Energy & Emissions at Cellular Base Stations

Smart Cell Site Design for Energy Efficiency & Reduced Carbon Footprint

John Willson, P.Eng.
EXECUTIVE SUMMARY

Wireless telecom operators are coming to realize that energy costs can no longer be dismissed as a minor factor in the cost of doing business. Telecommunications systems continue to expand into remote areas where electrical grid power is unreliable or totally unavailable, making such sites an increasing portion of the operators' networks. Diesel power plants have been a source of rising costs in recent years, and will continue to expose operators to the risks of rising fuel prices and the future cost of carbon emissions.

Meanwhile, alternative energy technologies are rapidly becoming more sophisticated, reliable and cost-effective. WireIE can deliver carrier-grade solar and wind power systems that provide the reliability, remote configurability and monitoring capabilities that today's operators demand of every network element. A remote cell site can be powered with solar and/or wind energy at a long-term cost less than that of diesel.

This paper presents case studies of cell sites with no available grid power. Among the findings is that a hybrid solar and wind power system has an initial 32% cost premium versus a comparable diesel system, but pays back in operational savings after only six years\(^1\).

Wireless network operators can design and build radio access networks that minimize OpEx and exposure to cost risk, even where utility grid power is unavailable or unreliable. Renewable energy systems can meet the stringent requirements of world-class carriers, and achieve payback versus diesel generators in as little as six years. As a bonus, deploying solar panels and small wind turbines allows a company to demonstrate its concrete commitment to environmental responsibility.

\(^1\) Calculations based on a location in the Central Caribbean. Total energy system cost over 20 years is 28% less with the renewable energy system.
ABOUT THE AUTHOR

John Willson has over ten years of experience as an engineer in the wireless telecommunications industry. He has held a wide variety of roles from network design, optimization and traffic modeling to technology development and technology planning. John has built three generations of cellular networks, and was instrumental in launching GPS services at a major Canadian wireless carrier. John holds a Bachelor of Engineering Physics from McMaster University, and is a licensed Professional Engineer in the province of Ontario. No stranger to translating between dollars and decibels, John is adept at producing analysis at the complex intersection of performance and cost. He is currently exploring opportunities to reduce the energy, carbon and waste footprints of the telecom industry.

CONTACT INFORMATION

<table>
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<th>EMAIL</th>
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INTRODUCTION

Wireless telecom operators are coming to realize that energy costs can no longer be dismissed as a minor factor in the cost of doing business. Telecommunications systems continue to expand into remote areas where electrical grid power is unreliable or totally unavailable, making such sites an increasing portion of the operators' network. Diesel power plants have been a source of rising costs in recent years, and will continue to expose operators to the risks of rising fuel prices and the future cost of carbon emissions.

Meanwhile, alternative energy technologies are rapidly becoming more sophisticated, reliable and cost-effective. WireIE can deliver carrier-grade solar and wind power systems that provide the reliability, remote configurability and monitoring capabilities that today's operators demand of every network element. A remote cell site can be powered with solar and/or wind energy at a long-term cost less than that of diesel.

This paper first looks at decisions that can be made at the site design stage to reduce power consumption over the lifetime of the site. It then examines the issues and analyzes the current business case for solar and wind power at sites where grid power is unreliable or unavailable.
POWER EFFICIENCY AT THE BASE STATION

Hybrid Configuration BTS

Base Transceiver Stations (BTSs) are now generally available in hybrid configuration from all major vendors, in which the high-power analog circuitry is packaged separately from the low-power digital components. The outdoor RF Head Units (RHUs) are sealed elements that contain transmit power amplifiers (PAs) and first-stage receivers. RHUs are located outside of the shelter or cabinet, as close to the antennas as possible. The remaining low-power digital components comprise the base-band unit (BBU). Some BBUs are suitable for outdoor mounting, while others require an indoor environment, shelter or cabinet.

Hybrid BTSs greatly reduce HVAC requirements at the cell site, because a large portion of power consumption (and therefore heating) occurs outside the shelter or cabinet, in units which are cooled passively. A hybrid BTS can cut the required HVAC capacity at a site by 50% compared with the traditional BTS configuration, or eliminate it altogether, yielding both capital and operational savings. The operator will also realize typical link budget improvements of 2-5 dB due to minimized cable loss, which can improve service, capacity, or reduce site count in greenfield deployments.

