World Journal of Engineering and Technology, 2024, 12, 885-894
https://www.scirp.org/journal/wjet
ISSN Online: 2331-4249
ISSN Print: 2331-4222

Renewable Electricity Generation: Solution to GHG Emissions in Nigeria Telecom Industry

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How to cite this paper: Oliyide, R.O. and Olugbemi, M.F. (2024) Renewable Electricity Generation: Solution to GHG Emissions in Nigeria Telecom Industry. *World Journal of Engineering and Technology*, **12**, 885-894.
https://doi.org/10.4236/wjet.2024.124054

Received: April 13, 2021
Accepted: June 20, 2021
Published: October 10, 2024

Abstract

Continual release of greenhouse gases emission into the atmosphere is the main cause of climate change. Climate change and its consequent impacts have been source of concerns for all as it directly affects the sustainability of life on the planet earth. Greenhouse gases emission must be reduced in all sectors to avert the inherent dangers of climate change. This work investigates the emission of greenhouse gases in the Nigerian Telecoms industry. Empirical data from Nigerian Telecoms industry are gathered and technically evaluated to investigate the carbon footprint of operations in the sector. The work further estimates the environmental gains in terms of reduction in greenhouse gases emission and economic gains in terms of reduction in fuel costs achievable with deploying renewable energy solution (solar-powered inverter with backup batteries) to power base stations.

Keywords

Telecoms, Greenhouse Gases, Base Stations, Renewable Energy, Climate Change, Power Inverter

1. Introduction

Globally, Information and Communication Technology (ICT) contributes between 1.8% and 3.9% of the world's greenhouse gases (GHGs) emissions [1]. Mobile communications systems make up a large part of the ICT sector because they afford people with convenient means of communication that facilitates efficient and effective business operations and social interactions, thereby making them pivotal to business and daily life development. Therefore, the demand for mobile communications systems is on the increase and would continue to be for foreseeable future as more daily human activities are becoming digitalised. As a result, in the decade between 2002 and 2012, the GHG emissions that are directly connected with ICT increased at a rate twice as fast as the overall global emissions [1]. Hence, the focus must be on mobile communications systems in the efforts of reducing GHG emissions in the ICT sector.

In mobile communications systems, the Base Stations (BSs) account for more than 70% of the total energy requirements of the systems [2]. However, as the demand for mobile communication and data traffic continue to increase, the Mobile Network Operators (MNOs) increase installations of more BSs and reinforcement of existing ones in order to maintain high reliability and efficiency of service to customers. Therefore, the source of power supply to the BSs, their energy consumptions, energy efficiencies have become interests of research of many studies.

Authors in [3] established from measurements, a direct relationship between traffic load of BSs and their power consumptions, and developed a linear BS power consumption model which could be deployed in interdependence of BSs. Research in [4] aimed at achieving power availability at BSs with minimum overhead expenses in respect to fuel consumption on sites' generators by using solar energy as the main supply of power. Optimisation techniques for power consumptions of BSs were developed and deployed in [5] and [6]. Both Single Input Single Output (SISO) and Multiple Input Multiple Output (MIMO) techniques deployed yielded some reserve power which could be exported to other sites.

The other two major sectors contributing significantly to GHG emissions globally are the electricity (power) and transportation sectors [7] [8]. However, in this work, the GHG emissions from the Nigerian Telecoms industry, specifically due to the operations of BSs, are estimated based on empirical data. The work further estimates the environmental gains in terms of reduction in greenhouse gas emissions and economic gains in terms of reduction in fuel costs achievable with deploying renewable energy solution (solar-powered inverter with backup batteries) to power base stations. Thus, one of the objectives of this work is the analytical estimation of GHG emissions in the Nigerian Telecoms industry. Another objective is the detailing of technical analysis of renewable energy solutions (in terms of solar-powered inverter) as power sources for telecom base stations in Nigeria.

