United States Environmental Protection Agency | Office of Solid Waste and Emergency Response (5104A) | EPA 550-F-01-010 September 2001 www.epa.gov/ceppo

Chemical Accidents from Electric Power Outages

The Environmental Protection Agency (EPA) is issuing this *Alert* as part of its ongoing effort to protect human health and the environment by preventing chemical accidents. EPA is striving to learn the causes and contributing factors associated with chemical accidents and to prevent their recurrence. Major chemical accidents cannot be prevented solely through regulatory requirements. Rather, understanding the fundamental root causes, widely disseminating the lessons learned, and integrating these lessons learned into safe operations are also required. EPA publishes chemical safety *Alerts* to increase awareness of possible hazards. It is important that facilities, SERCs, LEPCs, emergency responders, and others review this information and take appropriate steps to minimize risk. This document does not substitute for EPA's regulations, nor is it a regulation itself. It cannot and does not impose legally binding requirements on EPA, states, or the regulated community, and the measures it describes may not apply to a particular situation based upon circumstances. This guidance does not represent final agency action and may change in the future, as appropriate.

Chemical Safety

ALERT

Problem

Power outages and restarts could potentially trigger a serious chemical accident.

Electric power outages are often caused by lightning, high wind, or ice storms, as well as accidents at power plants or transmission lines. Hot weather power demands could trigger rolling blackouts. Although planned rolling blackouts can cause process shutdowns or upsets, they are preferable to power system overloads and failure, or to low voltage brownouts which can be destructive to electrical equipment. The recent energy crisis in California illustrates the aggravation caused by power outages. Power interruptions at chemical handling facilities are a particular concern because of the possibility of a chemical accident. Incident data from the National Response Center (NRC) shows that during 2000 there were about 240 chemical releases reported due to an electric power interruption; only a few were related to planned rolling blackouts. A number of releases were associated with power resumption and restart of operations (see **Table 1**).

Accidents

One accident occurred when power was interrupted and another during restart after power resumption.

Gramercy, Louisiana, July 1999. This plant converts bauxite to alumina in a series of steam-heated pressure vessels. A loss of power stopped all pumps including those that circulated process material through heat exchangers for cooling. However, steam injection stayed on causing temperatures and pressures to increase. Pressure relief valves and piping were blocked or choked with solid deposits hindering their ability to relieve the increasing pressure. Several vessels over-pressured and exploded. The force of the explosion and release of highly corrosive caustic material injured 29 employees and extensively damaged the plant.

Several lessons can be learned from this accident: Process operations must be evaluated for the consequences associated with a power outage to ensure that the process reaches a safe condition. In this case, if process flow and cooling pumps are critical to the safe state of the process when electric power is lost, then a backup power supply or steam driven spare or backup pumps should be evaluated. In addition, interlocks that stop steam heating upon loss of flow or cooling should be considered. Finally, pressure relieving systems must be inspected and maintained to ensure their ability to function as intended.

Richmond, California, May 2001. This plant was running normally when a truck struck a utility pole, causing a power interruption and total plant shutdown. Shortly thereafter, sulfur dioxide (SO_2) and sulfur trioxide (SO_3) began to escape from a boiler exit flue. When power was restored a short time later, a steam turbine that is required to keep the boiler exit flue under negative pressure could not be immediately restarted. Troubleshooting revealed that an automatically controlled governor valve had malfunctioned and the turbine was restarted. During the time the turbine could not be restarted, residents near the plant were instructed to remain indoors. Around 50 to 100 individuals sought medical attention following the release.

As above, equipment or procedures critical to safe shutdown, continued operation, or restart conditions must be identified, maintained, tested, and kept in a ready-to-operate state. The plant installed backup power systems to keep the steam turbine running through a power outage. In addition, preventative maintenance on the steam turbine valves has been enhanced to ensure that these valves operate properly when needed.

Table 1. Some chemical release causes reported to the NRC during 2000:

- Fueling pump automatically restarted when interrupted power was restored;
- Power outage during product transfer caused tank and secondary containment overflow;
- Power outage to computer control system during startup caused release from pressure relief;
- Utility company's hot weather power reduction caused plant's excessive flaring;
- Power loss caused shutdown and valves did not close;
- Scheduled power outage caused flaring; and
- Power outage caused shutdown of pollution control device and release of material.

Hazard Identification

Find potential weak spots early or ultimately they will find you!

When power is lost for any reason, pumps stop pumping, compressors stop running, stirrers quit mixing, lights go out, and instruments and controls may malfunction. These equipment outages may lead to tank overflows, runaway chemical reactions, temperature or pressure increases or decreases, all of which could lead to a spill, explosion, or fire. Even if there is no immediate release, there may be a delayed reaction caused by thermal shock or other factors that can compromise equipment mechanical integrity during subsequent operation. When power is restored even after a brief interruption, some equipment may automatically restart before process operations are ready while others may need to be reset and manually restarted.

