'Single-Owner' Plant as an Alternate Solution for Electricity in Rural Areas

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Abstract*—Electricity is considered as a flexible form of energy and critical resource for modern life and a vital infrastructural input for modern economic development. Now-a-days in all types of area like economies, households and companies have extensive demand for electricity which is due to industrialization, extensive urbanization, population growth, rising standard of living and modernization of the agricultural sector of a country. The scarcity of energy in rural areas of developing country like Bangladesh is acute and bears little sign of improvement for future. Energy from commercial resources accounts for only small percentage of all energy used in the domestic sector and again which is not uniformly distributed to the all peoples. Only a small number of villages have access to electricity in these modern days. Complete rural area electrification will always entail high transmission and distribution costs. Recently biomass is used recklessly. This irrational and unplanned exploitation of biomass resources is resulting in environmental degradation heavily. Bio-gas technology can be considered a partial but significant solution to electricity scarcity and also many other problems of energy which is a simple technology generally referred to as 'intermediate', and have every prospect to have an extensive use in developing countries like Bangladesh. But important fast is that, adoption of this new bio-gas technology does not only end with the construction of a plant, but also it requires some proper planning with respect to creation of social and economic acceptability apart from technological diffusion. In recent times 'single-owner' plants is very much encouraged by the Government of Bangladesh, where only a segment of population like the house having 5-6 cow, have the access to derive its benefit accordingly. But system would be much economic when larger plants can be constructed to serve a community as well as to bring a large group of population under its great benefit. But adoption of the community approach will require activities like mobilization of community supported by, awareness in building, proper supervision of credit, training among all the users regarding its operation and maintenance system and so many things. The research paper proposed a system which is able to meet the electricity requirement without taking any electricity from grid for individual house and where cow-dung generated bio-gas is used as a primary energy source for the generation of electricity.

Keyword - Single-Owner Plant, Biogas, Digester, HRT, Renewable Energy.

I. INTRODUCTION

The electricity infrastructure plays a vital role in social economic growth and generation of employment in developing countries more than the developed ones [1]. In Bangladesh, expansion of economic activities is restrained due to underdeveloped electricity infrastructure. Where, energy sector is poorly managed not only for limited coverage of supply, inefficient machines, poor quality of services but also huge government subsidies [2]. The supply of electricity is inadequate to meet the present growing demand which results frequent electrical power outages or load-shading to reduce the gap between power generations with the demand of electricity in Bangladesh [3]. The production of electricity is increasing with a reasonable rate but still cannot meet the huge demand of electricity leading to acute shortage in electricity supply. Therefore, from the old days Bangladesh is regarded as an electricity deficit country which has shown clear impact on its economic activities. It is one of the least per capita electricity consuming economies in the world with the per capita electricity consumption rate of 321 in 2016 which increased from 75.88 Kilowatt hour (kWh) in 1995. From the analysis of Bangladesh Power Development Board (BPDB) peak demand in electricity sector will be approximately 12 thousand Megawatt (MW) in 2017 and will increase more in near future. In Bangladesh, natural gas is the main source of electricity generation causes the establishment of gas-based power plant in a large amount. About 17% of total electricity is produced from fuel plants and rest of the electricity produced from natural gas in 2016. Huge amount of public and private investment is required in power sector to fulfil the huge demand of electricity for near future. For this reason, recently Government has undertaken some necessary steps to raise the foreign and domestic investment in power sector [4]. The excess use of traditional fossil fuel causes harmful environmental, health and social effects that has enhanced the growing interest to find an alternate sustainable source of energy globally to reduce the present demand in some extent [5]. A developing country like Bangladesh heavily depends on wood-fuel as a primary source of fuel contributing around 70% of the primary energy supply with

crude oil and hydro making up the rest for electricity [6-7]. Bio-gas is the by-product of anaerobic digestion of organic waste [8-10]. It has proved to be a practicable and promising technology with a very successful, reliable and clean source of energy when proper management program is followed. There are vast biomass resources including organic waste [11-13] in Bangladesh that have the potential for use as feed-stock for bio-gas production to reduce the over reliance of wood-fuel and fossil fuel, and to help reduce greenhouse gas emissions which may be affecting climate change. Bangladesh is expected to see a surge of bio-gas plants in next five years as initiatives have already been taken to set up around 150,000 such plants in rural households by 2017 [14]. This paper represents the energy scenario, the present condition and utilization with the potential benefits, prospects and challenges of the bio-gas technology in Bangladesh [15]. Due to the availability in the mass potential of bio-gas resources in Bangladesh, rural people can easily generate electricity to fulfil their household demand by using their own bio-gas potential [16]. They can also utilize as much energy as they consume over the course of a year [17]. This is the concept of Single-Owner plant for every person to overcome electricity shortage in recent days especially in rural areas.

