Smart Energy Solutions Using Fuel Cells

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***Abstract*— The availability of adequate and reliable energy sources is becoming more challenging throughout the world. The reasons vary widely from the development of grid not keeping pace with the demand, inherent poor reliability, political unrest, natural disasters, shifts to renewable sources, depletion of energy reserves, and environmental concerns. The communications sector uses a significant and growing amount of world's total energy which impacts both the total available amount of energy and OPEX of the communications sector. These issues are directly related to our industry and our ability to provide services on a global scale. Telecommunications operators need new tools and schemes to manage their energy consumption in order to help balance their OPEX, sustainability objectives and network reliability.**

This paper will provide an overview and a model framework of using fuel cells to manage a telecommunications operator's energy at distributed sites. Fuel cells are available in many scales from megawatt to a few watts. This paper will focus on small 1-20kW fuel cells typically deployed to support backup power requirements at broadband or wireless sites. Today's fuel cells are intelligent, networked, managed devices that provide capabilities well beyond just backup power to address a grid outage. The fuel cell can be controlled to operate at specific times of the day or to support the recharge of a battery or to match the request of an electric utility for a peak demand usage period. This capability allows the fuel cell to be an integral part of a Smart Energy Solution for the telecommunications operator.

Keywords-energy, fuel cells, smart grid, managed devices, smart energy, backup power

I. INTRODUCTION

ReliOn has been a leader in providing reliable fuel cell technology and backup power solutions in the communications market since the company was established in 1995. Purpose designed products and integrated systems have been widely accepted throughout the world resulting in nearly 4 megawatts of deployed systems.

The benefits of using a managed fuel cell are difficult to see when taken individually with only a few kilowatts of power capacity at a single site. However, when the solution is aggregated across a network area, the value of the concept comes into focus. In simple terms, the fuel cell becomes a distributed solution that can support hundreds of kilowatts or even megawatts of power that is now under managed control by the telecommunications operator. When the operator can remotely start hundreds of systems to reduce their peak energy demand, they can positively impact their utility rates and receive credits from the electric utility or government agencies. If the fuel cell is supported by renewable hydrogen, the benefits can be greater in terms of capital equipment offsets and carbon accounting.

The need to manage energy consumption and production is solved by intelligent systems and control schemes. In the end, the fuel cell becomes a viable tool in a telecommunications operator's overall energy management model and the side benefit is a robust, long run-time, clean backup power system.

II. BACKUP FUEL CELLS

A. *Market Applications*

Today, fuel cells are used primarily in stationary power and material handling applications. Telecommunications, government communications, security, transportation communications operators and others use fuel cells for backup power in grid-powered locations. Fuel cells are also used in remote and off-grid applications as one component to a hybrid power solution which can involve any of the following other power sources: solar arrays, wind turbines, batteries, and/or generators. In addition to backup power, fuel cells are gaining acceptance as a source of power for lift vehicles used in material handling in large warehouse facilities.

Other applications of fuel cells range from continuous power, sometimes using the heat from the fuel cell to heat facility water (combined heat & power) for homes and businesses including hotels, grocery stores, manufacturing facilities and hospitals. They are also used as power devices for on-board equipment in the Recreational Vehicle industry, primarily in Europe. Automotive fuel cells are moving towards a proposed commercial rollout by 2015, as has been stated by Toyota, Honda and Ford motor companies. Fuel cell cars and buses are currently being used in varying quantities around the world where hydrogen refueling stations are available.

There are currently more than 1,300 telecommunication sites using fuel cell power solutions in North America alone. While this represents a small percentage as far as total telecom sites, it is clear that fuel cells are a viable solution to the need for reliable energy for sites in locations as diverse as cities, suburbs, rural, off-grid and environmentally sensitive areas.

B. Technology Overview

A fuel cell is a device that converts the chemical energy of a fuel (hydrogen, natural gas, methane, methanol, etc.) and an oxidant (air or oxygen) directly into electricity. While there are a number of fuel cell technologies available, the most common and practical technology for small to medium-sized standby power is the proton exchange membrane, or PEM, fuel cell. Proton Exchange Membrane (PEM) fuel cells generate electricity through an electrochemical reaction using hydrogen and oxygen. This process happens without combustion. A fuel cell operates electrochemically through the use of an electrolyte, just like a battery, but it does not run down or require recharging. Figure 1 shows a simplified diagram showing the various components at a cell level. It is similar to a generator in that it operates as long as the fuel is supplied; but unlike an internal combustion generator, it is simple, quiet, and clean with few moving parts.

