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BTS Power Consumption Cost Reduction Using Solar PV System in Nigeria

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Abstract

This paper presents solar photovoltaic (PV) system as the cheapest means of powering base transceiver station (BTS) in Nigeria. There are many schemes that can be used to provide power to BTS. They include solar photovoltaic (Solar PV) system, Diesel generator, Power Holding Company of Nigeria (PHCN) and Batteries. In Nigeria many base transceiver stations (BTS) are provided power with diesel generators because PHCN (National grid) supply is very epileptic and unreliable. This makes the cost of Global System for Mobile Communication (GSM) services to be very high.

The methodology used in this work was to visit a certain GSM base station in Benin City, Edo State of Nigeria to obtain information on the type of equipment located in the Base Station and their load demand. The daily power outage of the base station was recorded daily for six months from May to October 2011

These data were analysed and the cost of powering the base station with solar PV system and diesel generator were compared. It was found that the cheapest means of powering a base transceiver station is power supplied by solar photovoltaic system at a cost of N46767160:00.

***Keywords*:** Solar photovoltaic system, diesel generator, base transceiver station power outage, load demand.

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
- Nm – Total numbers of Solar panel
- Np – Number of Solar panel in parallel
- Ns – Number of Solar panel in series
- P_P – Peak power
- PV - Photovoltaic

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- RE – Renewable Energy
- Tmin – Sunshine hour
- 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)

1.0 Justification for the Work

The cost of Global System for Mobile Communication (GSM) services in Nigeria for both voice and data are very high. This high cost in GSM services are due to several reasons such as cost of power consumption at the Base Transceiver Station, cost of installation of facilities and acquiring/ leasing of site locations, operation and maintenance cost of equipment and facilities. The most expensive in all these costs is cost of powering the BTS with diesel generators hence this paper present the cheapest means of providing the BTS with solar PV system

1.1 Introduction

Telecommunications infrastructure is the most important infrastructural facility for the economic development in all Nations in the World. It is the life wire of other sectors of any economy and is indispensable in cases of National Emergency and Disaster Management for a developing country like Nigeria, the establishment and maintenance of an adequate, functional and efficient telecommunication system is imperative. More so there is the need to participate effectively in the emerging global communication market [1]

The Nigeria Telecommunication sector was partially and fully liberalized in 1992 and 1999 respectively. After the liberalization and introduction of Global System for mobile Communication [GSM] in 2001 during the third republic under the leadership of President Olushegun Obasanjo [1999-2007] where the Nigeria Communication Commission (NCC) was given the mandate to license mobile service provider, the Nigeria Telecom Market became the biggest and fastest growing in Africa and the eight fastest growing in the world [1]. NCC has granted license to various Telecom Operators (MTN, AIRTEL, GLOBACOM, MTEL, ETISALAT) to provide GSM services. Code Division Multiple Access (CDMA) network license was also granted to some operators (STARCOM, MULTILINK, and ZOOM) to mention a few.

The telecom sector had improved service quality, attracted foreign direct investment and employment generation. However the operation cost and service tariffs of telecom companies are still very high as a result of the inefficient and unreliable power supply in the country.

A base transceiver station (BTS) is an integral part of the GSM network. A BTS links the major hub and the mobile phone users. The major hops are themselves linked to the mobile switching centre via backbone sites. A BTS is fixed station in a mobile radio communication system. It is located at the centre or the edge of air coverage area and consists of radio channel and transmitting and receiving antennae mounted on a tower. Many of these base stations are kept in operation in rural/urban areas with or without power supply from the National grid and have two diesel generators as back up source in case of power failure or outages. In rural areas two diesel generators are installed to allow for continuous generation of energy in the event that one generator fails. 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 worth of fuel worth. According to the Nigeria Communication Commission (NCC), the total number of telecommunication base transceiver stations installed by network operators currently stands at over 25,000 [2]. Enormous cost is involved in the running of the BTS with diesel generators.

Photovoltaic (PV) system is a method of generating electrical power by converting solar radiation in direct current electricity using semiconductors that exhibit the photovoltaic effect. Photovoltaic power generation employs solar panels composed of a number of solar cells containing a photovoltaic material [3].

Diesel generators of 17KVA or 18KVA are also used to power base transceiver station equipment. These generators are usually associated with the following; (i) make a lot of noise. (ii) Consume a lot of diesel-sometimes 2 litres or 2.5 litres per hour. (iii) The fumes from the generator pollutes the environment (iv) diesel are usually stolen at the base transceiver station.

2.0 Previous Work

In a study by infinite focus group on solar power, it was presented that a typical telecommunication operator with 10,000 BTS spends over 1.2 billion dollars on diesel within a ten year period. This cost excludes inflation, maintenance and other associated costs. [4]. This study reveals that the cost of using diesel generators to power GSM Base Station equipment is very high.

