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Biogas-An Alternative Fuel for Distributed Generation

Neha Gupta[1,*] Sunil Kumar Mahla[2]
[1]Department of Mechanical Engineering, Shri Venkateswara University, Amroha, UP , India
[2]Department of Mechncial Engineering AIET, Faridkot, Punjab, India

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Abstract

The electric energy sector is facing problems of fuel scarcity such as coal shortage, average losses of power transmission, distribution rise, insufficient or poor infrastructure and connectivity in distribution lines etc. Renewable energy sources are considered as clean sources of energy and when use optimally, these resources minimize environmental hazards, produce minimum secondary wastes and are sustainable based on future energy demands. Since Internal combustion engines are developed more than a century ago, IC engines are the most common of all distributed generation technologies. In this paper a review has been done on use of biogas as an alternative sustainable fuel to be used in internal combustion engine for distributed generation. The main objective of this paper is to investigate bio-gas generation, its properties, desired characteristics and factors affecting the biogas generation from organic wastes by the anaerobic digestion. The biogas primarily comprises of methane, which is used for combustion. Use of methane reduces harmful engine emissions, and keeps the environment clean. It is economical and slurry can be used as organic manure. The main aspect of stationary internal combustion engines for electrical generators use is for isolated farms and rural areas.

1. Introduction

Electric power is a key driver of economic growth and prosperity for any nation. Per capita global energy consumption and demand are rapidly increasing in the last few decades. With rapid increase in population and use of electricity in agriculture, industrial and the domestic and public sectors, dynamic economic growth and modernization, India's electric energy demand continues to rise in spite of slowing global economy. The critical phase of population explosion is being faced by many of the countries in the world including India and the increasing population demands more energy inputs. With increasing demand of energy fuels like natural gas, coal and nuclear fuel, there is a rapid increase in green house gas emissions and thus there is an urgent need of alternative fuels, which decreases the emission of CO_2. The renewable energy sources like hydro energy, solar energy, energy of wind and biogas meets domestic energy requirements and has the potential to provide clean environment. All these sources of energy are renewable, but biogas is especially important due to possibility of use in inner combustion engines, and it is the main power source for transport vehicles and also commonly used for powering of generators of electrical energy. The electricity is still not available in many of the remote and very poor areas, and there are least chances to connect these areas to the national grid due to national financial constraints. However, the wide use of internal-combustion engines (ICEs) for distributed generation (DG) applications. They are available from sizes of a few kilowatts for residential backup generation to generators on the order of 10 MW [1]. Since distributed generation, such as medium sized users of electricity, and users in remote locations, would like to have their own small power generation source, which is affordable, and also reliable.

2. Bio-Gas As Alternate Fuel For Electricity Generation

Since the second half of the 19th century biogas has been produced. India is the largest cattle breeding country; raw material required for production of biogas is available in abundance. India was one of the revolutionary countries, which has been generating biogas from manure and kitchen waste for household purposes. Biogas is the gas generated from anaerobic digestion (AD) of organic matter that includes animal-human excreta, kitchen-agricultural residues, municipal wastes and algal-plant biomass etc. with balanced carbon cycle. Biogas typically refers to a gas produced by anaerobic digestion of various organic matters in the absence of oxygen. Organic waste such as dead plant and animal material, animal dung, and kitchen waste can be converted into a gaseous fuel called biogas.

***Corresponding Author,**
E-mail: guptaneha2207@gmail.com; Phone No--+919313479644

The anaerobic digestion or fermentation of biodegradable materials such as biomass, manure, sewage, municipal, green waste, plant material and crops produce biogas. Biogas comprises primarily methane (CH_4) and carbon dioxide (CO_2) and may have minute amounts of hydrogen sulphide (H_2S) and moisture. The gases methane, hydrogen and carbon monoxide (CO) are used in combustion process and release of this energy allows biogas to be used as a fuel. Biogas can be used as a fuel in any country for domestic cooking and heating, can also be used in a gas engine to convert the energy in the gas into electricity.

The various types of fuel to be used in engine must be designed to satisfy performance requirements of engine system, in which they are used. The main limitations on fuels are that the fuel must be easily movable through the fuel system to the combustion chamber, and that the fuel release sufficient energy in the form of heat upon combustion to make use of the engine practical. Biogas can be compressed, much like natural gas, and used to power motor vehicles and stationary generators. Methane separated from biogas is equivalent to CNG but economical than CNG. There are many advantages of biogas; they are clean, sustainable, reduce global warming. To convert cow manure into methane biogas via anaerobic digestion, the millions of cows are required which re available in the India and would be able to generate one hundred billion kilowatt hours of electrical power, sufficient enough to power millions of homes across the India. [2].

