Infrastructure System Overview (ISO): Extended Electric Outages

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SCOPE

The Department of Homeland Security's Office of Cyber and Infrastructure Analysis (DHS/OCIA)[1] produces Infrastructure System Overviews to provide a synopsis of how particular infrastructure systems operate. Infrastructure System Overviews are not intended to describe threats, vulnerabilities, or consequences of any aspect of the infrastructure system.

The Infrastructure System Overview: The Bulk Power System (23 September 2013) provided analysts, policymakers, and homeland security professionals with a baseline understanding of how the electrical grid functions and how it is managed. This Infrastructure System Overview is intended to provide information about the functioning of critical infrastructure systems during an extended electric power outage.

This Infrastructure System Overview was coordinated with the Federal Emergency Management Agency (FEMA), DHS Office of Infrastructure Protection (IP), the Department of Energy, and the National Infrastructure Simulation and Analysis Center (NISAC).

INTRODUCTION

Since nearly all critical infrastructure depends on electric power, the loss of electric power in a major metropolitan area can have devastating consequences. However, it is highly unusual for a large metropolitan area to experience wide scale black-outs for more than a few days (e.g. the June 2012 derecho left more than 2 million customers in the dark and the majority of service was restored within 48 hours). Power outages do occur regularly and cost the Nation about $80 billion annually.[2] Lifeline systems, such as telecommunications and emergency services, have temporary back-up power in the form of batteries or diesel-fueled generation, but the complete loss of electric power for an extended period of time (such as what occurred in New Orleans following Hurricane Katrina in 2005) could lead to significant hardship and loss of confidence in government.

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[1] In February 2014, NPPD created the Office of Cyber and Infrastructure Analysis by integrating analytic resources from across NPPD including the Homeland Infrastructure Threat and Risk Analysis Center (HITRAC) and the National Infrastructure Simulation and Analysis Center (NISAC).

[2] Chen, Allen "Berkeley Lab Study Estimates $80 Billion Annual Cost of Power Interruptions," Lawrence Berkeley National Laboratory, February 2, 2005, http://newscenter.lbl.gov/news-releases/2005/02/02/berkeley-lab-study-estimates-80-billion-annual-cost-of-power-interruptions/, accessed May 20, 2014.

After an extensive outage, utility providers will assess the condition of the affected system before taking the necessary steps to restore power to as many customers as possible within the shortest amount of time. If an outage is caused by a natural disaster, the assessment process will begin when it is possible for utility crews to safely reach the equipment. For example, utilities will usually not begin assessments following a hurricane until the wind speeds have dropped below 30-35 miles per hour.[3] Complete restoration may take more than two days in urban environments and 7 to 10 days in less populated areas, depending on the degree of damage to assets. Damage to major transmission equipment, such as transformers, may take much longer to repair, but is typically rare. Full restoration for a significant, widespread event such as a major hurricane could potentially take weeks for all customers, who can receive power, to be restored.

Electric power service is usually restored methodically and follows established restoration plans which prioritize the restoration process, with high-priority customers receiving immediate attention, when possible. These high-priority customers include hospitals, water supply facilities, water treatment plants, and emergency services After the high priority customers have had their power restored, the utilities prioritize repairs in order to restore the largest number of customers in the shortest time.

TIME-RELATED IMPACTS OF ELECTRIC POWER OUTAGES

The impacts of electric power outages can be assessed in terms of immediate, short-term (4 to 24 hours) and longer-term effects (up to 1 week).

IMMEDIATE EFFECTS

- Nuclear power plants are required to have a stable external power source to maintain safe operations, so a nuclear power plant receiving power from substations located in a region without power will shut down, by a structured process for safety reasons. A nuclear power plant has a much longer start-up period than any other electric power plants because of the safely protocols required when restarting the plant. It can take over a week to return the plant to full operational status, if it were completely shut down.
- Facilities without uninterruptible power supply (UPS) battery back-up systems or generators will lose power immediately. Facilities with UPS battery back-ups may continue to function normally at the time of an outage, but, generally, UPS systems usually are designed to provide power for a few hours at most.
- Emergency lighting should function if systems have been routinely inspected and batteries are functional.
- Facilities with diesel-fueled back-up power generation will see momentary power interruption until back-up generators start, unless they have battery backups to prevent the temporary outage. Historically, some back-up generators have failed to start, while others failed over time, due to lack of diesel, lack of replacement parts, or lack of proper maintenance.

