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Comparative Techno-Economic Analysis of Hybrid PV/Diesel and Hybrid Wind/Diesel Energy Generation for Commercial Farm Land in Nigeria

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Abstract- This paper describes a commercial farmland application in Nigeria. The objective was to demonstrate the technical, economic and institutional viability of renewable energy (Hybrid system) for commercial farmland as well as to allow local partners to gain experience with hybrid/renewable technology, resource assessment, system sitting and operation. A commercial farmland of 30Km^2 (5kmx6km) is considered with a peak energy demand of 90kW and base demand of 40kW. It consists of wind, photovoltaic, and conventional generators. It is usually associated with a single generator source, and uses conventional generators to complement shortfall in supply. In this paper Homer software was use to perform techno economic and feasibility analysis for the system and result shows that wind/dieseal hybrid is more cheaper than the PV/dieseal.

Keyword:Hybrid System, Homer Sofyware, PV.

I. INTRODUCTION

Nigeria is located between latitudes 4 and 14°N and longitudes 3 and 14°E, along the Gulf of Guinea. The country currently occupies an area of 923,768 km^2 (comprising 910,768 km^2 of land and 13,000 km^2 of water) Of the total land area, approximately 33% or 300,550 km^2 is arable, while 3.1% or 28,234 km^2 is under permanent crops and approximately 2,820 km^2 or 0.31% is under irrigation (CIA 2009). In a survey conducted by the practicing farmers association of Nigeria (PMAN) two third of this resources is underutilized and even the little that have been utilized is not for commercial purposes so many reasons have been attributed to this some of are the lack of energy source, increase in fuel price, skills … which results in decreasing the contribution of agriculture to the overall GDP of the country.

The trend in global fuel price increase after the 1970 fuel crisis had drawn serious attention of moving in to renewable energy sources. There is large dependence on diesel consumption for electricity generation; therefore this makes the renewable energy a good alternative not only in the cost of diesel but also on the pollution to the environment and likely hood of depletion. Solar and Wind energy are among the major source of renewable energy.

Therefore, integration of renewable energy sources with standalone diesel generators (generally known as the hybrid system) these combinations provide a very significant application in energy generation as seen in Luiz Carlos Guedes Valente et al. [5] performed an economic analysis on hybrid PV/diesel system and demonstrated that the system has advantages over standalone diesel system. With cost analysis over a 20-year period, hybrid system was proven to reduce fuel consumption, operation and maintenance costs while improving the quality of service. This is exceptionally true for small villages with up to 100 families. In addition Ngala et al. [4] also discussed the viability of wind energy as a source of power generation in northern Nigeria. The paper also identified that wind turbine operating in parallel with diesel engines can reduce the consumption by 40% in determining the suitability of the hybrid system; a homer software is used to analyses techno-economic of the system

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II. HOMER SOFTWARE

Homer is a computer model that simplifies the task of evaluating design options for both off-grid and grid connected power systems for remote, stand-alone and distributed generation (DG) applications [6]. It has been developed by United State (US) National Renewable Energy Laboratory (NREL) since 1993. It is developed specifically to meet the needs of renewable energy industry's system analysis and optimization. There are three main tasks that can be performed by HOMER: simulation, optimization and sensitivity analysis. In the simulation process, HOMER models a system and determines its technical Feasibility and life cycle. In the optimization process, HOMER performs simulation on different system configurations to come out with the optimal selection. In the sensitivity analysis process, HOMER performs multiple optimizations under a range of inputs to Account for uncertainty in the model inputs

III. SYSTEM DESIGN

This study is concerned with designing a system with minimum total cost of unit of energy to be delivered, to get this various parameters on the system performance needed to be evaluated for optimal design. A sensitivity analysis of the hybrid power systems was performed using HOMER software package developed by the National Renewable Energy Laboratory (NREL), Colorado, United States was used, (http://www.nrel.gov/ homer) to evaluate the influence of different parameters on the system performance (*e.g.*, wind/solar potential of the installation site, fuel price, number of PV panels, number of wind turbines, number of inverters, etc).