Illustration 1: Hybrid configuration base station, showing Remote Radio Head Units (RHUs) and outdoor Base-Band Unit (BBU).
The table below shows the energy savings yielded by the hybrid configuration for a model rural UMTS cell site. Results are comparable to those for other modern wireless standards (HSPA, CDMA/EV-DO, WiMAX, LTE).

<table>
<thead>
<tr>
<th>Model Rural UMTS Cell Site – Energy Requirements</th>
<th>Traditional Indoor /Cabinet BTS Morphology</th>
<th>Hybrid Outdoor BTS Morphology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transmit power / RF carrier</td>
<td>40 W</td>
<td>40 W</td>
</tr>
<tr>
<td>sectors</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>RF carriers / sector</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Total Tx power of BTS</td>
<td>120 W</td>
<td>120 W</td>
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<tr>
<td>PA efficiency</td>
<td>40%</td>
<td>40%</td>
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<tr>
<td>RHUs / Transceivers max power draw</td>
<td>330 W</td>
<td>330 W</td>
</tr>
<tr>
<td>2 BBUs / Digital shelf Total power draw</td>
<td>500 W</td>
<td>500 W</td>
</tr>
<tr>
<td>HVAC requirement</td>
<td>1123 W</td>
<td>0 W</td>
</tr>
<tr>
<td>Security and Lighting</td>
<td>200 W</td>
<td>200 W</td>
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<tr>
<td>DC and Battery plant</td>
<td>323 W</td>
<td>155 W</td>
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<tr>
<td><strong>TOTAL site power draw (max)</strong></td>
<td><strong>2476 W</strong></td>
<td><strong>1185 W</strong></td>
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<tr>
<td>Peak hours /day</td>
<td>4 hrs</td>
<td></td>
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<tr>
<td>Channel occupancy: peak hours</td>
<td>80%</td>
<td></td>
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<tr>
<td>Channel occupancy: off-peak hours</td>
<td>20%</td>
<td></td>
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<tr>
<td><strong>TOTAL site power draw (peak hours)</strong></td>
<td><strong>2114 W</strong></td>
<td><strong>916 W</strong></td>
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<tr>
<td><strong>TOTAL site power draw (off-peak hours)</strong></td>
<td><strong>1626 W</strong></td>
<td><strong>709 W</strong></td>
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<tr>
<td><strong>TOTAL site power draw (Daily)</strong></td>
<td><strong>41 kWh/day</strong></td>
<td><strong>18 kWh/day</strong></td>
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<tr>
<td>Relative energy savings</td>
<td></td>
<td><strong>56.00%</strong></td>
</tr>
</tbody>
</table>
OTHER BTS FEATURES

Power on-demand functionality

Power efficiency by tight regulation of transmit power is an integral feature of all 3G and 4G digital wireless standards. Such interference-limited schemes require fast power control to attain high spectral efficiency. Transmit power is reduced by 80% or more during low-traffic periods, compared with peak hours.

Features that switch unused portions of the base station to standby mode are also becoming common. During low traffic periods, the majority of base station capacity is unused for many hours. On-demand functionality can reduce total base-station power consumption by 60% compared to the always-on state, with no effect on network performance. OEMs are also adding on-demand functionality to some existing equipment via software upgrade.

High-capacity cards

The digital shelves of modern base station equipment become more power efficient with every hardware revision as a result of miniaturization and integration of functions. At sites where low power consumption is particularly important, capacity upgrades should not be performed by adding more capacity elements such as channel cards. Rather, the operator should swap in new higher-capacity cards, such that the site can run on the fewest modules possible (ideally one redundant pair). Lower-capacity legacy modules can be re-deployed to other sites where grid power is available and reliable. Such a program can save a few tens of Watts per low-power site. The power savings thus realized may also reduce HVAC requirements, depending on site design.

