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Report on the Follow-Up to the Downers Grove Substation Fire

Presented to:

The Staff of the Illinois Commerce Commission

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I. Introduction

A. Background

The September 2005 contract between the Illinois Commerce Commission (ICC) and The Liberty Consulting Group (Liberty) required that Liberty:

- investigate the circumstances and determine the root cause(s) of the Downers Grove substation TDC 580 outage in August 2005, (Why did the Downers Grove substation TDC 580 fail?) and any relation of such outage to the outages at the Fisk and Sawyer substations in June 2005.
- determine whether other substations in ComEd's power delivery system could fail in a way similar to the Downers Grove Substation TDC580 failure
- determine to what extent ComEd's system is vulnerable to other widespread electric service interruptions due to insufficient switching capacity when an entire substation is lost.

The contract also required that Liberty prepare report(s) on its findings and estimated that Liberty would provide a final report in early December 2005.

Liberty issued a report on December 16, 2005. That report provided a complete root cause analysis of the Downers Grove substation cable-space fire. The report also contained the conclusion that there is a significant risk of additional incidents like the Downers Grove fire at other similar substations. Liberty indicated that ComEd had not yet fully developed a firm, comprehensive, and verifiable cable-space fire-protection program and that it was not clear at that time that ComEd had identified all of the substations that are at risk to a cable space fire.

With regard to the third objective listed above, Liberty found that ComEd had not considered nor made contingency plans for the total loss of all substation equipment. Liberty also found that, on a preliminary basis, there exists substantial customer risk to long duration substation outages. However, just prior to issuance of Liberty's report, ComEd informed Liberty that it had conducted studies to determine the effects of and switching requirements for the loss of a number of critical substations.

B. Objectives

This report describes the work Liberty performed after the issuance of the December 16, 2005, report. This work included the evaluation of ComEd's:

- Substation Fire Protection Program

Liberty reviewed cable-space substation fire-protection plans to determine whether ComEd appropriately prioritized substations for fire protection enhancements and whether ComEd identified all substations that have a significant risk of cable-space fires. This work included a review of the February 18, 2006, Lakeview substation fire.

- Total Substation Outage Planning

Liberty reviewed ComEd's plans for evaluating the risks of, and preparing for restoration from, a total substation loss. This work included reviewing ComEd's existing contingency plans.

- Responses to Liberty's Recommendations

Liberty reviewed ComEd's responses to all six recommendations contained in the December 16, 2005, report. The purposes of this work were to assure the ICC that ComEd clearly understood Liberty's recommendations and that ComEd's responses were definitive and could satisfy the intent of the recommendations when fully implemented.

C. Overall Conclusions

ComEd's responses reasonably satisfy the intent of Liberty's recommendations. ComEd has a substation fire-protection program that, if fully implemented, should be effective in reducing the likelihood of a catastrophic substation fire. It started a substation cable-space infrared testing program to identify potential problem connections. It identified some substations as very critical and developed restoration plans for them. ComEd is in the process of evaluating other substations for the effects of a total loss, and plans to create conceptual restoration plans for additional substations. ComEd improved its root-cause analysis methods. ComEd improved its cable-splicer training and plans to include cable-splicing fundamentals and skill verification in its refresher course for seasoned splicers. It created reasonable guidelines for operations with heavily loaded cables. Finally, ComEd is modifying operating procedures related to substation fires, fire alarms, and general awareness of actions that personnel should take in off-normal events.

To supplement these improvements, Liberty suggests that ComEd do the following:

- Expand its consideration and identification of conditions and incidents that could lead to a total substation outage. For example, ComEd could encourage its substation-related personnel to think "outside-the-box" during day-to-day work with regard to what could happen that could cause or contribute to a total substation outage. ComEd may ultimately judge some incidents as extremely unlikely, or may determine that protection against some incidents would be unreasonably cost-prohibitive. Nevertheless, there may be others that, considering the consequences of the outage, may be worthy of additional protection.

- Review findings and recommendations from earlier investigative reports to ensure that there has been adequate follow-up on recommendations and that it has completed programs developed because of earlier incidents. For example, ComEd should affirm that its current substation fire-protection program covers the recommendations made in ComEd's reports on substation fires that occurred before the one at Downers Grove.

II. ComEd's Substation Fire Protection Program

A. Background

1. Liberty's Conclusions

In its December 16, 2005, report, Liberty concluded that:

- ComEd did not complete all actions identified in earlier substation fire reports.
- The design of substations similar to Downers Grove did not adequately consider the possibility of fires in the cable space.
- There is a significant risk of additional incidents like the Downers Grove fire.

Liberty recommended that ComEd continue to inspect, evaluate, and implement changes at substations with vulnerabilities to fires like those that have occurred in the past.

2. Cable Spaces

Many of ComEd's substations have cable spaces, basements, corridors, or tunnels under control buildings or switchyards. Typically, ComEd's cable spaces contain power and control cable. Personnel access the space through floor hatches and have to meet confined-space procedures. Personnel generally gain access to basements and cable tunnels through stairs and doors and are not required to meet confined-space procedures.

Cable spaces provide a convenient room for the installation of and changes to power and control cables. As ComEd increased substation capacity over the years, it installed power and control cables in close proximity with one another. The power cables in some cable spaces, mostly in Chicago, are lead-jacketed.[1] In others, the power cables are plastic-jacketed.[2] In some locations, ComEd installed plastic-jacketed cables among lead-jacketed cables. Although ComEd stopped designing cable-space substations in 1995, it installed additional plastic-jacketed cables in existing cable spaces. More recently, new power cable installed in cable spaces is supposed to be fire-retardant jacketed and devoid of joints.

3. Cable-Space Fires

Significant fires started by electrical faults in the plastic-jacketed cable joints, and in one case in the cable itself,[3] occurred in the cable spaces of Pleasant Hill in 1993, Bartlett in 1996, Schaumburg in 2001, and Downers Grove in 2005. At Downers Grove, the connector in a cable joint overheated causing the joint insulation to fail and setting afire the joint's plastic jacket.

[1] Lead jacketed cable uses oil and paper for insulation as is called paper-insulated lead cover (PILC) cable. ComEd has not reported any cable space fires caused by PILC cable.

[2] Plastic or "poly" jacketed power cables use solid dielectric insulation made of either cross-linked polyethylene (XLPE) or of ethylene propylene rubber (EPR).

[3] An electrical fault in a cable caused the 1993 Pleasant Hill Substation cable space fire. "Water treeing" likely caused this fault in the non-strand-filled, extruded, cross-linked polyethylene (XLPE) cable insulation. ComEd stopped installing this cable in the 1980s. Electrical faults in cable joints caused the 1996, 2001, and 2005 fires.

These fires spread and caused other cable failures and, in some cases, major damage to critical equipment. The substations had to be de-energized to fight the fire and start repairs. The reasons for propagation or significance of the fires included:

- Plastic jackets on cables and joints were set afire by electrical arcing from an electrical fault and by the flames from other cable jackets already afire.
- Power cables, and in some cases control cables, were in close proximity to the fire without fire barriers. Burning of the control cables at Downers Grove caused the loss of automatic and manual control of switching equipment and this in turn delayed de-energizing the buses.
- There were unsealed floor penetrations to switchgear and the main floors in cable-space ceilings allowing cable-space fires to ventilate and causing heat, smoke, and arcing damage to switchgear components.
- There were no automatic fire suppression systems.
- ComEd did not de-energize the substations in a timely fashion, even though fire alarms activated for the last two cable-space fires.
- There were no site fire plans to assist fire fighters.
- Heat from the cable-space fire radiated through a steel hatch cover causing the station battery on the main floor to be set afire.
- One of the station battery leads ran through the cable space. The cable space fire burned the lead open causing the loss of main dc control power.

