IOSR Journal of Electrical and Electronics Engineering
e-ISSN : 2278-1676, p-ISSN : 2320-3331
PP 58-63
www.iosrjournals.org

Design of Biogas Scrubbing, Compression & Storage System

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Abstract- *The ever increasing demand of Electrical energy due to industrialisation and urbanisation has led to concentrate on the use renewable energy sources at the fullest. Under the renewable energy sources the biogas energy source is the most challenging one to cope up with the scarcity of electrical energy. The biogas from the biogas digesters can be compressed and bottled. This stored biogas can be put in use to the extent where it is required and it also reduces transportation costs, which is a major hurdle in the biogas usage. This paper summarizes an idea that can be carried out for effective biogas compression and bottling process and it also includes 3D model of the proposed method developed in Solid works software.*

Keywords- *Biogas compression, Bottling, Compressor, Manifold system, scrubbing unit,.*

I. INTRODUCTION

Due to rapid industrialisation and urbanisation in last few decades there is a huge pressure on fossil fuels and need for the alternatives. Biogas is one of the most important renewable source which would cope up to cater for heat and power. At present it is not possible to transport biogas over long distances and to put in use to the extent where it is required. Biogas is a clean-burning, renewable fuel that is 60-70% methane and can be used to power household appliances and generate electricity [1]. Biogas is becoming an increasingly important source of energy for rural areas in developing countries, as can be seen by the increased construction of bio digesters. Biogas has become an important fuel source because it is driven by readily available biomass. Because of this, there is a need to increase the versatility and availability of this natural fuel source to accommodate increased use. This biogas is produced by bio digesters that are currently in place. At present there is no system available to store the gas that these digesters produce, so all the gas that is created must be used at the same rate that it is produced. Biogas projects face a number of technical problems when implemented in the developing world. [2]

1.1 Storage – It is suggested that limitations also exists based upon maximum requirements of biogas in the user community. Most digesters will have limited capacity to store the product of their fermentation and, should demand not exceed supply, biogas production will be slowed. This is inefficient and occurs due to the lack of safe methods of transportation and storage.

1.2 Manageability/Transportation - Generally if biogas is stored, it will be at the digestion site in large impermeable bags [1]. These are impractical to transport and require direct connection to cooking/lighting apparatus. In regions where piping systems are unachievable, biogas systems prove to be unsustainable and such systems may fail. So it is necessary to compress the biogas & store it in bottles/Cylinders so that it can be used in place of LPG and can be transported as per requirements. Even it can be used in place of CNG cylinders as a clean & green fuel to the vehicles.

II. PROPOSED METHOD

The biogas compression and bottling process consist of different steps such as biogas purification, compression and bottling. Fig. 1 represents the typical arrangement of biogas compression and bottling process. It consists of three basic units viz scrubbing unit, compressor unit and storage unit. The raw biogas from the digester is first allowed to pass through a set of three scrubbing units for removal of removal of impurities as shown in Fig.1.The methane rich content biogas is now allowed to compress by passing it through a compressor. The compressed gas is finally stored into small cylinders with the help of manifold system and adapter. The manifold system used in the prototype is of single input and double output. Gas cylinder is connected to one output port where as a pressure gauge is connected to the other output port. The reverse flow of the biogas is avoided by using Ball valve and Non return valve

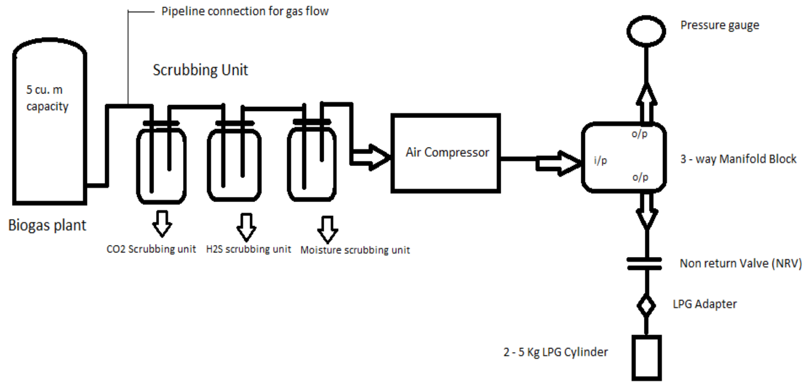

Fig 1. Typical arrangement of biogas compression and bottling process.