II. PROCESS LAYOUT

The designed system is similar to a small power plant where bio gas generated from cow-dung will be the input of the plant [18]. Several farms can also facilitate the waste for bio-gas generation in this system. The total load of the system is calculated and based on the calculation the digester is designed [19-20]. All the necessary household requirements of electricity can be easily fulfilled by this plant output. The system detail process diagram is shown in Fig. 1.

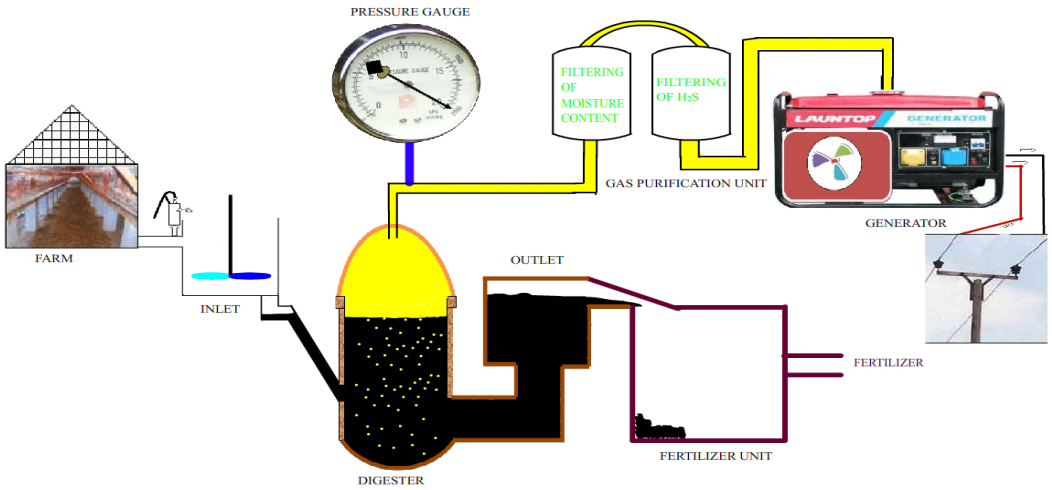

Fig. 1. Detail process diagram of the system

III. LOAD FORECASTING

A. Daily Load Demand

Load forecasting is an essential part to the operation and planning of an electrical utility house. It helps an electric utility to take decisions on purchasing and generating electric power, load switching, and infrastructure development of the belongings. Usual load consumption purposes are depicted in Fig. 2.

TABLE I. Load Demand of the System

Load Name	Rating (Watt)	Quantity	Power (Watt)
Energy Bulb	20	10	200
Ceiling Fan (48")	70	03	210
Colour TV (21")	120	01	120
Computer	150	01	150
Refrigerator (10 CFT)	400	01	400
Total Consumed Power			**1080 Watt**

The gas containing capacity of the digester in our designed system is 210 CFT which is considered as the standard value to neutralize the selected house [21]. The energy demand of the designed system is shown in Table I.

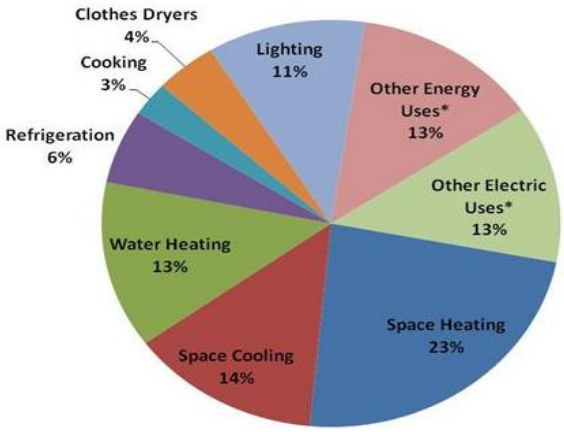

Fig. 2. The proportionality of daily energy consumption

B. Load Flow Analysis

Load flow analysis has a great impact on future expansion of planning, in stability studies and in determining the best economical operation for existing systems. It results are very important for setting the proper protection devices to insure the accurate security of the system. According to the energy demand the amount of daily load is calculated as shown in Table II and daily load curve is depicted in Fig. 3.

