USING HOMER POWER OPTIMIZATION SOFTWARE FOR COST BENEFIT ANALYSIS OF HYBRID-SOLAR POWER GENERATION RELATIVE TO UTILITY COST IN NIGERIA

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ABSTRACT
HOMER is a micro power optimization software used in evaluating designs of both off-grid and grid-connected power systems for a variety of applications. The cost benefit analysis of a wind turbine-solar hybrid system was done using HOMER software and comparison was also made with the cost per kilowatt of central grid or utility supply. The hybrid system have a pay-back period of about thirty-three years and at current costs, central grid power is the least expensive option but may not be available to most rural households far from the grid. Hence it is necessary to supply these areas from isolated power sources.

1. INTRODUCTION

Nigeria is endowed with abundant renewable energy resources, the significant ones being solar energy, biomass, wind, small and large hydropower with potential for hydrogen fuel, geothermal and ocean energies. Except for large scale hydropower which serves as a major source of electricity, the current state of exploitation and utilization of the renewable energy resources in the country is very low, limited largely to demonstration and pilot projects.

The main constraints in the rapid development and diffusion of technologies for the exploitation and utilization of renewable energy resources in the country are the absence of market and the lack of appropriate policy, regulatory and institutional framework to stimulate demand and attract investors. The comparative low quality of the systems developed and the high initial upfront cost also constitute barriers to the development of markets.

The transmission network is overloaded with a wheeling capacity less than 4,000 MW. It has a poor voltage profile in most parts of the network, especially in the North, inadequate dispatch and control infrastructure, radial and fragile grid network, frequent system collapse, exceedingly high transmission losses.

Access to electricity services is low in Nigeria. About 60 percent of the population (approx. 80 million people) is not served with electricity. Per capita consumption of electricity is approximately 100kWh against 4500kWh, 1934 kWh and 1379 kWh in South Africa, Brazil and China, respectively [1].

The objective of this work is to analyze the cost benefit of a solar-wind power hybrid system and determine the pay-back period when compared to cost per kilowatt of utility power supply.

2. WIND ENERGY

The energy available in the wind depends on the density and air velocity. The density, as any other gas, changes with the temperature and pressure which varies with the high level of the sea. The energy of a mass of air which is displaced is determined by the Kinetic Energy (K.E) flux [2].

$$P_0 = \frac{1}{2}\rho A V^3 \qquad (1)$$

When wind move across the wind turbine, the static pressure drops to a lower pressure than the atmospheric pressure. As the air follows its trajectory, it takes its atmospheric value again, inducing an extra wind deceleration. By this way, in a distance between upstream of the turbine and downstream, behind the turbine, there is no change in static pressure, but there is a reduction in kinetics energy. This phenomenon is represented by the Betz law in eqn (2).

$$P_{MAX} = \frac{8}{27}\rho A V^3 \qquad (2)$$

Wind is a natural phenomenon related to the movement of air masses caused primarily by the differential solar heating of the earth's surface. Seasonal variations in the energy received from the sun affect the strength and direction of the wind. The ease with which wind turbines transform energy in moving air to rotary mechanical energy suggests the use of electrical devices to convert wind energy to electricity. Wind energy has also been utilized, for decades, for water pumping as well as for the milling of grains.

A study on the wind energy potentials for a number of Nigerian cities shows that the annual wind speed ranges from 2.32 m/s for Port Harcourt to 3.89 m/s for Sokoto [3]. The maximum extractable power per unit area, for the same two sites was estimated as 4.51 and 21.97 watts per square metre of blade area, respectively. When the duration of wind speeds greater than 3 m/s is considered, the energy per unit area is 168.63 and 1,556.35 kWh per square metre of blade area, again for Port-Harcourt and Sokoto.
Although use of wind energy for water supply has been known and used for hundreds of years, in recent times efforts have been directed largely towards the use of wind power for the generation of electricity and in the past twenty years or so rapid changes in technology have occurred and major wind powered generating plants have been installed, especially in the rural areas of the developed countries.

