Emergency Power For All Disasters

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Abstract

Anytime and anywhere, a man-made or natural disaster can happen. The impact can be as minor as a lightning strike temporarily knocking out power or as major as a hurricane affecting thousands of people, damaging homes, businesses and civic infrastructure. Electrical utilities can be damaged or destroyed, leaving people without power for water, sanitation, medical services, refrigeration and communications.

In 1989, following Hurricane Hugo, portable solar-powered consumer items such as lamps, chargers and radios were first used in response to a disaster. At that time, there were a few solar-powered homes and business and passive natural energy buildings. These homes and businesses had solar electric systems which included batteries for storage and were connected to the utility grid. When disaster struck and utility power was out, these buildings generated their own electricity. Since then, the use of photovoltaic with or without storage has become more common and is moving towards becoming mainstream in various configurations.

Also, growing is the application of zero-energy building design with energy efficient appliances and passive energy design. These buildings, powered by the sun, can achieve real resilience and sustainability. Distributed generation of passive and renewable energy balances generation with conservation in a holistic design approach. With the introduction of enhanced building codes and fortified structural designs, plus the implementation of sustainable renewable energy, it is now possible to minimize the impact of disasters and climate change.

Keywords: Disaster, Emergency, Outage, Power, Photovoltaic, Electricity, Solar, Resilience, Sustainability.

1. Introduction

Disasters, man-made or natural, can happen at anytime, anywhere. Major disasters can leave several hundred thousand people homeless and disrupt power utilities, water works, businesses, medical services and communication. Impacted businesses, industry, government and homes may not recover for days, weeks and even years before services can be fully restored. Although the American power utilities and industry are some of the best in the world, the Federal Emergency Management Agency plans for full recovery efforts to take up to three years.

Based on reliability and low lifecycle cost, the National Aeronautics and Space Administration (NASA) has used photovoltaics (PV) on satellites since 1958; the U.S. Coast Guard uses PV on navigation devices for remote power.

Since Hurricane Hugo in 1989, solar technology has been used to provide backup electricity during and following disasters. In response to Hugo, portable consumer-powered solar items were deployed, such as lamps, chargers, water pumps, radios and small camping refrigerators. Early solar adopters already owned stand-alone solar-electric systems with batteries integrated into their remote cabins and homes. A few utility interactive systems with batteries for grid connected systems were being used in homes and businesses in urban settings. This relatively small group of people had not necessarily planned to use solar in disasters, but found their motive to be independent and sustainable rewarded them well.

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By the year 2000, technology and codes had taken a new direction. Net metering was introduced and batteries were eliminated from many photovoltaic (PV – solar electric) system designs to lower costs. A new configuration of grid-tied inverters on PV systems without on-site storage became common. Simpler design and installation made solar more accessible and less expensive, as the utility acted as storage. But disasters have a way of revealing flaws in preparedness, as did Hurricane Charlie in 2004. Grid-tied PV systems did not provide a consistent power supply when the local utility connection went down. The concept of utility interactive or solar+batteries began to look more appealing. Critical power distribution panels were added to meet emergency power needs such as medical equipment, lighting, refrigerators and communications. These three PV configurations (stand alone, utility interactive and grid-tied) address most of the energy needs of the general public and businesses.

The all-electric home was introduced in the 1980s, as electric utilities worked to corner the power market. This movement has advanced as older devices and equipment are replaced by electronic "smart" technologies. Building science and passive design technology have also advanced and zero-energy building design fulfills goals of sustainability and resilience. As the cost of photovoltaics goes down, a 'competition' exists between choices of adding PV power or investing in energy efficiency. Whatever happens to the power utility should not impact people in a disaster-resistant home or business. A zero-energy building is both disaster-resistant and sustainable. To achieve true sustainability and resilience without an external energy source other than the sun, all technologies must be integrated and a building should generate as much energy as it consumes.

