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Biomass generator to reduce the gas emission and operation cost in a grid-connected renewable energy systems

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Abstract : This paper shows how a biomass systems can reduce the emissions and the operational cost in an energy supply system. The main objective of this paper is to boost the use of biomass-based systems with the final purpose of reduce the global gas emissions using renewable energies. The systems has been simulated in HOMER Pro ® software which can estimate the operational costs and the emissions on energy systems using renewable energies. The system is compounded by an energy grid, a biogas generator with an output power of 3 kW, an inverter with a max. Output power of 1.15 kW and a photovoltaic system with a max. Output power of 0.29 kW to supply a scaled annual average of 33.64 kWh/d. The data values obtained reveal that the biomass generator reduce to 20.34 % annual operation cost, 17.55 % of the total operation cost and a 38 % of the total emissions.

1 Introduction

At the global level, states have encouraged communities to integrate renewable energy into their cultures in order to contribute to climate change mitigation and the reduction of energy consumption from conventional sources (1), so the European Energy Commission specifies that climate targets should be geared towards an assumed share of renewable energies in total energy consumption and that it should be about 20% by 2020 (2), as predicted by the Institute for Sustainable Energy Policies, by the year 2050, only 33% of non-renewable energy will be available for energy generation if, to meet the required demand, the remaining 67% be replaced by renewable energy sources (3), In addition, non-renewable energy sources currently account for approximately 85% of the world's energy, where 68% of fossil fuels are used for electricity generation (4), therefore multiple are the arguments based on studies for the use of renewable energy in order to generate electricity.

In relation to studies of quantity and quality of biomass various countries such as Norway, Sweden, Denmark and Finland make comparisons where it is shown Norway is the country with the greatest potential in biomass energy generation (5), countries such as Bangladesh, India and China Ericsson apply an approach based on available and used resources to assess the potential of biomass in 15 European countries (6). The categories of biomass including the different ones are based on forest residues, by-products of the forest industry, straw, maize residues and energy crops, Portugal being an import dependent country to satisfy its energy needs use energy from biomass taking into account that more than a third of the territory is forests, biomass is one of the most potential renewable energy sources (7).

This shows that all countries in one way or another carry out the inclusion of renewable sources for the generation of electricity, as a main input for the state development of the countries. The main objective of this paper is to boost the use of biomass-based systems with the final purpose of reduce the global gas emissions using renewable energies, therefore can supply the energy load with less operational cost and take care of the environment.

2 Methodology

This section of the paper presents a system description with a technical specifications of the components used to supply the energy load in the simulated case study, in addition the fundamentals equations required to estimate the data values in this simulation are presented.

2.1 System description and location specifications

The proposed system to supply the primary load is integrated by an electrical grid (a), an inverter (b), a photovoltaic(PV) system (c) and a Biogas generator (d) as shown on Figure 1. The location of the systems is the Universidad Del Atlántico which is in the Colombian Caribbean Region, which represents the 11,6% of the total Colombian surface with a territorial extension of 132,288km2, in terms of coordinates, its location is 12°60′N - 7°80′N of latitude and 75°W - 71°W of longitude (8).

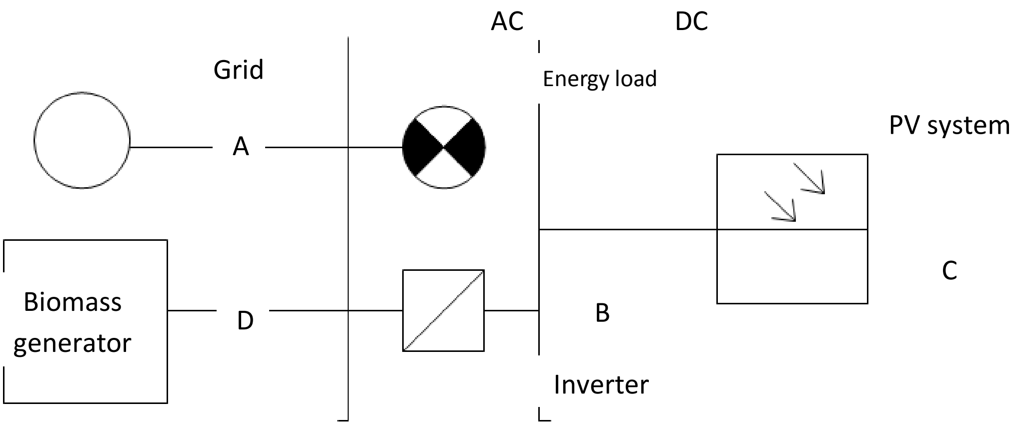

Figure 1. Schematic Diagram of the proposed grid-connected renewable energy systems

The grid used to supply the energy load had a cost of $ 0.17 USD/kWh. The PV system worked parallel to the electrical grid and the biogas generator, in order to supply a little percent of the total energy load, generating the same amount of energy with less emission. The PV module was a Canadian Solar All-Black CS6K-290MS as shown on Figure 2a with an output power of 0.29 kW, an inversion of $ 640 USD, with a replacement cost of $ 600 USD, the O &M cost considered was $ 5 USD/year and a lifetime of 25 years.

