Superstorm Sandy: Fuel Cell Design for Disaster Recovery vs. Backup Power

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Abstract

Superstorm Sandy impacted the east coast of the United States and Canada at the end of October 2012, causing destruction valued in the billions and creating power outages lasting between hours and weeks for millions of people. Effective recovery from such events includes having power and communication systems that have been designed for resiliency.

Fuel cells have been used at communications facilities for more than a decade. They have provided backup power through many service-impacting events including hurricanes, winter storms, and electrical storms. Backup power, however, is somewhat different than power required to facilitate disaster recovery. At that point, it becomes more of a grid supplement paradigm and fuel availability and delivery become paramount to continuous coverage. This session will discuss the differences between backup power and power for disaster recovery and the fueling solutions necessary for successful operation during and after natural disasters.

In late 2008, The U.S. Department of Energy released a Funding Opportunity Announcement, targeting Market Transformation for stationary fuel cells for communications backup. This program has been discussed at Intelec both in 2008 and 2010. One specific requirement of this program was the capability to provide 72 hours backup on compressed hydrogen. Since the inception of this program, ReliOn has installed over 425 sites with bulk storage of hydrogen. Many of these sites have fuel storage in excess of 72 hours, based on actual system load and fuel usage. This option—patterned on bulk gas deliveries to industrial users—can provide extended run time, reduce labor requirements and transport logistics, and decrease hydrogen wastage. This is an excellent alternative to large battery cabinets or internal combustion engines.

In the case of large scale disasters, the existing infrastructure can be overwhelmed by the need for support and re-supply. ReliOn is working with the industrial gas suppliers, third party support groups, technology developers and end-users to develop a pre-established plan with additional infrastructure, small scale mobile storage, and refueling capability to facilitate a more nimble and timely response.

In addition to this work in North America, a grid supplement model, which calls upon ReliOn experiences in emerging markets, can augment our understanding of what constitutes an effective response to long term utility grid outages. In the emerging market model, large refueling reserves are required to be in place in a standby capacity. Grid downtime – several hours a day in many cases – and subsequent consumption of fuel drives the supplier toward an alternative economic model. This model emphasizes the need for a scheduled routine response, higher capacity on site and a more-interchangeable (readily available) fueling support structure. This may include enlisting the support of third party vendors capable of filling in the re-supply gaps.

There are numerous lessons that can be learned both from historical disaster recovery and the practices of North American and emerging markets that have a place in the global telecommunications marketplace because of an increasing need for disaster recovery and preparation.

