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Solar Micro-grid for Remote Cellular Base Transceiver Station (BTS)

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ABSTRACT
The non-steady grid power supply has been a major source of worry for Nigerian electricity consumers. The telecom operators are not exceptions. Over a half of the base stations in Nigeria are powered by diesel generating sets with great operating costs. Most of these sites are solely off-grid systems to which a utility grid is not connected. Although some of the base transceiver stations (BTS) are grid-connected, they usually face frequent long-hour outages as well as poor quality electricity supply characteristic of Nigeria national grid supply. This later group of BTS consumers equally resorts to diesel generating sets as their default backups. This seminar paper describes an island ac-coupled solar micro-grid for remote cellular base transceiver stations. In this energy model, the BTS site houses the solar power plant which provides the energy need of the BTS site and in addition provides the energy need of the host community. This energy model gives room for excellent public private partnership (PPA) in energy provision services.

Keywords: Micro-grid, AC-Coupled, BTS, Photovoltaic

I. INTRODUCTION

One of the major challenges faced by the telecommunication operators in developing countries is inadequate power supply (Ani and Nzeakor, 2013). In Nigeria for instance, although many rural areas are yet to be reached with the national grid yet the telecommunication operators have extended their networks to these rural dwellers. The cost of extending electric grid to the dispersed localities is relatively high. This circumstance leaves the tower operators with no other choice than to use an alternative power supply. In Nigeria, the performance of grid power supply has affected the cost of telecom operations greatly. Recent statistics (Goshwe, Kureve and Okeleke, 2015) show that out of the total number of cellular base station sites in Nigeria that up to 56% of these sites are operated in off-grid mode power supply will 44% are unreliable grid sites. It therefore means that about half of the BTS site population is located in areas without access to grid power supply. According to (GSMA Green Power for Mobile, 2015) about 81% of the grid-connected BTS sites experiences up to 6 hours of power outage per day while despite the inherent advantages of renewable energy sources, only about 2% of these off-grid sites have deployed same. The percentage of grid-connected BTS sites that have deployed renewable energy sources as default backups is also comparable with the former.

About 55% of the off-grid BTS sites still rely heavily on diesel generator power, running 24 hours daily and the remaining 43% adopted battery hybrid solutions (GSMA Green Power for Mobile, 2015). The deployment of diesel generator power supply as backups to telecom BTS sites has its glaring demerits ranging from high cost of fossil fuels, diesel logistics and theft to the environmental impact of high carbon dioxide emission as well as noise pollution. These telecommunication tower operators are faced with several cases of thefts and equipment damage. Reported cases of stolen diesel generator sets abound. Incidences of vandalization of telecommunication solar plants have also been observed. In this paper, the deployment of a community based island ac-coupled solar micro-grid for remote cellular base transceiver stations is proposed. In this energy model, the solar power plant is provided by means of public private partnership (PPA) between the telecom tower operator and the host community. The tower operator may provide the greater part of the fund while the host community becomes the security provider ensuring that the installed facilities are protected against theft and vandalization.

II. PV MICRO-GRID ARCHITECTURE FOR BTS AND HOST COMMUNITY

A PV micro-grid is a small scale solar power supply grid that is designed to serve the

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energy need of a small community or limited load. This may be a house, an isolated community, a commercial or an industrial area (Sengprasong et al., 2010). In this case the load comprises the BTS and the energy need of the host community. A micro-grid consists of one or more distributed generators that are sizeable to the loads within the micro-grid. These distributed generators are in close proximity to the energy users (Abu-Sharkh et al., 2006) and thus under local control. The problems inherent in the use of lengthy lines are totally avoided. A simplified architecture of community based island ac-coupled solar (with other energy sources) micro-grid for remote cellular base transceiver stations is shown in Fig.1.

The three main determining factors of the power output of a PV generator are the PV cell material, the cell temperature and the solar radiation incident on the PV modules. The model with which the power output of a PV generator can be computed as given in (Panagiotis et al., 2013) is shown in equation 1.

$$P_p = n_p E_p G_t \qquad (1)$$

Where P_p is the PV generator efficiency, E_p (in m^2) is the area of the PV generator and G_t (in W/m^2) is the solar radiation incident on the PV module.

