White Paper

Alternative and Sustainable Power for Nigerian GSM/Mobile Base Stations

"Focusing on renewable and alternative power solutions to everyday needs"

Infinite Focus Ltd is registered in Ireland Number 432205.
This white paper is an authoritative report, business case and guide with a focused objective to provide an alternative, renewable but cost effective power supply solution to mobile/GSM/CDMA base stations. The essence of the paper is to provide solution that will help senior management of GLOBACOM make informed decision on renewable and alternative energy solutions to meet their everyday power needs.

1.0 THE CHALLENGES OF POWERSUPPLY FOR BASE STATIONS

Since the introduction of mobile phones in Nigeria and Africa at large, the communication services have seen considerable expansion. GSM, UMTS, and other mobile phone solutions are now connecting millions of subscribers in Nigeria, 2 billion worldwide with a further billion planned to be added by 2012.

Other mobile solutions such as WiFi and shortly WiMax are becoming commonplace, and secure radio systems such as Tetra are in widespread use for emergency and security services. Network operators face a number of challenges, with the increasing spread of wireless voice and data into remote areas, including towns and cities that lack basic power infrastructure.

Such challenges, in most locations in Nigeria, for example, includes for expensive and complex civil works, high installation and commissioning costs, expensive or not available electricity due to poor power infrastructure. Generators can be used, but they are becoming more expensive to operate due to increasing oil prices or scarcity. In addition, these sites will require security for the base station (BTS) and other associated equipment especially for the generators and diesel oil that power them. Security on remote sites is a significant issue, particularly if the power generating equipment can easily be used for other purposes. Diesel generators and fuel can easily be sold if stolen.

Power supply to these sites is often the key issue for service providers building in these peculiar locations, fraught with even more unusual challenges. Hence most providers have resulted in using expensive but secure way in meeting their power needs by the use of diesel generators.

Mobile telecom networks require an enormous amount of power. In markets with unreliable grid power, this energy often comes from diesel fuel. By some estimates, Nigeria alone already uses well over 150 million litres of diesel fuel every year to power telecom base stations when the grid power is not present or not available. This does not include the fuel needed to transport fuel to the mobile sites. Adding hundreds of millions of rural users can only multiply this destructive environmental impact — unless these users are supported by a sustainable alternative.

Most base stations are power-inefficient due to the power amplifiers (PAs). PA dominates the power consumption of the base station, accounting for approximately half of the total power used, and generating large amounts of heat. Power consumption can be effectively reduced by adopting advanced power magnifier technologies which can increase the efficiency of power magnifiers by 45%.
1.1 The Green Issues Challenge to Base Station Power

Most mobile network operators now include in annual reports worthy statements emphasising their corporate social responsibility, about what they are doing or plan to do to reduce the energy costs of running their base-stations. Operators are beginning to take the issues almost as seriously as how to solve the more consumer-oriented problem.

The increasing emphasis on energy savings, more and more wrapped round a desire to be seen as being good corporate “green citizens”, is not wholly unselfish or humane, as energy use equates directly to costs. Running mobile phone networks is getting more expensive and difficult, due to increasing energy costs in developing countries and as operators increase the number of base-stations in the infrastructure, so that they can offer third generation networks, wireless services at broadband data rates, power consumption is set to continue to rise.

Operators are therefore looking to alternatives to help them improve base-station efficiency and for the development of more efficient power amplifiers and reducing requirement for blown air and air conditioning in base-stations.

Recent studies indicate that radio/mobile networks account for about 80 percent operators’ electricity usage, so there are plans to introduce renewable cost effective power source to supplement or replace the power used at these stations.

1.2 Infinite Focus-Solar Power(IFSP) has recognized these challenges and is planning to facilitate or provide alternative, cost effective and renewable power solutions for communications operators. These solutions offered by IFSP will prove to be a significant initiative in addressing energy related operating expenditure, saving challenges of telecom operators and infrastructure companies. The IFSP solutions offer up to 60 percent or more in operating expenditure related power savings.

2.0 AVAILABILITY OF ALTERNATIVE POWER SOLUTIONS

Alternative power solutions are not commonly used in telecommunications systems today, but are being actively evaluated for difficult locations and limited deployments have been made. However because of the unusual Nigerian power environment, industrial and even domestic solar solutions are now at increasingly affordable prices compared to the diesel generator alternative.