BV- ball valve.
NRV- non return valve.
PG – pressure gauge.
MB – manifold block.

III. SCRUBBING UNIT

Raw biogas contains various impurities such as hydrogen sulphide, carbon dioxide and water. The table 1 depicts the detailed composition of biogas. [1][3]

Table 1. Detailed composition of biogas.

Substances	Biogas %
Methane (CH_4)	**50-60**
Carbon Dioxide (CO_2)	**34-38**
Nitrogen (N_2)	**0-5**
Oxygen (O_2)	**0-1**
Water Vapour (H_2O)	**6**
Hydrogen Sulphide(H_2S)	**Trace**

The scrubbing unit consists of the following sub units;
1. CO_2 separation unit.
2. H_2S separation unit.
3. Moisture separation unit.

The function of each unit is as follows,

3.1 CO_2 separation Unit - The raw biogas is first passed through a CO_2 separation unit. Limestone crystals are used to remove carbon dioxide. Limestone reacts with carbon dioxide to form calcium carbonate. The chemical reaction is as follows; [4]

$$CaO + CO_2 \rightarrow CaCO_3$$

3.2 H_2S separation Unit - Hydrogen sulphide is removed by using catalyst iron oxide in the form of oxidised steel wool or iron turning from any workshop. Once biogas comes in contact with this wool, iron oxide is converted into elemental sulphur. The chemical equations are as follows; [4]

$$2Fe_2O_3 + 6H_2S \rightarrow 2Fe_2S_3 + 6H_2O$$

$$2Fe_2S_3 + 3O_2 \rightarrow 2Fe_2O_3 + 6S$$

3.3 Moisture separation Unit – Finally the biogas is passed through a moisture separation unit. Here silica gel crystals are proposed to separate moisture. Silica gel crystals should be replaced after a specific time according to the rate of purification. The capacities of the scrubbing units are decided according to the size of the biogas plant. Now the out coming biogas from the scrubbing unit is 98% pure. Further, if the purification is required the multiple number of scrubbing units can be used. Fig. 2 depicts the actual assembly of the biogas scrubbing unit [4]

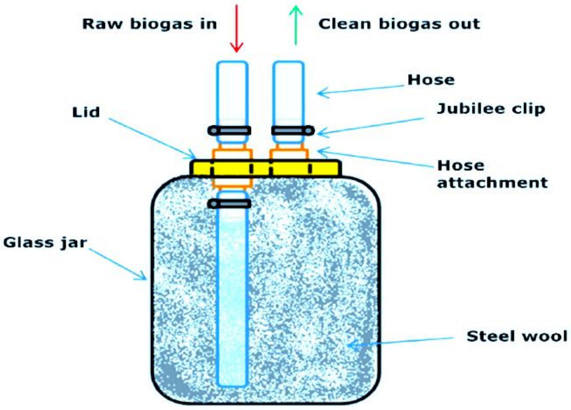

Fig 2. Biogas scrubbing unit.

It consists of one inlet for raw biogas to enter the unit and one outlet for clean biogas. The glass jar is tightly closed with a lid and hose attachment in order to prevent gas leakage. Likewise two more scrubbing units are connected in series for carbon dioxide and moisture separation. Finally the clean biogas from scrubbing unit is allowed to pass through a compressor.