2. Base Station Systems: Structure and Power Requirements

Base Station System (BSS) essentially consists of the Base Station Controller (BSC) and Base Transceiver Station. (BTS) [9]. The BSC is a network component in the Public Land Mobile Network (PLMN) which controls one or more BTSs. The BTS is the network component which serves one cell in the cellular network. The BTS also called the Base Station (BS) facilitates wireless communications between the users' terminal devices and the network. The BTS may host one or more Transceivers (TRXs). Figure 1 shows the functional architecture of a BSS. TRX is a network component which serve full duplex communication. TRX provides transmission and reception of signals to and from BSC. Other components of the BTS include the following.

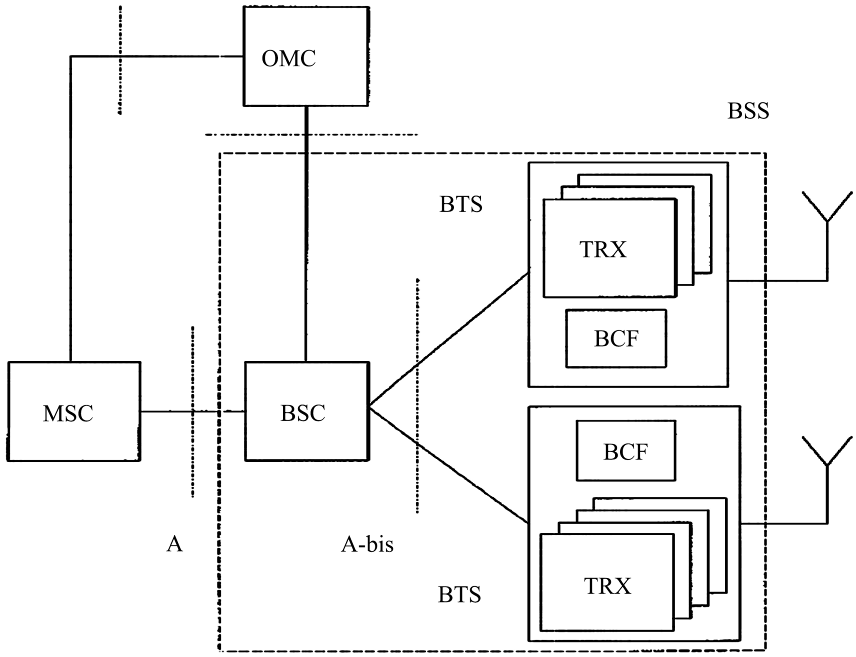

Figure 1. Functional architecture of a BSS [10].

- **Power Amplifier** (PA) which amplifies the signal from TRX for transmission through antenna.
- **Combiner** which mixes feeds from several TRXs so that they could be sent out through a single antenna.
- **Multiplexer** which selects and routes signals from multiple sources and transmit over a single channel, *i.e.* signal processing and control. Multiplexer performs other functions such as memory addressing, error detection and correction.
- **Antenna** which provides cellular connectivity for transmission and reception of radio signals mostly between BS and users' terminal devices. Antennas are usually mounted on towers in BS.
- **Base Control Function (BCF)** which handles the control functions including software, within the BTS.

The BSS connects with a number of Mobile Stations (MSs) over a set of logic channels on the radio path. The BSS through the BSC communicates with the Mobile Switching Centre (MSC) on the network side by passing the set of logic channels over the A-interface. The MSC provides the interface between the Public Land Mobile Network (PLMN) and the Public Switched Telephone Network (PSTN). The MSC interfacing both PLMN and PSTN makes it responsible for the necessary functions of handling of calls to and from the MSs. Both the MSC and the BSC communicate with the Operations and Maintenance Centre (OMC) over the A-interface. The OMC performs remote network management over the A-interface. Some of the function of the OMC include security management, network configuration, maintenance activities, administration and commercial operations.

