African Journal of Biotechnology Vol. 12(10), pp. 1148-1154, 6 March, 2013
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB12.2506
ISSN 1684–5315 ©2013 Academic Journals

Full Length Research Paper

Performance of diesel cycle engine-generator operating on dual fuel mode with gasification gas

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Accepted 24 October, 2012

The Brazilian Federal Government aims to expand the electrical energy supply to the low income Brazilian citizen through Light for Everyone Program. The objective of this study was to use the program as a vector of social and economical development. One of the obstacles was to reach even the isolated communities. In this work, the performance of a cycle diesel motor generator running in dual mode, diesel and gasification gas, as an option for decreases, the dependence on diesel by the isolated communities was evaluated. The process was based on obtaining gas through the partial biomass burn, which in high temperatures is converted to fuel gas that may be used in internal combustion engine. Among the results, it was observed that there is a reduction of 30.7% in the diesel consumption, a better voltage adjustment and a maximum current at the generator, leading to a power increase of 43.8% saving R$ 0.86 for each kW h^{-1}. These results show the possibility of using the biomass gasification to decrease the diesel consumption to produce electricity in the isolated communities.

Key words: Energy, biomass, diesel consumption reduction, gasifier.

INTRODUCTION

The Light for Everyone Program of the Brazilian government has as goal to bring access to electrical energy to the low income families, with the purpose that electricity becomes a vector of social and economical development, and assisting to poorness reduction, increase of income to families and a rise in the Human development index. The access to electrical energy makes easy the integration of social programs of federal government as health services, education, water supply and sanitation. One of the main blockage found by the program is to assist the isolated communities. Those places are far away from the electricity network available and they are difficult locations, with low population density, especially those ones located in Amazonia.

The available technology includes decentralized generation systems mini and micro hydro electrical centers, hydro kinetics systems, thermal plant, hybrid systems and aero generators, among others, prioritizing the use of alternative available energies on electricity production. This work evaluates the use of biomass as gas to run a diesel micro generator operating in dual mode, diesel and gasification gas, a gas obtained from a gasification counter flow unit, located at West Parana State University - UNIOESTE, as a solution to minimize the use of diesel on electricity generation at isolated communities, with the use of local and sustainable local energy resources.

MATERIALS AND METHODS

The conversion of biomass to energy takes place by combustion or biological process. The combustion may be partial or total. In the total combustion, all biomass is consumed and it is converted to heat, and in the partial combustion a part of biomass is converted to gas. The stoichiometric ratio (ʎ) is linked to the theoretical amount of biomass and air and the real amount in a chemical reaction (Brady, 2009; Puig-Arnavat, 2010). The amount of air on total combustion is overestimated (ʎ > 1), aiming the heat production,

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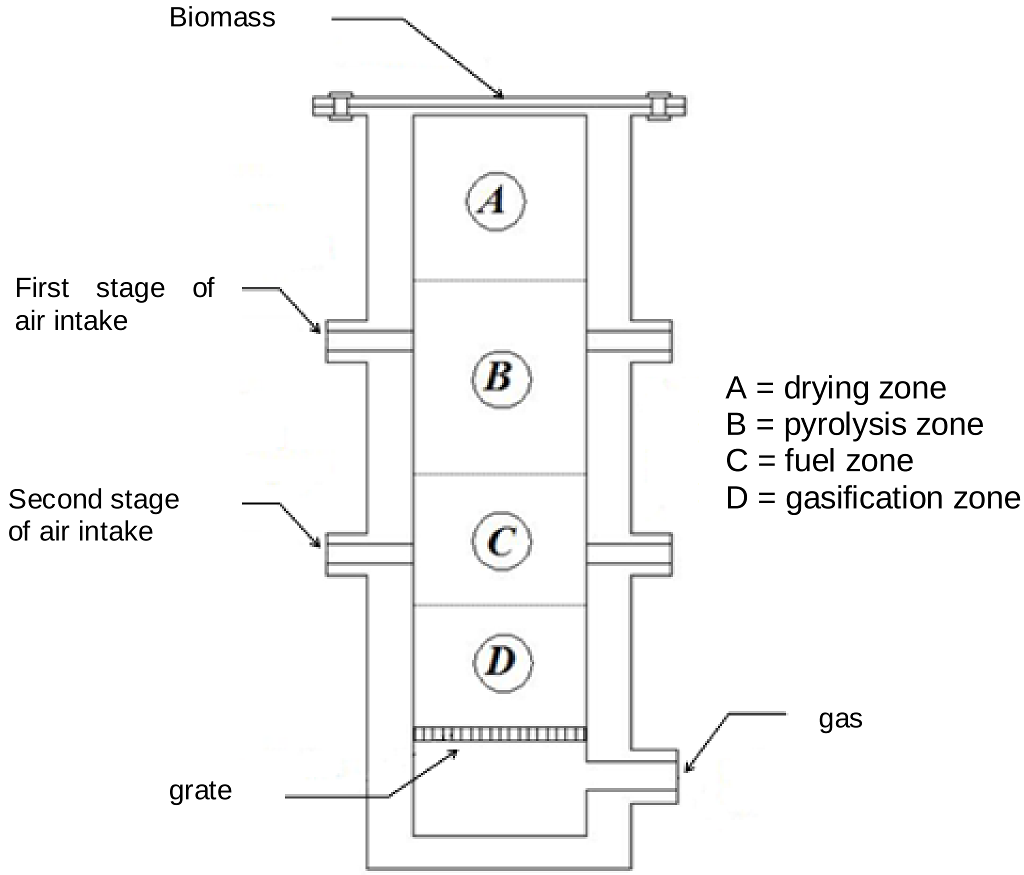