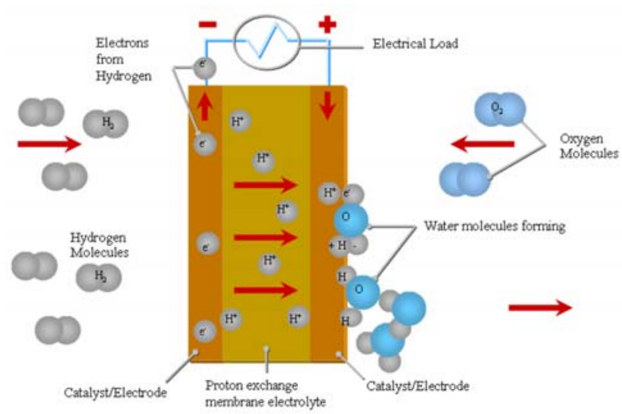

Figure 1. Proton Exchange Membrane (PEM) Fuel Cell Diagram

Based on technology available today, customer sites can be provisioned with fuel for hundreds of hours of runtime. Refueling allows the system to run continuously as long as needed for extended outages.

Most fuel cells being used for backup power today range from hundreds of Watts to approximately 20 kilowatts. For sites with these relatively low power loads and outages lasting from hours to days, fuel cells can be the backup power source of choice.

C. Simple DC Solution

In most applications the communications equipment being powered operates on DC power and fuel cells provide DC power. The fuel cell can therefore provide backup to the grid in case of outages, the rectifiers in case of module failures, and the batteries in case of capacity issues. In a hybrid model, the DC-based solution can even negate the need for rectifiers at the site, as all power equipment can be DC. A diagram of a typical power solution at a telecom site is shown in Figure 2.

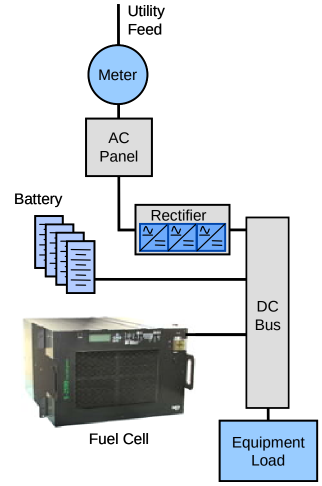

Figure 2. Typical Telecom Power System with Fuel Cell

D. From Random Sites to Scaled Programs

In order for the telecom fuel cell industry to continue to expand, it is necessary for corporations to move from testing one or two fuel cells to installing hundreds or thousands each year as part of defined programs. Telecommunications operators are beginning to transition from trials and limited deployments to scaled rollouts in North America, Asia, and Europe. Several operators have transitioned to programs deploying hundreds of fuel cells. As a backup system, a fuel cell is a viable robust solution, but it is seen fundamentally as an insurance policy to reduce losses due to power outages. Using the backup fuel cell as a component in energy management provides value beyond just backup and will allow further adoption of the technology.

In a backup model, the fuel cell and associated bridge energy storage support the entire load for the duration of the outage as is shown in Figure 3. During normal operation however, the generation and storage assets are in a standby state waiting for the next power disturbance. In other words, they are back to being an insurance policy.

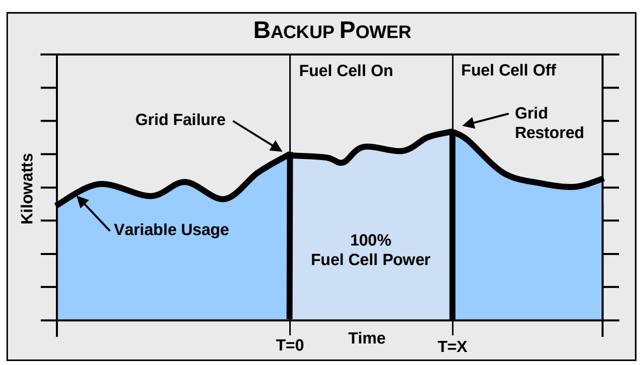

Figure 3. Backup Power Model

III. Beyond Backup

A. First Things First – Efficiency and Reduction

This paper is proposing smart energy solutions. To be smart, the first order of business is to do an assessment of consumption and efficiency. Over the past few years, numerous Intelec papers and other publications have shown significant improvements in energy consumption by taking advantage of new equipment and architectures. Next generation telecom equipment is more efficient and intelligent than previous generations. It may also have extended operating temperatures that reduce the need for active cooling. Base stations that were previously 3-4kW are now closer to 1kW. In power conversion, the new power plants are more efficient and smart enough to stay operating at their highest efficiency possible. Cooling systems consume as much as 25% of the energy at a remote site.[1] New systems using direct-air cooling, heat exchangers, and economizers can save as much as 40% of the energy of legacy compressor-based systems. Because of the compounding effects, 30% to as much as 70% overall power reductions can be achieved with new technology and architectures. Efficiency and reduction are clearly the best first steps to take before implementing plans around smart energy or alternate energy solutions.

