HOMER Analysis of the Feasibility of Solar Power for GSM Base Transceiver Stations Located in Rural Areas

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Abstract—The recent explosion in the deployment of cellular networks across the globe has brought two very pertinent issues to the forefront of academic and technical discuss: the energy cost of running the networks, and the associated environmental impact. Cellular networks have made the greatest impact in developing countries where availability of electric power is mostly unreliable. Telecommunication networks on the other hand, are critical infrastructures which require assured power 24/7, and this power is provided at very great financial cost and damaging exchanges with the environment. In all, renewable energy technology appears to hold the most reliable solution to this lingering impasse. The authors in this paper used the HOMER® software to access or demonstrate the feasibility of deploying solar PV in providing power for BTS in rural areas as a long term solution to the near absence of grid electricity in rural areas.

Index Terms—Base Transceiver Station, HOMER, Chiller, Insolation, Renewable Energy, Cellular Networks, OPEX.

I. INTRODUCTION

Telecommunication networks and the underlying infrastructure is a critical index that portrays the level of development of any country. Since the liberalization of the Telecommunication industry in Nigeria in 2001, there has been an upsurge in the deployment of the Global System of Mobile communication (GSM). This is a cellular based system of communication which is quickly replacing the wired system of telephone exchanges which were the norm. At the end of 2018, Nigeria has an estimated 162 million mobile subscribers [1, 2]. The National bureau of Statistics in 2013 reported that 96% of telecommunication subscribers are serviced by mobile networks [3]. These mobile networks run on a critical infrastructure which includes Base Transceiver Stations (BTS) requiring electric power twenty-four hours a day and seven days a week. Though the Nigerian telecommunication space has shown a lot of promise, it has left much to be desired when compared with other African countries with far lesser population as depicted in Fig. 1 below;

Figure 1: Plot of Population against Subscriber Penetration for Some African Countries [4]

The subscriber penetration of urban Nigeria stood at 34% while that of rural populace stood at 24% as at 2013 [4], see Fig. 2;

Fig. 2 Plot of Subscriber Penetration in Rural and Urban Nigeria [3]

From the forgoing, it is visible that the future Nigerian telecommunications market will tend to be in the rural areas.

It is a known reality that as one approaches the very rural areas in the country especially those with bad terrains, the probability of having a reliable grid sourced electricity becomes very slim or non-existent. Erratic power supply is responsible for over 70% down time across Nigeria, which results in poor quality of service in the Nigerian telecommunication industry [21].

The upsurge in the use of mobile applications such as WhatsApp, Facebook, twitter, Instagram, skype etc. by the youths and most active telepopulation in Nigeria has occasioned an increase in the use of heavy data. These extensive use of data for video calls and a lot other applications are gradually becoming a norm among phone users. As a result, network operators are challenged with the task of providing their equipment with reliable power, in order to provide efficient service, and maintain a good profit margin while balancing environmental concerns. It is

estimated that Nigerian telecommunication operators use about 1.4 million liters of diesel per day to power BTS, costing them about 15 billion Naira annually [4]. The fueling cost amounts to 60% of network cost [1, 2, 6].

In remote rural areas, BTS are situated at the base of telecommunication towers and need steady power supply, especially one that will mitigate the high environmental damage that the diesel generator options cause.

II. BASE STATION POWER REQUIREMENT

The energy loads at a base station shelter consists of telecommunication load, cooling load and miscellaneous loads [12].

A. Telecommunication Load:

This refers to the load offered by telecom equipments. This load type does not vary very significantly over the day; the load profile is assumed to be a constant. Typically, 800W is consumed by a new BTS [5, 8]. Although, the load profile might be higher in older BTSs which require more power to function effectively.

B. Cooling Load:

This is the energy consumed in the processes of heat expulsion from the BTS shelter. The electronic equipments at telecom base stations have a maximum temperature at which they can function optimally. In light of the above, depending on the ambient temperature in the shelter, air conditioners are deployed to start operation at some specific temperature; usually 35°C is set as cutoff temperature at which air conditioners come into operation. Power consumed by air conditioners are estimated at 2kW. Also, the lifetime of a battery is a function of the ambient temperature depending upon the type of the battery. As the temperature increases by 10°C, the lifetime of a typical lead acid battery is reduced to half of its actual value [6, 7]. Batteries also produce heat while charging, which accounts for increase in the temperature of the battery unit. Experimental results show that a typical battery has the best lifetime when maintained at 27°C. Since other equipment in the shelter can operate at higher temperatures, this results in excessive cooling and high power bills. An alternative used sometimes nowadays, is to place the battery in a separate cabinet, which is cooled separately. A battery chiller is used for this purpose. Depending on the size and the nature of batteries used, the power consumption of the chiller would vary. Typically, a chiller consumes 100 to 300W of power [1].

C. Miscellaneous Loads:

Battery charging is also a load that needs to be considered. Other additional loads include fans and lights in a shelter, which typically consume about 100W [13, 14].