IFSP has spent the last two years re-evaluating and re-engineering the solar solution to overcome these challenges. The development of high efficiency and affordable solar power has progressed to the point that domestic solutions are feasible in areas of high sunlight like Nigeria. New solar cell technologies are moving the price point steadily down at a time when fossil fuels are increasing in cost. In addition incentives such as when there is excess power this can be sold back to the local power company may be available soon in Nigeria. (See Figure1 & 2)
Once installed solar arrays require minimal maintenance, though occasional cleaning will prevent a gradual loss of panel efficiency from dust or bird droppings. Cloud and rainfall may reduce power output for a period, but can have the benefit of cleaning the solar panel surface.

**Figure 1. World Isolation Map**

Figure 1 shows a world map with average annual solar irradiation levels. The differences in irradiation are due to a combination of climatic and purely geometric effects. The map legend gives dark red as 6.0-6.9 kWh per square meters per day, where the absolute theoretical maximum value is approaching $24/\pi$. This expression can be found by integrating the power per day that will reach the ground at a location where the sun rises at 6am, reaches zenith at local noon and sets at 6pm without any clouds interfering at any time.

**Figure 2. World Solar Radiation Map**

This map shows mean solar radiation received at the surface, expressed in W/m². It oscillates between a maximum of 275 W/m², in the cloudless regions of the Sahara and Arabia, up to a minimum of 75 W/m² in the misty isles of the Arctic. The global mean is 170 W/m².
3.0 THE IFSP SOLAR POWERED BASE-STATION

3.1 Target Configuration

There are several types of base station configurations with variety of equipments. There are Terminal sites, backbone sites, MSS site offices and a single-sector base station with Baseband Card, a MicroTCA chassis and a remote radio head.

The table below gives some indication of the power required and peak power draw at different BTS. These examples need to be seen as indicators of possible configurations and the local conditions may require larger or smaller solutions.

<table>
<thead>
<tr>
<th>Application Site</th>
<th>Power</th>
<th>Typical Range</th>
<th>Peak Power draw</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSM Base Station 2/2/2</td>
<td>600-1800W</td>
<td>1.8kW</td>
<td></td>
</tr>
<tr>
<td>GSM Base Station 4/4/4</td>
<td>900 – 2300W</td>
<td>2.3kW</td>
<td></td>
</tr>
<tr>
<td>UMTS Node B Macro/Fiber 2/2/2</td>
<td>750 – 1000W</td>
<td>1.0kW</td>
<td></td>
</tr>
<tr>
<td>UMTS Node B, Macro/Fiber — 4/4/4</td>
<td>1300 – 1700W</td>
<td>1.7kW</td>
<td></td>
</tr>
<tr>
<td>Large WiMax Base Station</td>
<td>1.3kW (4 Sector)</td>
<td>2.3kW</td>
<td></td>
</tr>
<tr>
<td>Metro WiFi</td>
<td>&lt;30W, includes a backhaul solution</td>
<td>100W</td>
<td></td>
</tr>
<tr>
<td>P2P link (two heads)</td>
<td>110W for two units</td>
<td>190W</td>
<td></td>
</tr>
</tbody>
</table>

On average, a fully loaded GS/3G BTS using traditional PAs is estimated to need 3 kW of power at peak draw. Hence our targeted configuration will be for the worst case scenario in terms of energy consumption i.e. the 3.0kW peak power draw BTS. Studies have also shown that this BTS will consume an average of 12,500kWh of electricity in a year.

3.2 The Solution

An IFSP designed solar-powered system, which consists of solar panel modules, deep cycle battery arrays and charger controller. The battery array powers the base station while the charger controller regulates power to the base station and controls charging of the battery. Solar panels provide power to charge the batteries. The battery array will have a backup capability of 2 days, while the solar modules are designed in such a way that in only needs 4-5hours of sunlight to recharge the batteries.

3.2.1 Solar Power Storage System

The nature of power systems which utilize solar, wind or hydro power is that there will be frequent periods where excess power will have to be stored for use when there is reduced power output. In our research on optimizing site power solutions IFSP has developed more efficient methods of managing this process, minimizing the amount of generated power that has to be wasted buy utilizing the cost effective and efficient technologies in power storage.

