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Solar Energy Potentials for Remote CommunityElectricity Supply:a Case study of Sankwala Solar Power in Cross River State

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Abstract:*Access to electricity is a measure of economic and social development. It is argued that, electricity is an essential commodity and the government is responsible for the availability of this commodity. But, from the business point of view, electricity a commodity with cost implication, the willingness and readiness to pay creates availability. Therefore, investing in electricity generation is a profitable venture that investors must take advantage of. The question remains; why is there huge shortage of electricity? In considering solar power, which has huge initial cost, it becomes the cheapest and most reliable in the long run. This paper, proposes the adoption of solar power mostly for rural dwellers where extension of transmission lines proves almost impossible and outrageously expensive after about fifteen kilometers. The paper estimates the economic implication of renewable energy to conventional sources of electrical energy.*

Keywords: *Renewable energy, solar power, sustainable power, economic development, HOMER*

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I. Introduction

Steady access to electric power has a direct influence on the development of an area and an overall positive impact on the sustainability of the environment. Unfortunately, Nigeria as a country with a population of over a hundred and eighty million people has about 55 % of her total population without access to electric power, which is an evidence of underdevelopment[1,2,9]. Incidentally however, Nigeria's drive to attain improved capacity for electricity production and consumption has not yielded commensurate outcomes. While installed capacity of electricity in Nigeria stands at 8644MW, only 4000MW is operational of which only about 1500MW generation is available, even this power is epileptic in nature andresults in unannounced load shedding [5]. According to the Transmission Company of Nigeria, the poor power supply is also attributable to system failures and inadequate transmission infrastructure. Currently, electricity generation, transmission and distribution accounts for less than one percent of Nigeria's GDP [5, 11]. On the other hand, Nigeria is endowed with so much energy resources; Non-Renewable and Renewable. The former deals with the popular conventional fossil based sources of energy which has placed our environment in serious danger from emissions.

Renewable Energy (RE) can generally be defined as energy that comes from resources which are naturally replenished on a human time scale [1]. Renewable Energy sources includes; solar, wind, biomass, tidal, etc. solar is becoming a brand name for renewable energy. Sunlight can be used directly for heating, lighting, generating electricity among a host of other applications. In another way, the sun's heat also drives the winds whose energy can be captured with the aid of wind turbines for power generation and other applications.

Nigeria is located on the latitude and longitude 10°00'N and 8°00'E with a compact area of 923,768 square kilometers (approximately 924 million hectares), [3,4], which is considerably a high sunshine belt and thus has enormous solar energy potentials. The mean annual average of total solar radiation varies from about 3.5 kWh/m^{2}day in the coastal latitudes to about 7 kWh/m^{2}day along the semi-arid areas in the far North. On the average, the country receives solar radiation at the level of about 19.8 MJ/m^{2}day. Average sunshine hours are estimated at 6hrs per day. Solar radiation is fairly well distributed. The minimum average is about 3.55 kWh/m^{2}day in Katsina in January and 3.4 kWh/m^{2}day for Calabar in August, and the maximum average of 8.0 kWh/m^{2}day for Nguru in May [1]. This gives an average annual solar energy intensity of 1934.5 kWh/m2/yr; thus over the course of a year, an average of 6,372,613 PJ/year (≈1,770 thousand TWh/year) of solar energy falls on the entire land area of Nigeria. This is about 120 thousand times the total annual average electrical energy generated by the Nigerian power sector. With a 10% conservative conversion efficiency, the available solar energy resource is about 23 times the Energy Commission of Nigeria's (ECN) projection of total final energy demand for Nigeria in the year 2030 [8,1,11]. Also, it is reported in [6,7], that given an average solar radiation level of about 5.5 kWh/m^{2}day, and the prevailing efficiencies of commercial solar-electric generators, then if solar collectors or modules were used to cover 1% of Nigeria's land area of 923,773km2, it is possible to generate 1850000 GWh of solar electricity per year. This is over one hundred times the current grid electricity consumption level in the country [4].

Cross River State [5], depends heavily on subsistence agriculture and tourism for its economy. Sankwala is a local town located in the Northern region of the State in close proximity to one of the State's premier leisure resorts the Obudu Cattle Ranch and depends heavily on agriculture and has an abundance of renewable energy resources foremost of which is the solar irradiance and clearness index of the area. This work seeks to proffer a solution to the near absence of electric power in this area as this community is not connected to the National Grid and any available power is sourced from captive power sources such as fossil fueled Generators which are expensive to run and are serious contributors to the increase in Green House gases in the atmosphere. Meeting the current electrical energy needs of the area and providing spare capacity potential for new users will give the state comparative advantage in attracting and retaining new tourists and investments around the ranch.

II. System Design and Modeling

The proposed model is a hybrid system consisting of solar photovoltaic (PV) modules; which depend on the photoelectric effect to convert solar energy into useful electrical energy and a battery bank of deep cycle batteries that serves as a backup storage system when solar radiation is not available. Sankwala is located on latitude 6̊ 33'N and longitude 9̊13'E, and is 361Km from Calabar, in Cross River State with a good solar energy potential as expressed in the solar radiation pattern shown in Figure 2. The system was optimized using HOMER® software, the micro-power optimization model to evaluate a range of equipment options over varying constraints to optimize small power systems [7].

