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Life Cycle Cost Analysis for the Economic Viability for Solar and National Grid for Powering BTS

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Abstract
In this work, an analysis of BTS power supply cost between solar photovoltaic (PV) system and National Grid in Nigeria. The BTS power supply cost analysed include cost of BTS power equipment acquisition, operation and maintenance.The methodology used in this work was to visit a BTS and access the load demand. The demand was now used to compute the life cycle cost for PV system and the National grid system. The result obtained shows that the cost of the National grid system was ₦47, 665,843.00 which was far cheaper compare to solar PV at ₦239.51M but because National grid power is epileptic and unsatisfactory. Solar PV is proposed to be used to power BTS in Nigeria
Keywords:photovoltaic system, National Grid, Base Transceiver Station, Life Cycle Cost, Solar Array etc.

LIST OF ABBREVIATIONS/ NOMENCLETURE

- BTS – Base Transceiver Station
- C – Capacity of Total Batteries
- Cb – Capacity of one Battery
- E – Load demand
- Er – Energy required
- Esafe – Safe Energy
- Fsafe – Safety factor
- GSM – Global System for Mobile Communication
- Idc – Current for all modules
- Isc – Short circuit Current
- MDOD – Maximum Dept of Discharge
- NCC – Nigeria communication Commission
- PV - Photovoltaic
- RE – Renewable Energy
- Tmin – Sunshine hour
- Lcca= life cycle cost analysis
- Vb – Battery rated Voltage
- V_{DC} - Direct voltage
- Vr – module rated voltage
- Wh – Watt hour
- WKh- Kilowatt hour
- η_T – Total product efficiencies (Inverters, Regulators, Batteries)
- D – Days of Autonomy(Days of no sunshine)
- NWS- Net work service
- LRC-Life cycle replacement cost
- ARC-Annual replacement cost
- E_R-Escalation rate (inflation)
- D_R- Discount rate
- N- Life cycle period
- LMC- life maintenance cost
- AMC-Annual maintenance cost
- CT- Total cost
- CC-Capital cost

- LFC- life fuel cost
- Fe- Escalation value
- AFC-Annual fuel cost
- LEC- Life energy cost
- AEC- Annual energy cost

ASSUMPTIONS

The economic parameters assumed for this case study are mostly from base station operator in Benin City.

- Load = 310.566KWh
- Average monthly sunshine hours = 6hrs/day
- Solar system operating voltage =48Vdc
- Modules support structures, cables battery house, lightning arrestor etc =5% of modules cost
- Interest rate = 10.8% [Oyakhilomen, O and grace, Z,R 2014]
- Inflation rate= 10.8% [Oyakhilomen, O and grace, Z,R 2014]
- System life span =30years [Benjamin O. Agajelu et al 2013, Microsoft,2010]
- Battery depth of discharge = 90%
- Battery life span = 5years
- Inverter life span = 10years
- Charge controller life span = 10years

1. JUSTIFICATION FOR THE WORK

Electricity supply in Nigeria has remained unsatisfactory despite the huge investment put into the sector by the Government. The network providers are striving to provide effective services with affordable tariffs especially in the remote areas where they are no power at all. The use of alternative sources of energy to power base station in rural areas readily comes to mind.

LCC analysis is used to compare solar powered BTS with that of the National grid with a view to determine the economic viabilities of power.

2. INTRODUCTION

Obtaining a reliable cost effective power solution for the worldwide expansion of telecommunication into rural and remote areas presents a very challenging problem. Grids are either not available or their extensions can be extremely costly in remote areas. Most of these base stations are in rural areas with or without any power supply from the national grid with two diesel generators as back up source in case of power failure or outages. [Wale Kadeba] In addition, some sites are so far from the point where diesel can be obtained that they required tanks to store up to three months fuel. The initial costs are low for conventional powering systems of sites which require significant maintenance, high fuel consumption and delivery costs due to hike in fuel price especially diesel.

Using renewable energy source (solar power) as an alternative power source is more cost effective in the long run for a 25-30 year of life span and no pollutions and environmentally friendly over the conventional diesel generator. [Wale Kadeba] The air pollution, Co_2 emission and the harmful gasses from conventional diesel generators on the environments can be reduced by using renewable energy source as alternative power.

The present use of conventional power is assumed to be the reason for the high cost of tariff while the use of renewable energy source in running telecommunication BTS will enhance overall system efficiency through improved sustainable energy, service delivery, network performance, and reduced/stabilized GSM tariff payment plan for subscribers.

Life cycle cost analysis economic tool was used to compare proposed solar powered BTS with the conventional method and National grid with a view to determine the economics of solar over diesel generator sets. Solar investments become very attractive after ten years.

