Emergency Power for All Disasters

William Young, Jr.

SunTree Consulting, Senior Research Engineer
612 Indian River Ave., Titusville, Florida, USA, 32796
Florida Renewable Energy Association
www.energyfordisasters.org and www.cleanenergyflorida.org
Retired – Florida Solar Energy Center

Abstract

Disasters can happen anytime and anywhere, whether man-made or natural. 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 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 solar with or without storage has become 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 building energy design. Distributed generation of passive and renewable energy resources balances generation with conservation in a holistic design approach. These buildings, powered by the sun, can achieve real resiliency and sustainability. With the introduction of enhanced building codes and fortified structural designs, plus the implementation of resilient and sustainable renewable energy, it is now possible to minimize the impact of disasters.

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.

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.

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.

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.

Resources in Play

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. First responders must evaluate needs and move into place quickly with the right resources. 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. Building survival is dependent upon enhanced building codes and fortified structural designs.

The Institute for Business and Home Safety (IBHS) offers a Fortified Building Program with standards beyond traditional building safety codes creating stronger, safer buildings. 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.

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.

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.

Solar farms, community solar, micro-grids produce power for facilities or small complexes may be very large systems being integrated into distributed generation configurations for utility providers to utilize diverse resources for the economy, power outages and load demands providing system resilience.

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.

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.

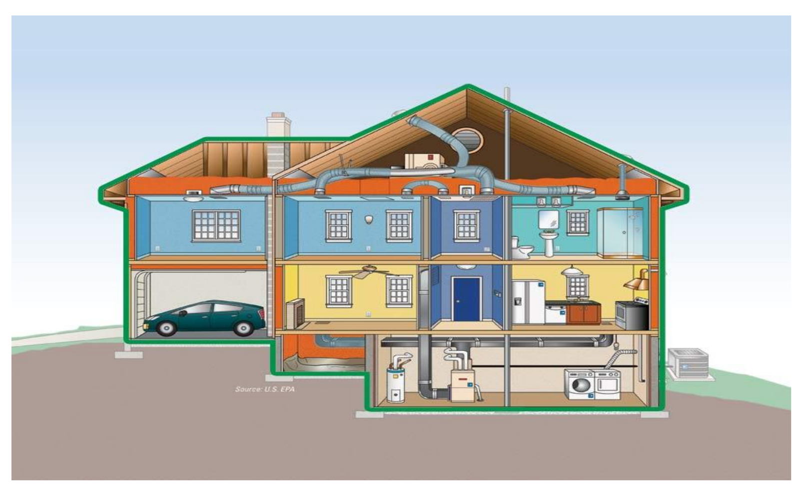

Fig. 1. Building Energy Efficiency, 2011 (DOE/EPA)

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.

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.

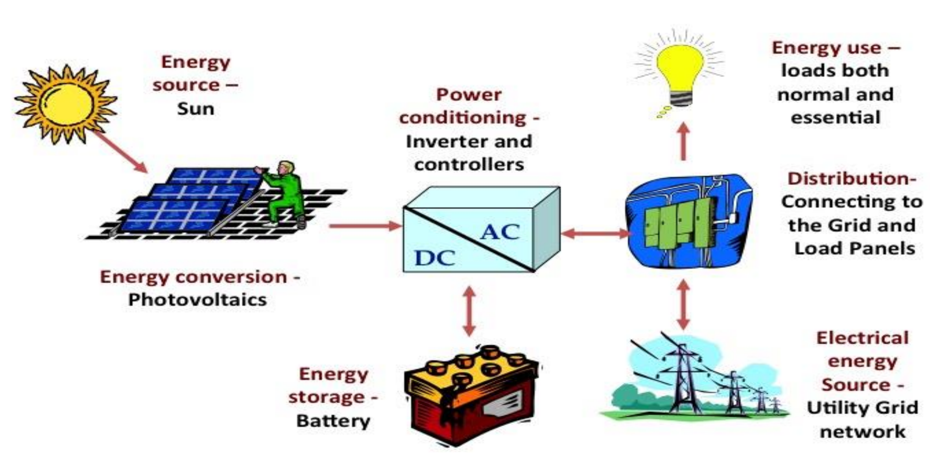

Fig. 2. Typical PV System Diagram. (FSEC)

There are three major PV system configurations 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.

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.

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

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.

.

Fig. 3. Building Energy Efficiency, 2011 (DOE/EPA)

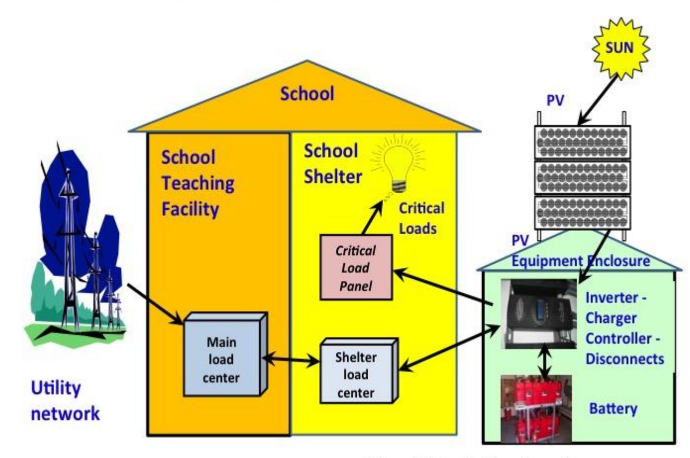

Fig. 4. Essential school loads and supply - (FSEC)

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.

Conclusion

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.

References

- Young, William, Photovoltaic Applications for Disaster Relief, FSEC-CR-849-95, Florida Solar Energy Center (FSEC), Cocoa, Florida, USA, March 2001
- Young, William, and Susan Schleith, "Florida's Emergency Shelters Go Solar", FSEC, ASES Solar 2007 Conference, American Solar Energy Society, Cleveland, Ohio, July 2007.
- Young, William, Distributed PV Design for Emergency Power, ASES Solar 2016, American Solar Energy Society, San Francisco, July, 2016.
- Michael, Hordeski, Emergency and Backup Power Sources: Preparing for Blackouts and Brownouts, CRC Press, Boca Raton, FL., 2005.
- Ali, Keyhani, Smart Power Grid Renewable Energy Systems, IEEE, John Wiley & Son, Hoboken, New Jersey, 2011.
- Guidelines for Hurricane Resistant Residental Construction, Institute for Business and Home Safety, Tampa, Florida, 2009.
- A Homeowner's Insurance Guide to Natural Disasters, Federal Alliance for Safe Homes, Tallahassee, Florida, 2015.

American Solar Energy Society (ASES), Solar 2020 Conference, Virtual, USA, July 23-24, 2020