LOW COST ENERGY GENERATION SYSTEM USING BIOGAS FROM A SANITARY LANDFILL

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Abstract. *This paper describes the developed and put in operation prototype low cost energy generation system that uses biogas proceeding from a sanitary landfill in Porto Alegre (RS - Brazil).*
This system was idealized for the use in the handling of a sanitary landfill during its life time as biogas producing. Also applicable for industrial processes that generates organic residues which should be treated biologically.
The prototype generation system consists of an internal combustion engine coupled to an electrical motor.
A minimum treatment in the biogas was made.
An approximate measurement of the gas amount that should flow to the regular engine operation was made and some experiments to characterize the produced electric power quality were done.
It was concluded that the system is operational and it can, in a short period, be used for the sanitary landfill handling maintaince, the quality of the obtained electric power is acceptable, and projecting the engine durability in relation to its cost, it is possible to conclude that this correlation can be extremely favorable to the system, competing economically with any other energy and with important results in the environmental aspect.

Keywords*: energy, biogas, environment, renewable.*

1. Introduction

Porto Alegre produces daily, a million kilograms of garbage, which is disposed in sanitary landfills. These landfills accomplish international environmental control standards, but they represent a problem to the place where they are implemented.

This study was developed at the Extrema sanitary landfill, which was concluded more than three years ago. However, an employees team continues monitoring, accomplishing repairs and handling liquid and gaseous residues that emanate from the sanitary landfill in matter.

The process of anaerobic fermentation, through which biological waste degradation in the sanitary landfill leads to the production of inflammable gas, known as biogas, is a well-known phenomenon. Depending on the kind and content of waste, the biogas could contain many elements, many of them inflammable, which can be used directly to power gas engines driving electric generators. Based on that, an electric power generator prototype was built and put in operation in the sanitary landfill in focus.

The great prototype differential is that it was idealized for use close to the source of gas, with a minimum of treatment of the biogas and small engine adaptations, besides the use of an asynchronous generator. The system is quite simple, fast to be implemented and cheap.

This system can be applied in any company that generates organic residues that have to be biologically treated.

2. Methodology

This study treats four main aspects: the sanitary landfill and the gas reception form, the engine adaptation to operate with biogas, the combination and polarization of an asynchronous motor for electric power generation and advantages economical, social and environmental of the process.

2.1. The sanitary landfill and the biogas reception

The sanitary landfill of the Extrema, located in the Porto Alegre, was the first planned sanitary landfill created by the city hall. It consists of a depression provoked by the gravel exploration, which was made properly impermeable and for 5 years received more than 800 million kilograms of solid residues according DMLU (Municipal Department of Urban Cleaning). These dejections were conditioned in closed cells by clay layers, with a drainage system of liquid and gaseous residues. In Fig. 1 the garbage disposition in the Extrema sanitary landfill during its operation is presented.

Represent 1. Garbage disposition in the Extreme sanitary landfill. Source DMLU

The biogas originating from sanitary landfill is directly burned, without any energy use. In Fig. 2, the gas exit piping disposition is presented, and, in the detail, the pipe used for collection and a flare where the biogas is burned.

Represent 2. Capture and burning points at Extrema landfill.

The biogas reception is made directly by a piping that comes from a single suitable cell shown in Fig. 2. The biogas goes then through a 32 mm piping and for 85 m distance to a single filter where goes through iron filingses and though the air purifier system. The biogas molar composition of the Extreme sanitary landfill is shown in Tab.1, and it was verified in the work of Azevedo (2000).

Table 1. Biogas molar composition of the Extreme sanitary landfill.

Components	Molar volume (%)
O_2	0,72 ± 0,02
N_2	2,00 ± 0,02
Ar	0,02 ± 0,02
CO	0,00 ± 0,02
H_2S	0,00 ± 0,02
CO_2	27,99 ± 0,02
CH_4	69,27 ± 0,02

2.2. The engine

The system used a GM (General Motors) carbureted engine manufactured in the 80’s, whose characteristics are presented in Tab. 2.

Table 2. The prototype GM engine characteristics.