3. SOLAR ENERGY

Solar energy is the most promising of the renewable energy sources in view of its apparent unlimited potential. The sun radiates its energy at the rate of about 3.8 x 10^{23} kW per second. Most of this energy is transmitted radially as electromagnetic radiation which comes to about 1.5kW/m^2 at the boundary of the atmosphere. After traversing the atmosphere, a square metre of the earth's surface can receive as much as 1kW of solar power, averaging to about 0.5 over all hours of daylight. Studies relevant to the availability of the solar energy resource in Nigeria have indicated its viability for practical use. Although solar radiation intensity appears rather dilute when compared with the volumetric concentration of energy in fossil fuels.
Nigeria receives 5.08 x 10^{12} kWh of energy per day from the sun and if solar energy appliances with just 5% efficiency are used to cover only 1% of the country's surface area then 2.54 x 10^6 MWh of electrical energy can be obtained from solar energy [4]. This amount of electrical energy is equivalent to 4.66 million barrels of oil per day. Typical of such applications are in drying, cooking, heating, distillation, cooling and refrigeration as well as electricity generation in thermal power plants.
In solar photovoltaic applications, the solar radiation is converted directly into electricity. The most common method of doing this is by the use of silicon solar cells. The power generating unit is the solar module which consists of several solar cells electrically linked together on a base plate. On the whole the major components of a photovoltaic system include the arrays which consist of the photovoltaic conversion devices, their interconnections and support, power conditioning equipment that convert the dc to ac and provides regulated outputs of voltage and current; controller, which automatically manages the operation of the total system; as well as the optional storage for stand alone (non-grid) systems.

4. HOMER SOFTWARE

HOMER, the micro power optimization software developed by Mistaya Engineering, Canada for the National Renewable Energy Laboratory (NREL) USA, used in this analysis simplifies the task of evaluating designs of both off-grid and grid-connected power systems for a variety of applications.
In designing a power system, many decisions about the configuration of the system are to be made: components to include in the system design, size of each component to use etc. The large number of technology options and the variation in technology costs and availability of energy resources make these decisions difficult. HOMER's optimization and sensitivity analysis algorithms make it easier to evaluate the many possible system configurations [5].
HOMER simulates the operation of a system by making energy balance calculations and displays a list of configurations, sorted by net present cost that can be used to compare system design.

5. ENERGY GENERATION SYSTEM DESIGN

The 400W FD Series wind turbine and solar module rated 100W are installed on the roof top of Faculty of Engineering, University of Ilorin building (Block 10) as shown in Figure 1. These unit serves as a backup power supply to the Very Small Aperture Terminal (VSAT) equipment housed inside the VSAT room where the inverter and battery bank are installed as shown in Figure 2.

Figure 1: PV Panel and FD series Turbine

Figure 2: Battery Bank and Converter

6. ENERGY ANALYSIS

6.1. Load profile

The load profile is based on a hypothetical apartment and the profile is shown in Figure 3. A small base load of 10 W occurs throughout the day and night and small peaks of 80 W occur in the evening. The total daily load average 903 Watt-hours per day.

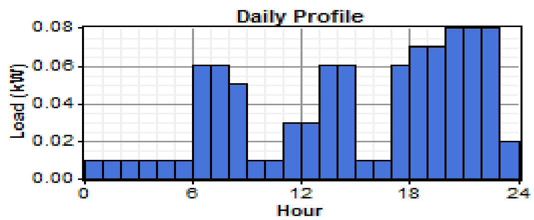

Figure 3: Hourly load profile

6.2. Solar radiation profile

Figure 4 below shows the solar resource profile over one year. The solar resource data for Ilorin, Nigeria was obtained from NASA surface Meteorology and solar energy website [6]. The approximate location of the site used is 8° 26' N and 4° 29'E. It has been observed that the solar intensity ranges from 550 W/m^2 to 1075 W/m^2 with total incident energy per day of 17 MJ/m^2 to 25 MJ/m^2 in Ilorin, Nigeria [7].

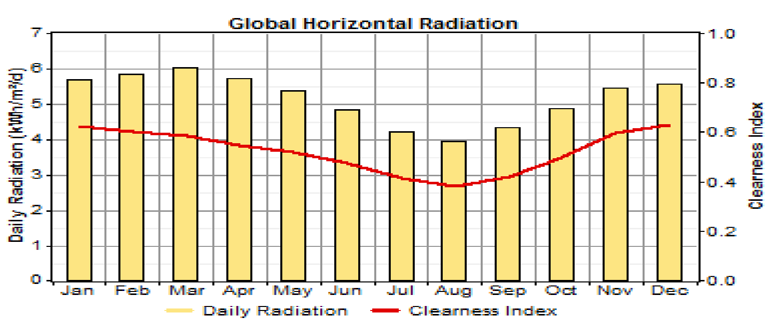

Figure 4: Solar Radiation profile for

6.3. Wind resource data

Figure 5 shows the wind resource profile over a year period for Ilorin. This was obtained from NASA surface metrology and solar energy website [6]. The daily average wind speed is 2.5 m/s measured at anemometer height of 14.9 meters above ground level [8].