Figure 1. Two stage co-current gasifier.

ensuring that all the fuel is consumed. The main goal on partial combustion is the gas generation (gasification) and not the heat production, so the air amount is reduced (ʎ < 1) (Nogueira, 2003; Tinaut, 2006).

The gasifier and the diesel Motor Generator Group (MGG) belong to the gasification laboratory at the West Parana State University (UNIOESTE), Cascavel Campus. The biomass gasifiers differ by the biomass type that is used, by the heat value of the produced gas, by the gasification agent, by the work pressure and by the biomass flow when compared to gasification agent. The heating value of the produced gas is featured as low heating value ≤ 5 MJ Nm^{-3}; average heating value between 5 and 10 MJ Nm^{-3}; and high heating value between 10 and 40 MJ Nm^{-3} (Gómez-Barea, 2011). With respect to the gasification agent, it is featured as air, oxygen or water vapor. With respect to the work pressure, it is featured as low pressure or atmospheric pressure, and to 6 MPa of high pressure. With respect to the flow of biomass, it is featured as counter flow, direct flow, cross flow, fluidized bed or carried bed (Àngel, 2009).

On two stages co-current gasifier (Figure 1), the fuel gas output is on the bottom part, the flow is downwards on the same direction as of the flow of the solid material. In reaction to this flow, the gas components produced at the drying zone and at the pyrolysis are forced through the glowing coke bed where the phases of reduction with endothermic reaction occurs, as well as hydrogen, carbon monoxide, methane and ethane formation.

In the first phase, the partial burn of the biomass occurs in reaction to the gasifying agent (air), generating heat to the drying zone (Figure 1A), with temperatures between 100 and 200°C and evaporating the water of the solid biomass that is been used. On the pyrolysis zone (Figure 1B), at temperatures around 280 to 450°C, the solid elements (hemicellulose, cellulose, lignin etc), produced tar, light acids, non-condensed gases (CO, CO_2, H_2, CH_4, O_2), solids (ashes), and endothermic reactions of this phase.

In the second phase, the biomass oxidization occurs due to the air in the partial combustion zone at temperatures around 600 and 800°C. In this phase, the gases generated at the pyrolysis react with the oxidant agent in an exothermic reaction which is responsible for the heat generated by the gasifier and responsible for the reduction of tar on content lower than 75 mg Nm^{-3}. The reduction phase occurs in the gasification zone at temperatures around 800 and 1000°C, where the hydrogen reacts with the carbon monoxide generating methane and water (Ángel, 2009; Brown, 2009; Puig-Arnavat, 2010; Martines, 2012).