The first task is to identify and rank the process operations or equipment that pose the most serious potential for fire, explosion, or hazardous material release in the event of utility interruption. A good tool that can help identify and rank critical equipment and the consequences to the process upon loss of power is a formal process hazard analysis (PHA) within a sound process safety management system (PSM). For example, the Hazard and Operability (HazOp) or What-If analysis techniques coupled with good employee participation is a particularly strong combination for identifying hazards and failure mechanisms associated with power failure and restart. These tools and approaches can help you create a list of process equipment (pumps, valves, instruments) and to note exactly what happens to each device when power fails or is restored. Don't forget to include equipment that may be indirectly affected; for example, pneumatic devices that quit when air pressure falls because an electric-powered compressor stops. Equipment should "fail-safe;" in other words, when electric power or another utility (e.g. air or water) is lost, the equipment and process should come to a safe condition. And when power is restored, devices should keep the process in a safe condition until it is ready to resume normal operations. **Table 2** shows an example list of some devices and possible fail-safe and restored states.

Be sure to consider power dips, brief interruptions, and losses to only some equipment in your hazard evaluation as unexpected and unusual circumstances may occur. For example, some equipment may continue operating while others trip out.

Most chemical facility operators have developed sound contingency plans for responding to various types of plant utility interruptions, including electric power outages. After a power failure is over, evaluate how the process equipment and people responded to the situation to identify hazards and potential negative consequences that were not previously recognized. In some cases the type and magnitude of the disruption that occurred when power was interrupted was not fully anticipated. In other cases the problem was caused by adverse actions that took place when power was restored. Power failure contingency plans should be regularly reviewed, updated and tested.

Table 2
Sample Equipment List and Fail-Safe Modes

Device	Status When Power Fails:	When Power is Restored:
Reactor Feed Pump	Off	Off - manual restart
Reactor Steam Heat Valve	Closed	Closed until reset
Cooling Water Feed Valve	Full open	Open per temp. control
Reactor Vent Valve	Full open	Open per pressure control
Reactor Mixer	Off	Off - manual restart
Transfer Pump	Off	Off - manual restart

Problem Reduction

What actions should be taken to help neutralize the impact of the hazards identified above?

Using the results of the hazard evaluation, make sure that all process operations and equipment will reach a fail-safe mode upon loss of power. Make sure that devices you expect to operate upon loss of power are inspected, maintained, and tested as part of your equipment preventative maintenance program. And make sure that operating procedures and training address these hazards. Prepare plans and checklists and consider backup power systems to maintain critical services as described below.

Other actions that should be taken to prevent, prepare for, and respond to chemical emergencies triggered by power failure and resumption can be addressed by four categories: (1) preparing for an emergency forced shutdown such as with a rolling blackout or an approaching electrical storm; (2) preparing for immediate actions from an unexpected power loss; (3) restarting when power is restored; and (4) equipment to enhance continuity of critical services.

1. Emergency Forced Shutdown. Sometimes there may be a warning or brief notification, perhaps only a few minutes, that a rolling blackout or other outage (steam, instrument air, cooling water) is about to occur. Many companies have developed an Emergency Forced Shutdown Plan (EFSDP). This Plan addresses only those priority actions that need to be taken immediately if a power outage is imminent. The objective is to make the best use of the short time available to bring the plant to a safe shutdown condition and avoid unnecessary upsets that may be driven by a loss of power. The Plan should also address follow-up steps that could be taken if time permits and further steps to secure the unit or process after the outage. Finally, the Plan should also include "load shedding" steps to shut down less important operations, and thus conserve power, steam, cooling water, or instrument air for the most critical operations. This Plan should be well thought out, reviewed with all involved employees, and periodically tested.

2. Power Outage: Immediate Action Steps. As described above, when power dips or is interrupted unexpectedly, equipment should reach a fail-safe condition as specified and designed by you as a result of your hazard evaluation. Consider developing a checklist or other tools for employees to use to ensure that safe conditions are reached. As described above, the checklist might show the fail-safe mode for critical equipment and steps such as closing valves in reactor feed lines or fuel supplies to fired heaters, starting auxiliary power generators, and switching to steam or diesel driven backup pumps or compressors for critical services. In addition, steps need to be taken to ensure that there isn't an unintended action when power is restored and to get ready for restart. **Table 3** shows some lists of equipment and other checks that may need to be performed after a power outage.

