CHEMICAL ENGINEERING TRANSACTIONS
VOL. 39, 2014
A publication of AIDIC
The Italian Association of Chemical Engineering
www.aidic.it/cet
Guest Editors: Petar Sabev Varbanov, Jiří Jaromír Klemeš, Peng Yen Liew, Jun Yow Yong

ISBN 978-88-95608-30-3; **ISSN** 2283-9216
DOI: 10.3303/CET1439058

Electrical Parameters of the Electric Power Production Using Biogas

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In recent years, biogas has increasingly been used for electric power production. Due to this increased use, different technologies have been developed that manage to employ the energy produced by biogas, giving results in either power (kW) or energy (kWh).
This article will particularly review the different electrical parameters in a case of biogas usage to produce electric power; comparisons are made with other fuels and the quality of the energy produced is also reviewed.
By means of this article, steps will be taken to further and more properly consider the rest of the electrical parameters, such as frequency, voltage, the amount of harmonics, the power factor, among others.
Reference is also made to other factors such as the altitude at which the electric power production from biogas is taking place, this because the efficiency of the machines varies depending on the working altitude and temperature.
A case study is presented wherein biogas is used to produce electric power; the results obtained from the electrical parameters are studied as well.
The results presented show that particular care must be taken in regards of the quality of the energy whenever power is produced from a renewable source, biogas for this case, as the electrical parameters set forth by normative standards must be complied with.

1. Introduction.

The amount and quality of production from biogas depends directly on the type of organic matter used by degradation, with an average methane content ranging between 50 – 65 % vol. and CO_2 up to 30 – 35 % vol. (Pagliai and Felice, 2013); besides content, the technology used for its production is also important. Niesner et al. (2013) presents in his paper a review of the technology used for biogas production in Europe.
This paper will not review the calorific power of biogas, nor its production, this article will mainly focus on analyzing the electrical parameters resulting from power production using biogas by means of an engine-generator. Voltage, frequency, number of harmonics, and other factors, are important if we are to know the quality of the produced energy. For the case study, biogas gas with a filter is used; the filter makes the biogas to go 'purer' into the electric power generator. The 8,500 kW electric power generating plant's performance and behavior with two different fuels, petrol and biogas, is reviewed.
In this case study, the effects of altitude on internal combustion machines, such as the 8,500 kW generator, is not reviewed, as this case study is carried out at 1,700 m above sea level. As it is known, the decrease in atmospheric pressure and temperature affect air density and composition, and that also impacts, to some measure, the efficiency of the energy conversion. This case was already reviewed by Benjumea et al. (2009).

Please cite this article as: Hernández-Figueroa M.A., Martinez-Patiño J., Ireta-Moreno F., Lozano-García J.M., 2014, Electrical parameters of the electric power production using biogas, Chemical Engineering Transactions, 39, 343-348 DOI:10.3303/CET1439058

The major contribution of this article is that it presents relevant data regarding the harmonic distortion resulting from having low-quality electric power. And so, once the data is known, it becomes possible to improve the energy quality by applying a modulation technique aided by power electronics.

2. Electrical Parameters and harmonic distortion.

The quality of the stress wave must have constant amplitude and frequency, as well as a sinusoidal form, with constant 60 Hz frequency for most of the countries in the American continent, and 50 Hz for Europe; this form must comply with constant 1 pu amplitude.
Whenever a periodic wave lacks this sinusoidal form it is said to have harmonic content, which may alter its peak and/or RMS value; harmonic content is cause of alterations in the normal functioning of any equipment subject to that tension (voltage). The frequency of the periodic wave is known as fundamental frequency and the harmonics are signals with frequency of an integer multiple of that frequency.
There are different source generators of harmonics, among them electric arc furnaces, speed controllers, Inrush current of the transformers, AC to DC converters, among others. The effects of harmonics are perceivable in the wires, transformers, capacitors, engines (in rotating machines), electronic equipment susceptible to incorrect operation, among some other effects of harmonic distortion. (Arrillaga et al., 2000) and (Bollen, 2000)
Since in this case study it can be established that there is a small electric network conformed by the electric power production from the engine-generator and its connection with the electric power consuming devices, it is important to take into account that the document IEEE Std. 519-1992 is useful for the understanding of harmonics and the application of harmonic limits in power systems (Jouanne and Banerjee, 2001).