3. PREVIOUS WORK

Mohanlal Kolhe et al (2002) in a paper economic viability of stand-alone solar photovoltaic system in comparison with diesel powered system in India, stated that the cost of PV systems decreases and diesel cost increase, the break even points occur at higher energy demand.

Bejamin O. Agajelu et al (2013) in a paper Life cycle cost analysis of a Diesel/Photovoltaic hybrid power generating system stated that the economic analysis shows that the hybrid system has the least life cycle cost and cost of energy out of the three power system considered.

Bala E.J, et al (2008) in a paper assessment of diesel generator and solar PV for the use in the Global System mobile (GSM) phone industry in Nigeria showed that the solar PV is less costly to be deployed in the phone industry for period over five years.

Sheeraz Kirmani; et al (2010) in a paper techno economic feasibility analysis of a standalone PV system to electrify a rural area household in India, stated that the Life cycle analysis conducted to assess the economic viability of the system shows that it is encouraging to use the PV systems to electrify the rural sites in India.

4. ADVANTAGES OF THIS WORK

All previous work has nothing to do with BTS. Their works dealt excessively on residential buildings. This study concentrated BTS at both remote and urban sites. The power consumption of the sites considered are much higher than other previous works.

5. METHODOLOGY

The methodology adopted in this research work are:

a) The base transceiver station located at Ahor community Quarter, Benin bypass (along the express road) Benin City, Nigeria was visited and the load demand assessed. This is shown in Table 1.
b) A cost analysis using life cycle cost was carried out to evaluate the economics of the system and to compare solar with National grid.
c) Sizing of both solar and National grid were computed.

Table I: Base Station Load Demand – Remote Site: Ahor Community Benin Bypass (Along The Express Road): Solely On Generator Set.

S/N	DESCRIPTION	MODEL	TYPE OF VOLTAGE	POWER RATING (Watts)	HOURS USED	DAILY KWh USED
1	Air conditioner	LG	AC	1672	24	40.13
2	Multiplexer	Emerson	DC	480	24	11.52
3	Fluorescent Tube	Philips	AC	38	12	0.456
4	Base Transceiver	Ericsson	DC	960	24	23.04
5	Rectifier	Emerson	DC	3024	24	72.58
6	Power amplifier	Katherine	DC	6144	24	147.47
7	Converter (48/24)	Ericsson	DC	480	24	11.52
8	Aviation light	Ericsson	AC	25	12	0.30
9	Security light	Ericsson	AC	200	12	2.40
10	Microwave antenna	Huawei	AC	18	24	0.43
11	Pillar antenna (VHF/UHF)	Ericsson	DC	30	24	0.72
	Total average energy used			**13071**	**228**	**310.566**

Location of Base station Ahor, Benin City. Longitude 6^{0} 24$^{/}$ 14.47$^{//}$N AND LATITUDE 5^{0} 40$^{/}$ 46$^{//}$E

6. SIZING OF THE SOLAR ARRAY

Before sizing the array, the total daily energy in Watt-hours (E), the average sun hour per day $T_{min,}$ and the dc-voltage of the system (V_{DC}) must be determined. Once these factors are made available, the PV sizing can be determined. To avoid under sizing, losses must be considered by dividing the total power demand in Watt hour by the product of efficiencies of all components in the system to get the required energy E_r.[mohanlal kolhe el al, 2002]

Complete sizing from Table1 for solar array, inverter, charge controller, battery and wiring brought about numbers of items used for the investment cost generated in Table II below.

Table II: Solar PV Investment Cost for A 17.5KVA Power Station (48Vdc/230Vac)

S/N	Item	Qty	Unit cost (₦)	Total cost (₦m)
1	Modules	520	83,950:00	43,654,000:00
2	Deep cycle Batteries 200AH 12V	640	69,000:00	44,160,000:00
3	Charge Controller	92	48,300:00	4,259,600:00
4	Inverter 3000W, 220Vac	1	68,310:00	68,310:00
5	Supporting structures e.g aviation warning light, installation etc	Lot	5% cost of modules	2,182,700:00
	Total			**94,324,610:00**

6. LCC ANALYSIS OF PV (PHOTOVOLTAIC) SYSTEM

7. BATTERY REPLACEMENT AT 5 YEARS

Mohanlal kolhe el el stated that the life span of a well managed deep cycle battery is five years**.** From table 2 above the initial cost of battery is ₦ 44,160,000:00. Assuming inflation of 10.8%, the cost for five years is ₦ 48, 576,000:00

