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Powering Cell Sites for Mobile Cellular Systems using Solar Power

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ABSTRACT

The power consumption of wireless access networks has become a major economic and environmental issue, providing dedicated power supply for cell sites is one of the major issues for mobile communication system. In particular, base stations cause more than 80% of the operator's power consumption, which makes the design of base station a key element for determining both the environmental impact of wireless networking and the operational expenditure. Utilizing renewable energy sources such as the solar, wind and bio – fuels as an alternative energy would be the ultimate solution to the mobile telecommunication industry. This paper presents an overview of integrating solar energy as alternative renewable energy to power cell sites in mobile cellular systems. The power consumption for three and six sector site have been evaluated. Optimization strategies to reduce the power consumption deployed and hence, solar power solution for both the optimized and non optimized site has been design. Analysis of results shows that, the average power consumption for the site increase with increase in the number of transceivers per sector. It is note-worthy that an increase of 768W per transceiver was recorded for the three sector site. It was also found that, the number of required solar panels and batteries for both optimized and non optimized sites increase with increase in number of TRX per sector.

Key words: *Base Transceivers Station (BTS), energy conservation, power consumption, Solar, Renewable energy*

1. INTRODUCTION

The physical limitations of the wired line communication systems in satisfying the ever increasing demands seem to be in favor of wireless systems. The consequent phenomenal growth in demand has led to a world-wide number of mobile subscribers to be 6 billion as at July 2011, (ITU, 2011) and the demand of the wireless technologies and services increases rapidly every year. Wireless communication system is one of the most important technologies for contributing to social and economic development around the world. Studies have pointed to the significant contribution of mobile communications to GDP growth as a key to sustainability.

Mobile Communication is one of the most important technologies that contribute to the social and economic development around the world. The last decade has seen exponential growth in wireless communication. As mobile communication network expansion is moving extensively high, there is a need to provide an alternative energy sources. In Sunday Newspaper of 17 July, 2011 a new report by the GSM Association (GSMA) disclosed that Nigeria stands to gain an additional N862 billion by 2015 from mobile broadband.

Energy is one of the top expense items for mobile network operators. In particular, base stations cause more than 80% of the operator's power consumption, which makes the design of base station a key element for determining both the environmental impact of wireless networking and the operational expenditure (Vincenzo, 2011). Utilizing renewable energy sources such as the solar, wind and bio – fuels as an alternative energy would be the ultimate solution to the mobile telecommunication industry.

In 2008, the GSM Association (GSMA) gathered nearly 800 worldwide mobile operators to launch a plan for deploying renewable energy sources for 118,000 new and existing base stations in developing countries by 2012 to save 2.5billion liters of diesel and cut CO2 emission up to 6.3 million tons per year (Vincenzo, 2011). In Nigeria, Airtel Nigeria (Mobile Operator) has embark to upgrade 250 diesel powered stations to Green-sites, the company regretted that non-availability of regular grid power supply to sites across the country is responsible for over 70% of down time, resulting in poor QoS (Quality of Service) (Vanguard, 2011).

This paper presents an overview of integrating solar energy as alternative renewable energy to power cell sites in mobile cellular systems. The paper is organized as follows; Section 2 provides the theoretical power consumption of base transceiver station, Section 4 gives the realistic power consumption of BTS, Solar power design in Section 5 and finally, Section 6 concludes the paper.

1.1 Off-Grid Cell Site

An off-grid cell site is a cell site that is not connected to the power grid. Usually the site is off the grid because it is situated in a place which is difficult to get to or it is not connected to the main power grid. In Nigeria, off-grid sites could be found mostly in the rural areas.