[3] For example, see Entergy: http://entergy.com/isaacfaq/, FPL: http://www.fplenergyservices.com/storm/hurricane_jeanne_chronology.shtml, Delmarva Power: http://www.delmarva.com/welcome/news/releases/archives/2012/article.aspx?cid=2174.

- Facilities with natural gas-powered back up power generation will typically continue to function as natural gas supplies are rarely interrupted during natural disasters.
- Most communications systems should function on UPS or backup generator power, but some of the back-ups may fail.
- Modems and wireless routers in homes and businesses will not function without power, even if digital subscriber line service is available, so many people will not have access to the Internet via their home network. Mobile devices may operate, provided that they have power and local cellular towers are functioning.
- Some telephone systems will not work without power. Most residences will continue to have telephone service through hardwired local area networks (LANs), as long as their phone systems do not rely on electric power. More specifically, hardwired phones should continue to work while wireless devices will not as their batteries run out.. Cellular service will likely be available until battery banks at cell towers start to fail.
- Radio and television broadcasts may have back-up generation, but most people may not be able to see or hear these broadcasts due to a lack of power. (Those with battery, solar, car radios, or hand-operated radios could possibly receive broadcasts.)
- Most businesses and residences could be without power and many of these businesses may have to close for the duration of the power outage.
- Traffic lights, subways, and streetcars may not function. This will likely lead to congestion on the roadways, especially if an outage occurs during rush hour.
- Intelligent transportation equipment, such as cameras, loop detectors, variable message signs that rely on external power, toll collection equipment, and pumps to control flooding in depressed roadways mayl not function. Systems that rely on solar power will continue to operate.
- Most gasoline stations will not be able to pump gas, although some gas stations have back-up generation, particularly in hurricane-prone areas.
- Automated Teller Machines (ATM) will likely not function.
- Elevators may not function, possibly trapping people inside, depending on whether back-up power is operating.
- Tall buildings may lose water supply, especially if electric pumps are needed to pump water to higher floors.

SHORT-TERM EFFECTS (4 TO 8 HOURS)

Facilities with battery back-up power will function until battery power is exhausted. During this time:

- Cell towers will function, but may be overloaded by the volume of calls. This could result in busy circuits and dropped calls. The battery banks at cell towers may start running out of power as well, degrading the functionality of the cellular network over a 4 to 8-hour period.

- Businesses with data storage equipment should be able to save essential data before batteries are depleted.
- Emergency lighting in commercial, industrial, and governmental buildings should provide means of exit before batteries are depleted.
- Batteries on cell phones will fail, after several hours of use, if alternate charging schemes (such as car batteries with converters) are not available.
- Grocery stores may not be able to operate because checkout systems and refrigeration rely on electric power, and there may not be enough emergency lighting to provide a safe environment for customers.
- Some food in refrigerators may need to be discarded if its temperature remains at over 40 degrees for more than two hours. With no power, food in freezers will eventually begin to thaw. If they thaw and then remain above 40 degrees for more than two hours they may need to be discarded as well.[4]
- Residences without back-up generators will face increased health risks. If a blackout occurs during a period of high temperatures, hospitals without back-up power should expect to see increases in heat-related cases. During the winter, home heat may not function, including some natural gas-fueled systems, since modern thermostats are electric (natural gas fireplaces should continue to work). Hospitals should also expect an increase in cold-related cases.
- Wastewater services may be impacted, especially if lift stations and pumps do not have power. Gravity-fed potable water systems will continue to operate normally, since sufficient amounts of water and pressure will remain in the pipes for a time. Systems on a well will need hand pumps to operate.

LONGER-TERM EFFECTS (UP TO 1 WEEK)

Facilities with back-up diesel generators will function unless fuel supplies are exhausted, parts are unavailable (such as air filters), or the equipment fails from extended use. As the outage extends to a week:

- Fuel depots may be unable to pump and deliver fuel adequately if they do not have sufficient back-up generation.
- Although many water pump facilities and wastewater treatment plants have back-up generators, historically, there have been regular failures that led to boil-water notices, sewage spills, and loss of fresh water supply. Back-up generators may not be designed to operate an entire facility for extended periods.
- Many businesses will likely lose revenues during an outage. Small businesses will be disproportionately affected by a power outage lasting over a week.
- Large businesses with data servers may function, but a lack of cooling may result in computer failure.