The gasifier used for the study was a two stage co-current gasifier, CD60, fabricated in 2005, developed by Termoquip. The gasifying agent is air with a flow rate of 0.35 Nm^3 min^{-1}, that is pasteurizes under work pressure of 1.0 bar (Figure 2). The gas produced has low quantity of tar < 75 mg Nm^{-3} and a particulate content from the bag filter of < 20 mg Nm^{-3} (Termoquip). These are necessary conditions to the internal combustion engine operation. The biomass used for the experiment was the "Itaúbe", *Mezilaurus Itauba sp,* according to Quirino (2005), it has a higher calorific power of 22 MJ kg^{-1}. The residues were taken from the logging industry of the region, cut into cubes of 2 to 4.0 cm according to the fabricant's specifications. The GMG diesel was a BD-6500CFE, Branco, single-cylinder engine of 10 cv, with continuous power of 9 cv, compression ratio of 19:1, direct injection, consume of 2.15 L

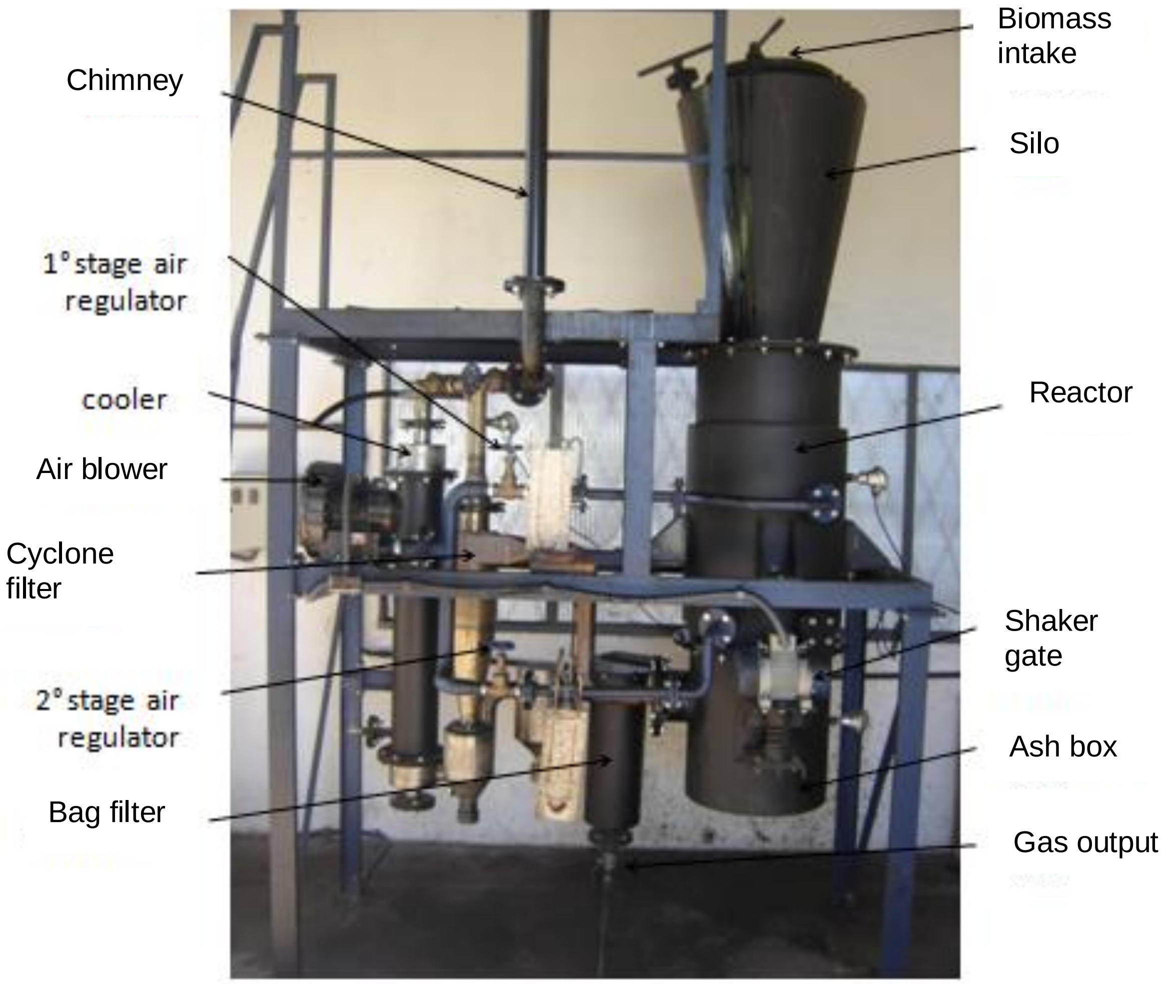

Figure 2. CD60 termoquip gasifier.

h^{-1} and generator of 5.0 kVA continuous electric power, single-phase with voltage of 127/220V.