In the mobile communication system, the BS takes the largest share of the total energy consumption. The BS consumes more than 50% of the total network power consumption [3]. The power consumption of BSs varies according to volume of data traffic they handle. The volume of data traffic they handle is a function of number of subscribers and time of the day. In spite of newer energy-efficient components of higher cellular generations being deployed in the network, the energy consumption of the mobile telecoms sector seems not abating. This is because the increasing installations of BS cancel out the energy efficiency gains of deploying newer energy-efficient components of higher cellular generations.

Power-consuming components of the BS can be categorised into main radio frequency components and support components. The main radio frequency components include transceivers, power amplifiers, antennas, multiplexers, and combiners. Support components include AC/DC converters, air-conditioners, A/D converters, lightings, etc. Table 1 gives the power ratings of equipment at a typical 3G/4G BTS in Nigeria.

Table 1. Power ratings of equipment at a typical 3G/4G BTS in Nigeria [5] [6] [11].

Equipment	Power Rating (W)	Quantity	Total Power (kW)
Transceiver (3G) (DC)	800	4	3.2
GSM Antenna (DC)	20	3	0.06
Multiplexer (DC)	240	1	0.24
Microwave antenna (DC)	5	5	0.025
Baseband unit (DC)	180	1	0.18
Router (DC)	330	1	0.33
Intermediate frequency links (DC)	20	9	0.18
Rectifier (AC)	2400	1	2.4
Air conditioner (AC)	1700	2	1.7
Indoor light (AC)	60	2	0.12
Security light (AC)	100	2	0.20
Total Power			**8.635**

To ensure quality of service, there must be uninterrupted 24-hour electric power supply to the BS.

3. Telecoms and Power Supply in Nigeria: State of Affairs

The Telecoms industry in Nigeria has grown rapidly with a broadband penetration of 38%, representing a total of more than 72 million subscriptions as of 2019 [12]. Total active voice subscriptions reached 184.7 million in 2019, representing a mobile penetration level of 96.76% [12]. Telecoms industry contributed 10.6%

of Nigeria's gross domestic product in 2019 with a foreign direct investment in excess of $942 million [12]. Thus, the Telecoms industry is vital to the Nigeria's economy and still holds more economic potentials as the industry grows and expands.

The growth and expansion of telecom industry depend on key direct and support infrastructure. Chief amongst the direct and the support infrastructure is the BS and power, respectively. Higher growth in the number of BS is important for driving an improved broadband/telecoms service delivery to more Nigerian subscribers. Power supply infrastructure is essential for the smooth and uninterruptible running of the mobile network with a near-perfect uptime in order to maintain high reliability and quality of service. An unreliable and poor power supply to the telecom BSs hinders the efficient running of the MNOs' operations.

There has been increasing infrastructural growth in the Nigeria Telecom industry including a total of 34,033 BSs, over 102,000 km of fibre optic cable deployed, and 124 microwave gateways as at 2019 [12]. However, there has not been corresponding infrastructural growth in the Nigeria power sector. In the 4th quarter of 2019, average generation capacity fell by 7.01% to 6.238 GW with highest peak daily generation of 5.157 GW and average daily generation of less than 4.5 GW [13]. In the years between 2018 and 2019, access to electricity in Nigeria is 64%, with urban electrification of 91% and rural electrification of 46% respectively [14]. While the average power availability in the areas having access to electricity is 7 hours between the same period [14]. This state of affairs in the Nigeria power sector is capable of adversely impacting on the reliability and quality of telecom services if alternative solutions are not found. The MNOs are, therefore, mostly relying on diesel generators to power their BSs. According to [15], an estimated of 26,000, representing 76% off-grid BSs can be found in Nigeria, out of which only 3% of these are powered by renewable energy. **Table 2** gives a summary of total BSs in Nigeria and average daily power supply availability as at 2019.

Table 2. Summary of BSs in Nigeria and average daily power supply availability as at 2019.

