WHITE PAPER

Alternatives for Powering Telecommunications Base Stations

Introduction

The last decade has seen exponential growth in wireless communication. The growth of mobile networks coupled with intense competition has sharpened operators' focus on deployment logistics, security, and cost. One challenge is how to power the telecommunication networks. Inconsistent power grid coverage, challenging terrain, and potential theft, add to the cost of traditional fuel based power systems. In addition, legislative pressures and the potential for Carbon trading revenues are causing the Mobile Telecommunications Industry to become mindful of its impact on carbon emissions. "Green" considerations are coming into prominence in network design.

There are many alternative power options. This paper looks at four technologies under review at Motorola. Table 1 provides an overview of the ideal setting, benefits and issues, and the state of the industry for each. In addition, under normal conditions, there will be times when an alternative power solution provides excess electricity. The paper ends with an overview of energy storage

Table 1: Overview of Wind, Solar, Fuel Cell, and Pico Hydro Technologies

Ideal Setting	Benefits	Issues	State of the Industry
Wind			
- Coastal locations or hilly areas - Wind speeds of 4mph - 30mph, averaging at least 8 mph across a 4 hour period	- Minimal OPEX and efficient for DC generation - Small footprint	- Cost per kW produced currently higher than Solar or Diesel - Minimum wind speed ~4-6 mph needed	Commercial installations available for domestic applications and for specific technology applications, particularly in remote areas such as Artic and UK Hebbridean islands
Solar(Photo- Voltaic or PV)			
- Areas with long/good sunlight ~ 6-8 hours/day - Space available for the array	- Minimal OPEX - Cheaper than turbines for same KW output, expecting further price reduction	Cost higher than diesel, array can be a target for vandalism of theft	Fairly mature, commercial installations. 3rd generation PV may offer significant cost savings.
Fuel Cell			
- Access to atmosphere for oxygen and water vapor output - Protected from very low temperatures	- Energy efficiency - Fuel flexibility	- Hydrogen fuel source availability and storage - Cost - Maturity of alternatives to Hydrogen	Commercial systems proven and available
Pico Hydro			
High rainfall, hilly terrain	Not as susceptible to short weather conditions	Requires specific water flow conditions (e.g. river with a gradient)	Small, localized applications

WIND AND SOLAR

1. http://en.wikipedia.org/wiki/Solar_power

2. http://en.wikipedia.org/wiki/Wind_power

3. http://news.bbc.co.uk/1/hi/programmes/click_online/6668535.stm

Solar and wind power have progressed in recent years with costs steadily falling. The point is being reached where they can be considered as supplementary or even the primary power source for cell sites in difficult locations. As the cost of wind and solar technology continues to fall, and the cost and scarcity of fossil fuels increase, solar and other renewable energies will become increasingly cost effective compared with more conventional power sources. While wind and solar are independent power sources, here they are combined to highlight how Motorola is combining the two sources to provide reliable energy to base stations.

Solar power is generated using the photovoltaic properties of semi-conductors to convert light energy into electricity. Manufacturing costs for solar cells have been declining by 3-5% per year in recent years, leading to growth capped only by silicon supply issues[1]. For wind power, a wind turbine attached to an electrical generator converts wind power to electrical energy. Globally, wind power production quadrupled from 2000 to 2006. It accounts for 20% of electricity use in Denmark, 9% in Spain, and 7% in Germany[2]. The global adoption of wind and solar as commercially viable technologies, together with the falling costs and growing reliability of the technologies, make them cost effective technologies to adapt to a telecommunications environment.

Motorola has been conducting an extensive study on the use of a wind and solar combination as a source of power. In 2005, a wind and solar trial was launched at Motorola's facility in Swindon, UK. Wind and solar energy power a Horizon II DC Mini BTS in a 4 carrier configuration 24 hours per day, 7 days per week. Currently, a four month wind and solar trial is being conducted with MTC Namibia. Wind and solar energy will power live traffic from a commercial base station in a 6 carrier configuration using a Horizon II DC Macro BTS. MTC explains, "In a sparsely populated country like Namibia rolling out a network to communities that are widely dispersed is very expensive…Combining both solar and wind power we're able to do that in a more cost effective manner, and also a lot more rapidly.[3]" Results from this trial will be available in Q3 2007.