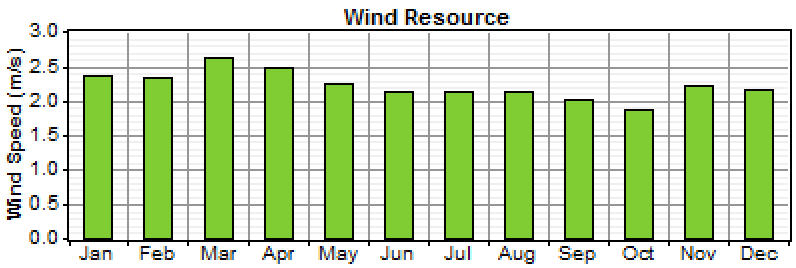

Figure 5.Wind Resource Profile of

7. Economic Analysis

An annual interest rate of 6% was considered, while the project life year was taken as 20 years. All calculations are done with exchange rate of $1 to N160. The tariff of the utility company in Nigeria, The Power Holding Company of Nigeria (PHCN), is N4 per kWh ($0.024).

Constraints are conditions which a system must satisfy for it to be feasible. HOMER discards systems that do not satisfy the specific constraints so that they do not appear in the optimization or sensitivity result. Maximum capacity shortage is set at 5%.

A survey of ten households having similar electricity consumption pattern showed that the average consumption per month for a household is 400 units. This amount to N1, 736 ($0.026) per month or N20, 832 ($130.2) per annum and is equivalent to N416, 640 ($2,604) for twenty years of consumption.

8. IMPLEMENTATION OF HOMER CODE

8.1 System equipment configuration

Figure 6 shows the equipment considered in the optimization. The equipments considered are photovoltaic solar cells, wind turbine, converter, battery bank and loading system.

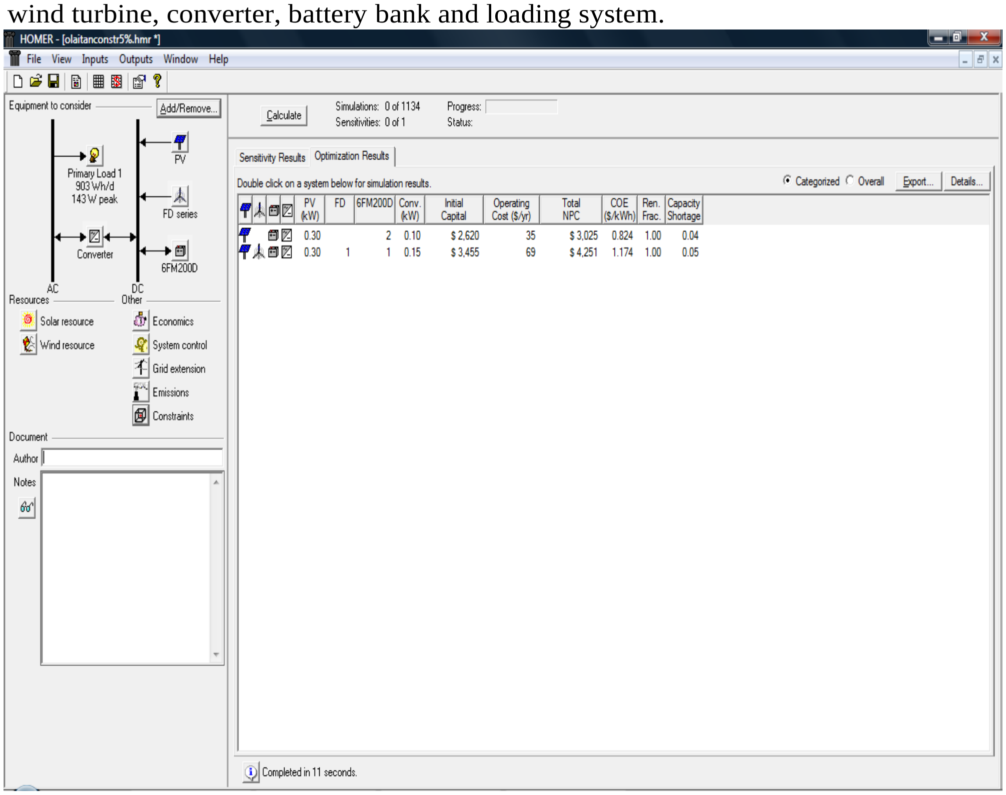

Figure 6: Equipment considered in the optimization

The size of the components under consideration, the acquisition cost, replacement cost, operation and maintenance cost and the expected lifetime as input into the HOMER software is depicted in table 1 below.