In this regard, the battery type adopted is the deep-cycle battery typically used in solar-powered systems. There is a wide choice of deep-cycle batteries on the market that vary according to capacity, weight, build type and form factor. The choice for this target
configuration is the industrial lead-acid, eep-cycle Rolls Series 5000 12 CS 11PS battery, designed for solar-powered systems (specs below). The 100-hour rate of this battery provides a capacity of 503 amp-hours and the 72-hour rate provides a capacity of 475 amp-hours. Ten units of these batteries are required. It is capable of providing two days of backup time while still meeting the current required by the base station.

The Rolls Series 5000 12 CS 11PS
- Capacity $c = 503$ amp-hours (100-hour rate at 5.03 amps), $c = 475$ amp-hours (72-hour rate at 6.59 amps)
- Voltage: 12 volts
- Dimension 55.9 cm x 28.6 cm x 46.4 cm
- Warranty 10 years
- Lifetime 3300 cycles – Average life expectancy: 15 years

The battery pack array comes with all weather secure steel cabinets for storage. See appendix for images of battery cabinets.

3.2.2 The Solar Panel Modules
The number and size of the solar panel required is dependent on the solar radiation received at the surface. Our module is designed for a typical location in Nigeria.
For example a 1 kilowatt peak Solar System will generate around 1,600 kilowatt hours per year in a sunny tropical climate and about 750 kilowatt hours per year in a temperate climate.

Some simple examples are that a 1kWp Photovoltaic System will produce approximately:
- 1800 kWh/year in Southern California
- 850 kWh/year in Northern Germany
- 1600-2000 kWh in Nigeria

A wide range of photovoltaic solar panels made up of silicon nitride crystalline is available in the market with varying power output, peak current and efficiency. In this application note the panels are considered, are the SHARP ND-200U1 module (200w) and BP Solar BN200 solar panel or any 200W module.

Table 2 below gives the average daily solar radiation pattern and based on this pattern our system will require 40 no. 200w modules to generate sufficient current to charge the battery array and to account for an allowance of 15% inefficiencies in transporting the solar power to the battery array. The modules or solar panels are required to be in parallel connection, because the battery array is 48 volts, two panels are required in series for the module types, as a result, an even total of modules are required.
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<table>
<thead>
<tr>
<th>Unit</th>
<th>Climate data location</th>
<th>Project location</th>
</tr>
</thead>
<tbody>
<tr>
<td>Latitude</td>
<td>°N</td>
<td>7.4</td>
</tr>
<tr>
<td>Longitude</td>
<td>°E</td>
<td>3.9</td>
</tr>
<tr>
<td>Elevation</td>
<td>m</td>
<td>198</td>
</tr>
<tr>
<td>Heating design temperature</td>
<td>°C</td>
<td>20.2</td>
</tr>
<tr>
<td>Cooling design temperature</td>
<td>°C</td>
<td>30.9</td>
</tr>
<tr>
<td>Earth temperature amplitude</td>
<td>°C</td>
<td>10.5</td>
</tr>
</tbody>
</table>

Note the average daily solar radiation pattern and the annual average of 4.90kWh/m²/d. This is much higher than that of a town in Germany (Berlin) with 2.74kWh/m²/d and yet Germany accounts for over 43% of the world photovoltaic market after USA with 18%.

The preferred module option is the SHARP ND-200UI

- Peak power 200 W
- Dimensions 64.6” (L) x 39.1” (W) x 1.8” (H); (164 x 99.4 x 4.6 cm)
- Weight 46.3 lbs (21 kg)
- Limited warranty 25 years
- Requirement 40 units – Total area: (65 m²)
- Total weight: 370.4 lbs (168 kg)

Peak power output is about 6.8kW with an allowance for 15% loss or inefficiency. This is more than enough to generate 12,500kWh year and a sustained peak power draw of 3kW as required for fully loaded BTS.

Table 2: Climate Data for Typical location in South-West Nigeria (Ibadan)

