A LOOK AT THE FUTURE FOR OUTSIDE PLANT (OSP) BACKUP POWER

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ABSTRACT

This paper will discuss the current backup power systems and challenges for the telecom and utility industries, specifically the 500,000 outside-plant backup power systems that exist. It will examine how fuel cell technology compares to current backup systems, and how they may one day be part of the new technology to replace the current back-up power systems.

The paper will compare fuel cells to battery sources in the areas of: cost, durability, weight, and environmental issues. As well, it will look at the differences and costs of maintenance and service throughout the lifespan of the products.

Telecom and utility operators are exploring cost-effective alternatives that surpass traditional technologies in reliability, flexibility and durability. The challenges for fuel cells remain, particularly concerns surrounding providing hydrogen and/or creating the infrastructure to ensure adequate supplies. Will there be a new set of installation issues and rules governing hydrogen?

The paper will conclude that fuel cells can already compete with, and compliment batteries for the outdoor backup power market on an economic level. But what needs to be done to make hydrogen fuel cells an attractive alternative for the telecom and utility industries? How long before fuel cell manufacturers dent these markets, and what will be their marketing messages and advantages to replace or supplement batteries so that energy managers will take the chance.

INTRODUCTION

Across the telecom, cable broadband, and utility industries, a confluence of factors has made the upgrade of backup power a top priority. Reliability continues to be the driving force in network system design. Trends including circuit to packet network migration; Voice over IP (VoIP) Telephony; annual doubling of IP traffic; remote monitoring of grid infrastructure; and reliance on the Internet for worldwide commerce are all driving network DC power additions and increased reliance on backup power. Tremendous telecom wireless growth, the propagation of digital network technologies and fiber infrastructure all lead away from central office reliance towards remote sites and outside plant power demands. As traditional voice, video, and data carriers work to “bundle” communication services, power requirements for a given network increase. Utility deregulation, widespread overloading of transmission grids, and reduced capital investment are all contributors to the declining quality of utility power. Networks are straining to handle the burgeoning number of products and the skyrocketing demand for them. At the same time, networks must provide the reliability that consumers expect. In 2003, the blackouts on the East Coast of the U.S. revealed the extent of this pressure. Not surprisingly, carriers are striving to optimize every aspect of their networks, including backup power, and are realizing a need for new backup power solutions to handle the harsh conditions of the outside plant (OSP) environment.

Traditional technologies, such as lead acid batteries and engine-generator sets, have long provided reliable backup power inside central switching offices. However, as wireless networks extend into remote outdoor environments, the traditional solutions become less effective.

Valve-regulated lead acid (VRLA) batteries are temperature-sensitive and are too heavy for many outdoor applications, such as rooftop installation. In addition, they are often unable to keep pace with the energy demands of OSP wireless technology. Engine-generator also present challenges, such as combustion emissions, noise and high maintenance requirements. With wireless sites scattered across wide geographic areas, preventative maintenance is a serious issue.

Fuel cell technology is rapidly emerging as a viable alternative or adjunct to incumbent battery backup power in network infrastructures. Over the last several years, service providers, in a continual effort to increase network reliability and decrease infrastructure costs, have been evaluating existing prime and backup power solutions for the network. Recent reliability issues surrounding the existing battery plant during power interruptions, lifecycle costs and maintenance have further imposed the urgency of finding a solution in the near term.

During the last decade, several emerging technologies have been considered as replacements for batteries, such as micro-turbines and fuel cells. Offering advantages in the areas of cost, efficiency, and environmental operating conditions, fuel cell technology has emerged as a viable alternative (Table 1). When first introduced to the market, the fuel cell was offered at a price point that was prohibitive to wide-scale network deployment. In recent years however, the price of the fuel cell has declined dramatically to one that is on par with existing backup power solutions due to advancements in manufacturing, technology and volume production.

Table 1 - Cost Comparison of Available Backup Technologies[1]

Technology	Estimated Cost of 5kW Plant
Lead Acid Batteries	$15,000-$19,000. Estimated replacement of plant at year 5. Does not include monthly maintenance and disposal fees.
Hydrogen Fuel Cells	$17,000-$20,000. Estimated life of 10 years. Includes maintenance costs.
Micro-Turbine	>$35,000.00, 30kW system. Requires additional hardware, extended start-up period and primarily used for prime power.
Photovoltaic	>$25,000-$40,000. Requires connection to the grid and additional generator or batteries for operation when grid is not available. May require additional real estate for installation of arrays.

