Assuring Power in a Disaster and Providing Energy Security

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Presented at:
American Solar Energy Society (ASES)
Solar 2004 Annual Conference
Portland, Oregon
July 11-14, 2004

Publication Number

FSEC- PF-376-03

PROFESSIONAL PAPER

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ABSTRACT

Daily use of a myriad of electrical and electronic devices has contributed to a steadily increasing dependence on electric power. The degree of importance of electricity is temporarily highlighted with any type of power outage, whether caused by a disaster as destructive as a Hurricane Andrew or as minor as an afternoon thunderstorm knocking down local utility lines. After September 11, terrorism added a new dimension to our definition of energy security. While the American public is dependent on utility providers to meet energy needs, it is the right and the responsibility of each citizen to become aware of energy security issues and to accept a shared accountability for meeting personal and collective energy needs.

In recent years, a few emergency organizations have used photovoltaics (solar electric) to meet critical power needs in a disaster, but energy assurance requires a broader solution. By implementing an integrated approach to critical energy issues, utility providers, regulators and consumers can collectively assure an improved level of energy security and reliability. This approach includes 1) implementation of conservation measures, 2) application of distributed generation and 3) use of renewable energy sources. These actions would promote energy assurance and provide protection against any type of energy disruption.

1. INTRODUCTION

In 1992, Hurricane Andrew destroyed over 85,000 buildings and leveled more than 12,000 miles of power lines, leaving 1.4 million people without electricity for days and weeks after the storm. On September 11, 2001, terrorism added a new dimension to our definition of "disaster" and has made us painfully aware that energy security means more than having adequate resources. On August 14, 2003, over 50 million people in the Northeastern United States experienced one of the largest and longest lasting utility blackouts in history. While weather-related events such as hurricanes, floods, lightning storms and tornadoes provide some type of advance warning, earthquakes, hazardous material disasters and terrorist attacks do not.

Whether natural or man-made, a disaster can leave many people without adequate medical services, potable water, sanitation, electrical service and communications for days and even weeks. Individual lives, businesses, communities, the economy and the environment are impacted. Shelters, medical facilities, hospitals, fire stations and police stations are especially affected by the loss of utility service. Emergency organizations, businesses and homeowners are hampered in the recovery process by the loss of electrical power. For years, emergency management organizations have maintained a formal plan to respond to all types of disasters. While their immediate goal is still to provide life-supporting resources – water, food, medical services and shelter – Hurricane Andrew and the Twin Towers attack changed the way disasters are handled by emergency management, building officials and insurance companies. They learned that increasing needs for electricity, coupled with the fact that many buildings and structures are not disaster-resistant, require a critical focus on physical and energy security.

The important role of electricity is highlighted with every power outage, whether caused by a disaster as destructive as Hurricane Andrew or as minor as an afternoon thunderstorm knocking down local utility power lines. Dependence on electrical power characterizes our daily lives through the use of computers and communications products, refrigerators, televisions and other electric and electronic devices. At the very least, loss of power can disrupt our daily routine and at worst, our health and financial welfare.

Fig. 1: Utility pole destroyed by Hurricane Andrew

Most people do not understand where energy comes from and how their lifestyle choices affect energy security. The utility industry relies primarily on five energy sources – coal, natural gas, hydro, nuclear and oil – and consumes three percent of our declining oil resources. (4) Hydro turbine generators in dams provide natural electricity generation, while combustion turbine and boiler generators are the country's mainstay producers. Electricity demands are growing steadily, putting pressure on availability of all energy sources.

- What is the underlying infrastructure that delivers electricity to support our energy needs?
- What are the risks that can compromise energy security?
- What options are available to improve energy reliability?
- What are the energy security and reliability responsibilities of utility providers, regulators and consumers?

2. ENERGY SECURITY AND THE ELECTRIC GRID

Electric utility companies in the United States utilize a complex electric grid to distribute energy across wide geographic areas. The electric utility industry has two central security risk issues. One is associated with operational system failures from weather, physical failure, human error or market-based instability and the second is the intentional disruption of a power system (sabotage). Both issues pose short and long term national security concerns.

Present realities have caused many utilities and regulators to consider investing in a "resilient" network architecture in order to provide energy assurance. Such networks are designed so that the system can keep operating in spite of multiple disruptive events. The existing electric grid has been constructed and operated under an operational standard designed to maintain uninterrupted operations, even with the loss of the largest single resource on the system.(2) This standard assumes a low probability that more than one part of the system will fail at any given time. However, this probability can no longer be assumed, given present threats and the complex arrangement of integration links. Because gas-powered electric generators increasingly being used cannot store large quantities of gas, pipeline and other supply interruptions also directly affect the electric system.