Cost of battery of 5yrs = ₦ 48,576,000:00

Installation cost for battery only

= ₦ 2,182,700:00/4= ₦ 545,675

LRC=ARCX$\left(\frac{1+Er}{d-Er}\right) x \left\{1-\left[\frac{1+Er}{1+Dr}\right]^{N}\right\}$ [Mohanlal Kolhe, el al.]………………….. [1]

LCR = Life replacement cost

ARC = Annual replacement cost

E_R = Escalation (inflation rate)

A value of 10.8%

D_R = discount factor of 9.5%

N = Life cycle period (0-30 years)

ARC = $\frac{cost\ of\ battery\ for\ the\ year\ of\ replacement+installation}{priod\ of\ replacement}$ ………………………[2]

ARC = $\frac{48{,}576000+545675}{5}$ = ₦ 9,824,335:00

Using LCCA Factor = 5.1380(appendix 1)

LRC = ARC X LCCA Factor

LRC = 9,824,335:00 x 5.1380 = **₦50, 477,433.00**

Battery replacement, N= 10years

Using the same procedure as used for 5years

53.43 + 0.545675 = 53.975675

53.975675/10 = 5.3975675

Multiply by the LCCA factor of 10.5137

We have N56.75 M

Above procedure can be used to calculate for 15, 20, 25 and30 years respectively.

8. REPLACEMENT OF INVERTER FOR EVERY 10 YEARS

The inverter is used for A.C load as it converts D.C TO A.C.

Also from previous work replacement period is ten years.

ARC for inverter = $\frac{cost\ of\ inverter+installation\ cost}{No\ of\ years}$ ……………………………………[3]

ARC_{INV} = $\frac{68310+545675}{10}$ =₦61,398.50

LRC_{INV} = ARC x LCC analysis factor of 10 years……………………………………………[4]

₦61,398.50 x 10.5139

= ₦645,537.69

LRC_{INV} =ARC x LCCA factor of 20years

Using the equation (53) of replacement above

ARC_{INV} = $\frac{68310+545675}{20}$

=₦30,699,25

= N30, 699.25 x 22.0236

= N 676108:00

LRC = ARC x LCC factor of 30 years

= N20, 466:167 x 34.6237

= N 708,612:00

9. REPLACEMENT OF CONTROLLER FOR EVERY 10 YEARS

The controller as the following functions: charges the batteries, switches from solar to batteries depending on the output voltage level, regulates batteries over charge and discharge states level, temperature monitoring etc. Research replacement has be determined at very ten years

Using the same equation for general replacement and LCC analysis factor.

ARC = $\frac{4259600+545675}{10}$

= ₦ 480,527:50

$LRC_{Controller}$ = ₦ 480,527.67 x 10.5137 for 10 yrs (appendix) = **N 5,050,122:00**

$LRC_{controller}$ = ARC x LCC factor of 20 years

$= \frac{4259600+545675}{20}$

= 4805275/20

= 240263.75 x 22.0236

= **N5,291,472.70**

LRC $_{controller}$ = ARC x LCC factor of 30 years

$= \frac{4259600+545675}{30}$

= ₦160175.83 x 34.6236 = **N 5,545,863.90**

10. LIFE MAINTENANCE COST (LMC).

Life maintenance cost of solar is a provision for the minor preventive maintenance which assumed to be 2% of capital cost of annually.

It is a recurring cost and it is given as

LMC =AMC x $\left(\frac{1+Er}{Dr-Er}\right) \times \left[1 - \left\{\frac{1+Er}{1+Dr}\right\}^N\right]$ [Mohanlal Kolhe, el al.2002]

Where,

Er = general escalation rate of 10.8%

Dr. = Discount factor 9%

N = Life cycle period 30 years used

AMC = Annual maintenance cost (2% of capital cost of item)

LMC = Life cycle maintenance cost

AMC = 2% x ₦ 94,324,610

= ₦1, 886,492.20

LMC = AMC x LCCA factor for numbers of years (N) needed.

For N for 30 years

LMC = ₦ 1,886,492.20 x 34.6236

= ₦65, 317,151:00

11. FE REPLACEMENT COST

Life replacement cost consist the overall cost of batteries, inverters controller and installations. Solar is not included because the life span is thirty years.