Otasowie and Evbomwan[5], in a paper Energy Cost reduction in GSM Base Station in Nigeria reveals that the cheapest and most efficient power scheme for base station in Nigeria is power supplied by PHCN and batteries. This scheme is not practicable because power supply by PHCN is epileptic and unreliable.

3.0 Methodology

In this work, the base transceiver station located at Amayo Quarter, Off Upper Sakponba road Benin-city, Nigeria was visited and the load demand assessed. The power outage for six months from May to October 2011 was recorded as shown in Tables 1 to 8.

Table 1: Base Transceiver Station Equipment and Their Ratings/Hours Used

S/ N	DESCRIPTION	MODEL	QUANTITY	POWER RATING (Watts)	HOURS USED	DAILY HOUR USED (KWh)
1	Air conditioner	LG	2	1492	24	35.81
2	Base Transceiver/3G	Huawei	1	2400	24	57.60
3	Bulb	Philips	2	120	12	1.44
4	Rectifier	Kathrein	1	1800	24	43.20
5	Radio	Kathrein	2	480	24	11.52
6	Aviation light	Ercsson	1	25	12	0.30
7	Security Light	Ericsson	1	200	12	2.40
8	Microwave antenna	Ericsson	4	18	24	0.43
9	Pillar antenna (VHF/UHF)	Huawei	2	20	24	0.48
	Total average energy consumption			**6555**	**180**	**153.180**

Table 2: PHCN daily hour outage in the base station at Amayo Quarter, Off Upper Sakponba Benin City in May 2011

	DAYS OF THE MONTH																														
TIME	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	
12.00-1.00am	X	X	X	X	X	X				X	X	X	X	X	X	X		X							X	X	X	X	X			
1.00am-2.00am	X	X			X	X			X	X	X	X	X	X	X			X							X		X					
2.00am-3.00am	X				X	X			X	X	X			X																		
3.00am-4.00am									X	X	X																					
4.00am-5.00am										X	X																					
5.00am-6.00am						X	X	X		X	X																					
6.00am-7.00am	X					X	X	X		X	X						X		X	X		X										
7.00am-8.00am	X									X	X						X		X	X		X										
8.00am-9.00am	X	X								X	X					X	X	X	X	X		X		X	X			X	X			
9.00am-10.00am	X	X								X	X					X		X	X	X	X	X		X	X			X	X			
10.00am-11.00am	X	X								X	X					X	X	X	X	X	X	X		X	X			X				
11.00am-12.00am	X	X	X							X	X					X	X	X	X	X	X	X		X	X			X				
12.00-1.00pm	X	X	X							X	X					X	X	X	X	X	X	X		X	X							
1.00pm-2.00pm	X		X							X	X					X	X		X	X	X	X		X	X							
2.00pm-3.00pm										X	X					X	X		X	X	X	X		X								
3.00pm-4.00pm										X	X					X	X		X	X	X	X		X								
4.00pm-5.00pm										X	X					X	X		X	X	X	X		X		X	X	X				
5.00pm-6.00pm		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X		X	X	X	X			
6.00pm-7.00pm		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X		X		X	X	X	X			
7.00pm-8.00pm	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X		X	X	X					X					
8.00pm-9.00pm	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X					X					
9.00pm-10.00pm	X		X	X	X	X	X	X	X	X	X			X	X	X	X	X		X	X	X				X		X				
10.00pm-11.00pm	X		X	X	X	X	X	X	X	X	X			X	X		X	X			X	X				X		X				
11.00pm-12.00pm	X		X	X	X	X				X	X			X	X		X	X			X					X		X				
TOTAL	16	11	10	8	10	12	8	8	8	24	24	6	4	10	9	15	17	14	12	16	13	17	NIL	11	8	7	7	10	5	NIL	NIL	320

DIESEL PRICE = 160 NAIRA TOTAL DIESEL CONSUMPTION=320X2=640LITRES X MEANS POWER OUTAGE
CONSUMPTION=2.00LITRE/HOUR COST OF DIESEL= 160 X 640 =N102,400:00

Table 3: PHCN daily hour outage in the base station at Amayo Quarter, Off Upper Sakponba Benin City in June 2011

