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PROTOTYPE DESIGN OF SMART BIO-GAS PLANT FOR GENERATION OF ELECTRICITY

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***Abstract*—A number of non-conventional energy resources are studied worldwide due to the increase demand of fossil fuels and environmental risks. Biogas generation plants are becoming more popular due to benefits associated with it i.e. low pollution, renewable resource and low cost. Biogas plants are already used in many applications i.e. heating, transport etc. Biogas plant needs high degree of monitoring and control process. The plant with better monitoring and control process will generate more electricity and in a less time and is known as smart bio-gas plants. An attempt has been made to generate the gas from the biogas plant in a less time and in accurate form. For this, the temperature sensor is used which check the temperature of slurry, if temperature will fall from the mentioned, a microcontroller will switch on the motor to start the reaction again. Digester is also designed by calculating the output energy. This gas is then stored in a storage tank to fed to the Internal Combustion Engine, which is converted to electrical energy. The main objective of this paper is to examine biogas generation and factors affecting the biogas generation from cow dunk as an organic matter by the biological breakdown. The calculated energy is applied by designing the digester.**

***Keywords*—biogas, Internal Combustion Engine, Slurry, digester**

I. INTRODUCTION

Biogas is a renewable energy fuel gas mixture consisting of methane and carbonic gas that comes from various raw materials such as agricultural waste, manure, food waste, cow dunk etc. Biogas system can produce bio-gas that can be used for cooking, lighting, and other energy needs. Bio-gas is produced using bio digester, which is a special type of chamber in which the waste gas from different raw material is converted to bio gas in presence of bacteria which exchange organic waste to methane by the process called anaerobic digestion. These bio digester needs some temperature to operate the reaction. Most of the biogas plants are manually operated i.e. their temperature levels are manually fixed which takes a lot of time to operate and produce the gas [1].

In this paper a high performance controller is used, that will operate automatically as a bio-digester system and can control its operation i.e. mixing the waste in a given certain range of temperature. With this controller the reaction time will be less and biogas will be produce before long [2].

The proposed method is to have a controller for a bio-digester that will automate the operation of the system. The controller consists of a micro-controller and the temperature sensor. This controller will start and stop the mixing of the waste material within the defined temperature. The LCD will be present to show the temperature range.

The paper contains the literature review, energy calculated using formulas, software implementation of the controller and then the hardware of the digester for the energy calculated using formulas.

II. BIOGAS PRODUCTION PROCESS:

It is important that values of pH and temperature are in stable operation during the process of plant. Biogas with methane content higher than 45% is flammable [3]. It has specific properties which are listed in Table 1.

Mixture	55.0 – 70.0% methane (CH_4) 30.0 – 45.0% carbon dioxide (CO_2) Traces of other gases
Energy content	6.00 – 6.50 kWh m^3
Fuel equivalent	0.600 – 0.650 L oil/m^3 biogas
Explosion limits	6.0 – 12.0% biogas in air
Ignition temperature	650.0 – 750.0 ° C (with the above - mentioned methane content)
Critical pressure	75.0 – 89.0 bar
Critical temperature −	82.50 ° C
Normal density	1.20 kg m^3
Smell	Bad eggs (the smell of desulfurized biogas is hardly noticeable)
Molar Mass	16.0430 kg k mol^1

Table 1: General features of biogas plant

A. Biogas plant structure:

In the first step the waste material and water are mixed in the digester with the ratio of 1:1 i.e. equal amount of water and waste [4]. Temperature is set using smart controller. In second phase anaerobic fermentation process take place in the digester, producing biogas. In third step the biogas is stored in the storage tank and then converted to electrical output by internal combustion engine.

B. 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. The process contains the following parts [5].

- Hydrolysis

Un-dissolved compounds in hydrolysis of the anaerobic digestion get degraded into their monomers that are amino acids, fatty acids and sugar. Water is used in abundant to cut the covalent bond by extracellular hydrolytic enzymes in the polymers.

- Acidogenesis

Organic short chain acid in fermentative bacteria further degraded these monomers in this phase which are produced in hydrolysis. They split it into one to five carbons. Hydrogen with partial low pressure in stable process formed the Fermentative bacteria such as carbon dioxide, hydrogen and acetate. At high hydrogen pressure more intermediates such as alcohols and volatile fatty acids are produced. Further breaks down of organic matter in acidogenic bacteria occurs while it is still unusable for production of methane and acidogenesis is needed.