<table>
<thead>
<tr>
<th>Month</th>
<th>Air temperature</th>
<th>Relative humidity</th>
<th>Daily solar radiation horizontal</th>
<th>Atmospheric pressure</th>
<th>Wind speed</th>
<th>Earth temperature</th>
<th>Cooling degree-days</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>°C</td>
<td>%</td>
<td>kWh/m²/d</td>
<td>kPa</td>
<td>m/s</td>
<td>°C</td>
<td>°C-d</td>
</tr>
<tr>
<td>January</td>
<td>26.1</td>
<td>59.6%</td>
<td>4.51</td>
<td>99.0</td>
<td>2.7</td>
<td>28.3</td>
<td>499</td>
</tr>
<tr>
<td>February</td>
<td>26.4</td>
<td>65.2%</td>
<td>3.34</td>
<td>98.9</td>
<td>2.7</td>
<td>28.6</td>
<td>459</td>
</tr>
<tr>
<td>March</td>
<td>26.0</td>
<td>79.5%</td>
<td>5.54</td>
<td>98.9</td>
<td>2.8</td>
<td>27.6</td>
<td>496</td>
</tr>
<tr>
<td>April</td>
<td>25.9</td>
<td>83.8%</td>
<td>5.70</td>
<td>98.9</td>
<td>2.5</td>
<td>27.0</td>
<td>476</td>
</tr>
<tr>
<td>May</td>
<td>25.7</td>
<td>84.5%</td>
<td>5.28</td>
<td>99.0</td>
<td>2.3</td>
<td>26.7</td>
<td>487</td>
</tr>
<tr>
<td>June</td>
<td>24.9</td>
<td>85.6%</td>
<td>4.89</td>
<td>99.2</td>
<td>2.2</td>
<td>25.7</td>
<td>447</td>
</tr>
<tr>
<td>July</td>
<td>24.0</td>
<td>85.6%</td>
<td>4.45</td>
<td>99.3</td>
<td>2.7</td>
<td>24.5</td>
<td>433</td>
</tr>
<tr>
<td>August</td>
<td>23.9</td>
<td>84.8%</td>
<td>4.11</td>
<td>99.3</td>
<td>2.8</td>
<td>24.5</td>
<td>431</td>
</tr>
<tr>
<td>September</td>
<td>24.3</td>
<td>85.7%</td>
<td>4.63</td>
<td>99.2</td>
<td>2.6</td>
<td>25.1</td>
<td>430</td>
</tr>
<tr>
<td>October</td>
<td>24.7</td>
<td>85.0%</td>
<td>4.95</td>
<td>99.1</td>
<td>2.1</td>
<td>25.5</td>
<td>454</td>
</tr>
<tr>
<td>November</td>
<td>24.9</td>
<td>81.0%</td>
<td>4.94</td>
<td>99.0</td>
<td>2.5</td>
<td>25.8</td>
<td>446</td>
</tr>
<tr>
<td>December</td>
<td>25.4</td>
<td>67.7%</td>
<td>4.54</td>
<td>99.0</td>
<td>2.4</td>
<td>26.8</td>
<td>476</td>
</tr>
<tr>
<td>Annual Av.</td>
<td></td>
<td></td>
<td>4.54</td>
<td>99.0</td>
<td>2.5</td>
<td>26.3</td>
<td>5,534</td>
</tr>
<tr>
<td>Measured at</td>
<td></td>
<td></td>
<td>10.0</td>
<td></td>
<td>0.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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4.0  ECONOMIC PAYBACK

The cost estimate for the fully functional IFSP designed solar-powered system, which consists of solar panel modules, deep cycle battery arrays and charger controller for a fully loaded 3kW BTS is $30,550.00. This excludes custom clearing cost and site specific installations.

In comparison, a fully loaded BTS is typical powered by twin 15 kilo volt ampere (KVA) or more diesel generators which consumes over 2.5 litres of diesel every hour up to 20 hours daily will cost about $12,026.00 in diesel fuel per year(assume 0.66cents/litre or N110/litre) and €15,000.00 for 2 no. generator excluding other maintenance and associated cost.

4.1 Comparative Price based on 10years for Telecom operator with 10,000 BTS in operation.

A typical telecom operator with about 10,000 BTS would have spent well over $1.2 billion on diesel fuel and generator within a ten year period. This cost excludes inflation, maintenance and other associated costs. As well as these costs, such a level of consumption is estimated to lead to a carbon footprint of about 11 tonnes of carbon dioxide for each cell site, each site per year, while the solar option is estimated to cost $306.50 million over the same period. The solar option would have zero carbon footprint, because the CO2 used in production of the system would have been eliminated within the first 2 years of operation.

This is a highly significant savings in cost ($900 million) of energy consumption over a period of ten years using a renewable energy source with added social benefits.

The Infinite Focus-Solar Power(IFSP) solutions offer will prove to be a significant initiative in addressing energy related operating expenditure, saving challenges of telecom operators. The solutions offer more than 75% in operating expenditure related power savings over 10years and over 48% within the first 5years i.e. about $293.5million (for 10,000 BTS).