III. SOLAR PV POWERED TELECOM BASE STATION

High telecommunication and data traffic is usually observed during daylight hours. Thus, cost effectiveness, efficiency, sustainability, and reliability, which are key features of power source requirements for BTSs can be

achieved by exploiting available energy from solar resources. This is considered a long-term ideal solution for cellular network operators. Moreover, because it is freely available, sunlight is an ideal alternative that can reliably supply power to remote areas being that Nigeria is blessed with good solar insolation [12, 14]. However, designing a solar system requires a feasibility assessment, which can mitigate any poorly designed power supply system, especially those that can inefficiently power a BTS. [5]. In this paper, we seek to use the HOMER software to demonstrate the economic feasibility of a solar powered rural BTS located in Ebranta Community in Boki Local Government Area of Cross River State.

A. About Homer

HOMER is a software application package used in designing, and weighing the options of either off-grid or on-grid power systems based on their technical and financial viability. It was developed in 1993 by the National Renewable Energy Laboratory in the United States for internal Department of Energy (DOE) [6, 16].

HOMER has optimization and sensitivity analysis capabilities, which helps point to answers of difficult design questions when designing off-grid and grid-connected systems: Which technologies are most cost-effective? What size should components be? What happens to the project's economics if costs or loads change? Is the renewable resource adequate? HOMER finds the least cost combination of components that meet electrical and thermal loads, simulates thousands of system configurations, optimizes for lifecycle cost, and generates results of sensitivity analyses on most inputs. After simulating all of the possible system configurations, HOMER displays a list of feasible systems, sorted by lifecycle cost. You can easily find the least cost system at the top of the list, or you can scan the list for other feasible systems [9]. Sometimes you may find it useful to see how the results vary with changes in inputs, either because they are uncertain or because they represent a range of applications [16].

B. System Model

A general model of a solar powered telecommunication base transceiver station (BTS) is as depicted in Fig. 3 below which consists of all accessories necessary for a good quality solar power. For this study, Ebranta Community in Boki Local Government Area located on Latitude 6° 16'26"N and Longitude 9° 00'36"E was taken as a reference rural community. This community is located on a high sunshine belt and thus has enormous solar energy potentials as depicted by the solar irradiation pattern chart presented in Fig. 4 with average sunshine hours estimated at 6hrs per day and is fairly well distributed.

IV. RESULTS AND DISCUSSION

After synthesizing input information using the HOMER; the optimization software to ascertain the best setup which will have the best output at the least cost. The best case solution preferred the construction of a stand-alone 5kVA solar power system. The system architecture will contain a battery bank with a nominal capacity of 30kWh, an 8kW

rated PV system, an 80AMPs charge controller and a 5kVA among other equipment making a foot print of about 24m².

System Setup and Economics

The battery system with a nominal capacity of 30kWh can be made of 12 number of 12V/200Ah DEKA Solar batteries at a unit cost of ₦210,000 arranged on a battery rack. The battery system has a bus voltage of 48 volts and an autonomous operation time of 40hours totaling about 8,800 hrs/yr. In order to maintain the operational life of the batteries a 80A MPPT charge controller needs to be

incorporated at a cost of ₦200,000.

The desired power output can be achieved by the use of 24V/300W mono-crystalline PV modules. The series parallel combination involves 24 of this modules at the cost of ₦70,000 per module making a foot print of 24m². The PV system will be in operation for an estimated four thousand four hundred and sixty-two hours in a year (4,462 hrs/yr) spanning about 24 years. To aid power conversion, a 5kVA (48V) genus inverter can be deployed at a cost of ₦420,000.

Fig. 3 Model for Solar Powered BTS

Fig. 4 Solar Radiation Pattern of Ebranta Community

A. Project Payback Period

The average life span of a PV solar power system is about 25 years while that of the battery and system converters is about 10 years when the right depth of discharge (DOD) is maintained on the batteries. Assuming an annual discount rate of (11%), the net present cost of the project over its twenty-five-year life time stands at ₦8,139,800 with an initial capital cost of ₦5,790,716. The initial capital cost takes into account: cost of PV modules, battery, converter systems, cost of solar PV and battery racks, labour, cables and other useful accessories. The remaining ₦2,349,084 is the cost of replacement of battery and system converters after a span of ten years. This cost also takes into

consideration the operation and maintenance expenses (OPEX) of the entire system. Spreading this cost over the 25-year period, the cost of providing power for a single base station will be about ₦900 per day and ₦330, 000 per year over the time period. So at a modest cost of ₦2000 per day, the system pays for itself in 11 years.

V. CONCLUSION

Increase in the use of mobile networks and devices has positive effect on the economy of nations where they are deployed and enjoying these services at cheaper rates is even more gratifying to the customers and network operators. Nigeria has about 39,000 base transceiver stations (BTS) spread across the country [2]. It is estimated that these BTSs consume about 1.4 million liters of diesel per day; and a liter of diesel sells at ₦230. From the above, it will take about 36 liters of diesel to power a base station for a day at a cost of about ₦8,300, and about 3 million naira a year not taking into account the cost of maintaining the diesel gen-set. From the results obtained, it can be gleaned that power generated using solar PV is the most economically viable configuration for telecommunication base transceiver stations in rural areas because cost of BTS electrification comes down to about ₦2,000 per day as against ₦8300 needed to fuel a diesel gen-set for a day. The reduction in OPEX will result in reduced network cost. Aside network cost, it greatly reduces the amount of air pollutants emitted into the atmosphere; which is estimated to be about 6369.5 tonnes/year in each state of Nigeria [18].

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