Green Village Electricity Project; a Suitable Model for Reliable Renewable Energy Deployment in Nigeria

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Abstract – As a result of the pressing challenges in the Nigerian power sector and the looming effects of global climate change, the need arises for engineers to design and implement reliable renewable energy systems to mitigate the duo. This paper proffers the Green Village Electricity Project as a suitable model for providing off-grid solar electricity to remote settlements in Nigeria while dousing the effect of climate change on a Micro scale.

I. INTRODUCTION
The Nigerian state has over the years been experiencing epileptic power supply, transmission and distribution problems. The country has an installed capacity of 15,000MegaWatts of electricity drawn from such sources as hydro, coal, steam, and gas generation stations, but the amount of energy available for distribution as at end of January 2009 was a pauper 1600MegaWatts which cannot be compared with her large population of over 150million inhabitants. This means energy per capita of 10.67Watts and has been one of the major setbacks to her rapid socio-economic development.

Equally conventional power stations are obsolete with little or no maintenance operations resulting to poor performances and high carbon and green house gases emission in this era when our environment is threatened by serious environmental problems caused by the emission these gases. Furthermore, the areas connected to the national grid lack constant supply of electricity not to talk of those living in remote regions of the country that has no hope of receiving electricity. Equally it would be economically impossible to connect these areas judging by their distances from the grid lines.

This paper discusses the various sources of generating electricity in Nigeria, highlighting the pros and cons of each. It equally compares the energy generation index of the Nigerian state with that of the developed countries of the world.

Consequently, the paper suggests the adoption of solar as a viable alternative/ supplement to conventional energy sources in the country. It discusses the analysis, pre-design, design, installation, maintenance, and troubleshooting methodologies of solar electricity systems for both domestic and industrial utilization. The paper also highlights possible causes of solar electricity malfunctions and ways to mitigate them.

Furthermore, the paper examines the economic implications of adopting solar electricity while pointing out the various economic and environmental advantages of its utilization both to the primary consumer and the entire human race.

Ultimately, the paper presents Green Village Electricity Project a brainchild of the IEEE Presidents’ Change the World Students Competition which is intended to serve as a suitable Micro scaled model for reliable solar electricity deployment in Nigeria so as to jump-start economic sustainability.

II. NIGERIA POWER SECTOR IN REVIEW
Conventionally, electricity generation in Nigeria is drawn from such sources as coal, hydro, thermal and predominantly Oil& Gas. The organization responsible for electricity production and supply in Nigeria is the Power Holding Company of Nigeria (PHCN).

Nigeria has 15,000MW of installed capacity; however the country is only able to generate 1600
MW because most facilities are poorly maintained. The country has proven gas reserves and about 8000 MW of hydro development has been planned. The country has plans to increase access to electricity throughout the country to 85% by 2010. This implies the construction of 16 new power plants, approximately 15,000 KM of new transmission lines as well as distribution facilities.

The Nigerian power sector has high energy losses (30-35% from generation to billing), a low collection rate (75-80%) and a low access to electricity by the population (36%, energy per capita of 10.67watts). Presently, only about 10% of households and 40% of the country’s total population have access to electricity. The Nigerian Energy Commission and the Solar Energy Society of Nigeria have been tasked with generating a solar-powered solution for the remote rural dwellers not served by the national power grid.

Nigeria has fourteen power stations consisting of:

<table>
<thead>
<tr>
<th>S/No.</th>
<th>Description</th>
<th>No of Power Stations</th>
<th>Composition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>FuelOil/ Coal Power Stations</td>
<td>7</td>
<td>Egbn Electric Power Business Unit, Afam Electric Power Business Unit, Delta Electric Power Business Unit, Shiroro Electric Power Business Unit, Jebba Hydro Power Station, Shiroro Hydro Power Business Unit, Kainji Hydro Power Station</td>
</tr>
<tr>
<td>2.</td>
<td>Gas Turbine Power Stations</td>
<td>3</td>
<td>Afam, Sapele and Delta Power Station</td>
</tr>
<tr>
<td>3.</td>
<td>Hydro Power Stations</td>
<td>3</td>
<td>Jebba, Kainji, Shiroro</td>
</tr>
<tr>
<td>4.</td>
<td>Thermal Power Stations</td>
<td>1</td>
<td>Egbn</td>
</tr>
</tbody>
</table>

Table 1. Power generating plants in Nigeria

Furthermore, comparing the Nigerian energy indices with that of other countries of the world gives rise to the following charts.