B. Generation and Storage

A telecommunications operator can move beyond "just backup" power when they begin to look at their power assets as dynamic generation and storage tools. These are tools that utility grid operators want to take advantage of to balance, offset or avoid grid-related power issues. The telecommunications operator can take advantage of the utility programs around demand response, peak shaving, time of use and "selling" back the commitment and/or results of their participation.

One of the hurdles that must be cleared for a telecommunications operator to use their power assets in demand side programs is reliability. It is highly unlikely that an operator will relinquish control of their network to a utility or a third party aggregator. Using the fuel cell allows the operator to manage or control their own assets via their own procedures. Also, the operator will not want to diminish capacity or put their network at risk of failure or outage. The concept of balancing the sources of energy to meet the objectives of a smart energy program is a key to managing the risk at the network level. Working with the DC power equipment allows sharing of sources and therefore nothing is put in the "power availability" critical path. Simply put, the load can be shared between the rectifiers and the fuel cell based on voltage thresholds. Using DC is also more efficient simply due to the differences between the generators and conversion to accomplish the same function with AC power. In case of failure using in a DC based system, nothing needs to switch or start or transfer as all the systems are still online and able to support 100% of the load at any time. The energy supplied from the generation and/or storage reduces, but does not eliminate, the demand at the AC meter, yet supports the needs and the intent of the utility grid operator's programs. The only challenge in this model is that it requires new ways of measuring and recording where each kilowatt-hour comes from to support the accounting requirements of the external programs.

C. Value/Cost of Generation and Storage

If backup power at a site is a foregone conclusion to ensure continuity of service during a power outage, then the investment in the power equipment has already been justified. In some cases, regulations require backup power and in some cases, it is protection of revenue (insurance again), but whether it is 4 hours or 48 hours of backup, the resource exists. The costs of using the existing resource vary. The cost of generating power from a fuel cell depends on fuel supplies and can range from approximately $0.40 to $2.00 per kW-hr. For a battery, it is the cost of the recharge energy plus any life factor due to the discharge/charge cycle. The recharge energy cost is highly variable depending on source: grid (peak/off-peak), renewable sources, fuel cell, etc. The cost of using the generation and storage assets can create value for a corporation, but not necessarily on every continent, in every geographic region, with every government or with every utility operator. It can't be a broad brush solution and specifics must be identified and modeled.

IV. It's a Networked World

A. Smart Grid Concepts

The power grid has historically been a uni-directional series of transmission and distribution elements to deliver power to the consumer. There was no need for feedback or mediation, just a meter to measure consumption. In effect it was a one-to-many star architecture where the one was the utility. The vast capability of communications and intelligent controllers has given rise to the Smart Grid. Yes it is a buzz word, even over used, but a valuable capability in our need to manage energy. Distributed generation by non-traditional suppliers (e.g. consumers, grid synchronized/tied alternate energy like wind and solar) has given rise to the many-to-many model. Policy and intelligence is needed to manage the growing instability and many predict it will get more challenging as more grid-scale renewable energy is added.[2]

The evolving world of smart grid has given rise to words and phrases that are unfamiliar to many. A "prosumer" is a producer and consumer of electricity.[3] Telecommunications operators can potentially be prosumers by using their backup power resources to produce electricity. MDM is a key to smart grid and stands for Meter Data Management or how to handle the extensive data being gathered and transmitted by smart meters and devices. This is an area where there is significant collaboration between the telecommunications operators and the electrical utilities since the electrical utilities have not historically been experts at data networks and storage.

Many components in a telecom power solution can be either connected into the smart grid world or can be a direct component of the smart grid. Today's power systems, including fuel cells, have intelligent controllers and network interfaces resulting in smart, remotely manageable devices with interfaces that provide standard protocols for Machine to Machine Interfaces or Human to Machine Interfaces.