A NEW SOLUTION

Proton exchange membrane (PEM) fuel cell systems offer an alternative to traditional backup solutions. Operating on gaseous hydrogen (>99.95% purity), backup fuel cell systems produce zero emissions; heat and clean water are the only byproducts. This, combined with recycling programs administered by many fuel cell companies that eliminate disposal issues, makes fuel cells particularly attractive to the OSP environment, as they match the strengths of batteries without imposing the environmental challenges. Fuel cell companies have designed fuel cell systems specifically for stationary backup power applications, and several major telecom carries have announced plans to implement fuel cell technology as part of their ongoing infrastructure strategies.

Fuel cells for backup applications are designed to reliably provide immediate, extended response to power interruptions over a broad range of outdoor conditions. Systems meet most zoning requirements for urban and rural installations: at less than 100 lbs per square foot, they meet the requirements for normal rooftop loading limits, providing a high degree of flexibility in installation location and application, and with no moving parts, they produce very little noise. Backup fuel cell systems include on-board diagnostics which provide the capability to monitor and predict real-time remaining runtime on the system, a critical feature for allowing maintenance and operations staff to effectively plan support visits.

Backup fuel cell systems offer the flexibility of separating application power needs from application energy needs. Backup runtime is directly proportional to the amount of fuel stored at the site, making fuel cell systems scalable power sources and ensuring performance during extended power interruptions. Hydrogen fuel is readily available from industrial gas suppliers, and can be stored safely onsite—similar to hydrogen presently in use for generator cooling.

In conjunction with these benefits, fuel cells promise to generate cost savings. Although they are still more expensive at first purchase than VRLA batteries, fuel cells, with a three-year maintenance schedule and longer life, carry a lower lifecycle cost. Backup fuel cell systems are designed and tested to provide an operating life of at least 10 years in the outside plant environment. By contrast, traditional VRLA systems have exhibited a field life of between 3 and 5 years, requiring more frequent and expensive replacement.

Hydrogen PEM fuel cell systems on the market today are available in 24Vdc, 48Vdc and 120Vdc configurations. They are designed for outdoor installations and can operate in –40°C to 50°C environments, and some have achieved Network Equipment Building Systems (NEBS) compliance. NEBS approval indicates that a product will endure operation in harsh environmental conditions while protecting people from injury and the network from outages. It assures providers that fuel cells can be reliably integrated into the network.

Other certification developments are providing further assurance. A growing number of systems have been UL-certified to ANSI Z21.83, a U.S. product standard for fuel cells. Several fuel cell manufacturers are working closely with rating agencies like CSA International and UL.

PEM FUEL CELL OPERATION

Individual fuel cells combine to create a fuel cell stack; the more cells in the stack, the more power can be produced. A fuel cell system is essentially a fuel cell stack integrated with subsystems for providing fuel, air, cooling, control and power conversion. Once hydrogen enters the system, it flows to the stack where the hydrogen molecules are separated from each other in the presence of a catalyst on the anode side of an electrochemical cell. The protons pass through an impermeable non-conducting membrane to the cathode side of the cell. This membrane is known as a proton exchange membrane or a polymer electrolyte membrane. The electrons pass around the membrane through the electrical load to the cathode side. The hydrogen protons combine with the electrons and oxygen molecules from the air in the presence of the cathode catalyst to form water (Figure 1).