	DAYS OF THE MONTH																															
TIME	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
12.00-1.00am											X		X		X		X		X		X		X		X							
1.00am-2.00am											X		X		X		X		X		X		X		X							
2.00am-3.00am											X		X		X		X		X		X		X									
3.00am-4.00am											X		X		X		X		X		X		X									
4.00am-5.00am											X		X		X		X		X		X		X									
5.00am-6.00am											X		X		X		X		X		X		X									
6.00am-7.00am											X		X		X		X		X		X	X	X									
7.00am-8.00am											X		X		X		X		X		X	X	X									
8.00am-9.00am											X		X		X		X		X		X	X	X	X	X							
9.00am-10.00am											X		X		X		X		X		X	X	X	X	X							
10.00am-11.00am											X		X		X		X		X		X	X	X	X	X							
11.00am-12.00am											X		X		X		X		X		X	X	X	X	X							
12.00-1.00pm											X		X		X		X		X		X	X	X	X	X							
1.00pm-2.00pm											X		X		X		X		X		X	X	X	X	X							
2.00pm-3.00pm											X		X		X		X		X		X	X	X	X								
3.00pm-4.00pm											X		X		X		X		X		X	X	X	X								
4.00pm-5.00pm											X		X		X		X		X		X	X	X	X								
5.00pm-6.00pm				X	X	X	X	X	X		X		X		X		X		X		X	X	X	X								
6.00pm-7.00pm				X	X	X	X	X	X		X		X		X		X		X		X	X	X	X								
7.00pm-8.00pm				X	X	X	X	X	X		X		X		X		X		X		X	X	X									
8.00pm-9.00pm				X	X	X	X	X	X		X		X		X		X		X		X	X	X									
9.00pm-10.00pm				X	X	X	X	X	X		X		X		X		X		X		X	X	X									
10.00pm-11.00pm				X	X	X	X	X	X		X		X		X		X		X		X	X	X									
11.00pm-12.00pm				X	X	X	X	X	X		X		X		X		X		X		X	X	X									
TOTAL	**NIL**	**NIL**	**NIL**	**7**	**7**	**7**	**7**	**7**	**7**		**24**		**24**		**24**		**24**		**24**		**24**	**18**	**24**	**11**	**8**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**247**

DIESEL PRICE = 160 NAIRA TOTAL DIESEL CONSUMPTION=247X2= 494LITRES X MEANS POWER OUTAGE

CONSUMPTION=2.00LITRE/HOUR COST OF DIESEL= 160 X 494 =N79,040:00

Table 4: PHCN daily hour outage in the base station at Amayo Quarter, Off Upper Sakponba, Benin City in July 2011

DATE/TIME	DAYS OF THE MONTH																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
12.00-1.00am									X	X	X	X						X								X	X	X	X		X	
1.00am-2.00am									X	X	X	X						X									X		X		X	
2.00am-3.00am									X	X	X																		X		X	
3.00am-4.00am									X	X	X																		X		X	
4.00am-5.00am									X	X	X																		X		X	
5.00am-6.00am									X	X	X																		X		X	
6.00am-7.00am									X	X	X								X	X		X							X		X	
7.00am-8.00am	X	X	X	X	X	X	X	X	X	X	X								X	X		X							X		X	
8.00am-9.00am	X	X	X	X	X	X	X	X	X	X	X							X	X	X		X		X	X			X	X		X	
9.00am-10.00am	X	X	X	X	XX	X	X	X	X	X	X							X	X	X	X	X		X	X			X	X		X	
10.00am-11.00am	X	X	X	X	X	X	X	X	X	X	X							X	X	X	X	X		X	X			X	X		X	
11.00am-12.00am	X	X	X	X	X	X	X	X	X	X	X							X	X	X	X	X		X	X			X	X		X	
12.00-1.00pm	X	X	X	X	X	X	X	X	X	X	X							X	X	X	X	X		X	X				X		X	
1.00pm-2.00pm	X	X	X	X	X	X	X	X	X	X	X								X	X	X	X		X	X				X		X	
2.00pm-3.00pm	X	X	X	X	X	X	X	X	X	X	X								X	X	X	X		X	X				X		X	
3.00pm-4.00pm	X	X	X	X	X	X	X	X	X	X	X								X	X	X	X		X	X				X		X	
4.00pm-5.00pm	X	X	X	X	X	X	X	X	X	X	X								X	X	X	X		X			X	X	X		X	
5.00pm-6.00pm	X	X	X	X	X	X	X	X	X	X	X	X						X	X	X		X		X			X	X	X		X	
6.00pm-7.00pm	X	X	X	X	X	X	X	X	X	X	X	X						X		X		X		X			X	X	X		X	
7.00pm-8.00pm									X	X	X	X						X		X	X	X					X		X		X	
8.00pm-9.00pm									X	X	X	X						X		X	X	X					X		X		X	
9.00pm-10.00pm									X	X	X	X						X		X	X	X				X		X	X		X	
10.00pm-11.00pm									X	X	X	X						X			X	X				X		X	X		X	
11.00pm-12.00pm									X	X	X	X						X			X					X		X	X		X	
TOTAL	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**12**	**24**	**24**	**24**	**9**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**14**	**12**	**16**	**13**	**17**	**NIL**	**11**	**8**	**4**	**7**	**10**	**24**	**NIL**	**24**	**337**

