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Hybrid PV and Wind Grid-Connected Renewable Energy System to Reduce the Gas Emission and Operation Cost

Farid Barrozo Budes, Guillermo Valencia Ochoa and Yulineth Cárdenas Escorcia

Energy Efficiency Research Group - kaí, Engineering Faculty
Universidad del Atlántico, km 7 antigua vía Puerto, 081008
Barranquilla, Colombia

Abstract

This paper presents the methodology and results of the simulation and optimization of a hybrid renewable energy system for supply to a workstation reducing the gas emissions and the operation costs, so that to determinate the optimal system. The fundamentals equations used to estimate the operational costs are presented. The software used to simulate and optimize the purposed system is HOMER Pro®, this software can simulate energy systems with renewable fractions and optimize those systems to obtain the best system to use. In addition, the hybrid PV/Wind system replace 23.01 % of the grid purchases when they are working in parallel, the hybrid PV/Wind system take a reduction of the 12.46 % annual operation cost over the 100% of grid purchased and 9.3 % of the total operation cost over the 100% of the grid purchased. Finally, it can be concluded that the use of renewable energy systems takes greatest reductions on the supply systems if it takes the optimal design to develop the supply system.

Keywords: Energy management system, Renewable energy systems, Hybrid PV & Wind system, Gas emissions

1 Introduction

At the global level for the energy aspect in different sectors of the economy, optimization studies have been required from the generation to the distribution, being a key factor the costs that this implies for the end user [1]. Almost 30% of world energy consumption is produced in the commercial and domestic sectors with an increasing demand [2][3], for this reason the Non-Conventional Energy Sources (FNCE) have become the major attraction for senior leaders in their decision-making process [4]. Among the most widely used renewable energy sources for community integration and improved electricity service, wind and solar power [5] taking into account their intermittent characteristics are challenging, it is thus that 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 in building [6], additionally the integration of FNCE considered part of the solution to mitigate the environmental problems caused by the use of conventional energy sources. Its annual average growth was estimated at 7.6%, with the installation and use of solar and wind energy with the highest growth, solar energy capacity growth of 28.3% in 2014 and wind power capacity in 16 % [7] in this sense, these sources offer clean energy generation, which allows the electrification of unconnected and remote areas, contribute to decrease dependence on fossil fuels, have also improved their technologies and reduced costs [8], this way we provide studies of optimization of hybrid systems for generation to communities or different sectors of the economy we evaluate different combinations of technologies and sources of energy, including solar / fuel cell [9], photovoltaic and solar thermal [10], solar / wind power system [11] among others [12]. Different countries of the world have conducted studies on optimal management of energy resources where several efforts have been made to optimize the size of the photovoltaic (PV) system connected to the grid [13][14], in other places they measure the reliability of hybrid photovoltaic wind energy systems [15]. For the proper design of a hybrid solar photovoltaic system, the stochastic behavior of the sun and wind must be taken into account [16], its intensity of randomness, the nonlinear characteristics of the system components and their integration, the difference between energy demand and load generation, high implementation and maintenance costs, the use of backup systems and generators conventional, among others. The main contribution of this paper is to show the results obtained from the simulation and optimization by HOMER Pro software about a hybrid PV/Wind renewable energy system, with the final objective of reduce the gas emissions and operation cost to supply energy load, and show how this system can works to reduce those settings.

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 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 Wind 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 [17].

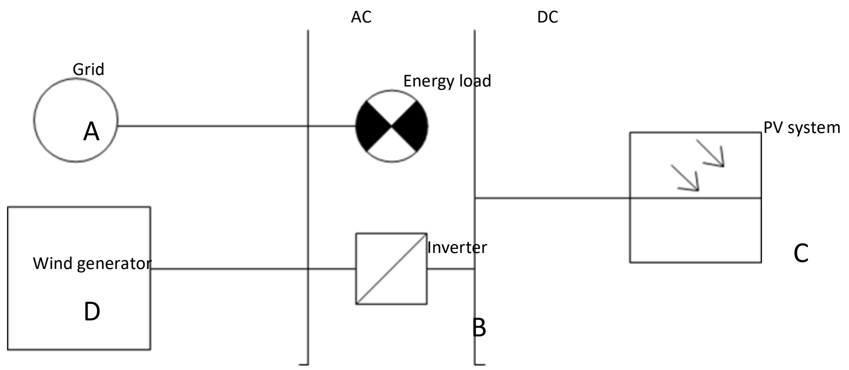

Figure 1. Schematic Diagram of the proposed grid-connected renewable energy systems

The grid used to supply the energy load had an estimated cost of $ 0.17 USD/kWh. The PV system worked parallel to the electrical grid and the Wind 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 CanadianSolar All-Black CS6K-290MS, 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 is DC; 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, 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 Wind generator simulated to reduce the annual operational cost and the emissions generated. The Wind generator is an AWS HC 3.3kW Wind Turbine, with a DC power output of 3.3 kW, the inversion cost was $ 600 USD, the replacement cost of $ 550 USD, the O&M cost of $ 20 USD/year, a useful life of 20000 hours, and height of hub of 10 meters.

