

Wind-Solar Hybrid Systems in Eastern Jamaica

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1 Introduction

Jamaica is a developing country in the Caribbean region. It is not endowed with domestic reserves of fossil fuel, such as oil, coal and gas. The result is that the country heavily depends on imported fuels, mainly petroleum. Alternative sources such as Wind, Solar, Hydro and Biogases contribute a smaller amount (less than 10%) to the present Jamaican energy mix. The price of crude oil keeps escalating, more than US$ 110 a barrel at present, and there is a growing demand for energy and a need to reduce the expenditure on imported petroleum. Also adverse environmental and health impacts due to emissions from petroleum products are matters of concern. Wind and solar are attractive supplementary sources of energy. They have advantages and disadvantages peculiar to each one of them. With advanced technologies, wind, now has become a primary source of energy in many regions of the globe. However, wind has two disadvantages. Wind is intermittent and wind speeds acceptable for power generation may be available only at certain locations in a given country. Solar, on the other hand, although power production is somewhat costlier than wind, has become competitive with the advancement of photo voltaic materials and is more attractive because of its abundance and aesthetic values. An approach to balance the disadvantages of one energy source is to utilize the advantages of the other source through hybrid systems.

This paper presents the preliminary results of a study performed on the feasibility of wind solar hybrid systems in Eastern Jamaica. On a commercial scale the parishes (St. Mary, Portland, and St. Thomas: figure 1) in Eastern Jamaica are less developed than the parishes in the other regions of the country. Main sources of income in the parishes are: Farming (agriculture and animal) and tourism. Most locations of the parishes are habitable but lack basic commodities such as running water and electrical power. If suitable power generating

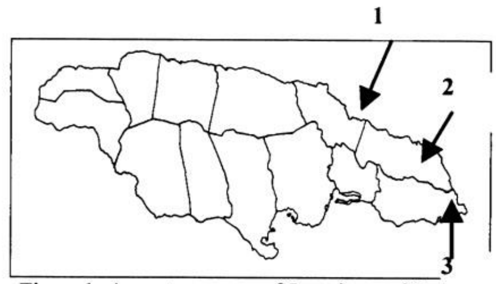

Figure1. A contour map of Jamaica and Ea...... parishes: 1- St. Mary, 2- Portland, 3- St. Thomas

systems exist the electrical power can be used in communities, schools, health clinics, hotels with proper sizing of the systems, and for water pumping and irrigation.

2. Methods

The feasibility was done using the software HOMER(V 2.2, NREL). Different scenarios were simulated. The required wind data was obtained from digitized wind maps(Amarakoon and Chen, 2002; WindMap v 2.1) generated using the software WindMap. Solar radiation data was obtained from a solar radiation map developed by the Physics department, UWI (Anthony Chen, 1994). A total of 162 locations were considered in the three parishes. Elevation varied from 7 m to 2110 m and roughness from 0.001 m to 1.125 m. Annual average wind speed at 40 m varied from 4 m s^{-1} to about 9.0 m s^{-1}. Average daily radiation was about 16 MJ m^{-2} per day. The basic system architecture used in the simulations is shown in table 1.

Table 1. Basic system architecture for HOMER

Input	All parishes
PV array (kW)	0.1 to 2
Wind turbine (kW)	0.9 to 1
Cut-in-speed of turbine (m/s)	~ 4
Converters (kW)	2.4
Battery storage (kWh)	2.4
Grid power cost (US$/kWh)	0.25
Grid extension cost (US$/km)	25,000.00
Primary load (kWh/day)	8.5

Figure 2 presents the manufacturer's power curve for Whisper 80 turbine (H 80) that was primarily used in the scenario generation. Standalone systems and grid connected systems were considered that enabled the estimation of the breakeven grid extension distance and the viability of the hybrid system. HOMER calculates the net present cost (NPC), levelized cost of energy (COE), breakeven grid extension distance (BGED), and grid sales with appropriate inputs (Tom Lambert, 2004).

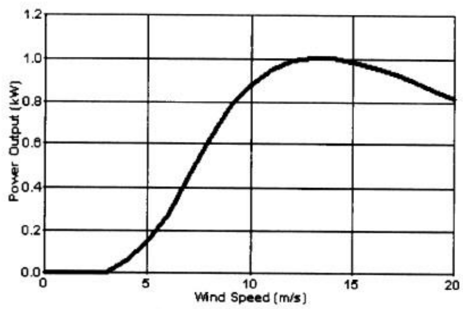

Figure 2. Whisper 80

3. Results

Figures 3a, 3b and 3c present results for stand alone systems in the three parishes; St. Mary, Portland and St. Thomas. The COE values plotted correspond to the optimal system values based on the NPC. The wind speeds shown are annual average wind speeds at the different locations, a total of 162 in the three parishes. There was one to one correspondence between NPC and COE. At low wind speeds solar systems dominated the optimal systems and at high wind speeds wind systems dominated. Figures illustrate variation of COE and BGED with wind speed. BGED is based on the NPC.