DIESEL PRICE = 160 NAIRA
CONSUMPTION=2.00LITRE/HOUR

TOTAL DIESEL CONSUMPTION=337X2=674LITRES
COST OF DIESEL= 160 X 674 =N107,440:00

X MEANS POWER OUTAGE

Table 5: PHCN daily hour outage in the base station at Amayo Quarter, Off Upper Sakponba Benin City in August 2011

	DAYS OF THE MONTH																															
DATE/TIME	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	
12.00-1.00am	X	X	X	X	X	X	X									X		X							X	X	X	X	X			
1.00am-2.00am	X	X	X		X	X	X											X							X		X					
2.00am-3.00am	X		X		X	X	X																									
3.00am-4.00am																																
4.00am-5.00am																																
5.00am-6.00am								X																								
6.00am-7.00am	X		X					X									X		X	X		X								X	X	
7.00am-8.00am	X		X					X									X		X	X		X							X	X	X	
8.00am-9.00am	X	X	X					X								X	X	X	X	X		X		X	X			X	X	X	X	
9.00am-10.00am	X	X	X													X		X	X	X	X	X		X	X			X	X	X	X	
10.00am-11.00am	X	X	X													X	X	X	X	X	X	X		X	X			X	X	X	X	
11.00am-12.00am	X	X	X													X	X	X	X	X	X	X		X	X			X	X	X	X	
12.00-1.00pm	X	X	X													X	X	X	X	X	X	X		X	X				X	X	X	
1.00pm-2.00pm	X		X													X	X		X	X	X	X		X	X				X	X	X	
2.00pm-3.00pm																X	X		X	X	X	X		X					X	X	X	
3.00pm-4.00pm																X	X		X	X	X	X		X					X	X	X	
4.00pm-5.00pm																X	X		X	X	X	X		X		X	X	X	X	X	X	
5.00pm-6.00pm		X		X	X	X	X	X								X	X	X	X	X		X		X		X	X	X	X	X	X	
6.00pm-7.00pm		X	X	X	X	X	X	X								X	X	X		X		X		X		X	X	X	X	X	X	
7.00pm-8.00pm	X	X	X	X	X	X	X	X								X	X	X		X	X	X					X		X	X	X	
8.00pm-9.00pm	X	X	X	X	X	X	X	X								X	X	X		X	X	X					X					
9.00pm-10.00pm	X		X	X	X	X	X	X								X	X	X		X	X	X				X		X				
10.00pm-11.00pm	X		X	X	X	X	X	X									X	X			X	X				X		X				
11.00pm-12.00pm	X		X	X	X	X	X	X									X	X			X					X		X				
TOTAL	**16**	**11**	**17**	**8**	**10**	**10**	**10**	**11**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**15**	**17**	**14**	**12**	**16**	**13**	**17**	**NIL**	**11**	**8**	**7**	**7**	**10**	**14**	**14**	**14**	**282**

DIESEL PRICE = 160 NAIRA

CONSUMPTION=2.00LITRE/HOUR

TOTAL DIESEL CONSUMPTION=282X2=564LITRES

COST OF DIESEL= 160 X 564 =N90,240:00

X MEANS POWER OUTAGE

Table 6: PHCN daily hour outage in the base station at Amayo Quarter, Off Upper Sakponba Benin City in September 2011

DATE/TIME	DAYS OF THE MONTH																														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	
12.00-1.00am		X	X	X	X	X				X	X	X	X	X	X	X		X							X	X	X	X			
1.00am-2.00am		X			X	X			X	X	X	X	X	X	X			X							X		X				
2.00am-3.00am					X	X			X	X	X			X																	
3.00am-4.00am									X	X	X																				
4.00am-5.00am										X	X																				
5.00am-6.00am						X	X	X		X	X																				
6.00am-7.00am	X					X	X	X		X	X						X		X	X		X									
7.00am-8.00am	X									X	X						X		X	X		X									
8.00am-9.00am	X	X								X	X					X	X	X	X	X		X		X	X			X			
9.00am-10.00am	X	X								X	X					X		X	X	X	X	X		X	X			X			
10.00am-11.00am	X	X								X	X					X	X	X	X	X	X	X		X	X			X			
11.00am-12.00am	X	X	X							X	X					X	X	X	X	X	X	X		X	X			X			
12.00-1.00pm	X	X	X							X	X					X	X	X	X	X	X	X		X	X						
1.00pm-2.00pm	X		X							X	X					X	X		X	X	X	X		X	X						
2.00pm-3.00pm										X	X					X	X		X	X	X	X		X							
3.00pm-4.00pm										X	X					X	X		X	X	X	X		X							
4.00pm-5.00pm										X	X					X	X		X	X	X	X		X		X	X	X			
5.00pm-6.00pm		X		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X		X	X	X	X		
6.00pm-7.00pm		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X		X		X		X		X	X	X	X		
7.00pm-8.00pm	X	X	X	X	X	X	X	X		X	X	X		X	X	X	X	X		X	X	X					X		X		
8.00pm-9.00pm	X	X	X	X	X	X	X	X	X	X	X	X		X	X	X	X	X		X	X	X					X				
9.00pm-10.00pm	X		X	X	X	X	X	X	X	X	X			X	X	X	X	X		X	X	X				X		X			
10.00pm-11.00pm			X	X	X	X	X	X	X	X	X			X	X		X	X			X	X				X		X			
11.00pm-12.00pm			X	X	X	X				X	X			X	X		X	X			X					X		X			
TOTAL	**11**	**11**	**10**	**8**	**10**	**12**	**8**	**8**	**8**	**24**	**24**	**6**	**4**	**10**	**9**	**15**	**17**	**14**	**12**	**16**	**13**	**17**	**NIL**	**11**	**8**	**7**	**7**	**10**	**3**	**NIL**	**313**

