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Optimization of a Biomass, solar and fuel cell Hybrid energy systems for a specific energy load using Homer Pro software®

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Abstract : This paper shows how HOMER Pro software simulates and optimizes a hybrid biomass energy system to can estimate the best option for a particular case of energy load. The main objective of this paper is to inform people what type of systems are the most effective to use in energy supply system and show how HOMER pro software works to simulate and optimize the different energy supply systems purposed. The systems have been simulated in HOMER Pro ® software which can estimate, simulate and optimize the operational costs and the emissions on energy systems using renewable energies. The simulation is integrated by a diesel generator with an output power of 15 kW, a fuel cell generator with an output power of 3 kW, a biogas generator with an output power of 3 kW, energy storage with a nominal capacity of 1.02 kWh, an inverter with a max. Output power of 1.15 kW and two photovoltaic systems with a max. Output power of 0.29 kW to supply a scaled annual average of 165.44 kWh/d. The data values obtained reveal that the total operational cost difference between the optimal system and the worst system is around 75%, the annual operation cost difference is around 64% and the kWh cost for the users takes a difference of 76%; and the reduction of CO_2 emissions take a value of 57% between the optimal system and the worst system. This confirm the importance of realize a simulation before design the system to use.
Keywords: Biomass, solar, fuel cell Hybrid energy systems, energy load, Homer Pro software.

1 Introduction

In the context of the available renewable energies a world-wide level, the solar power and the energy obtained from the biomass are the most abundant a global level (1), even though it is essential to consider the contraindications that this leads, for example the use of solar energy carries previous studies in order to predict the fluctuation of it (2),which makes complementarity with other energy sources necessary, for example with biomass and wind. Studies show that the combination of solar energy and biomass can solve the energy problem by using the hybridization of these two sources (3). The hybridization of solar energy with the combustion of biomass is complemented, both seasonally and diurnally, to overcome its individual disadvantages and results in a continuous and uniform supply of many companies worldwide (4), so studies show that efficiency improves if you use hybrid systems in exchange for unique energy systems (5).The dynamics of energy generation through hybrid system is carried out worldwide, for example in Sharjah is designed a Hybrid Solar-Biomass Micro grid System where the main objective was to explore the renewable resources available in this area and determine the configuration optimized to meet the desired electrical loads of the city, it was necessary to perform hourly simulations with sensitive analysis to calculate the energy of each component and design the most favorable renewable energy system (6). In Europe on the other hand, it studies the suitability for hybridization with biomass in Europe, where aspects related to the Solar Tower (ST), Parabolic Channel (PT), Linear Fresnel (LF) and Photovoltaic Solar. Technologies, climatic data and economic performance in order to identify the main drivers of the selection of systems in the choice and design of large solar biomass hybrid plants (7), India has discussed several aspects related to hybrid biomass-solar power generation facilities such as the availability of biomass resources, direct solar irradiance (DNI). The average daily DNI where it is considered as 20%, 40%, 60% and 80% and the remaining heat is taken from the biomass resource in the hybrid plants of this country (8), Pakistan for its part analyzes the techno-economic viability of an off-grid biomass solar system for the electrification of remote rural areas, through simulations, through HOMER is one such energy modeling tool, which is being used by the purposes of optimization and modeling. Hybrid optimization model of electric renewables (9), in general different countries with different tools, study and use hybrid systems for generating energy in order to meet the demand for energy in the countries. The main contribution of this paper is to present the simulations results of this energy systems with the main objective of inform people what type of systems are the most effective to use in energy supply system and show how HOMER pro software works to simulate and optimize the different energy supply systems purposed.

2 Methodology

This section of the paper presents a system description with technical specifications of the components used to supply the energy load in the simulated case study; in addition thefundamentals 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 a diesel generator (a), an inverter (b), two photovoltaic(PV) systems (c), a biogas generator (d), a fuel cell generator (e) and energy storage (f) 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 (10).