One of the characteristics of the basic functioning of the diesel cycle engine is the autoignition of fuel through compression. In the compression phase, the intake air is compressed, and its temperature increased, with this, the direct injection of the diesel occurs, which in contact with the heated air initiates the ignition, causing the expiation that causes work. Therefore, the use of gasification gas in diesel-cycle engines is only possible on dual mode, working with the ignition diesel in the gasification gas. For the functioning of the dual mode, the gasification gas goes through the air intake of the engine that was modified by the insertion of a venture mixer and a ball valve for the dosage of gas and air required on dual mode. Figure 3 shows in a simplified way, the system settings which is composed of the gasifier (GDE) and its parts, connected to a water-sealed gasometer (GA), for the temporary storage of the gas, related to the GMG and to a consumption balance and to a resistive load-banks.

The operational conditions are determined by the settings of the entrance of gas and of air in the venture under the conditions of 250 to 5000 W charge determined by an association of resistors connected to the generator. The consumption of diesel is determined with the use of a plastic beaker of 250 ml and a Gehaka BK2000 semi analytical balance, with maximum capacity of 2100 g and resolution of 0.01 g. The consumption/hour of the diesel of the system was determined with the use of a digital chronometer. The combustion consumption is expressed by

$$Cons = M_i - M_f \qquad (1)$$

Where, Cons is the combustion consumption (g); M_i is the initial mass of fuel (g); M_f is the final mass of fuel (g).

The final experiment consisted in submitting the system under the minimal condition of charge, 250 W to the maximum nominal condition of the equipment (5 kVA), with gradients of 250 W. The behavior of the system (voltage, electric current and electric power) when operating with diesel only, on normal mode, was taken as a reference and compared to the same system but on dual mode, using diesel combined with gasification gas. The time and the consumption on the distinct charge conditions show the specific consumption of fuel, diesel (CED). The CED is compared in equal charge conditions operating on normal mode and on dual mode as shown in equation 2.

$$CED = \left(\frac{3600 \times Cons}{V \times I \times T}\right) \qquad (2)$$

Where, CED is the specific consumption of fuel (kg kW h^{-1}); I is the electric current (A); T is the time (s); V is the voltage (V). The

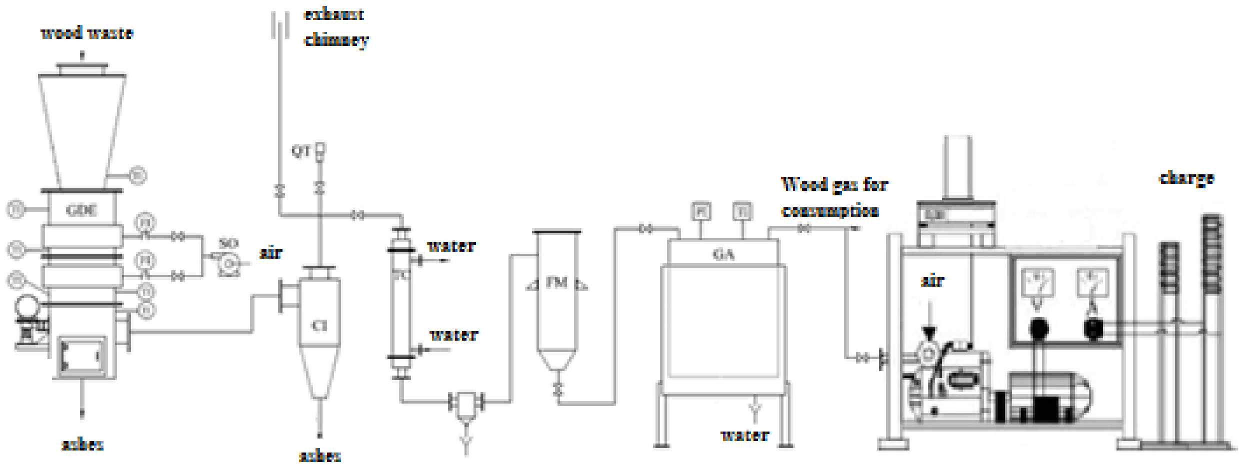

Figure 3. Experiment settings (Ángel, 2009).