- Acetogenesis

In this phase Methanogens uses directly the degraded acidogenesis. Further degradation of longer atoms and acids are degraded such as aromatic acid, carbon with two atoms, fatty acids and hydrogen and carbon dioxide in the acetogenic phase. For degradation to proceed H_2 producer acetogenic microorganisms, needs partial low hydrogen pressure So, in symbiotic relationship acetogens are found with consuming hydrogen methanogens, While the hydrogen pressure is kept low for the acetogenic microorganisms growth. Propionic, butyric, valeric acids and caprionic concentrations are increased which in turn are toxic for the methanogens at too high concentration of hydrogen.

- Methanogenesis

This is last step in anaerobic digestion. These microorganisms, strictly work under anaerobic conditions. In anaerobic reactor methanogens are different than other bacterial organism. As comparing with bacteria archaea are sensitive related to the stress in the reactor form the environment, i.e. different organic toxic materials. Hydrogen, Acetate, and carbon dioxide are usually used by methanogens. Production of methane raises up to 70% from the acetate, and 30% from hydrogen and carbon dioxide. The time of generation is 2-25 days in the reactor. So this step takes more time for hydrolyzed materials.

C. Biogas Process Parameters:

The following are the basic parameters during production of biogas [6].

- Light

The methane gas is produced in complete darkness.

- Temperature

For bacteria process a certain temperature is required to complete the reaction. This temperature is fixed inside the digester. The temperature sensor will monitor and adjust the temperature level.

- PH

The pH optimum of the methane forming microorganism is at pH of 6.7 – 7.5.

- Total Solid (TS)

The total amount of solid material without considering liquid part is called total solid and is shown as TS. 8% is the satisfactory value of TS for smooth fermentation process.

- Hydraulic Retention Time (HRT)

Time interval in which the waste particles or liquids lay in digester is known as HRT. Its formula is

HRT= Volume of digester/volume of slurry per day

It is expressed in days.

- Solid Retention Time (SRT)

It is calculated as:

SRT = Weight of volatile solid/weight per unit time of volatile solid leaving the system

- Liquid Part

To Make TS value to 8% water is added with the fresh discharge called liquid part.

D. Bio-digester design parameters/Size Calculations:

A chamber in which the digestion of organic waste matter by bacteria takes place with the production of a burnable biogas and a nutrient-rich slurry. It is termed as a digester because it is a large tank filled with bacteria that eats (or digests) organic waste and gives a flammable gas, called biogas [7]. In this work a simple digester tank made from plastic is designed and the volume is calculated as follow,

$$Vd = Sd(l/day) * RT(days)$$

Where

Vd = Volume of digester in liters

Sd =daily feedstock in liter per day

RT =Retention time in days

The daily feedstock corresponds to the quantity of organic matter produced per day and is equal to:

$$Sd = \text{solid waste} + water$$

The biomass corresponding to the total solid waste and the water have a 1:1 ratio i.e. equal amount of water and waste, therefore

Sd = (16$kgday$+16 liter water) = (32) l/day

RT = 14 to 16 days

So, 14+16/2 = 15 days

Then the final digester volume is equal to

Vd = (32) $l/day*15days$= 480 l/m^3

III. Methodology

The waste material selected for Biogas is the cow dunk. First the cow dunk is measured by using digital scale and then the water is added with cow dung with the ratio of 1:1 as previously mentioned. The initial temperature of the manure is checked by the heat sensor, LM35 which was transmitted to the microcontroller, it will check whether the temperature was in the specified range. If the temperature is not within the specified range, the microcontroller will control the heater and motor mixer to raise the temperature of the manure. Once the temperature is met within the specified range, the microcontroller will turn OFF the motor mixer and heater. The final temperature of the manure will be displayed by the LCD. After mixing and heating the manure it is kept for 3 to 5 days in a digester tank in air tight condition for obtaining the biogas. When biogas is generated, a storage tank is used which stores the gas to convert it to electrical energy. In our paper internal combustion is used to convert the gas to electricity.

IV. Results and Discussions

- *Energy Calculation:*

The total energy calculated from the digester tank is calculated as follows:

Gas from Cow dung production/kg = 0.05 m^3

Total gas produced = total dung in kg*00.05

Let suppose we have 2 animals and each producing 8 kg dung then total will be 8*2=16.

Total Gas =16*0.05=0.75m^3

If 1m^3=19 mega Joules so 0.75*19=14.25MJ

In KWH 14.25/3.6=3.95kwh.

Now electrical energy. In conversion into electrical energy 60% of energy is lost due to heat and other mechanical loses so

3.95*40/100=1.58kwh.