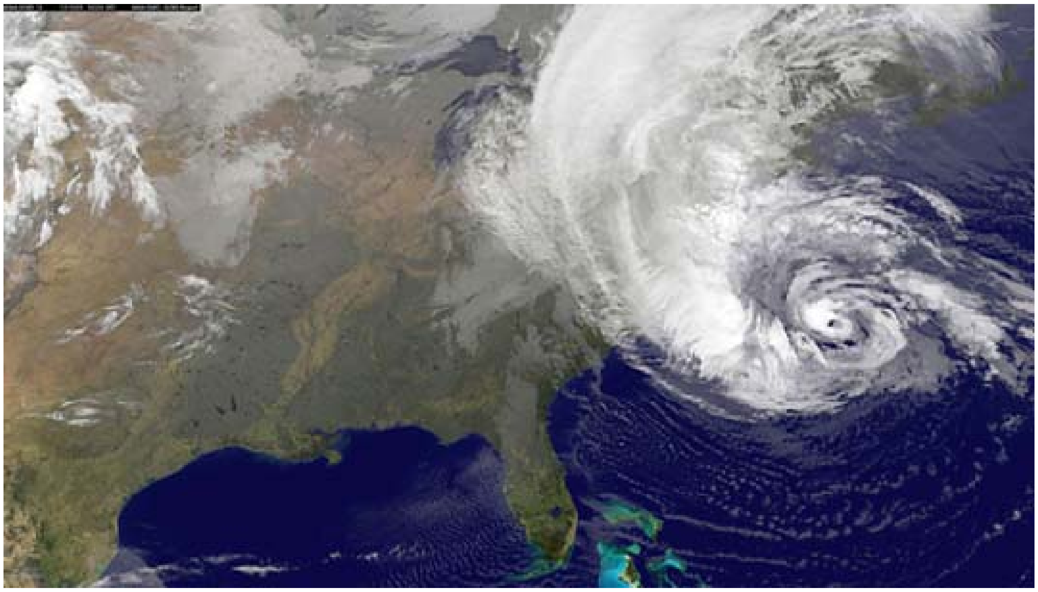

Figure 1 Satellite view of Superstorm Sandy[1]

1 Introduction

Superstorm Sandy slammed into the East Coast of the United States and Canada at the end of October 2012, causing destruction valued in the billions of dollars and creating power outages lasting between hours and weeks for millions of people (**Figure 1**). It was the most financially costly of approximately 900 natural catastrophes occurring worldwide in 2012. Effective recovery from such events includes ensuring that resilient power and communication systems have been deployed *before* these events occur.

There are a number of power options for telecommunications operators, including batteries, combustion generators, fuel cells, wind and solar. Each solution has its benefits and challenges and is chosen based on the needs of the individual site.

Fuel cells have been used at communications facilities for more than a decade. They have provided backup power through many service-impacting events including hurricanes, winter storms, and electrical storms. Backup power, however, is somewhat different than power solutions required for facilitating disaster recovery. When extended outages occur, solutions become more of a grid-supplement paradigm, and fuel availability and delivery become paramount to continuous coverage. This paper will discuss the differences between backup power and power for disaster recovery and the fueling solutions necessary for successful operation during and after natural disasters.

This discussion draws upon real-world experiences ReliOn has gained deploying fuel cells around the world. To date, more than 1,600 sites are supported by ReliOn fuel cells, in a variety of environments, power capacities, fuel storage capacities, and fuel storage architectures. Experience in multiple countries and regions, with a variety of fueling solutions, provide insights into the actual requirements for backup power vs. disaster recovery.

1.1 Superstorm Sandy: A Telecom-focused Overview

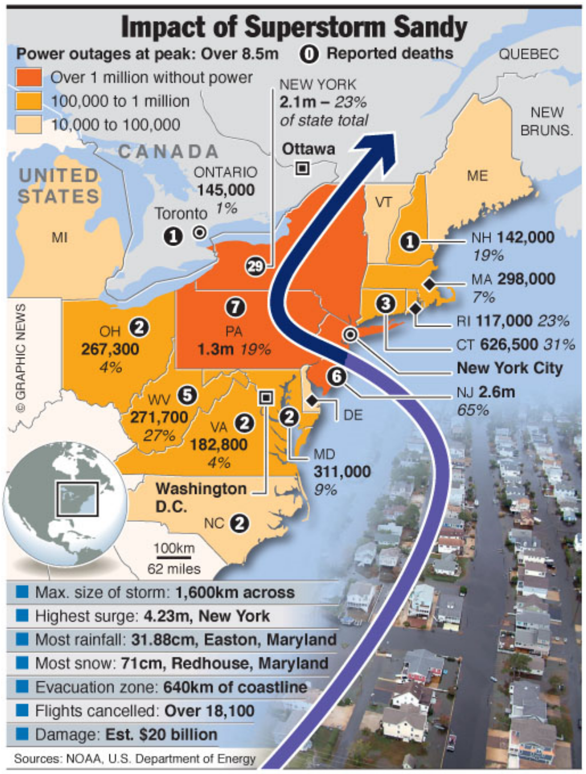

Figure 2 Impact of Superstorm Sandy

To recap the basic storyline, Superstorm Sandy made landfall in New Jersey on October 29, 2012. Sandy was a category 2 hurricane, but at 1,600 km across, walloped the East Coast, causing upwards of $50 billion in damages and claiming 210 lives.[2] **Figure 2** shows the impact of the storm. People in New Jersey continue to struggle as they clean up the damage and rebuild.