B. *Operations*

A smart energy solution in telecom must be able to be managed via traditional operations methods. In the models presented in this paper, the operations center should be able to control and manage multiple power systems at any given time using direct commands or preset scripts. When using small power systems like fuel cells at cell sites there is need to be able to manage potentially hundreds of devices to roll-up to a power level that makes a difference on the grid. Five or ten sites at 7kW won't interest the utility and really does nothing for the telecommunications operator's energy consumption. On the other hand, a network of 250 sites at 7kW now becomes quite significant at 1.75MW. Figure 4 shows a networked collection of fuel cells that are managed from the Network Operations Center (NOC) or by a third party services company. When there is a need to generate power, the command can be issued via the network to start generation, stop generation and gather statistics about the production of energy.

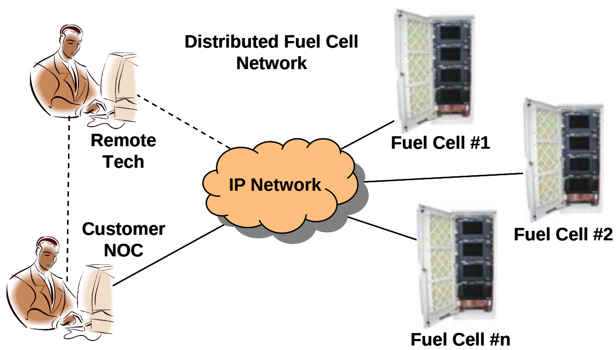

Figure 4. Networked Fuel Cells

C. *Statistics / Data Management*

The measurements and data required for the Smart Energy Programs, like the programs themselves, vary from country to country and utility to utility. In most cases, a key data point needed is a measure of the kW-hr produced, reduced, avoided, etc. Some way to account for the use of the DC power components and the energy they have produced must be established with the utility. Most utilities are more familiar with measuring using the AC meter and Meter Data Management issues, but a DC solution typically only makes the meter spin slower to maintain the power continuity and reliability the telecom operator demands. Again, nothing is switched off or put into simplex mode. In the United States, the electrical utilities must also comply with the state utilities commissions that have direct regulatory oversight as well as the Federal Energy Regulatory Commission.

V. Smart Energy Programs

A. *Incentives*

As has been previously described, smart energy programs are highly dependent upon government regulations and incentives. The data in Tables 1 and 2 show a summary of incentive programs in the United States for renewable and energy efficiency. At the federal level, fuel cells qualify for an Investment Tax Credit that is equal to the lesser of $3,000/kW or 30% of the cost basis. In addition, some states have tax incentives and further capital offsets when using certified renewable-generated hydrogen. It is highly recommended that the operator consult with their tax advisors and government officials to see what programs are available and if they must be taken singularly or can be compounded. In all investigated cases, the government programs were 100% complimentary to the utility programs.

Personal Tax	Corporate Tax	Sales Tax	Property Tax	Rebates	Grants	Loans	Industry Support	Bonds	Performance Based Incentives
41	41	43	72	496	55	192	38	3	66

Table 1. Summary of US Based Financial Incentives for Renewable Energy [4]

Personal Tax	Corporate Tax	Sales Tax	Property Tax	Rebates	Grants	Loans	Industry Support	Bonds	Green Building
13	11	9	6	1103	55	209	-	3	15

Table 2. Summary of US Based Financial Incentives for Energy Efficiency [5]

B. *Utility-Driven Programs*

As was shown in Tables 1 and 2, the electrical utility providers have numerous programs and incentives for energy management and efficiency. In the United States, most of the utility programs are tied back to the state level utility commission. Regulations in different countries around the world will ultimately dictate if a telecommunications operator can find a smart energy program to pursue. The operator must consult with their electricity provider to explore their specific programs and incentives. The three programs below represent generic examples of utility programs that the author has investigated. Many other programs are possible, but the one common thread is that the more commitment a customer is willing to make, the more financial incentive they are typically eligible to receive.