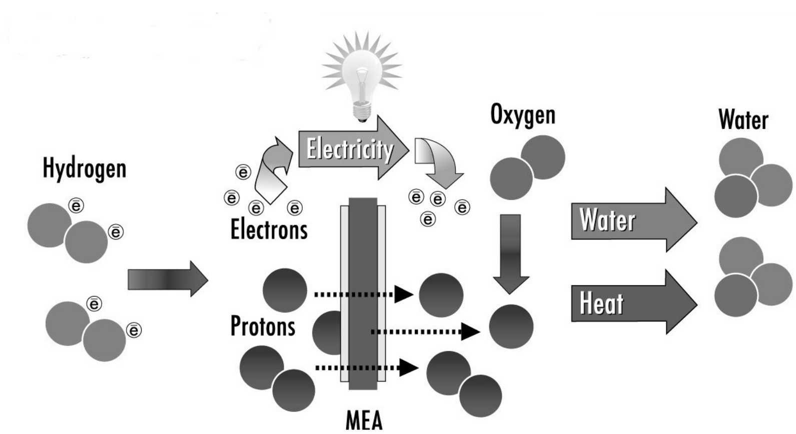

Figure 1 - PEM Fuel Cell Process

TELECOM WIRELINE AND WIRELESS

Telecommunication providers today are faced with unprecedented challenges for customer retention. Subscribers are constantly deluged with a vast array of choices for communication ranging from wireless, wire-line, and IP telephony. Recent mandates regarding number portability have further impelled consumers to reconsider their carrier loyalty. Never before has the level of stimulus for churn been so high. The slightest decrease in quality of service or variation in call plan options sends subscribers scurrying for alternative solutions. A recent J.D. Power and Associates poll indicated that one in four (26%) subscribers plan to switch service providers within the next 12 months[2]. Churn at this rate presents a significant economic challenge to providers since the average cost to acquire new subscribers is estimated to be between \$300 and \$425.

At the forefront of reasons cited by customers for churn was call performance and reliability. The benchmark of any reliable service, whether wireless or wireline, is its ability to provide uninterrupted service to the subscriber before and during power interruptions. Ongoing power blackouts throughout the United States, Europe and the rest of the world continue to provide evidence of the existing telecommunication infrastructure's vulnerability to long-term power fluctuations. As both wireless and wireline networks continue their migration toward high-bandwidth data networks, with their associated high value content, the need for more robust, redundant, cost-effective powering solutions will increase by an order of magnitude.

EXISTING CHALLENGES

A typical DC telecom power infrastructure consists of several components. A power plant houses the system monitor and control panel, AC/DC rectifiers convert incoming AC voltage to the required DC voltage level (-48Vdc or +24Vdc), and primary distribution utilizing fuses and circuit breakers serves as the connection point to the equipment. Batteries are used to provide backup power in order to continue system operation during power interruptions (Figure 2).[3]

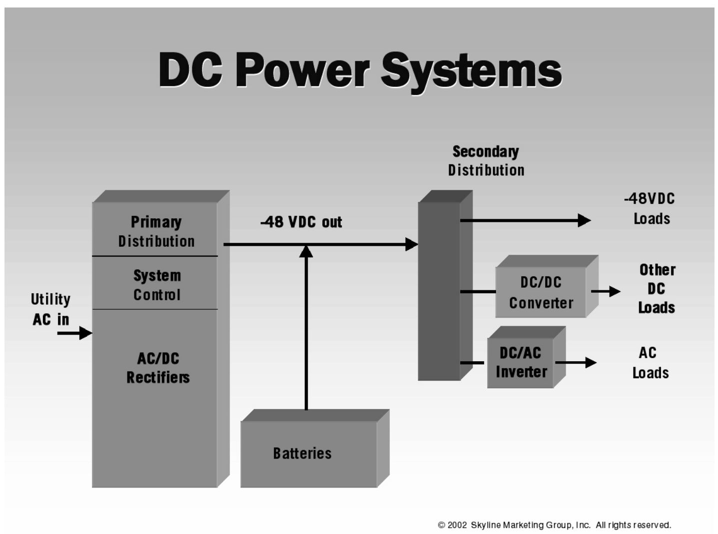

Figure 2 - DC Power Plant

The majority of these batteries—when new—are sufficient to provide backup power anywhere from two to four hours. However, as most operations managers are aware, the lifetime of these batteries can be adversely affected by extreme environmental conditions and maintenance levels, which can significantly decrease the performance and life expectancy of the batteries in the system. Most importantly, periodic maintenance requirements, premature replacement costs and disposal issues associated with batteries add to the overall lifecycle costs of the infrastructure.

UTILITY BACKUP APPLICATIONS

The vast majority of the over 100,000 utility-owned substations in the U.S. rely on battery based backup power to provide command and control during station power loss. Most of these systems consist of vented lead acid batteries in a single string.