- *Consumption*

60 watt of 1 blub and 80-watt fan can be run.

- *Software Implementation*

The controller is simulated in protius software. The controller has a default temperature range which is 200-350. When the sensor detects that the temperature is below the said temperature, the motor mixer and heater will turn ON. Likewise, if the temperature detected is above the range, the motor mixer and heater will turn OFF. The simulations are shown in Fig. 1 and 2 with temperatures ranges of 21 and 31^{0}C.

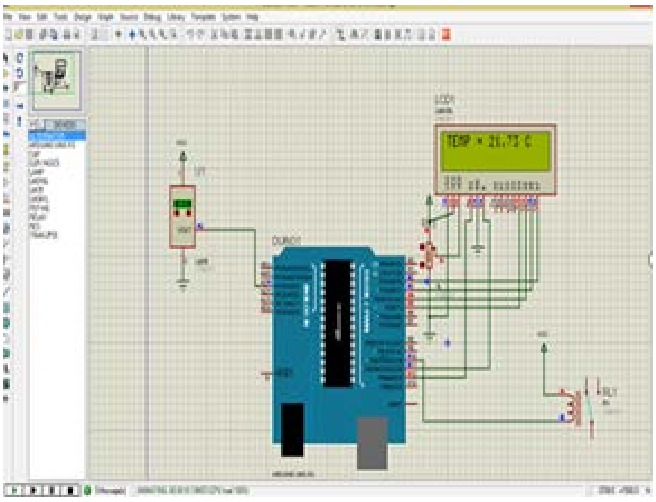

Fig.1. Sensor showing 210C

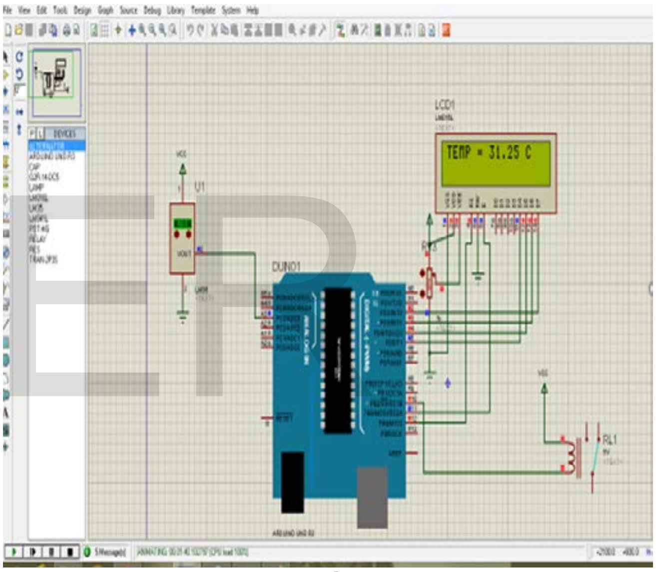

Fig.2. Sensor showing 310C

- *Hardware Implementation*

A prototype of the biogas plant is also designed which includes the following parameters.

- Design Procedure

In building the prototype for the system, we had undergone three phases. The first phase refers to calibrating the sensor for temperature since it plays a big part of the design. The movement of the machine will base on the recorded value of the sensor. The second phase pertains to the attachment of Arduino circuit, which is part of the major components of the design. It will be the bridge of the sensor and other major parts of the design like the heater and mixer. The third phase pertains conversation of biogas into electricity by using internal combustion engine.

- Calibration of sensor

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In this prototype we use temperature sensor Lm35 to sense the internal temperature of digester tank and automatic start the heater and motor. If the temperature reduce from the required limit, then the movement of the other major parts i.e. the mixer and heater will be based on the reading of the sensor. The LM 35 is an integrated-circuit temperature sensor, with an output voltage that is directly proportional to the Centigrade temperature of a system. The equivalent temperature then passes to the microcontroller, which has control to every part of the design and will pass the value of temperature displayed in the LCD. In our prototype, it is shown as Fig. 3.