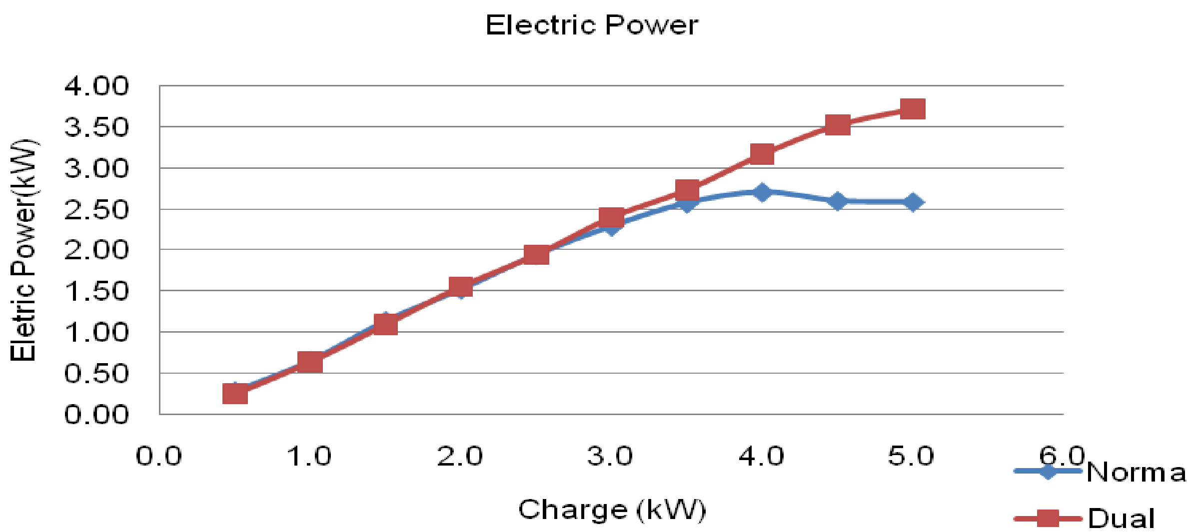

Figure 4. Electric power produced due to the charge.

difference of consumption on dual mode in relation to the consumption on normal mode is expressed by equation 3.

$$\text{Saving} = \left(\frac{\text{Cons}_{\text{normal}} - \text{Cons}_{\text{dual}}}{\text{Cons}_{\text{normal}}}\right) \times 100 \qquad (3)$$

Where, saving is the fuel saving (%).

RESULTS AND DISCUSSION

The use of the gasification gas contributes to better adjustments of the voltage of the generator with an average of 201 V on normal mode and 208 V on dual mode. The use of gasification gas also contributed to the increase of maximum current of 15.2 A on normal mode to 18.4 A on dual mode, representing a gain of 21.05% of the maximum current. Figure 4 relates the behavior of the electric power produced by the generator due to the required charge on normal and dual mode. The use of the gasification gas contributed to the increase of the maximum electric power of 2.58 kW on normal mode to 3.72 kW on dual mode, an increase of 43.8%. Figure 5 relates the behavior of the consumption due to the required charge on normal and dual mode. The use of gasification gas contributed to a decrease of consumption when the electric power of the charge is higher than 1.5 kW, reaching a maximum of reduction of consumption on 3.5 kW with 30.7% of reduction.