Battery systems are typically sized to provide four to eight hours of coverage, sufficient to cover short-duration interruptions and/or provide buffer time for utility technicians to be mobilized to the substation site with temporary engine generators. However, it is not uncommon to find redundant or extended runtime systems capable of producing 16 to 24 hours of power coverage in place.

Command and control systems are required to be available at all times, requiring backup power to be uninterruptible.

Substation equipment is rated at several different input voltages, sized in accordance with the application load and duty cycle. Typical equipment configurations are rated at 48Vdc (30%) and 120Vdc (65%), with a small percentage as high as 250Vdc (5%). Equipment is configured to operate with a floating ground, a capability relatively unique to the utility industry.

Industry surveys indicate that as high as 17% of present substations may not have any battery backup. These are believed to be smaller, isolated systems, or systems serving an individual customer.
Several battery technologies are in use, including vented lead acid (75%), valve regulated lead acid (VRLA) and nickel-cadmium (5%). VRLA batteries, though used at sensitive first-cost locations, are being phased out because of the shorter in-application life and concern over predictable operation.

EXISTING CHALLENGES

Reliability is the main concern and the highest priority in maintaining substation batteries. Assuring system integrity and actual capacity of the battery backup system can be difficult and is dependent on frequent maintenance and management of the cells, with a typical substation requiring 6 to 12 service calls per year. Actual battery capacity depends on the environment, steady-state float charge, discharge history, and cell interconnections. Tracking battery capacity though cell level condition monitoring is available, but this remains an expensive investment for a utility.

Utilities concerned with ensuring battery capacity and protecting their investment typically house systems within environmentally controlled spaces where air conditioning and/or heating aids in keeping the enclosure temperature between 55ºF and 95ºF. Maximum battery performance is supported at 77ºF.

Frequent and deep discharge, caused by simultaneous failure of the substation bus and need to operate all breakers on the bus, also reduces battery life (although it is a lesser factor than temperature), as does capacity testing of battery banks.

NEW DEMANDS

Utilities face a growing need to operate more efficiently, while ensuring higher reliability in all aspects of power quality and delivery. These companies are seeking to reduce maintenance activities while adding reliability and durability to the network by reducing time and money spent on low-value tasks performed by technicians, such as battery maintenance, and instead implement new programs that require technical resources to be assigned to more pressing needs.

As witnessed routinely in storm-plagued quarters, the need for substantial extended backup capability is critical to the safe and timely resumption of power delivery. Four to eight hours of back up is being routinely enhanced to 24 or 48 hours of backup, though this move contradicts the desire to reduce battery maintenance and operating expenses. In addition, design considerations for health, safety and environments are of increasing importance in substation battery systems. Maintenance visits on vented cells require specific employee protection equipment such as safety glasses, rubber aprons, rubber gloves and a portable eyewash station to avoid exposure to acid spills and electric shock. Lead recycling is also an issue, as is the need to reduce employee exposure to chemical and battery acid, which are affecting storage system design and procurement decisions.

FUEL CELLS: COST-EFFECTIVELY CHANGING HOW TELECOMS & UTILITIES DO BUSINESS

A fuel cell system capable of supplying up to 5kW of power has an installed first cost of $17,000 - $20,000. A battery backup system with equivalent power output typically has an installed first cost of $15,000 -$19,000.

Based upon a cost analysis, the initial capital cost of the battery solution may be lower than the initial cost of the fuel cell solution. However, ownership costs diverge sharply, with the lifetime ownership cost of battery backup nearing double that of the fuel cell system.

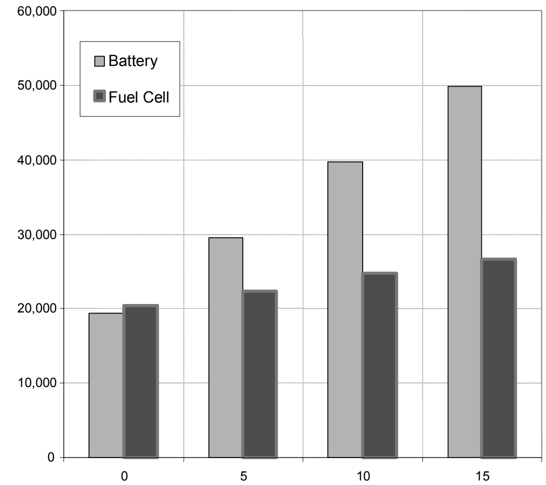

Figure 3 - Cost Comparison of New Battery Installation and Fuel Cell Technology

These cost differences are primarily due to the heavy maintenance schedules associated with the battery backup system, and do not show the enhanced benefits, such as extended runtime, greater safety and reliability, offered by fuel cell systems. In order to accurately calculate the overall costs of implementing a backup power technology, all costs must be considered.