In IT news Africa of Tuesday, 2 of August, 2011, the South Africa's second largest mobile operator, MTN plans to roll out over 1 000 Universal Mobile Telecommunications Systems (UMTS) base stations in rural areas over the next two years. Tagged, "*Rural mobile broadband project*". Providing dedicated low cost power supply for these sites could be challenging as most of the rural areas are not connected to the electricity grid and, even though they are connected, the availability of the supply is very limited to provide uninterrupted power to satisfy minimum required Qos. Usually the solution involves fuel cells connected to a generator; but this has high costs and high environmental impact. A new possibility is brought by renewable sources, mainly solar power and wind power as they are available where cell sites are placed. In Nigeria, towards the North East of the country, temperature can rose up to 40^0C during high solar activity. In Maiduguri, Nigeria, the average monthly temperature over the year in 2009 was found to be 34.75^0C. This value was calculated from the data obtained from (World Weather, 2009). In places like Sokoto, Nigeria, the warmest months are February to April, where daytime temperatures can exceed 45 °C (113.0 °F). Highest recorded temperature is 47.2 °C (117.0 °F), which is also the highest recorded temperature, in Nigeria (Wikipedia, 2011). All these areas could utilize solar as alternative solution. The solar or wind power could be backed up by a fuel generator system for redundancy which allows the cell site to work when the renewable sources are not enough.

2. THEORETICAL POWER CONSUMPTION OF BASE TRANSCEIVER STATION (BTS)

Base Transceiver Station (BTS) - is a transceiver and acts as interface between the mobile stations (MS) to the network. A BTS will have between 1 and 16 Transceivers (TRX) [6], depending on the geography and demand for service of an area. There are several power consuming components inside the BTS. Some components are used per sector such as the digital signal processing (DSP) which is responsible for system processing and coding, the power amplifier, the transceiver which is responsible for generating the signal and also receiving signals to the mobile station and the rectifier as shown in **Figure 1**. The power consumption of these components should be multiplied by the number of sectors when determining the power consumption of BTSs (Magrot *et al*, 2011). Within these components the transceiver and the power amplifier are one per transmitting antenna. Other components such as the air conditioning and the microwave link when no fiber link is available for backhaul are common to all sectors.