High-efficiency multi-channel PAs

Similarly, Power Amplifiers (PA) are also becoming more efficient through hardware improvements. Multi-channel power amplifier modules or RHUs offer about 30% improved power efficiency relative to single-channel units. Modern PAs exceed 40% amplifier efficiency (RF power out / electrical power in), with 50% claimed to be on the roadmap by some equipment manufacturers.

SITE DESIGN

Hybrid configuration BTS, elements located outdoors

The single most influential design decision that can be made to reduce the power requirement of the radio network is to specify a hybrid BTS configuration. As described in the previous section, by locating the PAs and receivers outdoors and close to the antenna, the link budget is improved by several dB, which may allow realization of coverage objectives using fewer sites. The greatly reduced cooling requirements of hybrid base-station equipment (by virtue of being placed outdoors) can reduce a site's HVAC requirements by 50%, or may eliminate the need for air conditioning altogether.
Fresh-air cooling

Where cabinets or shelters are used, fresh-air cooling and conscious design for airflow inside the cabinet can yield a 20%-40% reduction in HVAC power usage, depending on local climate. When outdoor temperatures are sufficiently low, the cabinet or shelter is cooled by air blown in from outside instead of by air conditioning. Modern fresh-air ventilation units incorporate high-efficacy dust filters with filter monitoring capability and multi-year filter lifetimes (depending on local conditions).

WHEN GRID POWER IS UNRELIABLE OR UNAVAILABLE

Diesel

Diesel generators, the traditional choice, have several drawbacks including:

- Regular fuel delivery to remote locations
- Regular maintenance of generators
- Fuel storage (environmental and safety liability)
- Green-house gas (GHG) emissions (54 tonnes/year CO2e, typical)
- Uncertain and rising cost of diesel fuel

Greenhouse Gas Emissions

World governments are working rapidly to place a mandatory price on the emissions of greenhouse gases, including the carbon dioxide (CO2) which is produced by the use of diesel fuel. In the future, businesses will be required to reduce emissions or to buy offset credits to offset CO2 emissions. There is currently a market for voluntary offsetting, with the price of emissions in the range of $6-$11 per tonne of CO2 emitted. There is general agreement that the price of emissions must rise to at least $200 /t CO2e in order to have the desired effect of reducing GHG emissions worldwide. The Canadian government is currently recommending a target price of $250 /tonne CO2e by the year 2025. For a network containing today's typical diesel-powered cell sites, the $200/t price of emission adds up to an additional operating expense of $10,800 (CDN) per year per site.
Solar & Wind

Solar and wind power generation offer several advantages:

- Reduced OpEx: no fuel costs, no fuel deliveries, reduced maintenance requirements
- Reduced environmental and safety liability: no on-site fuel storage
- Corporate social responsibility: No pollution, noise or GHG emissions
- Additional source of income: GHG offset credits
- No exposure to risks of rising fuel costs and emissions costs
- Solar and wind power can meet the strict requirements of a carrier-grade solution.

Reliability and Availability

The intermittent nature of solar and wind power can be effectively mitigated. Energy storage on-site (batteries) ensures that power is available when the sun isn’t shining or the wind isn’t blowing.

Pairing solar and wind collection systems at one site can provide diversity protection against the variable natures of both energy sources. Expert system design and dimensioning with consideration of the local sunlight and/or wind patterns maximizes energy capture through a broad range of common conditions.

Remote Monitoring, Configurability and Alarms

In a carrier-grade communications network, every element must provide alarms, and must be remotely monitorable and configurable from the network operations centre. WireIE’s Clean Power Management solution meets all of these requirements, fully integrating solar and wind power plants into the network.

Green-House Gas Emissions Credits

Some solar and wind projects will generate GHG emissions offset credits for the operator, which can be sold every year at market rate for five years after site commissioning (per current regulations), to businesses that need to offset their emissions. At projected emissions prices, sites built in 2010 will generate over $1300 in revenue from carbon credits over five years, while avoiding annual emissions costs that could approach $10,800 per year.

