An Innovative Energy Neutral Home System for Rural Areas of Bangladesh

C. K. Das[1*] and M. J. Alam[2]

[1]Assistant Professor, Dept. of Electrical and Electronic Engineering, Chittagong University of Engineering and Technology, Chittagong- 4349, Bangladesh.
[2]Professor, Dept. of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology, Dhaka, Bangladesh.
E-mail: [*1]choton46@yahoo.com; [2]mjalam@eee.buet.ac.bd

Abstract— **Nowadays, Power crisis is one of the greatest problems of Bangladesh. Most of the electricity produced in Bangladesh is based on non-renewable energy resources. The reserve of Natural resources or non-renewable energy sources such as: fossil fuels, oil, natural gas etc are limited. So this is the time to search such a system where the residential areas of Bangladesh become Energy Neutral. This paper demonstrates such a system in which an Energy Neutral Home (ENH) is designed and implemented for rural areas of Bangladesh. The designed system is able to meet the energy requirement with renewable energy resources without taking any electricity from grid. In this research, biogas is used as primary renewable energy source for the generation of electricity.**

Index Terms— **Biogas, Digester, Energy Neutral Home (ENH), HRT.**

I. Introduction

Bangladesh needs constant supply of power to become an economic tiger of any form. At present, its power demand is about 6000 MW where the generation is only 4,300 MW. So the country is currently facing 1,700 MW of power shortage causing serious dislocation in all spheres of life including production in fields and factories. Moreover only 43% of the population is connected to national grid. Per capita electricity consumption is only 168 kWh which is one of the lowest in the world [1]. Energy problem seems to be more acute than any other crisis of the country. About 86% power stations in Bangladesh are based on gas, 5% are hydro, 5% are fuel oil and 4% are coal based [2]. By including the renewable energy sources, the energy sector greenhouse gas emission reduces and energy security increases. Bangladesh has huge resource of biogas production. According to IFRD- there is potential of about million biogas plants in our country [3]. This mass potential of biogas resources can be used to minimize present energy crisis of Bangladesh. In rural areas, people can generate electricity to fulfil their household demand by using their biogas potential. They can produce as much energy as they consume over the course of a year [4]. This is the concept of energy neutral home system.

II. System Overview

The system to be designed is similar to a small power plant. To design a complete energy neutral system, the renewable energy sources will be taken as the input of the plant. Considering the cost, the biogas source is selected as primary source for the proposed system. Poultry farms facilitate the waste for biogas generation in this system. The chicken manure produces more gas than cow manure because the gas production rate is 0.07 m^3 per kg poultry manure whereas it is only 0.037m^3 per kg cow manure [5], [6]. The total load of the system is calculated and based on the calculated load the digester is designed. With this system all the necessary household energy requirements such as electricity generation, cooking etc. can be easily fulfilled. The system block diagram is shown in figure 1.

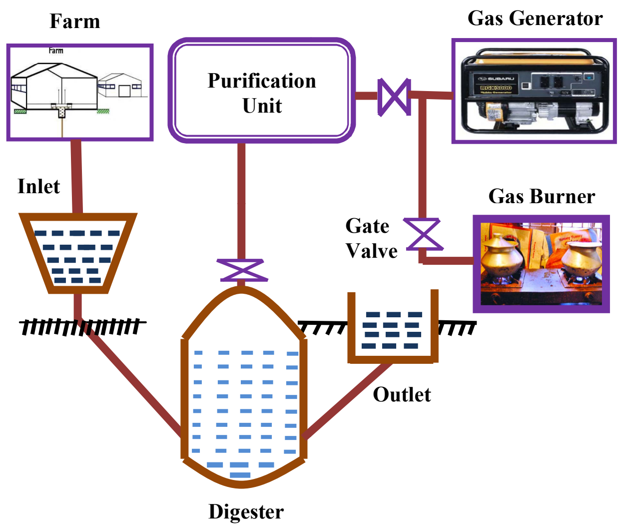

Fig 1 The Block Diagram of the designed system.

III. System Development

A. The Energy Demand of a Standard Home

The gas containing capacity of the digester in our designed system is 6 m^3 which is a standard value to neutralize a home. To meet the energy requirement the proportion of the produced gas is depicted in figure 2. The energy demand of the designed system is shown in table 1. According to the energy demand the amount of load is calculated as shown in table 2. The load curve is shown in figure 3.