HOMER is a complete set of software that performs sizing of components for both hybrid and standalone power systems that use renewable sources, and identifies the optimum technical and economical set of components able to comply with the desired demand of electric energy from the system, taking into account of other factors like capital cost, maintenance cost, fuel price and also the environmental constraints like the wind/solar potential of the location for the system.

The design of these systems was done based on three considerations viz; technical, economical, and environmental. The technical consideration was during the design specification and component selection, while the economic consideration was during the Homer simulation and also in the selection of the cost effective option, environmental consideration was taken into account when choosing a site for installation.

A. Technical

- The maximum power delivered by the hybrid power system to the proposed farmland is 90kW; thus, in sizing the DC/AC inverter it has to be at rated power of 90 kW to cover the power peaks of the local grid.
- The average electric energy consumption of the farmland is 569400 kWh/yr and a base load of 40kW daily.
- The DC bus voltage is set to 48Vdc, a smaller voltage may lead to high currents through the power electronics components of the inverter, hence a higher price;
- The PV panels have a rated power of 50Wp per unit, with output voltage of 24Vd.c.
- The wind turbines have rated power of 2.5kW each, induction generator type and an output of 240V/phase and a line Voltage 415V.
- The diesel generator should have a maximum power necessary to cover the load peaks that may occur in the farm and also supply when the other source is not available, the rated output power for the diesel generator is 50kW each, 11kV.

B. Economical

- The cost of a fixed PV panel of rated power 50Wp, 24Vd.c., is about NGN350000, and the lifetime of 25 years;
- The 5 kW inverter costs about NGN7.500M, and its lifetime is 15 years;
- The cost of wind turbine of rated power of 2.5kW and its accessories is about NGN700,000, with a turbine lifetime is 15years, while the accessories of the system lifetime is 25years;
- The diesel-electric generator of 50kW costs about NGN25M, and has a lifetime of 25years.
- The diesel fuel price is constant at NGN160.
- The overall hybrid system lifetime is 25 years and its autonomy should be complete, and should be able to supply continuous electrical energy supply.

C. Environmental

- The design accounts for the effect of ambient temperature in PV efficiency.

The wind potential of the installation site is based on the information obtained from Nigerian metrological Agency data for airport navigational guide. The average wind

- Speed is between 2.5 … 4 m/s at the northern region.

- The Solar potential of the installation site is based on the information obtained from NASA website. With solar average output of 6kWh/m2/d.

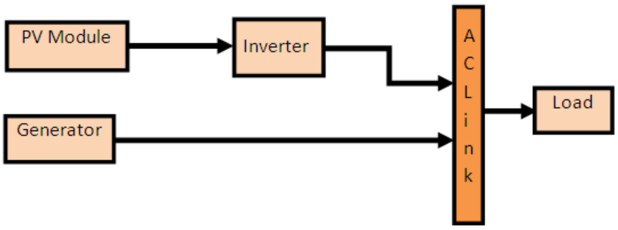

Fig 1 Hybrid PV/Diesel energy system

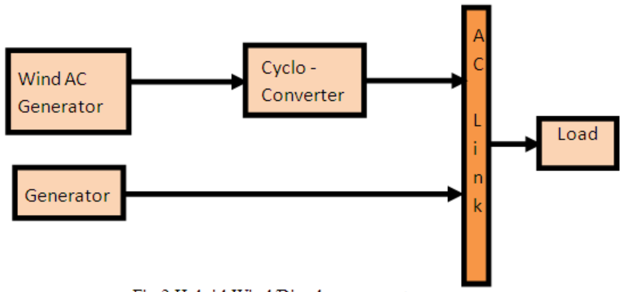

Fig 2 Hybrid Wind/Diesel energy system

IV. SIMULATION

Simulations were performed by comparing the use of PV/Diesel system and wind/diesel system. It was done based on estimate of 25 years life time. Homer assumes all prices escalate at the same rate, it is not possible to model the escalation of diesel price at different rates. Therefore, calculations are based on current prices and do not reflect the effects of possible further increases of the diesel prices. It is however possible to explore the effects of an escalating diesel price by doing a sensitivity analysis on the diesel price alone.

