Design of Automatic Control System for Generating Electrical Energy of Biogas from Wastewater

Ahmad Reza Taheri Asl¹, Amir Hossein Zaeri², Behzad Bahraminejad³, Foroogh Torki⁴
1- Department of Electrical and Computer Engineering, Islamic Azad University, Majlesi branch, Majlesi, Iran
E-mail: taheri_1977@yahoo.com
2- Department of Electrical and Computer Engineering, Islamic Azad University, Majlesi branch, Majlesi, Iran
Email: Amzaeri@yahoo.com
3- Department of Electrical and Computer Engineering, Islamic Azad University, Majlesi branch, Majlesi, Iran
Email: bahraminejad@gmail.com
4- Department of Electrical and Computer Engineering, Yazd University, Yazd, Iran
Email: f_torki@stu.yazduni.ac.ir

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ABSTRACT:
Limitation of fossil energy reserves, threats posed by environmental destruction, harmful effects of greenhouse gas emissions and problems arising from disposal and recycling of human excreta, livestock and municipal waste have caused to increasing public interest to utilization of renewable energy especially from waste and biogas production. The biogas production from wastewater treatment is a permanent process, so it proposes a new source of energy in every city and state. But obtaining permanent and stable energy of this source is possible which a robust automatic control system governs on process and works based on wastewater treatment process, biogas production and refining and electrical power production. In this article we propose a summary of possible actions to mechanize energy generation system of municipal wastewater biogas to increase efficiency and make the power generation system more viable and sustainable. Therefore, according to the wastewater treatment process and its factors that influence biogas production and refining and electric energy generation processes, suitable feedbacks will be used to appropriate decisions. Then we try to keep situation of the process near ideal case by locating operators in appropriate points and designing a logical system. In addition to improve efficiency of system we use some auxiliary units like secondary tank beside main digesters, gas storage tanks near the biogas refining system and heating system to help digesters in emergency times.

KEYWORDS: Biogas, Wastewater Treatment, System efficiency, Automation, Control system

1. INTRODUCTION
With increasing world population and energy resources limitation, all countries are faced with energy problem. According to growing need for energy and fossil fuels limitation and nonrenewable resources reduction, environmental pollution caused by burning these resources, increasing global temperature, climate change and saving in fossil fuels other sources of energy is essential. Some factors like landfilling of waste and producing energy of them and preventing of human, Livestock and municipal waste methane gas entrance to atmosphere have caused that use of biogas technology as the best way to deal with environmental pollution and environmental protection and one of renewable sources of energy should be considered [1]. But the distinguishing advantage of biogas from municipal sewage treatment plants and other renewable resources includes four main aspects, energy production, healthy environment, rich in fertilizer preparation and use of materials. What must be considered is how to produce the gas and using it So that the sewage treatment process does not distort into and the biogas production process and the production of electrical power is not interrupted [2]. Therefore we require a careful and critical control network is a set of electrical and mechanical operations and must be able to control and guidance system accurately. In this paper, we first summarize how the biogas production from sewage and main control parameters in order to continuous and interrupted production, then describe
control system, sensors and functions which are required to control and monitor the process and finally illustrate system performance by simulation results system.

2. BIOGAS OF WASTEWATER TREATMENT AND EFFECTIVE FACTORS ON ITS COMPOSITION

Biogas is a set of gases which are produced by fermentation of plant and animal droppings and activity of anaerobic bacteria without oxygen. Approximately 60 to 70 percentage of biogas is methane (CH4) that is a flammable gas. Because (unlike fossil fuels energy production and consumption are in a place, biogas is a good opportunity to energy production. Biogas can be made by fermentation of three types of biomass which are: livestock and agricultural waste, municipal and industrial wastewater and municipal waste [4], [5], and [6].

According to a study that is done by the Iran Ministry of Energy, Biomass potential in Iran is estimated to 74 million barrels of crude oil in the agricultural and forest waste, 36 million barrels of oil for livestock waste, 15 million barrels of crude oil for municipal waste, 5.5 million barrels of crude oil for food industry waste and 2 million barrels of crude oil for municipal wastewater. Therefore, according to more than 6.4 billion cubic meters of industrial and municipal wastewater, biogas production has high potential in Iran. So we limit our studies on energy generation of municipal wastewater treatment process [7].

In general, a wastewater treatment plant where produces biogas and then electricity will be produced from biogas is comprised of 10 units that can be seen in figure 1. [7]

Fig. 1 schematic graph of power and biogas generation in wastewater refinery process [3]

The volume and quality of biogas produced from municipal wastewater are affected by some factors like:

- Biological Oxygen Demand (BOD):
- Chemical Oxygen Demand (COD):
- Total Organic Carbon (TOC):
- Total Suspended Solids (TSS):
- Dissolved Oxygen (DO):
- Temperature:
- Pressure:
- PH:
- VS:

Biogas production processes from municipal sewage systems that have already been designed and
implemented have some defects that are heavily reduce system efficiency. Also existing wastewater treatment systems in the country are not utilized online. This Causes to that certain control over the production of biogas and electric power systems, does not exist. In addition, until now there is no wastewater treatment plant in country that can produce electrical energy from biogas continuously.

