Experimentation on Biogas Motor Generator Valves

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Abstract. The sudden switchover from the fossil-fuel energy machineries to renewable energy would throw 13% of the work force into joblessness. It would take close to two decades to reintegrate existing energy players in developing countries to renewable energy option. In this research we proposed a green solution where existing energy player can be integrated into renewable energy option at no cost. The biogas motor generator was proposed so that the poorest homes could afford it. The technicalities of the biogas motor generator was discussed i.e., considering the vital role of control valve in sending 52% methane into the generator. It was observed that a valve of cross-sectional area 0.8 mm² would withstand the anomalies of designing a biogas generator without the purifier chamber.

1. Introduction
The concept green solution is basically to provide better, greener environment using smart goals and outcome. It has been argued that green solution should be based on ethic and principles that drives the outcome. Some researcher believes that green solution must be closed ended i.e., all costs are internalized and accounted for in the products or services price [1]. The green solution concept have driven manufacturer to seek numerous solutions to make our environment better. The energy sectors of most developing countries have experienced versed irregularities that have destroyed the ecological system via pollutions [2]. For example, fossil-fuel generators have contributed to carbon dioxide emission in most developing countries than automobiles. Most homes in developing have one or two fossil-fuel electric generators. For example, it has been reported that Nigeria is the second largest importer of generators in Africa with more generators than all moving vehicles that consume fuel [3]. This report shows that most emerging and existing companies or industries rely on fossil-fuel electric generators. In other words, pollution from similar companies as Nigeria may be very difficult to estimate.

In developing countries that have high fossil fuel patronage, the spending on energy is typically high because of cost of oil, lubricating oil, maintenance and repair. The collective expenditure of individual and companies on fossil-fuel generators can build two smart grid systems in four years. IFC [4] reported that the amount spent on generator fuel alone is equivalent to 20 percent of government spending on education and 15 percent on health care in sub-Saharan Africa [4]. Unfortunately, since the fossil-fuel electric generator market is huge mostly in developing countries, it is a source of income to sizeable number of persons within the population. For example, the retailer, consumer, repairer, spare-part dealers, filling station makes high to moderate income from this business. Eradicating the fossil fuel completely simply means that sizeable population in the society would be jobless. Hence, the call for green solution in the energy sector salient to maximize resources.

In the bid to reduce pollution of the ecosystem, clean energy sources have been projected to replace fossil-fuel generators. Renewable energy is one of the clean energy sources because it is derived from
natural sources. Typical example of renewable energy sources includes sunlight, wind, rainfall plants, and geothermal heat. One of renewable energy option i.e. biodiesel is gradually replacing the fossil diesel with little impact on the ecosystem. Nigeria is the most populated black nation in the world with amazing economical wealth and different natural resources. However, Nigeria still falls among the poorest countries in the world. The energy crisis in Nigeria is huge and has lingered for decades. Nigeria has a robust market structure that will patronize cheap and sustainable energy options.

In this research, we examine green energy solution that would still keep existing jobs and reduce pollution of the environment. In this case, we examine the use of a biogas generator that is connected from sewage tank as presented in Figure 1. The idea of biogas electric generation in Ref [5] may be too complex and expensive for average homes in Nigeria.

![Figure 1. Proposed green solution to electric generators [5].](image)

In the past, the authors have embarked on the prospect of the human biogas i.e., based on its abundance, availability and accessibility [6-8]. This study is to see the possibility of estimating workable parameters that would help in the production of biogas electric generators. In ref [6-8], the specific challenge facing biogas production was discussed in details; hence the biogas dataset was generated in the worst condition so that the calculation presented in this paper would be the benchmark. More so, it is known that 1 kg cattle dung produces 40 litres of biogas [5]; 1 kg buffalo dung produces 30 litres of biogas [5]; 1 kg pig dung produces 60 litres of biogas [5]; 1 kg chicken droppings produces 70 litres of biogas; 1 kg of human excretal produces 44 litres of biogas [9]. Another technical shortcoming of the human biogas is the high contamination that reduces the methane content. Hence, most dummy project on biogas generator has processing units.

2. Methodology

Huge successes have been reported for natural gas generators [10]. Comparatively, biogas consists of 50-75% methane, 25-45% carbon dioxide, 2-8% water vapour and traces of O2 N2, NH3 H2 H2S, while natural gas contains 80 to 90% methane. The average calorific value of biogas is about 21-23.5 MJ/m³, so that 1 m³ of biogas corresponds to 0.5-0.6 l diesel fuel or about 6 kWh [11]. Since the objective of this study is to concentrate on very small generator sets (~ 0.5-10 kW), the biogas
generator framework that has been adopted is the gas motor design (GMD). GMD is projected to be the best biogas have high knock resistance i.e., can be used in combustion motors with high compression rates. The shortcoming of GMD is the inability of biogas to spark-up the ignition, hence, small amount of petrol (gasoline) is often used to start the engine. The first part of the methodology is to analyse biogas with respect to the percentage production of methane. Secondly we give the calculation of the control flow valve that would enable the flow of biogas as soon as the ignition is sparked up. The theoretical control valve is presented in Figure 2.