LRC = ARC x $\left(\frac{1+Er}{Dr-Er}\right) \times \left[1 - \left\{\frac{1+Er}{1+Dr}\right\}^N\right]$

Where: LRC = Life replacement cost

ARC = Annual replacement cost

Er = General escalation (inflation rate).value of 10.5% (CBN December 2011)

Dr = Discount factor, 9.5%

N = the life cycle period (0,1,2-----30years)

ARC = (batteries cost + inverter cost +controller cost + installation cost) / 30

Installation cost = N 1637025

ARC = 44160000+68310+4259600+1637025 / 30 = N 1670831.20

LRC = LCC factor of 30years x N 1670831.20 = 34.6236 x N 1670831.20

= **N 57,850,191.00**

12.COSTS PER KWH

Cost per KWh of PV solar system is given as

$$C_T = \frac{CC+LFC+LMC+LRC}{N \times 365 \times KWh} \quad \text{.....................[5]}$$

Where

C_T = Total cost per KWh

CC = Capital cost = ₦94, 324,610

LFC = Life fuel cost ₦00

LMC = Life maintenance cost = ₦65, 317,151:00

LRC = Life replacement cost = ₦ 57,850,191.00

$KWhday^{-1}$ = 310.566KWh

$$C_T = \frac{94324610{:}00+65317151{:}00+5785019100}{30 \times 365 \times 310.566} = 63.955097$$

C_T= ₦63.96 per KWh

Table III: LCC of Solar P.V. System (Cost In Million Naira)

Years	1	2	5	7	10	13	15	17	20	23	25	30
Capital investment												
Solar panel	43.65	43.65	43.65	43.65	43.65	43.65	43.65	43.65	43.65	43.65	43.65	43.65
Battery	44.16	44.16	48.58	48.58	53.43	53.43	58.78	58.78	64.65	64.65	71.12	78.23
Inverter	0.068	0.068	0.068	0.068	0.075	0.075	0.075	0.075	0.083	0.083	0.083	0.092
Controller	4.26	4.26	4.26	4.26	4.69	4.69	4.69	4.69	5.15	5.15	5.15	5.67
Sundry	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18	2.18
O & M												
Three attendants	0.72	0.79	1.16	1.40	1.87	2.49	3.01	3.64	4.86	6.47	7.83	12.60
Battery Replacement			50.47	50.47	56.75	56.75	63.85	63.85	71.80	71.80	80.78	90.92
Controller Replacement					5.05	5.05	5.05	5.05	5.29	5.29	5.29	5.46
Inverter replacement					0.65	0.65	0.65	0.65	0.68	0.68	0.68	0.71
Grand Total	**90.78**	**95.11**	**150.36**	**150.60**	**168.35**	**169.00**	**181.94**	**182.57**	**198.34**	**199.95**	**216.76**	**239.51**

13.LCC ANALYSIS OF GRID SUPPLY (PHCN)

Kwh of energy in Nigeria cost ₦11.36 for a commercial consumer in addition a meter maintenance charge of ₦750.00 and fixed charge ₦1,200.0 per month with inflation rate of 10.5%.

Life energy cost (LEC) = AECX $\left\{\left(\frac{1+Fe}{Dr-Fe}\right) \times \left[1 - \langle\frac{1+Fe}{1+Dr}\rangle^{N}\right]\right\}$ [Mohanlal Kolhe, el al]………..[6]

AEC = yearly cost per kWh x yearly fixed charge + yearly maintenance charge

KWh/day^{-1} = 310.655KWh

Cost per KWh = ₦11.36

Cost per KWh/day = 310.566 x 11.36 = N3528.03

Cost of KWh/year = 3428.03 x 365 = ₦ 1,287,730.90

Fixed charge per month = N1200

Fixed charge per year = ₦1200 x 12 = N14, 400.00

Cost of maintenance per month = ₦750.00

Yearly maintenance = ₦750.00 x 12 = ₦9, 000.00

AEC = 1, 287730.90+ 14,400.00 + 9000.00 **= ₦1, 311,130** = ₦ 1311130x5% VAT

= ₦ 1,376,686.50

LEC = AEC x LCC A factor of 30 years

= ₦ 1,376,686.50, x 34.6236

= ₦47, 665,843.00

14.COSTS PER KWH FOR NATIONAL GRID.

$$C_G = \frac{LEC}{Period \times 365 \times KWh}$$

$$C_G = \frac{47665743}{30 \times 365 \times 310.566}$$ **= N14.02/KWh**

15.DISCUSSIONS OF RESULTS

From the result in Table 1 it was observed that the annual power consumption for a BTS is **113,356,590Wh (113.3566MWh).** Considering Nigeria of about **30,000BTS,** (as at time of this research case study the total average power consumption will be **3400697700Wh (3.4007TWh)** units. It was noted that the power consumptions of power amplifier at **147.47KWh** was the highest followed by that of rectifier at **72.58KWh** and air conditioner at **40.13KWh.** The economic viability of the system was done carefully using Life Cycle Cost analysis calculation of Solar P.V. system, and National grid system. Table 3 shows that the initial cost for P.V system is **₦94,324,610:00.** This because solar energy components are very expensive and imported except for cables and other accessories.