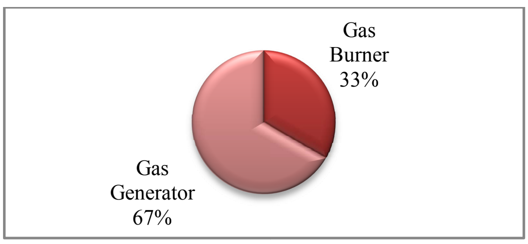

Fig.2 The proportion of gas for electricity and cooking.

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TABLE I
ENERGY DEMAND OF THE PROPOSED SYSTEM

Load	Rating (Watts)	Number	Total Power (Watts)
Energy Bulb	15	3	45
Energy Bulb	25	2	50
Energy Bulb	11	2	22
Ceiling Fan	75	4	300
Color TV	100	1	100
Refrigerator	150	1	150
		Total	667

TABLE III
LOAD CALCULATION ACCORDING TO THE DEMAND

Time	6-8 am	8-10 am	10-12 am	12-2 pm	2-4 pm	4-6 pm
Load(W)	0	0	0	250	300	0
Time	**6-8 pm**	**8-10 pm**	**10-12 pm**	**12-2 am**	**2-4 am**	**4-6 am**
Load(W)	400	400	300	300	300	300

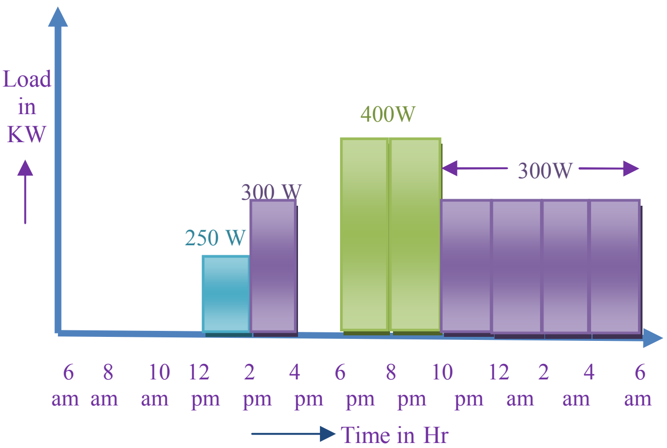

Fig. 3 Load Curve for electricity supply

B. System Design

1) Design of Digester

As the digester is the main part of the system, it is designed at first by considering some geometrical assumptions as shown in table 3 [7].

The design parameters are shown in figure 4. 800 number of poultry layer hen is required for the proposed ENH system. Considering the Hydraulic Retention Time (HRT) = 40 days (for temperature 30°C)

100gm manure is obtained per day from every layer [7], [8].

So, total discharge=800$\times$ 0.1 kg = 80kg

Total Solid (TS) of fresh discharge=0.2 $\times$ 80kg = 16kg

8 kg solid equivalent 100 kg of influent

$$\therefore \text{ 16 kg solid equivalent } = \frac{100 \times 16}{8} = 200 \text{ kg}$$

So, total influent required, Q= 200 kg.

Required water to be added to make TS value 8%

$$=200 - 80\text{kg} = 120 \text{ kg}$$

Working volume of digester= $V_{gs} + V_f$

$$V_{gs} + V_f = Q \times HRT = 200 \frac{\text{kg}}{\text{day}} \times 40 \text{ days} = 8000 \text{ kg}$$
$$= 8\text{m}^3$$

TABLE IIII
GEOMETRICAL ASSUMPTIONS FOR DIGESTER DESIGN

For Volume	For geometrical dimensions
$V_c \leq 5\%V$ $V_s \leq 15\%V$ $V_{gs} + V_f = 80\%V$ $V_{gs} = V_H$ $V_{gs} = 0.5(V_{gs} + V_f + V_s)K$ where K=gas production rate per cubic meter volume per day. For Bangladesh K=0.4 m^3/day	$D = 1.3078 \times V^{1/3}$ $V_1 = 0.0827D^3$ $V_2 = 0.05011D^3$ $V_3 = 0.3142D^3$ $R_1 = 0.725D$ $R_2 = 1.0625D$ $f_1 = D/5$ $f_2 = D/8$