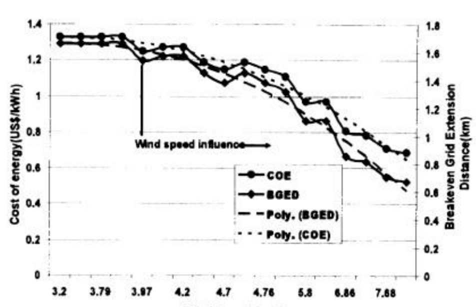

Figure 3a. COE and BGED for St. Mary

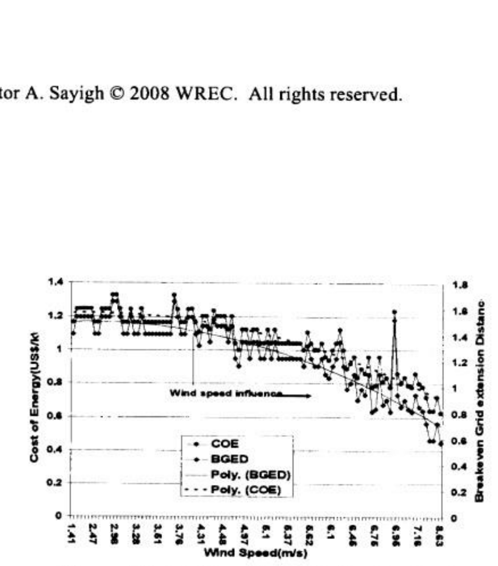

Figure 3b. COE and BGED for Portland

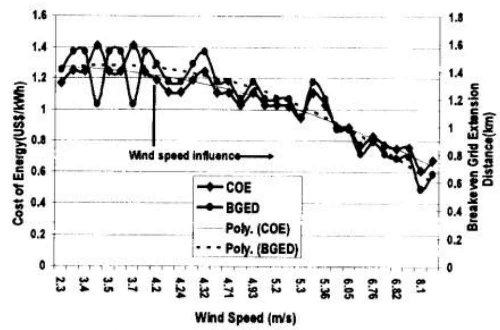

Figure 3c. COE and BGED for St. Thomas

Results on the standalone systems indicated that;

- Stand alone systems are costlier, based on the COE, compared to present average grid power price of US$0.25, in areas where grid power is available.
- COE is on the average US$ 1.3 per kWh up to a wind speed of about 4 m/s, after which COE becomes sensitive to wind speed as depicted by the polynomial COE trend lines in figures 3a, 3b and 3c. The COE is low around US$ 0.65 to 0.80 at high wind speeds, a two fold decrease approximately.
- The BGED is on the average 1.45 km till about 4 m/s, and thereafter decreases in a manner similar to the COE trend. At high wind speeds BGED drops to about 0.6 km. The BGED trend is depicted by the polynomial trend lines similar to the COE trend lines in figures 3a, 3b and 3c.
- There is one to one correspondence between COE and BGED trends.

The cut-in wind speed of the turbine is around 4 m/s. This accounts for the insensitivity of COE and BGED to wind speed up to about 4 m/s, and solar energy is the power source in the stand alone system till the cut-in speed is reached. Wind energy contribution increases as speed increases against the solar energy contribution and vice versa, which has to be expected. Further studies revealed that COE does not exhibit sensitivity to roughness at a given primary load, but shows sensitivity to primary load served. The COE appeared to decrease with the primary load. The study on the sensitivity to roughness was accomplished through the sensitivity to power law exponent. Power law exponent is a measure of roughness and it increases with roughness. Power law exponent values of 0.14, 0.18, 0.20 and 0.25 were considered. The insensitivity to roughness may be implying the fact that turbulent loss of energy is small in the scenarios considered.

Figures 4a, 4b, 4c, 4d, 4e, 4f present simulated results for grid connected (GC) systems for the three parishes; St. Mary, Portland and St. Thomas. The figures illustrate the sensitivity of COE and grid sales (GS) to annual average wind speed. One location in each parish, with good wind, was chosen for this exercise. The COE for the corresponding stand alone (SA) systems are also plotted for comparison. With Portland data (figure 4c) two grid prices (GP) of $0.25 and 0.35, and also two selling prices (SP) of $ 0.1 and 0.05 per kWh were considered.