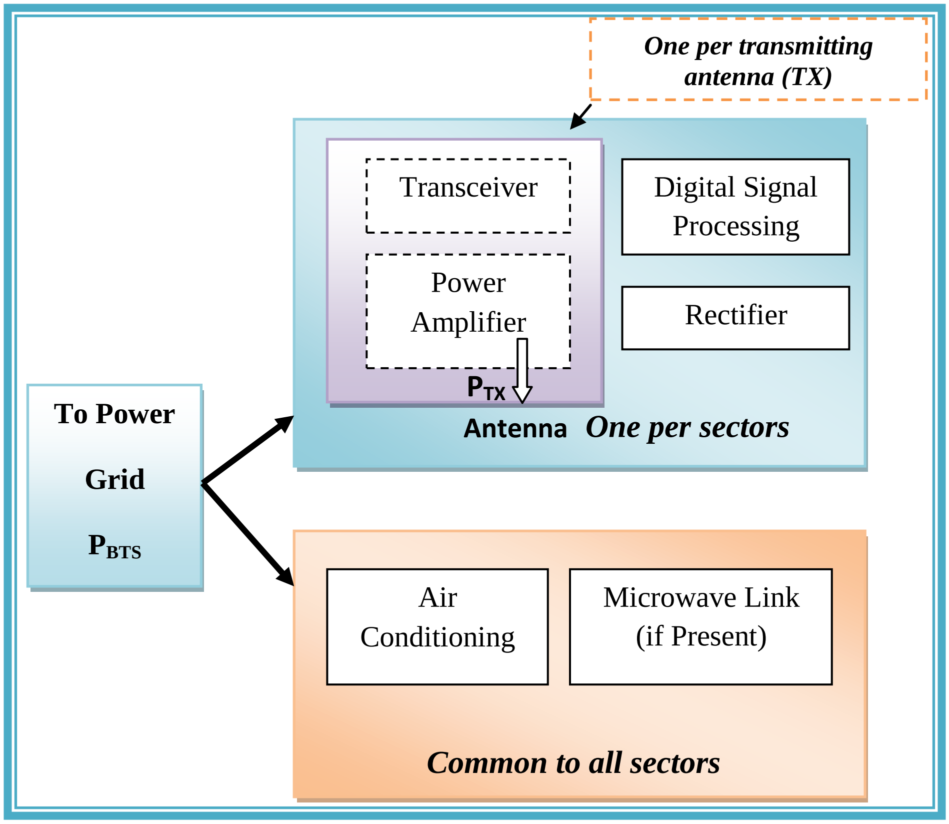

Fig.1: Block Diagram of Base Station Equipments

In theoretical based power consumption, analytic model is developed to estimates the power consumption of a base station. Though in some cases, the estimation never gives the realistic power consumption but somehow approximations. (Magrot *et al*, 2011), developed a model to determine the power consumption of base station. The model indicates that once the power consumption of individual components of the base station is known, the total power consumption could be evaluated. As a validation of their model, the power consumption of one sector base station with one antenna was found to be 761W this could only be achieved when the power consumption of AC of 225W as specified in the paper is used. In a typical situation in Nigeria BTSs, most sites uses two AC, Incandescent Bulbs and more than one microwave units. Therefore, there is need to modify the model proposed to suites the realistic situations in Nigeria.

In our proposed model, we include a relation that would take care of the number of ACs, microwave units and the incandescent bulbs as shown in equation (1):

$$P_{BTS} = n_{sector} * \left(P_{DSP} + n_{TR} * (P_{Amp} + P_{Tran}) + P_{Rec} \right) + \sum_{i}^{n} P_{AC_i} + \sum_{k}^{l} P_{micro} + \sum_{j}^{m} P_{LB\,j} \quad \text{....................(1)}$$

n_{sector} Is the number of sectors in the cell, n_{TR} is the number of transmitting antennas per sector and P_{BTS}, P_{DSP}, P_{Amp}, P_{Tran} P_{Rec}, $\sum_{i}^{n} P_{AC_i}$ $\sum_{k}^{l} P_{micro}$ and $\sum_{j}^{m} P_{LB\,j}$ are the total power consumption of the base transceiver station, the digital signal processing unit, the power amplifier, the transceiver, the rectifier, the air conditions, the microwave and incandescent bulbs respectively. Where *n, l and m* represents the total number of AC's, microwaves in the BTS and bulbs in the site. The total energy consumption (E_{BTS}) for the BTS is given in equation (2); this is the energy consumption of one site.

$$E_{BTS}=P_{BTS}*t \;\ldots\ldots\ldots\; (2)$$

Table1- Power Consumption of Different Components of the BTS

EQUIPMENTS	POWER	VALUE
Digital signal processing	P_{DSP}	100 W
Power amplifier (SISO)	η	12.8%
	P_{Amp}(Max)	156W
Power amplifier (MIMO)	η	11.5%
	P_{Amp}(Max)	10.4W
Transceiver	P_{Trans}	100 W
Rectifier	P_{Rec}	100 W
Air conditioner (AC)	P_{AC}	1170 W
Incandescent Bulb	P_{LB}	60W
Microwave Link	P_{micro}	80W

Where, t is the total time of usage (i.e. duration of power supply).

Table 1 gives the summary of power consumption of different components of the BTS. Some parameters value such as the power amplifier for SISO andMIMO and microwave were obtained from (Magrot *et al*, 2011).

3. SIMULATION RESULTS

The power and energy consumption for three and six sector site before and after optimization has been evaluated. The result is shown in **Figure 2 & 3**. The values in **Table 1** were used and also it was assumed the site has tow (2) ACs, two (2) bulbs and tow (2) microwave units. Equation (1) was used to calculate the power consumption. After optimization, no AC's and bulbs used (Nasir *et al*, 2011). From **Figure 2,** it was found that the average power consumption for the site increase with increase in the number of transceivers per sector. It is note-worthy that an increase of 768W per transceiver was recorded. The power consumption for the site with 1TRX per sector is found to be 3.988KW this increases to 5.524KW and 7.828KW respectively for 3TRX and 6 TRX representing 27.81% and 49.1% increase. When optimized, the power consumption for the site with 1TRX per sector was found to be 1.528KW and 1.0912KW respectively for SISO and MIMO representing 61.68% and 72.63% decrease.