DIESEL PRICE = 160 NAIRA
CONSUMPTION=2.00LITRE/HOUR
TOTAL DIESEL CONSUMPTION=313X2=626LITRES
COST OF DIESEL= 160 X 626 =N100,160:00
X MEANS POWER OUTAGE

Table 7: PHCN daily hour outage in the base station at Amayo Quarter, Off Upper Sakponba Road Benin City in October 2011

DATE/TIME	DAYS OF THE MONTH																															
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
12.00-1.00am												X	X	X	X	X		X							X	X	X	X	X	X	X	
1.00am-2.00am												X	X	X	X										X		X			X	X	
2.00am-3.00am														X																X	X	
3.00am-4.00am																														X	X	
4.00am-5.00am																														X	X	
5.00am-6.00am																														X	X	
6.00am-7.00am																	X		X	X		X								X	X	
7.00am-8.00am																	X		X	X		X								X	X	
8.00am-9.00am																X	X	X	X	X		X		X	X			X	X	X	X	
9.00am-10.00am																X		X	X	X	X	X		X	X			X	X	X	X	
10.00am-11.00am																X	X	X	X	X	X	X		X	X			X		X	X	
11.00am-12.00am																X	X	X	X	X	X	X		X	X			X		X	X	
12.00-1.00pm																X	X	X	X	X	X	X		X	X					X	X	
1.00pm-2.00pm																X	X		X	X	X	X		X	X					X	X	
2.00pm-3.00pm																X	X		X	X	X	X		X						X	X	
3.00pm-4.00pm																X	X		X	X	X	X		X						X	X	
4.00pm-5.00pm																X	X		X	X	X	X		X		X	X	X		X	X	
5.00pm-6.00pm												X	X	X	X	X	X	X	X	X		X		X		X	X	X	X	X	X	
6.00pm-7.00pm												X	X	X	X	X	X	X		X		X		X		X	X	X	X	X	X	
7.00pm-8.00pm												X		X	X	X	X	X		X	X	X					X			X	X	
8.00pm-9.00pm												X		X	X	X	X	X		X	X	X					X			X	X	
9.00pm-10.00pm														X	X	X	X	X		X	X	X				X		X		X	X	
10.00pm-11.00pm														X	X		X	X			X	X				X		X		X	X	
11.00pm-12.00pm														X	X		X	X			X					X		X		X	X	
TOTAL	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**NIL**	**6**	**4**	**10**	**9**	**15**	**17**	**14**	**12**	**16**	**13**	**17**	**NIL**	**11**	**8**	**7**	**7**	**10**	**5**	**24**	**24**	**229**

DIESEL PRICE = 160 NAIRA
TOTAL DIESEL CONSUMPTION=229X2=458LITRES
X MEANS POWER OUTAGE

CONSUMPTION=2.00LITRE/HOUR
COST OF DIESEL= 160 X 458 =N73,280:00

Table 8: Summary Of Power Hourly Outages For Six Months in Base Station at Amayo Quarters, Off Upper Sakponba Road, Benin City in 2011

S/NO	MONTH OF THE YEAR	OUTAGE HOURS (HRS)	NOS OF LITRES OF DIESEL USED	COST OF DIESEL (₦)
1	MAY	320	640	102,400:00
2	JUNE	247	494	79,040:00
3	JULY	337	974	107,840:00
4	AUGUST	282	564	90,240:00
5	SEPTEMBER	313	626	100,160:00
6	OCTOBER	229	458	73,280:00
TOTAL		**1,728**	**3,456**	**552,960:00**

4.0 Solar Photovoltaic System

In order to use solar PV system to power a Base transceiver Station (BTS), the sizing of the solar array has to be done followed by the sizing of the battery bank, voltage regulator, inverter and system wiring.
This is done in the next section.