Building survival is dependent upon enhanced building codes and fortified structural designs. While today's structural design options can complete the concept of full disaster resistance and efficiency, these features increase costs, creating potential tension between the goals of resilience and profitability for real estate brokers and building contractors. This paper does not address the politics or economics of this issue; rather the concept of creating sustainable and resilient buildings.

In the 1800's, various organizations began gathering data on weather, disasters, population growth and other factors affecting American lives. In 1870, The National Weather Service was formed and collected data on extreme weather, including hurricanes. The Federal Emergency Management Agency was formed in 1979, as the number of declared disasters in this country had increased in frequency by over 400 percent.

Hurricane Donna crossed Florida in 1960, damaging many homes. As Florida became more and more appealing as a retirement destination, a few home builders began to offer "hurricane houses" as a marketing advantage over other builders. Houses were built with a lower rise roof angle and secondary power panels for critical load items and an electrical outlet was added for connecting a fossil fuel generator for backup power.

In 1992, Hurricane Andrew caused such damage in Miami, Florida, that building codes were strengthened by adding mitigation requirements. Miami now has the strongest building codes in the country. The adoption of new codes is controversial, as realtors and builders struggle for lower costs and insurance companies and emergency managers struggle for safety and disaster preparedness. The rapid succession of Hurricanes Charley, Jeanne, Frances and Ivan in 2004 changed the way the United States does business and the way FEMA responds to disasters. The most deadly, destructive and costly storm in the US was Hurricane Sandy in 2012. Sandy was a category 3 hurricane with winds over 115 mph, causing 285 fatalities and over 65 billion dollars in damage in 24 states and the Caribbean. Each disaster poses new challenges as lessons are learned and changes made.

2. Resources in Play

Emergency management suggests all families assemble a disaster kit that includes water, food, lights and first aid items and to be prepared to follow safety practices outlined in the "Are You Ready?" program. Local, state and federal emergency management organizations have a plan for response, recovery, mitigation and preparedness that provides guidance on maintaining and restoring a community to a point where the community can rebuild itself.

The most critical time for survivors after a disaster strikes is the first 72 hours when people are fending for themselves until help arrives. First responders must evaluate needs and move into place quickly with the right resources. FEMA teams with many disaster response organizations, like the American Red Cross, Salvation Army, Volunteer Organization Active in Disaster, International Association of Emergency Managers and religious and citizen organizations. It takes about three days to a week to respond to a disaster, as much as three months to start recovery and in some cases three years for people to rebuild.

FEMA promotes mitigation over response as being more cost effective and safer. Before a disaster, mitigation means building structures to higher than minimal codes and paves the way for safer disaster operations. After a disaster, FEMA promotes rebuilding to safer practices and codes.

Additional organizations have a stake in the process as well, particularly insurance companies, that have research institutes and test facilities that evaluate historical data on damage caused by disasters. The Institute for Business and Home Safety (IBHS) offers a Fortified Building Program with standards beyond traditional building safety codes with three levels of design for creating stronger, safer buildings. They research and test materials and technologies to save lives and property through mitigation. National building codes are minimal based on historical averages related factors such as wind speed, temperature, and ground density. The IBHS plan is to reduce disaster-related damage and financial loss by creating buildings that are truly disaster-resistant and built beyond present codes. One of their programs promotes the construction of safe rooms in which to shelter.

Another non-profit, the Federal Alliance for Safe Homes (FLASH), was formed after Hurricane Andrew. They are a consumer advocacy organization that encourages safety and resilience through education. They empower the community with knowledge and resources designed to foster preparedness and mitigation.

Research completed by the Florida Solar Energy Center, in conjunction with other organizations, confirms solar systems designed and constructed to code will survive the destructive forces of most disasters, tornados being the potential exception. Given the many safety, fire, electrical and building codes applied to components and systems today, owners of solar equipment can be encouraged about their investments' functionality and resilience.