TABLE II. Load Analysis According to the Demand

Time	*0-2 am*	*2-4 am*	*4-6 am*	*6-8 am*	*8-10 am*	*10 am-12 pm*
Load(W)	960	305	0	0	0	0
Time	**0-2 pm**	**2-4 pm**	**4-6 pm**	**6-8 pm**	**8-10 pm**	**10 pm-12 am**
Load(W)	0	685	460	930	1080	1080

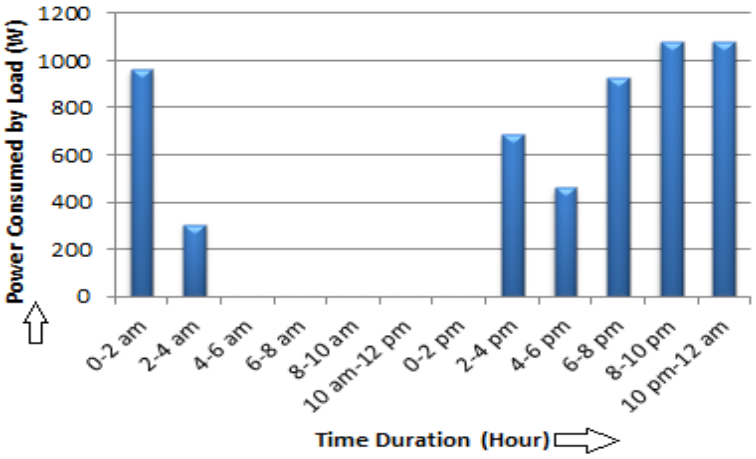

Fig.3. The daily load curve of the house

IV. SYSTEM LAYOUT DESIGN

The designed system will only serve for individual house [22-23] just like a mini power plant for a single house. In Fig. 4 the system approximate design layout is depicted.

Now, system where it will be used that house has 6 cows of average body weight 220 Kg each

At Temperature=30℃ , Hydraulic Retention Time (HRT) for the cow-dung =40 days

Total discharge by the cows = (10 × 6) = 60 Kg per day

Total Solid (TS) Value of fresh discharge= (60 × 0.16) =9.6 Kg

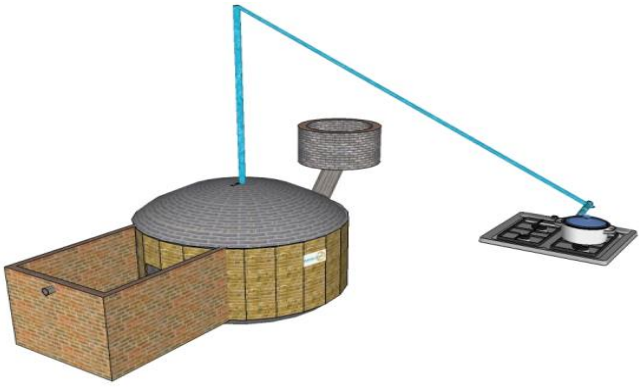

Fig.4. The design layout of the plant

For 8% concentration of TS

Influent from 9.6 kg solid $= \frac{100\times9.6}{8} = 120\text{kg}$

So, Total amount of influent, Q = 120 kg.

Amount of water for the 8% concentration of TS= $(120 - 60) = 60$ kg

A. Digester Chamber Design [24-25]

As the digester is the main part of the system, cross-section of the digester is depicted in Fig. 5.

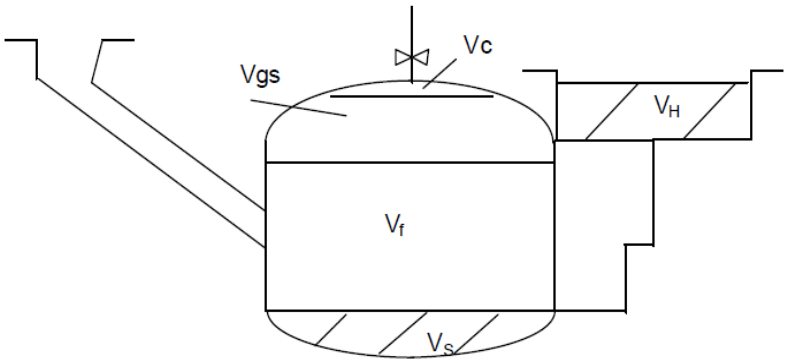

Fig.5.Cross section of the designed diegester [24]

Where,

Volume of gas collecting chamber = V_C

Volume of gas storage chamber = Vgs

Volume of fermentation chamber = V_f

Volume of hydraulic chamber = V_H

Volume of sludge layer = V_S

Total volume of digester V = $V_c + V_{gs} + V_f + V_s$

Now,

Working volume of the digester =$V_{gs} + V_f = Q.\text{HRT} = 4800\text{kg} = 4.8\text{m}^3$

This design require some geometrical assumptions which are shown in Table III.

