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Research Article

Biogas Monitoring System for Measuring Volume using Micro-controller & GSM

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Abstract

Biogas plants are slowly becoming popular due to the benefits associated with them like non-polluting and renewable energy source, reduces landfill and cheaper. They are already being used for public transport, industrial heating and many more applications. The demand for monitoring and control process is increasing. Better monitoring and control system can improve process stability and enhance process performance for better economy of the biogas plants. Biogas plant monitoring system gives an overall picture of the biogas generation process. It will be used to predict the current level of biogas so as to manage the input accordingly. Alerts will be sent using GSM and Android to monitor the input slurry. It will help to identify upcoming instabilities in anaerobic digesters before a crash happens. It can also accompany a successful start-up or re-start of a plant. All the data will be stored for quick reference and data mining algorithms can be applied in order to predict the behavior of the plant in different conditions. An attempt has been made to find the different ways to improve the overall performance of biogas plant. The objective is to develop a method for assessing and improving the efficiency of agricultural and household biogas plant operation.

Keywords: *Biogas Monitoring System, GSM Etc.*

Introduction

Biogas plants are biological systems involving various interacting microorganisms that anaerobically degrade organic matter. The main product is biogas, a gas rich in methane (CH4) that can be used as a renewable fuel for vehicles or to generate heat or electricity for local use or for use via energy distribution grids(Bernhard Drosg,2012) .So Biogas is one of the major sources on which the world can survive in the future. Biogas refers to a gas produced by break down of organic matter in the absence of oxygen (Sunil MP ,2013). Organic wastes such as kitchen wastes can be converted in to a gaseous fuel called as biogas. Use of dung, firewood as energy is also harmful for the health of the masses due to the smoke arising from them causing air pollution. We need an eco-friendly substitute for energy. Biogas serves this, as it does not have any geographical limitations nor does it require advanced technology for producing energy, also it is very simple to use and apply (Sunil MP ,2013).

Fig. 1 explains the importance of monitoring and control of a biogas plant. Process monitoring can help to understand what happens in a biogas plant and help to maintain a stable process. In many cases, a strongly inhibited microorganism population or a total crash of the whole plant can have severe financial consequences for the biogas plant operator. In addition to the biological parameters, there are also technical parameters that need to be monitored in a biogas installation. The basic idea of the Biogas Monitoring system is to to use software system to make it reliable source to generate energy from portable equipment developed and controlled system for plant with minimal cost (Sunil MP ,2013). Various researches have been conducted to improve the production and yield of the biogas. Earlier the biogas plants in India were operated with animal dung as slurry and the gas produced was also known as gobar gas. But with time the type of substrate used in the biogas production has changed. In some parts around the world huge biogas plants have been developed which operate with agricultural wastes and food wastes as substrates.

Biogas monitoring system aims to

1) Identify upcoming instabilities in anaerobic digesters before a crash happens.
2) Accompany a successful start-up or re-start of a plant.
3) Calculate volume of gas.
4) Detect gases.
5) Make Biogas Plant Intelligent.
6) Give accurate measurements of remaining gases.

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7) Understand the effects of various process parameters on gas production.

Figure1. Need of Biogas Monitoring System

Process of biogas generation

In the process of each plant it is important that values of relevant process parameters, such as temperature and pH, are established during stable operation. By recording these process parameters over the life of the plant, any change from normal can be identified quickly.

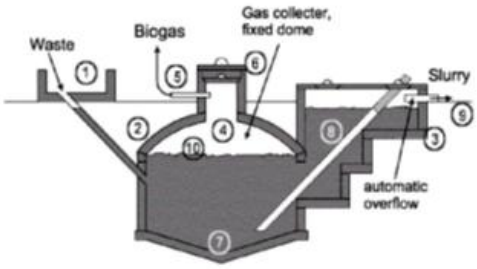

Figure 2. Simple Sketch of Household Biogas Plant

A) Structure of Biogas Plant

In the first phase the substrate is made available, stored and treated in accordance with requirements and fed into the bioreactor . In the second phase, anaerobic fermentation processes take place in the digester, producing biogas. In the third phase the gas is treated, stored and utilised. Finally, in the fourth phase, the fermentation residues are utilised (e.g. as fertiliser in the agricultural sector).The main component of biogas is methane (about 50-70 %). One cubic metre of biogas contains about six kilowatt hours of available energy and is equivalent to about 0.6 litres of fuel oil in terms of its average calorific value (Jürgen Wiese). Biogas is produced by a highly sensitive and complex process (Jürgen Wiese). Fig. 2 shows that there are three primary ports in the tank. Two of them are for input of the excrement and fermentable material.