The energy needed to power a single 100W bulb for 1day is 2.4 KWh and infact the electricity produced by manure of cow per day is 3KW. SO, biogas is cheaper and clean energy sources to be used for generation of electricity.

The rural areas where grids connection is not possible then local power generating plant is suitable at the consumer site. Distributed generation (DG) may be defined as a source of electric power connected to a distribution network or a customer site, representing an innovative and efficient way to both generate and deliver electricity, because it generates electricity right where it is going to be used. Biogas plants are best suited for the rural electrification at the demand site gives lower-cost electricity and high power dependability.

3.Biogas Production

A biological process that takes place in the absence of oxygen and in the presence of anaerobic organisms at temperatures (35-70ºc) and atmospheric pressure is called a digestion and the container in which, this process occurs is known as digester. The treatment of any slurry or sludge containing a large amount of organic matter utilizing bacteria and other organisms under anaerobic condition are commonly referred as anaerobic digestion or digestion.

As illustrated in figure 1[3], anaerobic digestion consists of the following three stages. The three stages are (i) the enzymatic hydrolysis, (ii) acid formation and (iii) methane formation.

3.1 Stage One – Hydrolysis

During this stage the long chain organic compounds (e.g. proteins, fats, carbohydrates) are broken into more uncomplicated organic compounds (e.g. amino acids, fatty acids, sugars) through bacterial action.

3.2 Stage Two - Acidogenesis

In this stage the products of previous stage are transformed by acidogenic bacteria the into short chain fatty acids (e.g. acetic acid, propionic acid, butyric acid, valeric acid) and alcohol. During this phase acetic acid, hydrogen and carbon dioxide are also produced which act as initial products for methane formation.

3.3 Phase Stage Three - Acetogenesis

During this phase, the organic acids and alcohols are splited into bacetogenic bacteria into acetic acid, and the source compounds for biogas production that are hydrogen and carbon dioxide.

3.4 Stage Four - Methanogenesis

In this process, the products from the last phases are transformed by methanogenic micro organisms (archaea) into methane and carbon dioxide. The end product obtained is a combustible gas called biogas.

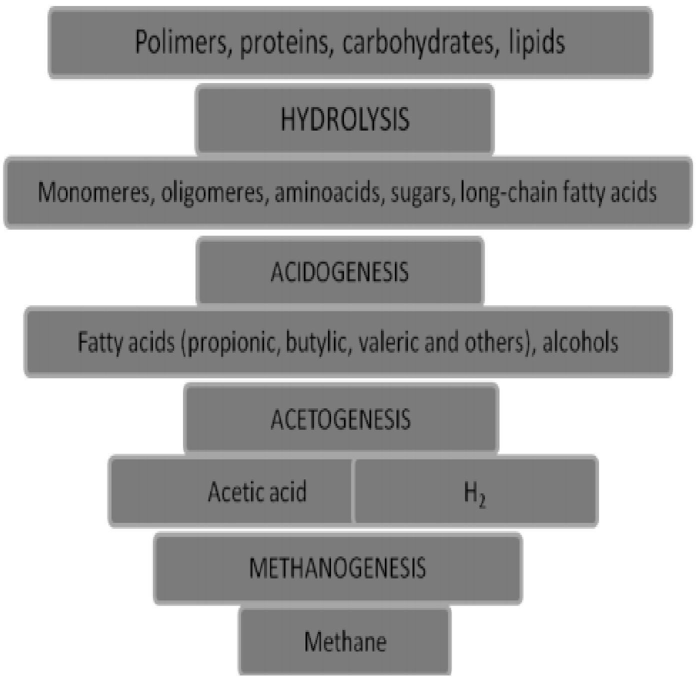

Fig. 1- Typical representation of anaerobic of complex substrates to biogas

4. Types of Biogas Plants

Biogas plant is an airtight container that facilitates fermentation of organic material in the absence of oxygen and in the presence of anaerobic organisms at temperatures (35-70ºC) and atmospheric pressure. This is a composite unit of a digester and a gasholder wherein gas is collected and delivered at a constant pressure to gas appliances through distributed systems. Other names for this device are 'Biogas Digester', 'Biogas Reactor', 'Methane Generator' and 'Methane Reactor'. The BGP also acts as mini bio-fertilizer factory; hence it is also referred as 'Biogas fertilizer plant' or 'Bio-manure plant'. Depending upon the type of raw material to be handled, there are two types of biogas digester- single chamber or double chamber type. Anaerobic fermentation is of continuous and bath type. The continuous process is suitable for free flowing suspended materials while the batch process is suitable for light materials. The following models of biogas plants are available in India[4];