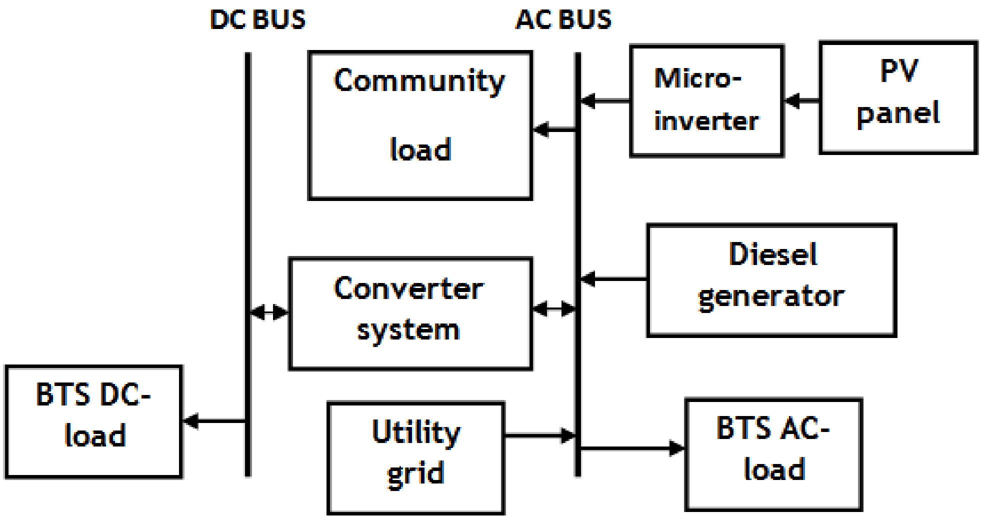

Fig.1: Hybrid Micro-grid architecture

2.1 Configurations of Solar Power System

An off-grid solar system is made up of the following: an array of PV panels which in the presence of sunlight generates direct current electricity, a storage battery bank which stores the DC power for later use, a charge controller that regulates the charging of the batteries, and an inverter/charger unit for converting the battery-stored energy from DC to AC for powering AC loads (Nwankwo and Azubogu, 2016), as shown in Fig.2. This is a typical hybrid system. Solar power systems can be said to be either DC or AC coupled depending on its output voltage type. In DC coupled system, the PV generator is connected through a special DC/DC charge controller while in AC coupled system, a PV micro-inverter is used for feeding power to the load and the grid. A DC coupled system has all loads and generators coupled exclusively at the battery voltage level (SMA Solar Technology, nd). In an AC-coupled solar system, each PV panel is fitted with its own micro-inverter which permits it to directly produce a 240V (ac) power. In this system, all generators and loads are directly connected to the AC bus. The output side of AC coupled system may be connected to the conventional utility grid for the purpose of synchronization, hence the term, grid-tied.