2 Not applicable in all regions.
CASE STUDY: DIESEL VERSUS WIREIE’S CLEAN POWER MANAGEMENT

Assumptions:

- A modern WiMAX, UMTS or similar base transceiver station (BTS) can be configured to operate on approximately 1kW of power (assumed for peak utilization in this case study).
- Remote site; grid power is unavailable
- 1 RF carrier, 3 sectors, 40W Tx power, hybrid BTS configuration
- Diesel fuel cost of approximately $0.79 /L in 2010 (fuel costs vary widely by country)
- considering rising costs of fuel and emissions (credits), and future value of money
- (for calculation details and full list of assumptions, see appendix).

Solar Power

The capital cost of the DC power plant, including batteries and charging equipment, is 50% more ($48k) with solar than with diesel (all figures in US dollars). The investment in solar pays for itself in less than five years, or eight years considering a 9% cost of capital. The solar panels have a 20-25 year lifespan.

Cumulative Cost of Energy System (NPV) – Off-Grid Cell Site

Solar Verses Diesel

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3 Refer to Appendix “A” for details and assumptions
Solar + Wind Power

The capital cost of the DC power plant, including batteries and charging equipment, is 32% more ($30k) with solar and wind together, than with diesel (all figures in US dollars). The investment in renewables pays for itself in the fifth year, or in the sixth year considering a 9% cost of capital. The solar panels have a 20-25 year lifespan, and the wind turbine requires annual maintenance plus an overhaul every 15 years.

Cumulative Cost of Energy System (NPV) – Off-Grid Cell Site
Solar+Wind Verses Diesel

CONCLUSION

The rising costs of energy and green-house gas emissions must now receive full consideration in the design and purchase decisions of every business. Telecommunications operators can design and build radio access networks that minimize OpEx and exposure to cost risk, even where utility grid power is unavailable or unreliable. Carrier-grade solar and wind power systems are now available that offer the reliability, remote configurability, alarms and monitoring that the top operators demand. Renewable energy systems can meet the stringent requirements of world-class carriers, and achieve payback versus diesel generators in as little as six years.

As a bonus, deploying solar panels and small wind turbines allows a company to demonstrate its concrete commitment to environmental responsibility.
APPENDIX “A” CASE STUDIES ASSUMPTIONS

WIMAX/UMTS/HSPA/CDMA/LTE Base Transceiver System (BTS)

- 3 sectors, 1 RF carrier per sector
- 40W Transmit power per sector-carrier
- hybrid Indoor/Outdoor BTS configuration
- 26 kWh Site daily energy requirement (including HVAC)

Solar Power Solution

- 54 Solar Panels, 200W each (1.0 x 1.5 m)
- 6 hours Peak solar equivalent hours per day
- $64,800 Solar hardware costs
- $0 Solar fuel & maintenance costs (annual)
- $30,000 Solar civils & installation

Hybrid Solar + Wind Power Solution

- 24 Solar Panels, 200W each (1.0 x 1.5 m)
- 6 hours Peak solar equivalent hours per day
- $28,800 Solar hardware costs
- $0 Solar fuel & maintenance costs (annual)
- 1 Wind turbine, 3kW capacity (3.7m diameter)
- 5 m/s Equivalent mean wind speed at hub height
- 20% Capacity factor
- $14,000 Wind hardware costs
- $40,000 Wind civils & installation
- $1,500 Wind fuel & maintenance costs (annual)

Diesel Power Solution

- 1 Diesel genset 13kW capacity
- 4419.68 Litres of fuel usage (annual)
- $0.79/L Initial cost of diesel fuel (Jamaica – price will be country dependant)
- 5% Annual inflation rate on diesel fuel
- $17,000 diesel hardware costs
- $30,000 diesel civils & installation
- $4,500 diesel fuel & maintenance costs (annual)

DC Battery Plant

- 1 day Back-up period
- 50% Depth of discharge
- 85Ah Battery capacity (each)
- 48V System voltage

Greenhouse Gas Emissions

Renewable power system will earn emissions credits for first 5 years of operation
Diesel power system will incur emissions costs in each year of operation

- 13.6t/year CO2e of GHG emissions (annual)
- $10/t CO2e cost of emissions in year 2010
- $250/t CO2e cost of emissions in year 2030
- 9% Cost of capital (annual)