4.1 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/day by the product of efficiencies of all components in the system to get the required energy E_r. [6]

$$\text{Er} = \frac{daily\ average\ energy\ consumption}{Product\ of\ component's\ efficiencies} = \frac{1.3*E}{\eta} \quad - \quad - \quad - \quad - \qquad (1)$$

To obtain the peak power, the previous result is divided by the average sun hours per day for the geographical location $T_{min.}$

$$\text{P}_\text{p} = \frac{Daily\ energy\ requirement}{Minimum\ peak\ sun-hours\ per\ day} = \frac{Er}{Tmin} \quad - \quad - \quad - \quad - \qquad (2)$$

The total current needed can be calculated by dividing the peak power by the DC voltage of the system.

$$\text{I}_{\text{DC}} = \frac{Peak\ power}{System\ DC\ voltage} = \frac{Pp}{Vdc} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (3)$$

Modules must be connected in series and parallel according to the need to meet the desired voltage and current in accordance with the number of series modules which is equal to the DC voltage of the system divided by the rated voltage of each module V_r.

$$\text{N}_\text{S} = \frac{System\ DC\ voltage}{Module\ rated\ voltage} = \frac{Vdc}{Vr} \quad - \quad - \quad - \quad - \quad - \quad - \quad - \qquad (4)$$

The number of parallel modules which equals the whole modules current divided by the rated current of one module Ir.

$$\text{N}_\text{P} = \frac{Whole\ module\ current}{Rated\ current\ of\ one\ module} = \frac{Idc}{Ir} \quad - \quad - \quad - \quad - \quad - \quad - \qquad (5)$$

Finally, the total number of modules Nm equals the series modules multiplied by the parallel ones:
N_m = number of series modules x number of parallel modules = N_s x $N_{p....}$(6)

4.2 SIZING OF THE BATTERY BANK

The amount of rough energy storage required is equal to the multiplication of the total power demand and the number of autonomy days E_{rough}=E x D. For safety, the result obtained is divided by the maximum allowable level of discharge (MDOD):

$$E_{safe} = \frac{Energy\ storage\ required}{Maximum\ depth\ of\ discharge} = \frac{\text{Erough}}{MDOD} \quad - \quad - \quad - \quad - \quad - \qquad (7)$$

We needed to make a decision regarding the rated voltage of each battery V_b to be used in the battery bank. The capacity of the battery bank needed in ampere-hours can be evaluated by dividing the safe energy storage required by the DC voltage of one of the batteries selected:

$$C = \frac{Safe\ energy\ storage\ required}{Battery\ voltage} = \frac{\text{Esafe}}{Vb} \quad - \quad - \quad - \quad - \quad - \qquad -(8)$$

According to the number obtained for the capacity of the battery bank, another decision has to be made regarding the capacity C_b of each of the batteries of that bank. The battery bank is composed of batteries that are connected in series and in parallel according to the selected battery voltage rating and the system requirement. The total number of batteries is obtained by dividing the capacity C of the battery bank in ampere-hours by the capacity of one of the battery Cb selected in ampere-hours:

$$N_{bateries} = \frac{Capacity\ of\ the\ battery\ bank}{Capacity\ of\ one\ battery} = \frac{\text{C}}{Cb} \quad - \quad - \quad - \quad - \quad - \qquad -(9)$$

The connection of the battery bank can be then easily figured out. The number of batteries in series equals the DV voltage of the system divided by the voltage rating of one of the batteries selected:

$$N_s = \frac{The\ system\ DC\ voltage}{Battery\ voltage} = \frac{\text{Vdc}}{Vb} \quad - \quad - \quad - \quad - \quad - \quad - \qquad -(10)$$

Then number of parallel paths N_p is obtained by dividing the total number of batteries by the number of batteries connected in series:

$$N_p = \frac{The\ total\ number\ of\ batteries}{Number\ of\ batteries\ in\ series} = \frac{N_{batteries}}{N_s} \quad - \quad - \quad - \quad - \qquad -(11)$$

Once the sizing of the battery bank is available, we proceed to the next system component.

4.3 Sizing Of The Voltage Regulator

According to its function it controls the flow of current. A good voltage regulator must be able to withstand the maximum current produced by the array as well as the maximum load current. Sizing of the voltage regulator can be obtained by multiplying the short circuit current of the modules connected in parallel by a safety factor F_{safe}. The result gives the rated current of the voltage regulator (I):

I = parallel modules short circuit current x safety factor = N_p x I_{Sc} x F_{safe} - (12)

The factor of safety is employed to make sure that the regulator handles maximum current produced by the array that could exceed the tabulated value. And to handle a load current more than that planned due to addition of equipment, for instance. In other words, this safety factor allows the system to expand slightly.