Due to the electrical bus of the PV system isDC, an inverter to change the current from DC to AC is required to bring the supply to the energy load. The inverter used was a CyboEnergy Grid-Interactive C1-Mini-1000A as shown on Figure 2b, with a maximum AC power output of 1.15 kW, 240 V, 60 Hz. The inversion and replacement cost was $ 70 USD, and a lifetime of 10 years.

Finally, the Biogas generator simulated to reduce the annual operational cost and the emissions generated as shown on Figure 2c.The biogas generator power DC output is 3 kW, with a fuel cost of $ 1 USD/kg, the inversion cost was $ 600 USD, the replacement cost of $ 250 USD, the O&M cost of $ 0.0023 USD/hour and the useful life of 20000 hours. The biomass scaled annual average was 6954.427 ton/day, with a cost of $ 25 USD/ton, and the biogas generator was working 8 hours per day excluding weekend since February to June and since August to November.

Figure 2. Main components of the grid-connected renewable energy systems,a) Canadian Solar All-Black CS6K-290MS, b) CyboEnergy Grid-Interactive C1-Mini-1000A, c) Biogas generator 3 kW

2.2 Fundamentals equations

HOMER's main financial output is the total net present cost (NPC) and cost of energy (COE) of the examined system(s) configurations. NPC analysis is an appropriate gauge or scale for the purpose of economic comparison of different energy systems classification and configuration, the reason is that NPC balances widely divergent cost characteristics of renewable and non-renewable sources. As well, it explores and summaries all the relevant associated costs that occur within the lifetime of the energy project. The economic performance parameters of a photovoltaic-biomass hybrid power system with storage and converter in El-fayoum governorate is calculated through modeling the system. For economic aspect, (NPC) and (COE) of the system are investigated. HOMER uses total net present cost (NPC) to represent the system's life cycle cost. The NPC is calculated as

$$NPC(\$) = \frac{TAC}{CRF}, \quad \text{(a)}$$

where TAC is the total annualized cost, CRF is the capital recovery factor which can be calculated by the following equation

$$CRF(\$) = \frac{i(1+i)^N}{(1+i)^N-1}, \quad \text{(b)}$$

where, N is the number of years and i is the annual real interest rate (%).

Cost of energy (COE), which is the average cost per kilowatt-hour ($/KWh) of electricity produced by the concerned system is estimated as

$$COE(S) = \frac{C_{ann,tot}}{E}, \quad \text{(c)}$$

where, $C_{ann,tot}$is the annual total cost, $. E is the total electricity consumption, KWh/Year (9).

3 Results and discussions

The RHG solar resource (10)and the daily temperature (11)for the location are shown in Figure 3, which are important factors to determinate the right function of the PV system.

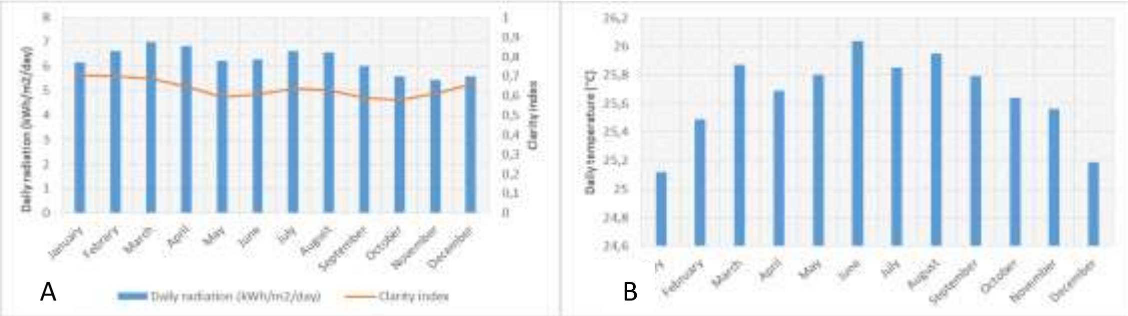

Figure 3.Energy source: a)RHG Solar resource, b) daily temperature.

To generate the primary load was necessary the technical specifications of all components in the case study, as shown in Table 1.

Table 1. Technical specifications of the primary load components

Component	Energy load (Watts)	Units
Sylvania led continuum 32W WW SP	32	6
Cooling system 24000 BTU/h	2440 ON; 2 OFF	1
High-end table computers	150 ON; 3.3 OFF	10

Considering a random variability of the 10% day to day, a scaled annual average of 33.64 kWh/d, a peak of 7.16 kW and an average of 1.4 kW,a monthly average load profile was calculated for 25 years. A typical annual load profile is shown on Figure 4.