Terrorism has increased our awareness of the need to protect critical energy infrastructure from physical and cyber attacks. Likely targets are those with high potential impact and more than one target could be involved at any given time. Energy resources from well and mine to meter, whether electric grid or gas pipeline, are accessible and vulnerable. Different generating technologies produce different possible consequences from failure. Due to the vast size and complexity of the system, it is difficult to project the tangible and intangible costs of protecting all electric facilities from any possible attack or failure.

3. BUILIDING A RESILIENT NEWORK

Issues related to meeting energy security include proximity to load, fuel availability, facility protection, facility size, geographic location and vulnerability of technology. The key options for improving security for the electric system are:

1. Improving energy efficiency through conservation
2. Application of distributed generation
3. Use of renewable energy sources

Applying energy-efficient practices, distributing energy sources and using renewable resources on a network creates resiliency and provides more effective energy security than building fortresses around large, fragile facilities and defending thousands of miles of transmission lines and gas pipelines. Conservation and energy efficiency practices can be implemented quickly, thereby reducing risk and increasing security. Distributed generation employs multiple sources of energy and offers the advantage of shorter distribution lines in proximity to the load, reducing exposure to widespread power failure. Renewable resources are more modular, cause minimal impact to the system when lost and do not require fuel delivery. Renewable resources, such as photovoltaic, biomass, geothermal, small hydro and wind have attractive security attributes and reduce the risk of pipeline interruptions and central station outages.

4. SOLUTIONS – UTILITY/REGULATOR LEVEL

Until recently, fuel shortages and price spikes have been a main focus for regulators, energy providers and consumers. Now, all stakeholders must assess and seek to limit the effect of new risks, while remaining vigilant in achieving central goals related to utility management, cost, reliability and environmental impacts. (2) In order to ensure an effective network, regulators and utility providers must planfully mold network architecture into a resilient system. Such a system provides fewer critical facilities to impact. Utility providers can then protect those critical facilities, distribute resources effectively and allow for graceful failure and recovery. In order to ensure maximum benefits, consumers must also begin to assume a more active role in energy management within their individual and collective spans of control.

Regulators need to structure the economic and regulatory environment so that public and investor-owned utilities can meet customer needs and public goals within the framework of a resilient network. Integrated resource planning increases coordination and strategic decision-making between government, regulators and the electric industry. Most new power station decisions have been made based on size, location and fuel sources. Changing times have made security of the grid and the fuel supply a public concern, as potential security failures represent a significant public risk and cost impact. The insurance industry has shouldered large losses due to damage claims and business losses. Hurricane Andrew resulted in a total economic loss of $25 billion, of which insurance companies covered claims totaling $16 billion. (9) The real cost of electric power to the economy needs to reflect the cost of security and must not hide security costs associated with the National Guard or other national defenses.

5. SOLUTIONS – CONSUMER LEVEL

Consumer demands and expectations drive the market to provide low cost, reliable electricity. As recently as the late 1800s, before the common use of electricity in homes and businesses, individuals were responsible for meeting their own energy needs. With the development of energy technology, responsibility for energy production shifted to utility providers and regulators. Individuals have minimal input into how investor-owned and public entities choose to meet electricity needs. As discussed previously, limitless access to utility-produced energy is no longer a given. In order to fully address risk issues, consumers must see themselves as key stakeholders and assume a meaningful level of responsibility for implementing the same solutions proposed for utilities and regulators. This requires greater awareness, acquisition of new knowledge, assumption of cost exposure and implementation of personal energy solutions.

Just as utilities and regulators seek to improve electric system security through conservation, distributed generation and renewable resources, consumers can and should implement the same measures to improve their personal energy security. Consumers willing to take responsibility for generating part or all of their energy needs must learn to understand the energy requirements of their many appliances and electrical devices, whether connected to the grid or their own energy systems. Informed consumers will choose more energy efficient appliances and properly manage energy resources to meet their needs, which will also reduce overall and peak loads for utility providers. Through the use of renewables, consumers become “utility owners and operators” and enhance private and public energy security.

For the individual consumer, ultimate energy security is a home or small business that requires zero external energy input. This means that all of the energy used is generated by the consumer, thus making the consumer completely sustainable. (8) A few zero energy homes do exist today. Modern technology, innovative building designs, broad application of conservation measures and the use of renewables make it possible. Several good examples of this concept are found in remote locations that use biomass, photovoltaics and solar thermal systems to meet home energy needs.