4.4 Sizing Of The Inverter

When sizing the inverter, the actual power drawn from the appliances that will run at the same time must be determined as a first step. Secondly, we must consider the starting current of large motors by multiplying their power by a factor of 3. Also to allow the system to expand, we multiply the sum of the two previous values by 1.3 as a safety factor.

5.0 Mathematical Method for BTS Visited Using Table 1

Daily energy demand of site visited on Table 1 = 153180Wh
Sunshine hour for Benin City = 6
Assume value Safety factor = 1.3

5.1 Sizing Of Solar Array

To avoid under sizing we begin by dividing the total average demand per day by the efficiencies of the system components (inverter, charger, battery) to obtain the daily energy requirement from the solar array:

$$E_{required} = \frac{Daily\ average\ energy\ consumption * 1.3}{Product\ of\ component\ efficiencies} = \frac{1.3*E}{\eta} \quad - \quad - \quad - \quad - \qquad (13)$$

Where η is the product component efficiencies for Inverter, Regulator, and Batteries.
Let 0.9 be the efficiency value for each product.

$$E_{required} = \frac{153180 * 1.3}{.9\ x\ .9\ x\ .9} = 273160.49\text{Wh}$$

$$\cong 273.160\text{KWh/day}^{-1}$$

Then the peak power is, $P_P = \frac{Daily\ energy\ requirement}{Minimum\ peak\ sun\ hour\ per\ day}$ - - - - (14)

$$= \frac{273160}{6} = 45526.748\text{Wh}$$

The total current needed can be calculated by dividing the peak power by the voltage of the system which is 48Vdc

$I_{dc} = \frac{PP}{Vdc} = \frac{45526.748}{48} = 948.47392\text{A} \cong 950\text{A}$ - - - - - - (15)

Number of panel in series, $N_S = \frac{System\ D.C\ Voltage}{rated\ voltage\ of\ module} = \frac{Vdc}{Vr}$ - - - (16)

The rated voltage of the module or panel is 24 volts, therefore

$N_S = \frac{48}{24} = 2$

Number of panel in parallel, $N_P = \frac{whole\ module\ current}{rated\ current\ of\ one\ module} = \frac{Idc}{Ir}$ - - - (17)

The rated current of one module is 7.45A, therefore

$N_P = \frac{950}{7.45} = 127.51678 \cong 130$

Finally the total number of module N_m

$N_m = N_s\ X\ N_p$ - - - - - - - - - - (18)

= 2 x 130 **= 260**

1.15.2 Sizing of the Battery Bank

Assumptions

- Wiring efficiency =90%
- Battery charge/Discharge efficiency = 90%
- Battery maximum depth of discharge =90%
- Numbers of day of autonomy i.e days without sunshine is assume to be 3 days

E_{rough} = 153180Wh x 3 = 459540Wh

$E_{safe} = \frac{Required\ energy\ storage}{Assumed\ efficiencies} = \frac{459540}{.9\times.9\times.9} = 630370.37\text{Wh}$ - - - - (19)

If the rated battery voltage is 12 volts then the capacity of the battery in ampere-hours required, (C) is given as:

$C = \frac{Esafe}{rated\ battery\ voltage} = \frac{630370.37}{12} = 52530.864\ \text{AH}$ - - - - - (20)

If the selecte dbatteyr is 210AH then the number of battery needed in series is,

$N_{batteries}, = \frac{C}{battery\ rate}$ - - - - - - - - - (21)

$= \frac{52530.864}{210} = 250.14697 \cong$ **250**

If the system have a dc voltage of 48V and a battery rated voltage of 12V, then the parallel branches will be 48/12=4.
Then the number of parallel batteries will be N_P=250/4 = 62.5 - - - (22)

$\cong 63$

Total Batteries = 250 + 63 **= 313**

5.3 Sizing of Voltage Regulator

Assumptions:

Number of modules = 260, shunt current=8.03A and safety factor=1.3

Total current required I = 260 x 8.03 x 1.3 = 2720.9A ≅ 2722 A

The total number of regulators required is

N = 2722/60 = 45.366667 ≅ **45**

Where the rated voltage regulator is 60A

5.4 SIZING OF INVERTER

From Table 1 the total A.C load energy consumptions is given as shown in Table 9

Table 9: A.C Load Demand From BTS Visited

S/NO	DESCRIPTION	MODEL	QTY	POWER ATING (WATTS)	HOURS USED	DAILY HOUR USED (KWh)
1	AIR CONDITIONER	LG	2	1492	24	35.81
2	BULBS	PHILIPS	2	120	12	1.44
3	AVIATION	ERICSSON	1	25	12	0.30
4	SECURTY LIGHT	ERICSSON	1	200	12	2.40
TOAL				**1837**		**39.95**

The A.C load demand is 39.95KWh

The required AC load demand = 39950 x 1.3 = 51935W ≅ **5,000W**

Where 1.3 is an assumed safety factor

The inverter needed must be able to handle about 5,000W.