Table 1: System Components

Component	Size	Capital Cost($)	Replacement Cost	O&M Cost ($)	Lifetime
PV Panels	0.05 – 0.4 kW	$7,500/kW	$7,500kW	0.00	20 years
Vision6 FM200D Battery	200 Ah / 12 volt (bank size: 1-8 batteries)	$175/battery	$175/battery	$2.00/year	917 kWh of throughput per battery
FDseries Wind Turbine	0.4 kW DC	$2,500/kW	$2,500/kW	$10/year	15 years
Converter	0.1 – 1.5 kW	$200/kW	$200/kW	$20/year	15 years

8.2 *System performance*

8.2.1. PV system

The capital and replacement costs were specified with $7.50/W. No maintenance cost was considered for the PV system because little or no maintenance is needed for the panels. A derating factor of 90% and 20 years lifetime was considered as shown in Figure 7 below.

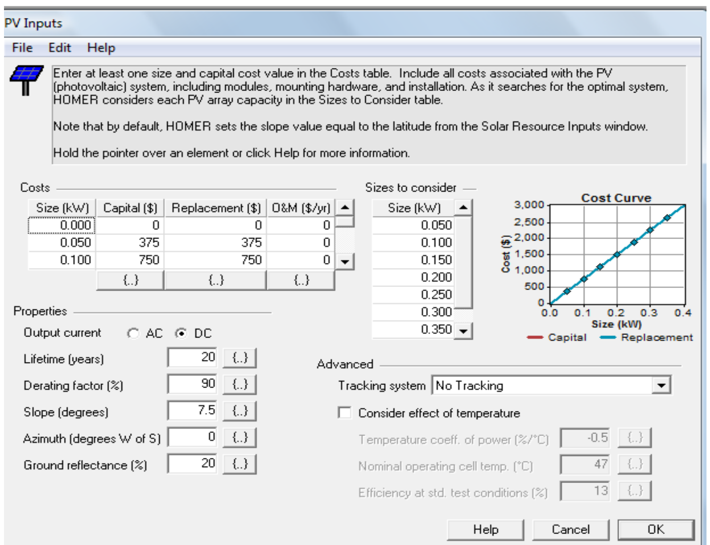

Figure 7: Photovoltaic Solar Input

8.2.2. Wind system

The FD Series Wind Turbine was considered for the simulation in Figure 8. The capital and replacement costs of $2.50 were specified.

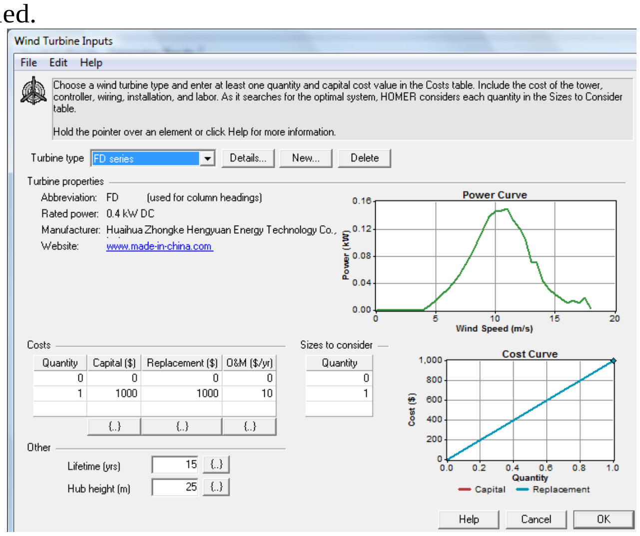

Figure 8: Wind Turbine Input

8.2.3. Battery storage

The battery chosen is the 6FM200D series. It has a nominal voltage of 12 Volts and nominal capacity of 200Ah (2.4 kWh). Two batteries were considered by HOMER in the simulation shown if Figure 9 below.

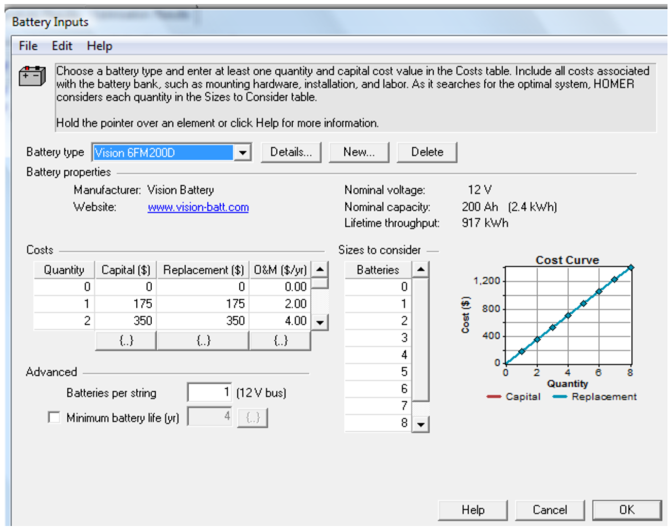

Figure 9: Storage Batteries Input

8.2.4. Converter and Inverter

The inverter and the rectifier efficiencies were assumed to be 90% and 85% respectively for all the sizes considered.The sizes considered varied from 0.1 kW to 1.5kW. The converter input is shown in Figure 10.