This initiative becomes even far reaching with the telecommunications industry striving to improve the energy efficiency of its latest generation base stations, achieving energy consumption levels of 800W and 500W respectively for typical GSM and WCDMA base stations and has set even more ambitious targets, to further reduce the energy consumption of its GSM and WCDMA base stations to the 650W and 300W respectively by 2010.

The impact of this ambitious target will be extremely significant in terms of cost and environment, the solar solution to provide 800W of power is less than half of the estimated cost quoted above. Coupled with the fact that the price point of photovoltaic technologies is moving steadily down at a time when fossil fuels are increasing in cost. Rural and isolated markets suddenly become viable.
5.0 THE INFINITE FOCUS SOLAR POWER INITIATIVE

“The country is likely to have around 40,000 GSM base stations by 2010, in addition to approximately 10,000 CDMA towers. Nigeria currently has around 2,000 CDMA towers and 10,000 GSM towers”. Ernest Ndukwe, the chief executive and executive vice-chairman of the telecom regulator of Nigeria.

It is our desire to work with telecom operators by providing a green energy efficient and cost effective base station that will serve as model for other industries.

Infinite Focus Solar Power can assist in reducing the current cost on energy by as much as 70% over the next 5 years. This is achievable by simply adopting advanced power magnifier technologies like DPD and A-Doherty, which can increase the efficiency of power magnifiers by 45% with a suitable IFSP solar power option.

IFSP is planning to deploy an estimated 10,000 solar option solutions across Nigeria and 20,000 within West/East Africa in the next 5 years. This initiative will help save 150 billion kilowatt hours of electricity in the year of full deployment, equalling a reduction of carbon dioxide emissions of burning 40,000 tons of coal thus helping operators better achieve sustainable development.

IFSP have also developed solar solutions for residential, industrial and mixed developments. The initiative is to reduce dependence on grid power and possibly sell back to the local power company if such opportunity is available.

Infinite Focus Solar Power is currently at the planning stages of developing a fully functional photovoltaic manufacturing plant in Nigeria, with capacity of 5 to 10 Megawatts of crystalline silicon modules a year depending on demand. A guide to the capital investment is $1M/MW. This is a high capital intensive part of the manufacturing chain, hence IFSP seek to centralize this activity and production will typically service Nigeria and West Africa markets from a single facility.

Infinite Focus Solar Power is in talks with Power Holding Company Nigeria with an aim to develop Policies and Private Finance Initiative on Effective Sustainable Energy Generation. This is to develop a framework that will facilitate private investments in green power generation.
6.0 BENEFIT TO GLOBACOM

"Globacom Nigeria has found that the market will not allow it to raise prices and, as a result, it needs to cut costs."

The IFSP solutions offer up to 60 percent or more in cost savings in relation to BTS electricity consumption. Recent studies indicate that networks operations account for about 80 percent of operators’ electricity usage. Arguably, this could reduce Globacom’s OPEX by 40 to 45%, given them the competitive edge and advantage needed for growth, margin increases coupled with a very high green credentials.

The highlights and benefits of IFSP system:

- Significant reduction in energy costs of running base stations
- Green solution that promises to help operators reduce pollution and carbon footprint
- Feasible deployment of services in grid deficient location and locations with unreliable source of power
- Minimal to zero maintenance requirement
- Renewable source of power
- Rural markets can be reach at lower cost
- Innovative business models can easily be developed for growth and expansion
- Possibility of BTS sharing without the significant increase in energy cost.
- Availing of future trends in sustainable energy, which is just about to become an essential part in everyday life

7.0 CONCLUSION

IFSP has demonstrated by means of aggressive power saving measures and careful analysis that BTS can be powered from sustainable energy sources. IFSP is now ready for the rapid introduction of its solar generating sets to power GSM/CDMA BTS installations in Nigeria and West Africa in general.

The solution is both economically and technically very attractive and represents a major step forward in the efforts of providing comprehensive power infrastructure solutions to GSM/CDMA base-stations.

As the cost of fossil fuels increase and mobile telecommunications systems are deployed in more remote areas without mains power, the value of alternative power solutions will become more and more apparent. IFSP can assist in providing planning tools, implementation skills, and purchasing power to assist service providers to implement these solutions where they will be highly cost effective. We look forward to opening discussions with Globacom in relation to these solutions.
TYPICAL DRAWING OF SOLAR MODULE MOUNTING SYSTEM

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DEEP CYCLE BATTERY CABINET TYPES

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