Both dual mode and normal mode show a high CED when the system operates with low charge that characterizes a lower performance of the engine. With

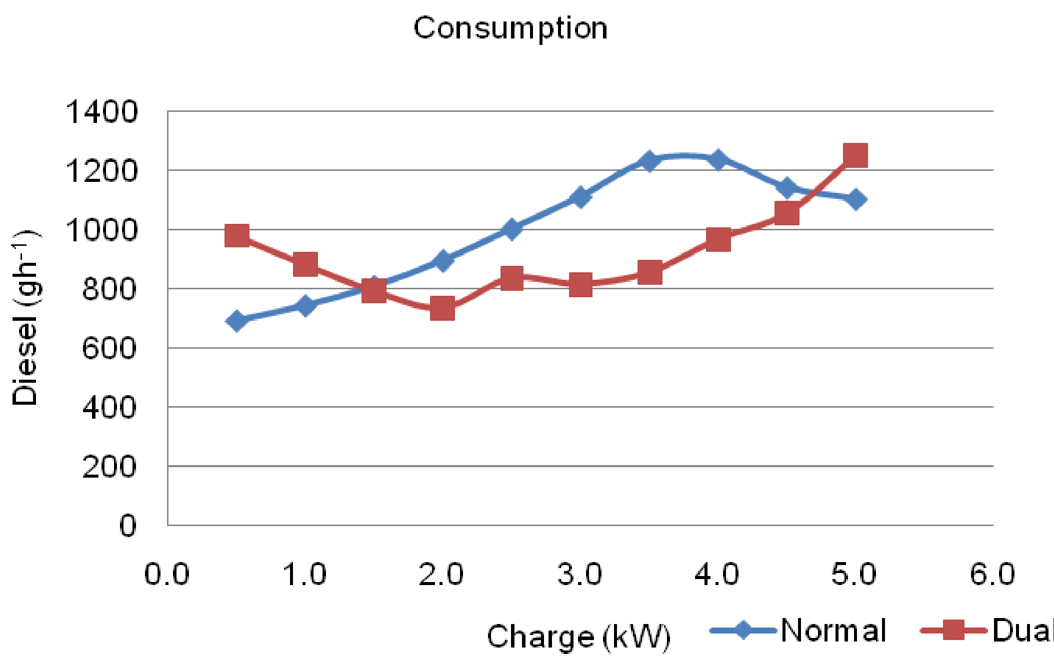

Figure 5. Consumption due to the charge.

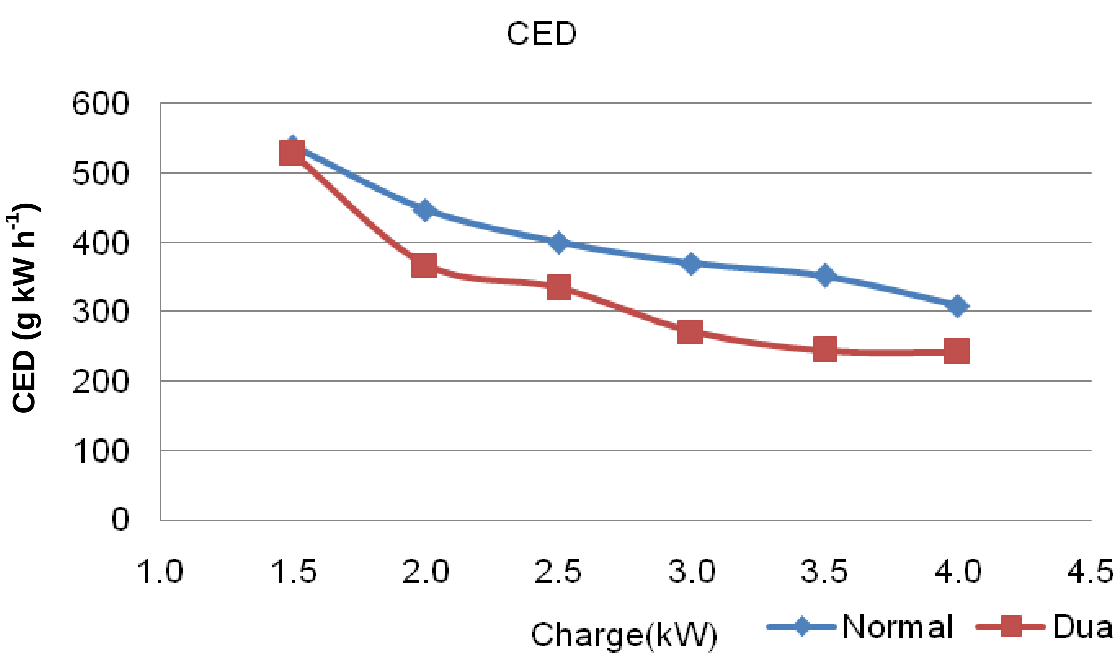

Figure 6. Low range of charge consumption.

