroller-Based Fuzzy System to Optimize the Anaerobic Digestion in Biogas Reactors, Lecture Notes in Computer Science, 2206, 2-10.
14. Petis M., 2005, Üzemszerű biogáz-termelés biomasszából. „Biomassza-energia” a mezőgazdaságból. Háromhatár konferencia. FVM. MGI. Nyitra, 121-124.
15. Petis M., 2007, Biogázról a gyakorlatban. Bioenergia. Bioenergetikai Szaklap. Szekszárdi Bioráma Kft. Szekszárd. 2007/2:21-25.
16. Petis M., 2008, Biogáz hasznosítása. Energiapolitika 2000 Társulat. Energiapolitikai Hétfő Esték. Budapest. 2008. február. 11.
17. Sembery P., Tóth L., 2004, Hagyományos és megújuló energiák, Szaktudás Kiadó Ház, Budapest, 274-279.
18. Szunyog I., 2008, Magyarország elméleti biogázpotenciálja. Egy európai uniós kutatási projekt szemszögéből. Energoinfo. Energia Ügynökség Kht. 2008/2:4-5.
19. Tamás, J., 2010, Integration of agricultural biogas production and GPS/GIS technology based on LCA. In: Proc.
20. Yadvika A., Santosh A., Sreekrishan T.R., Kohli S., Rana, V., 2004, Enhancement of biogas production from solid substrates using different techniques - a review. Bioresource technology. 95, 1-10.