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

$$NPC(\$) = \frac{TAC}{CRF}, \quad (1)$$

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

$$CRF(\$) = \frac{i(1+i)^N}{(1+i)^N-1}, \quad (2)$$

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

$$COE(S) = \frac{C_{ann,tot}}{E}, \quad (3)$$

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

3. Results and Discussion

The RHG solar resource [18] and the daily temperature [19] for the location are shown in Figure 2, which are important factors to determinate the right function of the PV system.

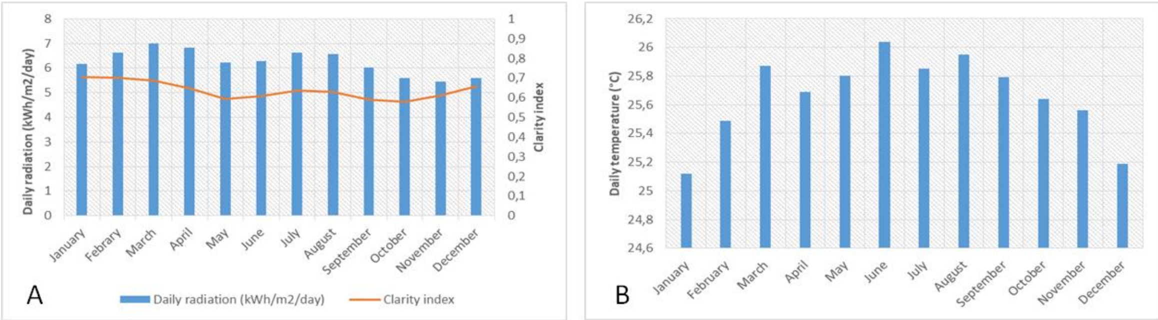

Figure 2. Energy source: a) RHG Solar resource, b) daily temperature.

The wind resource [20] for the location is shown in Figure 3, which is an important factor to determinate the right function of the wind generator.

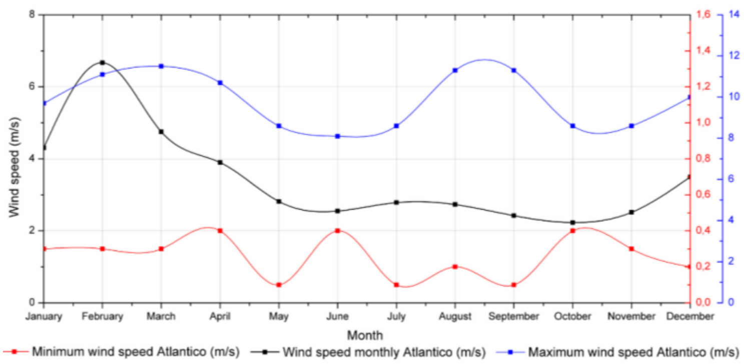

Figure 3. Energy source: Wind speed for the location to study

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

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

Table 1. Technical specifications of the primary load components

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 were calculated for 25 years. A typical annual load profile is shown on Figure 4.

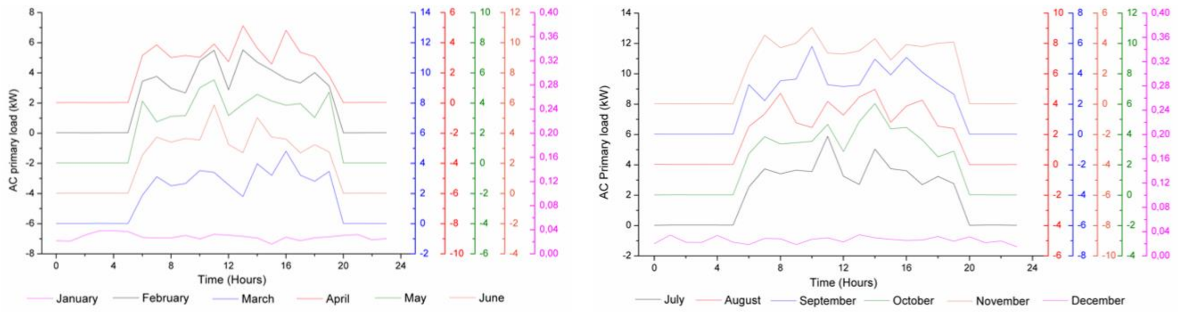

Figure 4. Monthly average load profile

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

Component	PV/grid (kWh/year)	%	PV/grid + Wind (kWh/year)	%	Wind/grid (kWh/year)	%
PV	549	4	549	4.01	0	0
Wind turbine	0	0	2603	19	2603	19
Grid purchases	13166	96	10562	77	11112	81
Total	13715	100	13715	100	13715	100