3. Types of electric loads.

Technological advancement has led to an exponential use of active loads: microwave ovens, energy saving lamps, computer systems, sound equipment, telephone systems, and others. These types of loads generate, besides reactive loads, unwanted signals such as the previously described harmonic signals.
Another important piece of information to take into account is the power factor generated by the equipment consuming electric power, this because a low power factor will give place to large amounts of energy sent back from the load to the generating source, which reduces the efficiency of the power generating device and shortens its useful life.
Voltage harmonic distortion does not suffer any important change with passive loads; however, it goes through important variations when electronic loads are connected to an electric system. As for the harmonic distortion in the current, in presents high variations exception made of resistive loads.
This case study will later on show the behavior of electric power production by biogas with an engine-generator and its behavior with different electric loads.

4. Electric power production using biogas.

The use of biogas with different composition ranges has extended over to the production of electric power in the whole world. Its use has been well-received for internal combustion engines that would otherwise generally use gas from fossil fuels only.
Internal combustion engines working with biogas are a new and widely applicable technology in the field of thermal and electric power production, even when it is known that a stoichiometric mixture of biogas-air provides an average of 85 % the power of a diesel-air stoichiometric mixture.
However, the use of biogas presents certain complications due to the quality of its chemical composition, as it a relatively poor fuel, containing high CO_2 levels and contaminants such as particulate matter, humidity and hydrogen sulfide (H_2S).
This makes necessary to at least run a cleaning and drying pre-treatment for the biogas and a careful selection of the engine (hence the importance of a biofilter). There are different providers for these engines in the market, as well as providers for the basic accessories, such as filters, dehumidifiers, heat recovery and dissipation systems, electric network control and connection systems, and providers for complete packages, suitable for the needs of every interested party and every engine (Arango et al., 2014)
This article presents the case study of electric power production with and without a filter for the biogas.
According to (Santos, 2000) the efficiency of biogas conversion into electricity with OTTO cycle internal combustion engines is 25 %, and biogas inferior calorific power is 6.5 kWh/m^3 (60 % CH_4).
With the following Eq(1) and Eq(2), we can see the efficiency of the electric power conversion using biogas (Souza et al., 2013):

$$SFC = \frac{BCH}{AP} \quad (1)$$

where:

SFC = Specific Fuel Consumption (m^3/kWh)
BCH = Biogas Consumption per hour (m^3/h)
AP = Active Power (kW)

$$\eta = \frac{AP}{BCH * ICP} \quad (2)$$

where:

η = Engine-generator system efficiency
ICP = biogas Inferior Calorific Power (kWh/m^3)

This article does not prioritize the review of the energy conversion, even if it does present a comparison between the electric power produced from biogas using biogas and using petrol. The focus of this paper is reviewing the quality of the electric energy produced with an engine-generator using biogas.

5. Case study.

This case study took place in the city of Irapuato, Mexico, at a 1,730 altitude above the sea level. This piece of information is relevant to take into account when analyzing the efficiency of the engine-generator. Table 1 shows the characteristics of the engine-generator.

Three different types of tests were performed using two fuels: biogas and petrol. For biogas, two tests were performed, one of them using a biofilter and the other one without a biofilter (Table 2).

Biofilters of biological filters are known to be devices that eliminate a wide range of contaminant compounds. The biofilter system used for this case study is comprised of a separating tank and a biofilter.

Once the characteristics of the generating equipment are known, it is necessary to also know the different types of loads connected at different times to the electric power generating device; these details are given in Table 3. Table 3 shows them to be resistive loads (bulb) and inductive loads (engine).

Table 1: Engine-generator data.

	Characteristics
Time of operation with 50% load	6.80 hours
Maximum power	8.50 kVA
Rated power	6.80 kVA
Voltage	120 V / 240 V
Alternator	Maintenance free
Frequency	60 Hertz
Phases	Monophasic / Biphasic
Contacts	120/ 240 V
Cooling type	Air

Table 2: Types of electric loads used for the tests.