3. ComEd's Responses to Previous Cable-Space Fires

After the 1996 Bartlett fire, ComEd began installing flame-retardant jacketed cables for new and replacement cable installations in cable spaces. In 1998, it started identifying and replacing deteriorated plastic-jacketed cables in some of its cable-space substations. By 2005, it had spent nearly $7.5 million for these cable testing and replacement programs. Also in 1998, ComEd developed its "TDC/TSS Cable Space Improvements Guidelines," which indicated the need to install fire barrier material under control cable pans, the need to increase the distances between transformer, feeder, and control cables, the need to seal open floor penetrations, and the need to stop installing joints in cable-space, plastic-jacketed cables. The guidelines also indicated that ComEd should wrap cable joints with fireproof tape. Because ComEd had already stopped building cable space substations, the guidelines were intended for the installation of additional circuits or when working on cable-space improvements. ComEd did not indicate that it planned to use these guidelines as a general retrofit fire prevention program for cable space substations.[4]

Following the 2001 Schaumburg fire, ComEd's investigation team recommended that ComEd:

- complete fire protection enhancements in the Schaumburg cable space as indicated in its 1998 guidelines
- implement a program and complete "high value" fire protection improvements in its cable-space substations

[4] However, on April 19, 2006, Liberty observed that ComEd had wrapped joints and sealed floor penetrations in the Arlington Heights substation. ComEd had performed this work before the Downers Grove fire occurred.

- implement a procedure that requires the fire department be called whenever there is smoke or fire in a substation
- issue a safety alert to keep hatches closed and fire barriers in place.

From substation inspections, Liberty observed that ComEd had marked its cable hatches with instruction to keep them closed, and, in some cable spaces, installed fire barrier material under control cable pans. However, ComEd had not completed other fire prevention enhancements.

4. Lessons from Cable-Space Fires

After these four cable space fires, it became obvious that:

1. ComEd needed to inspect its substations to determine the vulnerability to cable-space fires. ComEd also needed to prioritize its fire protection actions based on the vulnerability (e.g., number of plastic-jacketed joints) and on the potential consequences of a total substation outage (e.g., number of potentially stranded customers).
2. Workmanship problems caused plastic-jacketed cable joints to fail. Improved training and quality control would not prevent faults originating in existing cable joints. ComEd had to take actions to identify defective joints. While testing of cable and joint insulation quality is not practical, infrared inspection of joints can be effective in the identification of defective connections in joints.
3. Even if a joint in a cable-space feeder fails, ComEd needed to take measures to limit the service interruption to those customers on the faulted feeder. ComEd needed to take actions to prevent cable-joint fires from spreading to other cables and equipment. These actions could include things like cable wrapping, floor penetration sealing, and automatic fire suppression.

As noted above, Liberty recommended that ComEd should continue to inspect, evaluate, and implement changes at substations with vulnerabilities to fires like those that have occurred in the past. More specifically, Liberty indicated that ComEd should evaluate substations that are similar in design to Downers Grove to determine which have the potential to result in long duration outages to a large number of customers and implement the lessons learned from the Downers Grove and other earlier fires in a manner that mitigates this potential loss of service to customers. Liberty said that ComEd should:

- Continue, and complete as soon as practical, its infrared inspections of joints in cable spaces.
- Develop a formal method for prioritizing cable-space fire-protection enhancements to most effectively reduce the outage risks caused by cable space fires.
- Evaluate for effectiveness various options to reduce fire risk at the most vulnerable substations. For example, wrapping joints in a substation with a low transfer capacity and serving a large number of customers may be more cost-effective that doing full enhancements at several smaller substations with higher transfer capacities.

5. ComEd's Response to Recommendation No. 4

ComEd agreed with the recommendation and outlined several actions it would take to reduce the risk of customer and equipment outages caused by fires. ComEd's plan for 2006 and 2007 included a review to ensure that it has identified all cable-space substations, inspections and thermographic (infrared) testing, a prioritization method for implementing improvements, and specific physical changes (e.g., wrapping cables, sealing floor penetrations, and re-routing substation battery cable leads).

B. Analysis

To evaluate ComEd's response to these recommendations, Liberty interviewed ComEd personnel with knowledge about, and reviewed documents concerning, the substation fire protection improvement program. Liberty also inspected (1) the Lakeview substation, where an oil fire occurred on February 18, 2006, (2) the York Center substation, where ComEd had completed a fire protection project, and (3) six other important substations.

1. ComEd's Multi-Year Fire Protection Plan[5]

After a transmission cable fire in the Fisk substation in 2005, ComEd formed a substation fire-protection engineering group to develop plans for preventing and mitigating the effects of substation fires.[6] After the Downers Grove substation fire, this group included cable-space fire-prevention enhancements in a "Multi-Year Fire Protection Plan for Major Substations." In total, this plan addresses about 350 major ComEd substations and a few cable tunnels.

ComEd identified the types of fire risk to consider at its major substations. These risks include:

- cable space fire
- switchgear fire
- switchgear smoke damage
- control cable fire
- transformer fire
- battery failure
- false detector alarm
- lost alarm
- alarm system down
- other, upstairs, non-switchgear fire.

For each of these risks, it determined consequences and preventive measures that it may need for each substation.[7] These actions included things like:

- wrapping cables and installing control pan fire barriers in cable spaces
- sealing floor penetrations
- re-routing battery leads

[5] Response to Data Request #310.
[6] Response to Data Request #309.
[7] Response to Data Request #310.

- installing or upgrading fire detection
- installing fire suppression
- developing site fire plans
- installing reclose-inhibit in case of cable-space fire
- performing transformer fire protection upgrades
- performing miscellaneous other enhancements such as joint removal and cable pan relocations.

The actions that ComEd identified for completion in 2006 through 2008 focused on those items that would be effective in preventing or mitigating the consequences of a fire like that which occurred at Downers Grove.

2. Identification of Cable-Space Substations

Before it could assess the risk of cable-space fires, ComEd had to determine which substations have cable spaces, which have fire risks similar to Downers Grove, and which have other cable-space fire risks. It also had to identify which substations had basements and cable tunnels, and the fire risks in those locations.

ComEd has approximately 800 substations, of which it considers about 350 as major substations. By January 2006, ComEd had audited its substations and had identified 139 locations, 30 of which contain no plastic-jacketed cable, and 109 that have at least some plastic-jacketed cable.[8] Of these 109 locations, 96 have 20 percent or more plastic-jacketed cables and 80 have at least one cable joint. ComEd considers these 96 substations as having a fire risk similar to that at Downers Grove before the fire.[9]

ComEd reported that it verified its list of substations with cable spaces and basements against its list of substations with sump pumps, is checking for cable spaces as it prepares site fire plans for all substations with buildings, and will review its digital substation equipment database for cable spaces.[10] ComEd scheduled infrared inspection of substations with cable spaces. During the infrared inspection, ComEd verifies whether the substation cable space contains plastic-jacketed cable and joints.

Liberty concluded that ComEd's efforts to identify all cable-space substations were reasonable.

3. Substation Cable Space Audit and Infrared Testing

After the Downers Grove cable-space fire, ComEd inventoried its 109 cable-space substations that have at least some plastic-jacketed cables, noting the number of joints, fire detection, fire proofing, and location of substation battery leads.

[8] Response to Data Request #307.
[9] Response to Data Request #310.
[10] Response to Data Requests # 312 and #307 and interview on April 19, 2006.

Because a causal factor of the Downers Grove fire was an overheated connector in a plastic-jacketed cable joint, ComEd performed infrared inspections of electrical connections in the cable spaces of 83 substations.[11] ComEd will also infrared inspect about 66 more substations, which may also have cable spaces, by the end of 2006.[12]

Because of the results of the infrared inspection, ComEd replaced ten joints with new cable sections, replaced one termination, repaired one termination, and repaired five neutral connections.[13]

Liberty concluded that ComEd's actions and plans for inspecting substations were reasonable.

4. Prioritization of Fire Protection Work

Plastic-jacketed joint faults caused three of the four cable-space fires at ComEd. Therefore, it is reasonable to assume that cable-space fire risk relates to the number of plastic-jacketed joints in a substation. In addition, once a fire has started to propagate, open floor penetrations allow the fire to ventilate and may expose heat and smoke to the switchgear and controls. Therefore, risk also relates to the number of open floor penetrations.

A cable-space fire could cause a total substation outage and some customers fed from the substation may experience an extended outage if ComEd cannot transfer them to another substation. Even short outages can have a large effect on critical customers. Therefore, the number of critical customers, the total number of customers, the total peak load, the number of feeders, and percentage of stranded[14] load are all measures of the potential effect of a cable space fire.