\[ Q = \mu A \sqrt{2 \rho \Delta P} \]  

where \( \mu \) is the flow coefficient, \( A \) is the pipe’s cross-section area, \( \rho \) is the fuel density and \( \Delta P \) is the pressure difference. The second region is govern by differential flow rate equation presented below [12]:

\[ y(\Delta P) = \frac{m}{\rho g} \cdot \frac{d^2 \Delta P}{dt^2} + \frac{\theta}{\rho g} \frac{d \Delta P}{dt} + k(\Delta P) \]  

where \( m \) is the slide valve’s mobile parts’ mass, \( \theta \) is the viscous friction co-efficient, \( g \) is the acceleration due to gravity, \( t \) is the time , and \( k \) is the membrane and spring equivalent elastic constant (coefficient). Since the density of the biogas cannot be constant because it is connected directly to the septic tank, equation 1 was substituted into equation 2.

\[ y(\Delta P) = \frac{Q^2}{2\mu^2A^2\Delta P g} \cdot \frac{d^2 \Delta P}{dt^2} + \frac{Q^2}{2\mu^2A^2\Delta P g} \frac{\theta}{dt} \frac{d \Delta P}{dt} + k(\Delta P) \]  

\( \Delta P \) is multiplied through equation 3 to give:

\[ \frac{Q^2}{2\mu^2A^2 g} \frac{m}{\rho g} \cdot \frac{d^2 \Delta P}{dt^2} + \frac{Q^2}{2\mu^2A^2 g} \frac{\theta}{dt} \frac{d \Delta P}{dt} + \Delta P(k(\Delta P) - y(\Delta P)) = 0 \]  

Equation 4 was numerically solved.

3. Results and Discussion

The methane content of the human biogas from the septic tank of a public building was obtained. It was observed that methane content in the biogas is between 51% and 52.6%. The methane increase
may not be permanent as it might reduce based on the anaerobic condition in the septic tank. Generally, low methane percentage is inversely proportional to impurities (Figure 3).

Figure 3. Methane percentage from human biogas from septic tank

The high impurities in the human biogas have significant effect on the control valve of the biogas motor generator. In this experimentation, the control valve was tested mainly on cross sectional area, differential pressure, variable valve timing, membrane and spring equivalent elastic constant (coefficient) and flow coefficient. Three cross sectional areas were considered i.e. 0.8 mm$^2$, 1.2 mm$^2$ and 1.6 mm$^2$. It was observed that at $k = 0.005$. It was observed that the differential pressures of 0.8 mm$^2$ and 1.2 mm$^2$ had significant interception at 45 seconds when the biogas flows through the valve. The control valve tends to converge at a certain-maximum differential pressure magnitude. In practical terms when non-laxity of the valve at cross-sectional area 1.2 mm$^2$ would lead to early damage when the impurities in the biogas is high (Figure 4). Figure 5 shows the differential pressure when $k= 0.05$.

Figure 4. Differential pressure when $k=0.005$
Unlike Figure 4, the differential pressure is lower. These conditions still show the tendency of differential pressure at 1.2 mm$^2$ to converge at higher temperature. Hence, the control valves of the biogas motor generator favour cross-sectional areas at 0.8 mm$^2$ and 1.6 mm$^2$. When $k$ is further increased to 0.5, the material experiences more strain than stress. At this point, control valves of 1.2 mm$^2$ and 1.6 mm$^2$ converge when variable valve timing increases (Figure 6). This result means that the control may likely crash with low differential pressure. In other word, 0.8 mm$^2$ control valve work better at this differential pressure. When $k$ is increased to unity, 1.2 mm$^2$ and 1.6 mm$^2$ valves converge at shorter times leading to immediate damage (Figure 6). At the very low differential pressure, reverse flow occurs when water vapor flows upstream of the control valve.

**Figure 5.** Differential pressure when $k=0.05$

**Figure 6.** Differential pressure when $k=0.5
It was observed that the 0.8 mm$^2$ control valve work better as it shows high precision in allowing the flow of biogas into the biogas motor generator. When the differential pressure further reduces at k=5, it is observed that 1.2 mm$^2$ and 1.6 mm$^2$ valves showed oscillations at lower valve timing and converges at shorter time. However, the 0.8 mm$^2$ control valve showed the ability to go through unusual stress and recover as presented in Figure 8.

**Figure 7.** Differential pressure when k=1

**Figure 8.** Differential pressure when k=5

4. Conclusion
Green solution is highly needed for solving energy crisis in Nigeria. With the mathematical estimation of the right control valve for the proposed biogas motor generator, the dream of having a low cost biogas motor generator is close to reality. This major breakthrough would reduce the cost of energy provision in the poorest homes by 65%. Secondly, there would be no need for destroy the job chain created by the fossil-fuel generator market. More so, the volume of air pollution via carbon (IV) oxide...
would reduce by 80%. Further study is recommended for the thermal response of the valves at 0.8 mm². It is recommended that government create a level playing ground i.e., needed for rapid growth, for affordability, for security, and economical balance.

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