It is well known fact that the National grid is very unreliable and epileptic, this has eventually made mandatory for network providers to generate power through the use of generators for their BTS sites. Previous work by Ezomo P.I and Otasowie P.O, in the paper 'BTS power consumption cost reduction using solar PV system in Nigeria revealed that for power outage hour observed for six months of 1,728 hours cost **₦552,960:00** of diesel consumption at the of **160:00** Naira per litre. When translated to one year it is **₦ 1, 105,920:00.** With 30,000 BTS in Nigeria and 60,000 generator sites the gross total cost diesel consumed for one year is ₦

66,355,200,000:00 (₦66.355 Billion). While cost PV remains at the cost of ₦ **94,324,610:00.** The LLC cost for PV solar and National grid is **N90.78** and **₦47.67** respectively. PV system is higher than the National grid. With back up of generators sets and diesel consumption the cost of National grid become very high compare to solar PV system.

The cost per KWh for PV is **₦63.96** while National grid is **N14.02.** When other factors like logistic, pilfering of petroleum products, hike in diesel due to scarcity, unstable political environment, epileptic power failure, therefore for a longer period of time, solar become the cheapest means for powering base transceiver station.

16.CONCLUSION

From Table II the initial cost of installation of solar energy system is high. Considering LLC used the cost of powering BTS at the remote location with National grid is higher when compared with the installation of PV system. The stand alone solar energy to power BTS is a viable alternative to power base station at urban/rural area considering fuel consumption and associated problems such as operation and maintenance, hike in price of product due scarcity pilfering of product and others. Solar PV system is less expensive in cost because it attracts less maintenance at minimal cost as there are no moving parts. From the LCC analysis conducted to assess the economic viability, the result shows that the solar system should be encouraged to power remotely located BTS. This investment will go a long way to reduce tariff and energy efficiency.

Finally, Nigeria is endowed with abundance of solar energy resources. Nigeria lies within a high sunshine belt and thus has enormous solar energy potentials. Solar radiation is fairly well distributed with average solar radiation of about 19.8MJm-^{2}day^{-1} and average sunshine hours of 6 hour per day. It is possible to generate 185x103GWh of solar electricity per year. This is over hundred times the current National grid electricity consumption level in the country [Emmanuel O Akinpelu,]

These resources could be harnessed along side with energy efficiency to stimulate economic growth and social development as well as energy sustainability. The use of solar energy to power BTS will go a long way.

REFERENCES

[1] Aboaba, A. Abdultattah, power management scheme for wireless telephony services provider, continental Journal of Engineering sciences vol. 3, pp 72-79 2008
[2] Bala E.J. elecetra. Assessment of Diesel Generator and Solar PV for Use in the Global System Mobile (GSM) Phone Industry in Nigeria. Nigerian Journal of Solar Energy 2008 vol.19-1 pp. 94-98.
[3] Benjamin O. Agajelu et al. life cycle cost analysis of a Diesel/photovoltaic hybrid power generating system. Industrial Engineering letters 2013 vol. 3. No. 1 pp. 19-30
[4] Life Cycle Cost Analysis Manual 1991. State of Illinois Capital Development Board.
[5] Mohammed Abubakar Mawoli, Liberalisation of the Nigeria telecommunication sector; A critical review. Transcampus interdisciplinary Research and study group Journal of research in national development vol 7 no 2 December 2009.
[6] Mohanlal Kolhe, el al. Economic viability of stand-alone solar photovoltaic system in comparison with diesel-powered system for India. Energy economics 2002 vol 24 pp 155-165.
[7] Morea F, el al. Life cycle Cost evaluation of Off-Grid PV-Wind Hybrid Power systems. Telecommunication Energy Conference, 2007. INTELEC 2007 IEEE 29th International. Pp.439 441.
[8] Oyakhilomen Oyinbo and Grace Z. Rehwot. The relationships of inflationary Trend, Agricultural Productivity and Economic Growth in Nigeria. CBN Journal of Applied statistics Vol. 5, No.1 June 2014.
[9] Sheeraz Kirmani et al. Techno economic feasibility analysis of a standalone PV system to electrify a rural area household in India. International Journal of Engineering Science and Technology Vol. 2(10), 2010, pp 5231-5237
[10] Telecom Operator; suggest solar, gas, as alternative energy sources. Punch Sunday, 19th June 2011
[11] Emmanuel O Akinpelu, Sizing and cost assessment of solar P V system for energy supply to telecom industry in Nigeria, Journal of Engineering and a applied sciences vol. 6(2) pp 130-134, 2011