News coverage by USA Today during the storm reported on the impact on communications: *"The cellphone outage, as estimated at 10 a.m. Tuesday, covered 158 counties from Virginia to Massachusetts, CNET says.*

The main issue affecting the restoration of service to cell sites is the fact that commercial power may be out for several days or even weeks in some areas. Between 7 million to 8 million people are reportedly without power in areas affected by the hurricane, officials said."

"Some cell sites have already been running on backup power. But the FCC was unable to say exactly how many. Still, the commercial power issues mean that these sites could also go down in the next day or so, especially if repair crews are unable to get to sites that need battery replacements and generators that need refueling." [3]

At the height of the outages, approximately 25% of cell towers were out of service, according to reporting done by Fierce Wireless. *"FCC Chairman Julius Genachowski said Tuesday afternoon that 25 percent of cell sites in 158 counties in 10 states from Virginia to Massachusetts were not operational. He indicated that service would get worse for those affected before it gets better as backup batteries and generators at cell sites fail."* [4]

1.2 Worldwide Catastrophes

Each year, several hundred natural catastrophes happen around the world. Superstorm Sandy was the costliest (in U.S. dollars) of 905 events logged in 2012 by the Geo Risks Research department of the insurance firm Munchener Ruchsversicherungs-Gesellschaft (shown in the map in **Figure 3**). [5] In fact, six of the top ten costliest events for 2012 were located in the United States. These include the Midwest drought (not a power outage) as well as tornados and severe storms in "Tornado Alley" in March, April, May and July. The remaining four costliest events on the list were located in Italy, China and Pakistan. Though this research did not track duration of electrical outages for these events, the point is that there are a large number of weather- and nature-related outage events that happen each year.

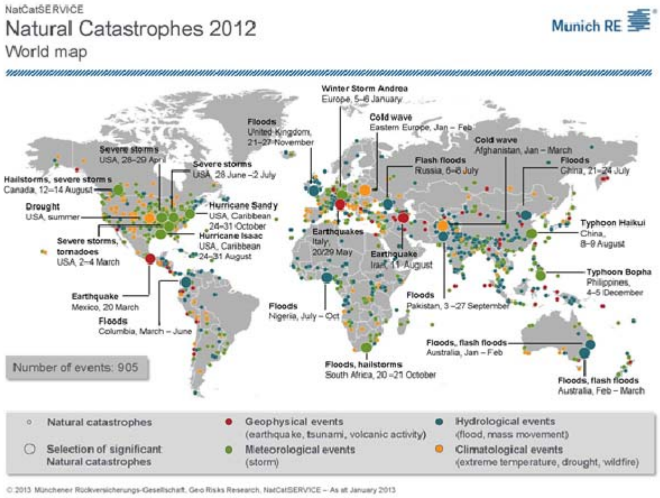

Figure 3 Natural catastrophes 2012 world map

1.3 Contingency Planning: Short-term Backup and Disaster Recovery

When large scale disasters occur, the existing telecommunications infrastructure, including operations and maintenance, is often overwhelmed by the need to provide continuous service. As the population continues the transition to wireless networks for their primary communications mode, regulators are struggling with ways to ensure reliability and resiliency. In the U.S.A., ATIS (Alliance for Telecommunications Industry Solutions) and the FCC, as well as other organizations around the world, continue to push for improvement and agreed-upon best practices.