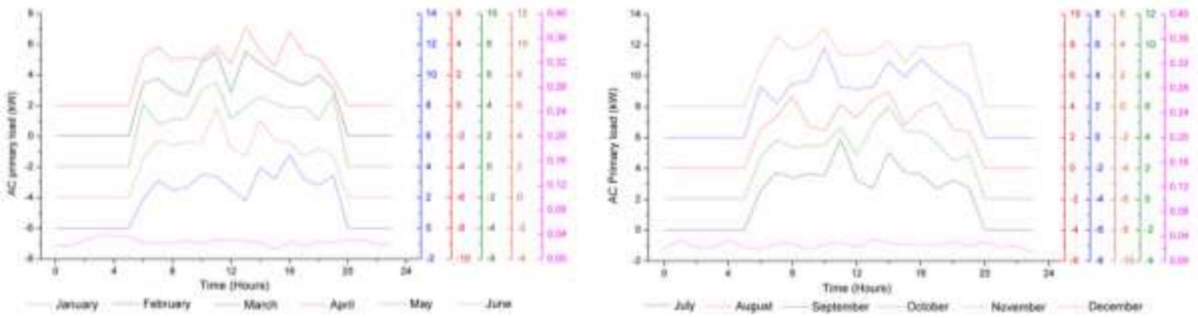

Figure 4.Monthly average load profile

A comparative study was developed between the system with the Electric Grid/PV module, and the Electric Grid/Hybrid Biogas/PV Generator, obtaining the energy generation from each component in both systems as shown in Table 2.

Table 2.Energy generation comparative

Component	PV/grid (kWh/year)	%	PV/grid + Biogas (kWh/year)	%
PV	549	4.43	549	4.44
Biogas gen.	0	0	4476	36.1
Grid purchases	11863	95.6	7388	59.5
Total	12412	100	12414	100

It can be seen how the biogas generator replace 36.1 % of the grid purchases, and that means a big operational cost and emissions reduction as shown in Figure 7and Table 3.

A comparative analysis operational cost at 1 year of simulation and 25 years of simulation can show the difference between the systems with the biomass generator and without it and show how the biomass generator works to reduce the grid purchases and therefore the amount of energy taken from the grid.

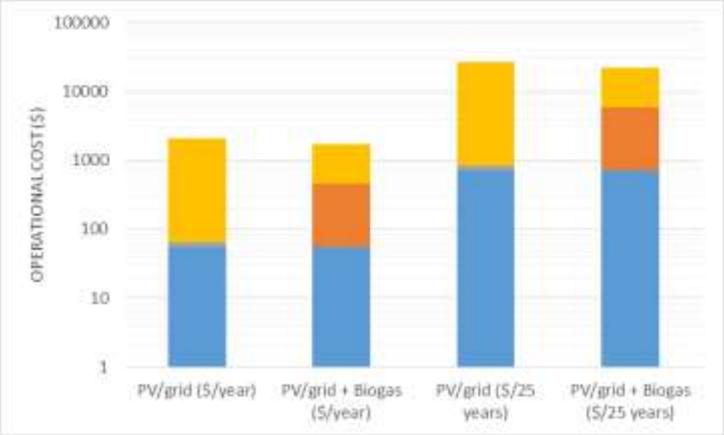

Figure 7.Comparative analysis operational cost.

Figure 7is an accumulated bar chart, where blue is the PV module, Yellow is the grid, grey is the inverter and orange is the biogas generator and the vertical axis is in logarithmic scale.

Anyway, it can be seen how the biogas generator reduce the annual operational cost and the total operational cost for a 25 years simulation; talking more specifically the biogas generator take a reduction of the 20.34 % annual operation cost and 17.55 % of the total operation cost.

The gas emissions are a very important factor to observe; because it needs to take control of environment and try to reduce as much as possible the amount of gas emissions issued by the system, therefore is relevant to observe how the biomass generator acts on the system and modifies the emissions of gases.

Table 3: emission generation comparative

Emission	PV/grid (kg/year)	PV/grid + biogas (kg/year)	Reduction (%)
Carbon dioxide	7427	4600	38,06382119
Carbon monoxide	0	0,0269	-0,0269
Sulfur dioxide	32,2	19,9	38,19875776
Nitrogen oxides	15,7	9,77	37,77070064

It can be seen how the biogas generator influence on the emission generation is in this system, the reduction of the emissions is notable and it is around 38% of all emissions excluding the carbon monoxide. This is a very important factor because in many countries government give a monetary incentive to the industries to industries that emit low proportions of pollutant gases, and that means a little percent of income that can supply part of the total operational cost.

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