III. RENEWABLE ENERGY

By definition, renewable energy are those energy sources that are replenishing in nature, which do not contribute to further global warming and global climate change.

They are also those sources of energy and/or power that non-polluting in nature and are fundamentally environmental friendly.

The sources of renewable energy are:
1. Solar:
2. Wind
3. Geothermal
4. Oxygen/ Hydrogen
5. Timber
6. Fruits and Vegetables
7. Meat from Animals
8. Water

Of all these sources the most adopted form of global renewable energy are; wind, solar, biomass, water and geothermal.

IV. SOLAR ELECTRICITY CASE STUDY
Solar Electricity is the generation of electricity from the radiations of the sun through the use of photovoltaic cells.

![A Photovoltaic cell](image1)

Fig. 3 A Photovoltaic cell

The generated power in DC form can be converted to AC through the use of inverters for a wide range of applications.

The basic components of solar electricity generation are:

- a. Sun
- b. Solar Cell Module
- c. Charge Controller
- d. Battery (Energy Storage)
- e. Inverter (DC to AC)

![Solar electricity generation process](image2)

Fig 4. Solar electricity generation process

In recent times, solar electricity generation has found widespread application in many developing and developed countries of the world. This is as a result of the relative availability of her primary element (sunlight), its environmental friendliness, zero pollution nature, low or no maintenance nature and the use of no traditional fuel.

In China for instance, solar electricity is the major supply source in the Tibet region and other remote villages where grid connecting is both practically and economically challenging.

![Electricity distribution in Nigeria](image3)

Fig. 5. Electricity distribution in Nigeria

The nation has a total of about 50MW of solar electricity supply from about 1000 installed PV arrays in various remote energies.

Equally, solar electricity has been proved to have diverse areas of application. This flexibility in utilization has enhanced the call for its utilization. Recent developments allow the integration of energy from various sources for both commercial and domestic utilization, this equally contribute to the flexibility of solar electricity.

![Solar Power Application](image4)

Fig 7. Applications of solar energy.

However, solar electricity has the following down turns;

- a. High installation cost
- b. Needs large area for solar panels
- c. Production is affected by weather conditions.

Nevertheless, the positive attributes of solar electricity greatly outweighs the above demerits.

V. GREEN VILLAGE ELECTRICITY PROJECT

The Green Village Electricity Project (A.K.A. Project Spread the Light) is a student design project and was a competitor in the maiden IEEE Presidents’ Change the World Students Project Competition. The project is designed to provide off-grid solar electricity (Lighting points, wall sockets to power small gadgets and streetlights) to about twenty houses in a remote settlement. The project emerged fourth (4th) out of about two hundred (200) competitors globally. The aim of the project is to canvass the concept of renewable energy in Nigeria while helping the country overcome her climate change challenges.
Equally, the project was developed to inspire youths in developing countries towards creativity and productivity. Most importantly, the project was designed to serve as a model for reliable renewable energy deployment throughout Nigeria specifically in remote settlements where it will be most economically and technically effective to implement such micro systems.

The project was specifically designed to suite the Nigerian state which has high availability of sun-hours. The project team is constituted of undergraduates from the department of Electrical/Electronics Department, Federal University of Technology, Owerri, Imo State. The project will utilise student volunteers who will assist in the wiring of the individual houses, installation of the solar module and in the sensitization phase. PSL has an estimated execution time of twelve (12) months after which the planned maintenance phase follows. PSL will operate with six full and part time staff members. In addition, a Governing Body made up of community leaders and university staff will operate to provide overall sanctioning of the project implementation. Periodic evaluations will be conducted to assess the effectiveness of PSL based on its evaluation indices as stipulated in this proposal. Equally, the sustainability of the project is highlighted and discussed in a later section of the proposal.

VI. PROJECT TECHNICAL DETAILS

The project design details are as represented below:

SYSTEM LOAD ANALYSIS

**Hourly consumption per house**
- No of bulbs: 4 (13 watts each)
- No of sockets: 2 (40 watts each)
- Tolerance per house= 13 watts
- Total utility per house= (4*13) + (40*2) + 13 = 145 watts

**Hourly utility for power house**
- No of bulbs: 2 (13 watts each)
- No of Street Lights: 30 (15 watts each)
- Tolerance: 24 watts.
- Total utility= (2*13) + (30*15) + 24 = 500 watts.
- **No of houses**: 20
- **Total System Utility**= (20*145) + 500 = 3.4 KiloWatts.