Following this logic, ComEd determined a priority factor for the 109 cable-space substations using a formula that includes:[15]

- potential for stranded load during peak load conditions
- number of cable joints
- percent of plastic-jacketed feeder cables
- number of critical customers at each substation
- percent of unfilled floor penetrations
- substation load
- number of substation feeders.

Liberty found that the use and weighting of the risk and effect factors as used in ComEd's priority formula was logical and reasonable.[16]

[11] Response to Data Request # 313.
[12] Interview of January 31, 2006 and ComEd presentation to the ICC, March 28, 2006.
[13] Response to Data Request #306.
[14] Stranded loads are customer loads that ComEd cannot transfer to other substations in a reasonable time. A useful guideline for determining *stranded* customers or load is the failure to restore service within 24 hours.
[15] Response to Data Request #307.
[16] Response to Data Request #324.

5. Substation Changes, 2006-2007.

ComEd based its cable-space fire protection project work completed or planned for 2006 through 2008 on the substation priority method modified where required to optimize labor costs. The plan includes:

- wrapping cables, installing control cable pan barriers, and sealing floor penetrations
- installing fire detection systems
- re-routing station battery leads
- installing fire suppression systems
- developing site-specific fire plans.

a. Wrapping plastic joints, sealing open floor penetrations, and installing fire barrier material under control cable pans

Installing a fire suppression wrap to plastic-jacketed joints and nearby cables will reduce the possibility that a fire started by a plastic-jacketed joint fault will propagate. The material used for wrapping joints and cables is the same as ComEd uses in its high-rise buildings since the early 1990s. ComEd is using a material for sealing open floor penetrations in cable spaces that expands when heated, and is installing fire barrier material, where not already installed, under its control cable pans in cable spaces.[17]

A contractor is sealing floor penetrations in suburban substations and ComEd's Fix-It-Now teams are performing the seal installations in the Chicago substations.[18] ComEd intends to have cables wrapped and open floor penetrations sealed in all 139 cable-space substations by the end of 2008. ComEd plans to seal all floor penetrations in Chicago TDC and TSS substations on the list by the end of 2007.[19] By the end of March 2006, ComEd had wrapped all cable joints and sealed open floor penetrations in the York Center substation. It completed joint wrapping and penetration sealing in the Pleasant Hill substation cable space in April 2006. ComEd said that sealing open floor penetrations at a large substation,[20] which does not have plastic-jacketed cable joints, may be moved up from 2007 to 2006.

b. Installing Fire Detection Systems

To react properly to a cable-space fire, load dispatchers at the Operations Control Center (OCC) need prompt notification. ComEd has SCADA control and monitoring at all of its TSS and TDC substations. However, 31 substations do not have cable-space fire-detection systems. Included in its cable-space fire protection plan is the installation of fire detection systems in 20 cable spaces during 2006 and 11 more during 2007.[21] Twenty of these systems will have smart detector heads so that a load dispatcher can determine if more than one detector has alarmed.[22] This will help

[17] Response to Data Request #311.
[18] Interview of January 31, 2006.
[19] Interview of March 13, 2006.
[20] Northwest. Liberty found that the Northwest substation Terminals #1 and #2 have a few plastic-jacketed cables, but no joints. All other cables in Terminals 1, 2, and 3 were lead jacketed.
[21] Response to Data Request # 307.
[22] Interview on January 31, 2006.

the load dispatcher verify that the alarm was not from a faulty detector and that the dispatcher should possibly de-energize the substation.

c. Re-routing station battery leads

After the Downers Grove fire, ComEd recognized that routing one or both of the main leads of the substation battery through cable spaces, even for a few feet, may cause the loss of automatic and local electrical control of the substation during a cable-space fire. Included in the cable-space fire protection plan is the re-location of 20 station battery leads during 2006, and 25 more during 2007.[23]

d. Installing fire suppression

A fire suppression system could prevent cable-space fires from propagating, and automatic fire suppression systems may even prevent the need to de-energize a substation. Although wrapping cable joints should prevent a joint fault from causing a propagating fire, the wrap would not stop a cable fault, such as that which occurred at Pleasant Hill substation in 1993, from starting a propagating fire. ComEd included in its plan the installation of fire suppression systems at 13 of its highest risk-impact cable-space substations, 8 in 2006 and 5 in 2007.[24]

NEETRAC[25] surveyed other utilities for ComEd to determine the types of substation fire suppression being used. Also, ComEd assigned a consultant and a fire risk engineering company the task of determining the type of suppression system to use for installation in eight substations in 2006.[26] It is evaluating type, cost, effectiveness, and safety concerns, and is considering using water deluge and spraying, carbon dioxide, and other methods. ComEd currently uses carbon dioxide gas suppression systems at several of its Chicago substations. ComEd has yet to determine the type of suppression systems it will install in the selected substations.[27]

e. Substation site fire plans

There was some delay in starting the fire fighting and the following clean up and repair of equipment during and after the Downers Grove fire. This occurred because no information was readily available to fire fighters about how to contact directly the dispatch center, and what electrical and chemical hazards were present. ComEd developed a prototype site-fire plan, which it is reviewing. Liberty reviewed this prototype fire plan and found it to include phone numbers, layout diagrams, instructions, photographs, warnings, and material safety and data sheets. ComEd said that it would place the site fire plans in lock boxes at locations convenient to fire fighters.[28]

[23] Response to Data Request #307.
[24] Response to Data Request #307.
[25] National Electric Energy Testing, Research & Applications Center; Response to Data Request # 315.
[26] Response to Data Request # 314.
[27] Interview of January 31, 2005.
[28] Interview of March 13, 2006.

ComEd plans included having site fire plans in place for 30 cable-space substation by the end of 2006, and at the remaining 109 cable-space substations by the end of 2008.[29] All substations on ComEd's system determined to have control buildings will get a fire site plan by the end of 2011.[30]

6. Lakeview Substation Fire[31]

The Lakeview substation fire was an outdoor oil fire that spread into a cable corridor.[32] Lakeview has three transformers, a cable corridor, and a switchgear room. The corridor arrangement is different from a Downers Grove-type cable space because it has doors and not access hatches, and contains only lead-jacketed cable.

On February 18, 2006, a major oil fire occurred at Lakeview causing a total substation outage, and resulting in service interruptions for about 7,400 customers, some for about five hours.[33] On March 8, 2006, Liberty inspected the site and interviewed personnel. A 12 kV cable terminating device (called a pothead) at a transformer had apparently failed causing the transformer's oil-filled terminating cabinet to expel oil. Flaming oil traveled toward the drain leading to the oil retention pit, down the transformer cables to the cable corridor below, and behind the transformer. The heat from the flaming oil traveling to the drain, and cool fire-fighting water caused the transformer's 69 kV oil-filled switch compartment and its 69 kV cable oil reservoir system piping to expel oil, which also caught on fire.

Flaming oil, some carried by water from the fire fighting effort, entered the cable corridor and damaged a lead-jacketed power cable and the control cables for the other transformers. Smoke contamination caused a fault at the transition bus compartment located on the main floor connected to the corridor by stairs. The smoke detection system operated and sent a fire alarm to the alarm monitoring company, which then called the Humboldt (Chicago North) Control Center and the OCC. ComEd de-energized the substation about 30 minutes after notification of the OCC. Fire fighters extinguished the transformer fire using both the built-in fire extinguishing standpipe system and by spraying water over the wall.

Because there was sufficient transfer capacity for Lakeview, ComEd was able to transfer all load to other substations within a few hours. However, the oil fire in the corridor damaged much of the control wiring for all three transformers. It was eventually replaced with temporary wiring so that two transformers could be returned to service. The fire severely damaged the third transformer.

Liberty addresses ComEd's root cause analysis of the Lakeview fire in the section on Recommendation #1 later in this report. For the purposes of evaluating ComEd's response to this recommendation (#4), the Lakeview incident is important because:

- it showed that fires can get to areas containing power and control cables in ways other than that experienced at Downers Grove

[29] Interview of March 13, 2006 and Response to Data Request # 307.
[30] Response to Data Request # 310. ComEd estimates that approximately 350 substations will get site fire plans.
[31] Substation visit and interview on March 11, 2006.
[32] The oil came from reservoirs in a transformer.
[33] Interview with RCI Team Lead, April 18, 2006.