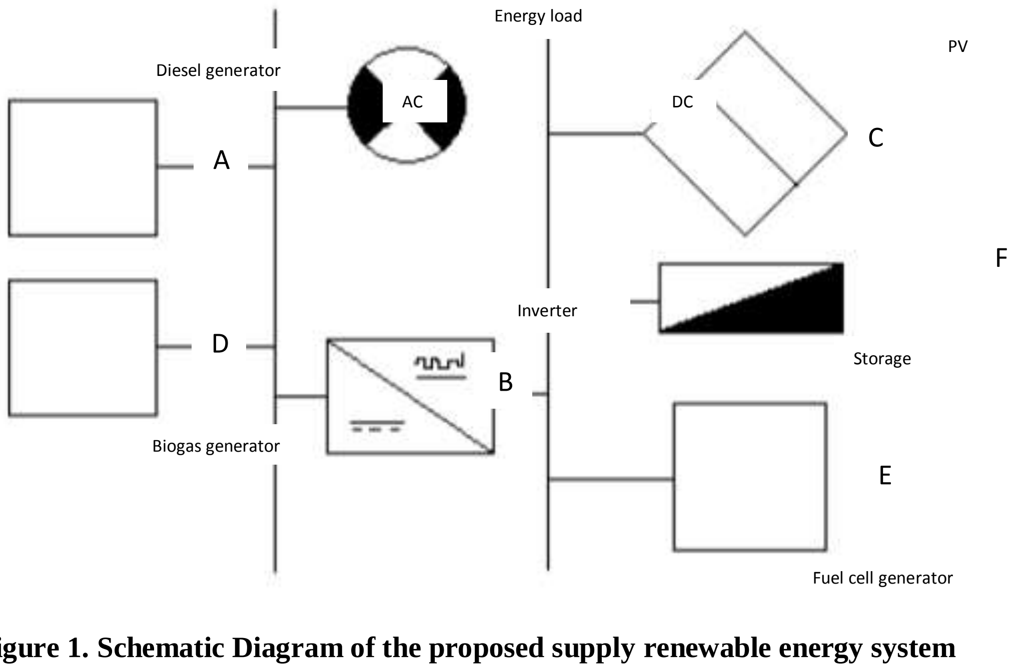

Figure 1. Schematic Diagram of the proposed supply renewable energy system

The diesel generator works with an AC output power of 15 kW, with a fuel cost of $ 0.7 USD/L, the inversion cost was $ 3000 USD, the replacement cost of $ 2000 USD, the O&M cost of $ 0.01 USD/hour and the useful life of 15000 hours. The fuel cell generator used to reduce the amount of diesel and generate the same energy works with an AC output power of 3 kW and his fuel is natural gas with a cost of $ 0.54 USD/m^3, the inversion cost was $ 2000USD, the replacement cost of $ 1500 USD, the O&M cost of $ 0.01 USD/hour and the useful life of 50000 hours. Finally, the Biogas generator simulated to reduce the annual operational cost and the emissions generated works with a power AC output of 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 5 ton/day, with a cost of $ 25 USD/ton.

The PV systemsworked parallel to the biodiesel generator, the fuel cell generator and the biogas generator, in order to supply a little percent of the total energy load,generatingthe sameamount of energy with less emission. The PV modules works with an output power of 0.29 kW each one, an inversion of $ 640 USD/unit, with a replacement cost of $ 600 USD/unit, the O&Mcostconsideredwas $ 5 USD/year*unit 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 works with a maximum AC power output of 8.5 kW, 240 V, 60 Hz.Theinversion and replacement cost was $ 517USD, and a lifetime of 10 years.

As the load energy profile changes with the time, it is possible that the system generates more energy than the required in those moments, therefore energy storage is required to use in this system. The energy storage implemented works with a nominal capacity of 1.02 kWh and a nominal voltage of 3.7 V, the inversion cost was $ 600 USD, the replacement cost of $ 600 USD, the O&M cost of $ 10 USD/year.

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

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

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

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

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

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

where, $C_{ann,tot}$ is the annual total cost, $. E is the total electricity consumption, KWh/Year (11).

3 Results and discussions

The RHG solar resource (12)and the daily temperature (13)for the location are shown in Figure 2, which are important factors to determinate the right function of the PV system.

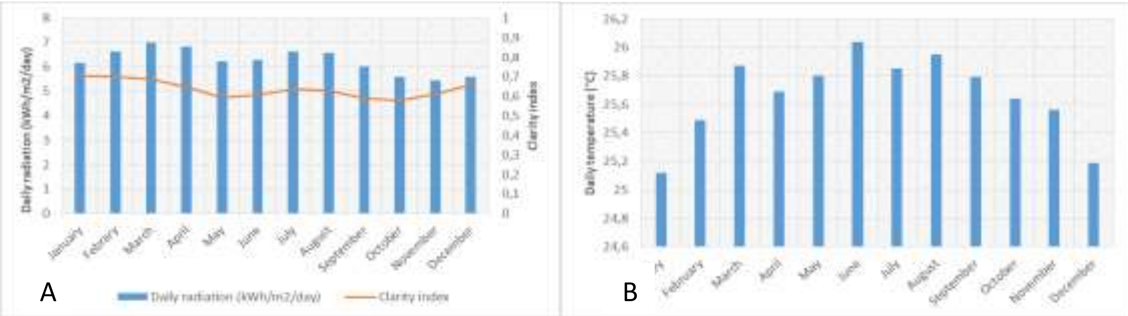

Figure 2.Energy source: a)RHG Solar resource, b) daily temperature.

The primary load used to simulate the study case was predetermined by HOMER Pro software considering a random variability of the 10% day to day, a scaled annual average of 165.44 kWh/d, a peak of 20.46 kW and an average of 6.89kW,a monthly average load profile was estimated for 25 years. A typical annual load profile is shown on Figure 3.