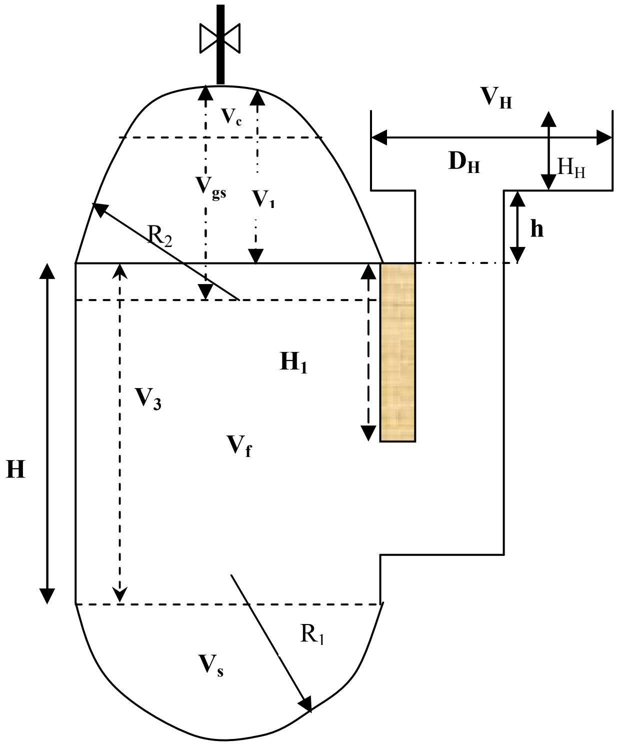

Fig. 4 Design Parameter of Digester

From geometrical assumption:

$V_{gs} + V_f = 80\%V$

Or, 8=0.8V [Putting the value of $(V_{gs} + V_f)$]

Or,$V = 10\text{m}^3$

And $D = 1.3078V^{1/3} = 2.817\text{m} \approx 2.82$ m

Again,

$$V_3 = \frac{3.14 \times D^2 \times H}{4} \quad \text{Or, } H = 1.13\text{m}$$

Now from assumption and the value of ‘D’ and ‘H’ the following values are found:

f_1= D/5=0.564m, f_2=D/8=0.3525m, R_1=0.725D=2.04m

R_2=1.0625D= 3m, V_1=0.0827D^3=1.85 m^3

V_c= 0.05V= 0.5 m^3

2) Design of Hydraulic Chamber

From assumptions,

$V_c = 0.05V = 0.5 \text{ m}^3$

$V_s = V - (V_{gs} + V_f + V_c) = 1.5 \text{ m}^3$.

So, $V_{gs} =$ TS $\times$ gas production rate per Kg TS

$= 16 \times 0.35 = 5.6 \text{ m}^3$

So, out let discharge, $V_{dis} = \frac{200 \text{ kg}}{1000} = 0.2 \text{ m}^3$

Let the normal pressure of the digester is $P_i = 4$ kPa.
and final pressure after gas being stored = P_f

So, according to Boyle's law,
$P_i \times (\text{total gas produced} + 2.55) = P_f \times 2.55$
Or, $P_f = 12.78$ kPa
Let, height of the hydraulic chamber is h.

$$P_f + H\rho g = H\rho g + h_1\rho g + h\rho g$$

$$\text{Or, } h + H_1 = \frac{P_f}{\rho g} = \frac{12.78 \times 1000}{1000 \times 9.81} = 1.3 \text{ m}$$

$$\text{Let, } H_H = 1\text{m, Thus, } \pi\left(\frac{D_H}{2}\right)^2 H_H = 0.2$$

$$\text{or, } D_H = 0.167 \text{ m}$$

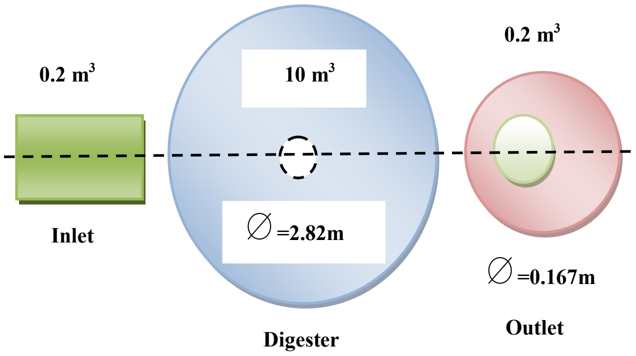

Fig. 5 Top view of Digester for a standard home

IV. System Implementation

The design factors of the system are selection of site, the availability of waste, the nature of waste, the size of the digester, the amount of load and the capacity of the generator. By considering these design factors the location of the system is selected. The address of the selected location is Village: Pomora, Talukder Para, P.S.: Rangunia, District: Chittagong, Bangladesh. The Owner of the selected home is Mr. Anil Kanti Das. Some photographs of the system implementation are revealed in figure 6, 7, 8, 9, 10 and 11.