Immediately following a brief interruption, there may be a strong desire to quickly get the process back on-line. Rushing to put a unit, process, or certain equipment back on-line may compound problems associated with the outage as described below.

3. Restarting When Power is Restored. When power is restored, there are a number of steps that should be taken to ensure the process (1) remains in a safe mode and (2) it is ready to return to operation. Also, if the process remained on-line using backup systems, it must be returned to normal operation. As mentioned above, facilities may want to develop plans, procedures, and checklists for restarts or restoring backup services.

Since power outages are often very short, consider developing preplanned warm restart procedures for certain units, processes or equipment. A warm restart procedure addresses the unique circumstances that might arise if a unit is not completely shutdown before power is restored and the unit restarted.

Be sure that other necessary support utilities (steam, instrument air, cooling water, flare gas system, fire fighting systems, etc.) have been returned to service and are fully operational before restarting operations.

Table 3. Sample Check Lists of steps that may need to be performed following a Power Outage:

✓ List manually operated switches that may need to be moved to the "off" position;
✓List valves that need to be checked for proper position;
✓List utilities such as steam, instrument air, nitrogen blanketing, cooling water, flare system, fuel system, radio telephone, pager communications, etc. that need to be verified for operability;
✓Check backup power generators, fire fighting systems, and other emergency response equipment for operability;
✓Verify feedstock inventory and availability of product storage free space;
✓List instrument controls, alarms, detection devices, automatic shutdown or trip out devices that must be reset or have operability verified;
✓List automatic startup power consuming equipment that should be shut down for safety and to minimize load demand when power is restored; and
✓List upstream and downstream and other affected parties to be notified of shutdown.

Caution: *After a very brief outage, there may be a temptation to quickly restart certain process operations to avoid the hassle of warm restart or complete shutdown and restart procedures. Explosions and accidental releases have occurred when, for example, fired heaters and furnaces were restarted without proper purges or following all prescribed safety steps. Some equipment must be brought completely down and purged, then put back into service following prescribed steps. The warm restart procedure must address the process equipment that must first be stabilized and checked out before restarting, even for a brief outage.*

4. Continuity of Critical Services. As described above in the Hazard Identification section, if there is critical equipment that needs to operate to ensure the safe state of the process or work area, facilities should install backup power supplies and services. Services such as emergency pumps, lighting, alarms, and instruments and controls, particularly computer operated distributed control systems (DCS) may need to operate using backup power generators or uninterrupted power supplies (UPS). Steam or diesel driven pumps should be considered to maintain critical flows while a process is shutting down or otherwise dealing with the power outage. And as with all critical equipment and procedures, they should be maintained, tested, and verified for operation regularly.

Caution: *Backup power generators must be selected and installed by a qualified electric service contractors or facility personnel. It is particularly important to avoid improper switching which can lead to power being fed back into the regular power system. This feedback can cause equipment damage and injury. The utility company should be notified of the installation of any backup generators.*

Recent experiences at large, well established organizations as well as small and medium size operations have verified that a greater awareness of the hazards of power failure and restart is necessary, especially with thunderstorms and greater electricity demands in hot weather or ice storms in freezing weather. Facilities should re-examine and ensure that all hazards are identified and addressed and that equipment, procedures and staff are developed, maintained, and ready so that chemical accidents are prevented and those that do occur are mitigated.

Education and Training Resources

Here are some useful resources for additional information on power failure and backup power:

Recommended Practice for Emergency and Standby Power Systems for Industry and Commercial Applications.
The Institute of Electrical and Electronics Engineers, Inc., (IEEE).
IEEE Operations Center
445 Hoes Lane, P.O. Box 1331
Piscataway, New Jersey 08855-1331 USA
732 981 0060
Fax: 732 981 1721
http://www.ieee.org

Caterpillar Alban Engine Power Systems

Describes capacity ranges of portable power generating equipment and some typical applications.

http://www.dcat.com

National Fire Protection Association (NFPA) codes include:

NFPA 70 - National Electric Code (latest edition)
NFPA 1600 - Disaster Management (latest edition)

National Fire Protection Association
1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269-9101
617-770-3000
Customer Service: 800-344-3555
http://www.nfpa.org

Occupational Safety and Health Administration (OSHA)
Process Safety Management (PSM)
202-219-6151
http://www.osha.gov

Mine Safety and Health Administration (MSHA)
Kaiser Aluminum accident investigation report, including photographs, Gramercy Works Alumina Plant Explosion, July 5, 1999.
http://www.mhsa.gov

For More Information...

Contact EPA's Emergency Planning and Community Right-to-Know Hotline

(800) 424-9346 or (703) 412-9810
TDD (800) 553-7672

Monday-Friday, 9 AM to 6 PM, Eastern Time

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