- some lessons learned from earlier substation fires were applicable to this oil fire and ComEd demonstrated improved performance in some areas, such as timely de-energizing of the substation.
- although this event did not strand load, ComEd should use lessons learned because similar oil fire incidents at other substations could have more severe consequences to reliability.

7. Other Substations Inspected By Liberty

Liberty inspected several substations to determine how they related to ComEd's fire protection plan.

a. [redacted]

[redacted] is one of the 109 prioritized, cable-space substations. ComEd wrapped its plastic-jacketed joints, added fire retardant material to hatches, and sealed its floor penetrations in March. ComEd plans to re-route the battery leads and install fire suppression in 2006.

b. [redacted]

[redacted] is not one of the 109 prioritized cable space substations because nearly all of its cables are lead jacketed. However, it is 1 of the 30 other cable-space substations and gets a site fire plan and its floor penetrations sealed in 2007. However, because [redacted] is an important substation, ComEd moved the floor penetration sealing up to 2006.

All [redacted] switchgear buildings ([redacted]) at [redacted] have cable spaces. However, [redacted] have a few plastic-jacketed cables, and these cables appeared not to have joints. The battery lead in [redacted] needs to be re-routed. [redacted] is new, is at a distance from the other two terminals, and has an automatic carbon dioxide fire suppression system. The only concern is that [redacted] are back-to-back and only a wall and steel doors separate the switchgear rooms.

c. [redacted]

[redacted] is one of the 109 prioritized, cable-space substations. It is to receive a site fire plan, its plastic-jacketed joints wrapped, its floor penetrations sealed, and a fire suppression system installed in 2006. Liberty observed that there is a mix of lead-jacketed and plastic cables in the [redacted] cable space.

d. [redacted]

[redacted] is not one of the 109 prioritized, cable-space substations because all of its cables are lead jacketed. However, it is one of the 30 other cable-space substations and gets a site fire plan in 2006 and floor penetrations sealed in 2007.

Rather than a cable space, [redacted] has a very large corridor that runs, under a street and between the four transformer vaults and the switchgear located on several floors of a large building. The cables in the vault are lead jacketed, and are separated by substantial distance from one another and from the runs of control cable conduits. ComEd recently sealed some floor penetrations. Carbon dioxide fire suppression is installed for the transformer vaults. There are many old oil (1940s) circuit breakers in the building. However, they contain small amounts of oil and are separated with concrete barriers.

e. [redacted]

[redacted] is one of the 109 prioritized, cable-space substations. ComEd plans to wrap the plastic-jacketed cable joints, seal floor penetrations, and re-route battery leads in 2007. [redacted] does not have a cable space, but rather a basement room with old (early 1940s) oil circuit breakers. Cables are lead jacketed. Two of the transformers are in vaults in the building. However, the vault doors are wood. The tops of the oil circuit breaker enclosures are open. There appears to be fire risk because of oil-filled equipment.

f. [redacted]

[redacted] is not one of the 109 prioritized, cable-space substations because most of its cables are lead jacketed. However, it is one of the 30 other cable-space substations and gets a site fire plan and floor penetrations sealed in 2006.

ComEd should review the placement of the plastic-jacketed cable. At one place the cable was touching a lead-jacketed cable. In addition, at other places the methods used to support the plastic-jacketed cable were probably not consistent with construction standards. However, there were no joints in the plastic-jacketed cable. Penetrations to the main floor were sealed.

g. [redacted]

[redacted] is one of the 109 prioritized, cable-space substations. ComEd plans to generate a site fire plan, wrap the plastic-jacketed cable joints, and seal the floor penetrations in 2006. [redacted] has two control buildings and a cable space under each building. Liberty could not enter one cable space because there was about ½ inch of water on its floor. ComEd said that it is planning to correct this problem soon. Liberty inspected the other cable space. It had lead-jacketed cable. Compound leakage was observed on a pothead in the cable space. ComEd immediately conducted an investigation to determine whether repairs were necessary. ComEd relocated the substation battery leads out of the cable space.

C. Conclusions

Liberty found that ComEd's initial responses and planned actions satisfy the intent of Liberty's recommendation. ComEd's efforts to identify all cable-space substations, its actions and plans for inspecting substations, and its method of prioritizing work were all reasonable.

ComEd's cable space infrared project has identified some inadequate cable joint and termination connections in cable spaces. ComEd has taken appropriate actions to correct connection problems identified by its infrared project.

ComEd's planned and completed actions should effectively minimize the possibility of cable-space fires that cause total substation outages. It includes plans for wrapping plastic-jacketed cable joints, sealing floor penetrations and installing control cable pan fire barriers, re-routing station battery leads, and installing fire suppression as appropriate in many of the 139 cable space substations. It plans to develop site fire plans for all 139 substations.

Liberty also reviewed ComEd's actions taken after the Lakeview oil fire. ComEd did apply some of the lessons learned from the Downers Grove and Fisk fires in 2005.

III. ComEd's Total Substation Outage Planning

A. Background

ComEd has about 800 substations, including about 350 major substations. As a minimum, ComEd typically designs its distribution system for appropriate customer restoration if one substation element fails. For its major substations, it has redundant incoming transmission lines, multiple transformers, multiple distribution buses, and feeder ties. Liberty concluded that ComEd's substation and system design criteria are consistent with the practices of other utilities. However, if multiple elements fail, or are destroyed by fire, catastrophic weather event, or terrorist act, stranding, or causing extended outages, of customers is possible.[34] The Downers Grove cable-space fire stranded customers because the fire damaged more than one distribution bus in the substation and several feeder cables. ComEd could not restore service to the stranded customers until it repaired one of the two damaged buses.

If there is a complete substation outage and the distribution buses cannot be restored quickly, loads fed by the substation may become stranded, particularly during peak load conditions. ComEd has already determined the percentages of load that it can transfer to other substations for each of its TSS and TDC substations during peak conditions. Load transfers are limited by the number of ties to other substations, and the capacity of feeder ties and substation buses. Although there were stranded loads after the Downers Grove cable-space fire, there was no load stranding after the Pleasant Hill, Bartlett, and Schaumburg substation cable-space fires, and after the Fisk and Lakeview fires, because ComEd made repairs quickly or the transfer capacity was adequate for the existing conditions. However, the loss of some substations for an extended time, particularly on peak load days, could result in substantial amounts of stranded load.

[redacted] It created plans for restoring the transmission system to normal and for restoring critical customers if one of these critical substations was lost. Some of these plans included feeder-by-feeder switching procedures and generator needs for restoring all customers. [redacted] ComEd did not intend for them to prevent or limit stranded load in case of any substation outage.[35]

In its report on the Downers Grove fire, Liberty recommended that ComEd conduct risk-based analyses of all substations and make appropriate plans for the recovery of substations, assuming a total loss of all substation equipment. Liberty did not suggest that ComEd re-design its system so that it had the capacity to be able to transfer all loads from all substations to other substations. However, Liberty said that ComEd should identify substations that may be vulnerable to extended customer outages, identify possible causes of outages, and have at least conceptual plans for restoring customers after a total substation outage. Liberty also noted that ComEd should review its portable equipment inventory and determine if additional equipment would be beneficial.

[34] A useful guideline for determining *stranded* customers or load is the failure to restore service within 24 hours.
[35] Interviews on February 14 and April 20, 2006.

In its response, ComEd agreed with the recommendation and said that it will determine the number of customers at risk during total distribution substation outages, and will create a restoration strategy based on substation configuration categories for each substation that directly serves distribution load. The plans will focus on restoring all loads and will include using portable transformers, generators, and possibly portable switchgear. It will also evaluate and categorize its transmission substations based on the effect of a total transmission substation outage on transmission system stability, and on the effect on service to the customers. From this evaluation, ComEd plans to create a document to provide a coordinated response to transmission substation outages. ComEd's response in regard to transmission restoration is important relative to Liberty's recommendation because transmission substation outages may cause distribution substation outages.