Table 10 Solar PV Investment Cost For A 17.5kVA Power Station (48Vdc/230Vac)

S/N	Item	Quantity	Unit cost (₦)	Total cost (₦m)
1	Modules	260	83,950:00	21,827,000:00
2	Deep cycle Batteries 200AH 12V	313	69,000:00	21,597,000:00
3	Charge Controller	45	48,300:00	2,173,500:00
4	Inverter 5000W, 220Vac	1	78,310:00	78,310:00
5	Supporting structures e.g aviation warning light, installation etc	Lot	5% cost of modules	1,091,350:00
	Total			**46,767,160:00**

Table 11 Diesel Generator Investment Cost

S/N	Item	Quantity	Unit Cost (₦)	Total Cost (₦m)
1	Gen. Set 17KVA	2	2,025,450.00	4,050,900.00
2	Sundry	Lot	25% of Gen set	1,012,725:00
3	**Total**			**5,063,625.00**

6.0 Discussions of Results

From the result in Table 1, it was observed that the daily power consumption for a BTS is **153.18KWh,** while the annual power consumption becomes **5910.7KWh, (55.910MWh).** Considering Nigeria of about **30,000BTS,** [1, 2] as at time of this paper the total average power consumption will be **1677321MWh (1.677321TWh)** units. From Tables 10 and 11 initial cost of ₦ **46,767,160:00** of P.V system is more expensive than that generator set which is **₦5, 063,626:00.** This is because solar energy components are very expensive and imported except for cables and other accessories and also because the PV components are very stable and do not wear out since there is no moving parts during operation. Table 8 is the summary of the six (6) months National grid hourly outage recorded. From the summary the total hour outage is **1728**, diesel consumption is **3456** litres and with a cost of **₦552, 960.00** to run a generator set. When translated to one year it is **₦1,105,920:00** With about 30.000 BTS in Nigeria and 60,000 generator sets the gross total cost of diesel consumed is **₦66,355,200,000.00(₦66.355Billion)**. Therefore, the cost of powering a BTS with solar PV system is **₦ 46,767,160:00** while the cost of powering a BTS with diesel generator will be N5,063,625:00 plus cost of diesel fuel, routine services, maintenance, attendance, logistic to mention a few. For ten years period, diesel will be **₦66, 355, 200,000.00(₦66.355Billion)** while solar PV remain the same at a cost of **₦46,767,160:00**

Therefore, for a longer period solar is the cheapest means for powering a base transceiver station.

7.0 Conclusion

From Tables 10 and 11 the initial cost of installation of solar energy system is high, when compared with the installation of diesel generator set. The stand alone solar energy to power BTS is a viable alternative to conventionally fuel powered 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.

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 [7, 8]
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 to provide efficient and sustainable energy/power to rural/urban areas without National grid.

References

[1] Chima, A. and Samson, A. (2011) “The Revolution that means freedom GSM @10: The gain, the pain, and what lies ahead”. IT and Telecom Digest Daily Magazine Tuesday 11th October. Pp 1-10.

[2] Nkechi, O. and Adeyemi, A. (2013) “Government Prescribes 60,000 Base stations to tackle phone service challenges”. The Guardian Newspaper June 20th.

[3] http://www.google.com “Photovoltaic Wikipedia” Accessed 28th March, 2013.

[4] Infinite Focus Solar Power (2012) “Alternative and Sustainable Power for Nigerian GSM Mobile Base Station”. White Paper Published by Infinite Focus Group, Ireland.

[5] Otasowie, P.O. and Evbomwan , O. (2010) “ Energy cost reduction in GSM base station in Nigeria”. Journal of the Nigeria Institution of Production Engineers, Nigeria Vol. 12. Pp 143-152.

[6] Assad, A.J. (2010) “A Stand-alone Photovoltaic System”. Journal of Applied Science in Environmental Sanitation. Vol. 5. Pp 81-91.

[7] Ijeoma, V.A. (2012) “Renewable Energy Potential in Nigeria” Conference Proceedings of the 32nd Annual Meeting of the International Association for Impact Assessment held on the 27th May in Portugal. Pp 1-6.

[8] Abubakar, S.S. (2009) “Strategic Development in Renewable Energy in Nigeria”. International Association for Energy Economics. Pp 15-19.