The information presented in the previous section will be used in the homer software to find the optimal hybrid system architecture that can be able to provide electric energy with the cheapest price ($/kWh). Fig () shows the data for environmental consideration used in Homer software for both solar/wind.

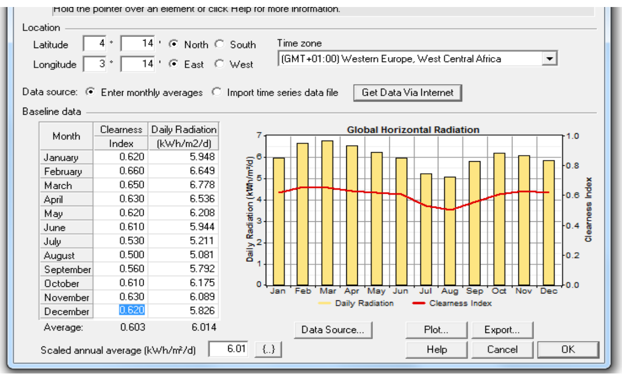

Fig 3 Data of Solar irradiance (NASA website)

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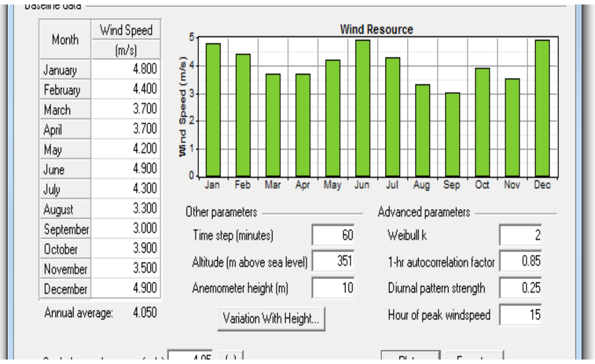
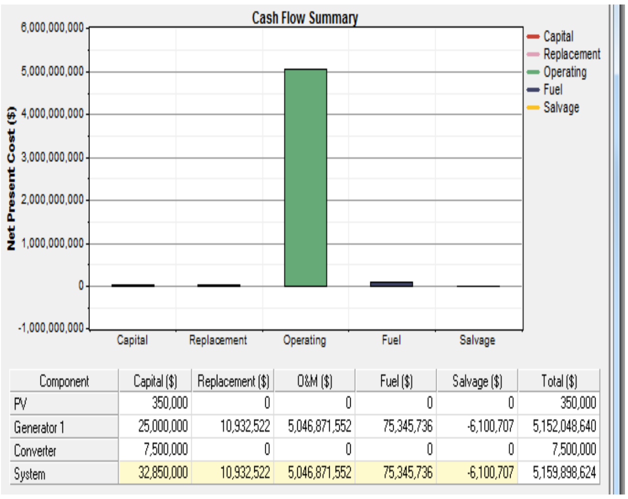


Month	Wind Speed (m/s)
January	4.800
February	4.400
March	3.700
April	3.700
May	4.200
June	4.900
July	4.300
August	3.300
September	3.000
October	3.900
November	3.500
December	4.900
Annual average:	4.050

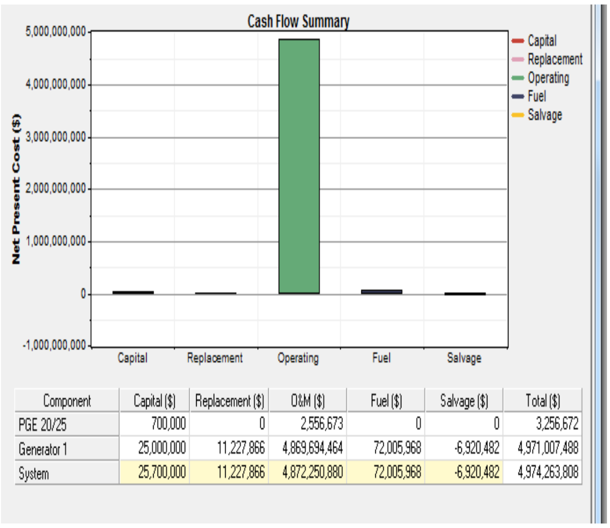
Fig 4: Wind data for Northern Nigerian state Obtained from.