B. Analysis

1. ComEd's Critical Substation Restoration Plans[36]

During the 2002 through 2005 period, ComEd created recovery plans for total outages of its critical substations. ComEd selected and categorized [redacted] major substations based on the effect of total substation outages on the transmission grid, or on critical customers, including those supporting national security. The selection process was not generally based on stranded loads caused by total substation outages. However, some of the distribution restoration plans included creating prepared direct and cascade feeder-to-feeder switching plans, identifying major distribution equipment needs and lead times, restoring protection and control systems, and estimating needed portable generator capacity to service resulting stranded loads. The transmission restoration plans included prepared drawings for bypassing damaged substations, lists of needed major materials and equipment needed with lead times. The critical substation restoration plans are provided to the operations personnel.

The critical substation restoration plans meet ComEd's intentions for these plans, which were to return the transmission system to normal and restore service to critical customers. However, in some cases, the plans provide prepared switching procedures and generator needs for restoring all customers. Some of the distribution recovery plans appeared to be more detailed than others. Although valuable, these plans only partially satisfy the intent of Liberty's recommendation. Liberty's simplified analysis of potentially stranded load showed that out of [redacted] substations that have the potential for stranding more than [redacted] customers or more than [redacted] MVA of load at peak-load conditions, only [redacted] were included in the critical substation restoration plans.

2. ComEd's Response

ComEd said that it is separating its substations into two main groups; substations serving distribution loads, and transmission substations not directly serving customer loads.

[36] Interviews on February 14 and April 20, 2006.

a. Distribution Substation Restoration

ComEd's distribution substation restoration planning process is intended to minimize restoration times and minimize the amount of stranded loads that may occur by an extended total substation outage. To accomplish this, ComEd said that it will identify and categorize distribution substations based on the effect to customers if a total substation outage occurs. It will then develop restoration strategies, options, and actions based on these substation categories.

1. Single Transformer Distribution Substations

By June 1, 2006, ComEd plans to have created a guide for operations to determine load restoration steps following the outage of single transformer substations. This guide will include switching procedures, and the number and size of portable transformers and generators needed for restoring stranded loads.

2. Multiple Transformer Distribution Transformer Substations

By July 1, 2006, ComEd plans to have determined transfer capacity after a total substation outage for each multiple transformer substation during the 90th percentile summer weather and during off-peak periods. It plans to have placed each multiple transformer substation into one of several categories. Each category will include substations with similar customer effect and similar initial restoration strategy. ComEd plans to have a list of feeders that do not have external ties; that is, those that cannot be tied to other substations.

By October 1, 2006, ComEd plans to have identified the number of customers at risk of stranding and a list of critical customers for those substations that do not have 100 percent transfer capacity during 90th percentile weather. It plans to have developed documentation to define and communicate categorization of multiple transformer substations based upon transfer capability and restoration strategies.

By December 1, 2006, ComEd plans to have developed a set of restoration options and tools that can be deployed to assist in restoring customers as a result of a catastrophic substation outage or supply side interruptions. These include items such as determining the feasibility of field connections for mobile 34kV-12kV transformers, determining the appropriate levels of mobile equipment, and evaluating 12kV mobile switchgear.

By January 1, 2007, ComEd plans to have communicated the categorization/risk assessment, highlighting substations where there is the greatest probability of extended customer interruptions given current strategies. Some of these substations may be included in the previously developed critical substation recovery plans.

3. Operations Drill at Arlington Heights[37]

Liberty observed how ComEd operations personnel handled a cable-space fire drill at the Arlington Heights substation. The drill scenario complicated the fire with a SCADA failure, a circuit breaker trip coil failure, and a feeder cable fault in a manhole. The scenario had similarities to the actual Downers Grove cable-space fire. ComEd's emergency preparedness group developed and provided oversight of the drill scenario. On-site, the drill involved the local fire department, Area (substation) Operators, Overhead Electricians (trouble men), a site-restoration management team, environmental management personnel and their contractor, safety personnel, and security personnel. The fire prevention manager was also on-site and worked with the fire department. At the OCC, the drill involved the emergency preparedness group, emergency management team, operations engineering, planning, and the load and operations dispatchers. ComEd had its new incident command center bus on site. It is equipped with high speed satellite internet service providing phone and email access, cell phones, computers, water, and microwave. Portable toilettes had been dispatched to the substation.

The main purpose of the drill was not so much to train operations personnel, but to verify procedures and identify actions that could improve decision-making, reduce delays restoring customers, and helping fire fighters become familiar with substation fires. The Emergency Preparedness group was to lead the lesson learned discussion after the drill.

Liberty observed that:

- the drill scenario was sufficiently complex and well designed to test the restoration procedure and to learn where ComEd can make improvements.
- ComEd implemented a new procedure for collecting and managing forensic data during an outage. This was apparently was identified as a need from the Downers Grove lessons learned.
- the satellite phone worked well. ComEd identified the use of a satellite phone as a need from the Downers Grove lessons learned when cell phones had some problems.
- the SRM and ERM teams made decisions with little, if any, assistance from the emergency preparedness group.
- The load dispatcher and the operating dispatcher did not have drill consoles with software to mimic alarms and breaker operations, and the trouble calls, that would have came in for an actual outage.
- There were some delays in evaluating the critical customer list and in preparing switching procedures. ComEd could have saved time if it had prepared substation restoration procedures in advance.
- The dispatcher could have de-energized the substation more quickly but in doing so would have interrupted service to more customers for at least a short period. The dc control power at Arlington Heights was lost for the drill. ComEd did not de-energize the substation was using the circuit switchers, but rather by several remote switching operations. ComEd could have saved a few minutes by hand-mechanical operation of the circuit switchers to interrupt substation load.

Liberty found that this initial substation fire drill was valuable in identifying where ComEd could improve its substation emergency response procedures. The drill indicated to ComEd operations

[37] Liberty observations at Arlington Heights Substation and the OCC in April 19, 2006.

personnel that ComEd is serious about improving its restoration procedures. Liberty suggests that ComEd continue conducting periodic substation fire drills to continue to improve its response to substation fires.

b. Transmission Substation Restoration

The purpose of ComEd's transmission substation restoration planning is to minimize undesired effects on transmission system stability, which could cause widespread distribution outages. In its response, ComEd said that it will categorize transmission substations into [redacted] categories; substation outages that may cause [redacted]. ComEd will then develop restoration documents and checklists to insure coordinated responses.

By June 1, 2006, ComEd plans to have categorized each transmission substation into [redacted] categories based on the impact to system security following its total loss. This will provide operators guidance as to the relative importance of each station to the reliability of the transmission system. The category definitions will be:

- [redacted]
- [redacted]
- [redacted]

By the end of 2006, ComEd plans to have created for transmission operators a guide and checklists to follow for recovering from a transmission substation outage. The guide and checklist will include roles and responsibilities, emergency contact information, and emergency procedures to reference. Transmission Operations Shift Managers as well as the Emergency Restoration Managers will be trained on this procedure by this date.

C. Conclusions

The intent of Liberty's recommendation was to encourage ComEd to restore customers more effectively after a total substation outage by identifying problems, creating solutions, and providing prepared substation outage guides to the operations groups. Assuming that ComEd includes its critical substations in the conceptual, total-substation outage restoration plans, ComEd's response should meet the intent of the recommendation. ComEd included reasonable milestones with completion dates in its response.

While ComEd's plans for classifying substations appear to be thorough and systematic, Liberty has several suggestions for additional improvement.

- ComEd has no conceptual restoration plans for some obviously critical substations. Liberty suggests that ComEd begin the plan development as soon as practical.

- ComEd should thoroughly follow-up on lessons learned from substation outage events. ComEd had not applied fully and promptly lessons learned from previous substation outage events. It took four cable space fires before ComEd formally planned its cable space substation fire protection work. However, its root cause investigations now appear to be more effective. It identified that oil soaked and inadequately sealed cables propagated the fire that caused the Lakeview outage. ComEd said that it is changing how it identifies and prioritizes pothead leaks, and that it is evaluating how it can prevent unintentional flow of flaming oil during a substation oil fire.

- In addition to determining the feasibility of mobile equipment field connections, ComEd should identify substations for which it would be especially valuable to know in advance where and how it can connect portable generators on feeders that it cannot tie to other substations.