Total cost can be represented by the following equation:

$C_t = C_i + C_m + C_a + C_c + C_d$

Where:
Ct = Total lifecycle cost
Ci= Total initial capital (system & install)
Cm = Estimated periodic maintenance
Ca = Auxiliary power requirements
Cc = Labor related to system callouts
Cd = Disposal cost at end of life

With fuel cell technology, several cost elements can be dramatically improved by reducing periodic maintenance and subsequent costs associated with personnel providing emergency overtime. Minimal maintenance is required only once every three years, and remote monitoring packages are available that allow the user to remotely supervise pre-scheduled system self-tests to ensure system readiness. Fuel cell manufacturers also offer recycling programs for backup power systems that eliminate disposal issues.

HYDROGEN AS A FUEL

In addition to system cost, hydrogen production, storage, and siting are chief concerns that may slow wide-scale adoption of fuel cells. Several companies have undertaken field projects to resolve these issues and have developed their own NEBS-certified storage modules.

Hydrogen has been mass-produced for more than 50 years, and in the United States alone, more than eight million tons are produced annually, mostly by steam reforming of natural gas. Hydrogen is routinely transported safely both as a cryogenic liquid and as a compressed gas for use in various industries. When hydrogen is stored, it is stored in either a compressed state under high pressure, or as a cryogenic liquid at temperatures less than minus 253 degrees Celsius.

Hydrogen is the lightest of all elements, which causes it to be buoyant and to rapidly disperse when released in air, so a leak is quickly diluted and rendered harmless. For a flammable mixture to exist, a four times higher concentration of hydrogen is required than that of gasoline (4% versus 1%). An electrostatic spark from the human body is just as likely to ignite gasoline as hydrogen at these minimum concentrations, and a hydrogen fire radiates very little heat compared to a petroleum fire. In addition, it is non-toxic and non-poisonous, and there are few significant environmental hazards associated with accidental discharge.

However, all fuels are energetic materials and pose fire and explosion risks, so they must be handled carefully. Hydrogen has a small molecular size, allowing it to leak more easily through porous materials than other gases at equivalent pressures. Systems storing liquid hydrogen and gaseous hydrogen at high pressure are robustly designed to handle the pressure and temperature extremes without leaking. Well-engineered hydrogen powered systems and associated hydrogen dispensing systems can be expected to be at least as safe as gasoline, natural gas and propane systems.

CONCLUSIONS

PEM fuel cells address many of the limitations of battery technology. While initial unit cost is higher than incumbent vented lead acid and valve regulated batteries, fuel cells offer the benefits of lower maintenance costs and reduced operator hazard. Fuel cell backup power systems are ready to perform when needed, without labor intensive testing or maintenance. Costs can be dramatically improved by avoiding mobile generator dispatch requirements and subsequent costs associated with personnel providing emergency overtime.

The emergence of the hydrogen fuel cell system as a viable alternative to batteries in telecommunications outside plant and utility substation applications promises to create a radical shift in how backup power infrastructures are designed in the future. New and existing high-value, data-centric communications infrastructures may one day be powered by clean, quiet, lightweight, reliable energy sources that have the potential to increase network reliability and decrease operating costs. This will lend itself to an increase in overall profitability for network service providers.

Future evolution of this technology shows promise for creation of a completely grid-independent prime power system capable of withstanding any type of power interruption. A quiet, lightweight and emission-free prime power source will greatly expand installation opportunities, benefiting telecommunications and utility providers and users. Fuel cells offer hope for a win-win situation: reliable service for customers, and lower cost for the service providers.

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[1] These and all following cost figures based on accepted industry averages.
[2] J.D. Power and Associates. *2003 U.S. Wireless Regional CSI Study*. 2003.
[3] Celentano, John M. "Telecom Power Market: Global Perspectives." Skyline Marketing Group, Inc. 2002.