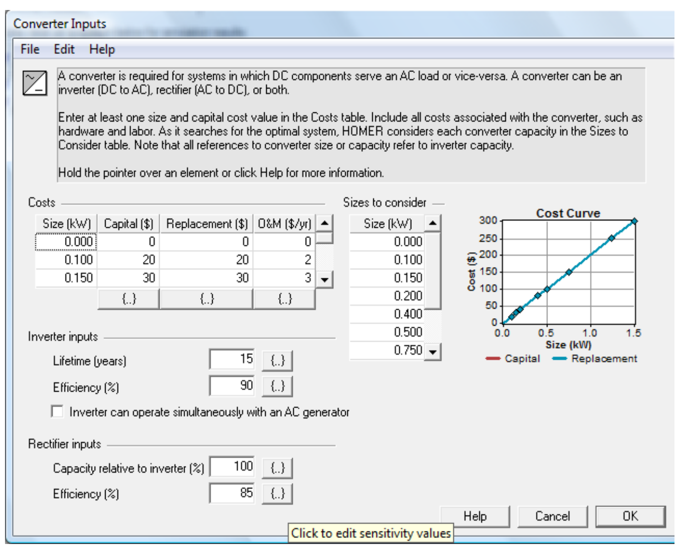

Figure 10: Converter Input

8.2.5. Load Levels

A typical household load was considered. The consumption includes 8-bulb points, television, DVD, refrigerator, 4-fans, washing machine and pressing iron as shown in Figure 11.

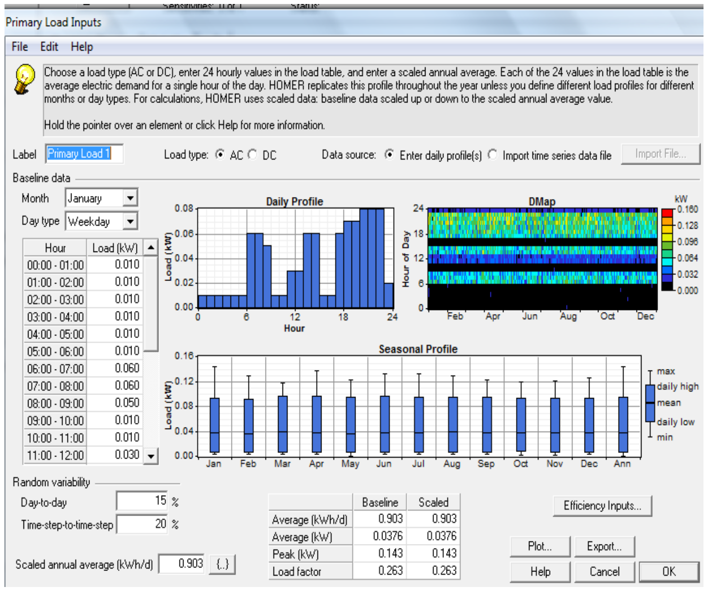

Figure 11: Load Input

9. RESULTS

The total net present cost is HOMER's main economic output. All systems are ranked according to net present cost, and all other economic outputs are calculated for the purpose of finding the net present cost. The result obtained from the optimization gives the initial capital cost as $3,455 while operating cost is 69 $/year. Total net present cost (NPC) is $4251 and the cost of energy (COE) is 1.74 $/kWh.

The utility tariff bill of was compared with the hybrid system net cost. At this rate, the system will have a pay back period of about thirty-three (33) years and not twenty years as specified by many manufacturers.

10. DISCUSSION

The cost benefit analysis of a wind turbine-solar hybrid system in comparison with utility tariff showed that the hybrid system is not economically cheap and have a system payback time of thirty-three years. At current costs, central grid power is the least expensive option but will not be available to most rural households.

A wind-solar cell hybrid energy system would be cost effective if there is reduction in component cost by installation of many of this hybrid system in a farm thereby lowering the investment cost per kilowatts. Its availability, sustainability and environmental friendliness make it a desirable source of energy supply.

The model developed is fairly general and may be adequate for preliminary results for energy consumption cost for household and industrial sector willing to adopt renewable energy sources.

11. REFERENCES

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