- ComEd should encourage operations and substation managers, supervisors, and engineers to identify situations that might lead to a total substation outage. Just because a situation has not caused a problem does not mean that it will not. Liberty inspected some major substations and observed that, while ComEd identifies and repairs obvious conditions such as leaking 138 kV bushings, a few less obvious potential problems existed.

  Liberty is not suggesting here that ComEd implement an administratively burdensome process that would seriously detract efforts away from other important work. Rather, ComEd should nurture an environment in which those people who spend time at substations be more aware of what could go wrong or what could happen that could cause or lead to a total substation outage. Liberty recognizes that a formal engineering investigation of every observation or question could be onerous. ComEd would need to devise a reasonable process for filtering, considering, and responding to observations.

  Examples of out-of-the-box thinking based on Liberty's observations include:

- Should we replace leaking oil-filled equipment and replace high or medium oil circuit breakers with gas or air circuit breakers to reduce fire risk in an important substation? Some major substations have numerous high voltage oil circuit breakers. At one substation, ComEd was monitoring and maintaining the oil levels in old large oil-filled potential transformers because they were leaking oil. Because the substation was important, ComEd should probably replace these potential transformers soon. A few old, but major, substations have medium voltage oil circuit breakers in the switchgear buildings. Flaming oil from oil circuit breaker failures, and other oil-filled devices, can propagate fire and cause a substation outage. ComEd replaced the oil circuit breakers at Jefferson Substation with gas circuit breakers after the 2000 oil fire. Replacing oil circuit breakers would be a major expense but could be included when considering re-enforcement of important substations.

- Should we be sealing the openings around cable penetrations into the air-filled cabinets on the new style 40 MVA transformers reduce the risk of a transformer fault? Liberty observed that on some of the new style transformers the cables were smaller than the openings. Possibly, small animals might be able to enter and short circuit a transformer bushing. If justifiable, Fix-It-Now teams could seal these openings.

- Should we be sealing open cable penetrations leading to cable ducts and trenches reduce the possibility of an oil fire from propagating into cable ducts, trenches, and cable spaces? If there is risk, corrective actions may be minor or major, or may not be practical. However, it may be worth evaluating, especially for important substations.

- Should we be testing the oxygen content in transformer nitrogen blankets after purging to verify that a there is insufficient air in the transformer to support combustion in case of an internal fault?

- Should we be removing oil residue on and around substation equipment from past oil leaks that could help propagate a fire? Liberty found that ComEd is actively cleaning up old oil spillage. However, this probably is for environmental reasons.

- Should we be verifying were roof leaks could cause switchgear failure? One substation has old exposed switchgear and bus where a roof leak could cause a substation outage.

- Should we be considering whether and where we should construct high strength walls around substations located next to a railway, major highways, streets, or [redacted] Installing walls

would be a major expense but could be included when considering re-enforcement of important substations.

- Should we take mitigating actions at substations located near rivers and possibly exposed to flooding? Although floods may be very rare and preventing floods may not be possible, plans for transferring loads if a river rises into a substation is probably appropriate.

- [redacted].

IV. ComEd's Responses to Liberty's Recommendations

A. Background

Sections II and III above discuss the responses to recommendations #4 and #6. This section covers the responses to recommendations nos. 1, 2, 3, and 5.

B. Response to Recommendations Nos. 1, 2, 3, and 5

1. Response No. 1 – Root Cause Analyses

a. Background

Liberty concluded that ComEd's root cause analysis did not address the underlying issues and problems associated with the fire at the Downers Grove substation. Consequently, Liberty recommended that ComEd assess its root cause analysis methods and consider obtaining formal root cause training.

ComEd agreed with the recommendation and committed to take several actions aimed at strengthening its corrective action and root cause analysis programs.

ComEd noted that it licenses a system called [redacted] that includes training materials and newsletters all directed at helping people use a systematic way to implement effective improvement strategies. The [redacted] textbook[38] defines the root cause as "the most basic cause or causes that can reasonably be identified that management has control to fix and, when fixed, will prevent or significantly reduce the likelihood of the problem's recurrence."

In its March 28, 2006, presentation to the ICC, ComEd indicated that it had received good feedback from Exelon's nuclear organization regarding root cause methods and that it was currently making improvements to its root cause investigation (RCI) process.

As noted elsewhere in this report, on February 18, 2006, ComEd experienced a fire at its Lakeview substation. ComEd formed an RCI team to investigate this event, and planned to issue a report from this investigation sometime in April.

b. Analysis

Liberty reviewed ComEd's response to this recommendation, comments made at the ICC meeting on March 28, 2006, and [redacted] training materials. Liberty also interviewed the lead member of ComEd's RCI team for the Lakeview fire and reviewed a draft of the team's report.[39]

Liberty concluded that ComEd's plans for improving its root cause process are reasonable and should improve the effectiveness of future investigation reports if implemented. The [redacted]

[38] Response to Data Request #302.
[39] Interview, April 18, 2006.

materials make many of the same points Liberty noted in its December 16 report and provides similar definitions of various types of causes. However, the [redacted] system appears to be overly complex for someone to learn from without actually attending the formal [redacted] courses.

From its review of the Lakeview RCI draft report and interview with ComEd personnel, Liberty found that ComEd appears to have identified a fundamental cause of the Lakeview event that interrupted service to many customers and significantly damaged substation equipment. It also appears that ComEd did a thorough forensic investigation of the direct cause of the fire.

In its investigation of the Downers Grove substation fire, Liberty found that ComEd did not systematically follow-up on its recommendations from previous, similar substation events. Moreover, Liberty found that had ComEd conducted investigations of these earlier events that identified basic root causes, it could have avoided or reduced the consequences of the Downers Grove event. (See conclusion #4 in December 16 report.) Therefore, in addition to looking ahead at improving its RCI process, ComEd should re-consider earlier, significant investigative reports. It would be difficult or impossible to determine the actual root causes of historical events simply because the people and facts may not be available. However, ComEd could review whether it has conducted sufficient follow-up on earlier events. For example, ComEd could determine whether its current actions and plans regarding substation fires effectively close out the recommendations made in the Bartlett substation fire report. ComEd should assure itself that its follow-up on other events, such as a significant personnel injury or death, has not fallen by the wayside as other priorities or reorganizations took place.

c. Conclusions

ComEd's response to recommendation #1 meets Liberty's intent and, if carried out, should improve ComEd's investigation and resulting follow-up actions to significant events. ComEd's formal root cause analysis method that it followed for the Lakeview fire defines the root cause as the most basic cause or causes that can reasonably be identified, that management has control to fix and, when fixed, will prevent or significantly reduce the likelihood of the problem's recurrence. Liberty suggests that ComEd ensure that it has adequately closed on the findings from earlier investigative reports.

2. Response No. 2 – Improve Cable Splicer Quality

a. Background

Plastic-jacketed, cable-joint failures caused catastrophic fires in the cable spaces at three substations, Bartlett in 1996, Schaumburg in 2001, and Downers Grove in 2005. In all three cases, investigators determined that ComEd had not constructed the cable joints in exact conformance with construction standards. ComEd determined that the 2005 Downers Grove fire started at an improperly compressed cable joint connector. Laboratory analysis indicated that the connector was probably excessively hard when installed.[40]

[40] NEETRAC studies – Responses to Data Requests Nos. 74, 85, and 109.

Liberty found that, regardless of the direct cause, the worker that installed the connector should have identified the improper compressions and should have aborted the joint installation. Therefore, it was concluded that poor workmanship was also a cause of the Downers Grove fire. Liberty recommended that ComEd study and improve the quality of training, instructions, and supervision given to personnel who construct cable joints. ComEd should also require cable-splicer qualification and maintain records to determine accountability if a cable joint fails.

Improving the quality of new cable splice construction will not greatly reduce the possibility of cable-space fires because ComEd does not allow the construction of new cable splices in cable spaces, unless specifically approved by engineering. ComEd intends to reduce the risk of cable-space fires by completing cable-space fire protection enhancements, including wrapping existing cable joints and surrounding cables with fire retardant tape. However, new transmission and distribution cable joints will still be constructed in manholes and tunnels. Therefore, it is important that ComEd constructs new cable joints exactly to standards to improve reliability and to reduce the possibility of manhole and transmission tunnel fires, such as occurred at the Fisk substation in 2005, and that started with an improperly constructed transmission cable joint.