SYSTEM DESIGN PARAMETERS

- Energy expected from solar panels= 2.5*Total Load= 2.5*3.4KW= 8.5KW/ Hr
- **Panel Ratings**:  
  - Power=210 Watts  
  - Voltage= 24 volts DC  
  - No of solar panels= 8500/210 ≈ 40 Panels.
- Charge Controller Rating: 80 Amperes  
  (this is to withstand the high DC current at this terminal)
- **Inverter Rating**:  
  - Power: 5Kilowatts  
  - Primary DC voltage input = 180 VDC  
  - Output Voltage= 220 Volts

NB: (this high input DC voltage is designed to drop the surging current at the charger and to ensure that a high fidelity output voltage is maintained irrespective of distribution losses and other parameters)
Battery Rating
Amp-Hr rating= 200AHR
Terminal voltage= 24 volts
Desired Bank array voltage= 192VDC

Bank Capacity Computation
No of batteries (N)= (L*T) / (V*AH*0.8)

Where:
L= system hourly load: 3.4KW.
T= No. of Hours of no sunlight (15hrs 17:00hrs – 08:00hrs of next day).
V= battery voltage, 24volts.
AH= Battery Amp-Hr rating
0.8= system efficiency.

N= (3400*15)/(24*200*0.8)
≈ 14 batteries.

N.B: To conform to desired battery output voltage, 2 additional batteries will be added resulting in a bank capacity of 16 batteries.

Transmission/ Distribution:
Transmission & Distribution is a hybrid of Ring, Serial & Star topologies.
   Ring: covers the settlement perimeter.
   Serial: transmits to four clusters of five houses each.
   Star: distributes to five houses within a cluster.

Cabling:
The 2.5mm cable will be used for the internal wiring of the individual houses and power house.
The 5mm TRS flex cable will be used for the overhead Star distribution cablings from the Low Voltage Distribution Board to the Individual houses.
The 6mm armoured cable will be used for the underground Serial transmission cablings from the ring circuit to a low voltage Distribution board.
The 30mm armoured cable will be used for the underground Ring cabling from the power source to two injection points in the ring to improve power integrity.

Isolators/ Breakers:
100Amp Circuit breaker= Mains between inverter and Distribution Board.
Two 100 Amps DC Isolators= between charge controller and inverter unit.
Two 100 Amps DC Isolators= between charge controller and battery bank.
Two 100 Amps DC Isolators= between PV array and the charge controller.
63 Amp Circuit Breaker= between house mains and House Distribution board.
Flow line fuses will be attached along the transmission and distribution line for proper isolation.

Panel Arrangement
The solar panels are designed to be arrayed 5 panels per stand, resulting in 8 stands for the total number of 40 panels in the system.

VII. Project Time Line
The project is intended to be roll out as follows;
Month One
Advertising of Project staff positions
Meeting with university administrators
Finalizing location of power house
Selection/hiring of remaining Project staff members
Preparation for project operation

Month Two
Execution of phase 1 of the project
Evaluation of progress

Month Three
Execution of phase 2 of the project
Evaluation of project operation

Month Four
Execution and evaluation of phase 3 of the project
Preliminary advertising/ publicity of project operations
Hosting community meetings
Recruitment/selection/training of student volunteers

Month Five – Twelve
Execution of phase four of the project
Conducting of regular formative evaluation
Final summative evaluation at end of twelfth month

The execution of phases 3 & 4 of the project will continue after the end of the first year of project execution.
Currently, the project team is working with the IEEE Humanitarian Technology Network HTN towards its implementation. Through adequate publicity, the project team intends to advocate the benefits of
widespread implementation of renewable energy solutions within the country and beyond. Included in the project scope is a sensitization scheme to educate the benefiting community(s) on basic electricity principles and optimal utilization of the system.

VIII. CONCLUSION
It is no longer news that the Nigerian power sector needs to be repositioned so as to meet up with challenges in the global scene. In this paper, the current situation of the Nigerian power sector was reviewed highlighting her generation and consumption capacity. Also, the various sources of renewable energy were discussed with predominant emphasis on solar electricity. Most importantly, the paper presents design details for the deployment of micro scaled solar electricity to remote off-grid settlements in Nigeria.

IX. REFERENCES