B) The anaerobic fermentation process

The fermentation of biomass is a four step anaerobic digestion process, which is brought about by the complementary activities of several species of bacteria (Ravi.P.Agrahari ,2013). The first step is hydrolysis. First of all, long chain substances, carbohydrates, proteins and fats are broken down into smaller fragments such as simple sugars, glycerol, fatty acids and amino acids. In the second step (acidification, acidogenesis), fermentative microorganisms convert these products into short chain fatty acids such as acetic acid, propionic acid and butyric acid. Lactic acid, alcohols, hydrogen and carbon dioxide are also formed. The third stage of acetic acid formation (acetogenesis) combines the prior acidification with methane formation. The starting substrates are a number of final products from the acidification phase, i.e. short chain fatty acids, propionic acid, polymer substrates (carbohydrates, fats, proteins) and butyric acid. Together with lactic acid, alcohols and glycerol, these substances are converted by the acetogenic microorganisms into acetic acid, hydrogen and CO2. In the final step, methane is formed. The methane bacteria produce biogas, which contains up to 70 % methane. All the described processes run almost simultaneously in a biogas plant. They are in a sensitive state of equilibrium, which is dependent on the pH and temperature(Jürgen Wiese). It results in residual waste which is of superior nutrient quality as a fertilizer.

Thus, in order to avoid imbalance of the biogas system controlling feeding rate, pH and temperature variation is necessary.

Biogas Composition

Methane (50% - 70%),Carbon dioxide (30% - 40%) Hydrogen (5% - 10%),Nitrogen (1% - 2%) , Water vapor (0.3%) , Hydrogen sulfide (traces) .The Biogas produced may vary in composition depending on the feed material. Biogas is lighter than air by 20% and the ignition temperature of biogas lies in the range 650 °C to 750 °C. Biogas is a colorless gas which burns with blue flame.

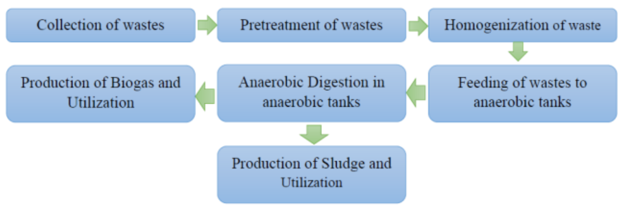

Figure 3. Anaerobic fermentation Process (Ravi.P.Agrahari ,2013)

The biogas can be used as a fuel in substitution to firewood, LPG, etc. and can also be used to produce electricity. Biogas has a calorific value of about 20 Mega Joules (MJ) /m3 and has been reported to burn with 60% efficiency when used for combustion in a biogas stove. Biogas has been found to have energy content of 6-6.5 kWh/m3. Biogas is equivalent to 0.6-0.65 l oil/m3 of biogas and it may explode when present in air at concentration of 6-12 % of air. Biogas has critical temperature of -82.5 °C, density of 1.2

kg/m3 and usually smells like bad eggs (Ravi.P.Agrahari ,2013).

Waste collection: The waste materials from various sources are collected and segregated. The materials like plastics that cannot be digested by the microbes are removed before the wastes are added to the digester so that they do not affect the activity of digester.

Pre-treatment: In this stage the waste materials are treated with water or other chemicals which aid in the digestion of these wastes.

Homogenization: In this stage the wastes are mixed and crushed in homogenizers to breakdown large particles into smaller ones as the smaller particles are easily digestible by the microbes.

Feeding: The substrate materials are fed to the digester tanks where water and other materials are added to allow the digestion of the wastes.

Anaerobic digestion: The wastes are digested by the various microbes involved in the process. The maintenance of pH, temperature and other factors influencing the digestion of the wastes for optimum digestion of the substrate and the production of biogas.

Production and utilization: The biogas produced due to the anaerobic digestion of the wastes concentrated in this sage by cleaning and removing contaminant gases. This biogas can be directly used by combustion. The sludge that is produced as by product is dried to remove water. This sludge can be utilized as fertilizer as it is rich in nutrients like phosphates, nitrates.

Monitoring process

One of the most focused topics in anaerobic digestion currently is online monitoring and control. The increase in number of large-scale biogas plants also increases the demand for proper monitoring and control of these systems (Ahring and Angelidaki, 1997). Monitoring and control systems are applied differently depending on the applications (Batstone et al., 2004b). With online monitoring and control, process optimisation is possible through maximising the utilization of process capacity and minimising the lost from process failure. According to Switzenbaum et al. (1990), while much progress has been made in anaerobic treatment technology, only through the development of better monitoring and control strategies will the anaerobic treatment process reach its full potential for waste management(Isbn 87-91855-101).