The purpose of Liberty's recommendation was to have ComEd assure the quality and reliability of its cable splices by providing appropriate training to its trainee and seasoned splicers. The intentions of Liberty's recommendation were that ComEd would have both trainee and seasoned splicers demonstrate that they understand why they must construct joints to the standard and that they demonstrate that they are properly constructing joints. In addition, Liberty's intentions included that ComEd would track joint ownership, and that ComEd would hold splicers accountable for proper construction.

ComEd responded to these concerns. To assure distribution cable-splice quality, ComEd plans to:

- review its distribution underground cable splicer-training program for adequacy.
- modify training for new splicers.
- modify refresher training for seasoned splicers.
- issue a new Field Bulletin with the purposes of illustrating the Downers Grove connector problem, as well as generally refresh all splicers on the details of joint construction on plastic jacketed distribution cables.
- create a procedure for maintaining and calibrating connector hydraulic presses.
- develop a checklist for cable space joint installations, which will include a method to track who installed the joint.
- perform periodic quality control audits during the installation of cable space joints.
- obtain specific approval from engineering before installing a new joint in a substation cable space.

To assure transmission cable-splice quality, ComEd plans to:

- include quality control requirements in its construction specifications.
- include a checklist requiring sign off by the splicer and supervisor for joint and termination construction.
- include record retention requirements for worker qualification.
- record and track who installed transmission cable joints.

- establish criteria for its transmission cable joint construction training and qualification program.
- modify its transmission joint construction-training program to address known quality issues and to meet its criteria.

To assess whether ComEd's modified distribution cable splicer training program will meet the recommendation's intent, Liberty reviewed ComEd's relevant training documents, interviewed its splicer training personnel, and inspected its training facility.

b. Analysis

Liberty reviewed ComEd's previous and modified distribution cable-splicer training programs to determine if changes made and planned will appropriately satisfy the distribution cable-splicer training aspects of the recommendation. Distribution underground cable-splice trainees generally start as meter readers who have passed both the seven-day climbing school and the general mechanical aptitude test. The extended splicer training schools include about 50 percent class work and 50 percent splicing table time. The steps of the two-year splicer training include:[41]

- the 50-day First Period School, which includes learning to work on an underground crew and to perform initial work task exercises including assorted simple splices and connections.
- working about nine months of on-the-job training and experience under direct supervision.
- the 4-week Second Period School, which includes four weeks of training about single-phase cable joints.
- working about 14 months of on-the-job training and experience under direct supervision.
- the 8-week Third Period School, which includes constructing trifurcating and Y-joints.

ComEd's program for new distribution cable-splicer trainees is formal, intensive, thorough, and requires passing both written and performance tests. However, the program was not fully complete because it did not include a review of examples of cable and joint failures, cable and joint failure modes, and splicer accountability. ComEd reported that it has included these subject matters into the courses.[42]

ComEd said that it included all of its approximate 250 seasoned, underground cable-splicers in 5-day refresher courses during 2005. Although cable identification methods and other topics were included in the refresher courses, the courses did not include fundamentals refresher training, review of cable-joint failures, or the verification of cable splicing techniques.[43]

ComEd recently revised material for its distribution cable-splicer training program includes:[44]

- sections on cable and joint parts and functions.

[41] Response to Data Request # 304.
[42] Interview on February 15, 2006
[43] Interview on February 15, 2006
[44] Interview on March 3, 2006 and Response to Data Requests Nos. 303 and 304.

- sections on electrical stress within a cable and joints.
- information and photos from a post-Downers Grove fire Field Bulletin indicating why the connector failed, the consequences of that failure, proper compressing, and other reminders of proper connector installation.
- examples of cable and joint failures.
- tests and demonstrations of cable splicing by trainees.
- emphasis that splicers are accountable for confirming that all ComEd procedures, materials, tools, and construction standards are used during each work step, and if not, that they must stop and contact their supervisor. ComEd said that it trains splicers and others to follow the requirements of Exelon's "Event Free Performance Tool Book." This document indicates how and why installers make errors, and what actions must be taken to prevent those errors.

ComEd said that it:

- will include in its splicer-training material more explanation about failure modes caused by corona, ionization, and partial discharge phenomena in cables, joints, and terminations.
- will show in its splicer-training material examples of defective and failed splices and terminations, as practical.
- will include a thorough review and demonstration of cable preparation, splicing, and termination in its refresher training.
- will require its about 250 seasoned splicers demonstrate that they are properly assembling distribution cable joints and terminations through a written test.

c. Conclusions

ComEd is modifying its cable splicer training to help trainees better understand the importance of constructing joints to standards. This will be included in the 2006 fall refresher course. ComEd also agreed to track distribution cable joint construction in cable spaces, including identifying persons constructing the distribution cable joints. ComEd also confirmed that its refresher training would include fundamentals training and joint construction skill demonstrations. Therefore, ComEd's response complies with the intentions of Liberty's recommendation.

3. Response No. 3 – Heavily Loaded Feeders

a. Background

A causal factor of the Downers Grove cable-space fire was connector overheating, caused at least in part by cable loading that exceeded the cable's normal rating numerous times. Liberty concluded that ComEd should develop guidelines for dealing with heavily loaded feeder systems.

ComEd agreed with the recommendation and said that it will take actions to provide guidance to its operations personnel for dealing with heavily loaded feeders. ComEd said that it will:

- Review and clarify the responsibilities of the Operations System Engineer to include prioritizing repairs based upon circuit loading levels and durations of above normal loading.
- Monitor repair status, expedited repairs, and escalated issues with delayed repairs.
- Review its existing reports, tools and reporting processes for adequacy. These include PI Historian, SCADA, electronic and paper maps, Switching Routine Database, BRIO reports from Passport, the Distribution Load Management Program and the weekly "out of configuration" report. Based on this review, ComEd will modify its reports and processes by March 1, 2006.

b. Analysis

ComEd reported that it collected and analyzed information from other utilities and research organizations such as EPRI and NEETRAC about industry practices for operating 12kV cables between normal and emergency levels. Based on the results of this research and analysis, ComEd plans to revise the cable operating guides to include guidance for operating distribution cables between normal and emergency limits. This will be completed by March 1, 2006.

Liberty reviewed ComEd Engineering Group's "Cable Operating Guidelines," dated February 28, 2006.[45] These guidelines indicated that:

- If a cable system[46] is operating above its emergency limits (ratings), ComEd is to take immediate action to reduce the loading.
- If a cable system has operated for four consecutive days, or 96 hours, at its 5-day emergency rating, operations has an additional 24 hours to reduce the load. The 5-day emergency rating is 90 percent of the emergency rating. The cable systems peak loading must be returned to the normal rating for a period of 120 hours to "reset" the 5-day emergency rating.
- If a cable system is operating above is normal rating, operations should analyze the situation, prioritize action considering the overload magnitude, and if system conditions permit, take action to minimize the overload.
- Work to repair or replace main stem components causing abnormal configurations will be prioritized at a minimum of Priority 20.[47]
- ComEd said that its Systems Engineering group monitors feeder loading on a daily basis and drives repairs to return feeder main lines to normal configuration. Repairs are expedited when a feeder load exceeds normal rating.[48]

ComEd said that the Operations System Engineer is now accountable for monitoring and driving actions necessary to prevent excessive overloading of ComEd's main line feeder cables. ComEd plans to formalize its current procedures for monitoring, taking actions, and accountability.

[45] Response to Data Request #305.
[46] Cable system includes cables, joints, and terminations.
[47] ComEd targets Priority 20 tasks to be complete within two weeks.
[48] Interview of March 20, 2006.

c. Conclusions

Liberty concluded that ComEd's response and current actions comply with intent of Liberty's recommendation. ComEd has created reasonable guidelines for operations for cables loaded in excess of normal ratings, and has placed accountability for monitoring and correcting conditions causing excessive overloading.