3. Energy Efficiency

The U.S. Department of Energy (DOE) and Environmental Protection Agency (EPA) offer excellent programs for your home's comfort and energy-efficiency. One such program is Energy Star which helps consumers, businesses and industry save money and protect the environment through the adoption of energy-efficient products and practices. The EPA manages products and the DOE manages energy usage. The goal is to design energy efficient applications and use natural passive energy resources to reduce energy consumption, as shown in Fig 1.

Leadership in Energy and Environmental Design (LEED) is another DOE energy efficiency program that looks long term at the holistic impact of building materials and lifestyle processes. LEED promotes best practices in green building strategies proven to reduce energy and water use, lower operating costs, reduce liability, improve indoor air quality and increase user comfort and productivity. LEED buildings typically consume 18% to 39% less energy than conventional methods of construction. Though initial up-front costs average 2% more, following LEED guidelines yields over ten times that in savings.

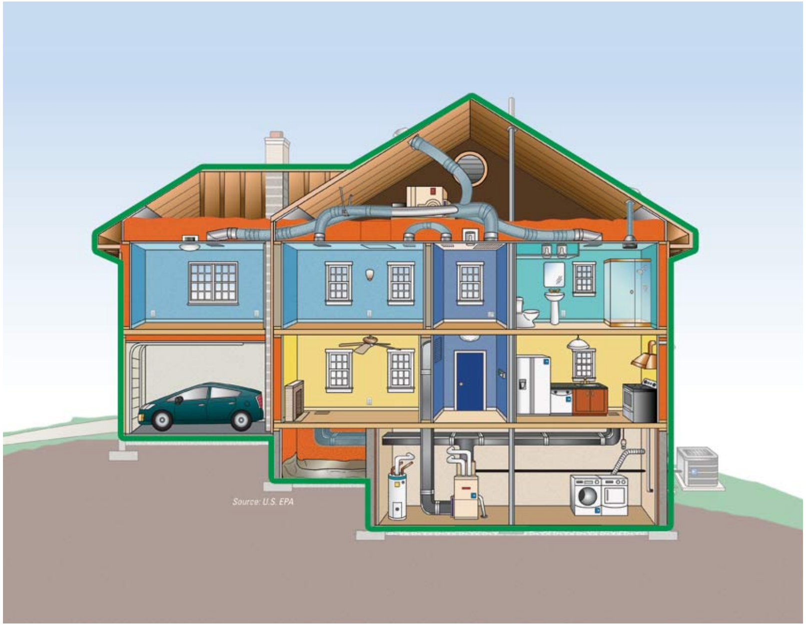

Fig. 1. Building Energy Efficiency, 2011 (DOE/EPA)

Many benefits are enjoyed by people who occupy a resilient, energy efficient building. During a power outage, inhabitants are not as uncomfortable or concerned about safety as in a conventionally designed building. Utility power bills are lower. With building power consumption reduced, the cost of a renewable energy supply to produce the needed power is also lower.

Various alternative energy sources can be added such as biomass, geothermal, biogas and others. Wood stoves and heaters using wood pellets can be use when available locally. Of course, solar energy in its many forms, like solar thermal or photovoltaic systems, are now main stream and cost effective.

4. Solar Design

The sun provides energy in different forms that are quiet, environmentally sound, abundant, and free. One form of solar energy is solar thermal for heating water. Solar hot water systems were actually patented in the early 1890s. Another application of solar energy is the photovoltaic cell, first developed in 1954 by Bell Telephone Laboratories, which converts photons of light into direct current (DC) electricity. Photovoltaic systems range from a few watts to as large as 100s of megawatts.

Early solar applications for disaster response included portable solar-powered devices for people who lost electricity for lights, medical equipment, communications, and refrigeration. Portable PV consumer items deployed included lanterns, flashlights, battery chargers, radios, portable power units, and trailer-mounted generators. Many of these items were low voltage direct current (DC) devices producing less than 5 watts which were carried to tent camps, damaged homes, businesses, and shelters. None of the items were designed for disaster relief, but camping equipment and portable/mobile stand-alone systems were adaptable to disaster relief applications. In 1998, FEMA purchased and tested trailer mounted stand-alone 1.8 kw PV systems to meet larger emergency power needs. Though solar consumer items were readily available and useful, they were not as cost effective as integrating solar into buildings.