IV. COMPRESSOR

Biogas compressors are readily available in the local market in the range of 2.5 bar up to 200 bars. Depending on the application a suitable compressor can be chosen. This paper proposes a suitable hand compressor with a compressibility of 4-5 bars. The hand compressor works on the principle of suction and compression similar to that of a bicycle pump. The hand compressor consists of one inlet for biogas to enter in and one outlet for compressed biogas. The hand compressor consists of specific valve at its base which consists of two ports, one port for suction and other for compression. Fig. 3 depicts the specific valve of the hand compressor. [4]

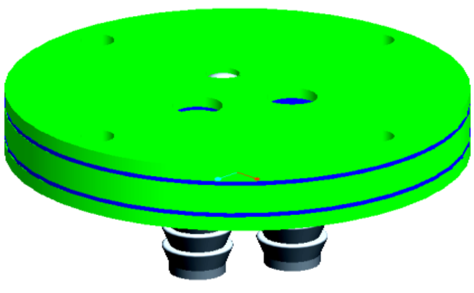

Fig 3. Hand compressor valve.

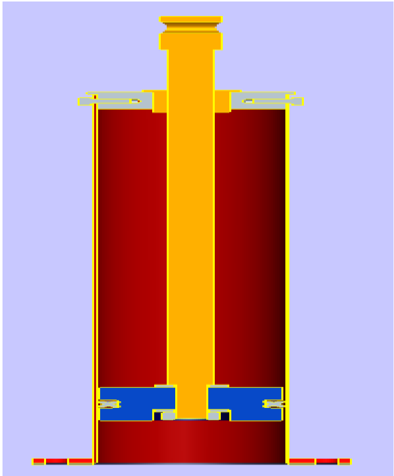

Fig 4. Outer view of Hand compressor

The compression of biogas occurs within this system, the gas inflow and outflow being regulated by the valve system. A sufficiently large stroke and small diameter is to be designed to reduce the compression force, while maximizing the swept volume. This reduces the number of pumps required to fill a cylinder.

V. DESIGN OF LEVER

The calculations of hand compressor are as follows,
By law of moments,

$$\boldsymbol{F \times 12 = f \times 11}$$

$$\boldsymbol{F = f \times \frac{11}{12}}$$

Where,
f = force applied or effort and
F = force obtained by leverage.
Now normally a person can apply a 30 kg force.
So take $f = 30\ kg$.
Now, $11 = 58\ cm$ & $12 = 5.3\ cm$ (considered).
Force applied for leverage,

$$\boldsymbol{(F) = 30 \times \frac{58}{5.3} = 328\ kg}$$

We know,

$$\boldsymbol{P = \frac{F}{A}}$$

$$\boldsymbol{50000\ N = {F}\Big/{\frac{3.14}{D^2}}}$$

$$\boldsymbol{50000\ N = {328 \times 9.81}\Big/{\frac{3.14}{4 \times D^2}}}$$

Diameter of cylinder D = 286mm = 290 mm
Stroke length l = 200 mm
Now for thickness of cylinder wall of cylinder,
We have,

$$\boldsymbol{t = \frac{pd}{2 \times ft}}$$

Where,
p = internal pressure,
d = diameter of cylinder
ft = permissible stress.
Ft = ultimate stress for cylinder material = 320N/mm^2

$$\boldsymbol{t = \frac{pd}{2 \times ft}}$$

$$\boldsymbol{t = \frac{328 \times 9.81 \times 290}{2 \times 230}}$$

$$\boldsymbol{t = 1.3\ mm}$$

Taking factor of safety = 4
Actual thickness $= \boldsymbol{1.3 \times 4 = 5.2\ m}$
The details of the hand compressor are tabulated in the table 2.

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Table 2. Details of hand compressor.

Parameters	Actual valve
Diameter of cylinder	290mm
Stroke length	200mm
Thickness of cylinder	5.2mm
Compressibility	5-6 bars

VI. BIOGAS CONNECTIONS AND FIXINGS.

Fig. 1 depicts the proposed model of compression and bottling unit which includes manifold block, flow meters, ball valves and non return valves. These are the secondary components required to enhance the flow of biogas. The manifold block used is a three way block which consists of one inlet and two outlets. One of the outlet is connected to pressure gauge whereas the other outlet is connected to a small cylinder through an adapter. LPG cylinder up to 2 kilograms and its adapter can be used.