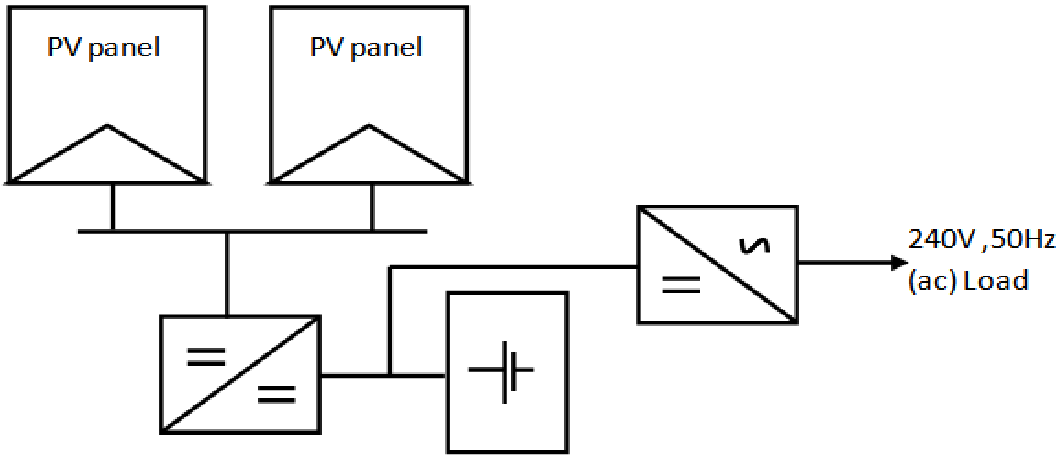

Fig.2: An Off-grid solar system

III. RURAL COMMUNITY ENERGY NEED

Most dispersed rural communities around the world usually rely on imported fossil fuels for their energy needs. In Nigeria, most remote communities have no electric grid supply. They rely on individual effort by procuring diesel or petrol generating sets for electricity supply. The cost of fueling these engines is actually prohibitive given the current pump price. A few of Nigerian remote localities are serviced by the utility grid but are plague by the long-hour non-availability that characterized Nigerian electric power supply. The telecommunication industry has achieved a great fist by penetrating into the remote villages making voice and data traffic possible. Virtually all the remote localities in Nigeria have telecom towers pointing to the sky. These base transceiver stations (BTS) require electric powers to work. These BTS sites deploy diesel generating sets either as a backup owing to poor supply or as a power workhorse which run 24 hours daily in cases of off-grid. The deployment of diesel generator power supply as backups to telecom BTS sites has its glaring demerits ranging from high cost of fossil fuels, diesel logistics and theft to the environmental impact of high carbon dioxide emission as well as noise pollution. MTN for instance spent over N34 billion on diesel for powering its cell sites in 2013 (NCC, 2013). A typical load profile for a remote locality, adopted from (Nayar, 2012), is shown in Fig.3.

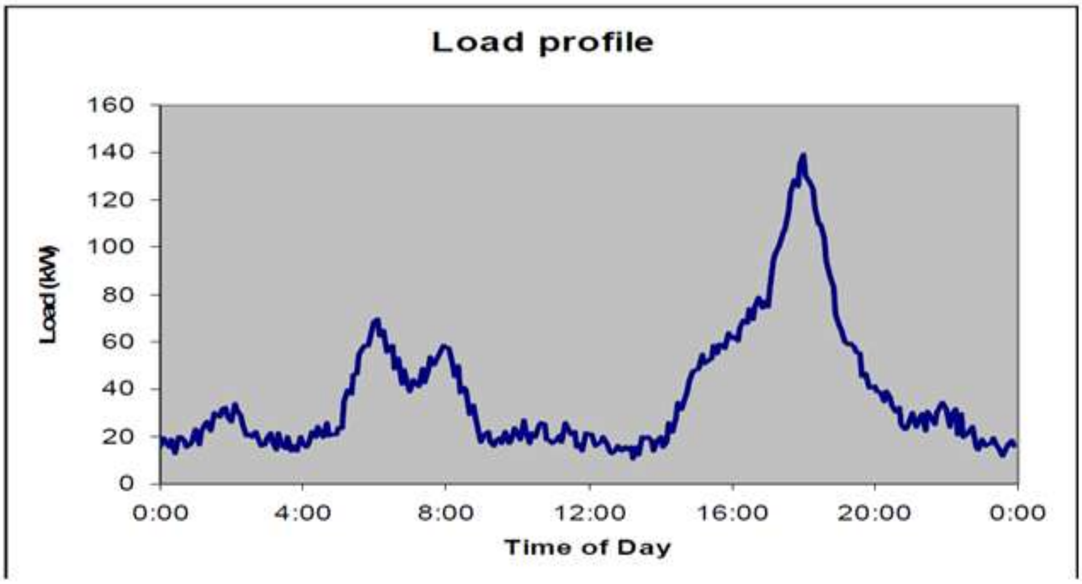

Fig 3: Typical load profile of a remote community [source: (Nayar, 2012)]

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3.1 BTS Architecture and Electric Energy Demand

Base Transceiver Station (BTS) performs an interface function between any two communicating mobile stations (MS) a cellular network. Based on geography and service demand of an area, a BTS may possess between 1 to 16 Transceivers (TRX) (Faruk et al., 2012). The two major energy consumers on a BTS are the radio and the cooling equipment. In order to produce the required RF power, the radio equipment consumes about 68%; the air conditioner accounts for about 30% of the consumption; 1% is losses on the feeder while only 1% goes to the final signal (Panagiotis, 2012).

Individual Power consuming components within a BTS are the digital signal processing (DSP), the power amplifier, the transceiver and the rectifier as shown in Fig.4. These components perform varied but coordinated function within the system. Some of these components occur in more than one sector; and to compute the net power consumption of the BTS, all these factors are taken into consideration. It must be noted that both the transceiver and the power amplifier are found one per transmitting antenna (Faruk et al., 2012). Components like the air conditioner and the microwave link when no fiber optic link is available for backhaul are common to all sectors.