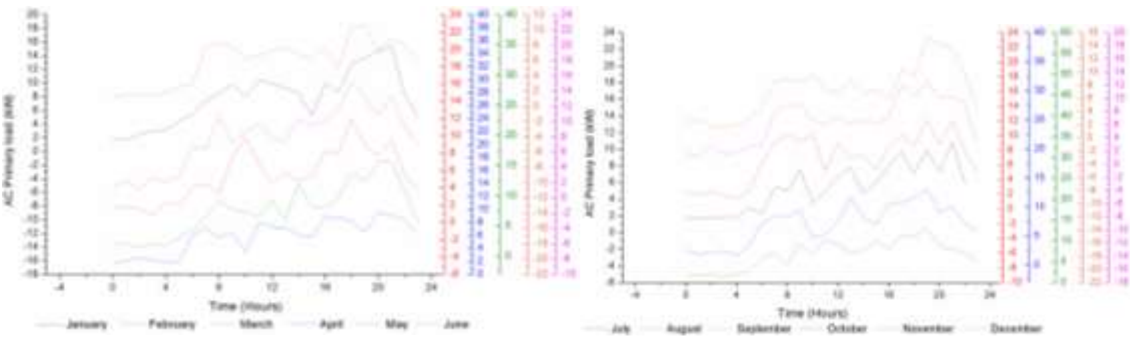

Figure 3.Monthly average load profile

HOMER Pro software® takes all components purposed to design the energy supply system and realize a simulation with optimization to determinate which components should have the optimal system, therefore this process could have many iterations for a simulation of 25 years and HOMER organize those iterations in general groups to facility the analysis and conclusions, as shown in the Table 1.

Table 1.Optimization results by HOMER pro software®.

Components											
C1	C2	A	D	E	F	B	Battery quantity	$/kWh	Total operation cost ($)	Annual operation cost ($)	System
							5	0,191	148901	10714	I
							5	0,193	150414	10880	II
							5	0,193	150414	10880	III
							5	0,195	151892	11044	IV
							0	0,215	167729	12402	V
							0	0,215	168092	12480	VI
							0	0,215	168092	12480	VII
							0	0,216	168380	12552	VIII
							2	0,245	191491	14302	IX
							2	0,248	193475	14505	X
							2	0,248	193475	14505	XI
							5	0,257	200707	14768	XII
							5	0,258	201781	14900	XIII
							5	0,258	201781	14900	XIV
							5	0,26	202903	15037	XV
							30	0,285	222672	15514	XVI
							362	0,763	595078	28859	XVII
							377	0,782	609966	29364	XVIII
							377	0,782	609966	29364	XIX
							387	0,795	620180	29740	XX

Where C1, C2 are the PV modules, A the diesel generator, D the biogas generator, E the fuel cell generator, F the storage, B the inverter, the green squares indicates the components on the system and the red squares indicates the components out of the system.

It can be seen that the optimal system may should have all the components purposed, this should be because when the diesel generator works alone, it can required long amounts of fuel and lot of batteries; that means greater investment of money required by the system, when the diesel generator works in parallel with another device, the operation cost decrease, because the fuel required it is not only diesel and the cost of the another fuels is lower than diesel, this without counting with the renewable energies that may have present on the system.

The total operational cost difference between the optimal system and the worst system is around 75%, the annual operation cost difference is around 64% and the kWh cost for the users takes a difference of 76%. This show how important is to realize a simulation of the all possible systems to development before the construction of the energy substation.

Another important factor to considerate is the emissions, for this situation it is the CO_2 who take the greatest influence, therefore it needs to make a comparison between all the systems to see how the amount of CO_2 changes, as is shown in the Figure 4.

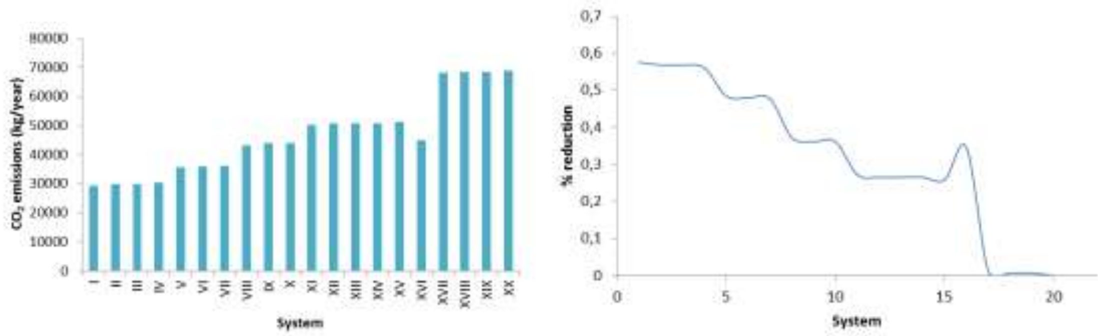

Figure 4.Comparative analysisCO_2 emissions.

Figure 4 shows two graphs about the change of the CO2 emissions in function of the system implemented, it can be seen that exist a big difference between the emissions of the optimal system (I) and the worst system to use (XX), speaking more specifically the reduction of the emissions take a value of 57% between the optimal system and the worst system. This confirms again the importance of a simulation before the construction of the substation.

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