In this paper we propose some solutions to resolve these deficiencies which are summarized in the following categories.

3.1. Adding a second tank next to the digester to enhance system efficiency
Several factors contribute to the amount of gas produced by the bacteria in the digester. The most important of these factors are the sludge retention time in the digester and the digester sludge concentration. Maybe in some conditions the amount of wastewater entering the plant is increased. So the amount of sludge entering the digester is also much higher speeds. Therefore the digester sludge before the desired retention period of 10 days has to be forcibly removed from the digester and will be replaced by fresh and non-processed sludge. This will reduce the efficiency of the digester and biogas systems. On the other hand, if some reasons, such as rainfall decreases the concentration of sludge in the pools before digester and this diluted sludge enters into the digester, gas production rates greatly reduced. It can also reduce system efficiency. A simple solution to this is Store processed and enriched sludge in a tank for use in emergency situations. Effective factors that can be used as controlling factor are PH level inside the digester, the digester volatile solids and the time that sludge has been entered to digesters.

3.2. Adding extra equipment to assist digestion mixture process.
Bacteria do not have mobility by themselves. Mixing can be effective in enhancing the efficiency of the anaerobic digester. The mixer can be controlled by a variable speed motor. This method is the most common one for mixing the digester and increased bacterial activity in the current biogas production systems. But sometimes this rate of mixing is not enough. For example, when temperature of digester sludge come down because of some reasons like cold surrounding environment or cool incoming sewage from treatment plants. Therefore, some operations such as heating the content of digester and injecting the obtaining gas into the digester could make more effective and more efficient mixing. Digester temperature, environment temperature and PH measurement can be the appropriate metrics for controlling the mixing operation. Operators that can assist us in critical condition are digester side and inner heaters, input gas valve to digester.

3.3. Increase the amount of feedback from the system in order to monitor more complete and comprehensive interoperability between wastewater treatment, biogas production and electricity generation systems to increase efficiency and reduce losses.
Biogas production systems which have used until now, are not able to control the process completely. And On the other hand, they do not have full-duplex comprehensive connection with the collecting and wastewater Treatment system. While the interaction between these two systems and in following with electricity produced system of obtained biogas is very important to increase productivity and reduce human errors. Therefore, need to get good feedback from various parts of the wastewater treatment system, biogas production and electricity generation for immediate logical decisions and apply these decisions in different parts of the system is necessary and undeniable. Therefore, we must use suitable sensors and operators at different points of the process.

3.4. Automation process of biogas production and process monitoring to online control.
The most important part that needs to be completely automatic and react to changes of the before and after parts and implement terms and conditions is the anaerobic digester.
After it we must control gas filtration part by our automatic system. In this part we can prevent of high pressure gas risks and polluted gas emission by measuring gas pressure and rate of some polluting gases like CO2 and H2S. Then we can assess stability of produced gas to ensure about sustainable production of electricity. What is noteworthy about this section is that to produce stable and continuous electricity from the biogas system, we must make up emergency situations of biogas lack. Therefore we should make a path of urban gas network to gas engines in parallel with the biogas production network.
Location of elements and relation between them in control system can be seen in figure 2.
4. SIMULATION RESULTS
Based on the mentioned criteria and rules that are established between them, we simulate our system in MATLAB. The results are showing that we can control the process in all situations. A scenario is illustrated in following. In this scenario, we change the PH rate in digester and will see acts and decisions of the control system to PH crisis. Therefore an unstable situation which is created in the digester can be seen in figure 3.

Fig. 2. Control system and Location of elements

If the rate of PH in digester comes down under 6.5 or than exceeds of 7.4, some actions should be done by priority to restore digester to its previous condition. What is presented here is the result of the control system to return to stable condition.

Fig. 3. PH changes in digester

Fig. 4. control system decisions for digester mixing due to PH changes

Fig. 5. changes of digester heaters

Fig. 6. changes of secondary tank

5. CONCLUSION
In this paper we propose an optimized automation system for power generation from wastewater which can control the process completely. This system is able to make up process in critical situations by receiving a lot of important feedbacks from all parts of system. We have placed various operators on different parts of process and control them by prepare rules that are affected by sensors. In addition, we have suggested some additional instruments to help process in critical conditions to repair itself faster. Simulation results are shown that using this system can improve efficiency of process and connect separate parts together.

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