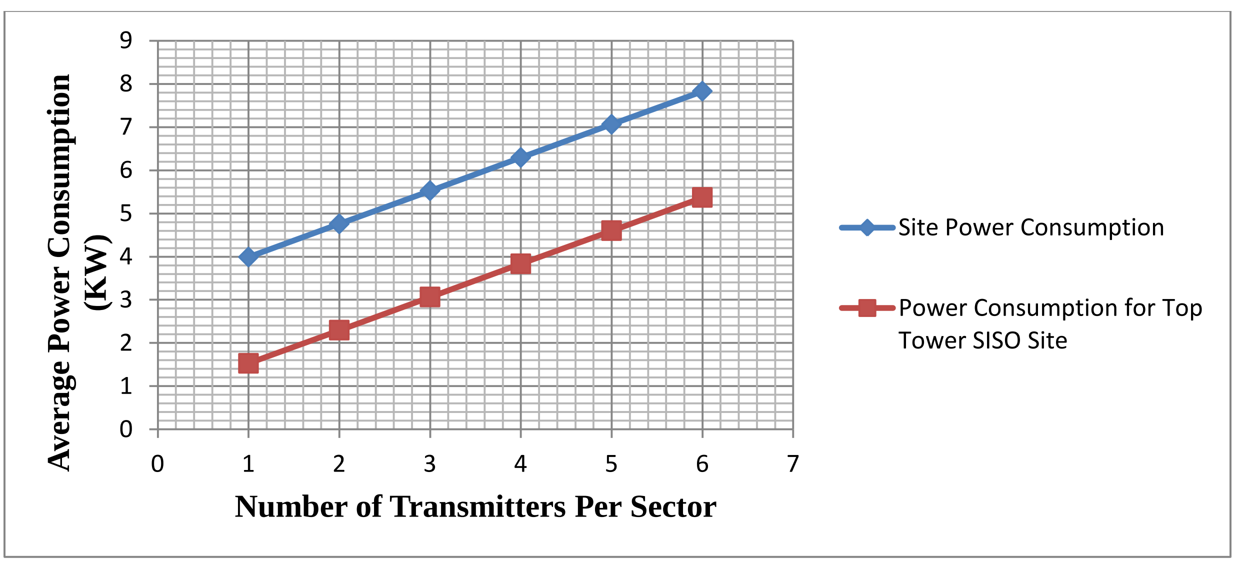

Fig. 2: Showing average power consumption (KW) with the number of transmitters per sector for three sector site

Furthermore, the energy consumption as a function of the number of TRX per sector and the duration of power supply for three and six sector site was evaluated., each component is assume to consume power for 24hrs/day except for the incandescent bulbs which is expected to provide lightning for 12 hrs/day during the night periods. The result is shown in **Figure 3.**