Table 2. Energy generation comparative

It can be seen how the hybrid PV/Wind system replace 23.01 % of the grid purchases when they are working in parallel, and that means a big operational cost and emissions reduction as shown in Figure 5 and 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 Wind generator, PV system, Wind/PV working in parallel, and only the grid; and show how the hybrid PV/Wind system works to reduce the grid purchases and therefore the amount of energy taken from the grid.

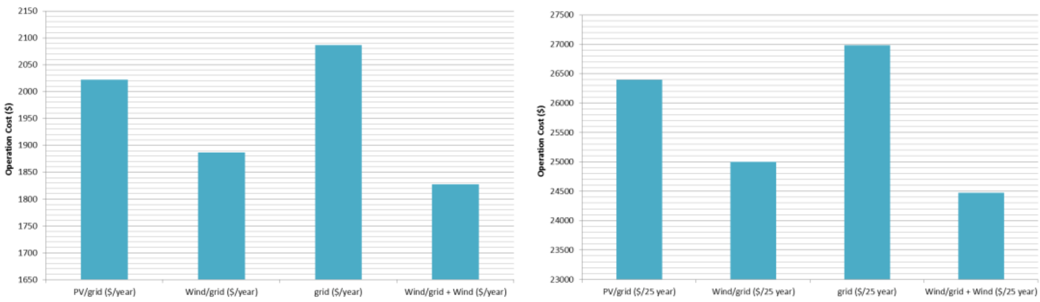

Figure 5. Comparative analysis operational cost

Figure 6 shows how the systems affect the unitary energy cost (kWh), and the renewable fraction on the supply system.

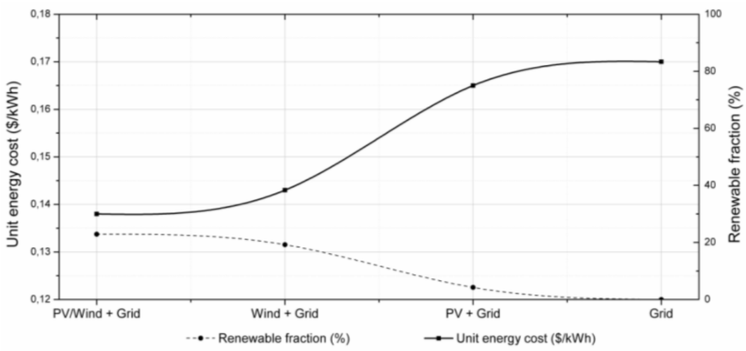

Figure 6. Unitary energy cost and Renewable fraction comparative

It can be seen how the hybrid PV/Wind system reduce in greater proportion the annual operational cost and the total operational cost for a 25 years simulation; talking more specifically the hybrid PV/Wind system take a reduction of the 12.46 % annual operation cost over the 100% of grid purchased and 9.3 % of the total operation cost over the 100% of the grid purchased; also it can be seen that as the renewable fraction on the system increase in function of the purposed systems, the unitary energy cost decreases. 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 hybrid PV/Wind system acts on the system and modifies the emissions of gases.

Emission	Grid (kg/year)	PV/grid + Wind (kg/year)	Reduction (%)
Carbon dioxide	7600	5781	23,93421053
Sulfur dioxide	33	25,1	23,93939394
Nitrogen oxides	16	12,3	23,125

Table 3. Emission generation comparative

It can be seen how the hybrid PV/Wind system influence on the emission generation is in this study case, the reduction of the emissions is notable and it is around 24% of all emissions. 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.

4. Conclusions

The use of renewable energies systems to supply an energy load in all fields of the engineering is growing so fast, with the final purpose to reduce the operation cost and gas emissions in a system; therefore, it needs the use of these systems in the different study case that could be presented. The results for this study case throw an optimal system composed by a hybrid PV/Wind system on grid-connected, with a reduction of the 12.46 % annual operation cost over the 100% of grid purchased and 9.3 % of the total operation cost over the 100% of the grid purchased, also the reduction of the emissions is notable and it is around 24% of all emissions.

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