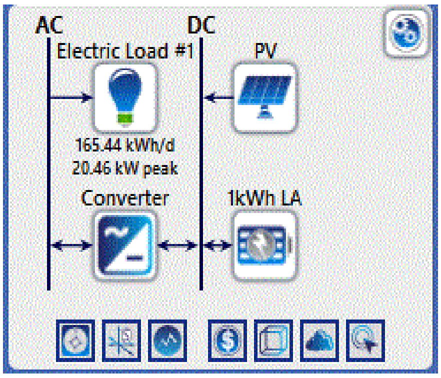

Figure 1: HOMER diagram of the proposed design

The load profile is synthetically generated based on a community size load demand with peak load between the sixteenth and twenty second hours of a twenty four hour/ day. The assumed scaled peak load on the system from the community is pecked at about 20.46kW with a load factor of 0.3369 as depicted in Figure 3.

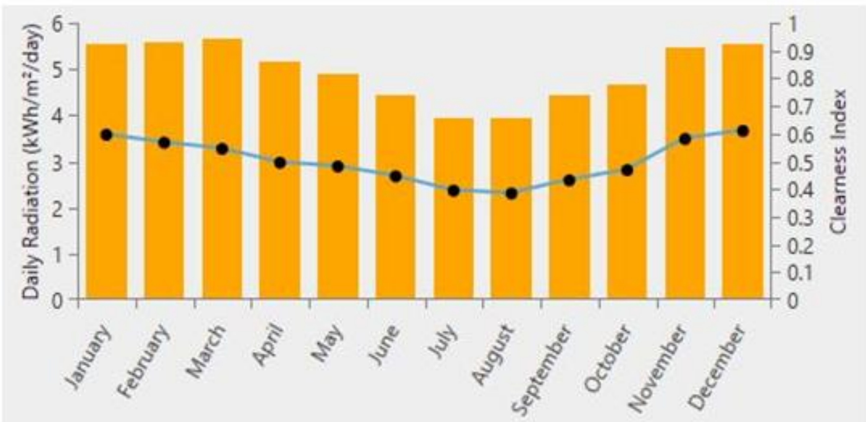

Figure2: Solar Radiation Pattern of Sankwala

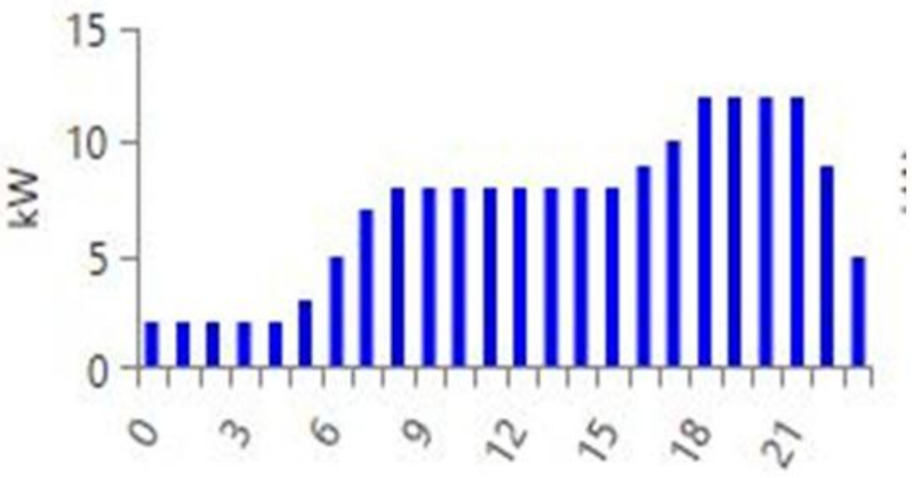

Figure 3: Electrical Load Profile of Sankwala

III. HOMER

HOMER is a software application package used in designing, and weighing the options of either off-grid or on-grid power systems based on their technical and financial viability. It was developed in 1993 by the National Renewable Energy Laboratory in the United States for internal Department of Energy (DOE), [10]. HOMER has optimization and sensitivity analysis capabilities, which helps point to answers of difficult design questions when designing off-grid and grid-connected systems: Which technologies are most cost-effective? What size should components be? What happens to the project's economics if costs or loads changes? Is the renewable resource adequate? HOMER finds the least cost combination of components that meet electrical and thermal loads, simulates thousands of system configurations, optimizes for lifecycle cost, and generates results of sensitivity analyses on most inputs. It simulates the operation of a system by making energy balance calculations for each of the 8,760 hours in a year. For each hour, HOMER compares the electric and thermal load in the hour to the energy that the system can supply in that hour. For systems that include batteries or fuel-powered generators, HOMER also decides for each hour how to operate the generators and whether to charge or discharge the batteries. If the system meets the loads for the entire year, HOMER estimates the lifecycle cost of the system, accounting for the capital, replacement, operation and maintenance, fuel and interest costs. You can view hourly energy flows for each component as well as annual cost and performance summaries. After simulating all of the possible system configurations, HOMER displays a list of feasible systems, sorted by lifecycle cost. The system least cost can easily be found at the top of the list, or other feasible systems can be found from the list. It is possible to see how the results vary with changes in inputs, either because they are uncertain or because they represent a range of applications [7]. Sensitivityanalysis can be performed on almost any input by assigning more than one value to any input of interest. HOMER repeats the optimization process for each value of the input so that the effect of the change in input can be examined. The designer can specify as many sensitivity variables of interest, and analyze the results using HOMER's powerful graphing capabilities.