4. Response No. 5 – Dispatcher and Operator Training

a. Background

Liberty concluded that ComEd's dispatchers were not responsive to substation fire events. Consequently, Liberty recommended that ComEd should:

- Improve dispatcher and operator training and qualifications related to substation fires, including instilling in its load dispatchers the expediency of returning system configurations to normal, de-energizing equipment under proper circumstances, acknowledging alarms, and absolute decision-making authority over the areas of the system for which they have jurisdiction.
- Train its Customer Service Representatives to be clear about whether a structure fire exists.
- Re-evaluate the priority given to substation fire alarms and the actions that dispatchers take after receiving such an alarm.
- Develop mechanisms that would reduce the verification time in determining that a fire exists at one of its substations.
- Have on-site accessible site fire plans and a direct access number to the dispatcher for fire personnel.

ComEd agreed with the recommendation and outlined several fire response initiatives aimed at strengthening training and awareness of actions that personnel should take in off-normal events such as a substation fire. These initiatives included:

- training field-operations personnel on substation fire-response procedures.
- holding meetings with Transmission System Operations (TSO) and the Distribution Operations Control Center (OCC) personnel to reinforce who has authority to de-energize equipment in the event of a fire.
- improving Customer Service Representative (CSR) fire response procedures.
- performing substation fire drills with OCC management, load dispatchers, area operators, site-restoration management personnel, and local fire departments.
- giving fire alarms a unique sound, and raising the priority of the fire alarms.
- developing new procedures for OCC and TSO responses to fire alarms.
- informing fire departments about substation fires.
- creating substation site fire plans.

- developing a technical document and training for the manual operation of circuit switchers and circuit breakers under load and fault conditions and when dc control power is lost.

Liberty reviewed a ComEd document used in departmental meetings and that dealt with the authority and responsibility to de-energize equipment in the event of certain circumstances like a fire. ComEd reported that actions taken by dispatchers during the February 18, 2006, Lakeview substation fire were appropriate.[49] In addition, Liberty observed a ComEd fire drill conducted on April 19, 2006.

b. Analysis

First Responders

ComEd had initiated its "First Responder" procedure and trained incident commanders before the Downers Grove Substation cable space fire.[50] However, ComEd reported that it will have trained its operations field personnel by July 1, 2006.

Authority to de-energize substations

When the Downers Grove Substation cable space fire occurred, fire-fighting did not begin as soon as it could have because of delays in de-energizing the substation. ComEd reported that in November 2005, it held meetings with TSO and OCC personnel to reinforce that operations shift managers have the authority and responsibility to de-energize equipment, and determine the necessary extent of equipment isolation, in the event of fire or catastrophic event. The document that addressed the authority and responsibility of TSO and OCC personnel was very clear and the vice presidents of transmission operations and dispatch operations signed it.[51]

ComEd reported that operations acted appropriately in de-energizing Lakeview when that fire occurred, and Liberty observed no reluctance to de-energize the substation

CSR response

Local fire fighters were waiting at Downers Grove Substation when the area operator arrived. Some time before the operator arrived, the fire fighters called the ComEd 800 number and spoke to a Customer Service Representative (CSR). However, the way that the CSR communicated with the OCC did not convey the significance of the fire. ComEd said that it was re-evaluating and modifying the CSRs' process for providing accurate and timely information related to substation emergencies to the OCC.

[49] March 28, 2006, ComEd presentation to the ICC.
[50] Response to Data Request #316.
[51] Response to Data Request #317.

Substation fire drills

ComEd performs periodic storm drills but has not routinely performed substation fire drills. ComEd said that it is developing and will perform Emergency Preparedness drills that will include a scenario for a substation fire. Drills will be held periodically and will involve Site Restoration Management, Operations and Load Dispatchers, Area Operators, and other departments as applicable. Local fire departments will be invited to participate in the appropriate portions of the drills. Lessons learned from these drills will be cascaded through the organization. The first substation cable space fire drill was held on April 19, 2006.[52]

On April 19, 2006, Liberty observed ComEd's substation fire drill.[53] One of Liberty's observers was at the Arlington Heights and the other at the OCC. The basic scenario was that a single feeder tripped and the OCC received a fire alarm. After some time and upon entering the building, fire department personnel noticed a flare-up and requested that ComEd de-energize the substation. ComEd simulated de-energizing the substation, the fire was extinguished, and customer restoration began. ComEd indicated that it would conduct a lessons-learned conference call the next day.

ComEd personnel took the drill seriously at both the OCC and on site. There was cooperation with the fire department and other departments within ComEd. The entire drill lasted about five hours.

Fire Alarms

During the Downers Grove cable space fire, smoke detectors sent an alarm via SCADA to the OCC. However, this alarm was missed, in part because fire alarms were priority 2 and because there was no special audible alarm for substation fire alarms. ComEd said that it has modified the priority of fire alarms from priority 2 to priority 1. Starting January 13, 2006, both the TSO and the OCC started receiving fire alarms from the same substation, where previously the transmission and distribution substations were segregated. In addition, on January 20, 2006, SCADA fire alarms received at the OCC have a unique audible sound.[54]

OCC and TSO response to substation fires

ComEd said that it has implemented a change in how the TSO and the OCC respond to substation fire alarms. ComEd will contact 911 immediately to initiate an emergency response, upon notification of a substation fire alarm along with other equipment operations and/or loss of telemetry. ComEd was to develop procedures that require the OCC and TSO to coordinate their responses to fire alarms and/or ADT fire calls by March 1, 2006.

[52] Liberty visit to the OCC and Arlington Heights Substation on April 20, 2006.
[53] See "Operations Drill at Arlington Heights," Section III.B.2.a.3.
[54] Response to Data Request #318.

Informing Fire Fighters

When the Downers Grove Substation fire occurred, fire fighters could not communicate directly with the OCC, and had to wait to proceed until the area operator arrived. ComEd said that it recognized that it must improve communications with firefighting organizations. ComEd has reinforced to local fire departments and ADT that the OCC is the single point of contact (SPOC). ComEd notified ADT of this in September 2005, and in December 2005, ComEd sent out letters to nearly 400 Fire Chiefs and Fire Protection Districts.[55]

Site Fire Plans

At the Downers Grove fire, fire fighters had to enter the control building filled with smoke from the cable space and station battery fires. Information about special hazards was not readily available to the fire fighters. The area operator was not familiar with the substation and ComEd environmental management personnel had to be contacted by telephone. ComEd said that, to assist fire fighters, it will create site fire plans for its TSS and TDC substations, and applicable transmission tunnels. These plans will include descriptions of fire systems, hazards, site geographic layouts, and 24-hour emergency contact numbers. The plans will be on file at the site. ComEd is contracting with an industry consultant for the development of these site fire plans. All TDC / TSS Chicago stations will be completed by the end of 2007. TDC Substations similar to Downers Grove substation will be completed by 2008. ComEd plans to install site fire plans at all substations with a building containing electrical power equipment or relay control equipment by the end of 2011.[56]

Opening circuit switchers and circuit breakers without dc control power

The Downers Grove fire caused the dc control power failure. The OCC and the area operators were not aware that the 138 kV circuit switchers could be safety opened by hand-mechanical operation under load and fault conditions. In its response, ComEd said that it is investigating whether operators can open circuit switchers and circuit breakers by hand-mechanical operation under load and fault conditions, without dc control power. Based on the results of this technical investigation, ComEd plans to develop a technical document for the hand-mechanical operation of circuit switchers and circuit breakers. ComEd will then determine the switching operations that can be performed in accordance with work practices and safety guidelines. If determined acceptable, training documents will be prepared by April 1, 2006. ComEd will also train personnel on hand-mechanical equipment operations that they can perform without dc control power. This will be completed by June 1, 2006.

c. Conclusions

Liberty found that ComEd's responses satisfy the intent of the Liberty recommendation. ComEd is modifying operations procedures related to substation fires, fire alarms, de-energizing substations, and general awareness of actions that personnel should take in off-normal events.

[55] Response to Data Request #319.
[56] Interview of March 13, 2006 and Response to Data Request # 310.

Assuming that ComEd completes these actions and continues to follow up with training and reminders, the response to substation fires by area operators, dispatchers, and fire departments should improve.