4.1. Floating Dome

a. KVIC
b. Pragati
c. Ganesh

4.1.1 Floating drum type

Floating drum type digesters were developed and popularized by the Khadi & Village Industry Commission (KVIC) of India and, and is commonly known as the KVIC model [5,6]. This type of plants consists of an underground digester (cylindrical or dome-shaped) and a moving gasholder as shown in figure2. The gasholder moves up and down and the gas produced is collected in this moving drum. The gas being lighter rises up and makes the gasholder to move up. Guiding frame prevents the drum from tilting. As gas starts collecting in a gas holder, more pressure is exerted on the slurry which is forced from inlet chamber to outlet chamber. The outlet chamber forced out the excess spent slurry into the overflow tank through outlet pipe. This slurry can be used as manure for plants. The gasholder cannot rise up beyond a certain level. As more and more gas starts collecting, more pressure begins to be exerted on the slurry. The gas outlet valve is opened to get a biogas supply. This construction becomes obsolete with new the introduction of fixed dome type digester.

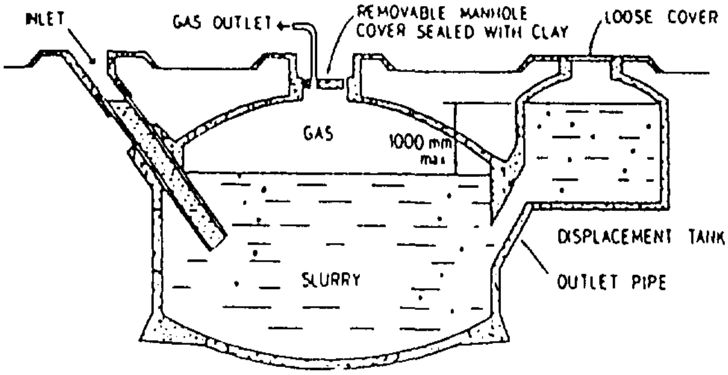

Fig.2- Schematic diagram of a KVIC biogas plant

4.2. Fixed Dome

a. Janata Biogas Plant
b. Deenbandhu Biogas plant
c. Ferrocement biogas plant

4.2.1 Fixed dome type

The design is based on Chinese origin and the Janata type biogas plant was made in view of its reduced cost [7]. It has low maintenance cost because there is no steel used and no moving part in it. To avoid the afterward-structural problems like cracking of the dome and leakage of gas, Good quality of bricks and cement should be used. The capacity of this model is higher when compared with KVIC model, hence it may be used as a community biogas plant. This design has longer life than KVIC models. Substrates other than cattle dung such as municipal waste and plant residues can also be used in janata type plants. The plant consists of an underground well sort of digester made of bricks and cement having a dome shaped roof, which remains below the ground level, is shown in figure. At almost middle of the digester, there are two rectangular openings facing each other and coming up to a little above the ground level, act as an inlet and outlet of the plant. Dome shaped roof is fitted with a pipe at its top, which is the gas outlet of the plant. The principle of gas production is same as that of KVIC model. The biogas is collected in the restricted space of the fixed dome, hence the pressure of gas is much higher, which is around 90 cm of water column

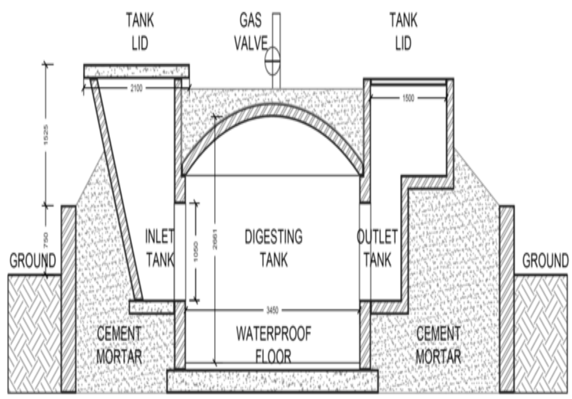

Fig. 3- Schematic diagram of a Janata biogas plant

4.2.2 Deenbandhu Biogas plant

The schematic diagram of Deenbandu biogas fixed dome model is shown in Fig. 3. Deenbandhu biogas plant was originally developed and patented by Punjab Agriculture University, Ludhiana (India) in 1984. It is an improved fixed dome model, where form work is used for construction. Due to shell structure the thickness is considerably reduced. The entire plant is built with brick in cement mortar. The digester, gas storage chamber and the empty space above the slurry are all provided in the spherical shell. As there is no displacement space on the inlet side, all the slurry displaced out of the gas storage chamber is stored in the outlet displacement chamber. The inlet is in the form of a pipe, which connects the digester with slurry mixing tank. The hydraulic retention time for this design is 40 days for summer season and in winter is 50 days.