The cost of basic monitoring is often much lower than the cost and lost revenue associated with re-establishing a biologically established plant (Bernhard Drosg,2012). The monitoring of parameters is concerned with stability of the anaerobic degradation process. These parameters are mainly driven by biological interactions and as a result, the monitoring of a biogas plant is very different from many other industrial processes. Apart from the off-line analysis of parameters, which means analysis of samples in a laboratory, a minimum of on-line process monitoring equipment will have to be installed in every biogas plant. The most important parameters for process monitoring and control can be put into the following groups (Isbn 87-91855-101)

- Parameters characterising the process
- Early indicators of process imbalance
- Variable process parameters.
- Parameters characterising the process which are considered:
- Quantity and composition of feedstock

Proposed system

Control system are systems that are used to maintain a desired result or value. In addition, A system can be define as arrangement of parts within some boundary which work together to provide some form of output from a specified input or inputs [6]. In order to contol biogas plant we have to consider factors such as pressure ,temperature, methane and carbon dioxide. Boyle's law is used for calculation of pressure in biogas plant. To measure the other factors,sensors are used.

Boyle's Law

Boyle's law sometimes referred to as the Boyle–Mariotte law, or Mariotte's law is an experimental gas law which describes how the pressure of a gas tends to decrease as the volume of a gas increases. A modern statement of Boyle's law is The absolute pressure exerted by a given mass of an ideal gas is inversely proportional to the volume it occupies if the temperature and amount of gas remain unchanged within a closed system.

Mathematically, Boyle's law can be stated as

$$P \propto 1/V$$

Or

$$PV=k \quad (1)$$

where P is the pressure of the gas, V is the volume of the gas, and k is a constant. The equation states that product of pressure and volume is a constant for a given mass of confined gas as long as the temperature is constant. For comparing the same substance under two different sets of condition, the law can be usefully expressed as

$$P1V1=P2V2 \quad (2)$$

The equation (1) and (2) show that, as volume increases, the pressure of the gas decreases in proportion. Similarly, as volume decreases, the pressure of the gas increases.

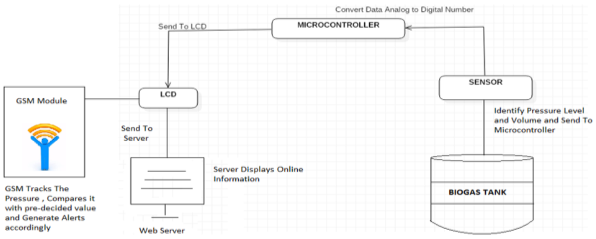

Figure 4 System Architecture

So as long as temperature remains constant the same amount of energy given to the system persists throughout its operation and therefore, theoretically, the value of k will remain constant. However, due to the derivation of pressure as perpendicular applied force and the probabilistic likelihood of collisions with other particles through collision theory, the application of force to a surface may not be infinitely constant for such values of V, but will have a limit when differentiating such values over a given time. Forcing the volume V of the fixed quantity of gas to increase, keeping the gas at the initially measured temperature, the pressure P must decrease proportionally. Conversely, reducing the volume of the gas increases the pressure. Boyle's law is used to predict the result of introducing a change, in volume and pressure only, to the initial state of a fixed quantity of gas. The initial and final volumes and pressures of the fixed amount of gas, where the initial and final temperatures are the same. Thus heating or cooling will be required to meet this condition are related by the equation (2). Here P_1 and V_1 represent the original pressure and volume, respectively, and P_2 and V_2 represent the second pressure and volume. Boyle's law, Charles's law, and Gay-Lussac's law form the combined gas law. These laws help us to generate the alerts by the control system.

Sensors

Pressure sensor integrates on-chip, bipolar op amp circuitry and thin film resistor networks to provide a high level analog output signal and temperature compensation (Sunil MP, 2013). SPD 100g as specialized for pressure detection is much preferred to be adopted for application. In design experiment, the Arduino microcontroller is chosen to take the role of ADC (Analog-to-Digital Converter). The output voltage of pressure sensor is an analog value which can not be used and shown on in the LCD screen directly. Therefore, as for the analog value converter to digital value, the arduino microcontroller and SPD 100g sensor are needed to connect. Smartec Pressure Sensor Features Commercial grade**,** DIP version for high volume production Gauge or absolute pressure, Resistive bridge technology, Voltage or current excitation, Applications Medical applications, Blood pressure Portable Gauges , Process control, HVAC controls.