1) *Demand-Response*

Demand Response (DR) has many different definitions, but is typically a program where customers plan for a certain amount of power to be switched on/off within specified lead times (response). This allows the utility to have some predictable control on the demand on the grid. If there are peak demand periods, the utility can notify a DR participant to reduce consumption of their committed amount for a period of time. For example, if the utility has customers with the capability to turn off load within 24 hours or 8 hours or even thirty minutes, then the utility can manage the grid and make decisions to balance between DR actions and deploying peaking generating assets or having to spot buy energy from a neighboring utility. In some cases, there are programs used to balance frequency issues on the grid that require response times in seconds. The DR programs compensate the utility customer (in this case the telecommunications operator) by the number of kilowatts or megawatts committed to the program, the speed of response (e.g. a 24 hour response would not get as much compensation as a 1 hour response time) and the commitment on the duration or frequency of DR events. Annual base compensation can be in the range of $40-80/kW committed. When a DR event is called, the customer reduces their committed power for a period of time and then is compensated based on the Locational Marginal Rate (LMR) for energy produced during their response period. A real-time LMR can be significant while an LMR for day-ahead timing may be just a fraction of the real-time rate. These rules are government and utility specific so they must be reviewed accordingly.

Figure 5 shows a DR model representing a point in time when the utility issues a DR call and the telecommunications operator controls the fuel cell to produce power, reducing net kilowatts of load on the grid by the corresponding power produced by the fuel cell.

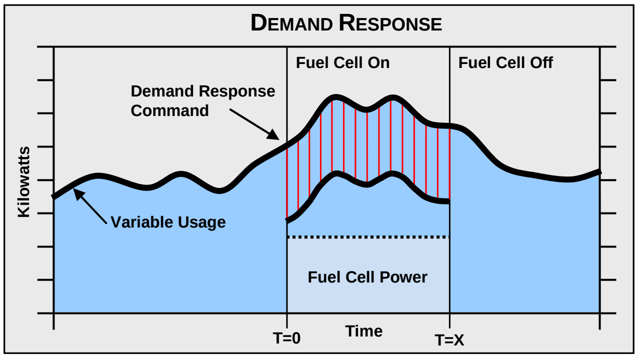

Figure 5. Demand Response Model

2) Peak Shaving

Peak shaving is a power threshold-based program. If a telecommunications operator has forecasted their consumption and manages their energy billing with the utility based on usage and forecasting, there is typically a large penalty if they cross their forecasted threshold. In some cases, cost per kW-hr can be 10-20X normal rates. The key to implementing programs for peak shaving is that the total cost of local generation to reduce the peak must be better than the higher price of grid power.

Figure 6 shows a Peak Shaving model that has an established threshold that triggers the fuel cell to generate power and "shave the peak" and therefore eliminate the customer from having to pay the high cost to the utility. When the total usage is below the threshold, then the fuel cells turn off and all power is again provided by the utility. A peak shaving program is simpler than a DR program to implement since it is up to the telecommunications operator to establish their forecast model with the utility and then just manage by deploying generating assets or even storage to not exceed their forecast. To manage this model, the operator must be able to see their aggregated power consumption dynamically and this is likely the most difficult task to implement peak shaving. Smart grid and meter technology are enabling this to be basically real-time management with the fuel cell responding to commands from monitors.

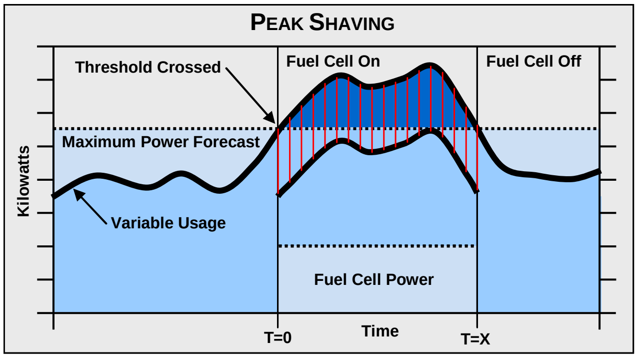

Figure 6. Peak Shaving Model

3) Time of Use

Time of Use (TOU) programs are quite similar to peak shaving, but the triggers are based on time and not power thresholds. Utility operators know their statistical seasonal and daily demands and establish programs to incent customers to use less energy during the critical times of year/day. In many regions of the world, the summer months during 4-6 midday hours are peak usage times. Utilities seek to have customers commit to reducing usage during the TOU periods by adjusting billing rates. Though the pricing differences are not as dramatic as a peak shaving model, off-peak to on-peak rates can still vary from about 3-8X. Figure 7 shows a TOU model with a time-based trigger to start the fuel cell, which then produces power for a predetermined time. These programs are not typically as high value to the telecom operator, but they are the easiest and most predictable to implement. The regular use of the fuel cell for a certain number of hours per day over a certain number of weeks can easily be programmed at the operations center. No real accounting needs to be done as every kW-hr produced by the fuel cell is a kW-hr that is not being purchased at the peak TOU utility pricing.