Figure 1: Wind/Solar Installation, Namibia
Left: Solar Array, Battery, and Power Controller
Right: Wind Turbine

4 Source : Fuel Cell Today, Opening doors to fuel cell commercialization, The Technology, Education kit 2 (www.fuelcelltoday.com)

5 Source : http://jazz.nist.gov/atpcf/prjbriefs/prjbrief.cfm?ProjectNumber=00-00-5450

6 Source: http://jazz.nist.gov/atpcf/prjbriefs/prjbrief.cfm?ProjectNumber=00-00-6962

FUEL CELLS

Fuel cells are emerging as a strong alternative power source candidate. The technology has matured in recent years and has many benefits compared to generators, such as fuel efficiency, climate resistance, reliable start-up, and being very compact (e.g. fitting in a 19" rack). Their silent operation means there will be no indication that a power source is operating on the cell site, reducing the likelihood of theft. Having reached volume manufacturing and with prices falling, they will challenge conventional engine driven generators in terms of cost and reliability.

Fuel cells operate by converting a fuel, such as hydrogen, into electricity without combustion. There are several types of fuel cells, of which the most promising for telecommunications is the Proton Exchange Membrane Fuel Cell (PEMFC). The PEMFC operates at low temperatures, and runs at 40-60% efficiency[4].

Motorola is involved in fuel cell research for networks and mobile devices. Figure 2 is the set up for a trial to use fuel cells to power TErrestrial TRunked RAdio (TETRA) networks, used in public safety communications and other Private Mobile Radio networks. Motorola is also exploring micro fuel cell technologies as a replacement for rechargeable batteries in mobile devices. In partnership with various companies, Motorola is developing technologies such as:

- Hybrid fuel cell technologies for radios
- A hydrogen generator as a miniature fuel-cell power source[5]
- Improving PEM fuel cell performance, durability, and manufacturability using single wall carbon-nanotubes (SWNTs)[6]

Fuel cell technology is maturing and evolving rapidly. We will likely seeing a growing number of commercial applications and the use of alternative fuels as the input energy source for fuel cells.

Figure 2: TETRA Fuel Cell Experiment

7. Source: http://eee.ntu.ac.uk/research/microhydro/picosite/

8. Pico Hydro For Village Power, A Practical Manual for Schemes up to 5kW in Hilly Areas. Philip Maher and Nigel Smith, May 2001

9. Community Pico Hydro in Sub Saharan Africa/Case Study 2/ Thima, Kinnyaga District, Kenya

PICO HYDRO

The term pico hydro refers to very small hydro systems. There is a large potential market for pico hydro due to the fact that[7]:

- Small water flows are required
- Small communities in the developing world are often not linked to a power grid
- Locally manufactured pico hydro systems have lower long term costs per kilowatt than solar, wind, or diesel systems
- Hydro systems provide constant energy during times of normal rainfall

Today, the primary use of pico hydro is for lighting and basic electrical needs in remote areas. However, areas with high rainfall, steep flowing streams and rivers provide an ideal source of power for wireless communication network base stations, allowing the low cost, low maintenance deployment of wireless communications to emerging markets.

Figure 3 is an example of a basic pico hydro system set up to power a base station. The potential energy stored in the elevated water supply flows through a pipe called a penstock, to drive a turbine which drives a generator which converts the mechanical energy to electrical power. Typical energy efficiency in such is a system is 40-50%[8] . Alternative hydro solutions include submersible and tidal systems.

Pico hydro as a commercial alternative power solution is very much in its early stages. Pico hydro systems have been successfully deployed in trials around the world. For example, in Kenya, the Micro Hydro Centre at Nottingham Trent University successfully generated 2.2kW of electricity for under $6500[9]. Commercially, governments and action groups are supporting hydro power. For example, the US government may provide grants, loans, or tax benefits. Further research and trials will be required to fully understand how best to deploy pico hydro, particularly, in the telecommunications sector.