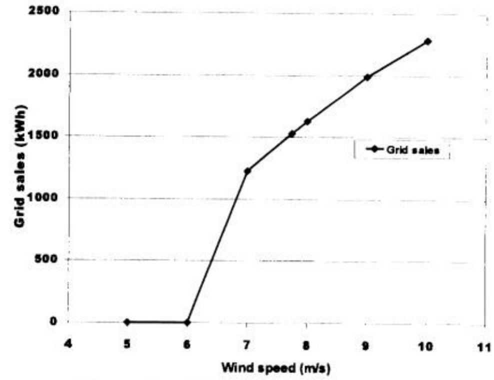

Figure 4b. Grid sales for St. Mary

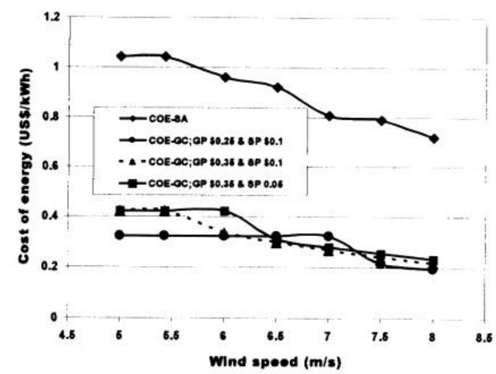

Figure 4c. COE for GC and SA systems: Portland

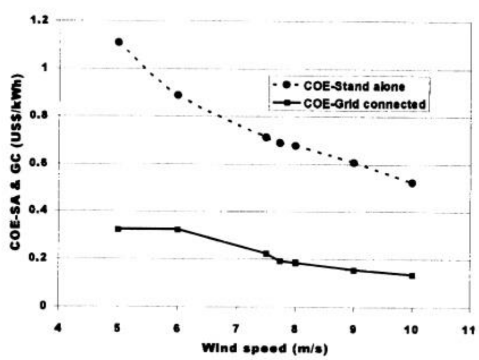

Figure 4a. COE for GC and SA systems: St. Mary

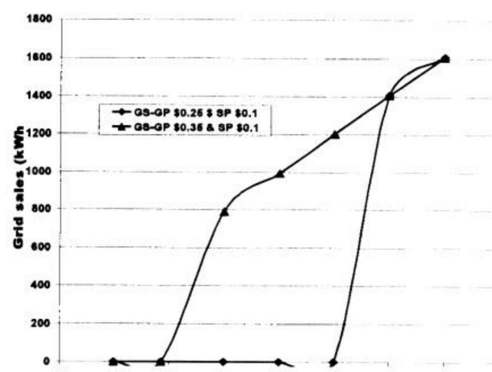

Figure 4d. Grid sales for Portland

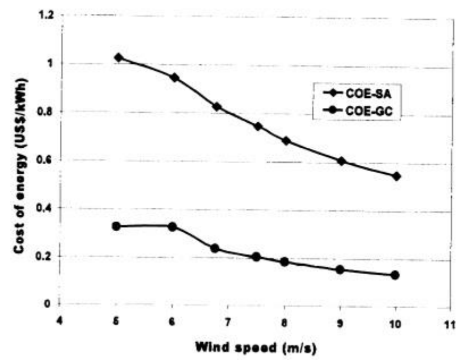

Figure 4e. COE for GC and SA systems: St. Thomas

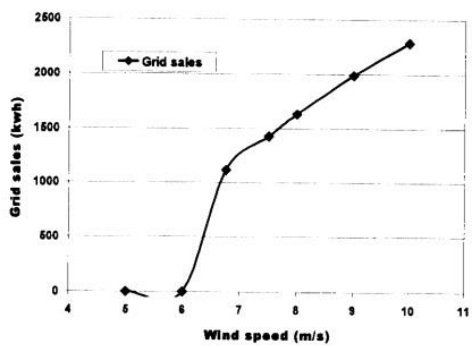

Figure 4f. Grid sales for St. Thomas

The simulation results for the grid connected systems indicated that;

- Cost of energy is cheaper compared to stand alone systems. The reduction in COE is nearly 4-fold. The COE becomes very competitive with the present average grid power cost of US$ 0.25 per kWh. If the sell back price is about US$0.10 per kWh, COE with the GC system begins to fall below the present average grid power cost of US$ 0.25 for wind speeds greater than about 6.5 m/s. This feature is present in all the charts presented in figures 4a, 4c and 4e.
- At higher grid prices the COE begins to fall below the grid price at lower speeds. An increase in grid price can occur with the ever rising price of crude oil. In figure 4c, COE appears to become cheaper than GP around 5.75 m/s for a GP of US$ 0.35 and a SP of US$ 0.10, and around 6.25 m/s for the same GP but for a SP of US$ 0.05.
- Grid sales are significant at wind speeds greater than about 6 m/s and very sensitive to wind speed as illustrated in figures 4b, 4d and 4f.

4. Discussion and conclusions

A feasibility study on wind-solar hybrid energy systems in the eastern parishes of Jamaica St. Mary, Portland, and St. Thomas was carried out. The solar radiation in the parishes averages to about 4.5 kWh m^{-2} d^{-1}. Results indicate that, based on the levelized cost of energy (COE), wind-solar hybrid systems are not feasible in areas where grid power is readily available. Grid power is available mostly at locations at low altitudes (less than about 400 m). However, wind-solar hybrid power is feasible and cost effective in two situations:

1. To meet the power requirements at locations outside the breakeven grid extension distance.
2. If customers are allowed to sell back the excess power from the hybrid system, via a proper Net Metering system, to the grid. COE then becomes competitive with grid power price and shall be cheaper at higher wind speeds, greater than about 6.5 m s^{-1}.

Situation 2 is more acceptable because:

- Customers pay less for their electricity consumption
- Power company (Jamaica Public Service Co) energy reserves boost up
- Zero contribution to green house gas emissions
- Customers can make remittances for the capital costs of their hybrid system using the savings and own a system after some years, or can make a profit.
- With such systems installed, especially at homes and incentives provided, people shall learn to conserve energy which is one method of reducing fuel consumption and hence the country's fuel bill.

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