The economic data above is input to Homer software for analysis as can be seen in fig 5 and 6 below.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PV	350,000	0	0	0	0	350,000
Generator 1	25,000,000	10,932,522	5,046,871,552	75,345,736	-6,100,707	5,152,048,640
Converter	7,500,000	0	0	0	0	7,500,000
System	32,850,000	10,932,522	5,046,871,552	75,345,736	-6,100,707	5,159,898,624

Fig 5: Economic analysis for PV/Diesel Hybrid system.



Component	Capital ($)	Replacement ($)	O&M ($)	Fuel ($)	Salvage ($)	Total ($)
PGE 20/25	700,000	0	2,556,673	0	0	3,256,672
Generator 1	25,000,000	11,227,866	4,869,694,464	72,005,968	-6,920,482	4,971,007,488
System	25,700,000	11,227,866	4,872,250,880	72,005,968	-6,920,482	4,974,263,808

Fig 6: Economic analysis for Wind/Diesel Hybrid system.

After the simulations Homer gives the proposed configuration with the optimal output. These can be seen from the figures obtained from the Homer simulation as given in figs below.

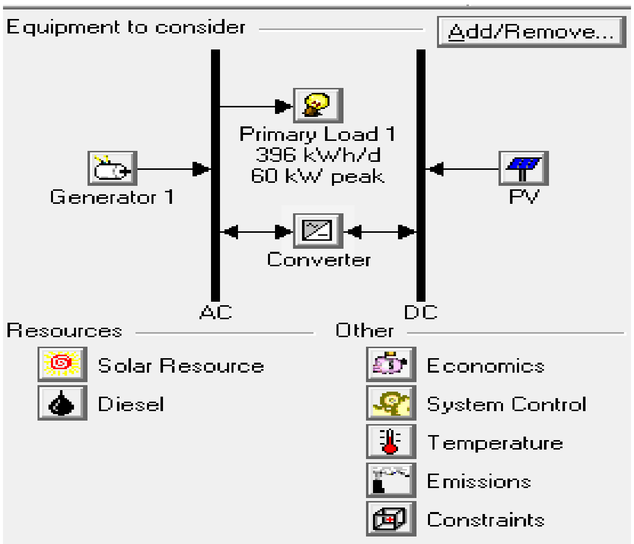


Fig 7A: Homer configuration of PV/Diesel.

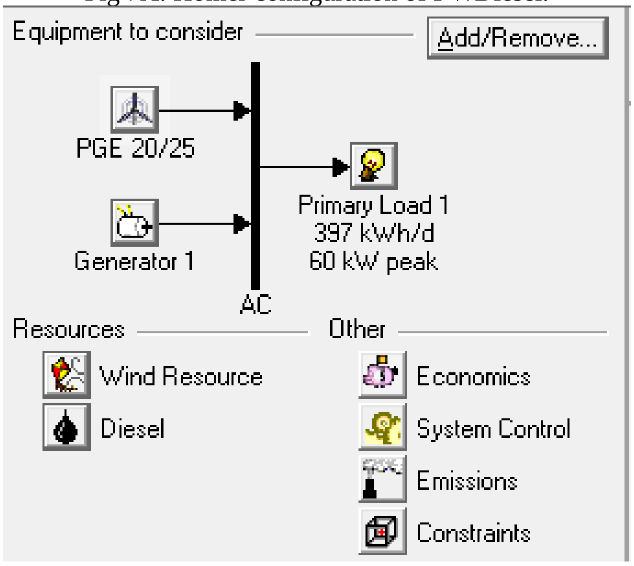


Fig 7B: Homer configuration of Wind/Diesel.

The Homer software also gives the economic analysis such as cost of energy generation, total NPC, total operating cost of the systems as shown in figures below.