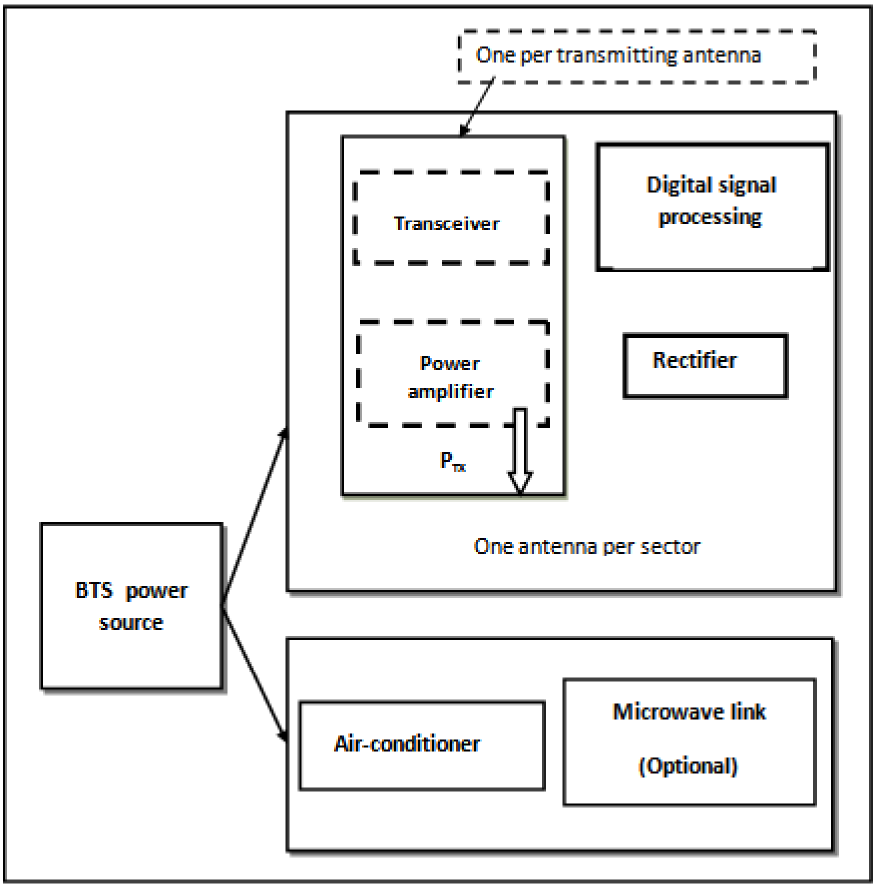

Fig.4: Block Diagram of Base Station Equipments [source: Faruk et al., 2012)]

An estimate of the net BTS power consumption can be made using an analytic model adopted from (Faruk et al., 2012) as shown in equation 2.

This model is based on the assumption that the power consumptions of individual components of the BTS are known.

$$P_{BTS} = n_{Sector} * (P_{DSP} + n_{TR} * (P_{AMP} + P_{Tran}) + P_{Rec}) + \sum_{i}^{n} P_{AC_i} + \sum_{k}^{l} P_{micro} + \sum_{j}^{m} P_{LB_j} \ldots\ldots\ldots (2)$$

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Where, n_{Sector} is thhhhhhe number of all the sectors in the cell,
n_{TR} is the number of transmitting antenna per sector,

P_{DSP}, P_{AMP}, P_{Tran}, P_{Rec}, $\sum_i^n P_{AC_i}$, $\sum_k^l P_{micro}$, $\sum_j^m P_{LB_j}$ are the total power consumption of the base transceiver station's digital signal processing unit, the power amplifier, the transceiver, the rectifier, the air conditions, the microwave and incandescent bulbs respectively. The variables n, l and m refers to the total number the respective components. A typical BTS load profile [adopted from (Olatomiwa et al., 2014)] is shown in Fig.5.