FCC Commissioner, Jessica Rosenworcel stated in public comments, "It is time for an honest conversation about network reliability in the wireless and digital age. It is time to ask hard questions about backup power, and how to make our networks more dependable when we need them most. Technology evolves, but our need to stay connected does not. If good comes out of Hurricane Sandy, it should be that we prepare better and develop new ways to keep us safe."[6]

It is human nature to react in response to a threat. Immediately following 2012 events including Superstorm Sandy, the widespread derecho wind outages in the U.S.A., and Cyclone Andrea in Europe, there was much attention paid to the performance of E-911 and cellular telecommunications networks. As each event recedes in memory, focus moves to other items of importance. It is vital that even after the initial urgency fades, disaster planning continue. There will be another event.

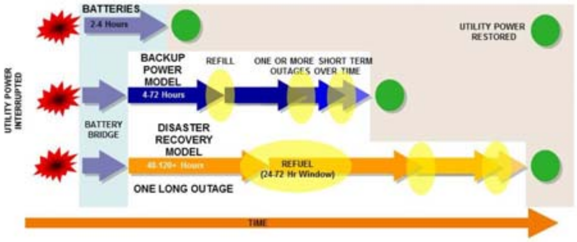

Figure 4 Outage power contingency models

Backup power and disaster recovery models are significantly different due to one key factor: duration. As was mentioned above, most people think of backup power covering a grid outage lasting up to a few days, but often a much shorter span of time. Disaster recovery solutions are needed for a much longer duration, generally at least five days, but often weeks. A solution for both of these models includes the concepts of *power* and *energy*. Power addresses the number of Watts or kilowatts needed at any given site. This does not generally change depending on the outage event. Energy addresses the amount of fuel needed to be stored in order to address the runtime needed between refueling windows. This does change.

Figure 4 illustrates the differences in duration and refueling windows between a backup power model and a disaster recovery model. Because the duration of a longer "short" outage seen in the backup power model approaches that of a disaster event, batteries cannot be the only solution for most sites. They must be utilized in tandem with at least one other power source. Most telecommunication sites currently use a combination of batteries and either a generator or a fuel cell to cover longer backup power events or disaster recovery outages. In both cases, the on-site batteries provide a bridge between the utility-provided electricity and the longer term replacement power source, in this case, fuel cells. In a disaster recovery scenario, the critical factor becomes the need for a fueling model that is suitable for the length of runtime required to fully restore normal operation. **Table 1** shows several options available for various runtime needs in backup and disaster recovery scenarios.

Solution	Runtime
Battery only	2-4 hours
Fuel cell with individual cylinder gas storage	Up to 54 kWh in one cabinet
Fuel cell with multi-pack gas cylinders	Up to 150 kWh in one 16-pack
Fuel cell with bulk refueling gas storage	Up to 300 kWh in one cabinet
Fuel cell with fuel processor	Up to 400 kWh in one fuel tank

Table 1 Runtime availability by solution type

2 Fuel Cell Power Solutions

Criteria for selecting a fuel cell system for a specific application include power requirements, frequency and duration of outages, response time to the site, environmental restrictions and serviceability requirements. Fuel cells can and are being used as the sole backup power solution in many critical applications; however, they can also be used as an added layer of protection for a site using incumbent solutions. This concept is analogous to a layered network security architecture where each layer of security, e.g. firewalls, intrusion detection devices, etc., add to the overall network protection. Fuel cells offer rack-mounting options within an equipment shelter as well as environmentally-hardened outdoor cabinets for flexibility to meet network design parameters.

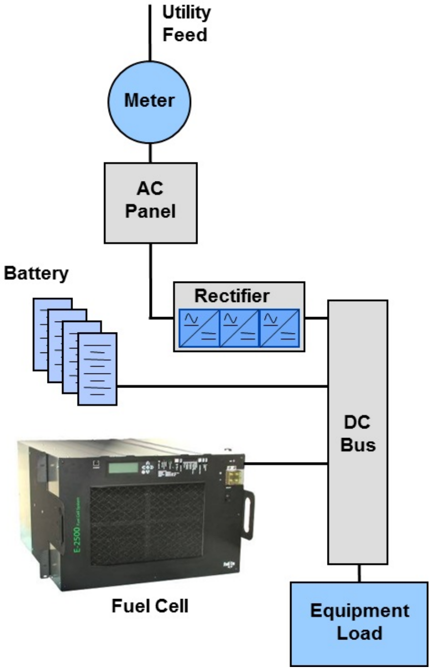

Figure 5 Fuel cell connection to DC bus

Most fuel cells being used for backup power today range from 50 Watts up to 20 kilowatts. 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 during extended outages. The key, as with any generator, is to have a refueling plan in place prior to a major outage.