the increase of the required charge, there was a decrease of around 1.5 and 4 kW of the specific consumption. Figure 6 relates the specific consumption of fuel due to the required charge on normal mode and on dual mode, around the range of 1.5 and 4 kW. On the charge range of 1.5 to 4.0 kW, the CED on normal mode was of minimum of 309.0 kW h^{-1} and maximum of 537.4 g kW h^{-1}, with an average CED of 402.5 g kW h^{-1}. On the same charge range, on dual mode, the minimum CED was of 241.6 g kW h^{-1} and a maximum of 527.3 g kW h^{-1},

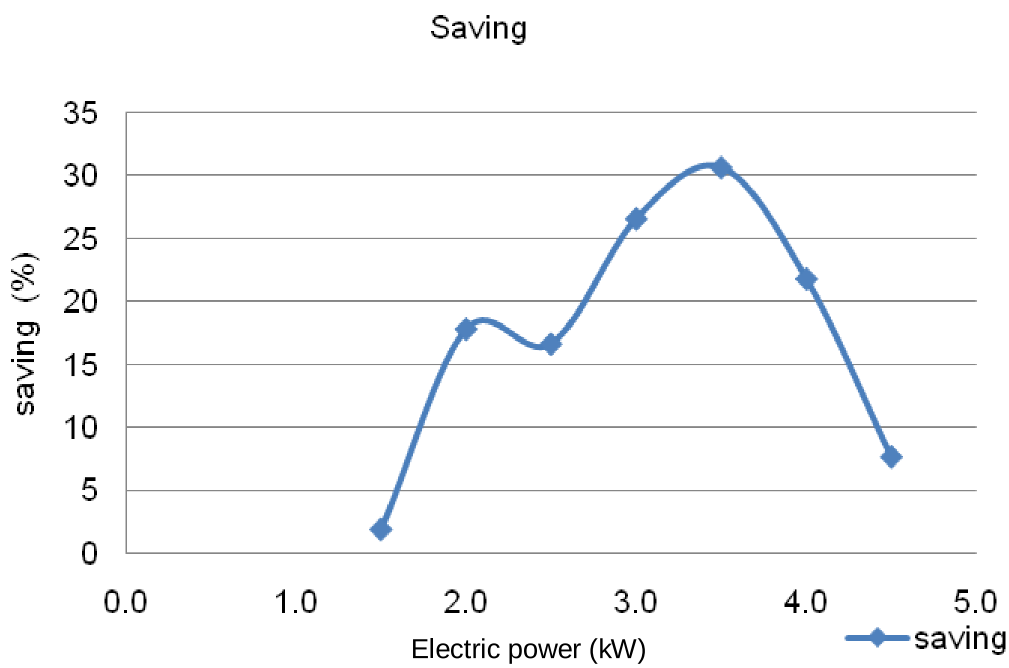

Figure 7. Percentage of saving of diesel due to the charge.

with the average of 330. 8 g kW h^{-1}. Figure 7 relates the saving of fuel due to the required charge on normal and dual mode, on the charge range of 1.5 to 4.5 kW. The use of the gasification gas contributed to a reduction of the consumption when the electric power of the charge is higher than 1.5 kW and lower than 4.5 kW, with an average of 17.8% of the consumption, and with maximum reduction on 3.5 kW, with 30.7% of reduction for a liter of diesel to R$ 1.89, representing a savings of R$ 0.86 h^{-1}.

Conclusion

At analyzed conditions, this study showed that using the Itaúba waste resulting in a gas with heating value ≤ 5 MJ Nm^{-3} we observe that:

1) The use of gasification gas with diesel has shown a 30.7% reduction on the fuel consumption;
2) The operation ratio with the lowest specific consumption is limited between 1.5 kW and 4 kW, and the best operation point is 3.5 kW;
3) It was observed an improvement in the adjustment of the voltage parameters and the maximum current of generator, with a significant increase at the maximum power with a raise of 43.8%;
4) A savings of R$ 0.86 for each kWh^{-1} for a load of 3.5 kW was verified.

These results show the possibility of using the gasification biomass on the diesel consume reduction to generate electrical energy to the isolated communities.

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