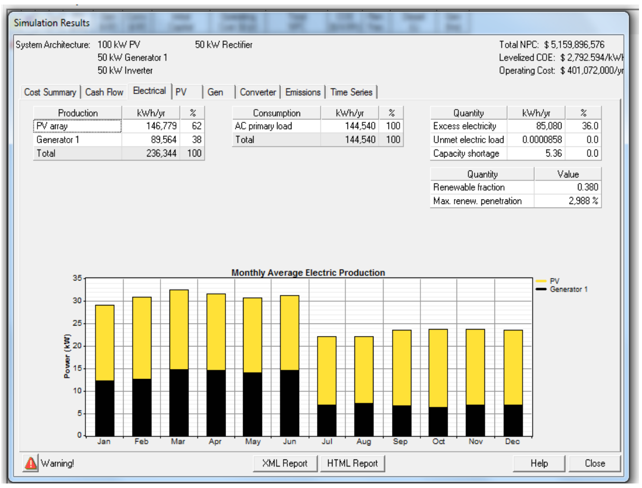


Fig 8: simulation results for PV/diesel hybrid system

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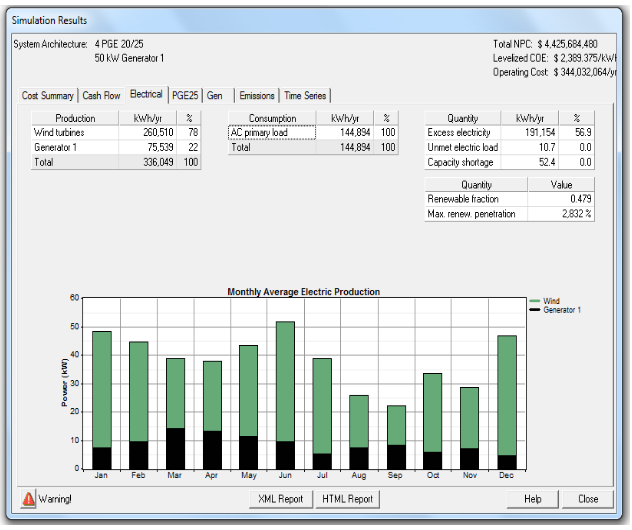

Fig 9: simulation results for wind/diesel hybrid system.PV module:

The type of module used and its specification is as given in table 1 below.

Table 1 PV Model SPECIFICATIONS

Model type	SNM-M50
Peak power(P□ax)	50W
Weight	5.0kg(11.0lbs)
Dimensions	719×555×34mm 28.3×21.9×1.3inch
Maximum power voltage (Vmp)	20.2V
Maximum power current (Imp)	2.48A
Open circuit voltage (Voc)	24.6V
Short circuit current (Isc)	2.81A
Maximum system voltage	DC □000V
Temp. Coeff. of Isc (TK Isc)	0.058 %／°C
Temp. Coeff. of Voc (TK Voc)	-0.367 %／°C
Temp. Coeff. of Pmax (TK Pmax)	-0.485 %/ °C
Normal Operating Cell Temperature	44.4±2 °C

Note: the specifications are obtained under the Standard Test Conditions (STCs): 1000 W/m solar irradiance, 1.5 Air Mass, and cell temperature of 25 ℃

From the above table all the data used for the simulation was got and it was found that this module type although is low in output power it is suitable for the purpose. In simulation the PV is modeled to have 133 modules in series and 15 in parallel to give a combination that produced an output of 303 V_{dc} and an output power of 999,400Watts Although both voltage and current are lower than the expected output and hence that is why the DC-DC boost converter was choosen.

The dimensions, configuration and the characteristics curve are given in the figure below. As stated the curve was the result from standard conditions and hence when installing in the real circuit it might not give the optimum performance as given in the curve.

V. BOOST DC-DC CONVERTER

The DC-DC converter was used as a condition system for the inverter. So that a steady DC input will be fed into the PV module in all conditions of PV output except when the output is below the minimum threshold level. In this case the boost DC-DC converter was used since it was observed that the output of the PV was less than the required input for the inverter.