Product description

The Smart Pressure Device SPD series of pressure sensors are silicon based and encapsulated in modified plastic Dual In Line packages, to accommodate six pins for through-board printed circuit mounting. The sensors come in two distinct types: Gauge and absolute. The gauge type merely measures the pressure with respect to the atmospheric pressure. The absolute type contains a reference vacuum chamber, which is formed on the die during manufacturing. The output voltages of both types are proportional to the pressure that is measured. Various pressure ranges are available. Our system uses SPD100G 0 – 6.5 Bar.

GSM Modem

The Global System for Mobile (GSM) communication is the Second Generation of mobile technology. Although the world is moving towards Third and Fourth generation but GSM has been the most successful and widespread technology in the communication sector. GSM technology paved a new way for mobile communication. In our design we have interfaced GSM Module with a Arduino microcontroller, when there is detection of 80% of biogas in the reactor the GSM module will send SMS to the user by intimating gas has been detected and also it will display on LCD. A line converter MAX232 is employed to convert the RS232 logic data of GSM Module to TTL logic so that it can be processed by the microcontroller (Sunil MP ,2013).

LCD Display

LCD technology has advanced very rapidly since its initial inception over a decade ago for use in lap top computers. Technical achievements has resulted in brighter displace, higher resolutions, reduce response times and cheaper manufacturing process. LCD can be used to display 20 characters in 4 rows. It has the ability to display numbers, characters and graphics. It has an inbuilt refreshing circuit, thereby relieving the CPU from the task of refreshing. The using parallel multi bit output. Data is sent serially into shift register at a very faster rate whereas the register transmits the same data to the LCD parallel data lines using D0 to D7 (Sunil MP ,2013).

To display on LCD using arduino controller

Microcontroller is a chip that combines the microprocessor with one or more other components. These components contain memory, ADC (Analog-to-Digital Converter), DAC (Digital-to-Analog Converter), parallel I/O interface, serial I/O interface, timers and counters. The microprocessor responses to arithmetically operate the binary data which likes a CPU in a computer. However, its speed, general purpose registers, memory addressing and instruction set are very low compared with a CPU, Therefore, it can be illustrated as a low level CPU. The memory is used for storing the data, programming instruction and results. It also provides this information to other units. So the microcontroller can be processed by pre-write instruction without computer or any other devices. The ADC and DAC can do convert signal between analog signal and digital. The analog signal usually is a voltage number in a range such as a temperature sensor. It can convert the temperature value to a specific voltage value. Then, this voltage value can be converted to digital value as binary via ADC. In addition, the parallel I/O interface and serial I/O interface supply one or more ports for connecting sensors on the microcontroller.

Working

1. Calculate the pressure
2. Calibrate the output
3. Pass the output to arduino microcontroller output pin.
4. Convert Analog to digital
5. Display values on LCD.
6. Upload Result on web browser using Ethernet module.
7.Send alert and compare level values using GSM module.
8. Take suitable action.

Conclusion

Among the process monitoring parameters, there are two different groups. The first group of parameters are early indicators of a process imbalance and they allow the biogas plant operator to react in time before a process imbalance happens. The second group are the parameters which characterize the process and can often help to detect and eliminate the cause of the imbalance. It is always necessary to adapt the monitoring strategy to the specific biogas plant and its feedstock. Many biogas plants will demand detailed process optimisation apart from pure process monitoring. The monitoring techniques and equipment available will continue to be developed and refined to support the new modernized model with higher efficiency, with compact size of reactor and low cost of biogas production.

The degradation processes in commercially operated biogas plants take place in a sensitive microbiological system. High, profitable gas yields and a sensor for measurement Safety fitting for mounting on plant then fermentation product that can be readily used for agricultural purposes can only be obtained if the plant process is controlled(Jürgen Wiese). The Biogas setup based on kitchen wastes was implemented on small scale setups to find the effects of the process parameters on the biogas production. It was found that the pH and temperature conditions had huge influence on the working of the biogas plant(Ravi.P.Agrahari, 2013). The paper theory has talked about the output voltage of pressure sensor and temperature sensor in the ideal situation. The paper discussion has described how to use the output voltage data in the Arduino microcontroller. And finally, the whole process from measuring the pressure sensor's to converting these values to alert on phone. Biogas is a crucial component of both the rural new energy development and sustainable development in India. The biogas digesters save more energy resources because of higher heat efficiency when comparing with coal-based or firewood-based energy consumption. It is reported that the utilization rate of the biogas potential is less. Hence, more research needs to be carried out in this field. So we have implemented partially the monitoring system for biogas plants for controlling the activities of different contents in biogas plant.

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