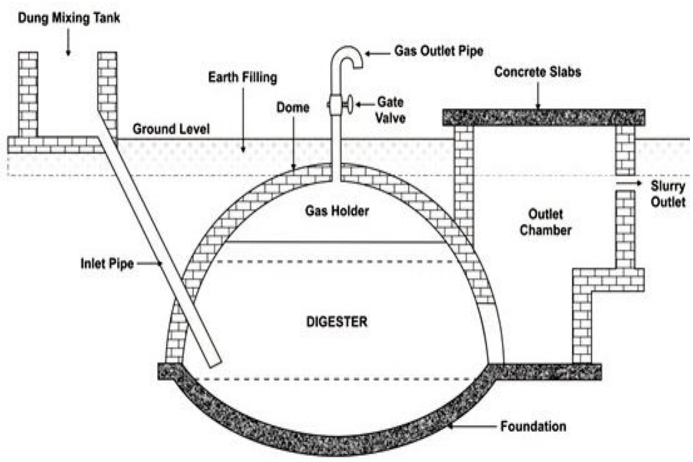

Fig. 4: Schematic diagram of a Deenabandhu biogas plant

5. Factors Affecting Biogas Production

The process parameters on which biogas plant efficiency depends are discussed as [8], [9], [10];

5.1 Temperature and Pressure

Anaerobic fermentation of raw cow dung can takes place at any temperature between 8°C and 55°C. But 35°C is considered as optimum. At 8°C the rate of biogas formation is very slow. Temperature variation should not be more than 2 to 3°C for anaerobic digestion. Methane bacteria work best in the temperature range of 35°C and 38°C. Temperature range beyond this value will yield more CO_2 .The production of biogas is fastest during summer and it decreases at lower temperature during winter.

5.2 Hydraulic retention time (HRT)

It indicates the average time for which added material remains in the digester before being pumped in the storage tank. The utilizable volume of the digester and the amount of organic material loaded calculates the HRT. The hydraulic retention time for this design is 40 days for summer season and in winter is 50 days, depends highly on substrate and plant components (e.g. covered storage tank). The target is to obtain the maximum gas yield or the complete digestion of the organic matter. For longer retention period, larger size digesters are needed and digestion of feed is more completed in the digester.

5.3 Volume load or organic loading rate

It indicates how many kilograms of organic dry solids are loaded per m^3 of digester volume and unit of time. It is important for digester (esp. mixer/agitator) and for the bacteria. If the organic loading rate is too high (over 4.0 kg DS/m^3d) technical components like mixers or pumps could be damaged or there will be an earlier maintenance needed than calculated due to an overload. Loading rate should be kept optimal. The under loading and overloading of the digester reduces the biogas production. The loading of feed must be carried out every day at the same time as to keep the solid concentration ratio constant in the digester.

5.4. pH value

It indicates the degree of acidity or alkalinity of a solution. The pH value is represented as the logarithm of the reciprocal of the hydrogen ion concentration in gm equivalent per litre of solution. A pH value between 6.8 and 7.8 must be maintained for best fermentation and normal gas production. It is difficult for the bacteria to survive above 8.5 pH.

5.5. Nutrients Concentration

The important nutrients required by the bacteria in the digester are N_2, P, S, C, H_2, and O_2 to speed up the anaerobic digestion rate. For accelerated anaerobic digestion the major nutrients must be supplied in correct chemical form and concentrations. The carbon in carbohydrates supplies the energy and the nitrogen in proteins is required for building of growth of bacteria. The bacteria responsible for the anaerobic process require both elements nitrogen and carbon, a specific ratio of carbon to nitrogen (C/N ratio) must be maintained between 25:1 and 30:1 depending upon the raw material used. The ratio of 30:1 is taken as optimum. The correct ratio of carbon to nitrogen will prevent loss of either fertilizer quality or methane content.

5.6. Water Content

The water content should be around 90% of the weight of the total contents. For anaerobic fermentation of cow dung to precede well the slurry should contain 8 to 9% solid organic matter. From one kg of dry cattle dung approximately 1 m^3 of biogas can be produced. For preparing slurry from fresh one kg cow dung an equal amount of water is required. It contains 8% dry biodegradable mass and has a volume of about 0.9 liters.

6. Conclusions

The most suitable power plant system to be installed at remote area is mini biogas power plant because of several reasons. First of all, this mini biogas power plant is easy to set-up because it is made in a modular system that could be installed or uninstalled and transferred easily everywhere and anywhere. When there is a Cattle, there will be waste. It is not hard to collect the wastes to be used in generating the energy rather than waiting for the sunlight that is dependable on the weather. If it is raining season, they villagers will not suffer to stay in dark it is renewable energy obtained from organic waste also used for producing valuable fertilizers for agricultural. It reduces global warming effect by reducing methane formation from organic waste and animal dung. Since methane has 21 times more global warming effect than the carbon dioxide. Controlled parameter may increase the production of biogas. Biogas can be used in IC engine to generate electricity for rural areas.

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