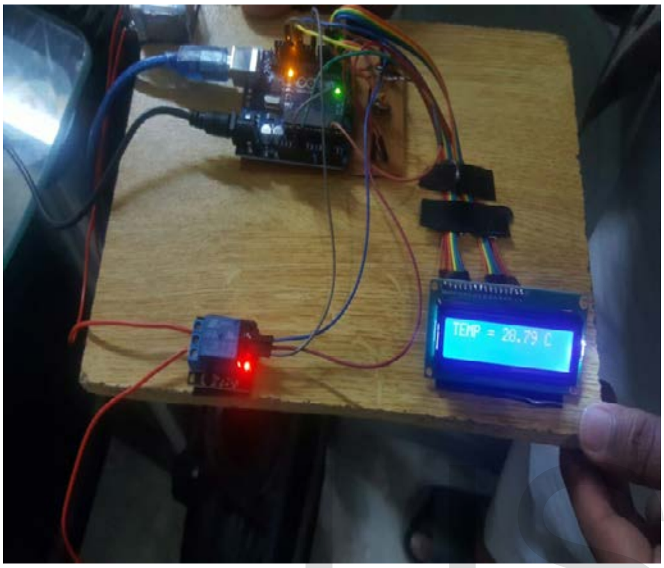

Fig. 3. Project Prototype

- Solid waste material:

Waste material used is cow dung, because carbon to nitrogen ratio (C/N) is 25 while this ia an important ratio in biogas production. For growth of bacteria in an anaerobic nitrogen is needed. While control parameters are needed for stable operation because it can inhibit methanogenic activity. 20 – 30 is the range of optimum C/N ratios for a digester that are too high inhibit the production of biogas. For the methanogenic bacterial to replicate themselves nitrogen levels are too low for the production of new cell structures. While on the other hand methanogenic activity due to low C/N ratio inhibits excess amounts of ammonium production which gear up in the digester alkalinity out of tolerable bound i.e. pH level of 8.51940 [8] [9].

The designed digester with the waste material is shown in Fig. 4 and Fig. 5.

Fig. 4. Digester Design

Fig. 5. Wastes Material

- Storage Tank

Storage tank are design to store biogas because after storage we convert biogas into electrical energy, so for conversation constant supply of gas is necessary there for we use separate storage tank to reduce the loss of gas. Storage capacity is up to 100bar but we store up to 60 bar in our prototype. Storage tank is shown in Fig. 6.

Fig. 6. Storage Tank

- Internal combustion Engine

In our prototype we use the phenomena of internal combustion engines in which we convert biogas into electricity. In Internal Combustion engine, biogas is used as a fuel to run the Dynamo i.e. (1 Kw). Two slip rings, armature, permanent magnet and carbon brushes are the main parts of an AC dynamo. The armature associated with insulated copper wire made coil and wounded on a soft cylindrical iron core N and S and horse shoe permanent magnet that gives a stationary magnetic field. Two different slips rings S1 and S2 in the armature are connected at the ends respectively. These rings rotate along with the armature about the same axis's has that of the coil.

B1 and B2 are the two brushes which are always in contact with the slips rings S1 and S2 respectively. While on other end of carbon brushes is connected to external circuit containing load resistance. ICE is shown in Fig. 7. The output electricity generated is shown in Fig. 8 and Fig. 9.

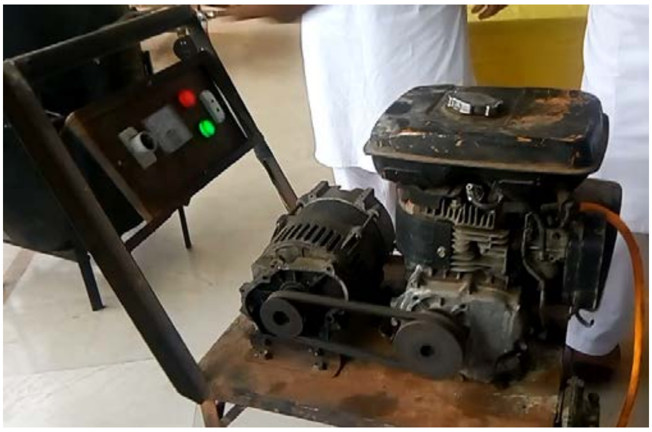

Fig. 7. Internal combustion Engine

Fig. 8. Electrical Output

Fig. 9. Output Power Generated

V. Conclusion

The objectives of this design project had successfully applied by the authors to meet the proposed solution. The authors build a controller based on micro controller and heat sensor that can automatically operate a bio-digester to produce bio-gas because the operation of the system depends on the temperature ranges selected by the author. Next the bio-digester is designed by calculating the volume for the digester. Then the cow dunk is used as a waste material in the digester and water is added. Mixing starts to produce the biogas. Gas is then stored in a storage tank to convert it to electricity. Internal Combustion Engine is used for conversion to electricity. The whole prototype is designed along with energy calculations.

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