Characteristics	Engine GM
Cylinders	4
Combustion chambers total volume (cm^3)	2500
Nominal potency (cv)	90 [(1)]
Nominal torque (kgf.m)	18,0 [(2)]
Compression tax	7,5 : 1

[(1)] (to 4500 rpm). [(2)] (to 2500 rpm)

The engine which operates with biogas does not suffers important adaptations, basically its structure doesn't change. A direct entrance of gas in the air purifier system and a control of air entrance in the engine is made so that it can aspirate the biogas from its source, such as presented in Fig.3. Trivial point adjustments and opening of spark plug electrodes have been done.

Figure 3. Gas entrance in the engine.

The engine is started with gasoline as fuel, after it enters in stable regime operation, the gasoline is cut and the engine works exclusively with biogas. After initiating the electric power generation process, the engine rotation was adjusted through the control of biogas and air entrance. The biogas flow stayed constant and for several hours of operation it didn't have variations superior to 5% in its rotation.

It is important to point out that the system, in the way it was idealized, must be adjusted to work with load lock or with small variations.

A verification in the engine conservation state was made, it was in perfect condition, still with marks of original burnishing and irrelevant cylindricity.

Simple consumption try out was accomplished with gasoline and biogas and presented in Tab.3, with an estimate consumption for hour in generation with load.

Table 3. Fuels Consumption.

Combustible	Amount
Gasoline (dm^3/h)	4,8 ± 0,5
Biogas (m^3/h)	7 ± 1

2.3. The combination and generator polarization

The traction system and generation was connected through belts that allow certain degree of oscillation freedom to the combustion engine, since it is sustained by flexible supports mounted on a metallic chassis. The generator is fastened directly in the same chassis, the joining system is indicated in Fig. 4. The relationship between pulleys is 1,86.

Figure 4. The joining system.

An important cost reduction factor was the adopted generator. It is an asynchronous motor of low cost of acquisition and maintenance.

The generator was polarized accordingly to the schematic diagram of Fig. 5. When the rotor reaches a rotation above 3600 rpm, the keys S1, S2 and S3 are activated, simultaneously, energizing the fields of the asynchronous motor, through the capacitors C1, C2 and C3, in a star configuration. Once started the process, the generator is self excited, part of the generated energy is used for the polarization of its stator windings. However, according to Homrich, Beluco and Livi (1994) the asynchronous motor is capable of generating a potency very close to its nominal value.

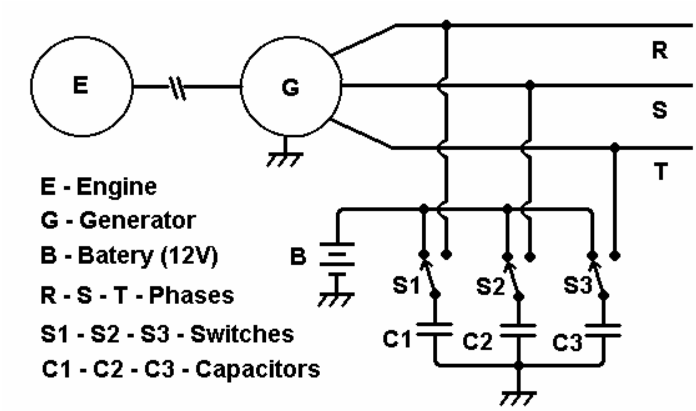

Figure 5. Schematic diagram of the generating system connection and polarization.

The characteristics of the asynchronous motor plate used as generator in the prototype are shown in Tab. 4.

Table 4. Nominal characteristics of the asynchronous generator.

Asynchronous motor	Nominal values
Potency (kW)	6,6
Tension for phase (V)	220
Frequency (Hz)	60
cos φ	0.87
Number of Poles	2
Rotation (rpm)	3480

The characteristics of the capacitors used in the polarization of the asynchronous generator are described in Tab. 5.

Table 5. Characteristics of the used capacitors.

Lorenzetti Capacitor	Values
Capacity (° F)	40 ± 2
Isolação tension (V)	380 ± 16
Operation frequency (Hz)	60 ± 10
Operation temperature range (K)	248 to 358

Some try-outs of electric power generation were accomplished using resistive loads, where the quality of the generated energy can be evaluated. For the energy distribution companies a voltage variation from 91 to 104% is acceptable according to ANEEL (National Agency of Electric power) during 7% of the measurement time. However, according to CSPE (Commission of Public services of Energy) in Europe, variations between 90 to 110% of the tension during 5% of the time of measurement are accepted. The equipment type to be linked in a system like that, doesn't request precision in the frequency of the net, a variation of 10% is acceptable, besides, modern equipments as the televisions work with tension values (between 100 and 240V) and quite flexible frequency. As demonstrated in the work of Homrich, Beluco and Livi (1994) rotation variations in the generator would provoke variations approximately of the same percentile order in the frequency and tension of the generator.