PV power systems for buildings are much larger than mobile, portable and consumer items. Power used in buildings is alternative current (AC) electricity at voltages from 120 to 1500 or more. An inverter is used to transform DC to AC at 60 cycles sine waveform, commonly known as 'home power'. A typical photovoltaic system consists of a PV array, controller, inverter, batteries, and conventional electrical equipment, comprising the balance of system (BOS) components, as shown in Fig 2. The BOS components consists of fuses, circuit breakers, a combiner box, power panel, wire, disconnects, and conduit.

As mentioned above, three major PV system configurations are in common use today: stand-alone, grid-tied, and utility-interactive/solar+batteries. Stand-alone PV is for remote locations without utility power and operates on its own. Grid-tied PV is interconnected with a utility power plant distribution system and requires grid current to operate and produce the utility electricity waveform. Utility interactive/solar+batteries combines the two configurations and can operate with or without the utility waveform. There are other system configurations; one such alternative system is called grid-tied with secure power, where the inverter produces single phase electricity without the grid during a power outage, as long as the sun shines. Hybrid systems where PV is combined with wind, fossil fuel engine generators or another power source are also available.

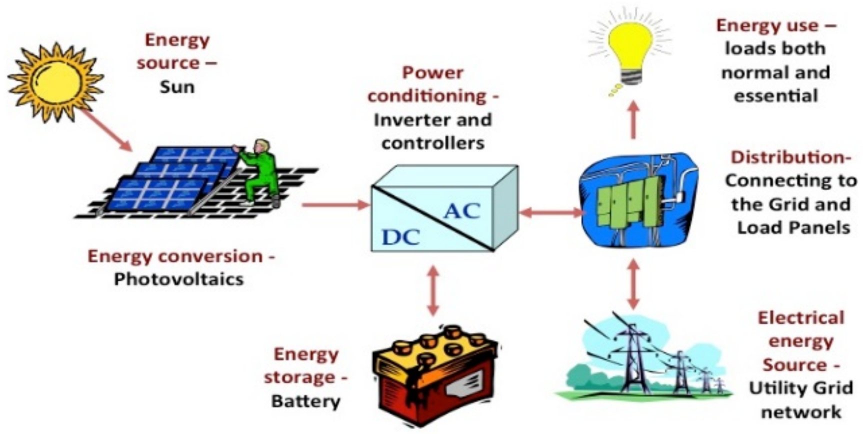

Fig. 2. Typical PV System Diagram (FSEC)

Grid-tied systems became more prevalent when net-metering law was amended in 2000 to provide compensation at the average retail utility energy rate. Grid-tied systems without storage are less expensive and less complex. However, the 2004 hurricane season brought forward the value of battery storage when grid-tied systems did not work during power outages.

Photovoltaic systems have advanced in efficiency, performance and reliability and rival anything utilities can do, in a more environmentally sound and cost-effective manner. PV systems are subject to similar failure issues as utility power plants, such as extreme weather interruption, fallen trees, loose or corroded connections, and heat stress. Like any other equipment, a preventive maintenance program can keep these failures at a minimum. The benefits of solar are that sunlight is free, renewable and produces no noise or pollution.

5. Designing for Disasters

Strong codes provide strong PV systems that can withstand the impacts of a disaster. Many PV systems have survived disasters and continued to work during resulting utility power outages. But resilience is more than strong codes. This author practices a design philosophy learned while working at Kennedy Space Center for manned space flight. The design concept is fault-tolerant architecture, that when applied to PV systems, provides power through any failure.