VI. INVERTER

This is also an important part of PV hybrid especially, it is the interface between the PV cells and the AC loads. The inverter converts the V_{dc} produced into V_{ac} for the loads.

VII. RESULTS AND DISCUSSION

The results from the simulations outlined above were obtained into two categories.

- Homer simulation results.
- Matlab simulink simulation results.

From the Homer simulation optimal configuration can be attained by means of the following system architecture for PV/Diesel Hybrid system:

- A diesel group with maximum power of 50 kW.
- 2000 PV modules of rated power 50Wp per unit, with output voltage of 24 Vd.c.
- One inverter of 90kW rating.

The system architecture for Wind/Diesel Hybrid system.

- A diesel group with maximum power of 50 kW.
- Four PGE20/25 wind turbines of 20kW rated power, induction generator.

The two hybrid systems can be compared from the outcome of the simulation as shown in table 2.

Table 2 Summary of comparative Analysis of the two Hybrid

	Wind/Diesel Hybrid	PV/Diesel Hybrid	Comment
Net present cost NGN	4425,684.48	5.159,896.576	
Operating cost NGN	344,032.06	401,072.00	Due to fuel cost.
Cost of energy NGN	2,389.38	2,792.59	
Renewable fraction	0.479	0.380	
Co_2 Emissions Kg/yr	122,587	128,272	High fuel burning

From the above table it can be seen that the option with less cost, higher penetration, and less emission is obtained in the combination of

- 4PGE 20/25 wind turbines of 20 kW each.
- A diesel group of maximum power output of 40kW.

This combination implies an operating cost of NGN344,032.06 , and a total over 25 years (*i.e.*, the system lifetime) of NGN 4425,684.48, and the corresponding average cost of electricity is NGN2,389.38/kWh.

VII. CONCLUSION

The numerical models developed using the HOMER software package proves to be an efficient and flexible tool for optimum sizing of hybrid power systems based on renewable sources and from the matlab simulink results it can be seen that output from the models will not give the required values without additional components used for control in order to have a nominal output.

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The waveforms as presented in the Appendix can be seen before and after compensation.

The wind model has more components for control than the PV model there by making it difficult and complicated to work with.

The proposed architecture of the power system that uses wind as renewable energy sources (wind/diesel) proves to be cheaper and than the other variant (PV/diesel) renewable source. But if other factors are considered like the complexity and resource availability the PV system seem to be the most preferred. For this proposal after careful considerations the PV hybrid system was taken as the best choice because of the availability of resources, ease of installation and operation, less maintenance, although the cost and emissions are higher but its just for a small percentage difference which is bearable.

REFERRENCES

[1] G.M. Ngala, et. al. "Viability of wind energy as a power generation source in Maiduguri, Borno state, Nigeria Science Direct Renewable energy vol.13, issue 32, pp 2242 – 2246, 2007

[2] L.O. Adekoya & A. A. Adewale. "Wind Energy Potential of Nigeria Renewable energy vol.2, issue 1, pp 35-39, 1992.

[3] I.M. Bugaje, " Remote area power supply in Nigeria: the prospects of solar energy ScienceDirect Renewable energy vol.18,pp 491 – 500,1999.

[4] T. Tudorache, & A. Morega, " Optimum Design of Wind/ PV/Diesel/ Batteries Hybrid Systems 2ND INTERNATIONAL CONFERENCE ON MODERN POWER SYSTEMS MPS 2008, 12-14 NOVEMBER 2008, CLUJ-NAPOCA, ROMANIA.

[5] United State (US) National Renewable Energy Laboratory's (NREL) Homer Software. See also, http://analysis.nrel.gov/homer.

[6] E.I. Barring Gould, A Village Microgrid: The Chile Project, 1997.

[7] CIA (2009), The 2008 World Factbook – Nigeria, Central Intelligence Agency (CIA), United States of America; http://www.cia.gov/library/publications.

[8] PFAN (2008) Report on Available Land for Agricultural purposes Practising Farmers Association of Nigeria

[9] www.energybay.org/sanyo-panel-hip-209ba19-200w

[10] National Aerounetics and Space administration (NASA)

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