One of the attributes of a fuel cell that makes it attractive for deployment in telecom environments is that a fuel cell produces DC power. This makes it akin to a DC generator, as the power provided from the fuel cell can be directly connected to the site's DC power bus without the need for a transfer switch (**Figure 5**).

In an outage situation, the fuel cell turns on automatically, providing DC power formerly provided by the rectifiers.

Fuel cell systems are intended to operate in parallel and augment the traditional DC power system components.

Because of the simplicity of tying directly to the DC bus, fuel cells are easily added to existing sites, and designed into new network locations. With hot and cold weather design features, many fuel cells are capable of serving loads in a wide variety of geographical locations.

The critical nature of communications during disaster recovery requires highly reliable power. This is one of the hallmarks of fuel cells, with ReliOn products receiving field reliability ratings of 99.9%.

A viable site-hardening plan involves combining one or more backup power technologies in parallel, increasing the availability of the site by providing a highly reliable "backup" to the primary backup power source. For instance, an AC-powered site that is normally equipped with VRLA batteries connected to the DC bus may benefit from a fuel cell also connected to the DC bus. The fuel cell solutions would carry the site load and charge batteries when the batteries dip below a certain voltage at loss of AC power or in the event of a rectifier failure. The fuel cell prevents the deep level of discharge on a battery string and allows the site to operate on backup power for much longer than on batteries alone, both because more energy (i.e. fuel) can be stored on site initially when compared to battery-only solutions, and because additional fuel can be delivered to keep the site operational during extended outages.

3 Fueling Options

ReliOn continually works with industrial gas suppliers, third party support groups, technology developers and end-users to develop a pre-established plan with additional infrastructure, small scale mobile storage, and refueling capability to facilitate a more nimble and timely response.

In addition to this work in North America, a grid-supplement model, which calls upon ReliOn's experiences in emerging markets, can augment our understanding of what constitutes an effective response to long term utility grid outages. In the emerging market model, large refueling reserves are required to be in place in a standby capacity. Grid downtime – several hours a day in many cases – and subsequent consumption of fuel drives the supplier toward an alternative economic model. This model emphasizes the need for a scheduled routine response, higher capacity on site and a more-interchangeable (readily available) fueling support structure. This may include enlisting the support of third party vendors capable of filling in the re-supply gaps.

There are three basic types of refueling models for hydrogen fuel cells, each with different strengths.

3.1 Packaged Gas

Traditionally, fuel cells have used hydrogen cylinders to store fuel (packaged gas). The refueling of hydrogen cylinders is accomplished by a vehicle transporting full cylinders to the site and exchanging them for the empties. Though somewhat labor-intensive, for many locations this remains the option of choice. A second version involves the delivery and replacement of a "storage pack" (see **Figure 6**). Given enough space, this option allows for a significant amount of fuel to be staged at a location prior to a forecasted outage event.

Figure 6 Packaged gas resupply

3.2 Bulk Refueling

A second option is bulk hydrogen refueling. Network operators and fuel cell manufacturers have worked with major global hydrogen suppliers and third-party suppliers, initially in the United States, to establish a refueling model similar to the diesel/propane model. In this model, the cylinders remain on site and are filled on site by the refueling truck (**Figure 7**). This development has broadened the market for fuel cells to address higher capacity installations and sites requiring extended run times of several days. This model provides the 24 to 72 hour window necessary for the fuel provider to move between the carrier's regional communication sites to continue to refuel during the span of an extended outage.