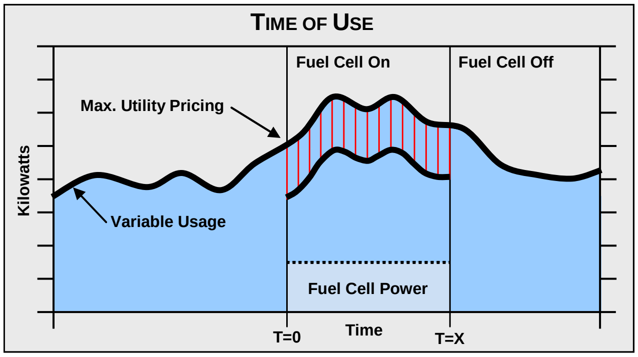

Figure 7. Time of Use Model

4) Other Values – Backup

Let's not forget the value of backup power in the operator's network. The backup model in Figure 3 showed the fuel cell powering 100% of the load during a grid failure condition protecting revenue, service continuity, and customer satisfaction.

VI. SMART ENERGY MODELS

A. *Typical Network*

For modeling purposes we have selected a hypothetical wireless network in California consisting of 300 base stations. Figure 9 shows the model network map where the cell sites are concentrated on cities, towns and along transportation routes. Each point on the map may represent one or more specific cell sites to illustrate the scope of the network.

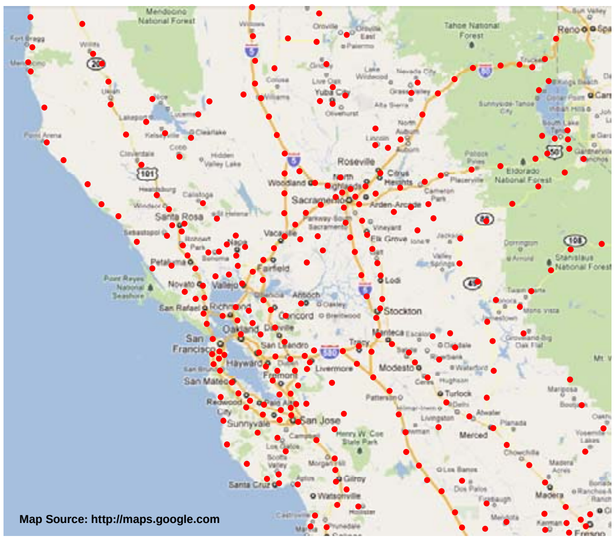

Figure 8. Model Network Map

1) *Geographic Area*

The target network for a demand side program should ideally fall within the service boundary of a single electrical utility. Another geographic consideration is whether a program will require extended operation of the fuel cells and result in refueling requirements. Refueling requires that systems should be geographically located such that fuel delivery can be accomplished within the program time bounds. The network in Figure 8 represents a network that meets the above criteria.

2) *Scale*

The scale of a network is limited by the telecommunications operator's service area and the capacity/coverage model they need for the serving area. The number of communications sites within an electrical utility's service area is easily hundreds and could be potentially more than a thousand. The more power assets that can be committed to a demand side program the more potential an operator has to produce financial return. While outside the scope of this paper, the operator could also contribute other assets, like lighting and HVAC systems, into demand side programs.

B. *Program Models*

Below, we will consider the model network of 300 fuel cell systems against the 3 demand side programs plus backup power to see the possible value and benefits to the operators.

1) *Demand-Reponse*

The demand response model is based on the following conditions and parameters. Because the fuel cells can respond quickly, even across a large network, this model uses a 30 minute response commitment. Obviously, in programs based on commitments and response time, if commitments are not met then there is a downside to the operator in the form of penalties and/or fees.

Program Conditions:

- 30 minute response time
  - $75/kW/year of commitment
- Maximum of 12 hours per event
- Maximum of 80 hours per year

Operating Parameters:

- Fuel cell operation = $1.10/kW-hr cost
- Locational Marginal Rate = $1.30/kW-hr
- 300 total committed sites
- Committed power per site = 5.5kW
- Total committed power = 1.65MW

Event Results:

- Energy Produced = 1,650kW * 12hr = 19,800kW-hr
- Cost = 19,800kW-hr * $1.10/kW-hr = $21,780
- Payment = 19,800kW-hr * $1.30/kW-hr = $25,740
- Financial Benefit = $25,740-$21,780 = $3,960

Annual Results:

- Energy Produced = 1,650kW * 80hr = 132,000kW-hr
- Cost = 132,000kW-hr * $1.10/kW-hr = $145,200
- Payment = 132,000kW-hr * $1.30/kW-hr = $171,600
- Financial Benefit = $171,600-$145,200 = $26,400
- Annual Commitment Payment
  = 1,650kW * $75/kW/yr = $123,750
- Total Annual Financial Benefit
  = $123,750 + $26,400 = **$150,150**

The Demand Response program generated over $150K of payment by using an asset already deployed for backup power in a beneficial utility program.