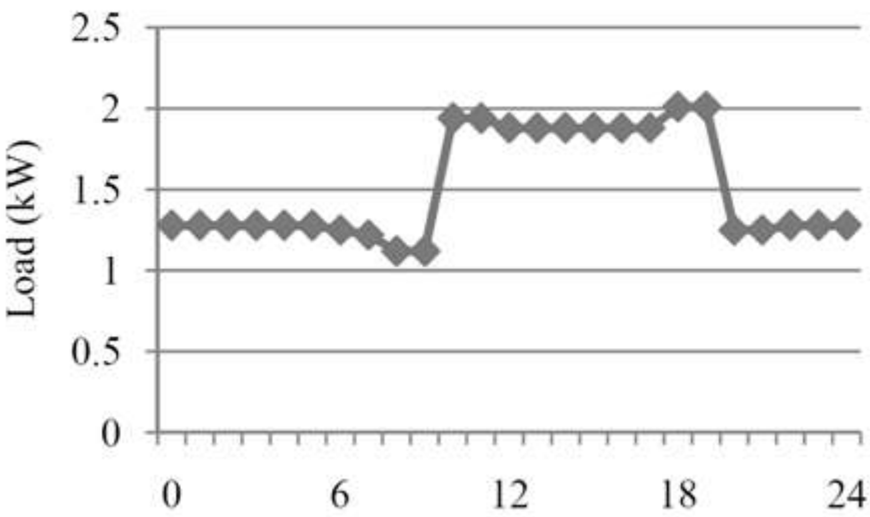

Fig.5. Daily load profile of a BTS site [source:Olatomiwa et al., 2014)]

3.2 Micro-inverter-based solar System

According to (Finn, 2014), a micro-inverter is a miniaturized inverter sized to suit an individual solar panel rather than a string of panels. A solar panel that has been fitted with a micro-inverter so that it generates an Alternating Current instead of Direct Current is called an AC solar panel. This is not without trade-offs, however. The AC outputs of all the micro-inverters need to be synchronized so that all the signals are in phase (Engineering.com, 2013). The output of the array is thus synchronized with grid voltage. This implies that a micro-inverter system works well, only when it is in a grid-tied configuration. If the grid goes down, the solar power system also goes down.

A number of difficulties encountered when using the traditional string solar panels are overcome by using the micro-inverter systems; these are discussed in (Engineering.com, 2013). All these benefits confer the property of flexibility and modularity of design as well as improved performance on AC-coupled system type.

3.3 AC-Coupled PV Micro-grid

AC coupling permits the use of micro-inverters with off-grid and battery-based photovoltaic systems (Enphase Energy, 2014). By this application, the micro-inverters and the battery-based inverter are coupled on their AC outputs, hence the term AC-coupling. AC coupling makes the grid-tied solar system to provide power during power outages. In AC-coupled system, the PV panels via micro-inverters feed-in directly to the AC-side. Frequency sweep technology may be employed in the inverter/charger to protect batteries from overcharging. AC-coupling has the advantage of high efficiency because the power produced by PV panels is fed directly to the AC loads via their efficient micro-inverters. Again, energy optimization is possible as any excess solar-generated energy is stored in the battery bank. AC-coupled systems are designed using modular approach and hence scalable.

3.4 Financial and Security Implications

Although the PV energy system of such magnitude will have a high financial implication, the remote community and the telecommunication company can jointly undertake the task. The energy load of the community and that of the BTS site will be properly accessed and proper costing done. The tower operator may contribute the larger part of the fund which will serve on one hand as their part of the investment cost and on the other hand as their social responsibility to the host community.

The host community may contribute a smaller percentage of the overall investment cost as their counterpart fund. The host community will however play a critical role of providing security for both the BTS equipment and the island power plant. Since the host community has equity investment in the power system which is located in the premises of the BTS site on one hand and that the power system supplies their electric energy need, they are duty bound to protect the facility.

The BTS sites that have diesel generating sets and/or grid supply can still use this hybrid power system and by means of optimization a cost effective energy use is obtained. A new BTS site can adopt an energy solution that employs only solar system without fossil fuel. This will eliminate CO_2 and noise pollutions.

IV. CONCLUSION

The application of an Island AC-coupled solar Micro-grid power system for remote cellular BTS has been discussed in this paper. The advantages of this model and the synergy it creates between the host community and the tower operator is also highlighted. The financial, social and security implications of this symbiotic public-private partnership are equally stressed. This power supply initiative, if embraced by the rural communities concerned and the telecommunication tower operators, will go a long way providing portable, steady and reliable power supply to both parties

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