Fig 5. 3- Way manifold block

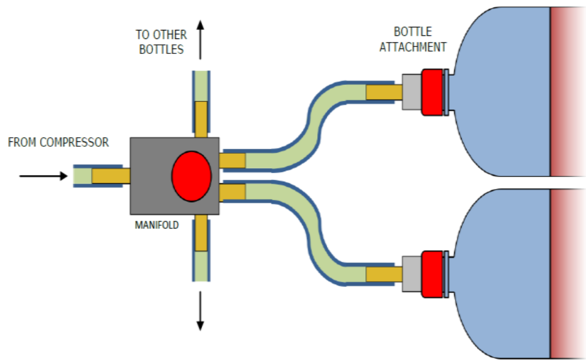

Fig 6. 1 Input, 4 Output manifold block.

Ball valve and non return valves are used to prevent the backward flow of biogas. The entire connections of the gas are made up of gas tube and the dimensions of biogas connections and fittings are tabulated in table 3

Table 3. Details of biogas connections and fittings

Sr. No	Items	Dimensions
1	Tube	12.7 mm OD
2	3-Way Manifold block	Height 60 x Width 62
3	1/2'' Ball valve (BV)	Length 42.7 mm
4	1/2'' Non return valve (NRV)	Length 42.7 mm
5	1/4'' Hose	1 metre

Depending on the requirement the manifold block specifications can be changed that is more number of outlets can be connected. Different manifold blocks with different configurations are readily available in the local markets.

VII. 3D MODEL IN SOLIDWORKS.

The modeling of the proposed prototype can be done by using **SOLID WORKS** software. To start with the modeling of the prototype, it is first necessary to fix the basic dimensions of every component in the prototype. It is also necessary to finalize the entire assembly of the prototype. Figure 7 depict a 3D Model of proposed biogas prototype.

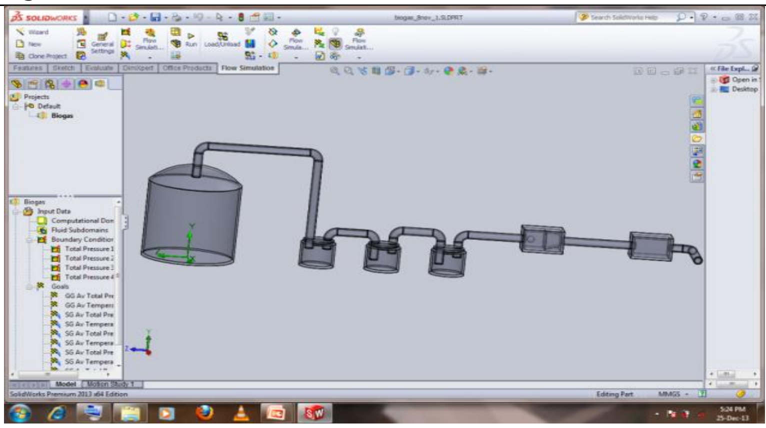

Fig 7 – 3D Model of proposed prototype

VIII. COMPRESSED AND STORED BIOGAS APPLICATIONS

The compressed and stored biogas in cylinders can be used for various purposes. The main application of stored biogas is to generate electricity which will help in bridging the supply and demand gap. It can also replace household LPG useful for cooking purposes [5]. CNG cylinders can be replaced by BIO CNG cylinders which will act as an environmental friendly fuel. This will help in achieving carbon credits. [6][3]

IX. CONCLUSION

Using the proposed method of Biogas compression and bottling system, the free natural fuel can be easily stored in cylinders or PET bottles. Depending on the requirements, the user should select between the air compressor and hand compressor. If the prototype is to be used for household application, then the hand compressor is best suited, whereas if it is used for industrial application, then air compressor with desired compressibility is suitable. The proposed method of bottling the biogas would definitely led to enhanced use of biogas from very site specific utility. The bottled biogas facilitates to be transported at the point of application which can be used for heat or power generation.

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