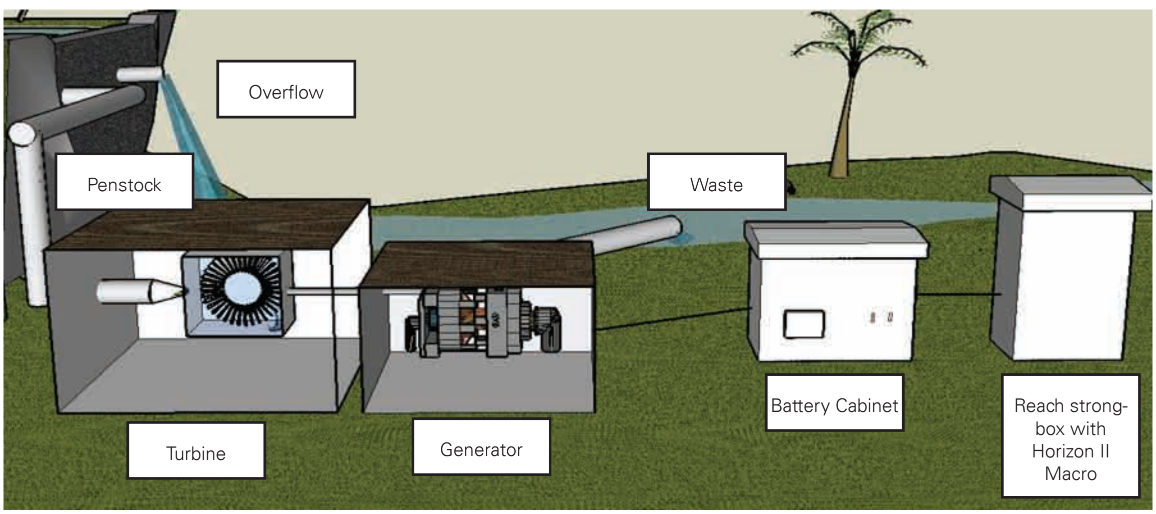

Figure 3: Pico Hydro Power Generation Schematic

ALTERNATIVE ENERGY STORAGE OPTIONS

Wind and solar solutions on trial today work with lead acid batteries to power the base station. Batteries are inexpensive, simple to manufacture, modular, and quiet, with quick response times and low maintenance. However, disposing of the batteries is environmentally unfriendly and they have a limited life, particularly at higher temperatures. Meanwhile, there are times when the alternative power generation solution in place provides excess power. Ideally, one would store this extra energy, increasing the efficiency of the system and providing better load management. Energy storage options that can capitalize on excess energy generation are reviewed in Table 2[10].

Table 2: Comparison of a Variety of Energy Storage Options

Methodology	Benefits	Issues	State of the Industry
Pumped-Hydroelectric storage			
Excess energy is used to pump water uphill to an elevated reservoir. Water is released to a lower reservoir to drive turbines	- Long period of storage - Relatively simple design - Mature technology	- Low energy density - Requires suitable topography	In operation for more than 70 years
Compressed-Air Energy Storage			
Off-peak electricity is used to compress air. This air is withdrawn, heated, and run through expansion turbines to drive an electric generator	- High storage capacity - Fast start up - Relatively small installation cost	Reliance upon geological structures may not make it a practical solution for smaller systems	Commercial. Has been in operation in Huntorf, West Germany since 1978
Flywheel Energy Storage			
An electric motor provides energy to spin a flywheel. Kinetic energy from the spinning wheel returns the energy to a generator	- Energy efficiency of up to 90% - Not affected by ambient temperature fluctuations	- Safety concerns due to high speed rotor - May be large and not proven for 10's of kilowatt hour applications	Small flywheels (up to 1kW for 3 hrs) have had good commercial success. Larger wheels under development
Hydrogen Energy Storage			
Off-peak electricity is used to generate Hydrogen via electrolysis. Used in a fuel cell to generate electricity	- Can be produced by a variety of sources - Environmentally benign	Practical solutions for storage of hydrogen still being developed	Primarily used in automotive industry, but also used as backup storage

10. Sources:
- "Stacking Up New Energy Storage Options", Bobby Maher
- "New Horizons for Hydrogen – Producing Hydrogen from Renewable Resources", National Renewable Energy Laboratory
- "Executive Overview: Energy Storage Options for a Sustainable Energy Future", Robert B. Schainker, IEEE, Jun2004

- Web sites: http://www.esru.strath.ac.uk/EandE/Web_sites/03-04/marine/tech_storage.htm, http://www.batteryuniversity.com/partone-6.htm, http://en.wikipedia.org/wiki/Flywheel_energy_storage , http://www.upei.ca/~physics/p261/projects/flywheel1/flywheel1.htm, http://www.nrel.gov/features/10-03_hydrogen_storage.html

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