6. CONSERVATION

As the population grows, so grows the load. By 2020, it is estimated that there will be a 45 percent increase in electricity consumption and a corresponding need to greatly increase generating capacity. This increased demand could be significantly offset by cost-effective investments in energy efficiency and conservation. Any reduction in load reduces needed generating capacity. Advances in technology often provide substantial energy efficiency gains in processes used by factories and businesses, as well as utilities. Utility companies and regulators need to remove financial and regulatory barriers to distributed generation, diversify energy mix with renewables and further conservation. Effort needs to move forward towards streamlining the permitting of clean distributed generation, accepting favorable standardized interconnection rules, reasonable standby/back-up rates and exit fees and appropriate insurance requirements.(3) Just as important are regulation changes that provide favorable financial incentives for clean energy, conservation, load management, net metering and tax incentives.

The key opportunity for consumers to support energy security is through conservation. What can the private individual do to conserve energy? Consumers control energy consumption by turning down their furnace thermostat in the winter and turning up their air conditioner thermostats in the summer. The use of timed devices can achieve the same or greater energy savings. Using fluorescent lamps in place of incandescent lamps promotes the use of devices that do the same job, but are more efficient. Use of insulation and efficient windows in buildings increases savings. Selecting devices that have the Energy-star rating or a high SEER rating can be a major energy saver. The object of conservation is not to do without, but to accomplish a similar or acceptable result using fewer resources. With increased commitment to conservation from consumers, utilities will benefit from a reduced energy demand, reduced need for new generating capacity and fewer distribution problems.

7. DISTRIBUTED GENERATION

Distributed generation (DG) employs multiple sources of energy instead of depending on one large source. As discussed previously, this application offers the advantage of shorter transmission and distribution lines, an energy source in closer proximity to the load and a modular structure that reduces exposure to widespread power failure.

Traditional, centralized networks are not modular. When a part or subsystem fails, the whole network can fail. Terrorists could attack one transmission tower and disable the whole network or target several selected components and disable the network for an extended period of time. In contrast, distributed generation, while still vulnerable, limits the extent of potential damage. Traditional DG systems utilized internal combustion reciprocating engine generators. This technology has been in existence for a long time and on many islands, is the only utility-generated source of electricity. Now, combustion turbine generators are typically used, due to their greater efficiency.

Natural gas is increasingly being used by utility companies for generation of electricity – in some areas up to 77 percent – making gas supply critical to the operation of centralized networks. A loss of gas can cause a loss of electricity in some utilities. Distributed generation allows for diversification of technologies and fuel supplies and use of renewables in the fuel mix, thus offering reduced dependence on any one source.

Consumers can choose to generate their own energy, which allows them to satisfy their own risk preferences to prevent outages. If excess generation is produced, it can be redistributed to the utility. Consumers, both homeowners and businesses, will need to evaluate their energy needs and operational activities. Identifying critical energy needs and incorporating the concept of critical power supply design into a home or commercial building would ensure needed power to maintain key operations.

During a power outage, a homeowner will want to have electricity for a lamp, an operating refrigerator and a radio. A business may need a few lights for safety and a cash register to complete sales. Most consumers would consider these items critical to maintaining business and personal lifestyle until power is restored. Small electrical and electronic devices can be powered through backup power sources. This can be accomplished by connecting a sub-panel to the main power panel. The sub-panel would then be powered by an alternative energy source, such as an on-site photovoltaic (PV) system. Examples of such back up systems can be found in some Florida houses built in the 1950s and are now sold as kits in building supply stores. This design concept integrates an energy source to a specific load, assuring energy security.

If more single family, residential homes were zero energy buildings, many people would enjoy energy assurance as well as long-term financial and environmental benefits. With the zero energy building, production is in closer proximity to load, there are no fuel availability problems, generation is personally protected and the size of generator is manageable. Zero energy apartments and condominiums may be a reality in the future, but for now they need utility type generation. For some time to come, factories and business will continue to be large energy consumers.

8. RENEWABLE ENERGY SOURCES

Renewable resources, such as photovoltaic, biomass, geothermal, small hydro, solar thermal and wind have attractive security attributes and reduce the risk of pipeline interruptions and central station outages. They are an environmentally benign and inexhaustible source of thermal or electrical energy. Renewable resources are more modular and cause minimal impact on the network system when lost. Energy and environmental issues have become inextricably linked to one another and involve concerns about air quality, toxic wastes and global climate change.