In 2003, the Florida Solar Energy Center implemented a DOE Solar for Schools Program which called for installation of PV systems on schools for educational purposes. By 2010, the educational mission was enhanced to a more meaningful objective to put PV on schools designated as shelters. The PV systems had a 10 kWp PV array connected to the grid with battery storage. This configuration was installed on 118 schools in Florida for solar education and emergency power. The SunSmart E-shelter for Schools became a real life, viable application, as shown in Fig 3. These utility interactive systems used a net meter connected to grid power to reduce the school's electric bill during normal times and to provide emergency power for critical/essential loads during utility outage. A critical load power panel for lights, communications, and special needs equipment was powered by the PV system during emergencies and normal times, as shown in Fig 4. The battery pack was kept full at all times to be able to provide emergency power through a bi-modal inverter for two days.

The PV array had fourteen PV strings of 3 modules to minimize array losses from shading, damage, or other failure in a fault-tolerant PV design configuration. When a string is damaged, only a small proportion of power is lost and not the whole array. There were three inverters, so an inverter loss did not cause a complete system failure. Since 2010, these PV systems have proven their worth each hurricane season.

Fig 3. SunSmart E-shelter school – (FSEC)

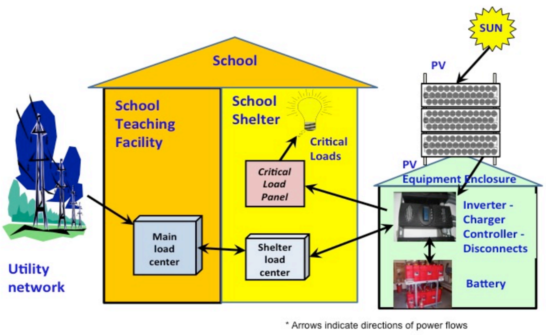

Fig 4. Essential school loads and supply - (FSEC)

6. Distributed Generation

Roof-top PV systems have advanced into other configurations such as solar farms that rival conventional utility power plants in size, with some as large as 100 mega watts. They may or may not have storage, but they are very large power plants that feed the utility grid distribution system. Community solar is usually smaller than solar farms and is dedicated to a community that is generally closed to outsiders, but have arrays in the mega watt size. Micro-grids are smaller arrays and produce power for facilities or small complexes that may not have a utility distribution system. Large storage systems in the mega watt range are coming into use as the cost of batteries becomes lower and can offset utility 'peaker' power plants. These varied, large systems are being integrated into distributed generation configurations for utility providers to utilize diverse resources for the economy, power outages and load demands. Additionally, smart grid technology integrates all available sources together, greatly enhancing the resilience of the modern grid.

7. Conclusion

Disasters can be very destructive, leaving thousands of people without shelter, power, water, sanitation, and communication. Renewables are viable in all four phases of a disaster: preparation, mitigation, response, and recovery. Through the years, the solar industry has learned about energy needs precipitated by disasters and disaster organizations have learned about the value of solar applications. Disaster-resistant building construction, low energy consumption, and renewable energy-powered buildings can mitigate the effects of a disaster and save on energy expenses during normal times.

Renewable energy applications, such as solar thermal, photovoltaics, micro-grids, community-solar, wind, and battery storage are making homes and businesses and the grid more resilient and sustainable. Conventional utilities are advancing to become more resilient and sustainable as they incorporate renewables into the grid through distributed generation of energy sources. Designing to fault-tolerant architecture concepts enhances the disaster resistance of PV systems. As these systems become more resilient and sustainable, they become more disaster resistant.

First, building to enhanced building codes and fortified structure design leads to physical disaster resistance. Then, integrating energy efficiency, renewable power sources, distributed generation connections, energy storage, and modern mitigation practices completes the process. Roof-top photovoltaics on homes should produce as much power as it consumes. This sustainability concept will lower costs and provide safe living conditions during any disaster as man gravels with climate change. Every home should be a hurricane home. Using these technologies and practices lessens man's exposure to the effects of changing weather patterns and natural and manmade disasters and makes meaningful inroads into mitigating the impact of traditional energy usage on planet Earth.

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