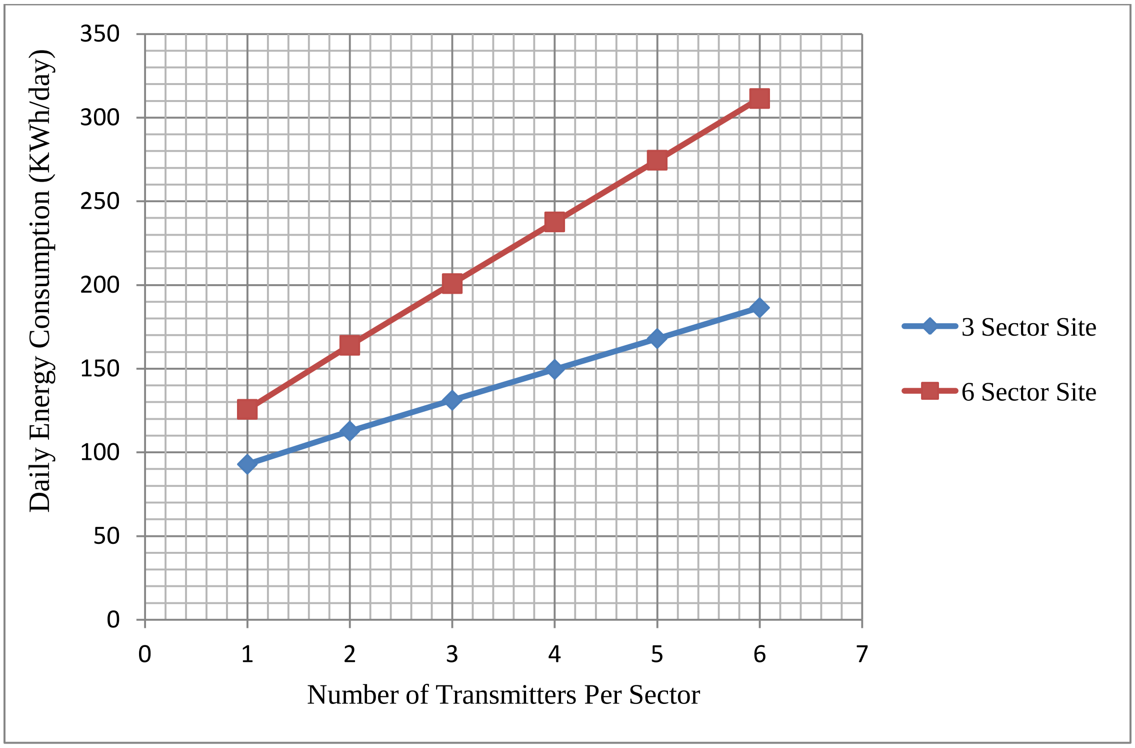

Fig. 3: Showing Daily energy consumption (KWh/day) with the number of transmitters per sector for three and six sector site

Equation (2) was used to calculate the energy consumption for the site. It is noted that, the energy consumption increase in similar vein with increase in the number of TRX in the site. For three sector sites, the energy consumption for 1TRX per sector was found to be 92.88KWh/day, this increase to 131.136KWh/day and 186.432KWh/day for 3 TRX and 6 TRX per sector respectively representing 29.17% and 50.18% increase in energy consumption. When observed, it was noted that, when transition from 1TRX to 3TRX per sector, the increase slightly higher in energy consumption as compared for power consumption for both three and six sectors sites. In **Figure 3** it is also noted than, the deviation in increase energy consumption for three and six sector site is higher as the TRX increase showing highest for 6 TRXs.

4. REALISTIC POWER CONSUMPTION OF MACRO BTS SITES IN NIGERIA

There are several factors that could affect the BTS power consumption; these include the traffic load which varies as a function of time due to varying nature in demand of the services and the statistical population of an area. Other factors could affects the power consumption of individual components which would subsequently alter the overall power consumption. The most power consuming components are the power amplifier and the air conditioning systems. These indicate that, the power consumption of individual BTS may vary with location area. Considering realistic power consumption for typical mobile operator in Nigeria BTS, this includes both the transceivers and the microwave radio unit for 2G network some sites are used for backbone only. In the event of network upgrade, 3G network is usually installed in the same BTS to minimize cost. This is shown in **Table 2.** In **Table 2**, the power consumption for the site with 6 PDH (Plesiochronous Digital Hierarchy) and 2 SDH (Synchronous Digital Hierarchy) is 5868W and this decrease to 4478W for 1 PDH and site. Generally, the power consumption increase with increase in either microwave units or the number of transceivers.

Table 2- Realistic Power Consumption of BTS in Nigeria

CONFIGURATION/EQUIPMENTS	Power (watts)
6 PDH RADIOS, 2 SDH RADIOS, (6TRX 900BAND, 12TRX 1800BAND)	5868
1PDH RADIO, (2G 6TRX BAND, 12TRX 1800BAND)	4478
5 PDH RADIO, 5 SDH RADIO, MUX, (6TRX 900BAND, 22TRX 1800BAND), 3G	8460
1PDH RADIO, 2 SDH RADIO, (8TRX 900BAND)	6108
2G 9TRX 900BAND, 36TRX 1800BAND	7240
2G 6TRX 900BAND 36TRX 1800BAND + 3G	8580

5. SOLAR AS ALTERNATIVE RENEWABLE ENERGY TO POWER CELL SITES

Solar power is more expensive to install, but for low and medium capacity sites like the microcell stations, it can prove a cheaper option than diesel generator system. In Nigeria where most of the site stations are not directly connected to the electricity grid, these sites are powered by diesel generators especially in remote (rural) areas; therefore, the solar power system should be a better option.

Solar – powered sites have a technical life time of 20 – 30years (Solar, 2011) and they could prove much more reliable than operation on diesel – generator system which needs regular maintenance and re – fuelling.

Reliability and availability are also important issues to be considered when chosen an alternative energy source. In terms of the environmental impact, the alternative source (Solar) produces no noise, CO_2 emission or smell, thereby reducing environmental pollution.