Distributed generation systems for utility use usually rely on generators several magawatts in size. Mechanical wind generators have been used for decades on farms to pump water, and modern generators harness the wind to rotate large blades that turn electrical generators. Wind generators range from 300 watts to 2 megawatts per unit, with some wind farms containing over a thousand generators. Fuel cell and hydrogen technology has been available for many years, but only recently have fuel cells been perfected and scaled for use as a stationary power source for residential and commercial buildings. Internal combustion engine (ICE) generators, by far the most common, typically use diesel fuel. However, bio-diesel fuel, made from oil in plants and animal fat, is beginning to show promise as a renewable fuel for engines. Natural gas turbine utility generators have been scaled down and designed as microturbines, producing power in the 25-500 kW range. (11) Most microturbines use natural gas, but some models are able to use propane, diesel, kerosene or bio-gas.

There are thousands of photovoltaic systems around the country, but only a few in the megawatt range. Photovoltaic modules generate quiet, safe, pollution-free electrical power. Solar-powered equipment requires no fuel and is less expensive to operate than gas or diesel generators. PV arrays are modular, allowing various outputs, and are easily arranged to increase or decrease energy output.

The Florida Solar Energy Center, Sandia National Laboratories and the National Renewable Energy Laboratory have jointly researched the application of photovoltaics in disasters. It has been determined that PV plays an important role in response, recovery and mitigation in disasters. The longer power is out, the greater the benefit of PV as a sustainable power source. There are many appropriate applications for PV – for years, it has powered monitoring systems for information and safety; now, PV-powered surveillance systems promote energy security in the battle against terrorism. Portable systems under 1 kW meets many of the needs of disaster organizations in response efforts, where 1-5 kW systems provide critical stationary power. Small utility-interactive PV systems with battery backup increase the effectiveness of disaster-resistant buildings and ultimately support communities in the power mix for distributed generation.

Photovoltaic use as one of the energy sources in distributed generation enhances security because PV would still operate after simultaneous attacks on both the electric and the natural gas networks. The report "Distributed PV's Contribution to America's Energy Security" revealed that supplying grid power with a small distributed PV system would prevent a tax revenue loss of more that $6,000 per kW from a one week grid power outage. (1)

9. BEYOND ENERGY SECURITY

Fault-tolerant architecture reaches beyond resiliency as an approach to energy security. It involves creating duplicate back up systems. This requires understanding the type and duration of failures that a power system can experience and designing preventative measures into the system to assure continuous operation. Distributed generation and multiple fuel supplies are forms of redundancy to prevent system failure. This type of design concept is costly and must be evaluated in light of the need for near 100% reliability.

From an emergency management aspect, disaster-resistant buildings and communities are the ultimate goal. Disaster resistance should have a meaning that reaches beyond creating a building that can physically withstand the forces of a disaster. Building design should provide a high probability of sustained operational use. Following a disaster, if a building is still standing, the home or business owner would need utility services or to have a self-sustaining energy system operational. Consumers can decide the degree to which they will take responsibility for generating their own energy, distributing it to meet critical loads, and to what degree they require a fault-tolerant energy supply.

10. CONCLUSION

The energy supply industry has created an incredible infrastructure to distribute reliable and cost effective electricity throughout our country. Its growth since the early 1800s has met our ever increasing needs for electrical power. The degree of importance of electricity is temporarily highlighted with any type of power outage, whether caused by a natural or manmade disaster or a minor weather-related event. While the American public is mostly dependent on utility providers to meet energy needs, it is the right and the responsibility of each citizen to become aware of energy security issues and to accept a shared accountability for meeting personal and collective energy needs.

Aging equipment, reduction in energy resources, losses from disasters and threats of terrorist activities have introduced new problems for energy providers to overcome, causing utilities and regulators to consider investing in resilient network architecture in order to provide energy security. This approach includes 1) implementation of conservation measures, 2) application of distributed generation and 3) use of renewable energy sources.

Just as utilities and regulators seek to improve electric system security, so too should the consumer implement the same measures to improve personal energy security. Consumers willing to take responsibility for generating part or all of their energy needs must learn to understand the energy requirements of their many appliances and electrical devices, whether connected to the grid or their own energy systems. Informed consumers will conserve energy by choosing more energy efficient appliances and properly managing energy sources to meet their needs. By becoming "utility owners and operators," consumers also enhance energy security by reducing overall and peak loads. Ideally, creating zero energy homes and buildings would ensure a high level of energy security. However, making modifications to homes and buildings by incorporating even minimal changes, such as the addition of a small photovoltaic array, would enhance energy security and yield long-term financial and environmental benefits for all.

The solution to energy security issues lies in the collective awareness and commitment of all stakeholders. Every producer or user of energy is a stakeholder. We are all stakeholders.

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