2) *Peak Shaving*

The peak shaving model is based on the following conditions.

Program Conditions:

- Forecast power requirements
- Normal Utility Rate = $0.10/kW-hr
- Peak Utility Rate = $1.80/kW-hr
  - Charged on usage above forecast

Operating Parameters:

- Forecasted maximum power 60MW
- Fuel cell operation = $1.10/kW-hr cost
- 300 total sites
- Power per site = 5.5kW

- Total available Peak Power Generation = 1.65MW

Event Results:

- Forecast Daily Energy Consumption = 1,440MW-hr
- Cost = 1,440MW-hr * $0.10/kW-hr = $144,000
- Peak Exceeded = 1.5MW * 4hr = 6MW-hr
- Fuel Cell Operated = 1.65MW * 4hr = 6.6MW-hr
- Operational Cost = 6.6MW-hr * $1.10/kW-hr = $7260
- Peak Cost Exceeding Forecast
  = 6MW-hr * $1.80/kW-hr = $10,800
- Event Financial Benefit = $10,800 - $7,260 = $3,540

Annual Results:

- Estimated Number of Peak Events per Year = 8
- Peak Event Savings = $3,540
- Total Annual Financial Benefit = 8 * $3,540 = **$28,320**

The Peak Shaving program avoided costs of $28,320 in the annual model. This savings was calculated only on their peak usage, or that energy above the forecast line in Figure 6. In some cases, the penalty of going over the forecast is that 100% of power consumed for the period is calculated at the peak rate.

3) Time of Use

The time of use model is based on the following conditions

Program Conditions:

- Normal Utility Rate = $0.14/kW-hr
- Peak Utility Rate = $1.12/kW-hr
  - Charged during peak times
- Peak Time = 4 months per year, 5 days per week, and 5 hours per day = 400 hours per year

Operating Parameters:

- Fuel cell operation = $1.10/kW-hr cost
- 300 total sites
- Power per site = 5.5kW
- Total available Power Generation = 1.65MW

Annual Results:

- Annual Peak Fuel Cell Energy Production
  = 1.65MW * 400hr = 660MW-hr
- Time Of Use Utility Cost
  = 660MW-hr * $1.12/kW-hr = $739,200
- Fuel Cell Generation Cost
  = 660MW-hr * $1.10/kW-hr = $726,000
- Total Annual Financial Benefit
  - = $739,200 - $726,000 = **$13,200**

The Time of Use program generated annual savings of $13,200 over utility purchases.

4) Backup

The backup model is unique in that is its value is not a simple financial calculation. The cost of operating the fuel cell system during a backup event is the same as the other programs. The difference is that this is the only source of energy during the event so the value comes from the network remaining operational for revenue traffic, prevention of lost customers or customer satisfaction issues due to outages, potential for penalties for service level agreements, regulatory reports and potentially fines. Monetary values would vary widely on these key performance metrics, but most operators would agree that there is significant value. Customer acquisition alone is expensive, reported to be about $350 per customer[6], related to marketing, advertising, promotions, subsidies, etc. Network reliability may be the most valuable part of all three of these programs.

C. Summary of Program Benefits

1) Financial

The example models represent potential value that can be achieved by using local backup power capacity in demand side programs. Since national and local regulations and electrical utility programs vary so widely, this data should be used only as a guideline. Across all programs, an operator should consider the benefits of upgrading to more efficient equipment and network designs to reduce their energy consumption to save money. Besides the backup scenario, the operator should also consider using assets like lighting and HVAC system to further contribute to their potential savings.

The summary in Table 3 shows that the demand response program model has a significantly better financial benefit. This is mainly a result of the per kilowatt payment for the committed reduction and response time.