	Characteristics
Case 1	Engine-generator using biogas without filter
Case 2	Engine-generator using biogas with filter
Case 3	Engine-generator using petrol

Table 3: Types of electric loads used for the tests

	Power
Engine 1	½ HP
Engine 2	½ HP
Bulb 1	75 W
Bulb 2	75 W
Bulb 3	75 W

Results in Figures 1-5 clearly show the variation behavior of the different electrical parameters. It is still necessary to add frequency data, which is an important factor in the behavior of engines, but this particular will be dealt with in a future article.

Figure 1 shows the behavior of the current when an inductive load (engine) enters the operation; with the resistive load there is almost no behavior, as it only increases the little load generated. Inductive load, upon entering the operation, produces a peak in the load curve, and this is easily identifiable due to the starting curve of any engine. It is important to take into account this peak as it may occasionally trigger some engine-generator protection and then cause the whole device to stop.

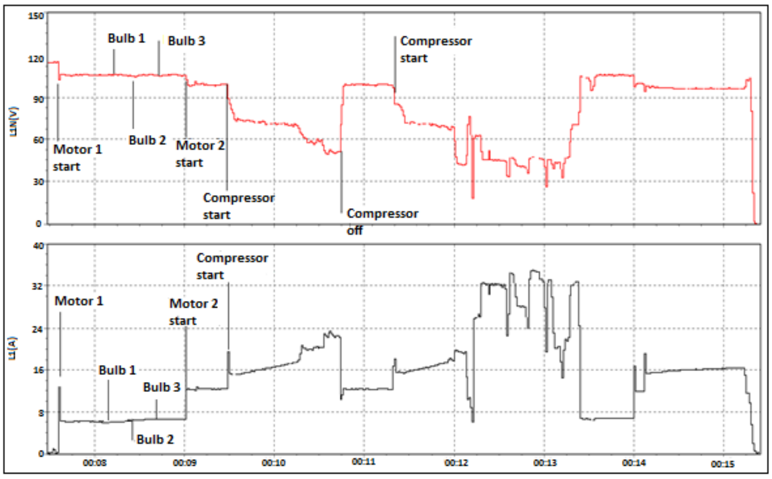

Figure 1: Shows the results of connecting different types of inductive and capacitive loads.

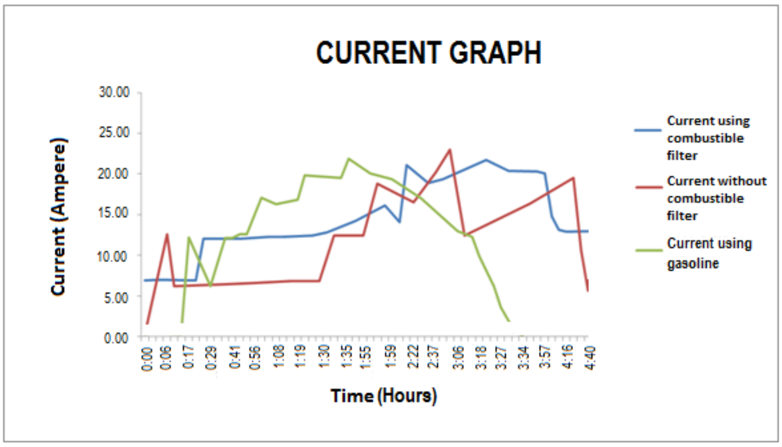

Figure 2: Current variation for the three tests and with different loads.

Figure 5 shows that the frequency generated in all the three tests is lower than 60 Hz, which clearly reflects the poor quality of the energy produced. This type of signal affects the powered devices, particularly engines.