Using solar system as an alternative energy source will greatly reduce total cost of ownership (TCO) which is the annual amount the network operator spends in order to maintain and sustain the level of performance of the network based on coverage area and capacity expansion (Bright, 2011). These includes costs such as operation and maintenance, site rental, power, spares, training and support, transportation and site visits. However, this would help to make communication more affordable to individuals and the society at large. On the other hand, one of the challenges facing solar energy system is that the highest efficiency of the system depends on full sunlight exposure and therefore it effectiveness varies from time to time and in particular, from location to location.

Fig 4: Photovoltaic cells (PV) at BTS sites: *Source:* (Vangurad, 2011)

6. SOLAR POWER DESIGN FOR MACRO CELL SITES

Solar power design for macro cell sites can be achieve by evaluating the total power consumption of all the equipments in each site which comprises of AC load and DC load. This total power consumption can then be use to design an alternative solar power system that will power the sites with the same capacity.

The total energy (E_t) required in (*Whr*) is defined as:

$$E_t = P_t \times t ------3$$

Where *Pt* is the total power consumption per site which comprises of (AC + DC) loads and *t* is the operating time of the equipments. Macro cell sites are operating 24hrs per day, which implies that the operating time of all the equipments is 24hrs (i.e. t = 24hrs).

In Nigeria, on a balance situation, there are 1885 sunshine hours annually. So the amount of available sunlight which is also known as the isolation value (I_V) is 5.2 hours/per day (Climate, 2011). The isolation value is interpreted as the kilowatt – hours per day of sunlight energy that falls on each square meter of solar panels at tilt latitude. This isolation value varies as a function of location. Therefore, the required solar panel input S_{ip} is defined as (Bright, 2011):

$$s_{ip} = E_t / I_v \text{ ....(4)}$$

The number of solar panels required N_{SP} is given as:

$$N_{sp} = S_{ip} / P_{out} \text{.......................................(5)}$$

Where P_{out} is the power output of each PV solar unit; this output power varies depending on the type of product module and its rating.

5.1 Battery Bank Sizing

A battery is needed in solar system in order to store charge and then be use when there is no sunlight (at night). In solar design, deep cycle batteries are used because these batteries are designed to be charged and discharged over a long period of time. They are not the same as car batteries which provide a large amount of current for a short period of time. To calculate the battery size required to provide for n days of back-up in the event there was no sun, the battery bank would need to be rated as follows:

$$(Et \times n) / (Vs \times \eta) \text{......................(6)}$$

Where: n is the Days of Storage i.e. period of back – up, this depends on the number of days for individual design, (V_S) is the operating voltage of the battery which varies with the capacity of battery to be used, η is the efficiency after system losses i.e. depth of discharge of the battery, which the maximum for deep cycle battery is 80%. This implies that the amps hours of battery storage required B_{AHR} is given as:

$$B_{AHR} = (Et \times n) / (Vs \times \eta) ....(7)$$

There are many sizes of batteries available in the market some includes: 12V/100Ah, 12V/200Ah, 12V/250Ah, 24V/100Ah, 24V/150Ah, 24V/200Ah, 48V/100Ah and 48V/200Ah

The choice of battery rating determines the number of batteries to be used, in order to minimize the number of batteries and available space, it is recommended to use high capacity batteries. Considering the capacity of battery to be use, the number of storage batteries required can be determine as (Bright, 2011)

$$N_{BTR} = B_{AHR} / I_b ....(8)$$

Where N_{BTR} , is the number of batteries to be use, I_b is the current rating of the battery chosen, B_{AHR} is the required amp hour of battery storage. The batteries can be connected together in either a parallel or serial manner.

5.2 Regulator

The main purpose of a solar regulator or charge controller is to regulate the current from solar panels to prevent batteries from overcharging. A solar regulator senses when the batteries are fully charged and stops the current flowing to the battery and also prevents the battery from feeding back into the solar panel at night when it is dark. Most solar regulators include a low voltage disconnect feature, that senses the battery voltage and if the battery voltage drops below a pre-determined level (cut-off voltage) the solar regulator will switch off the supply. Solar regulators are rated by the amount of current they can receive form the solar panels. The solar regulator should be capable of handling the total short circuit current of a solar panel. Therefore, the short circuit current (I_{cc}) can be determine as:

$$I_{cc} = N_{sp} \times I_{pm} \times 1.25..........................(9)$$

Where I_{pm} , is the panel maximum current rating and N_{SP} is number of solar panels required.
An additional 25% capacity is added for growth and also for the fact that some solar panels may exceed their rated output.