Program	Sites	Annual Run Hours	Cost	Revenue or Cost Avoidance	Financial Benefit
Demand Response	300	80	$145,200	$295,350	**$150,150**
Peak Shaving	300	32	$58,080	$86,400	**$28,320**
Time of Use	300	400	$726,000	$739,200	**$13,200**
Backup	300	variable	variable	variable	**variable**

Table 3. Financial Summary of Models

The peak shaving and time of use programs have less financial value, but still may have significant non-monetary advantages with public relations, corporate sustainability programs and even regulatory compliance.

2) Sustainabilty

In addition to the potential financial benefits, a telecommunications operator can use their backup power assets to support their own sustainability goals. Using fuel cells as the backup solution and in the utility programs further contributes to meeting sustainability goals. Legacy diesel generators generate emissions and have potential for costly fuel spills. Additionally, it is reasonable to expect that the regulations on internal combustion engine emissions and hours of operation on generators will continue to get more stringent over time.

In the UK for example, there is a program called STOR (Short Term Operating Reserve) that as of 2009 had some 2,369MW of committed generation. On the demand side, there was 839MW committed from 89 different sites. Sites can be aggregated to qualify for the minimum of 3MW. Of the 839MW, approximately 750MW was committed from backup power generation and 500MW of that is sourced from diesel generators.[7] For reference, this program requires 4 hour response time, a minimum of 2 hours delivery and the participant receives £40/kW/yr or about $65/kW/yr. 500MW of power generated by diesel engines, for even 2 hours contributes significant emissions.

Figure 10 shows a comparison of the emissions of a fuel cell model against a diesel generator model for the 300 sites we have modeled against a 150 hour annual runtime. This is showing carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM), and carbon dioxide (CO2). Diesel emissions are based on US Federal Tier 2 guidelines.[8] This is point of use emissions without taking into account the sourcing, production processing, or delivery of the fuel. The "well to wheel" model still favors the hydrogen fuel significantly even when generating the hydrogen from natural gas through steam reforming.

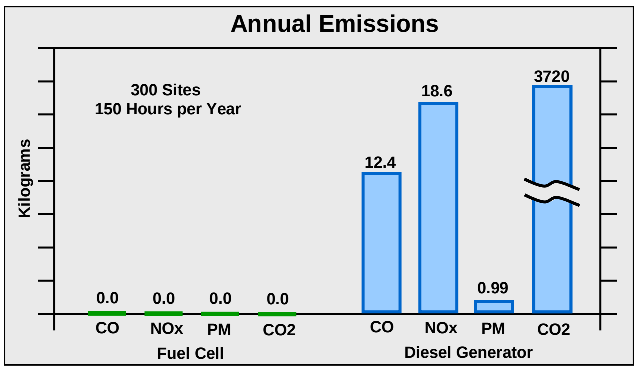

Figure 9. Emissions Comparison

The CO2 emissions for the estimated 500MW of diesel in the UK program above would result in about 826kg of CO2 for every hour of operation. Extrapolating then, the 500MW of diesel in for the 150 hours shown in Figure 10 would equate to almost 124,000kg of CO2.

Another advantage of using hydrogen in this model is that it can be obtained from several renewable sources or recovered from industrial processes. Hydrogen produced by water electrolysis from surplus wind or solar energy further improves the sustainability factor. Renewable hydrogen solutions are also finding favor in the forms of rebates and capital offsets. In the model network of 300 sites each fuel cell produced about 5.5kW for the program calculations. To net a contribution of 5.5kW for the demand side programs, the fuel cell capacity would likely be about 7.5kW at these sites. In California there is a program for deploying fuel cells with certified renewable generated hydrogen that provides a $3/watt capital offset. The value of renewable hydrogen is important relative to environmental issues, but to the telecom operator in our model it is also worth 300 * 7.5kW * $3/watt = $6.75M in offset to purchase and install the fuel cell technology.

VII. Conclusion

Smart energy programs come in many variations and are growing in popularity due to ongoing electrical grid issues. Worldwide electrical demand continues to increase resulting in capacity shortages and strain on grid infrastructure. Failures and instability are inevitable without corrections. Smart energy and demand side programs are step toward correction. Smart energy solutions along with intelligent devices offer valuable tools for the telecommunications operator to leverage their backup power assets for financial and environmental value. The operators can become a "prosumer" both producing and consuming energy. They are now active in the solution rather than purely a consumer of resources. Today's fuel cells offer a viable solution to support the necessity of backup power and the smart energy solutions. The telecommunications operator has a choice: they can buy a robust backup power solution and get a smart energy solution or they can buy a smart energy solution and get a backup power solution as a side benefit.

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