From geometrical data analysis,

$V_{gs} + V_f = 0.80V$

$=>V = 6\text{m}^3$

Now, Diameter $D = 1.3078V^{\sqrt[3]{V}} \approx 2.40$ meter

Again, Height, H= $\frac{4\times3.14\times D^3}{3.14\times D^2}$

≈ 1.00 m

TABLE III. Geometrical Assumptions for Digester Design [24]

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	$D = 1.3078 \times V^{1/3}$ $V_1 = 0.0827D^3$ $V_2 = 0.05011D^3$ $V_3 = 0.3142D^3$ $R_1 = 0.725D$ $R_2 = 1.0625D$ $f_1 = D/5$ $f_2 = D/8$

Similarly, from assumption f_1=0.48m, f_2=0.30m, R_1=1.74m, R_2=2.55m, V_1=1.143m^3, V_c=0.3m^3
Final design of diegester chamber is depicted in Fig. 6.

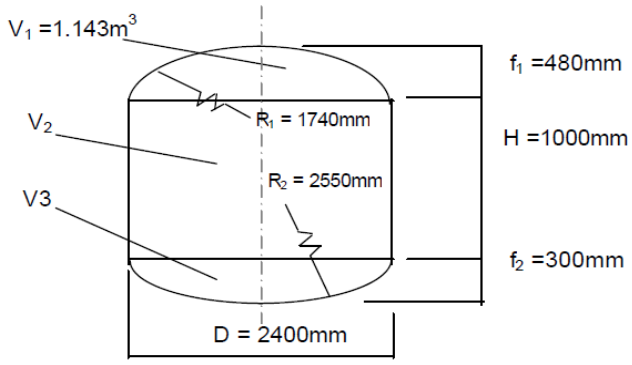

Fig. 6. The dimension of diegester chamber [24]

B. Hydraulic Chamber Design

From assumptions value, V_{gs} = 50%of daily gas yield
=0.5 × TS × gas production rate per Kg TS=1.344m^3
Now, V_1= [{(V_c+V_{gs}) −{ πD^2H_1}/4]
H_1=0.110m
If water volume h=800mm ; h=h_3+f_1+H_1
=>h_3=0.21m

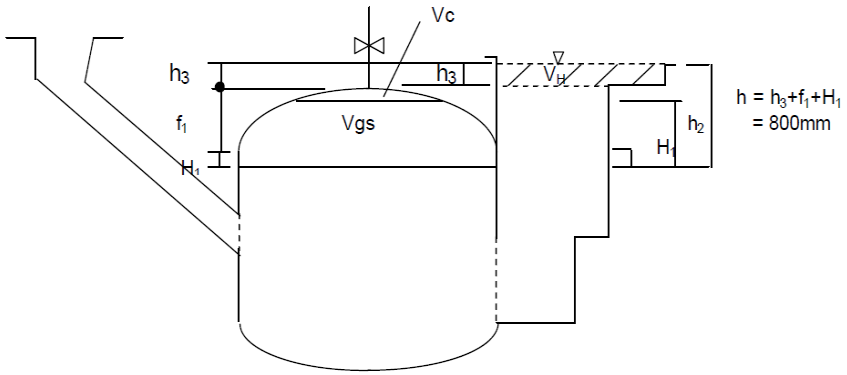

Fig. 7. The dimension of hydraulic chamber [24]

Again, V_{gs}= V_H
=>1.344m^3=3.14× $(D_H)^2$× $h_3/4$
D_H=2.85m
Final design of hydraulic chamber is depicted in Fig. 7.

V. DESIGNED SYSTEM IMPLEMENTATION

For efficient operation of a fixed home based biogas plant, it is necessary to keep it away from floodwater because, entering of floodwater into the digester chamber can break down its' operational capacity. Although a large part of Bangladesh experiences floods almost every year. So, it is extremely difficult work to prevent flood water in flood prone areas, which can collapse the gas production capacity of the plant. To overcome this problem, it is must to ensure water protected digester during design. The main design factors of the system are site selection, waste availability, waste nature, digester size, system demanded load and the generation capacity of the generator. By considering these design factors the location of the system is selected. The address of the selected location is Village: Meghnaghat, Police Station: Sonargaon, District: Narayangonj, Bangladesh. Some photographs of the system implementation are revealed in Fig. 8, 9, 10 and 11.