Total BSs (numbers)	Off-Grid BSs (numbers)		On-Grid BSs (numbers)	Ave. power availability (hrs)
	Diesel generator powered	Renewable energy powered		
34,033	25,220	780	8033	7

In the report of [16], MNOs in Nigeria use a 15 - 20 KVA power generating set at each of their BSs as source of power and diesel as the source of energy. Two of such generating sets are provided at every BS and are replaced sometimes every two years depending on wear and tear [16]. This is a huge investment on the part of the MNOs. In most cases, the generating sets are underutilised which makes their installations and operations uneconomical. A major environmental consequence of heavy reliance on diesel-powered generating sets is the GHG emission into the environment and ultimately the atmosphere. Thus, it is a case of big 'financial sacrifice burnt on the altar of reliable and efficient telecom services with GHG as the smoke.

The GHG emission due to the operations of BSs in Nigeria can be estimated using Equation (1) as adapted from [17].

$$Em_{Total} = 24\left(\frac{Em_{fac}}{\eta} \times BS_{load} \times N_{off\text{-}grid}^{BS}\right) + \left(24 - P_{avail}^{hr}\right)\left(\frac{Em_{fac}}{\eta} \times BS_{load} \times N_{on\text{-}grid}^{BS}\right) \quad (1)$$

where

Em_{Total} is the daily total emission ($kgCO_2$) due to the operations of BSs.

Em_{fac} is the emission factor (kg/kWh) of a particular fuel.

η is the thermal efficiency (%) of a particular generating unit/technology.

BS_{load} is the load demand (kW) of a BS.

$N_{off\text{-}grid}^{BS}$ is the number of off-grid BSs powered by diesel generators.

P_{avail}^{hr} is average daily power supply availability (hrs).

$N_{on\text{-}grid}^{BS}$ is the number of on-grid BSs.

Values from **Table 1** and **Table 2** are used in Equation (1). Emission factor of diesel according to [18] is 74.14 kg/MBTU. Converting MBTU to kWh ($10^6 \times 0.000293$ kWh = 293 kWh) the emission factor of diesel in kg/kWh is 0.25 kg/kWh and is used in Equation (1). Thermal efficiency of a diesel generator is about 40% in its designed optimum operating range [19]. Substituting all values in Equation (1), daily total emission, Em_{Total}, due to the operations of BSs is calculated to be 4003623.15 $kgCO_2$. This means that approximately 4000 tonnes of CO_2 are being released daily into the atmosphere due to the operations of BSs in Nigeria.

4. The Renewable Energy Solution

The renewable energy solution proffered is 15-kVA solar-powered inverter with battery bank storage. Assume operating voltage, V_{op}, and current, I_{op}, from solar panels array is 150 V and 120 A respectively. For a monocrystalline solar panel with the following specifications: peak power P_m = 550 W, open-circuit voltage V_{oc} = 49.9 V, short-circuit current I_{sc} = 14 A, maximum power voltage V_{mp} = 41.96 V, and maximum power current I_{mp} = 13.11 A, the number of solar panels in series array, N_s, is given by Equation (2).

$$N_s = \frac{V_{op}}{V_{mp}} \quad (2)$$

The number of solar panels in parallel array, N_p, is given by Equation (3).

$$N_p = \frac{I_{op}}{I_{mp}} \quad (3)$$

Substituting values in Equations (2) and (3), N_s and N_p are 4 and 10, respectively. That four of the above solar panels would be connected in series and there would be ten parallel arrays of such four series-connected solar panels.

Maximum power output, P_{o/p_max}, from the solar panels array is given by Equation (4).

$$P_{o/p\_max} = N_s \times N_p \times P_m \tag{4}$$

Substituting values in Equation (4), the maximum power output from the solar panels is 22 kW. From **Table 1**, the peak power demand of a typical 3G/4G BTS in Nigeria is about 8.6 kW. Assuming a unity power factor, the load current of a typical BTS is given by Equation (5).

$$I_L = \frac{\text{Peak power demand}}{\text{Nominal single-phase voltgae}} \tag{5}$$

Substituting values into Equation (5), the load current of a typical BTS is approximately 39 A. If the inverter would power the BTS for at least 11 hours, then the capacity of the battery bank required is given by Equation (6).

$$Bat_{cap} = I_L \times \text{hours BTS being powered by inverter} \tag{6}$$

Substituting values in Equation (6), the capacity of the battery bank required is 429 AH.