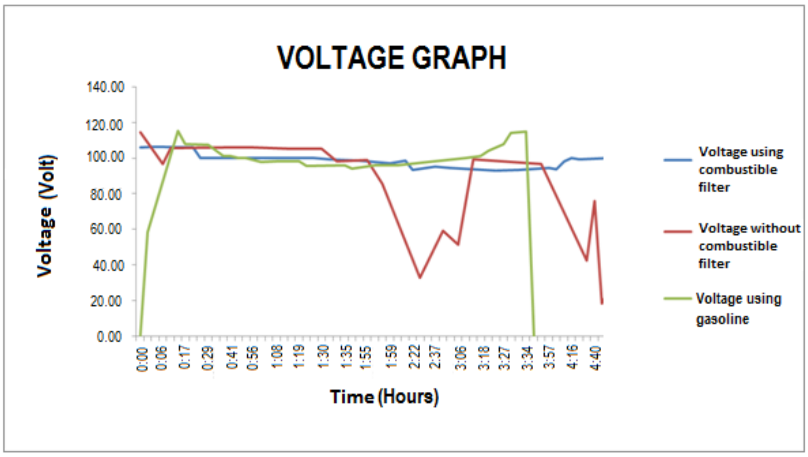

Figure 3: Voltage variation for the three tests and with different loads

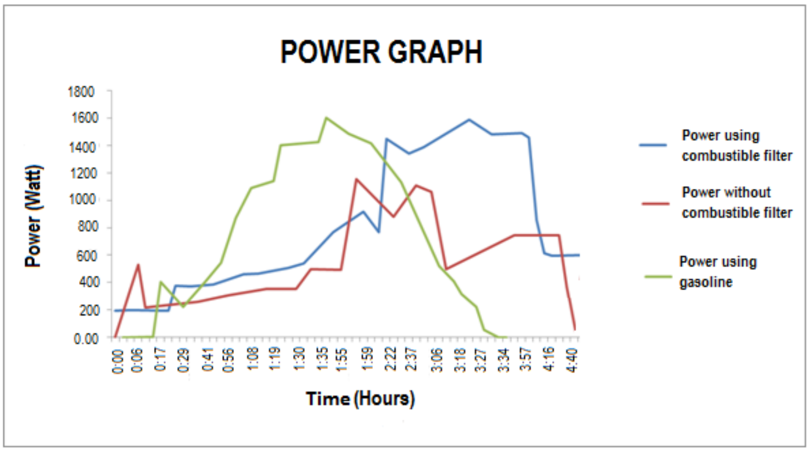

Figure 4: Electric power production for the three tests

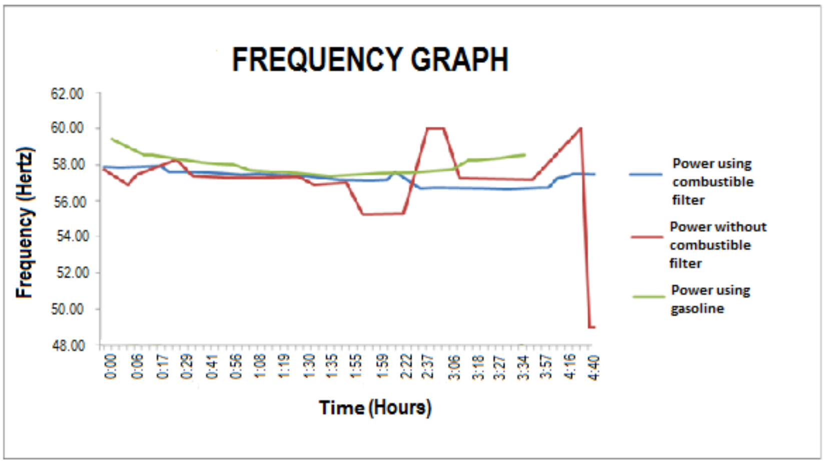

Figure 5: Frequency graph

6. Conclusions

A case study for the production of electric power by means of biogas is presented here, showing also a comparison of the quality of the energy using a biofilter. These tests were carried out at an altitude of over 1,700 m above the sea level, which impacts the efficiency of the engine-generator. Tests were primarily focused on assessing the quality of the energy being produced and the effects perceived when connecting inductive and resistive loads. The major effect in the current curves occurred when inductive equipment entered in the operations.

It was also observed that the results of power production where not high-quality in relation to frequency, which affects the efficiency of the equipment connected to the engine-generator.

All of the electrical parameters and the quality of the energy produced from any electric power generating source (renewable or non renewable) must be carefully reviewed, this with the purpose of ensuring that the efficiency of the powered equipment and devices is not affected and their useful lifetime is not shortened.

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