5.3 Inverter

An inverter is a device that converts a DC voltage (12/24/48V) to AC voltage (220/240V ac). There are some devices in the Base Station that uses AC voltage for example: Air Condition, Bulb, power amplifier etc. This means that an inverter is needed to convert DC voltage from the battery to AC voltage so as to power these AC loads i.e. an inverter increases 12/24/48-volt battery power to 110/240 AC power. The inverter's power capacity rating can be determined as follows:

$$P_i = P_{ac} \times 1.25..............................(10)$$

Where P_i is the power rating of the inverter and P_{ac} is the total AC loads power.

5.4 Simulation Result

The simulation was carried out for three sector site before and after optimization (OPT). **Figure 5** shows the results. It is noted that the number of required solar panels and batteries for both optimized and non optimized sites increase with increase in number of TRX per sector. The number of panel decrease drastically from 19 before OPT to about 7 after OPT. Similarly, the number of inverters varies as a function of the number of transceivers per sector for both optimized and non optimized site.

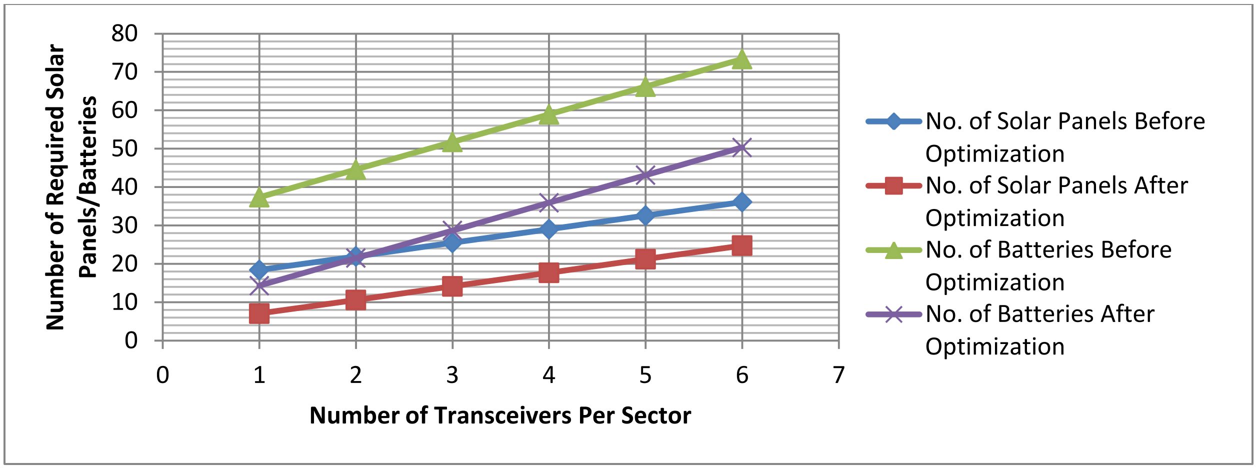

Fig. 5 Showing number of required panels and batteries as a function of number of transceivers per sector for three sector site before and after optimization

7. CONCLUSIONS

Providing dedicated power supply for cell sites is one of the major issues for mobile communication system. Typically, the base stations cause more than 80% of the operator's power consumption, which makes the design of base station a key element for determining both the environmental impact of wireless networking and the operational expenditure. In this paper, an overview of integrating solar energy as alternative renewable energy to power cell sites in mobile cellular systems was reviewed. The power consumption for three and six sector site have been evaluated. Optimization strategies to reduce the power consumption deployed and hence, solar power solution for both the optimized and non optimized site has been design. Analysis of results shows that, the average power consumption for the site increase with increase in the number of transceivers per sector.. It was also found that, the number of required solar panels and batteries for both optimized and non optimized sites increase with increase in number of TRX per sector.

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