If the operating input dc voltage of the inverter is 48 V. Four of 220-AH, 12-V tubular batteries are connected in series to give 48 V. Then two of four series-connected 220-AH, 12-V tubular batteries are connected in parallel to give a battery bank capacity of 440 AH.

The required number of hours for the battery bank to be fully charged is given by Equation (7).

$$H_{FC} = \frac{Bat_{cap}}{\text{Array Efficiency} \times I_{op}} \tag{7}$$

With a conservative 40% efficiency of the solar panels array and substituting other values in Equation (7), the number of hours required for the battery bank to be fully charged is approximately 9 hours. A 200-A, 48-V, maximum power point tracking (MPPT) charge controller would be used. The charge controller is capable of withstanding a maximum open-circuit voltage of $450V_{dc}$.

5. Discussion

The design of the proffered 15-kVA solar-powered inverter with battery bank storage is conservative and capable of powering a typical BTS at a peak demand of 8.6 kW for at least 11 hours. As conservative as the design is, the expenditure on diesel fuel by MNOs for the running of the BTS would be reduced by at least 46% and also the GHG emissions due to the operations of the BTS would be reduced by more than 45%. In Nigeria, a diesel-generating set powering a typical BTS consumes, on average, three (3) litres of diesel in one hour [16] [20]. With price of diesel at 227.92 Naira per litre as of September 2019 in Nigeria, according to [21], an off-grid BTS relying on diesel generating set for power would incur 16410.24 Naira as direct fuel cost on a daily basis. In the same vein, an on-grid

BTS with average grid power availability of 7 hours would rely on diesel generating set for an average of 17 hours thereby incurring 11623.92 Naira as direct fuel cost per day. Therefore, going by data from **Table 2**, a whopping 507.24 M Naira is spent daily on fuel by the MNOs.

The downstream oil and gas sector in Nigeria is usually volatile and is characterised by incessant products scarcity and frequent price increments. Thus, the MNOs reliance on diesel generating sets for the running of their BTSs is not only at a huge environmental costs of GHG emissions but also at increasing financial costs with some degrees of insecurity of scarcity of diesel. This condition is manifested in the high tariffs the MNOs charge for their services which are occasionally poor and/or not available.

The put off by the MNOs to adopting the renewable energy solution proffered in this work could be the initial capital cost of the solution, especially when the number of BTSs are considered. Also, adequate space requirement for solar panels arrays could as well be a constraining factor. Additional possible constraints of the MNOs to the adoption of the renewable energy solution proposed in this work are vandalism and theft, especially in remote and hotspot areas, of solar panels, batteries and other equipment. Furthermore, unwholesome practices in the supply and distribution of diesel and the value chain therein that are profiting from the status quo would always attempt to frustrate the MNOs in the quest of adopting renewable energy solutions.

6. Conclusions

In this work, the environmental impacts in terms of GHG emissions and the financial cost implications of the continued powering of BTSs by diesel generating sets in Nigeria are analysed and quantified. It is estimated that approximately 4000 tonnes of CO_2 are being released daily into the atmosphere due to the operations of BTSs in Nigeria with an estimated direct cost of fuel a bit above 0.5 B Naira per day.

The work proposed and designed a 15-kVA solar-powered inverter capable of meeting the peak demand of a typical BTS in Nigeria for at least 11 hours. The proposed solution would cut down GHG emissions due to the operations of BTSs by more than 45% and reduce direct fuel costs by at least 46%.

Barriers to the adoption of renewable energy solutions by MNOs are identified in the work. However, with strong policies and strict enforcement by the government, the MNOs would be compelled to circumspectively find means of overcoming the identified barriers.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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