Fig. 6 The base construction of the digester and hydraulic chamber

Fig. 7 The construction of outer structure of the digester and hydraulic chamber

Fig. 8:- The Inlet of the system with mixer

Fig. 9 The complete structure of the digester and hydraulic chamber

Fig.10 The stove burns and food is cooked using the gas produced by the system.

Fig. 11 The gas generator with the biogas purifier used in this system.

After completing the whole structure of the designed system, the digester is filled up with the required quantity of waste materials. The waste materials are kept airtight inside the digester till the HRT period for the production of necessary amount of gas. After the HRT period, the pressure of gas inside the digester is sufficient enough to be used for cooking purpose and running the generator.

V. Cost Analysis

A. Cost Calculation

The cost of the implemented system is divided into two parts as shown in table 4 and table 5.
Operating time of generator in 20 years
=8×365×20=58,500 hour
The overhauling cost of generator is 15% of total cost [9].

TABLE IVV
COST OF DIGESTER, INLET AND OUTLET

Description	**Quantity**	**Rate (BDT)**	**Amount (BDT)**
Bricks	2000 pcs	6.00	12,000.00
Cement	22 bags	350.00	7,700.00
Mass Rod	80 kg	50.00	4,000.00
Sand	170 CFT	20.00	3,400.00
Bricks chips	80 CFT	70.00	5,600.00
Paints	2 Liter	200.00	400.00
Appliances			1,500.00
Soil digging			4,000.00
Mason for construction			6,000.00
Total=			44,600.00

TABLE V
THE COST OF OTHER COMPONENTS OF THE SYSTEM

Description	**Amount (BDT)**
Cost of generator 1 (1.2kW)	26,890.00
Cost of generator 2 (1.2kW)	26,890.00
Purification Unit Cost	10,000.00
Manometer, Range 0-3000,water column	3000.00
Pipe Line, Special SS Ball Valves	3000.00
Electrical Change-over Switch (From grid to biogas power and vice-versa)	1400.00
Electrical Energy (kWh) Meter (Digital)	1200.00
Miniature Circuit Breakers	800.00
Electrical wiring	1000.00
Installation Cost	5,000.00
Total	52,290.00
Total Cost of Digester, Inlet and Outlet from table 5	44,600.00
The overall cost	1,23,780.00

Top overhauling (3 times) Cost
= 3 × (15% of 26890) BDT
=12,100.50 BDT
Major Overhauling (3 times) Cost = 3 × (50% of 26890)
= 40,335.00 BDT
Maintenance Cost (Gen 1) = 12,100.50+40,335.00
= 52,435.50 BDT
Maintenance Cost (Gen 2) = 52,435.50 BDT
Total Maintenance Cost of Generator= 1, 04,871 BDT
Cost of system in 20 years = Installation cost + maintenance Cost = (1, 23,780 + 1, 04,871) BDT
=2, 28,651 BDT

B. Per Unit Cost

Considering the total life time of the biogas plant is 20 years.
Electricity used in 20 years = 5.1×365×20 = 37230 kWh
Savings in Cooking = 500×12×20 = 120,000 BDT
Remaining Cost = (2,28,651 - 1,20,000) BDT= 108,651 BDT
Per unit cost = 108,651 / 37230 = 2.92 BDT

During the total life time of the biogas plant, no maintenance is required for digester. Including the evaluated maintenance cost of generator, the resulting per unit cost is only 2.92 BDT which is lower than the present determined unit price of electricity by the government of Bangladesh. The implemented system is for neutralizing only a home. The result shows that the unit price of electricity is only 2.92 BDT for a home. The system is designed for an area of 200 homes (capacity 85 KW) and then by similar analysis the unit price of electricity is found only 1.55 BDT. So, it can be said that the unit cost of electricity decreases with the increase of number of homes.

VI. CONCLUSIONS

In the designed system, the energy neutrality is proved by fulfilling the energy requirement without taking any electricity from grid. The implemented system can produce net 1kW (200w is considered as system loss) of electricity which is sufficient for a home if the full proportion of gas is used for the generation of electricity only. The system also supplies necessary gas for a home. The slurry of the system can be used in land as fertilizer. Thus the designed system is very fruitful for fulfilling the energy requirement with renewable energy source. Other natural resources like oil, gas etc. are limited and will be exhausted in course of time. So, the developed and developing countries consider their natural resources very precious and are cautious about extracting those. For this reason, this research is very much important for a country like Bangladesh where the people are facing great power crisis at present.

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