IV. Results Presentation and Discussion

After computer simulations were carried out using the HOMER optimization software to ascertain the best setup which will have the best output at the least cost. The best case solution preferred the construction of a stand-alone renewable energy system to the extension of the already existing public electricity grid at an estimated cost of 3.8 million Naira per kilometer [8]. The system architecture will contain a battery system with a nominal capacity of 480kWh, a 69kW rated PV system and a system converter of 23.2kW making a foot print of 410 m^2.

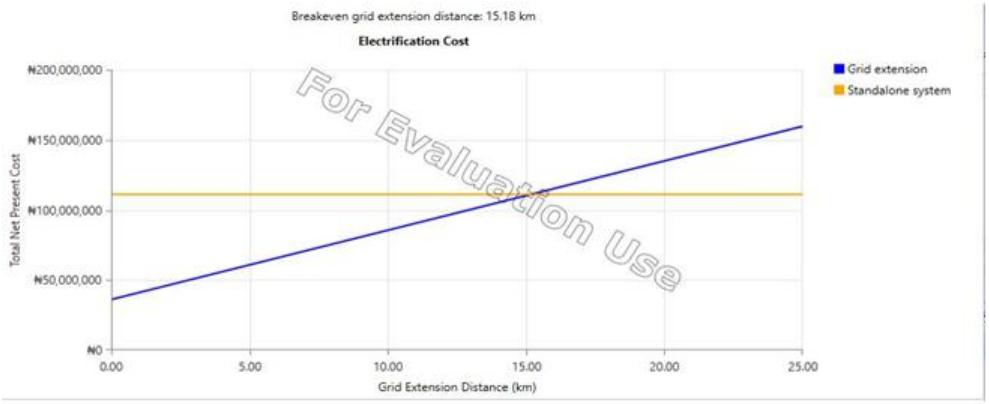

Figure 4: Comparison between Grid Extension and RE System

4.1 Battery/Converter System

The battery system that can produce a nominal capacity of 480kWh would be made up of 480 1kW Lead Acid battery units arranged in forty batteries having twelve parallel strings. The battery system would have a bus voltage of 480 volts and an autonomous operation time of 41.8 hours. The designed converter size for optimal performance is a 23.2kW converter system that performs at about 8,800 hrs/yr, with a mean output of 6.89 kW per day.

4.2 PV System

The PV system capacity is rated at 69kW. This can be achieved by the use of 24V/345W polycrystalline modules combined in twenty (20) strings, With each string containing ten (10) modules. Every string producing 3450W at a capital cost of ₦800,000 per string. Solar panels do not require extensive maintenance; usually it is only required to remove dust from the panels twice a year so the O&M cost has been calculated as one-day of labour plus transport costs.The PV system will be in operation for an estimated four thousand four hundred and sixty two hours in a year (4,462 hrs/yr),and produce 204,955 kWh/yr.

4.3 Electrical Output

The total electrical production from the system stands at about 204,955 kWh/yr.
From the load profile of the community, the maximum available load of 60,337kWh/yr leaving an excess electricity of 134,046kWh/yr.

Figure 5: Plot of Monthly Electric Production

4.4 Project PaybackPeriod

Assuming an annual discount rate of six percent (6%), the net present cost of the project over its twenty five year life time stands at ₦111,139,800 with an initial capital cost of ₦75,790,716.26 with the remaining cost for replacement of battery and system converters after a span of ten years and operation and maintenance of the entire system. This eclipses the option of extending the already existing public electricity grid at a breakeven point of 15.18 km as shown in Figure 4. The average cost per kWh of useful energy produced by the system is about fourty seven Naira (₦47) which is less than the cost of public electric power which stands at sixtyfive Naira (₦65) [6].

V. Conclusion

From the results obtained, it can be observed that power generated by this means is far cheaper and more reliable when compared to extension of the public grid or other means of generation such as diesel generators. It is closer to community members for proper security against vandals and theft, detection and rectification of faults. The steady and available power will also promote enterprise and foster preservation of agricultural produce and building of micro industries. Although renewable energy systems such as this has a high initial startup capital cost, when invested in yields a very lucrative and sustainable outcome in the long run over the life span of the project, because its maintenance cost is minimal and has an almost zero fueling cost and is a system that can pay for itself before spends even half of its life span.

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