[4] U.S. Department of Agriculture, "Keeping Food Safe During an Emergency," http://www.foodsafety.gov/keep/charts/refridg_food.html, accessed September 6, 2013.

- Hospitals have back-up power for priority systems (e.g., intensive care units), but they may have to re-direct ambulances to other locations for the duration of the power outage. While operating rooms are a priority system for emergency operations, air conditioning is not considered a priority system, which will impact the ability of the hospital to function during the summer. Prolonged outages may require evacuation of hospitals and senior care facilities.
- Control centers for utility systems could begin to fail, although supervisory control and data acquisition (SCADA) systems connected to back-up generators should allow operators to maintain control over their systems. Further, backup control centers located in areas not impacted by the event could take over all of the functions of the impacted control system.
- Airports have back-up power for essential systems, such as runway lighting and control towers. Power is not likely to be available for concourses, gates, and ticketing.
- Other systems that rely on back-up generation in order to maintain services include:
  - Emergency services,
  - Wireline centers,
  - Internet service providers (ISPs),
  - Air traffic control centers,
  - Tunnel lighting, and
  - Ventilation systems.

ISSUES TO CONSIDER DURING RECOVERY

- Some natural gas pilot lights will need to be relit individually for equipment and assets.
- Damaged electrical components must be repaired. Depending on the cause of the outage, this may be complicated by hazards including fallen power lines, debris, damage to roads, or lack of replacement components.
- Computer systems may experience data losses and recovery issues.
- Water treatment systems may take time to become functional; boil-water notices may be necessary after restart of a treatment plant, while the distribution system is flushed.
- Perishable foods must be restocked.

IMPORTANCE OF DIESEL FUEL

During an outage of electrical power in a major metropolitan area, all available back-up generation will be called into service. Diesel-fueled generators are the most commonly used source of back-up power, but there may be other potential power sources, including distributed generation, which allows energy collection from many small generation sources, like solar panels.

The reliability of diesel-fueled generators depends largely on maintenance practices and testing

frequency. According to a 2007 report prepared by the Center for Energy, Economic and Environmental Policy, back-up diesel-fueled generators used by nuclear power plants under emergency conditions are the most carefully maintained and tested, in comparison to those used by other critical infrastructure.[5] However, historically, approximately 1 percent of these generators will not start when required. The failure rate of these back-up generators will increase to approximately 15 percent after 24 hours of continuous use. Back-up generators at many critical infrastructure facilities (including hospitals) are tested less frequently and may be maintained less rigorously, which can result in failure rates up to 10 times higher than those at nuclear power plants.[6]

The availability of diesel fuel is another very important factor in the successful operation of back-up generation. Users of diesel-fueled back-up generators typically store fuel in preparation for emergencies. However, diesel fuel stored for more than 12 months begins to form sediments and gums.[7] The life expectancy of diesel fuel decreases as the ambient temperature increases. If diesel fuel is used after it has exceeded its shelf life, it increases the likelihood of damage to the generator. In addition, the amount of diesel fuel stored is usually only enough to fuel the back-up generators for a few days. Once the stored supply is exhausted, critical infrastructure facilities must receive fresh diesel fuel deliveries to continue to operate on back-up generation.

Owner-operators of critical infrastructure should ensure that they have standing contracts with diesel fuel suppliers in the event of an emergency. There are examples from Hurricane Sandy where critical infrastructure owner-operators had diesel fuel generators, but did not purchase diesel fuel, have a standing contract with a supplier, or test the generators. Further, care should be taken that the diesel fuel purveyors have adequate supply to meet their commitments and not be in a position of failing to meet their contractual obligations (and therefore have to declare force majeure) when the diesel fuel is needed.

The Office of Cyber and Infrastructure Analysis (OCIA) produces Infrastructure System Overviews that describe the critical infrastructure protection community's risk environment from terrorist attacks, natural hazards, and other events. The information is provided to support the activities of DHS, and to inform the strategies of Federal, State, local, and private sector partners. For more information, contact OCIA@hq.dhs.gov or visit our website: www.dhs.gov/office-cyber-infrastructure-analysis.

[5] Center for Energy, Economic and Environmental Policy; New Performance-Based Standards for Standby Power; December 2007.
[6] Ibid.
[7] BP Australia Limited, February, 2005; www.bp.com/liveassets/bp_internet/australia/corporate_australia/STAGING/local_assets/downloads_pdfs/f/Long_Term_Storage_ADF.pdf.