Figure 7 Bulk refueling delivery

3.3 Fuel Processing

A third option for providing hydrogen for fuel cells is the fuel processor, also called a “reformer”. The fuel processor takes a hydrogen-rich carbon-based fuel, such as methanol mixed with water and, using heat and catalyst, separates the hydrogen from that fuel in order to deliver it to the fuel cell. Because these fuels tend to be liquid, energy density is better than with gaseous hydrogen, allowing for more runtime to be stored on site in a smaller space. A liquid fuel is also easier to deliver in bulk, eliminating the heavy storage containers and specialized equipment necessary to handle high pressure compressed gas. However, reformers introduce additional cost and complexity to the fuel cell system and can reduce the reliability of the system as a whole. Hydrocarbon fuels, because they are not simple hydrogen, also emit low levels of pollutants during the reforming process. In locations where hydrogen is not readily available or is priced too high, a fuel processor may be the fueling option of choice. Like the bulk refueling option, the reformer allows a long enough window for the fuel provider to rotate between carrier sites in order to facilitate repeated refueling during extended outages.

Figure 8 graphically displays the variety of refueling options discussed above by length of runtime available and ease of refueling. For example, liquid fuels used in the fuel processing option enable the longest window between refueling services needed. This gives the customer the option to use it for both backup power and disaster recovery operations. On-site refillable hydrogen offers a similar runtime, though may be slightly less easy to refuel, depending on the location of the customer site. Cylinder gas, though not a difficult refill model, offers shorter runtimes between refuel servicing. This makes it better for a backup power scenario or a disaster recovery model where there are fewer locations in a geographic area, making it easier to visit them more frequently. A battery-only model is very challenging in a disaster recovery model where the utility grid is down, due to the need to recharge the batteries every 2-4 hours, depending on the amount of energy stationed at a particular location. Because of this challenge, batteries are generally utilized as bridge power and hybridized with a longer term power source, such as a fuel cell.

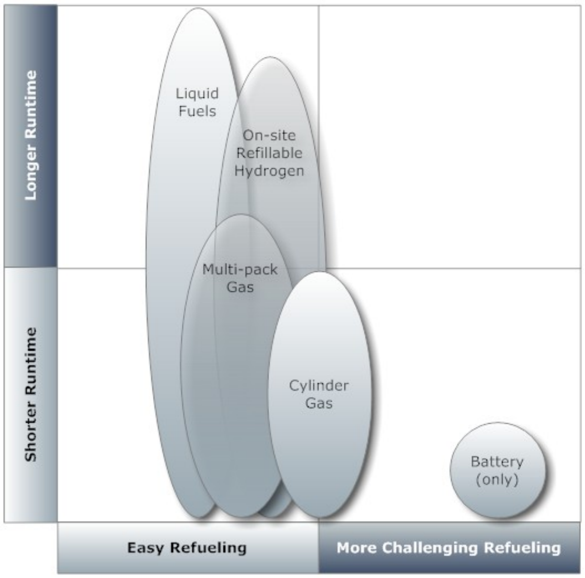

Figure 8 Runtime vs. Ease of Refueling during extended outages

4 Conclusions

Disasters cannot be prevented. They happen each year worldwide. The only variables are location and severity. The development and implementation of a plan for energy during disaster recovery is one of the many very important items a carrier and its partners need to complete. While a true disaster happens very infrequently in any given location, shorter outages needing backup power happen more often. Lessons learned from recent high-profile disasters and experiences in the U.S. and developing countries provide practical insights into what constitutes a viable solution for both. First, a solution that meets the power requirements of a given site must be selected. Secondly, a refueling plan and the contracts needed to implement it need to be put into place prior to the outage event. By utilizing backup power solutions in conjunction with a disaster recovery refueling plan, a carrier has the ability to cost-effectively address both needs. With continued planning and implementation, we can all be a little better prepared the next time disaster strikes.

5 References

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