Fig. 8. The designed system cow-dung collection

Fig. 9.The base construction of the digester

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

Fig. 10. Full constructional view of the designed system

Fig. 11. The house lighting from designed systemgenerated power

VI. COST ESTIMATION

A. *Digester Cost [25]*

The cost of the implemented system is mainly depending on digester cost. Detail digester preparing cost is shown in Table IV.

TABLE IV. Cost of Digester

Name of Item	Quantity	Unit Price(USD)	Total Price(USD)
Bricks	800 pcs	0.15	120
Cement	07 bag	5.71	40
Sand	25 CFT	0.40	10
Rod	30 Kg	0.86	26
Labour Cost			55
Total Digester Cost			**251 $**

B. Overall System Cost

The system detail overall cost is given in Table V.

TABLE V. Cost of Designed System

Name of the Item	Cost (USD)
Digester (210 CFT)	251
Hydraulic Chamber and Gas Collecting Chamber (11 CFT)	100
Purification Unit	75
Gas Generator 1200 Watt (Intraco)	340
Electrical Wiring Equipment	50
Miscellaneous Cost	25
Total System Cost	**841 $**

Now, considering 10% maintenance cost per year with the overall cost.

Total cost of the designed system = (841 + 80) USD = 921 USD

C. Per Unit Energy Cost

Here, calculated Load per day 1080W, considering utilization hours 10hr per day.

Energy Consumed per day (1080×10) =10.8kWh

Life time of the load generator 10 year

Total energy supplied in its whole life time = (10.8×10×365) = 39420 kWh

Per unit energy cost= $\frac{921\ USD}{39420}$ = 0.0234 USD = 1.87 BD Tk

Designed bio-gas plant, require no maintenance for digester in its whole life time. Including the maintenance cost of generator, the resulting per unit cost is only 0.0234 USD (1.87 BD Tk) which is lower than the present determined unit price (0.067 USD) electricity by the government of Bangladesh. The implemented system is used for neutralizing only a single house.

VII. ADVANTAGES OF THE SYSTEM

The biogas system has so many advantages some of these are given below [26].

- Work as a non-polluting and renewable source of energy.
- Effective energy conversion by saving fuel-wood.
- Drudgery in collecting and carrying of firewood, exposure to smoke in the kitchen are not required and time consumed for cooking and cleaning of utensils.
- Production of enriched organic manure, which can be supplementary or even replacement chemical fertilizers.
- Leading towards sound environment especially in sanitation and hygiene sector.
- Decentralization of the power generation.
- Generate employment opportunity in the rural areas.
- Designed system is very cheap and simple.
- Feed materials are available from 2-10% solids of dilute waste materials.

VIII. FUTURE ASPECT

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 1.1KW (100W 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. Land fertilizer can be gettable from the slurry of the system [27]. 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. The designed system providing electricity with a rate of 1.87 BD Tk (0.0234 USD) where country's normal rate from Rural Electrification Board is 5.36 BD Tk (0.067 USD) [28]. Natural resources are very precious for the developed and developing countries which make them always cautious about extracting those things. For this reason, this research is very effective for a developing country like Bangladesh where the people are facing acute power shortage day-by-day.

IX. CONCLUSION

Introduction of any new technology is an always a difficult task. It involves a tedious and lengthy endeavour of persuasion and motivation. In absence of appropriate institutional set up in rural areas for dissemination of biogas technology, the government and NGOs will have to play key roles in not only in popularization of the new idea but also in financing and institution building. Government may take up pilot projects to study the feasibility of community based projects in line with the ideas expressed above. If found feasible government may take up programmes to sanction fund and disburse them to groups as soft credit through NGOs. Affordability is a major aspect in the proliferation of the new technology. Without adequate level of income access to the new technology on a mass scale cannot be ensured. Therefore, attempt should be made to reduce the cost of production. Cultural prejudices are sometimes found as a handicap (in case of using human excreta as input) in many cases. This may be gradually eradicated through cultural development attained by promotion of education. In the face of increasing demand for energy against depleting supply of biomass there is hardly any option to biogas as a renewable source of energy in our rural areas. Popularization of biogas will not only protect environment but will also become a sustainable source of energy on other sources most of which are fund resources.

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