In Fig. 6, is presented a graph with the relation between the rotation of the engine and the exit tension in one of the phases (R) with load of 700W for phase.

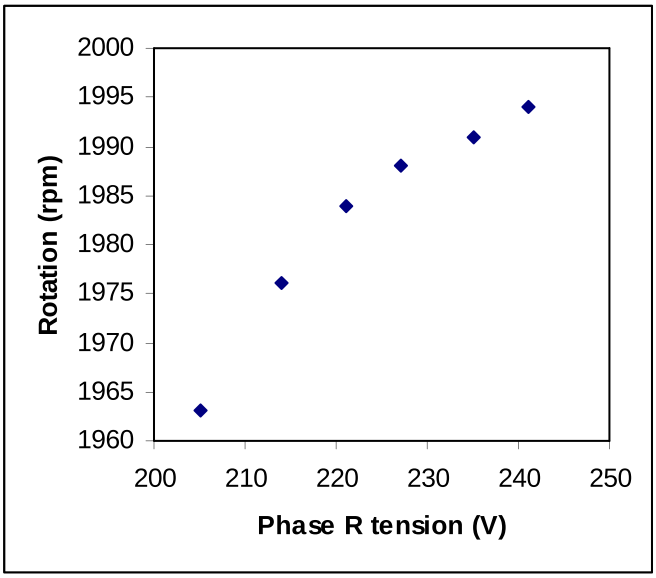

Figure 6. Graph of the relation between rotation of the engine and tension in phase R.

2.3. Economical, social and environmental advantages of the process

In the economical aspect, a generator with low implantation and operation costs and of fast installation was obtained. This system, besides, can be used whenever the spontaneous generation of biogas exists, for example, in industries that process organic material or sewers treatment systems.

The costs of generation for kWh can be calculated approximately by Eq. (1) where *P* corresponds to the value of the kWh in U$, *Ip* represents the implantation investment in U$, *Io* is equal to the operational cost in U$ for operation hour, *Lt* consists of the useful life time of the system without fundamental components replacements and *W* is medium potency generated in kW.

$$P = \frac{I_p + I_o . L_t}{W . L_t} \quad (1)$$

The prototype, considering an useful life of 2000 hours, has potency of 5 kW, an approximate cost of operation of U $0,15 per hour and it is considered, here, that it had zero implantation cost. The value of the kWh would be around U$0,03. If the prototype was operated with gasoline each kWh would cost U$ 0,94, because the operation cost would surpass U$4,52 per hour. This difference is due to the gratuitousness of the biogas.

The approximate implantation cost of an equipment similar to the one used in Porto Alegre and with potency up to 40 kW, is less than U$3.000,00, and it would have the same operation cost. A system as that could generate more than 80MWh in its useful life. With a total cost of approximately U$0,04 for kWh.

The sanitary landfills are preferentially installed in distant areas far from the urban areas, and preferentially already environmentally degraded, however, it is not rare to find communities that are relatively close to those equipments, and for that, they face a series of problems. A form of compensating those problems would be the offer of energy to the community with lower or no cost, the enlargement of the public illumination is also possible among other possibilities.

As for the environmental aspect, the system is positive, the biogas is a renewable fuel, in any way would be produced and in the best chances burned. The system can allow the sustainability of the sanitary landfill, once the generated energy can be used in its handling, further in the pumping of liquid effluents and in its stabilization.

3. Conclusions

In the technical aspect the system is simple of being executed.

The system is adapted for electric power generation in small and average climbs, mainly for the handling of the sanitary landfill and environs.

In the economical plan it is cheaper than any other energy.

In environmental terms it is renewable and maintainable, and it rehabilitates an energy which before was a problem.

Socially it can be allocated to give electricity to small places.

The generated energy can be used in the handling of the sanitary landfill lowering costs.

The quality of the generated energy is acceptable for most of the uses in the immediacy of the sanitary landfill.

The system can be implanted in industries which generate biogas.

The system can be implemented quickly and it has technical, economical, environmental and social viability.

4. Acknowledgements

To DMLU and the Municipal City Hall of Porto Alegre.

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6. Responsibility notice